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Preface

The German edition of the Handbook of Print Media – Technologies and Production Methods was published and introduced to the market during the book fair in Frankfurt/Main in October 2000.

The translation work for the English edition was started in 1999 immediately after the manuscripts for the German edition had been prepared.

The translation of the German preface follows this preface. The German preface describes in detail the origins of this handbook, the goals regarding contents and readership, and in particular the comprehensive cooperation with experts from academia and industry in the fields of science, research, development, education and from publishing and the communication industry worldwide.

I have expressed my recognition and gratitude to the many experts and partners in this cooperation and would like to do so again here.

The translation for the English edition was done by a team of international translators, headed by Dr. René Bosewitz (The Translators AG, Heidelberg, Germany).

The proof-reading and refinement, especially regarding specialist terminology and the optimization of the description of the technical content, was supported from the beginning by Professor Frank Romano and Professor Frank Cost of the RIT (Rochester Institute of Technology)/College of Imaging Arts & Science in Rochester/NY (USA) and myself.

In my capacity as editor, author within the large group of authors, and project manager I was responsible for the content of the handbook and its scientific and technical quality. I was deeply involved in the process of enhancing the translation and learned a lot with the translators when explaining the technical facts, answering questions and showing what had to be described.

This handbook is, therefore, not "only" a translation of the German edition. It includes many improvements, additional information and descriptions in text, pictures and graphs for enhancing the educational and technological presentation.

The handbook is written in "international" English. The rules for syllable separation and punctuation are based mainly on "Merriam-Webster's Collegiate Dictionary", and "The Chicago Manual of Style". The typographical details, the fonts and page layout are optimized for easy reading.

I would like to thank the whole team working on the translation, especially the afore-mentioned experts for their patience, efforts and support in creating a valuable international handbook, which is now ready for worldwide use.

The units for technical specification/quantities are stated in the international SI-system (metric) and only a few quantities are stated additionally in imperial units directly in the text. Detailed tables of physical/technical quantities and conversions are given in Section 14.2.

We took special care to choose terminology which is used and understandable worldwide and exploited this consistently throughout the whole book (sometimes giving additional terms). This was a great challenge and the reader should excuse us if some terms are different from those he is familiar with.

The bibliography (references and further reading) in the several sections/chapters is basically identical to that of the German edition. There is, however, some additional information from international publications to support the English speaking readership. In any case where an English edition exists we added this in or replaced the German edition with this.

Most of the addresses, for example of research institutes and associations, are stated in their native language. We have not given a translation for these. If official names exist in English, in some cases we have substituted them for the German or added them in.

Together with best regards and wishes from Bernhard Schreier (Dipl.-Ing.), the Chairman of the Management Board of Heidelberger Druckmaschinen AG to all readers, partners and experts from the printing, publishing and communications industry, I hope and trust both personally and on behalf of Heidelberg that readers will gain an equal amount of pleasure and profit from this book, the Handbook of Print Media. It should contribute to ensuring the continuing economic, high-quality production and availability of print media in today's age of information – both in conjunction as well as in competition with electronic media. The handbook should also help to ensure that the influence of innovations, advanced and new technologies, market and customer demands on these industries and their further growth be evolutionary rather than revolutionary, and that print media continue to contribute to the maintenance, expansion and further development of a high degree of education, culture, progress and quality of life throughout the world.

Helmut Kipphan
Heidelberger Druckmaschinen AG
Heidelberg, December 2000

Preface of the German Edition

The technological change and evolution in the printing, publishing and communications industry and increasing market requirements in terms of quality, costs and distribution of print media, have led to a considerable change in the technologies and processes used for their production. Digitalization, automation, synergistic technologies and innovations are further signs of improvements, developments and new production methods and processes. Demand on print media is also influenced by the spread of electronic media together with new possibilities in information storage and availability, production and design of print media and the creation of new multimedia products, in particular as well as the workflow stages involved in media production.

Processes and equipment used to produce print media require the use of a wide range of innovative technologies and components from all areas of technology and industry – the need for cross-functional, interdisciplinary working is particularly strong in the graphic arts industry and therefore involves cooperating with partners from many industrial sectors.

It is the advances in computer and networking technology, digital control and processing of production equipment within the total production chain in print media creation – that is from concept to the final print media product – which more than anything else have enabled the traditional production areas of prepress, press and postpress to evolve together and be realized for practical use.

Digital workflow has become a reality, Computer to ... technologies characterize production with their wide range of possibilities for realizing digital print production. Novel printing technologies, production methods and strategies have become possible and are being used in practice.

Digitalization has also created the premedia sector in which information for distribution is created as a digital master that forms the basis for duplication via both print media and electronic media.

In order to produce and supply media products and services, companies, management and technical personnel, trainees, teachers and instructors must adapt equally to existing and continually developing new structures, technologies and opportunities in today's information society. Investment decisions must be made from a commercial, technical, market and customer-specific point of view, based on a wide range of business and technical performance factors and criteria.

Information and knowledge on this meteoric development and new possibilities have been published in numerous books and papers in technical literature and presented and discussed at national and international symposia and conferences, but mostly only describing specific subjects. However, it is difficult for the individual to keep up-to-date and form a comprehensive picture based on traditional technologies and processes. In this respect the far reaching content and didactic design of the Handbook of Print Media should make it an essential aid and tool in everyday practice.

The original ideas for producing a handbook of print media are based on my conversations in June 1996 with Dr. Hubertus v. Riedesel (Dipl.-Phys.) of the Springer Publishing Company in Heidelberg during one of the symposia of the "Rhein-Neckar – discussion group for Physical Research in Industry and University" (an initiative of the University of Heidelberg and the industry). Conversations between the management of the publishing house, and Hartmut Mehdorn (Dipl.-Ing.), Chairman of the Management Board of Heidelberger Druckmaschinen AG at that time, and myself provided the impetus for putting these ideas into practice.

Fascination with the wide range of subject matter and products of the graphic arts industry and the experience of two successful globally active enterprises based in the same city of Heidelberg led to the unanimous decision by the Board of Heidelberger Druckmaschinen AG in December 1997 to publish the "Handbook of Print Me-

dia – Technologies and Production Methods" in German in the year 2000 and an English edition soon after.

It was, in particular, Hartmut Mehdorn, who undertook to meet the urgent need for further education and training in the printing and publishing industry and supported the project through his creative and extremely active involvement.

The following events lend particular significance to the year 2000 for the graphic arts industry and Heidelberg: the 600th birthday of Johannes Gutenberg, the inventor of letterpress printing using movable metallic type, the required tools and a printing press; the 150th anniversary of Heidelberger Druckmaschinen AG and, linked to this, the inauguration of the Print Media Academy based in Heidelberg.

With the Print Media Academy as a new center for communication, qualifications and knowledge within a worldwide network for the whole printing and publishing industry, and the Handbook of Print Media, Heidelberg continues to contribute to the improvement and dissemination of knowledge about the requirements of industry and promote the advancement of the graphic arts and communications industry.

An examination of the current literature showed that a large number of good text books and much educational literature is already available, covering most subjects and areas of the printing and publishing industry as well as a large quantity of individual publications, but also that there is considerable demand for an up-to-date, clear and comprehensive presentation of the whole subject.

Thus, the concept of the handbook took shape, whose main focus was the need to give state-of-the-art treatment to the whole spectrum of modern print media production and to make clear, topical facts available, explaining subjects, such as the following in particular:

- traditional technologies and new innovative processes in all stages of production;
- detailed treatment of novel digital printing technologies, especially non-impact printing processes;
- the positioning of print media, electronic media and multimedia;
- the positioning of the various printing processes based on their performance characteristics and the market segments of print media;
- presentation of the trends in the production of print media, taking economic and technological requirements into account;
- training, education, research, development trends and strategies;
- state-of-the-art production equipment, systems and technologies, taking account of the products of numerous well known manufacturers from around the world;
- environmental protection and safety technology;
- historical evolution of printing;
- reviews of standards, norms, training centers and research establishments, societies, associations and organizations of the printing and publishing industry, as well as international technical conferences, etc.

The handbook should therefore serve as a standard reference for technical communication and further education; it should provide technical personnel and managers of printing and publishing houses, of the graphic arts and communications industry, supply industry, scientific bodies, trade associations and experts in research and education, trainees and students with comprehensive information. In addition, however, it should give those who are not familiar with the industry the opportunity to learn about the theory and practice of print media production and to develop an awareness of new areas.

The wide scope of the handbook means that there has been a deliberate use of repetition in the individual chapters. This enables the reader to first become familiar with the broad area of a subject and then use cross-referencing to study the complementary information given in other chapters.

The handbook provides a solid foundation for acquiring basic information and gaining an understanding and knowledge of the subjects' interrelationships. References to specialist and complementary literature help to provide more in-depth information. It represents a building block and reference work for training programs and further education – also in the context of the programs of the Print Media Academy – and is aimed at an international readership having a broad range of different interests.

The CD-ROM that accompanies the handbook makes it a true multimedia product. The CD-ROM includes the complete handbook, enables a full text search and contains additional aids to provide a convenient and focused method of searching and information gathering. It also provides a user friendly guide to the extensive text and the numerous figures.

There is an up-to-date explanation of the state-of-the-art with respect to subject matter, referring in general to the end of 1999. However, many new products and technologies, which were not to be publicized until May 2000 at Drupa (the world's largest exhibition of print media) have already been taken into account. Statements on the trends and forecasts are based on current facts and extensive experience as well as information obtained around the world.

The editor and publisher have agreed to update the handbook in subsequent editions, so that it forms a standard work for the production of print media.

It is with pleasure that I undertook the extremely stimulating tasks which Heidelberger Druckmaschinen AG entrusted to me as leader of the project to create the handbook, as well as taking charge of the technical content, and acting as the editor. This afforded me a particular opportunity and responsibility for creating and making the subject matter available while Springer, in close cooperation, undertook the production and marketing.

The diverse subject matter as well as Heidelberg's aim to represent technologies, products and systems as independent of their manufacturer as possible led from the outset to the idea of creating the handbook by employing a team of authors drawn from science, research, education, academia and industry. This was coupled with the skill, knowledge, competence and experience of the Heidelberg Group, but predominantly with external authors.

One of the greatest challenges was to set up the team of authors, to discuss and agree on the subject matter and content, to match the authors to the current tasks and to complement the team during the editing process. The initial meeting of a core team of authors took place in Heidelberg in March 1998. Additional authors were still being included in the team until August 1999.

A great deal of thanks is due to all authors. They performed their tasks well and were willing to agree to suggestions and improvements so that the handbook could appear to come "from a single mold" despite the large number of authors. Thanks also go to the many experts, who are not named here but whose words and deeds contributed to the content and progress of the project.

Professor Arved C. Hübler (Dr.-Ing.) and Professor Wolfgang Beier (Dr.-Ing.) of the Institute for Printing and Media Technology at the Technical University of Chemnitz supported the coordination of the technical matter. In closest collaboration with the editor they contributed to ensuring that the manuscripts met the quality demanded of the handbook in terms of content and educational value, and that the contributions were as consistent as possible.

The English translation of the handbook was begun immediately following production of the German manuscript. The English translation team was supported by international experts with experience in the graphic arts industry, Professor Frank Cost and Professor Frank Romano of the RIT (Rochester Institute of Technology)/College of Imaging Arts & Sciences in Rochester/NY (USA). They undertook the task of performing a general check of the translations produced regarding the language and then once again for content, resulting in a number of improvements. This also meant that the experience and interests of international experts, teachers and readers could be taken into account to an even greater extent.

Special thanks are also due to the employees in my department of Technology & Innovation Research, Dr. Martin Schmitt-Lewen (Dipl.-Phys.) and Walter d'Heureuse (Dipl.-Ing.), who continually supported me during the whole project through their critical and constructive contributions on the clarification of technical questions, but also for their patience and understanding in the often difficult situations caused by scheduling. Special mention goes to their support in working on the manuscripts for proof-reading and correction as well as searching for and acquiring material for illustrations. Thanks also to SciTech Consultants GmbH/Heidelberg, Germany, who worked in close cooperation with us from the beginning of the project regarding communication and timing between the various parties for both the German and English edition. The work included the competent and accurate proof-reading of all the versions of the chapters right up to going to print.

I am particularly keen to thank all of the companies, experts and customers all over the world for the many conversations, the advice, suggestions and constructive criticism on the wide range of subjects and queries on the production of print media and the demands on the means of production. It was only with this information and support, mainly based on years of close cooperation and continual personal contacts, that we could take an up-to-date and comprehensive view of the

interests and requirements of the users of production equipment and systems as well as their customers. This applies both to the gathering of the material for the book and the handling and treatment of the individual topics. This ensured that the handbook relates to industrial practice, lends equal support to owners, managers and employees in the various workplaces of a printing/publishing company and also offers trainees and students useful, practice-oriented information, knowledge, skill and experience.

Many thanks also for the support received from colleagues and experts in the Heidelberg Group worldwide as well as the numerous contacts in companies in the supply industry, partners in cooperation and competitors, as well as experts and partners in institutions and organizations for industrial and academic research.

The selection and creation of illustrations posed a particular challenge and represented a subject of special interest to me personally, firstly with respect to the quality of the images and secondly from the point of view of a representative selection of examples of products from as many suppliers as possible. Special thanks to all companies and experts whose understanding and helpfulness provided us with illustrations and information either directly or indirectly. Great care has been taken to name all sources; if there are omissions, please accept our apologies.

The skills, competencies, abilities, experiences and partners of the Heidelberg Group and Springer were used to produce a high-quality handbook in terms of content, illustration and design in a relatively short time and to make it available to a broad readership. It was always a common goal for me, Heidelberg and Springer to produce the very highest quality. Readers and users of the handbook are urged to provide suggestions and advice on how it may be updated and improved. This information will help in the preparation of a subsequent edition broadly based on a desire for continuous improvement.

Personally and on behalf of Heidelberger Druckmaschinen AG and together with the best regards and wishes of the Chairman of the Management Board of Heidelberg, Bernhard Schreier (Dipl.-Ing.) to all readers, partners and experts in the printing, publishing and communications industry, I hope and trust that readers will gain an equal amount of pleasure and profit from this book, the Handbook of Print Media. It should help in allowing print media to continue to be produced and supplied economically and in high quality in today's age of information – both in conjunction as well as in competition with electronic media. It should also mean that the influence of innovations, advanced technologies and market and customer demands on these industries and their further development will be evolutionary rather than revolutionary and that print media will continue to contribute to the maintenance, expansion and further growth of a high degree of education, culture, progress and quality of life throughout the world.

Helmut Kipphan
Heidelberger Druckmaschinen AG
Heidelberg, April 2000

Authors and their Contributions

As explained in the preface, a team of authors from science, research, academia and industry was formed to create the handbook. Editing of the diverse and comprehensive subject matter resulted from close cooperation with Professor Helmut Kipphan (Dr.-Ing. habil.), the editor, who was also in charge of the content and scope of the handbook, its technical and scientific quality and who is also the main author.
Many contributions – sections as well as complete chapters – were produced by individual authors. Numerous sections also arose out of the cooperation of several authors, mainly author and co-author. Co-authors are named if they have made important contributions to the content and scope of the section. Sections or chapters which were written by one author in total or as the main author, are in bold print in the following list, while co-authors are named for sections or chapters in normal type (for contributions which are roughly equal there is no distinction made between author and co-author).
All contributions to the handbook were edited with a desire for unity of style of text, images and graphics, a clear structure and an educationally useful design with the support of the editor's staff, colleagues and the coordinators in cooperation with all of the authors.

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1.1 Communication Technologies

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1.1.1 Print Media

Topical surveys on the significance and use of print media prove that the need for print media is growing worldwide. This is indicated by the fact that at the end of the millenium *Time Magazine* acknowledged the sociocultural significance of the invention and utilization of book printing and elected Johannes Gutenberg's work as the most crucial event of the millennium. It is true that the age of electronic media has started; however printed information is and remains omnipresent.

Depending on level of education, income, and household type, between US$ 20 and US$ 55 per month and household were spent in Germany in 1997 on books, brochures, magazines, and newspapers.

The market for print products offers more variety than ever before. Usually, printed products are categorized into commercial printing and periodicals. This classification differentiates printed matter with regard to its *frequency of publication*. Since the production process also depends largely on these basic conditions, printshops usually specialize in one or the other market segment.

Commercial printing refers to print products that are produced occasionally (e.g., catalogs, brochures, leaflets, business cards, etc.). *Periodicals* are printed matter that appears periodically (e.g., newspapers, journals, magazines). Publishing houses and companies are the typical clients for periodicals printing.

The variety of print media is illustrated in figures 1.1-1 and 1.1-2. Another way of categorizing printed



Fig. 1.1-1
Variety of print media: magazines, brochures, posters, books, etc.

H. Kipphan (ed.), *Handbook of Print Media*
© Springer-Verlag Berlin Heidelberg 2001



Fig. 1.1-2 Packaging: bags, folded boxes

products is by splitting them into special product groups. These individual groups are described briefly in the following.

1.1.1.1 Books

Gutenberg's work and his invention, printing with movable lead type, in the middle of the fifteenth century triggered a revolution in book production. A much greater proportion of the population had the chance to acquire education, culture, and information than had ever been possible with hand-written books. Consequently, illiteracy decreased in the following centuries. Books continued to be colored by hand even after Gutenberg's invention, so that very colorful volumes of high quality comparable to earlier ones were still produced.

For over 500 years letterpress was the dominant printing technology for books. Only when phototypesetting and lithographic printing became widespread in the 1970s did the printed book turn into a low cost mass medium. It was not only more efficient production processes but also the availability of inexpensive paper that were decisive reasons for the breakthrough of books as mass media. The printed book developed its independent appearance over time. The form of the type used moved away from imitated script types to its own type forms.

The number of new book titles produced has grown continually since Gutenberg's invention. Even today, in the age of electronic media, annual growth rates in book production are still recorded. With close to eighty thousand titles produced annually, Germany is one of the biggest markets for books in the world today. Only China and Great Britain produced more titles in 1997 (cf. fig. 13.3-8). In 1998 more than 500 million books worth over 3.5 billion Euros were produced in Germany.

The extensive range of books is classified on the one hand in terms of content; on the other, it extends from high-quality, thread-stitched leather volumes with a gilt edge to simple perfect-bound pocket books/paperbacks. Books are offered both in one color (book printing) as well as in top-quality multicolor art publications. The range of books available today in Germany has risen to over 770 000 titles. The same applies to other printed products such as magazines, periodicals, newspapers, and brochures.

1.1.1.2 Magazines

The range of magazines consists mainly of periodicals, including trade magazines, journals, and illustrated magazines. Trade magazines cover a limited field, thus attracting a limited specialist readership. Unlike books, production costs for *magazines* are not paid for exclusively by the final consumer. Often more than half of the costs are financed by advertising.

Magazines are usually published by publishing houses just like books. Unlike books, magazines usually have a shorter lifespan. This is due to the content and it is a major characteristic of the periodical. Since magazines have a limited length of use and differ from books greatly in terms of content, their external form also differs from that of books.

Magazine production differs considerably from book production. Magazines are generally multicolored booklets with a flexible cover. They often have a high circulation and are bound using simple binding processes (e.g., wire-stitching, perfect binding). Depending on the circulation, magazines are printed with sheet-fed offset or web offset presses, but

rotogravure presses are also used for magazines with a very high circulation.

1.1.1.3 Newspapers

The newspaper is still one of the most significant mass media today. The first *newspapers* appeared at the start of the seventeenth century. Pamphlets in the sixteenth century were the precursor of the newspaper. Most newspapers are produced daily and have a high circulation. Some daily papers even appear a few times per day, to ensure that their content is very up-to-date. The two most important categories of newspapers are daily papers (dailies) and weekly papers.

The external appearance of newspapers differs considerably from that of magazines. Newspapers normally consist of large-size loose sheets. Several of these loose sheets are combined during production and form an individual section of the paper. A newspaper consists of several sections/parts with varying content called "newspaper books."

Generally, newspapers are produced on special newspaper printing presses. These presses are highly productive web presses, which can print on uncoated paper, at low cost. The traditional newspaper used to be black and white. Modern printing presses are able to print in color economically. This has created the opportunity to adapt the newspaper's appearance to today's expectations (color photographs, color TV), but also to conform to the wish of many advertising customers that their advertisements be published in color. The production of a newspaper is mainly financed by advertising inserts and advertisements. For this reason the ultimate consumer price for a newspaper is relatively low.

1.1.1.4 Brochures

Along with advertising inserts, which we come across every day in newspapers and magazines, there is a large market for leaflets and product descriptions. Such printed matter is referred to as *brochures*. Unlike magazines and newspapers, they are not published periodically. Brochures are commercial print work. Another significant difference from newspapers or magazines is the usually low print volume of brochures.

Today, brochures are generally printed in color and are available either as folded individual sheets or bound copies. They are of better quality than newspapers. Brochures are mainly used to describe something particular (e.g., company, product). Brochures are mostly used for advertising; therefore production costs are normally borne by the advertiser and not by the reader.

1.1.1.5 Other Printed Media

Packaging represents another important group of printed products. It can be made of very different materials such as paper, cardboard, plastic, metal, glass, and so on. In the first place, packaging is used to protect the actual goods inside, but it also makes for an attractive presentation. At the same time packaging is also printed on to provide information about the package content. All the major printing technologies are used for printing packaging – often in a combination of several technologies.

1.1.2 Electronic Media

Electronic media were developed in the twentieth century and together with printed products (print media) became important for communicating information. This trend continues today and is characterized particularly by the use of computers and the Internet. In addition to the latest developments in the Internet and World Wide Web, electronic media also include the more conventional radio and television along with the corresponding forms of storage such as video and audio recordings on CD-ROM and DVD-ROM as well as animations.

Electronic media, as is the case with print media, also involve a chain of creation and transmission which depends on the specific form of the media. As a rule, the first stage in this process consists in generating the *contents*, for instance, for recordings onto audio or video tape. In some cases, information is converted from one medium to another, such as from conventional film to video. In the case of web pages though, content can also be computer-generated, thus allowing for the use of content from both the real and the virtual worlds.

Animations may describe scenes and "tracking shots"; in the end, running an animation results in a chronological sequence of pixel images, that is, almost a video flow. The description of an animation can be considerably more compact and efficient than the transmission of the video sequence. Therefore, the actual animation may only be executed on a final output device such as a powerful presentation computer.

In the preliminary phase, scripts are usually compiled (at least in a professional environment) as we know them from traditional film. In the case of electronic media products, the specific demands on the *presentation* must already be taken into account in the design stage. The reasons for this include the low local resolution (in comparison to print products) and the restriction of the output format (e.g., the size of the monitors or even windows within the overall monitor display).

Distribution may be in a saved form on data media (CD-ROM, video tape/audio tape, and storage medium for sound) or be live, for instance, for transmission of a concert or sports event. In both cases, an attempt is made to restrict the volume of data because of the limited capacity of the storage media or because of the limited bandwidth of communication channels. *Compression techniques* play an important role here. They permit the reduction of data without a noticeable loss of quality. The underlying transmission technologies may be varied, ranging from Internet connections via dedicated switched connections, such as satellite routes, or high-speed links via cable or glass fiber, to private or company networks, also with various technology (company television, Intranets).

The presentation systems, for instance, computer monitors, television screens, projector devices, audio reproduction systems (loudspeakers, headphones) are generally at the end of the transmission chain. Before these systems can respond though, codings and compression processes might have to be reversed with corresponding components (software and hardware) to represent the transmitted data. In the place of presentation systems, *memory* can also be found there that records the data transmitted, for instance, to reproduce it at another time.

The use and dissemination of electronic media can be regulated with protection rights which are, however, relatively easily infringed; this applies particularly to digital data where the copy is just as good as the original. Modern procedures deal with protective mechanisms against unauthorized copying both in the

- *cryptography* field, that is, encoding data to prevent unauthorized use
  as well as
- in the *digital watermarking* field, that is, importing information into the digital data stream which is not visible to the normal observer, but which can be detected in order to determine the location at which the data was made available.

In a broader sense, electronic media also include in particular *interactive applications*: media which appear differently depending on user intervention. These include computer games, interactive simulations, or virtual reality applications. This leads directly on to multimedia concepts which are described in the following section. Please refer to chapter 11 for more details.

1.1.3 Multimedia

The term "multimedia" is closely connected with today's computers and output devices such as monitors, loudspeakers, and printers and their capacity for reproducing various types of information (text, images, sound, animation, etc.). Multimedia systems do not just output these different types of information; these systems make it possible to simultaneously create multimedia information and interact with other multimedia documents (data files on data storage units, such as a server and CD-ROM).

Although the term "multimedia" is relatively new, what lies behind it is not (see also sec. 11.7). *Multimedia* means nothing more than making use of several types of information (text, images, graphics, animation, video and audio sequences) in one publication. As illustrated in figure 1.1-3, this also includes print media (e.g., CD-ROM in a book).

Human communication is multimedial as humans transmit information, for instance in a conversation, by talking and gesticulating simultaneously. The technical application of using several media simultaneously to reproduce content is not new either. Thus, for example, television can simultaneously transmit information using text, image, and sound. The addressing of several sensory organs combined with the advantages of using individual media has synergetic effects making the multimedia product an attractive option.

The success of the multimedia concept becomes clear with television and the so-called "new electronic media" such as the Internet or CD-ROM publications. CD-ROM publications are not multimedia documents as such. A CD-ROM is merely a medium on which various types of information (such as text, sound, video, etc.) can be stored. Only if, for example, text, sound, and animation are combined on a CD-ROM, could one speak of a multimedia CD-ROM. *Types of information*

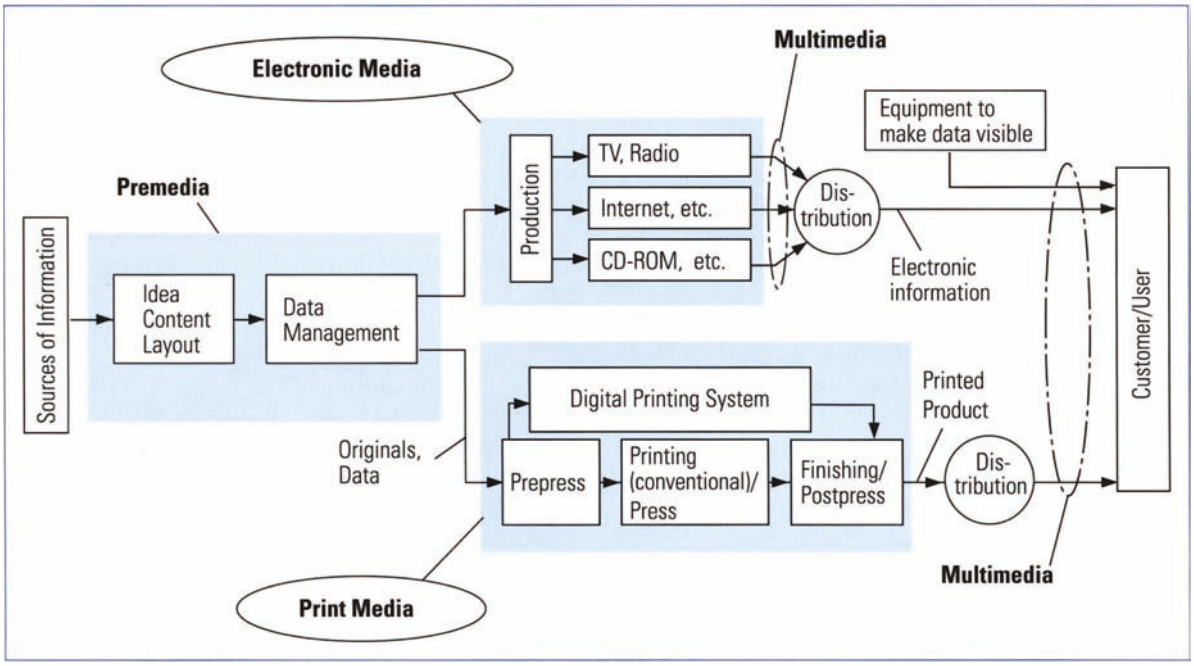


Fig. 1.1-3 Structure for producing electronic media, print media, and multimedia documents

(text, sound, image, video) must not be confused with *medium* (data carrier, e.g., paper, CD-ROM, disk, etc.).

The same applies to *Internet publications*; here too, different types of information have to be linked with one another before you have a multimedia presentation. *Hypertext* as an additional type of information is in itself not a multimedia document; only when hyperlinks point to multimedial contents does a hypertext become a *multimedial hyperlink document.*

The play-back devices (computer, television, etc.) for electronically stored information are not even close to addressing all the sensory organs of a human being. Today's multimedia products are not yet able to invoke the senses of smell and touch. A medium which can be used to pass on a fragrance to consumers, or to call on the sense of touch by certain surface properties in addition to transmitting text and visual information is, for example, paper. One might therefore say that paper is a multimedial product. However, printed information lacks dynamism and interaction. With play-back devices for electronically stored information there is also a potential for appealing to the senses of touch and smell in the future (e.g., transmission of vibrations/oscillations and temperature via operating elements).

1.1.4 Distribution and Market Volume

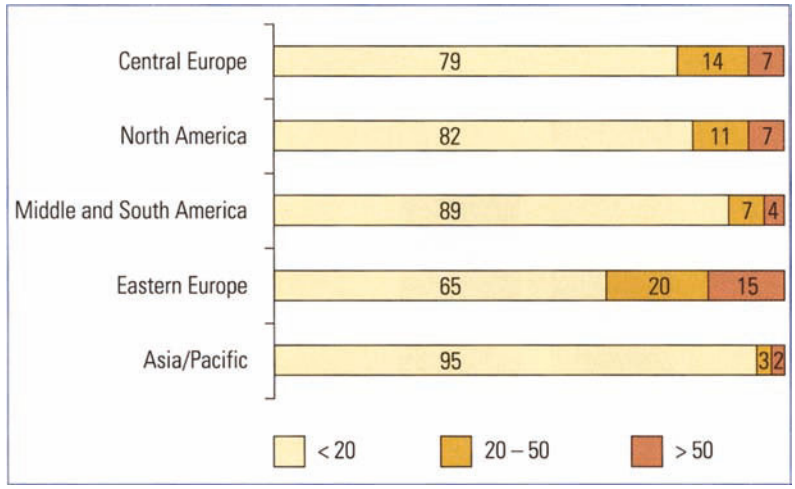
The printing industry is a sector consisting predominantly of small and medium-sized companies. Around 90% of all printing companies worldwide employ less than twenty people (fig. 1.1-4).

The growth of the printing industry is influenced essentially by macroeconomic factors such as economic development and consumer demand. Worldwide, the printing industry contributes 1–12% to the gross added value of the processing industry.

In the industrial countries the production volume of the printing industry has a share of 0.5–4% in the gross domestic product (GDP). In emerging markets this share may even amount to 20% of the gross domestic product. In the USA the printing industry is the sixth largest industrial sector and has therefore a clear economic significance for the country.

In 2000 the 430 000 printing companies worldwide will achieve a turnover in the range of 430–460 billion US dollars. Figure 1.1-5 shows the distribution of this volume according to individual product segments. The areas of advertising and commercial printing as well as packaging and label printing make up the most im-

Fig. 1.1-4
Segmentation of printing companies by number of employees (in %) (Heidelberg estimates on the basis of worldwide sources of information)



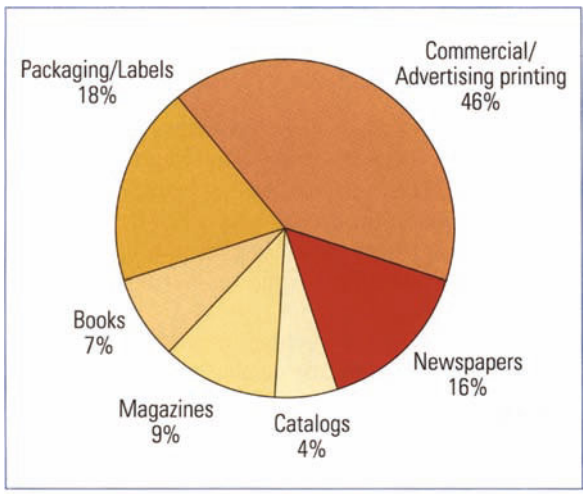


Fig. 1.1-5
Distribution of worldwide market volume by individual products (not including the SOHO/"Small Office, Home Office" market) (Heidelberg estimates on the basis of worldwide sources of information)

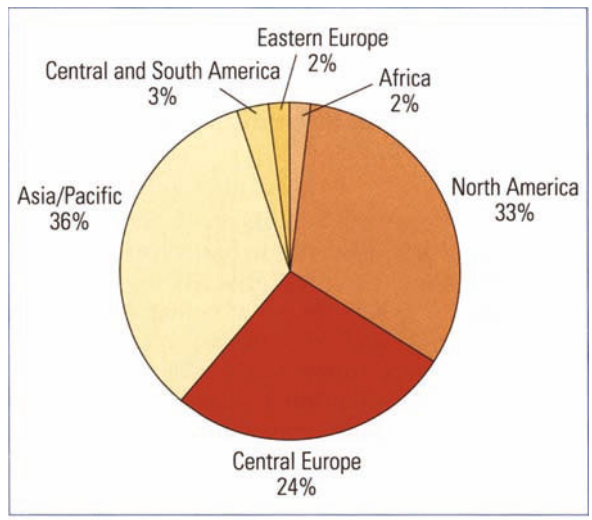


Fig. 1.1-6
Distribution of market volume by individual regions (Heidelberg estimates on the basis of worldwide sources of information)

portant product segments with current sales of 129–138 billion US dollars. Catalogs are the least important in terms of sales.

Figure 1.1-6 shows the segmentation according to region. It can be seen from the diagram that 93% of volume is concentrated in the regions of North America and Central Europe, as well as Asia/Pacific. Within these regions the most important markets are the USA, Germany, Great Britain, and Japan, which alone account for 50%.

North America has the greatest per capita consumption of print products per year. This is six times greater than the worldwide average consumption of 58 US dollars (fig. 1.1-7). An analysis of individual countries shows a more differentiated picture. Japan has the highest per capita consumption at 480 US dollars while the USA, at 342 US dollars, is closely followed by Singapore at 320 US dollars. The greatest future growth is expected to be in China, South East Asia, Latin America, and Eastern Europe.

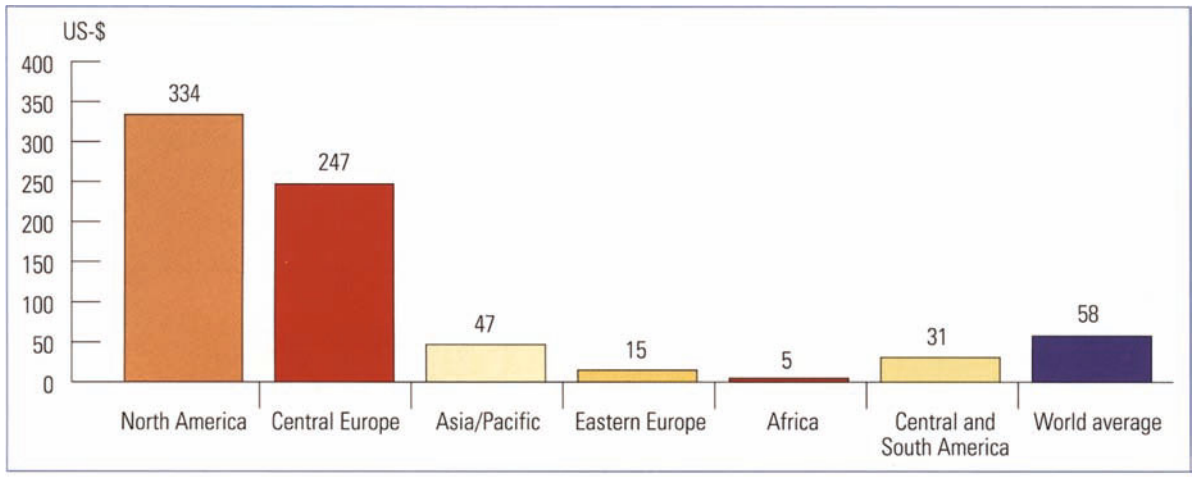


Fig. 1.1-7
Per capita consumption of print products per year in US dollars (Heidelberg estimates on the basis of worldwide sources of information, status: 1998)

1.1.5 Trends and Scenarios for the Future

The worldwide growth in gross domestic product up to the year 2002 is estimated to be 3.4% p.a. In comparison the volume of print products is predicted to rise by 2.5–3% that is, there is a potential market of 452–488 billion US dollars by the year 2002.

As far as printed matter world-wide is concerned, packaging and label printing shows strong growth while the other product segments such as advertising and commercial printing, newspapers, catalogues, magazines, and books show a moderate increase (fig. 1.1-5). There is an enormous variation in growth between individual regions or countries. Hence the greatest future growth rates are expected in China and other emerging markets, whereas the highly developed economies will show only slight increases.

The printing industry as a whole has generally been undergoing enormous structural and technological change for several years. Apart from the changes affecting the traditional printing sector, the integration of new media (e.g., CD-ROMs, online services) into existing product offers represents the greatest challenge to the graphic arts industry in the years to come.

1.1.5.1 Changes in the Traditional Printing Sector

The trend towards the "*one-man press*" as a result of increasing automation of all the steps in the process of a printing house will create an enormous potential for innovation in the field of machinery and equipment but also in processing in the coming years. The best example of this is in the area of prepress, where technological developments mean that the average expected product life cycle of the equipment is only eighteen months.

Printing processes are being increasingly controlled and adjusted electronically, which leads to consistent high quality and greater productivity. *Digital workflow* also means that productions are completed more rapidly. Hence more than half of the orders for commercial printers arrive in digital form. By the year 2002 this figure is expected to be over 65%. This is the only way of shortening delivery times for print products and meeting the high customer demand for quality.

All printing companies are expected to offer greater *flexibility* in the processing of a large variety of substrates, inks, and methods of print finishing. This means that there is a visible trend for all print products to employ multicolor as well as decorative and special colors. In addition, run lengths are getting shorter since experts believe that the greatest chance of growth lies in the market for small, color work with a fast turnaround time.

The information and communication sector is expected to provide a positive impulse for the whole printing industry. Recently, *electronic publishing* has revolutionized the world of prepress. The use of *com-*

puter to film, computer to plate and *computer to press* systems is already widespread and is undergoing continuous growth. In order to achieve a smooth flow of digital data from prepress via press to postpress, the integration, networking and digitalization of all processing steps is essential. Over forty leading manufacturers in the graphic arts industry are cooperating on an international scale to develop a *standard for data flow* through the so-called "CIP3 concept" (CIP3 international cooperation of prepress, press and postpress, see also sec. 8.2.3). Practical application and worldwide expansion are well on the way.

1.1.5.2 Integration of New Media

Beside the classical areas of activity – the production of print media – other services are becoming more important. Hence the design of print media, the creation of multimedia products (CD-ROMs, Internet sites, print media in combination with electronic media, etc.), consulting services, and individual training are being requested more and more by the printing and publishing industry. The increasing power of electronic media (especially CD-ROM, Internet) will increase competitive pressure on the print media and partially replace print products while at the same time creating new print jobs.

Despite strong growth in electronic media (fig. 1.1-8), the *market for print media* remains large and attractive since a high proportion of the ever-growing advertising expenditure flows into print media, and the demand for print and electronic media especially worldwide is increasing.

The trend towards increasing advertising expenditure in print media is shown in figure 1.1-9. North America and Europe show moderate growth with rates of 3.1% p.a., and 4.6% p.a. respectively. In Asia advertising expenditure in print media is rising by 6.1% p.a. The regions of greatest growth, admittedly starting from a low level, are Central and South America and the rest of the world with two-digit growth rates per year.

As the *Internet* continues to grow, the sale of goods and services via data networks is increasingly regarded as a new method of generating sales by many businesses. The customer is able to choose from an almost unlimited range of goods 24 hours a day. All that is needed is a PC, which the customer uses to connect via modem to the net. Figure 1.1-10 shows the spread of computers online worldwide, while figure 1.1-11 shows the distribution of connections by country.

In 1997 the Internet was used by around 90 million people. By the year 2005 it is projected that there will

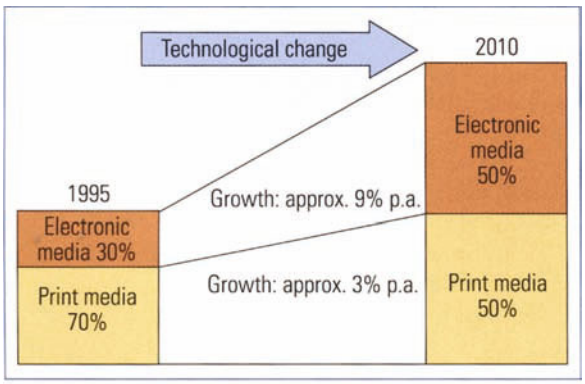
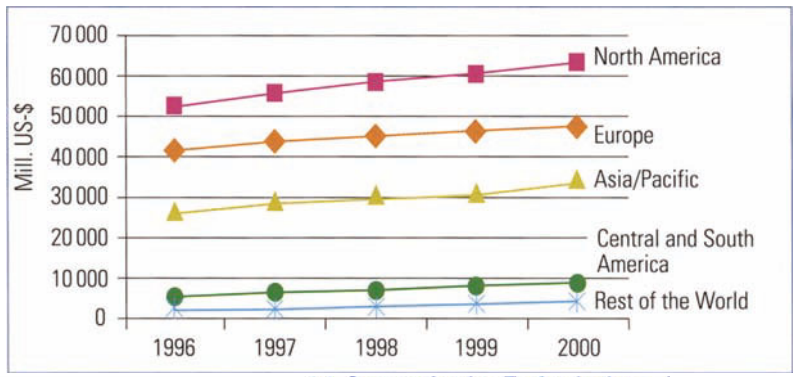


Fig. 1.1-8
Development trends in the market for print and electronic media (Status:1999; worldwide sources of information)

Fig. 1.1-9
Advertising expenditure for print media in individual regions [1.1-1]



be more than 400 million users. According to a study by Active Media Research, New York, three thousand companies interviewed worldwide said that annual turnover for online shopping via the Internet had increased four-fold. By the year 2001 the turnover from trade on the Internet (electronic commerce) is expected to have reached a level of US dollars 220 billion [1.1-4], equivalent to about 1% of the volume of world trade. Eighty percent of this is made up of transactions between individual companies (business-to-business). Even large, globally active businesses are still making little use of the opportunities the Internet has to offer. There are large global differences as far as online connections but also use of the Internet are concerned. With the exception of the Scandinavian countries, Europe lags far behind developments in North America.

At the turn of the millennium Internet users are creating great problems for advertising agencies. In about 80% of cases they are male, around thirty years old, educated, and have a passion for computers. Sixty percent of all users visit fewer than ten web sites per month. Hence it is impossible for advertising agencies to reach a particularly differentiated target group, in contrast to the possibility of targeted advertising messages in individual print media. Whether and at what rate the Internet is exploited depends to a considerable extent on the acceptance of the new technologies by a broad population base.

In this respect, participants in a study were asked about their expected use of print media in by year 2001. Figure 1.1-12 shows the result of this survey. The majority of the population expect to be making at least as much and possibly even more use of print media. This positive correlation in the use of new and old media has been established by several studies (amongst others [1.1-5] and [1.1-6]). The combined use grows proportionally with the level of education (e.g., [1.1-7]). Hence, from the point of view of the user, there is no indication that by 2002 the Internet will cover substantial parts of the print markets.

History has demonstrated that the "new media replace old media" theory did not hold true in the past [1.1-8]:

- During the 1920s:
  Radio was to replace printing.
- 1950s:
  Television was to replace printing.
- 1980s:
  The computer was to replace printing.

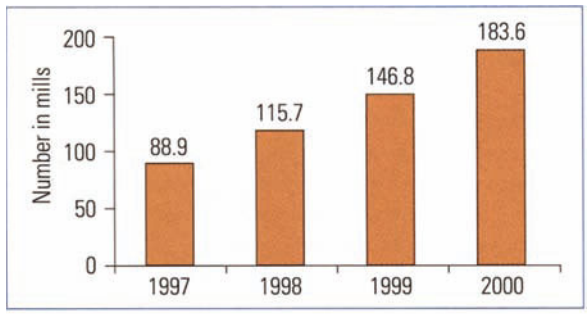


Fig. 1.1-10 Number of computers networked worldwide [1.1-2]

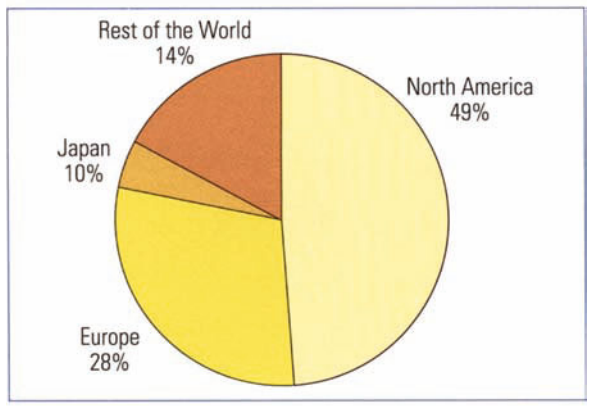


Fig. 1.1-11
Distribution of computers connected online by country [1.1-2]

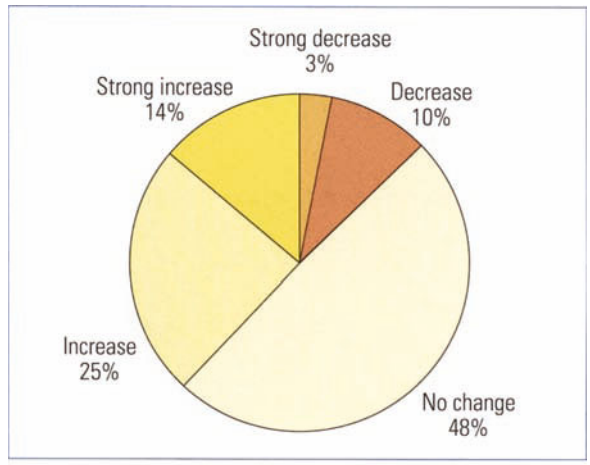


Fig. 1.1-12
Survey on the expected use of print media in 2001 [1.1-3]

- 1990s:
  The Internet was to replace printing.

The fact is that print is still a dominant medium and is continuing to grow.

Besides the Internet, the CD-ROM also has an important part to play. These powerful data carriers, on which a wealth of product information, pictures, video sequences, etc. can be stored easily and cost-effectively, have already firmly established themselves as a part of everyday life. However, as soon as the necessary infrastructure is in place and covers a large geographic area, the Internet should reduce the popularity of the CD-ROM as a medium for data transfer. As a medium for storage, the CD-ROM will be replaced by more efficient media.

We can very easily imagine so-called hybrid forms appearing – that is, combinations of various media such as magazine and CD-ROM, Internet and CD-ROM, or Internet and print. In other words: multimedia information transfer.

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1.2 Production of Print Media

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1.2.6	Premedia	38

As shown in figure 1.2-1, the *production flow* involved in the production of print media comprises the stages of *prepress*, the actual *printing process* (press) itself, and *finishing* (postpress). These individual production stages are connected by the *flow of materials*, such as printing plates between prepress and press and printed sheets between press and postpress. Interconnection between the production stages has become increasingly marked by the *data flow*. Information is exchanged both for the actual production of special printed products and for the organization of the business and the production cycles. Information and data are an essential requirement for the optimal and reliable functioning of individual production processes

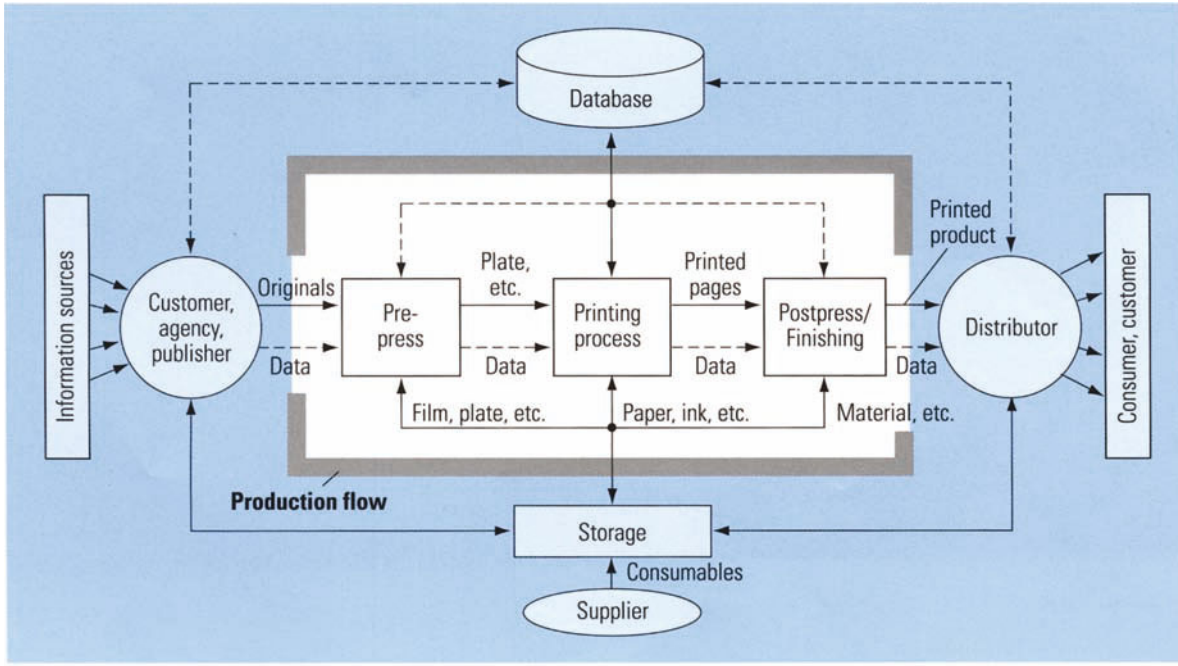


Fig. 1.2-1 Production flow, material and data flow for print media production

H. Kipphan (ed.), *Handbook of Print Media*
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and equipment, and for efficient, high-quality, and economic production.

Figure 1.2-1 shows that the content, layout, and form of the printed product are based on information in the form of originals and also particularly on data. Figure 1.2-1 also depicts how the printed product is delivered via the distribution system to the end-user/consumer; here, too, organization and distribution benefit from the data technology.

The production chain of prepress, press, and postpress is logistically interlinked through storage areas for the materials needed for the production as well as by storage areas for the semi-finished and end products of the printing job. The use of efficient production management and archive systems for data to link and support all the manufacturing stages in the creation of printed products is becoming increasingly the state of the art.

The individual stages and areas involved in the production of printed matter are explained below. Full descriptions with numerous details will be found in later sections of the book.

The quality of a printed product is ultimately determined by its content, effect, and benefit to the client/consumer. The visual quality is obviously affected by high-grade processes and procedures for producing the print media. However, it is to a large extent determined by the *conception of the print medium* in text, graphics, and pictures, the representational form of the contents, that is, by *layout*, *typography*, and *graphic design*.

Before going into the actual production process – the economical and high quality duplication of information through printing tailored to the customers and the market – we will describe the rudiments of design.

1.2.1 Layout, Typography, Graphic Design

The development of type, typography, and graphic design is an important part of the history of culture as a whole. Although knowledge of other spheres of culture such as painting, music, and literature is much more widespread, it is the symbols constituting language that make communication and the dissemination of knowledge throughout the world possible. These three areas are inextricably linked: *type* is an essential element of *typography* and typography is (besides illustration and photography) an essential part of *graphic design*. Each of these means of communication and design has its own subtly different historical development, which can provide detailed insights into the whole of human development from a historical, technical, and aesthetic perspective.

1.2.1.1 Type

Origin of Type

Type first developed over the course of time as a magical feat on man's journey out of the unknown. It was a *pictographic system* of type that probably grew out of the human craving for knowledge and communication. These pictographic symbols lacked accuracy and precision, they were ciphers in need of interpretation. As human understanding grew deeper and more refined, so too did the need to design and set down clearer, more universal and accessible codes.

Pictographic system was followed by *logograms*, which were derived from the sound of the spoken word (fig. 1.2-2). Each word had its own symbol, and the more distinctive and developed a spoken language was, the greater the number of symbols it had. There were well developed writing systems in China, India, Egypt, Mesopotamia and some other countries.

Around 3000 BC the Sumerians developed *cuneiform script*, a syllabic writing system made up of about six hundred characters. The next decisive step was the de-

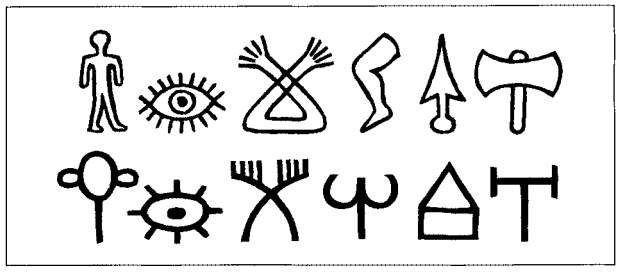


Fig. 1.2-2 Minoan hieroglyphs (above), Minoan linear type (below)



Fig. 1.2-3
Alphabets (Phoenicia, Greece, Rome; sixth to third centuries BC)

velopment of the *consonant alphabet* by the Phoenicians around 1400 BC. This alphabet consisted of twenty-two letters. It was derived as a simplified version of Egyptian hieroglyphs and Babylonian cuneiform script. The Phoenician alphabet (fig. 1.2-3) formed the basis of all European writing systems.

Around 1000 BC the Greeks adopted Phoenician script and introduced the symbols a, e, i, o, and u. The Roman alphabet was based on this development by the Greeks. The Roman capital script "Capitalis monumentalis" was developed (fig. 1.2-4), the increasing use of which led to the formation of the first *lower case type*. These early centuries AD also saw the move away from scrolls to the form of books still in use today.

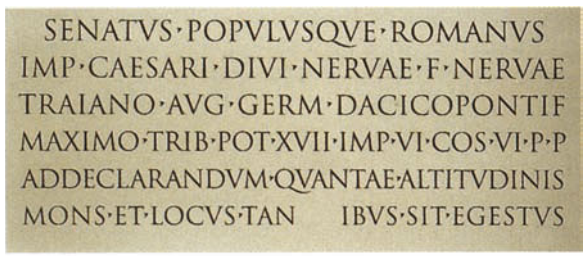


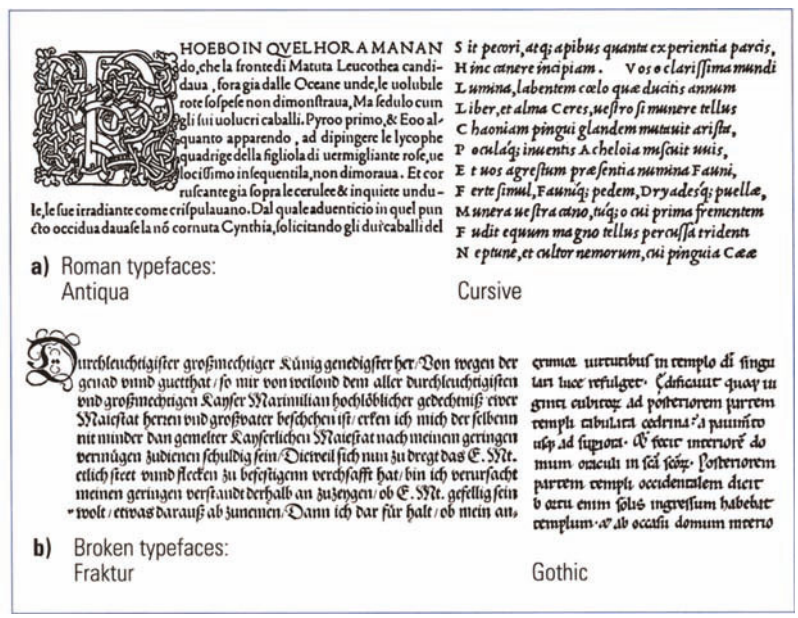
Fig. 1.2-4

Roman capitals "Capitalis monumentalis"; alphabet on the plinth of Trajan's column in Rome (AD 113)

The Middle Ages (fourth to fifteenth centuries) was a time of extensive writing and design. The carriers of written characters and text were clay, stone, wood, silk, papyrus, and then parchment. In the 7th century *paper* from China reached the Middle East, and from there Spain and the rest of Europe. The invention of duplicable printing first in China (c. 870), then in Korea with *movable metal type* (c. 1403), and finally Gutenberg's technical developments in letterpress printing (c. 1440) heralded a new era of communication, replacing the hitherto handwritten one-off texts which required rewriting in order to be passed on.

While at first old types were simply molded in lead for the new technology, new *typefaces* soon developed which have retained their formal elegance and character as model typefaces to this day: important designs originate from Claude Garamond (1480–1561), Nicolas Jenson (1420–1480), and Aldus Manutius (1459–1515). Soon after Gutenberg's invention two distinct technical concepts regarding typeface co-existed in parallel: the Roman types Antiqua and Cursive, and the broken types Fraktur, Gothic, and Schwabacher (fig. 1.2-5). From these basic forms, which were derived from the handwritten script, thousands of different typefaces were developed that had slight but important differences between them. Technical innovations as well as the quest for aesthetic improvements each led to yet more variants.

Fig. 1.2-5 Types.
a Roman types: Antiqua; Cursive
b Broken types: Fraktur and Gothic



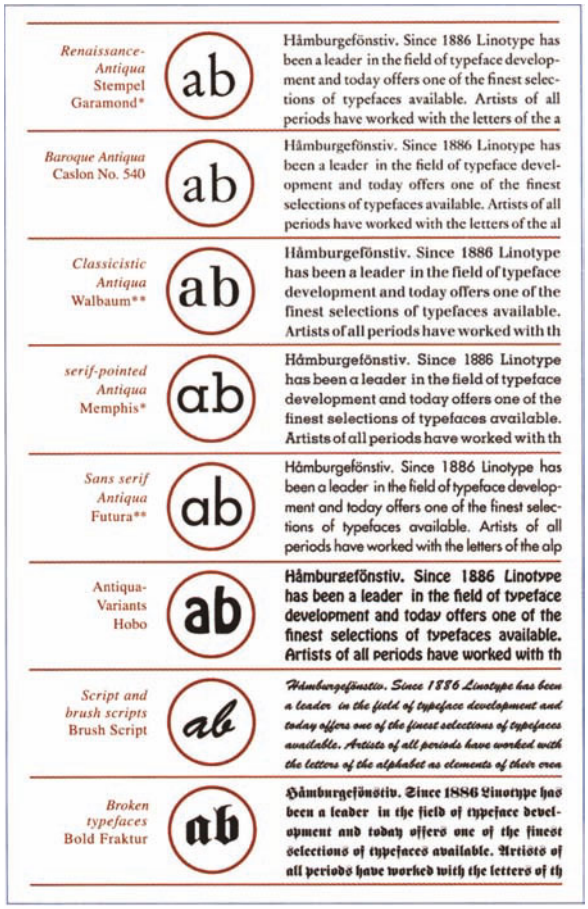


Fig. 1.2-6
Classification of typefaces (examples from DIN 16518, engl. version available)

Classification of Typefaces

The classification of typefaces formulated in 1964 (DIN 16518) allows the technical differences of all typefaces to be grouped into eleven distinct styles (see also examples of type in fig. 1.2-6):

1. Venetian Renaissance-Antiqua (Venitian)
2. French Renaissance-Antiqua (Old Face)
3. Baroque-Antiqua (Transitional)
4. Classical-Antiqua (Modern Face)
5. Serif-pointed Linear Antiqua (Slab Serif)
6. Sans Serif Linear Antiqua
7. Roman Variants (Decorative and Display)
8. Script
9. Handwritten Antiqua (Handwriting)
10. Broken types
11. Foreign types (non-Latin, non-Roman).

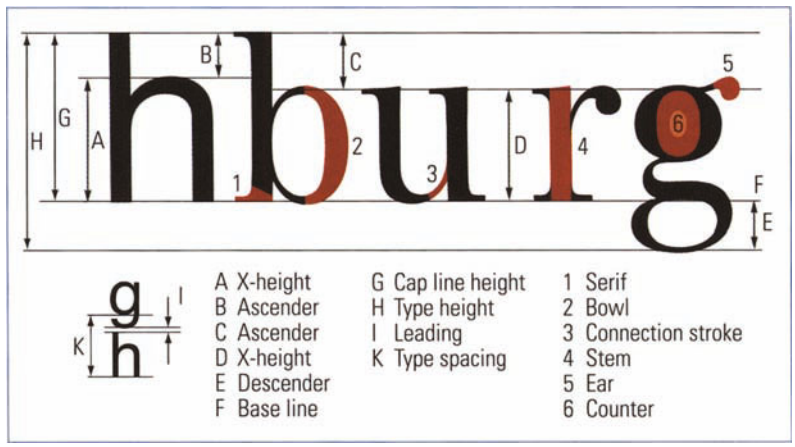
Even the latest typefaces may be technically understood and classified using these groups. At present there is a new amended DIN classification in preparation, the content of which is, however, still under discussion.

The basic construction of letters with their corresponding descriptions is shown in figure 1.2-7. The construction of letters in digital form is explained in section 3.1.1.3 and figure 3.1-2.

Design of Typefaces

Despite the numerous alphabets in existence, surprising new typefaces continue to be invented whose form best fits the spirit of their age. Some of the most important designers of the past were Anton Janson

Fig. 1.2-7
Construction of letters and naming of elements



(1620–1687), William Caslon (1692–1766), John Baskerville (1708–1775), Giambattista Bodoni (1740–1813), and Justus Erich Walbaum (1768–1837). Important typeface designers of the twentieth century were Emil Rudolf Weiss (1875–1942) with Weiss Antiqua and Weiss Gothic, Rudolf Koch (1876–1934) with Wallau and Cable, Paul Renner (1878–1956) with Futura and Plaque, Eric Gill (1882–1940) with Gill and Perpetua, Georg Trump (1896–1985) with City and Delphin, Karlgeorg Hoefer (1914–2000) with Salto and Permanent, Hermann Zapf (b. 1918) with Palatino and Optima, and Günter Gerhard Lange (b. 1921) with Arena and Concorde.

Among the typeface designers who create today's significant and widely used alphabets are Hans Eduard Meier (b. 1922) with Syntax and Syndor, Ed Benguiat (b. 1927) with Souvenir and Barcelona, Adrian Frutiger (b. 1928) with Meridien and Frutiger, Matthew Carter (b. 1937) with Galliard and Bitstream Charter, and Gerard Unger (b. 1942) with Swift and Gulliver. In the immediate present the new designs of Hermann Zapf and Adrian Frutiger are receiving particular attention. With his Zapfino typeface (1998), Zapf developed a calligraphic typeface that has achieved surprising technical versatility in this group of typefaces (fig. 1.2-8) by drawing on the possibilities of computer technology.

Frutiger's typeface Univers (fig. 1.2-9) was developed during the years 1953 to 1957 and became a classic of the modern age. In 1997 it was revised within the Linotype Library as Linotype Univers with 59 type styles (up to then, there were 21 type styles), making it all the more versatile in use.

Despite all the changes and advantages brought by technology compared to the Middle Ages, the design of typefaces is still a process which has lost nothing of the seriousness of the original way of thinking, of knowing what constitutes technical and aesthetic quality, and of the need to familiarize oneself with the essential elements of symbols for communication. Only few designers have so far succeeded in achieving the highest quality with their typefaces.

Besides Western typefaces (see DIN 16518 classification), there is an extremely large group of non-Latin, foreign types that have developed in their own way and have highly elaborate technical requirements: among others, there are Greek, Cyrillic, Hebrew, Arabic, Chinese, or Japanese types, which, with slight differences in typeface design, represent the languages of those regions and provide a diverse range of alphabets permitting typographic forms rich in detail (fig. 1.2-10).

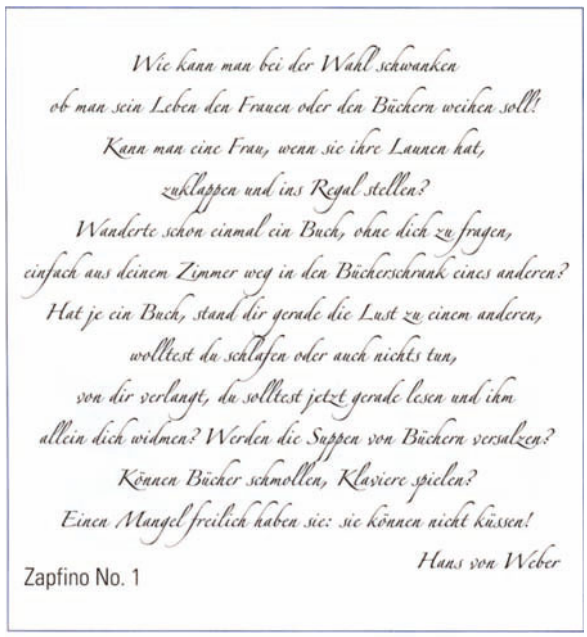


Fig. 1.2-8
Zapfino of Hermann Zapf (1998); Zapf wrote this text in his notebook in 1944; the characters were the beginnings of Zapfino

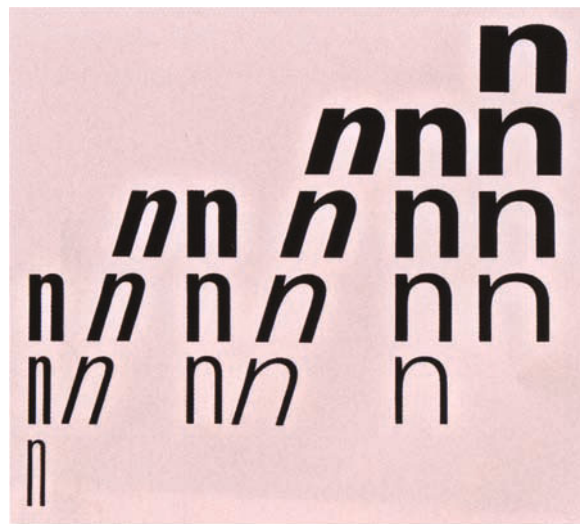


Fig. 1.2-9
Univers of Adrian Frutiger; examples of the various type designs (around 1955)



Fig. 1.2-10 Examples of non-Latin script

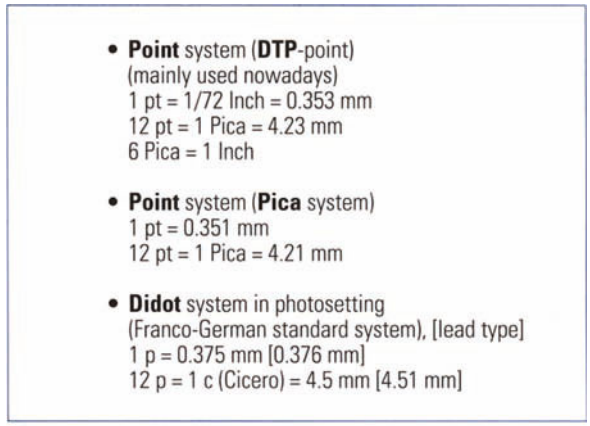


Fig. 1.2-11
Comparison of typographic and metric systems of measurement

1.2.1.2 Typography

Type in its various forms is a fundamental requirement of typography. To put it simply, typography is basically the *design of printed text* using and arranging typefaces to create continuous text on a printed page. The selection of available typefaces used to portray texts and textual content and the layout of words and texts on pages or other text carriers such as boards and signs is an area of design requiring many years of apprenticeship or study, followed by consistent practice for purposes of refinement, improvement, or change.

All printing elements such as text or lines, but also the non-printing segments such as empty areas or spaces, have their own measuring system, the *point system* (fig. 1.2-11). It was developed in 1795 by Francois Ambroise Didot and his son Firmin. One point (pt) measures about 0.38 mm. One Cicero corresponds to 12 points or 4.5 mm. In Anglo-American countries the unit pica/point is used, which, at about 4.2 mm, is smaller than the Franco-German system.

Choosing the individual *design elements* for the typographical job at hand is done by selecting from a system consisting of many interrelated parts. As with all design problems, there are no hard and fast rules for making this selection, but only approximations gained from experience, which can vary over time and from different perspectives. The designer's ability to interpret form is very important in choosing the font. The Linotype FontExplorer can be very helpful in this respect. This new typeface browser enables selection of the correct fonts according to many design criteria.

It is apparent that the sensitive use of typeface determines the quality of the typography and that a fresh approach must be used for every job. After the choice of *font* comes the setting of the *font sizes* (fig. 1.2-12) for the various parts of the text, the setting of the *type styles* (e.g., light, regular, or semi-bold), and the *inclination* (e.g., normal or italic). The font color and style (e.g., upper case, lower case, mixed) must also be determined.

Once these have been decided it is necessary to establish the *text structure*: how far apart the individual lines are, what degree of line spacing (leading) there will be, what column width should be set and which *justification* will be selected. There is a distinction between justified (fig. 1.2-13a), unjustified (fig. 1.2.-13b), and centrally justified. It is important to establish whether each of the text paragraphs is to have an *indent*.

A few of the recommendations for good, *legible typography* indicate what the basic problems of design are: there should be a maximum of around 60 characters per line and around 40 lines per page. Lengthy texts should be set no smaller than 9 point and no larger than 11 point. The leading (line spacing minus size of type height) should be 2 point.

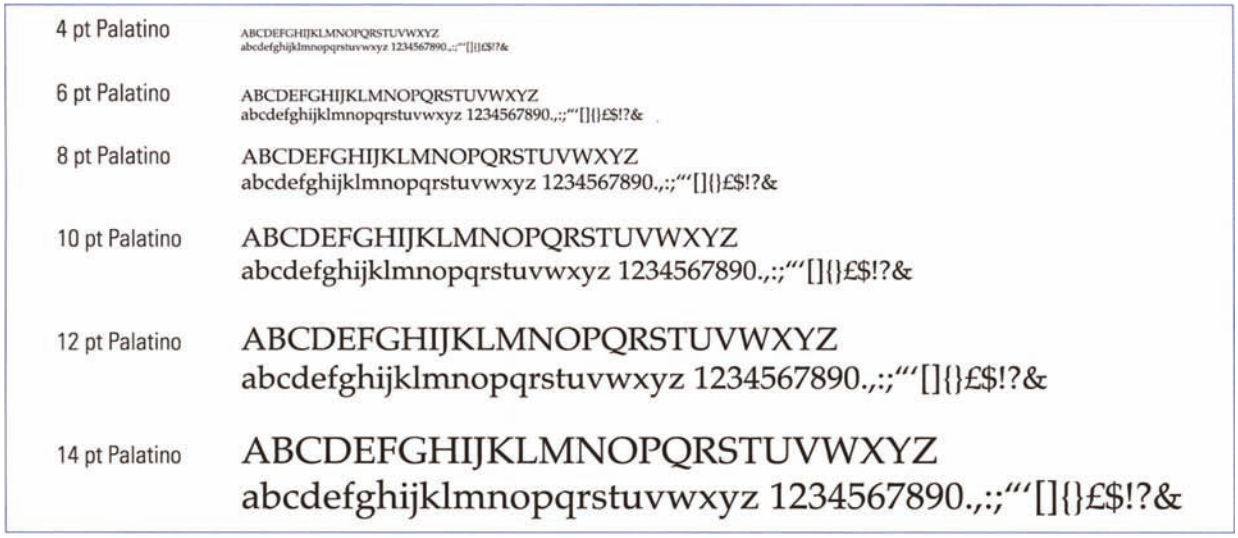


Fig. 1.2-12 Example of type sizes in Palatino

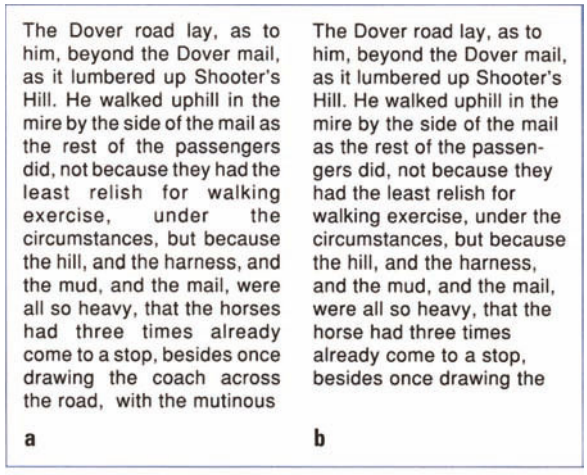


Fig. 1.2-13 Layout.
a Justified;
b Unjustified

The technical requirements of lead type and the typesetting system created for it determined to a large extent the form typography was to take. As a rule right angle designs with horizontal lines were created. Various aesthetic ideas repeatedly gave rise not only to new typefaces but also novel typographical styles.

The twentieth century saw the appearance of historically oriented shapes (figs. 1.2-14 and 1.2-15) and expressionist and pictorial styles. There were functional and elemental styles, as well as experimental fads such as psychedelic or punk typography (figs. 1.2-16 to 18). Typography used graphic and pictorial elements as typefaces or alternatively created pictures using lettering. However, the basic typographic styles for reading matter have not changed since Gutenberg's time, but have been continually refined.

Layout and Typography of the Present Book

The technical construction of the present book was established at the planning stage by making various mutually compatible decisions about the design. Taking this as an example the extracts show the best methods of designing a book to optimize its legibility and aesthetic impact.

Typefaces

Basic Typeface/Body Type:
Springer Minion Plus Regular, 10/11.3 pt (type size/ line spacing);
for marking (emphasis): Springer Minion Plus Italic, 10/11.3 pt.

Headings:
Linotype Univers Condensed Bold, in color (similar to Pantone 647c),



Fig. 1.2-14
Cover page of the trade journal Graphische Technik (July 1940)

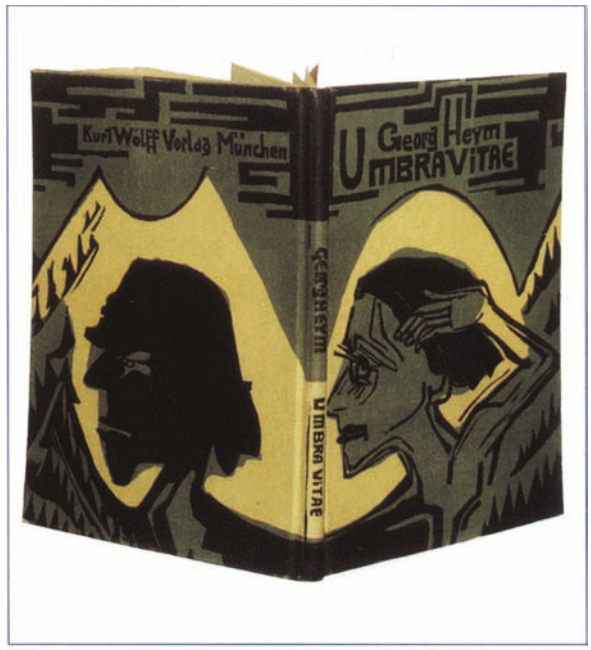


Fig. 1.2-16 Expressionist book jacket (Ernst Ludwig Kirchner 1924)

Fig. 1.2-15
Cover page of price list done in Art Noveau (approx. 1900)



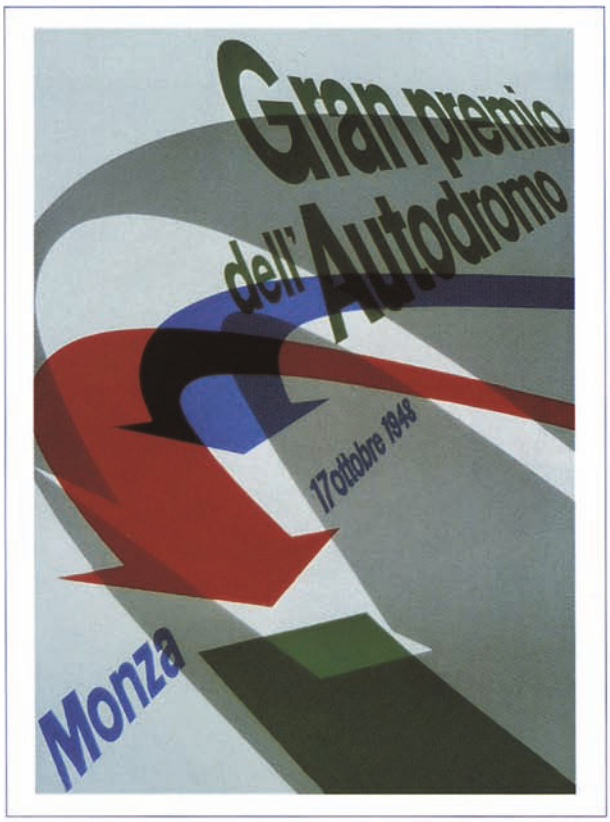


Fig. 1.2-17
Event poster with functional elements for representing the content (Max Huber 1948)



Fig. 1.2-18
Psychedelic poster for a concert from the flower-power movement (Wes Wilson 1966)

First-Level (title): 36/36 pt;
Second-Level: 18/19 pt;
Third-Level: 12/13 pt;
Fourth-Level: 10/11.3 pt.

Headers (Headings without Order Numbers):
First-Level: Linotype Univers Condensed Bold, 10/11.3 pt, black;
Second-Level: Springer Minion Plus Bold, 10/11.3 pt.

Numbering of Figures and Tables:
Linotype Univers Condensed Bold, 9/9.5 pt, in color.

Figure Inscriptions:
Linotype Univers Condensed Light, 9/9.5 pt, black.

Typeface for Captions:
Linotype Univers Condensed Light, 9/9.5 pt, black.

Column Lines/Running Head:
Linotype Univers Condensed Light, 9/9.5 pt, in color.

Special Typefaces:
Springer Symbol, Heidelberg Symbol.

Page Layout

The text is set justified on the base line grid in two columns; highlights are italicized; paragraphs start with a 3 mm indent in the first line.

A bullet is used as the first-level numbering symbol; a dash (en rule) is used as the second-level numbering symbol. There is an empty line spacing before and after a list. The following paragraph is not indented.

Besides pure typeface decisions all other aspects of the book were also determined:

- the page format (193 mm × 242 mm),
- the type area with two columns (156 mm × 200 mm),
- the column width (76 mm).

The figures are preferably single column, double column, or 1.5 column width; the frames are 100% colored and 0.4 pt thick (for figures without a background), all figures with a background (e. g., photographs) remain frameless; pictures are centered within the frame.

Figure captions appear below the figure and are set justified; for 1.5 column width figures they are next to the figure and unjustified; the distance between the caption lines and the edge of the picture is 3 mm.

The figure number stands on its own if the caption text is longer than one line, otherwise it is at the beginning of the line without a following period. The part-figure designations (a, b, c, etc.) are printed black and in bold. They are always placed on their own line.

1.2.1.3 Graphic Design

For many centuries design was of a conservative nature and governed mostly by religious content. The demand for consumer goods that increasingly accompanied the expanding economic systems after the French and particularly the industrial revolutions led to an avalanche of printed matter. Up to the late nineteenth century, designs were mostly black and white, printed on paper, and relatively rare. In the twentieth century printed products such as posters, advertisements, prospectuses, magazines, and of course books, became important media and were widely distributed. This meant that information had to be continually designed to attract attention. This was achieved through long print runs, large formats, a striking amount of color, but also topical subjects. Photographs soon came to be used as well as illustrations.



Fig. 1.2-19 Illustrative poster (Jules Cheret 1893)

Design in the Twentieth Century

The first high points of this new age were the great number of artistic-illustrative posters of surprising design produced by designers such as Henri de Toulouse-Lautrec, Jules Cheret, Eugène Grasset and A. A. Mucha (fig. 1.2-19). These designers were situated between the fine and applied arts, between the personal and general form. Informational subject matter also increased: the design of packaging, direction indicators, forms, charts, and corporate literature became tasks that no longer had to be solved with ardent artistic feeling but with clear conceptual designs.

It was the American William Addison Dwiggins who in 1922 first used the professional title "Graphic Designer" to describe more accurately the new type of designer, who was no longer to be an artist in the traditional sense. This title describes someone who has specialized in the *design of visual communication* and brings together the design tools of typography, illustration, photography, and printing with the aim of informing, teaching, or influencing. The term soon caught on.

The development of graphic design was influenced from widely divergent directions. On the one hand there were the traditionalists, who created designs using traditional artists' tools. On the other hand methods using new ideas of form and content arose, which made this new area of design an unmistakable part of twentieth century culture. The greatest contribution to this was the work of the "Bauhaus", a design school in Germany (fig. 1.2-20). The teachings of this school, which was in existence from 1919 to 1933, were further developed in Switzerland (fig. 1.2-21). After

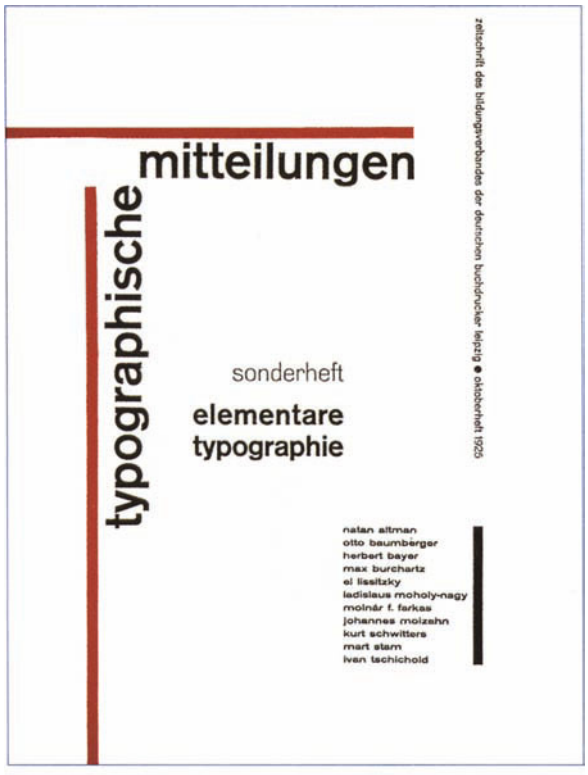


Fig. 1.2-20
Magazine cover in elemental design (Jan Tschichold 1925)



Fig. 1.2-21
Concert poster in the style of "Swiss typography" (Josef Müller-Brockmann 1960)

1945, exemplary achievements from the USA transformed this European development into the varied and differentiated field which characterizes graphic design in the world today (fig. 1.2-22).

1.2.2 Prepress

Prepress includes all the steps which are carried out before the actual printing, the transferring of information onto paper or another substrate (fig. 1.2-23). Traditional prepress is divided into three areas:

- *composition*, that is, recording text, formatting text, and pagination;
- *reproduction* of pictures and graphics, and particularly color separations for multicolor printing;
- *assembly and platemaking*, i. e., the assembly of text, picture, and graphic elements into complete pages, (page layout/make-up), from pages to print sheets,



Fig. 1.2-22
Advertisement for a magazine in contextual text-picture combination (Gene Federico 1953)

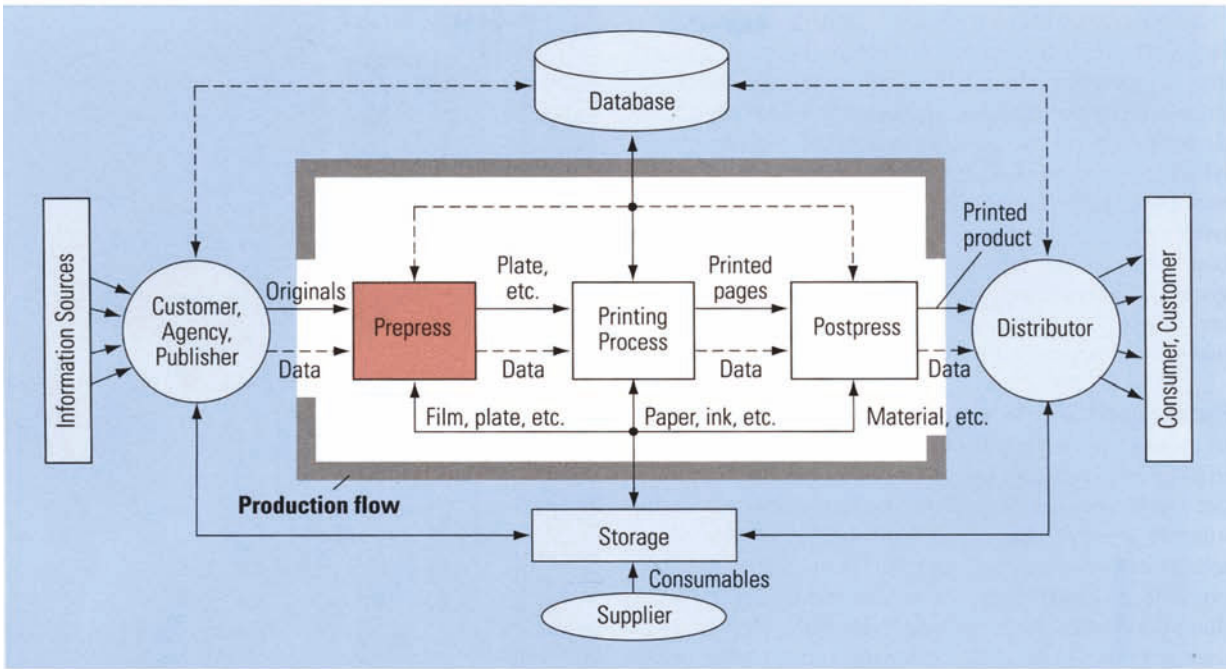


Fig. 1.2-23 Prepress in the production flow for the generation of printed products

and also the making of the printing plate as the vehicle of information in the printing press (fig.1.2-24).

Chapter 3 gives a detailed description of both so-called conventional prepress (sec. 3.1) and digital prepress (sec. 3.2).

Composition Technology

For centuries *composition technology* was dominated by the pioneering invention of Gutenberg – the letterpress with movable type. This process remained practically unchanged from the fifteenth until the end of the nineteenth century. Letters molded from lead were assembled into words, lines, and blocks of text (manual typesetting). Composition only became mechanized towards the end of the nineteenth century in the wake of industrialization. In 1885 Ottmar Mergenthaler developed a line casting machine, which became known by its trade name "Linotype." It made it possible to compose whole lines of matrices by means of a keyboard and to fill them with molten lead. This machine dominated composition until the 1960s – along with "Monotype", which operated in a similar way but produced individual letters, and the still indispensable manual typesetting.



Fig. 1.2-24
Prepress with conventional film stripping and digital master preparation (text, images, graphics) with EDP systems

As quicker and more effective printing technologies began to replace letterpress, particularly offset and gravure printing, the traditional lead composition was improved by innovations. *Photocomposition* began to be developed in the 1940s – at first, as an analog process, in which text was exposed letter by letter onto film through matrices. The breakthrough for photocomposition, and with it the decline of lead composition, first came at the beginning of the 1970s with *digital photocomposition systems*. This involved the transfer onto film of lines of text entered via a keyboard into the processor of a computer by means of cathode ray tubes and later by laser.

Pictures and Graphics

In the early days pictures and graphics were integrated in printed products in the form of woodcuts, and copper and steel engravings. *Reproduction technology* in the modern sense did not come in until the end of the nineteenth century as photographic procedures made it possible to capture pictures on film and to screen them, that is, to break them up into small dots. (*Screening* is necessary because with conventional printing technologies it is only possible to produce solid tints and not continuous tones. The continuous tone effect is simulated for the human eye by printing a number of tiny halftone dots of varying sizes next to one another.) An extra step with multicolor printing is the *separation of colors*, that is, the breaking down of color photos into the process colors used for the print (usually cyan, magenta, yellow, and black).

In *letterpress printing* the screened and separated film served first as an original for etching a relief in a metal surface (plate or printing block) from which prints were made. In *offset printing* the films can be used directly for platemaking. To check color reproduction quality before printing, a test print or proof can be made. This proof is produced photomechanically from the color separation films and simulates the result of the printing process.

In the 1970s the *scanner* emerged, which is used to optoelectronically scan, separate in colors, and screen originals and either directly record them on film by laser or first store them as digital data for further processing in a image processing system. Figure 1.2-25 shows a scanner for producing color separations, such as the ones for a four-color print shown in figure 1.2-26.



Fig. 1.2-25 Drum scanner for image capture (Tango, Heidelberg)

Platemaking

The task of platemaking is to assemble text, pictures, and graphics into pages and pages into sheets. Since the printing formats of most printing presses are essentially larger than the page format of the printed product, several pages are almost always printed on one sheet. The next step is to produce the plate for the particular printing technology.

The image carriers used for letterpress printing were traditionally made by combining blocks of text (consisting of individual letters or lines that were prepared in typesetting) and the blocks from reproduction to produce large metal forms. The platemaking for letterpress printing "flexography" is discussed in detail in section 2.3.3.

For offset printing the process films (text, graphics, and pictures) in accordance with the page arrangement are first mounted onto a film in the size of the printing format (offset assembly). The assembly then serves, at the subsequent stage for the purposes of photographic image transmission onto an offset plate in a contact method (offset platemaking). At the next stage the plate



Fig. 1.2-26
Color separations for four-color printing (Heidelberg)

serves as the image carrier for the offset press. In every printing technology a plate must be produced for each color to be printed.

Figure 1.2-24 shows how conventional methods (film assembly) as well as computer systems are used for artwork preparation (text, image, graphics) in prepress. Figure 1.2-27 shows how film assembly is set in the copying frame for platemaking in conventional copying process. Both films or plates can also be exposed using digital systems directly based on digital data, as is explained later.

For gravure printing, so-called Helioklischographs have been in use since the 1970s to make printing plates. Here, the films are mounted on the copy drum and the signals produced by an optoelectronic scanning head are transmitted to control an engraving stylus. This simultaneously engraves the image onto a copper cylinder which serves as the image carrier for gravure printing.

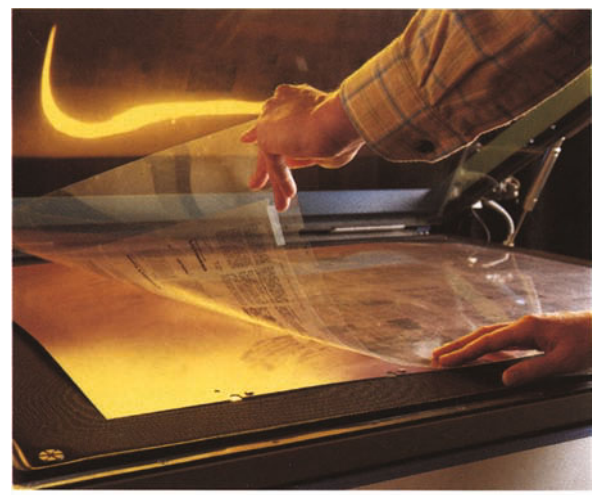


Fig. 1.2-27
Positioning of the film assembly in the copying frame for platemaking (Heidelberg)

Digital Prepress

Through innovations aimed at achieving digital prepress, an evolutionary change has taken place since the end of the 1980s in prepress which has almost entirely eliminated the classical division into the three areas of composition, reproduction, and platemaking.

During the 1980s, desktop publishing (DTP) became a serious alternative in prepress. This came as a result of the development of personal computers (PC) with full graphic capacity (e.g., Apple Macintosh), workstations, professional layout, graphic, and image processing software, the page description language PostScript, and high-resolution laser imagesetters with raster image processors (RIP).

Desktop publishing means that the capture and editing of text, the capture of pictures (scanning) and their editing, and designing of graphic elements, as well as the completing of pages (layout) can be carried out at one computer station. Used together with an output unit (imagesetter) the PC can also carry out color separations and screening of the finished pages, so that the whole page is exposed on a film (full-page film).

Obviously there are also programs for the digital sheet assembly which take over imposition and the positioning of printing aids (register marks, cutting

marks, etc.). With the help of a large-format imagesetter, films can also be produced in the format of the printing press. *computer to film technology* is the state of the art.

At the beginning of the '90s DTP took over the prepress almost overnight and has now almost completely replaced the specialized composition and image editing systems as well as photomechanical reproduction. Since around 1995 (even earlier for gravure printing), *computer to plate technology* (CtP) has played an increasingly important role. CtP means that the printing plate is imaged directly and the intermediate step of imaging a film is abandoned. In gravure, the cylinder is directly engraved using digital information. A further step in the production flow is therefore eliminated and ultimately all the prepress steps are carried out from a single computer workstation. There are already offset printing presses that use integrated exposure units to expose the plates in the press (direct imaging). Since no film is used in CtP, a previous proof must be made digitally, usually in the form of a proof print on a special dye sublimation, ink jet, or thermal printer.

Figure 1.2-28 shows how a full-page film is made in digital prepress with a computer to film unit and laser imaging of the film. Figure 1.2-29 shows how the printing plate is produced directly from the database of the digitally described printing sheet.

These technological changes in prepress have also brought about fundamental changes in the types of job offered in prepress. The tasks of the three classical occupations of compositor, reproduction technician, and platemaker can today be carried out at one work place by a single skilled worker. This was taken into account in Germany in 1998, when a new course training candidates to become "media designers" (see sec. 13.1.2) was created. After successful training the media designer is proficient in all prepress processes. Consequently, it is considered by many to be the most demanding occupation in the graphics industry.

Thanks to DTP practically any author or graphic artist who has access to a PC and the appropriate software can perform at least some of the steps involved in prepress. Although this has opened up many opportunities to individuals, it has, unfortunately, also resulted in an increasing flow of poor-quality printed products flooding the market. The creation of printed products by computer requires not only mastery of the program used and the necessary typography and design know-how, but above all an accurate understanding of the subsequent printing and finishing processes. It is usually only trained experts who are endowed with this expertise.



Fig. 1.2-28
Full-page film output on a computer to film system (Herkules, Heidelberg)

The diagrams in figure 1.2-30 show the process of evolution in prepress from the individual steps of composition, reproduction, and assembly to an integrated process for platemaking.

1.2.3 Printing

Printing is described as the process of transferring ink onto paper (or another substrate) via a printing plate (fig. 1.2-31). In the course of the centuries many different printing technologies have been developed and these can be divided into four main technologies according to the type of image carrier used as shown in figure 1.2-32.

In section 1.3 (and in particular in chaps. 2 and 5) the different printing technologies are dealt with in detail. In section 1.6 printing presses and systems are described in detail. First, a short overview.

Letterpress (Relief) Printing. Here, the printing elements (letters, lines, dots, etc.) are raised. When the printing plate is inked, the ink adheres to the raised (printing) parts and is then transferred under pressure onto the printing substrate. The main examples of this printing technology are *letterpress* which, until a few decades ago, was the dominant printing technology and *flexography* which, by the middle of this century, had started to be used more and more in packaging printing. With traditional letterpress



Fig. 1.2-29
Computer to plate system for digital imaging printing plates (Trendsetter, Heidelberg/Creo)

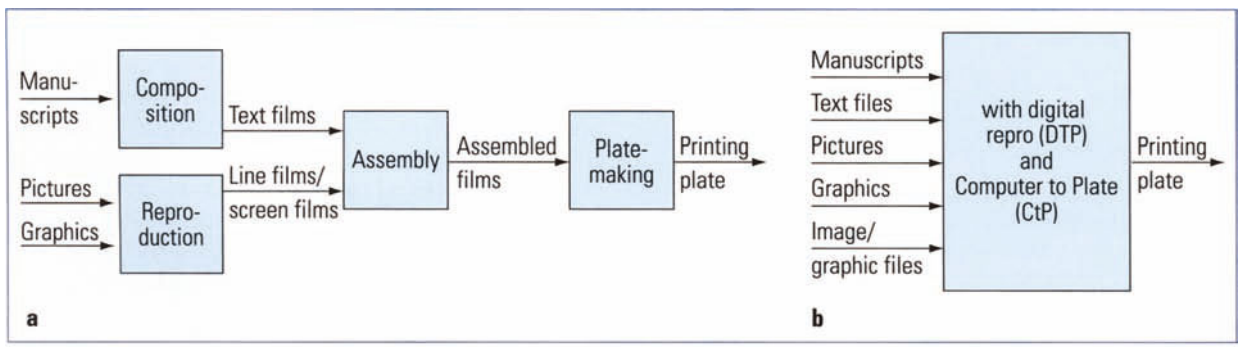


Fig. 1.2-30 Evolution in prepress through digitalization of the processing sections.
a Conventional prepress (around 1980);
b Digital prepress (around 1997)

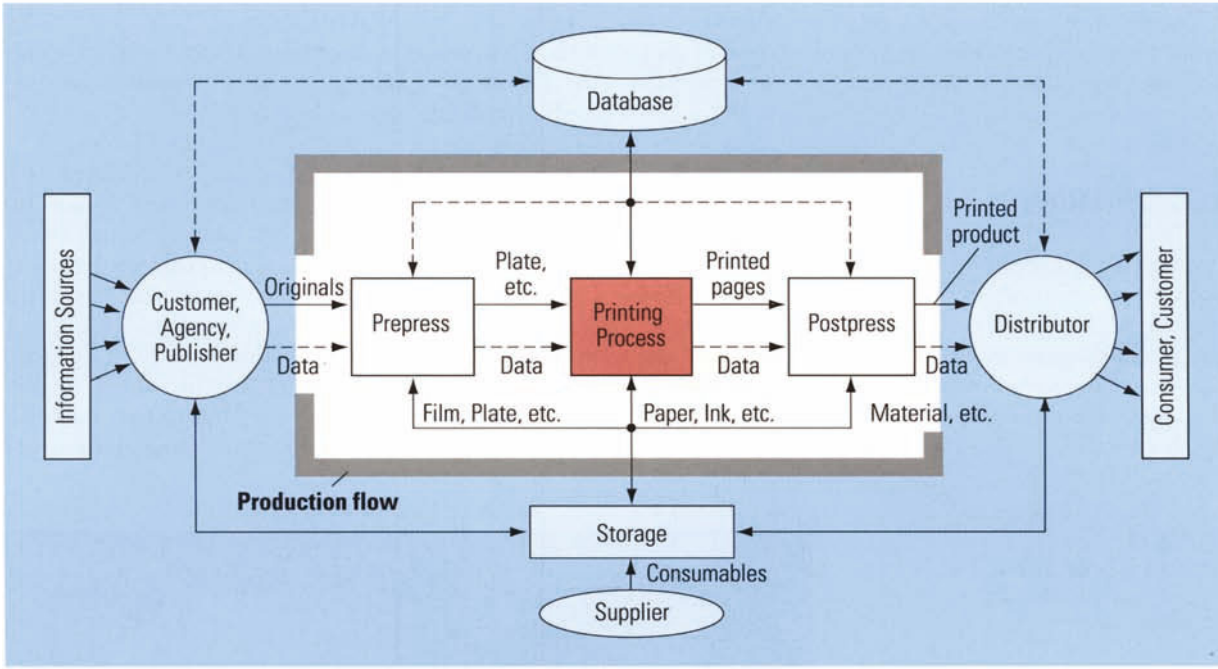


Fig. 1.2-31 The printing process in the production flow for printed products

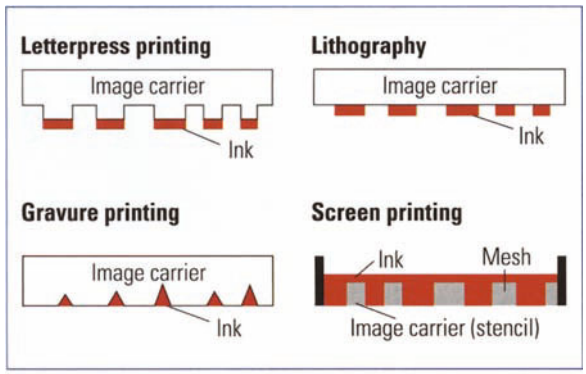


Fig. 1.2-32
The four main conventional printing technologies (in principle)

printing a hard metal printing plate (lead) is used and in flexography a flexible, soft rubber or plastic plate is employed.

Gravure Printing. Here, the printing elements are recessed. The gravure cylinder surface is covered with low viscosity ink ("flooded") and then passed under a doctor blade which removes all the excessive ink, leaving ink only in the recesses. The printing material is pressed onto the cylinder surface and takes up the ink from the recesses. The main examples of gravure printing are *rotogravure printing* and, in the area of arts and crafts, *copperplate engraving* and *die-stamping* (also security printing).

Lithography. Here, printing and non-printing elements are at the same planographic level but are usually made from different materials (e.g., aluminum and polymer coating) with different chemical and physical surface properties. During printing, the non-printing elements are usually made ink-repellent first (by wetting) and the plate is then inked so that the ink is taken up only by the printing areas. The main example of lithography is *offset printing*, which is today the dominant printing technology. Offset printing is an indirect printing technology, that is, the ink is first transferred to an intermediate carrier (rubber blanket) and from there onto the substrate (fig. 1.2-33).

Screen Printing. Here, the printing plate consists of a fine mesh (e.g., nylon). The non-printing elements of the mesh are blocked by a coating (stencil). As with

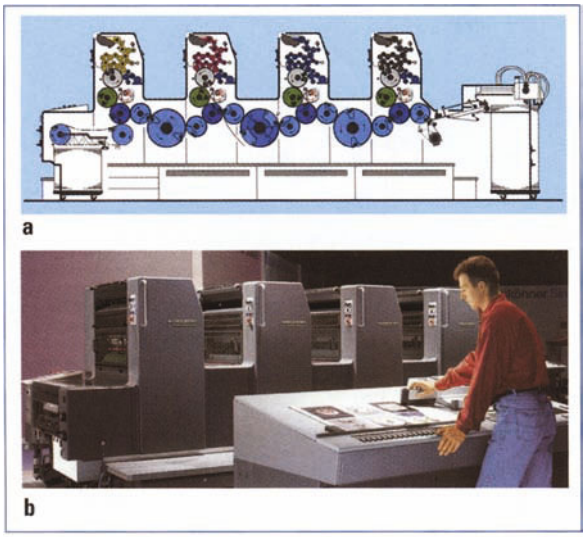


Fig. 1.2-33
Four-color sheet-fed offset press with a central control console and measuring and control technology.
a Press diagram;
b Press with remote control console (Speedmaster 74-4-P, Heidelberg)

gravure printing, the screen plate is covered with ink and a squeegee (blade) is passed over it. Through the pressure of the squeegee the ink is pushed through the screen onto the substrate lying below (see also fig. 2.4-11).

Printing Systems. In addition to the image carrier, each of these printing technologies require a back pressure element which presses the substrate onto the image carrier to transfer the ink. Gutenberg's press, an adapted wine screw-type press, worked on the principle of "plane to plane", that is, the image carrier and the back pressure element were flat. Middle- and large-sized letterpress machines of the nineteenth and twentieth centuries worked on the principle of "plane against cylinder", i.e., with a flat image carrier and a back cylinder which rolls on the image carrier. The currently dominant technologies of offset printing, as well as gravure printing and flexography, work entirely on the principle of "cylinder against cylinder" to achieve entirely rotating motion sequences in the printing unit. Only in this way is it possible to achieve the production speeds expected today of 5000 up to 100000 impressions per hour. Multicolor printing presses, where several printing units are located one after the other, are largely constructed on the cylinder/cylinder basis.

Figure 1.2-33 shows a multicolor *sheet-fed offset press* together with the relevant control and measuring equipment in the print room. Figure 1.2-34 gives an impression of the production process in the press room of a printing company.

The four classic (conventional) printing technologies have one thing in common: the image carriers (masters) have a physically stable structure and are therefore not variable, that is to say, with the same image carrier it is possible to reproduce the same image in high quality many times.

Beginning in the middle of the twentieth century several technologies have been developed that are known today as "*non-impact printing technologies*" (NIP technology). With these technologies, the printing plate is newly imaged for each printed copy (e.g., electrophotography) or the ink is directly transferred (without a plate or image carrier) onto the substrate (e.g., ink jet). One page after another can then be printed with a different content – even if there are limitations with respect to quality and productivity.

An example for a printing system based on electrophotography is the set-up for digital multicolor printing in figure 1.2-35. A detailed description is given in section 1.3.3 and chapter 5.

Until a few years ago the non-impact technology was no alternative to conventional printing technologies as far as either quality, speed of production or cost were concerned. However, in recent years in particular, electrophotographic printing has been greatly improved and has therefore become a genuine alternative in some print media market sectors. This is particularly true of low-volume printwork and jobs involving variable data



Fig. 1.2-34 Press room of a printing company

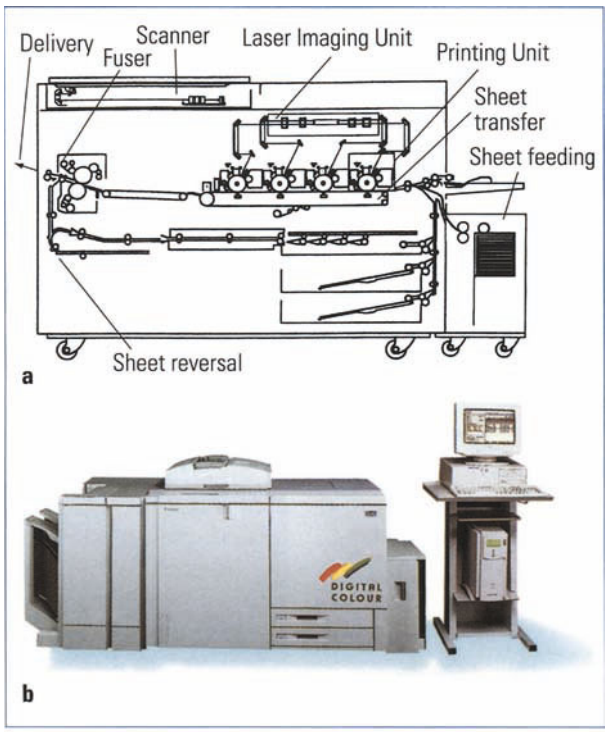


Fig. 1.2-35
Printing system for four-color printing (NIP technology: electrophotography).
a Schematic representation;
b Printing system (with sorter for collating individual sheets) (CLC 1000, Canon)

and/or information (such as mailings), since the image can easily be completely changed for each copy.

Sheet-fed and web-fed presses. Printing presses can be engineered as either sheet-fed or web-fed presses. *Sheet-fed presses* have a feeder, one or more printing units, and a delivery (see also fig. 1.2-33). In the feeder the sheets are taken from a pile, aligned, and forwarded to the first printing unit. The sheets are transported through all the printing units by grippers. In the delivery the printed sheets are collected in a pile.

Web-fed presses (fig. 1.2-36) have a reel stand, from which the paper web is fed to one or more printing units. This web is then fed straight to a print finishing unit or a rewinder after printing.

Web presses for high-quality print production are fitted with dryers to prevent smearing of the ink during print finishing. This is why heat-set inks are used



Fig. 1.2-36 Web-fed offset printing system (M-600, Heidelberg)

in offset printing. Newspaper offset printing is usually carried out with cold-set inks, which do not require a special dryer, but offer a lower quality. Gravure and flexographic (letterpress) printing requires a drying section after each printing unit, i. e. after printing each individual color.

Offset printing presses and non-impact presses are designed as web-fed and sheet-fed presses, while gravure presses and flexographic presses are almost exclusively engineered as web presses. Web presses reach higher speeds than sheet-fed presses and have the advantage that in-line finishing is easier to carry out. Web presses are usually designed for one particular type of product only (e. g., newspapers). Typical market segments are newspapers, magazines, packaging, and continuous/business forms. Sheet-fed presses have the advantage of shorter set-up times, less start-up waste, and variable formats and substrates. Almost all kinds of printed matter can be produced on sheet-fed presses where high quality and flexibility is a primary concern.

Conventional printing presses have become increasingly *automated* in recent decades. Today, almost all presses come with a *remote control* station which is used to control most of the press functions. Tasks which were previously always performed manually, such as format adjustment, changing of the printing plate, correction of the register, and cleaning of the rollers and cylinders, can now be carried out at the push of a button. A digital interface for prepress makes it possible to preset the ink flow for a particular printing plate. Several manufacturers already offer offset presses with integrated imaging systems, so-called computer to press/direct imag-

ing presses (see sec. 4.4). By their very nature, non-impact printing presses are already highly automated and can be almost completely controlled by computer.

In the last twenty years the automation of the printing press has led to a considerable increase in productivity and has raised the quality of both printed products and the work place while contributing to economically efficient production of printed matter.

1.2.4 Postpress/Finishing

Print finishing (postpress) includes all those steps which are carried out after printing on paper or another material has taken place (fig. 1.2-37). Finishing processes are as diverse as the methods of producing printed products, whether they involve books, newspapers, folding boxes, or sets of labels. In this section only the most common processes are described. Print finishing is dealt with comprehensively in chapter 7.

Processes such as *cutting*, *folding*, *gathering*, and *binding* are important print finishing technologies for producing a finished product. Figure 1.2-38 shows finishing processes using cutting and folding machines. The system shown in figure 1.2-39 is an example of gathering and finishing folded sheets. Figure 1.2-36 shows clearly how a web offset press, which includes a folder and other print finishing equipment, can produce complete brochures.



Fig. 1.2-38
Cutting and folding machines for finishing in the press room (Heidelberg)

Classical bookbinding, the production of hardcovers, today represents just a small part of the total finishing process. The following list includes the most important

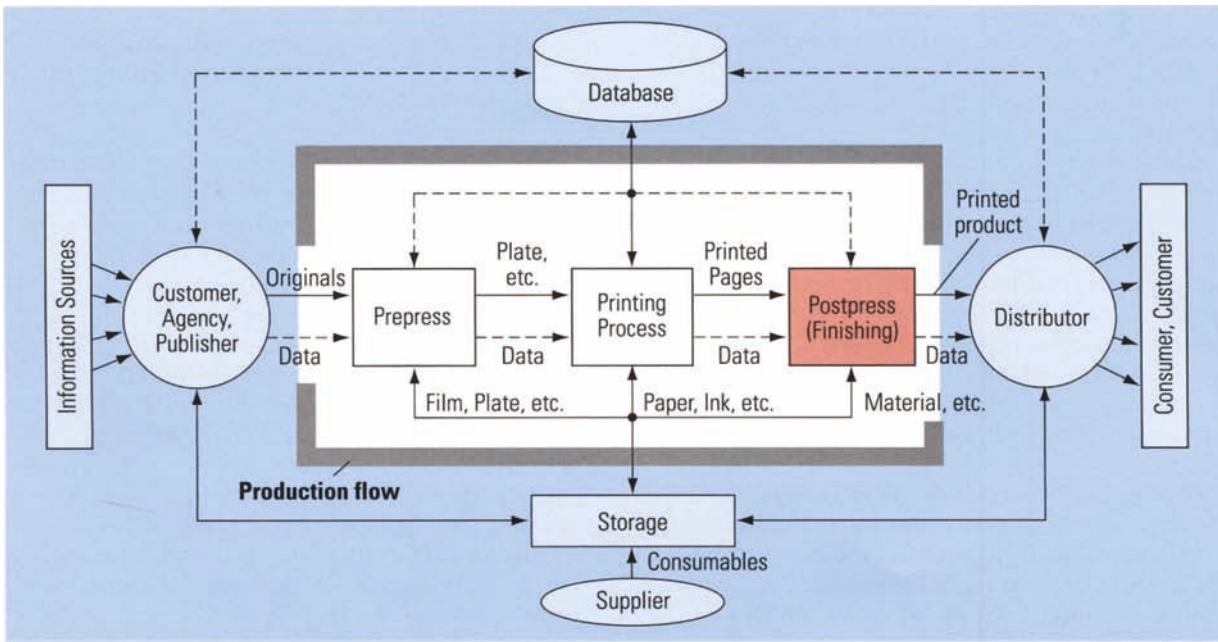


Fig. 1.2-37 Finishing processes in the production flow for printed products



Fig. 1.2-39
Gathering of folded sheets and further processing (stitching, cutting/3-side trimming, packaging) for the production of brochures (Prosetter 562, Heidelberg)

types of print finishing processes and related companies or departments of industrial print finishing:

- *Bookbinders* produce hardcovers and also perfect-bound (glued soft cover) brochures with higher print volumes.
- *Newspaper and magazine printing companies* have web printing presses (offset or gravure) with integrated print finishing units (in-line finishing).
- *Packaging printers* produce a great variety of packaging either off-line (e.g., folding boxes) or in-line (e.g., polyethylene carrier bags).
- *Label printers* are highly specialized in print finishing with automated cutting, die-cutting, and packing machines.
- Small and medium-sized printing companies are mostly connected with *finishers* where business stationery and other commercial printwork is processed, and perfect-bound and saddle-stitched brochures are produced.

Important print finishing techniques are explained below using brochure-making as an example: With *perfect-bound brochures,* glue is applied to the back and a stiff paper cover is attached (e.g., paperbacks, mail-order catalogues, and telephone books). *Saddle-stitched brochures* consist of several inserted double pages, which are fastened together at the fold with wire (e.g., magazines, periodicals). The production of brochures proceeds in five stages, which are explained below:

- *Cutting (guillotine cutting).* When several folded sheets (signatures) are printed with the same content on a large-format press, they must first be separated. The same applies to brochure covers and bound-in inserts (e.g., reply cards) which are mostly printed in multiple-ups, i.e. many copies with the same content on one sheet. Cutting machines work with vertical blades, which can cut through the paper pile to a depth of around 20 cm (see also fig. 1.2-38).
- *Folding.* The print sheets, which contain several printed pages, are folded with folders depending on format size (fig. 1.2-40). Imposition means arranging the pages on the sheet so that after folding and gathering several folded sheets, the pages are in the correct sequence. Imposition is a prepress process but always depends on the requirements or conditions of the finishing process.

In perfect binding (fig. 1.2-40b) the individual folded sheets are arranged behind one another, so sheet one contains pages 1–8 and sheet two contains pages 9–16. In saddle-stitching (fig. 1.2-40a) the folded sheets are placed inside one another, so sheet one contains the 8 outside pages (1–4 and 13–16) and sheet two, the inside eight pages (5–12).

- *Gathering/collating.* If a thirty-two-page brochure is printed with eight pages per sheet, it has four signatures. (The sections of a brochure are also called signatures). With a print volume of one thousand copies there will be four piles of one thousand folded sheets after folding. These must then be separated and arranged in accordance with the specifications of the brochure to be produced. Arranging sheets after one another (for perfect binding) is called collating and is carried out by special collating machines.
  Putting signatures inside one another (for saddle-stitching) is called gathering. This is carried out mostly on saddle-stitchers (fig. 1.2-39), which also carry out the sequential operations of stitching and three-side trimming.
- *Perfect binding/wire-stitching.* The assembled signatures for a perfect-bound brochure are first routed on

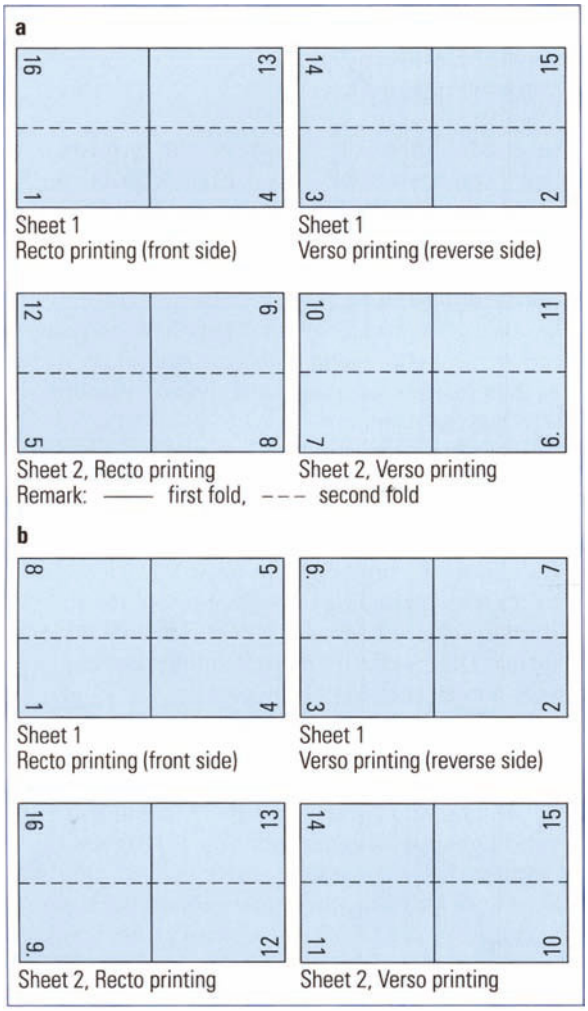


Fig. 1.2-40

Imposition layout (8-page, folded sheet) for two print sheets for a 16-page brochure.
a Layout for back-stitching (after gathering);
b Layout for perfect binding (after collating)

the spine to enable better penetration of the glue. The back (spine) is then thoroughly coated with glue (usually with hot-melt adhesive), and the cover is wrapped around it and stuck to the back. The machine for these operations is the perfect binder which can also be coupled with the upstream gathering machine and the downstream three-side trimmer.

In the gatherer-stitcher the assembled signatures of the saddle-stitched brochure are transported underneath the stitching heads, which push the staples through the back and bend them around.

- *Three-side trimming.* The sheets of the brochures bound in this way are not yet separated at the fold (e.g., on the head) as they still form a signature. Since they cannot be opened out at this stage, the folds have to be cut off. The brochures are usually cut on two, or all three sides (head, foot, and front), which at the same time means cutting the brochure to its final size. This cutting must be allowed for when preparing the job and in prepress, so that none of the contents are cut off. There are special three-knife trimmers used to trim three sides of a printed product. Modern gatherer-stitchers and perfect binders are equipped with in-line three-side trimmers.

Print finishing has been increasingly *automated* in recent years, but not nearly to the same extent as printing or, in particular, prepress. Due to the great variety of processes and the complexity of the mechanical processes, more manual intervention is required than in the other two areas (an exception to this is in-line finishing with web printing presses). That is why great efforts are being made in print finishing to introduce CIM (computer-integrated manufacturing) so that print finishing does not become the "bottleneck" in the production of printed material.

1.2.5 Digital Production Equipment in the Workflow

The production of printed products has increasingly changed from a craftsmen's trade into industrial production. As in other industrial sectors, *computer-integrated manufacturing (CIM)* is becoming important.

In recent years, computers and automated processing have had a considerable influence on prepress. The integration of prepress and press, as well as automation in printing and the integration of related processes, have also reached a certain maturity. In the other areas of production such as finishing, the integration of computers is by no means standard and is still in its infancy.

Complete digitization and integration of prepress, press, and postpress is unavoidable if computer-integrated manufacture of printed products is to be achieved. There are two main obstacles to its implementation. At the moment, partially incompatible systems and interfaces still exist and there is only a limited supply of machines and computers that can be electronically controlled, particularly in the print finishing sector.

Standardized data formats are of vital importance for the integration of prepress, press, and postpress since they facilitate an integrated interface for data which is necessary for the entire workflow.

Production planning and control are instruments for monitoring the production process. In chapter 8 the topic of material logistics and data flow will be dealt with in detail. Figure 1.2-41 relates to the theme of material logistics in the press room and in particular the transportation of paper pallets.

Planning the manufacture of a printed product is usually an upstream process, i.e., from postpress via press and back to prepress. This is best demonstrated with a simple example: A small sheet-fed offset printshop is given the job of making a catalog. The printshop has a prepress department with computer to plate equipment, a two-color press in 52 cm × 36 cm (approx. 20" × 14") format, a two-color press in 74 cm × 52 cm (approx. 29" × 20") format and a four-color machine in 74 cm × 52 cm format. The finishing department has a cutting machine, a folding machine, a gathering machine, a gatherer-stitcher with four stations and trimmers as well as a perfect-binder.

The customer's specifications for the making of the catalog require:

- binding: saddle-stitching,
- format: DIN A4,
- total pages: 32,
- paper: gloss coated art paper, 150g/m²,
- print: two color (black and cyan as decorative color), pages 1, 2, 31, 32 four-color CMYK,
- layout files with picture and graphics are already provided by the customer,
- run length: 1000 copies.

The maximum print format of the printshop is 74 cm × 52 cm, so 8 DIN A4 pages per sheet can be printed. Including the trimming allowance, a paper format of 62 cm × 45 cm is required. The number of pages comes to 32, and so requires 4 eight-page signatures. Printing and finishing require a 150 sheet waste allowance per signature for a run length of 1000 copies. Therefore 1150 × 4 = 4600 sheets are needed. Provided are: 4600 sheets of glossy art paper, 150g/m², in 62 cm × 45 cm format.

The production planning steps are as follows:

- *Finishing.* Because the customer wants a saddle-stitched catalog, the workflow is predetermined: the *folder* is set up for 2 right-angle folds, format 62 cm × 45 cm; folding of 4 signatures of 1000 sheets; makeready of the 4 *gatherer-stitcher* stations, format DIN A4; gathering, stitching, trimming of 1000 copies; *packing* of 1000 copies.
- *Printing.* In accordance with the sheet size, the 74 cm × 52 cm presses are used. The four outer pages are 4-color, all the others are 2-color. Since we are dealing with a saddle-stitched brochure, one 4/4 color signature (sheet 1) and three 2/2 colored signatures (sheets 2,3 and 4) are required. Making an allowance for waste, the print numbers per signature are: 1150 recto prints + 1150 verso prints = 2300 prints. The workflow is as follows:



Fig. 1.2-41
Transportation of material in the press room to supply sheet-fed presses with paper pallets

– four-color press: makeready – 1150 prints – change of printing plate – 1150 prints;
– two-color press: makeready – 1150 prints – 5 × change of printing plate – 5 × 1150 prints.

- *Prepress.* The pages are imposed according to the imposition layout for saddle-stitching and digitally assembled with 8 pages per sheet, taking into account the 3-side trimming. Folding and cutting marks are added for finishing and register marks and color control strips for printing. The individual printing characteristics of the two presses used for the job are taken into account for the plate exposure. Because of the quality demands of the customer, printing will be carried out on coated paper with a screening of 72 lines per cm. The printing plates are selected in accordance with the size requirements of the printing press.

With this *upstream planning*, a job can only be processed in prepress if the workflow for the subsequent areas is already laid out in accordance with the data provided. This means that almost all the information which is required for the printing and finishing processes flows into an image data file.

Digital workflow systems make use of these facts. They extract this information and make it available to the next work areas where it is used for the automatic set-up and presetting of the equipment. This means that existing data does not then need to be entered again at each press. Additional information can be taken from the computer-aided job preparation.

The following data which is relevant to production can be extracted from the image data file for the print job described (see also fig. 1.2-42):

- *For printing:* Sheet size, number of signatures for straight (recto) printing and perfecting (verso printing), number and type of inks, ink profile (ink distribution over the sheets in zones). Additional data from the job preparation: machine uti-

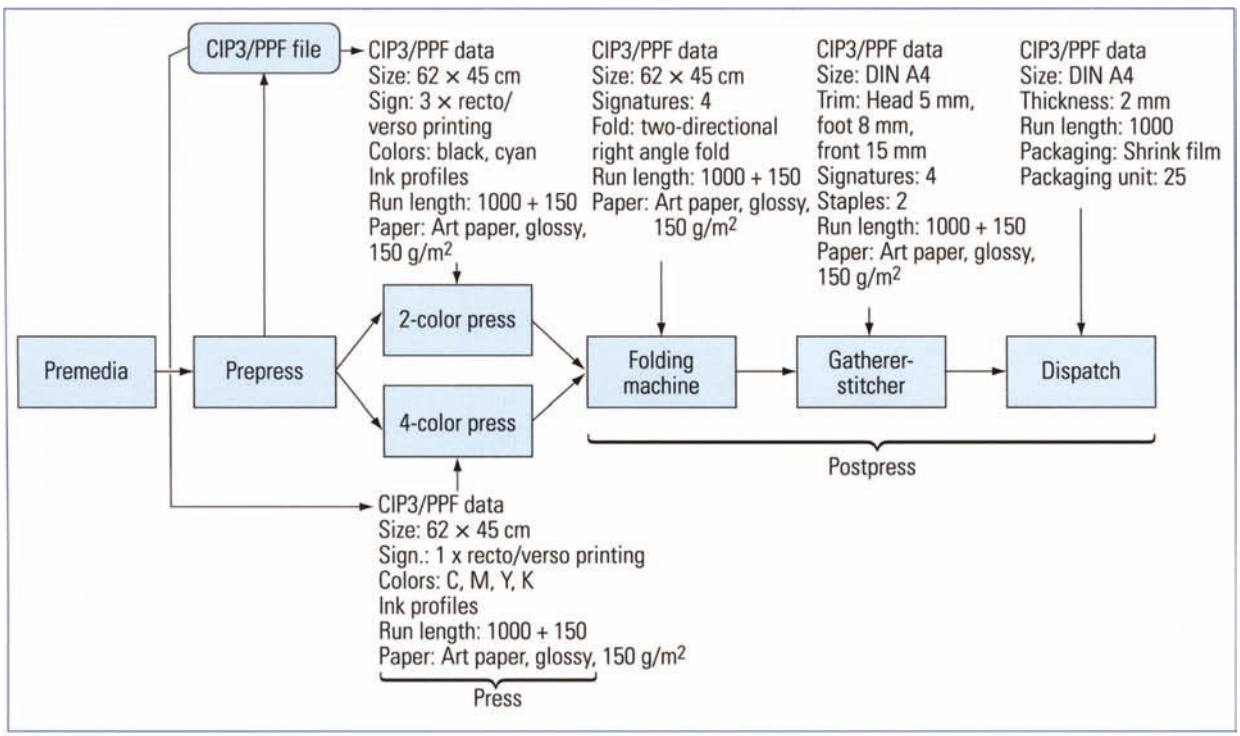


Fig. 1.2-42

Production equipment in the digital workflow for the production of print media with interfaces for processing CIP3/PPF data for the example given in the text of how a print job is processed (PPF: Print Production Format; CIP3: Cooperation in Prepress, Press and Postpress)

lization, run length, allowance for waste, type of material.

- *For finishing:* Sheet size, number of signatures, folding layout, type of binding and trimming. Additional data from the job preparation: machine utilization, run length, allowance for waste, types of material, packaging and distribution.

CIP3/PPF (Print Production Format) has been established as the standard format for the extraction and transmission of the data relevant to production. This format was worked out by a consortium of firms in the graphic arts industry (details are given in sec. 8.2.3). CIP3 stands for Cooperation in prepress, press, and postpress. Every printing and finishing machine with a CIP3 interface can be set up automatically for a particular job using a PPF data file. Printing presses with CIP3 interfaces are already available, and the technology is also beginning to penetrate the finishing sector. The aim of the development is the *networked printshop* where manual intervention in the workflow is minimized and throughput and delivery of the order can be sped up.

Figure 1.2-42 shows which CIP3 data can be used to control which machines.

1.2.6 Premedia

The preceding sections of 1.2 have shown how with today's prepress processes and equipment *the entire print job can be created in digital form* in a data file. On the basis of this data set, full-page films can be produced or the printing plate produced directly. There are printing systems which can be operated directly with the help of the job file. Print finishing also uses digital information to produce the end product. Printed matter can then be produced using modern technologies which are based on a "digital master" containing all the information on the product and its production.

The so-called "electronic media" transmit information to customers using CD-ROM or the Internet, which can be read and viewed using visual display units such as monitors and displays.

The "digital master" for the information, which is transmitted in printed or electronic form, is more or less identical. This has resulted in the creation of a premedia stage in the workflow, during which information is recorded, laid out, and made available as a digital data file, and the data is managed and organized. This "digital master" can now be copied and distributed

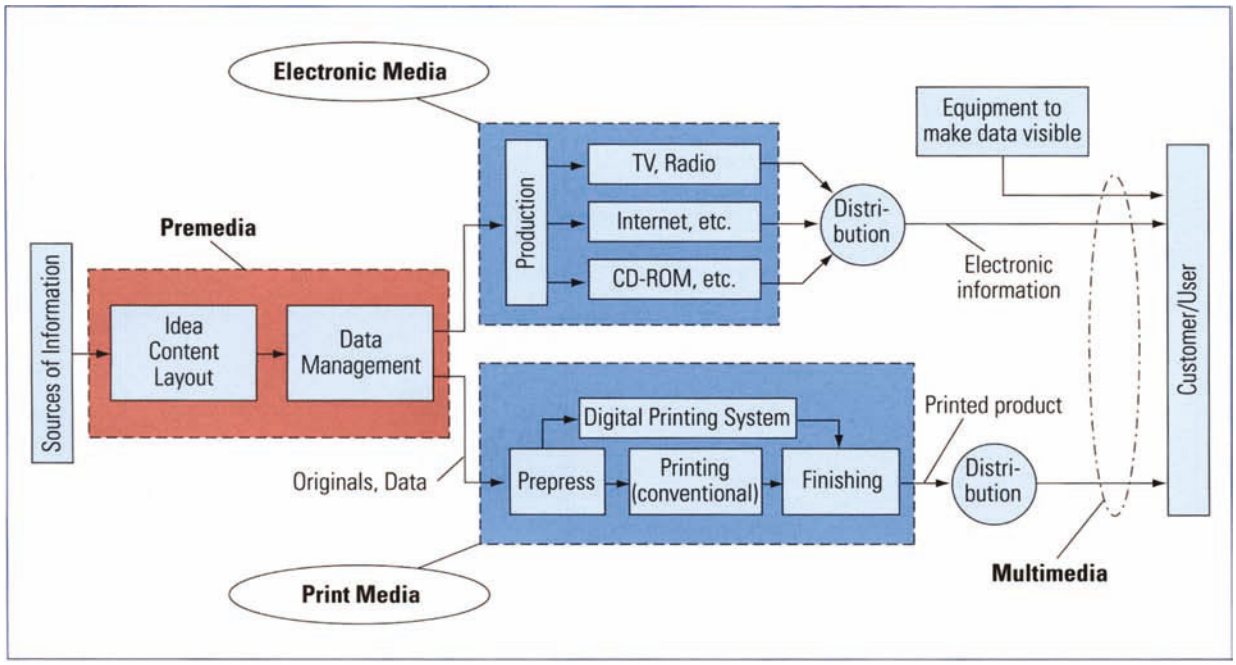


Fig. 1.2-43 Premedia in the workflow for the production of print media and electronic media

in printed or electronic form (print media or electronic media, see fig. 1.2-43).

The premedia production process, which does not depend on the output media, is also called "*Cross Media Publishing*" (CMP). A basic requirement for an effective cross-media publishing system is the assurance of consistency and integrity. All data must be available in digital form and be accessible through a data network.

Figure 1.2-43 also shows how premedia is linked with prepress, press, and postpress. It also demonstrates that a completely digital workflow depends on the level of digitization of the systems in the production chain. Figure 1.2-43 also demonstrates how the combination of an electronic medium (e.g., CD-ROM) and a print medium (e.g., a book) is a multimedia application that can be produced by one business.

This combination of different data carriers is also called "*Mixed Media Publishing*" (MMP). MMP can be used for the optimization of publications by combining the advantages of different data carriers. The value of a publication is not increased by the clever combination of individual types of information (text, tone, animation, etc.), but rather by a combination of different data carriers (e.g., CD-ROM, the Internet, and print).

Chapter 9 details potential production processes and strategies for printed media and, in particular, production strategies such as *print on demand* or *distributed printing* which can be executed on the basis of the workflow shown in figure 1.2-43 (from premedia via prepress, press, and postpress to the end product).

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1.3 Printing Technologies

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1.3.1 Overview of Printing Technologies

Current printing technologies are based on a wealth of inventions. The discoveries made in the engineering sciences, information technology, physics, and chemistry have left their mark on the development of printing technologies. In recent years it is computer and information technology that have had the most lasting impact on the printing industry and printing technologies, and this trend is continuing. The most important aspects in the history of printing technology are dealt with in section 13.1.

Definition of the Most Important Terms Relating to Printing Technology [1.3-1]

- *Printing* is a reproduction process in which printing ink is applied to a printing substrate in order to transmit information (images, graphics, text) in a repeatable form using an image-carrying medium (e.g., a printing plate).
- The *image carrying medium* is the storage element (i.e., printing plate or bitmap for controlling ink jet nozzles) that contains all the information needed to apply the ink for the reproduction of images and/or text by printing.
- The *printing plate* or *image carrier (master)* is the tool (material) by which ink is transferred to the printing substrate or an intermediate carrier for the reproduction of text, graphics and/or images. One printing plate usually generates many prints.
- The *print image* is the information provided by the entirety of all the print image elements in all operational stages of an image to be produced by printing.
- The *print image element* is an area that transfers and/or receives ink (e.g., letter type face, line, screen dot or cells) in any operational stage of the presentation to be reproduced by printing.
- The *ink* is the colored substance that is applied to the printing substrate during printing.
- The *printing substrate* is the material receiving the print.
- The *printing press* is the equipment with which the printing process is performed.
- The *printing process* serves to disseminate/reproduce information that is transmitted and processed within this procedural framework.

The relevant individual steps in the production of a printed product (see sec. 1.2) are illustrated in figure 1.3-1. The *printing stage* (press) is highlighted as the central production stage between prepress and postpress/finishing.

The production of printed products can be described as an information-processing system, within which the information specification and the information carrier change (i.e., original as slide, film, image, digital data record, impression, plate, print sheet, end product) [1.3-2]. The type of information carrier employed depends on the printing technology used.

H. Kipphan (ed.), *Handbook of Print Media*
© Springer-Verlag Berlin Heidelberg 2001

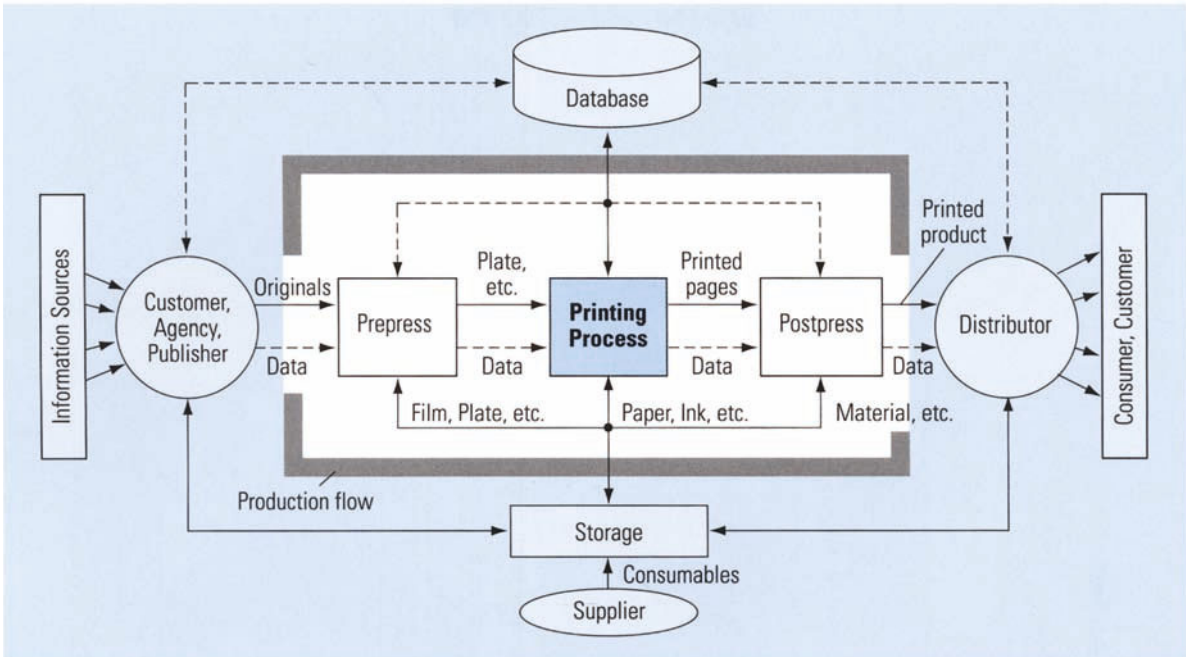


Fig. 1.3-1 Production flow (workflow), material and data flow for the production of printed products

An overview of printing technologies is given in figure 1.3-2. A distinction is made between technologies requiring a master, conventional procedures, and so-called non-impact printing (NIP) technologies which do not require a printing plate. Printing technologies requiring a printing plate are technologies like lithography (offset), gravure, letterpress, and screen printing. The most common NIP technologies are electrophotography and ink jet.

As can be seen in figure 1.3-2, all printing technologies have the task of transferring information to a substrate (i.e., paper in sheet or web form). The execution of this task requires the prepress phase for procedure-specific preparation of the printing process as well as the finishing phase for fabrication of the end product.

1.3.2 Printing Technologies with a Printing Master

Printing technologies with a master (see also fig. 1.2-32) are also referred to as conventional printing technologies. The printing plate is the information-carrying medium for all the procedures referred to in figure 1.3-3. Information is generated on the printing substrate by the partial surface transfer of ink. All information is denoted by image elements (transferred ink) and non-image elements (no ink).

To enable continuous *color tone values* to be reproduced in print, such as from photographic originals, the original has to be broken up into extremely small dots (screen dots) that vary in size or are at various distances from each other. This process is called *screening*. The main function of screening is to generate halftone values, which are intended to simulate the continuous tonal gradation, ending with the conversion of gray images into binary images (described in detail in sec. 1.4). Such screening is necessary because most printing technologies operate on a binary system and can therefore only perform one of two actions, namely to transfer ink (in an evenly distributed layer) or not to transfer ink. Unevenly distributed screen dots and dots varying in size and in shape are illustrated in figure 1.3-4.

With the exception of the variable-depth gravure printing technology, printing technologies requiring a printing plate transfer layers of ink to printing plate elements that are basically of the same thickness throughout (the printing plates are generally set up in this way, the printing units in the printing press being designed

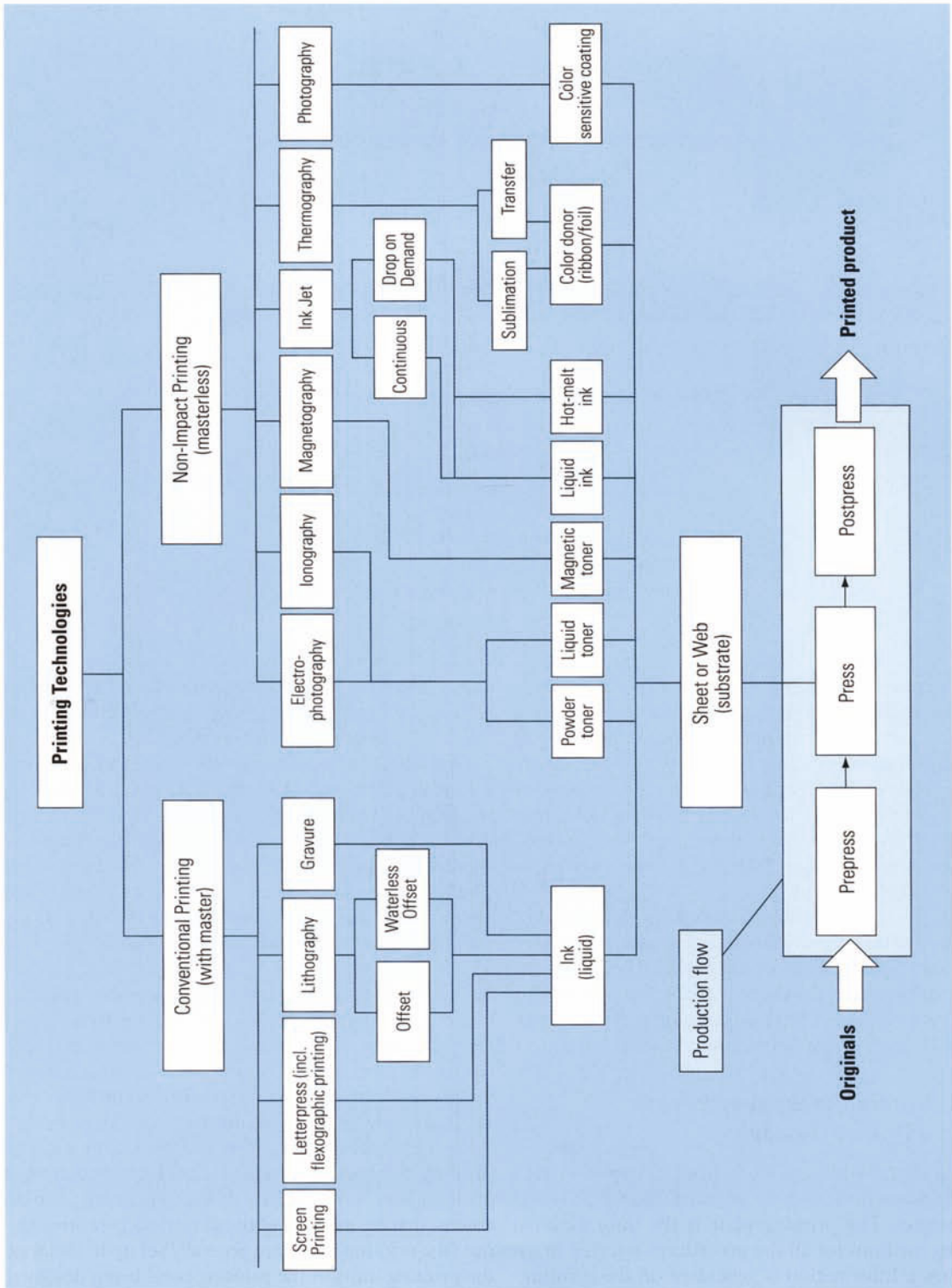


Fig. 1.3-2 Printing technologies and production flow for multicolor printed products

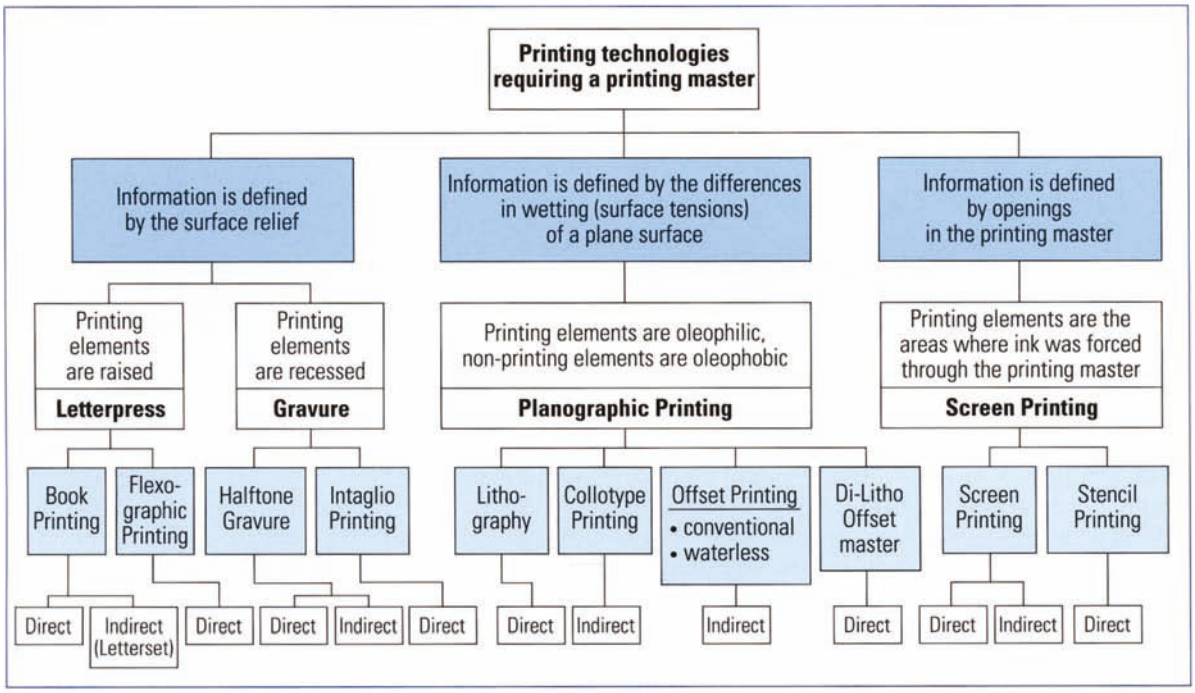


Fig. 1.3-3 Overview of printing technologies requiring a printing plate (master)

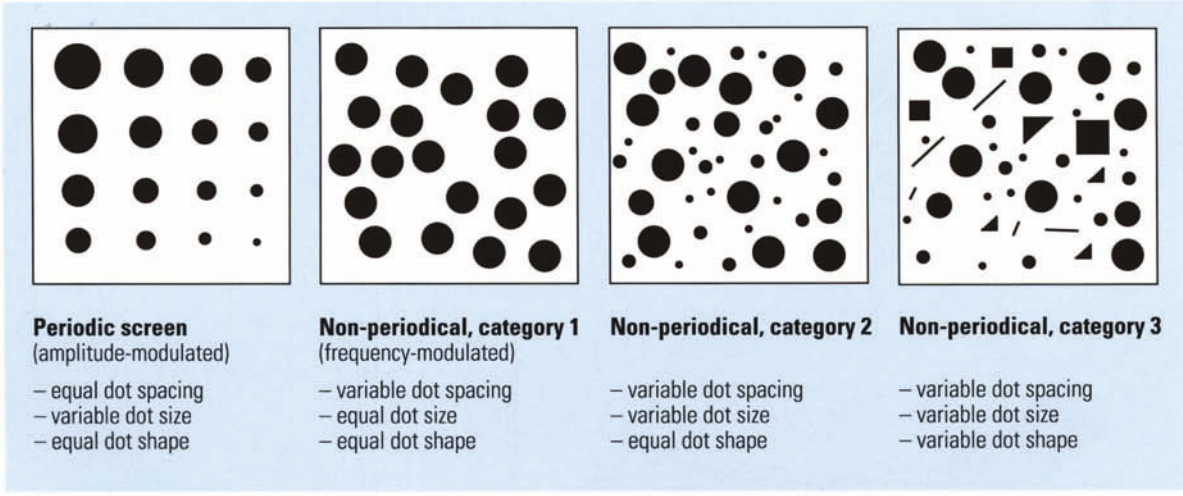


Fig. 1.3-4 Screen dot patterns and shapes

accordingly). It is only the area and configuration of the print elements on the surface of the printing substrate that vary, and it is by using this that different tone values can be reproduced. The observer receives the impression of a continuous gradation of tone if the human eye can no longer break down the image into its individual print elements. This phenomenon occurs if, for example, a 60 lines/cm (150 lpi) screen structure has been used (i.e., dot spacing of 0.16 mm) and it is observed from a distance of approximately 30 cm (1 ft).

Variable-depth gravure printing generates quantitative ink metering corresponding to the tone value during ink transfer. The printing elements of equal size (halftone dots) only vary in the thickness of their layers depending on the tone values of the original, although in principle the dot size of the individual halftone dots can vary in gravure printing as well as the quantity of ink.

All printing technologies requiring a printing plate therefore have in common that information is generated by the surface of the substrate being partially coated with ink. Ink is transferred in the contact zone (nip, printing zone of the surfaces involved) and sufficient process-dependent contact pressure must be applied between the printing plate and the printing substrate or an intermediate carrier. When the layer of ink on the printing plate or intermediate carrier is brought into contact with the printing substrate, only part of the layer of ink is transferred to the substrate. A residual layer remains on the printing plate. Thus the ink is not transferred in full, the ink layer is split.

Ink Transfer

Letterpress and Planographic Printing (see fig. 1.3-3). The transfer of ink to the printing substrate or intermediate carrier through *splitting the ink layer* is mainly affected by the following parameters:

- the thickness of the ink layer on the printing plate (ink supply),
- the period of contact (printing speed and geometry of the printing components),
- the contact pressure (also called printing pressure),
- the rheological properties of the ink,
- the temperature ratios (temperature has a marked effect on the ink's rheological properties),
- the surface properties of the printing substrate and printing plate or intermediate carrier (wettability, absorbency, roughness, etc.).

A further factor influencing the layer of ink on the substrate is the absorption properties of the ink in the printing substrate. The process of transferring ink from the printing plate to the substrate is illustrated in figure 1.3-5 [1.3-3].

With both absorbent and non-absorbent printing substrates, the ink transfer is reduced if the printing speed is increased, as the period of contact then becomes shorter. In indirect printing, ink transfer takes place in two stages. The layer of ink on the printing plate is brought into contact with a rubber blanket and then part of the ink layer adheres to the blanket. Ink is then transferred to the substrate.

Ink splitting processes and factors are still beset by many unresolved questions and corresponding research is underway worldwide (see sec. 13.1.3.2). Further information on ink splitting is given in section 2.1.1.3, as are the layer thickness ratios, with the simplified assumption of half-and-half ink splitting and zero absorbency.

Gravure Printing. With gravure printing (fig. 1.3-10) the ink remaining in the cells after doctoring is brought into contact with the printing substrate, at

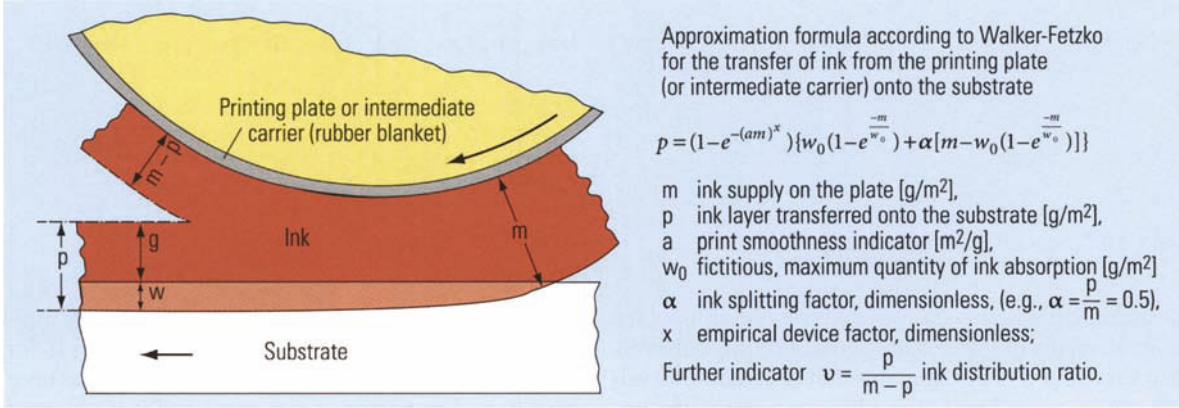


Fig. 1.3-5 Ink transfer to the printing substrate in the printing zone

which point part of this ink is transferred to the substrate. The emptying of the cells is incomplete because of the ink splitting. This transfer of ink is affected by

- the wetting properties of the printing substrate,
- the surface properties of the materials involved,
- the properties of the paper,
- the viscosity of the ink,
- the printing pressure,
- the printing speed, and
- the shape of the cells and their filling level.

In all printing technologies, a *multicolor print* is produced by the superimposed printing of several color separations using the appropriate printing plates (see 1.4.2). The printing plates for the primary color system of cyan, magenta, yellow, and black are produced in prepress. In a printing press with four printing units these four separated colors can be printed consecutively in one sheet pass, the multicolor print being produced corresponding to the original (see also fig. 1.2-33). The principle of the information flow and the basic steps in the process are illustrated in figure 1.3-6.

1.3.2.1 Letterpress/Flexographic Printing

(Examples of presses and details in sec. 2.3). A common feature of all *letterpress processes* is the fact that the printing elements of the plate are raised above the nonprinting elements. The printing elements that are at the same height (image areas) are coated with a layer of ink of constant thickness by the application rollers. This is followed by the transfer of the ink to the substrate. The printing principle of letterpress printing is illustrated in figure 1.3-7 in the form of a book printing process. The special features of flexographic printing can be seen in figure 1.3-9.

The letterpress printing technique is used with the following printing systems:

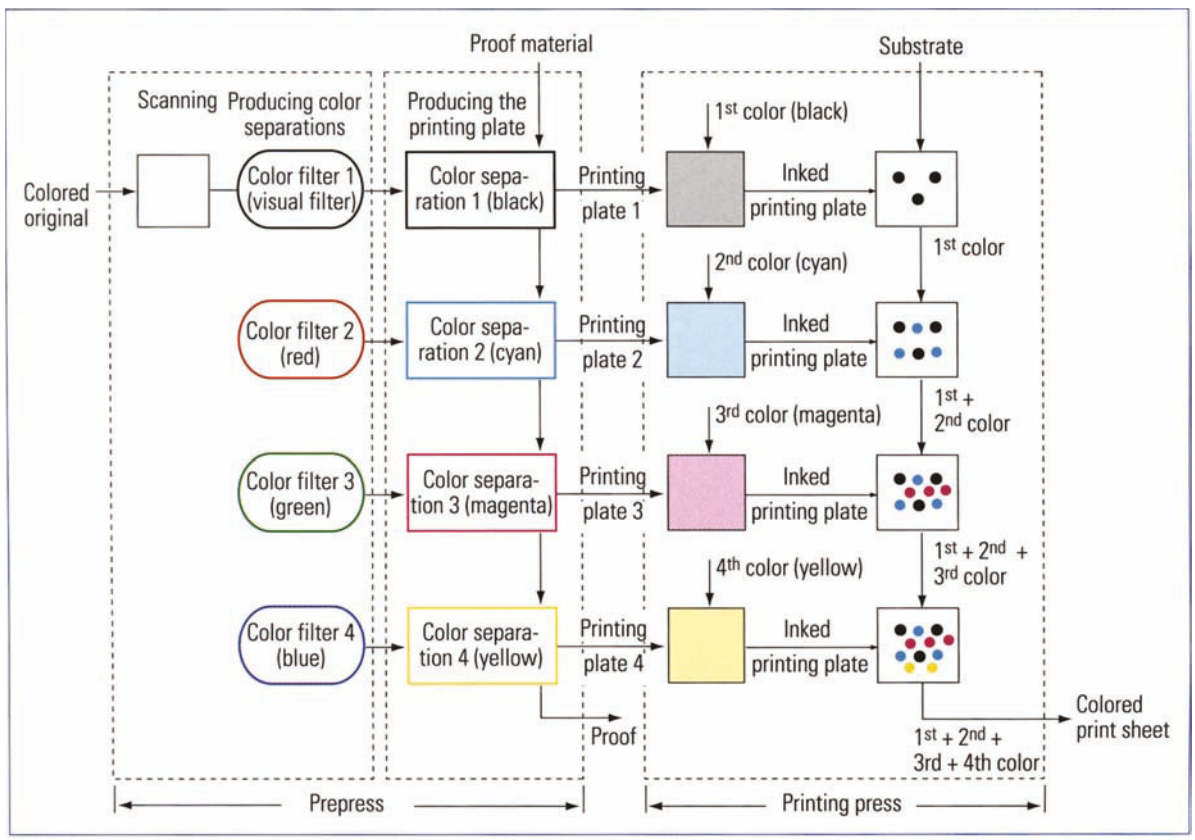


Fig. 1.3-6 Diagram on the creation of a four-color print (Note: screening function in prepress not included) [1.3.2]

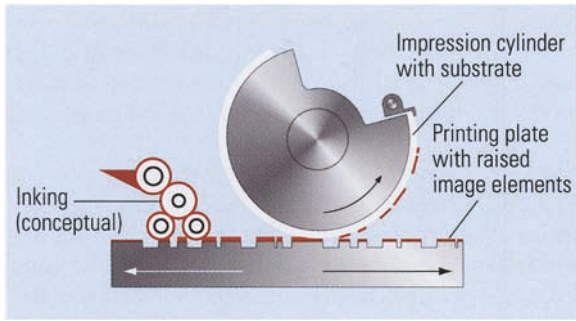


Fig. 1.3-7

- book printing,
- flexographic printing,
- letterset.

Book printing

Book printing is the oldest letterpress printing technology. As a result of Gutenberg's inspired discovery in the middle of the fifteenth century of how to produce individual, moveable type from lead alloy, it became possible to reproduce type elements economically and quickly, and thereby to reproduce books by printing. The following printing principles are applied in book printing (see also fig. 1.6-1):

- plane-plane = platen press;
- plane-cylinder = flatbed cylinder printing (fig. 1.3-7, historically: automatic cylinder press);
- cylinder-cylinder = rotary printing.

The importance of letterpress printing has diminished in recent decades, mainly because of the expense of producing printing plates.

Quality printing in larger formats can only be achieved on flatbed cylinder presses and only low printing outputs are possible with these presses. The variety of printing plates and printing-plate components that can be used is characteristic of letterpress printing: hot-metal composition printing plates, original letterpress plates, copies of letterpress plates. These may, in turn, consist of various materials: lead alloys, zinc, copper, and photopolymer plastics, and, in art printing, wood and linoleum.

Printing plates for *platen printing* and *flatbed cylinder printing* consist almost exclusively of several fixed, rigid, flat individual component parts. Semicircular cast lead plates (stereos) or flexible plastic plates, so-called wash-off printing plates, are suitable for *rotary printing*.

Hot-metal composition and photocomposition are suitable for the *production of printing plates* for text in book printing. The hot-metal composition process, which predominated up to the end of the seventies, now plays only a minor role in small-format commercial printing, in older letterpress printshops, and in the printing of collector's items. Photocomposition for the production of letterpress printing plates is described in sections 2.3.2 and 3.1.7.

Various letterpress printing plates (also called blocks) are used to print images and graphics in the letterpress printing process:

- Manually produced printing plates (such as woodcuts) still play an important role in original graphic artwork.
- Letterpress printing plates produced by photomechanical/etching techniques and by electronic engraving are outdated.
- Photomechanical/wash-off procedures predominate. Photopolymer plates are now used instead of the formerly exclusively used metal (particularly zinc) plates.

Wash-off printing plates (photopolymer plates) can be produced quickly and reliably. The range of wash-off printing plates available includes an extensive variety of different printing plates with various wash-off systems, depths, and base materials. Nyloprint printing plates (made by BASF), for example, are made of a light-sensitive plastic that is firmly connected to the base material by a bonding layer. The base material consists of aluminum, steel, or plastic, depending on application. Printing plate production is described in section 2.3.2.

Figure 1.3-8a shows a micro-photograph of a section of a letterpress printing plate (brass printing plate). Prints produced using the letterpress technology can be recognized by an accumulation of ink at the edges (fig. 1.3-8b).

Flexographic Printing

Flexographic printing is the only letterpress process that is still showing growth, mainly in packaging, label, and newspaper printing. The main feature of flexographic printing is the use of flexible printing plates that are relatively soft compared to book printing plates and enable special ink feeding.

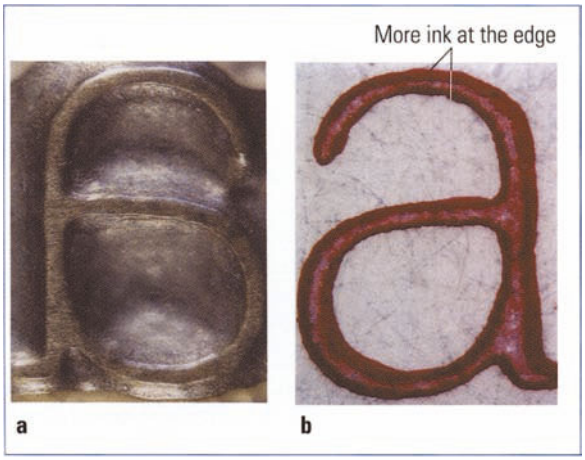


Fig. 1.3-8 Microphoto of letterpress printing.
a Detail of the printing plate;
b Impression on the printing substrate (FOGRA)

Using the *flexible (soft) printing plate* and the appropriate ink (low viscosity) for the printing substrate, it is possible to print on a wide range of absorbent and non-absorbent printing substrates. The principle on which a flexographic printing unit works is illustrated in figure 1.3-9. The low-viscosity ink is transferred to the printing plate via a roller that is evenly screened with cells, the so-called screen roller/anilox roller (screen width 200–600 lines/cm, ceramic or hard-chromed metal surface). The rubber or plastic plate is attached to the printing plate cylinder. Ink is transferred to the printing substrate by the pressure of the impression cylinder. The use of a blade (together with the ink supply system) on the screen roller has a stabilizing effect on the printing process resulting from even filling of the cells on the screen roller.

With the rubber plates in exclusive use earlier, only a low to moderate printing quality of solid motifs and rough line drawings could be achieved. For today's higher-quality requirements, especially in the printing of packaging, photopolymer wash-off plates are used, such as "Nyloflex" from BASF and "Cyrel" from DuPont. These allow screen resolutions of up to about 60 lines/cm.

Letterset

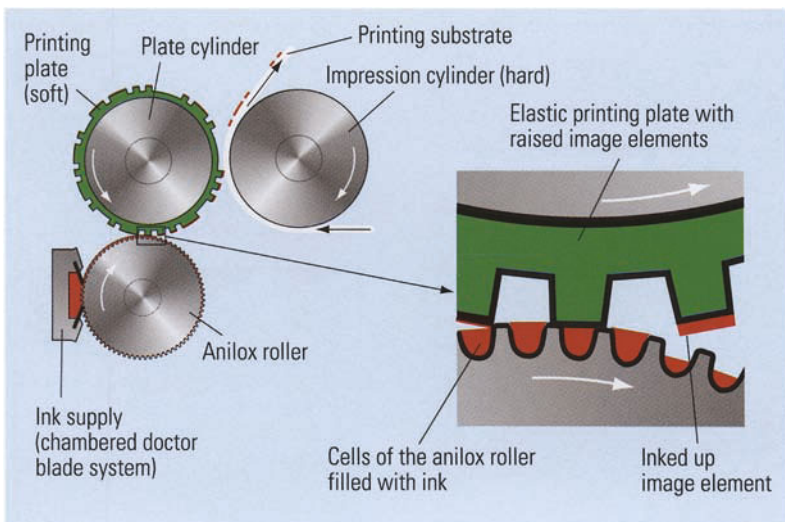
In letterset printing, the image of the letterpress plate (stable, hard letterpress plate) is transferred to the paper via an intermediate carrier (a cylinder covered with a blanket) – that is by *indirect letterpress printing.* By analogy with the offset printing process as an indirect lithographic technology, letterset printing could also be called offset letterpress printing technology – but to avoid misunderstandings, the term lithographic offset printing would need to be used rather than the term offset printing.

Printed Products

The following are typical letterpress printed products:

- small-format jobs,
- business cards,

Fig. 1.3-9
Flexographic printing unit (rotary letterpress, schematic diagram)



- form printing,
- packaging printwork (flexographic printing),
- labels (flexographic and letterpress printing),
- carriers and bags (flexographic printing).

1.3.2.2 Gravure Printing

(See sec. 2.2 for examples of presses and other details). The distinctive feature of gravure printing technology is the fact that the image elements are engraved into the surface of the cylinder. The non-image areas are at a constant, original level. Prior to printing, the entire printing plate (non-printing and printing elements) is inked and flooded with ink. Ink is removed from the non-image (by a wiper or blade) before printing, so that ink remains only in the cells. The ink is transferred from the cells to the printing substrate by a high printing pressure and the adhesive forces between printing substrate and ink. The principle of gravure printing is illustrated in figure 1.3-10.

Rotogravure printing is used for the economical production of long print runs. *Gravure printing forms* are usually cylindrical. A special feature of industrial *rotogravure printing* is the fact that a whole cylinder (and no plate) is used per color separation. This means that in a four-color press four separate cylinders have to be changed for each new job. Consequently, a company that has a lot of repeat jobs is forced to store a large number of cylinders. Depending on the printing format, gravure printing cylinders are generally rather heavy and require special conveying and handling gear systems.

The various gravure printing techniques for reproducing the continuous tones of the original are shown in figure 1.3-11. It should be noted here that only variable-depth gravure printing and more particularly variable-area/variable-depth gravure are of any significance, due to their high quality. Pure variable-area (halftone) gravure is scarcely used nowadays.

Traditional, that is to say only variable-depth, gravure printing is also increasingly losing its importance since the printing plate production is based on complicated copying and etching processes that are almost impossible to standardize (see sec. 2.2.1). It is for this reason that variable-area/variable-depth gravure printing processes, which in industry are based on *electronic/mechanical engraving* (using a stylus) of the gravure cylinder, are becoming prevalent.

There are two familiar options for the *structure of the gravure cylinder* (fig. 1.3-12). The steel cylinder has an electroplated coating of base copper (typically about 2 mm thick), with an approximately 100 µm-thick coating of engravable (cuttable) copper applied onto it. The steel cylinder has either the directly electroplated engraving copper or a so-called ballard skin on the base copper layer. This peeling layer is also applied by electroplating onto the base copper, over a separating layer, and the print image is engraved into it. (There are also rarely used cylinder surface recycling methods as described in sec. 2.2.)

In screening for gravure printing, the image is broken up into printing elements, the cells, and then the non-printing elements, the cell walls. The cell walls serve to guide the blade when excess ink is being stripped. After the doctoring process, ink remains only in the cells. If ink were to remain on the cell walls, scumming would occur in the print, and if there were localized blade defects, blade streaks.

Figure 1.3-13a shows a microphotograph of the surface of a gravure printing cylinder. The cells and cell

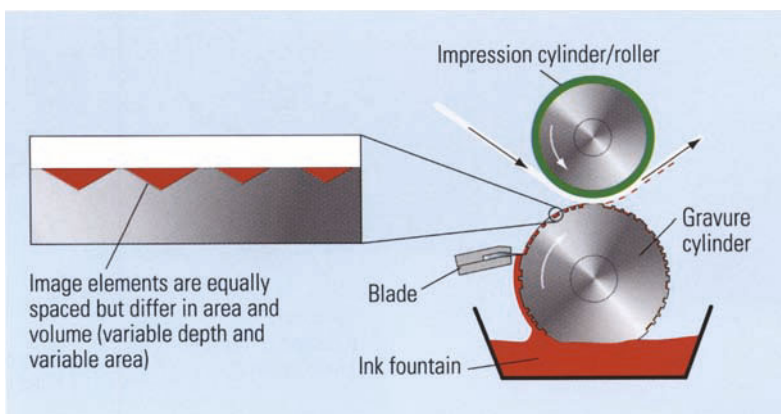


Fig. 1.3-10
Gravure printing (schematic diagram)

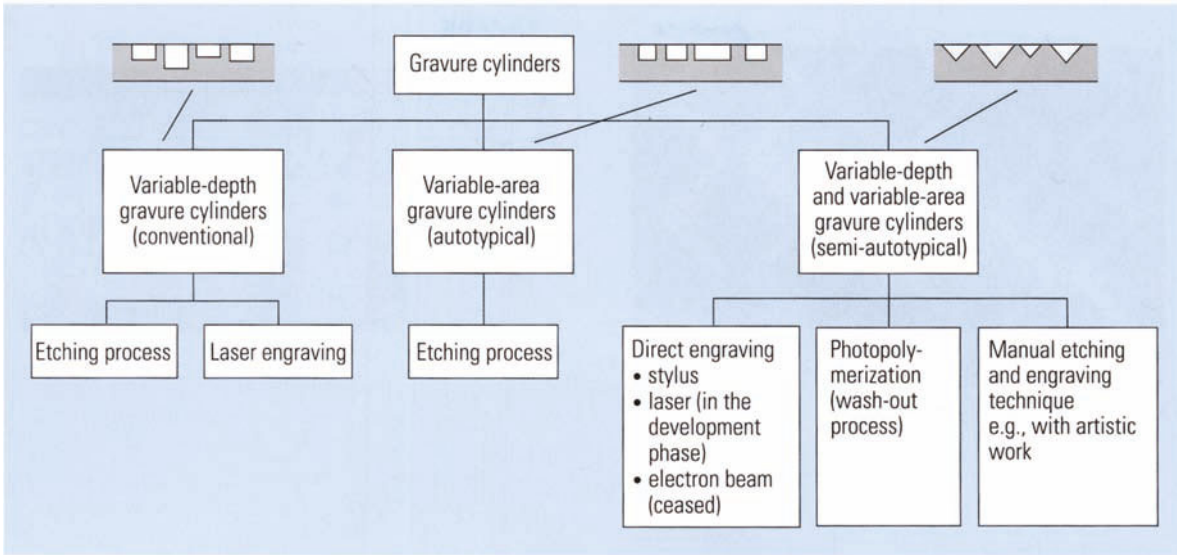


Fig. 1.3-11 Overview of the production of gravure cylinders

walls can be detected. On the one hand, this cell structure can be seen in the printed product (fig. 1.3-13b) and on the other, the "flowing apart" of the individual image elements can also be seen – the individual cells are no longer visible in the impression because of "cell wall flooding." Gravure printing cylinders for variable-depth gravure printing are produced by etching. This topic is dealt with in greater detail in sec. 2.2.1.

A brief explanation of the conventional method of *electromechanical engraving* is given in figure 1.3-14. The scanning drum and the form cylinder to be engraved are either connected to each other by mechanical means or by a "self-synchronous system." A bromide film (the positive of the print image) is scanned optically on the *scanning drum* with the respective gradation and density range. A corresponding amount of light is reflected, depending on the brightness of the pixel which has already been scanned on the bromide film and this is converted into an electric signal.

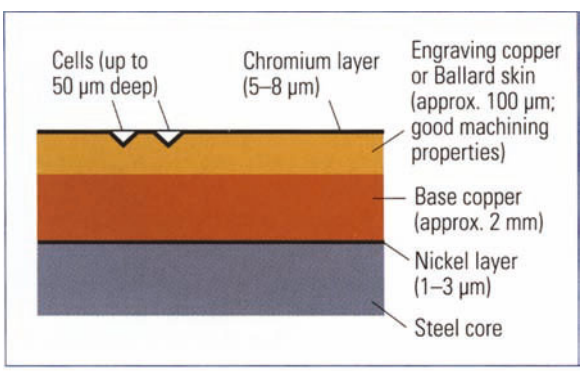


Fig. 1.3-12 Structure of a gravure cylinder

The output signals of the scanning head, the image data, are processed electronically in the computer and the *engraving head* (fig. 1.3-15 shows an electromechanical engraving head) can be controlled accordingly. The computer feeds two signals to the engraving head – the actual image signal and the screen signal defining the screen resolution and the angular position. Both produce a modulated signal to control the engraving head. The angular position of the screen is produced by the superimposed motion of the engraving head (feed and frequency) and the cylinder (circumferential speed). Nowadays engraving is mostly done directly instead of scanning a bromide film, with the signals for the engraving head coming from the digital database containing the printing cylinder specifications.

Engraved printing cylinders are more prone to "missing dots" (cells which do not print completely) than etched printing cylinders since the cells transfer less ink to the printing substrate due to their shape. Electrostatic printing aids that raise the meniscus of the ink surface in the screen cells for improved wetting of

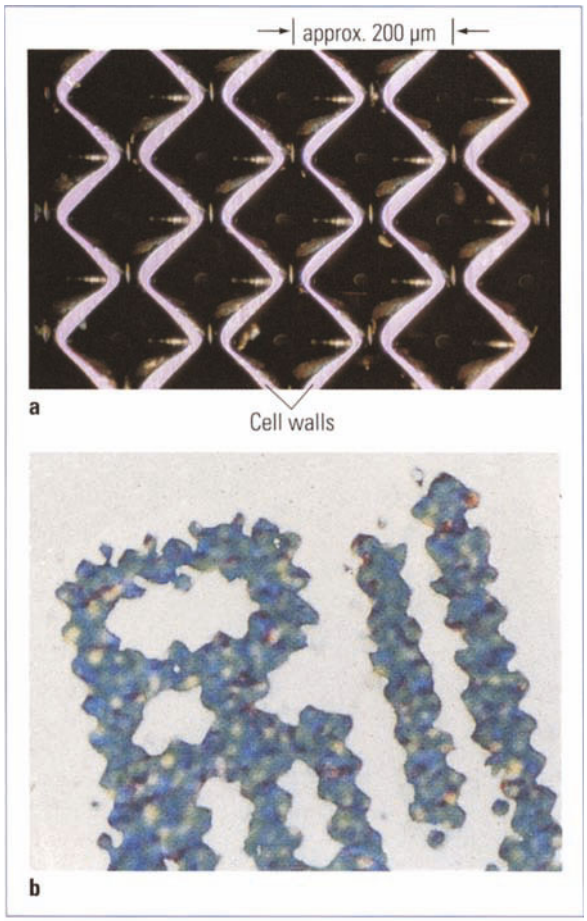


Fig. 1.3-13 Microphoto of gravure printing.
a Electromechanically engraved gravure cylinder;
b Print of an engraved gravure cylinder (variable area/variable depth, four-color). The "serrated teeth structure" at the edges is clearly discernible – a characteristic of gravure printing

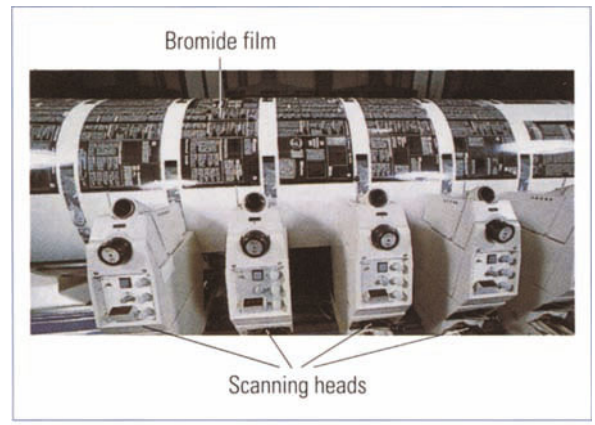


Fig. 1.3-14
Scanning the bromide film (with positive image), scanner with up to 12 scanning heads (Helio-Multiscan, Hell Gravure Systems)

the printing substrate are used to eliminate or prevent "missing dots" in *rotogravure printing*.

The very high costs that printing cylinder production entails is the decisive reason why *rotogravure printing* can only be used cost-effectively to print mass-circulation products (run length > 500 000).

The screen resulting in gravure printing (and also in etching) is a periodic screen. A moiré effect is often produced in *multicolor printing* when periodic screens are used. The moiré effect is minimized in offset and/or letterpress printing by the screen being suitably angled for each individual printing ink. In gravure printing a screen angle can be simulated by elongating or compressing the cells.

Some typical gravure printing values are listed in table 1.3-1.

The *printing unit* of a gravure printing press is illustrated in diagram form in figure 1.3-16. (A detailed description is given in sec. 2.2.)

The *gravure cylinder* is immersed in the ink, which is contained in an ink trough. The gravure cylinder cells are completely flooded in the ink trough. Excess ink is removed by the blade, so that ink remains only in the cells and the cell walls are free of ink. Hydrodynamic back-pressure is built up beneath the blade, which mainly depends on the contact angle of the blade, the speed of the press and the viscosity of the ink. In modern, very high-powered gravure printing presses, a steep angle of blade contact is now mostly preferred.

In *multicolor gravure printing*, drying must be carried out downstream of each printing unit (drying zone) since wet-on-wet printing, such as offset printing, is not possible with low viscosity gravure printing inks (typical value approximately 0.1 Pa·s). The drying of gravure printing ink (pure evaporation/vaporization drying) is described in section 1.7.1.2.

Pad printing (indirect gravure printing) is dealt with in section 2.5.4. Here, an intermediate carrier is used for the print image rather than printing directly onto the printing substrate from the printing cylinder.

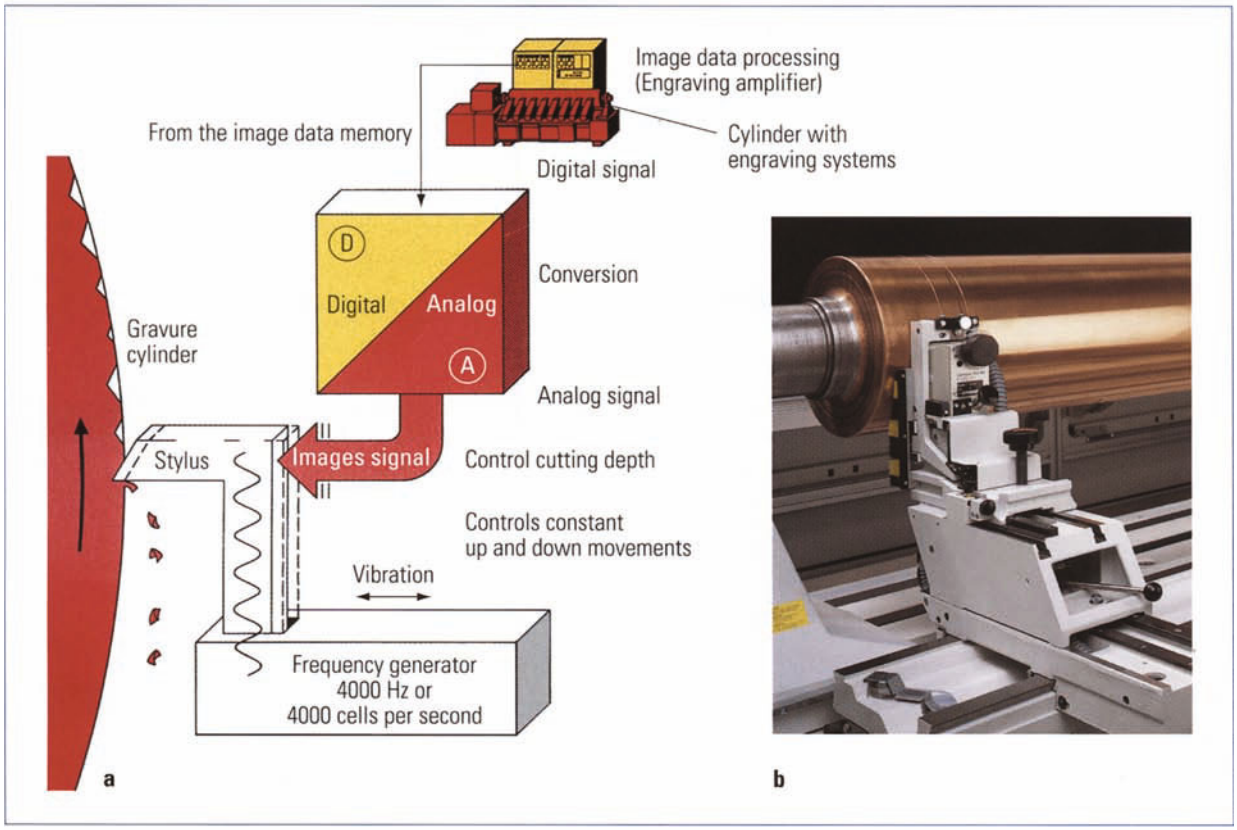


Fig. 1.3-15 Cylinder engraving with stylus.
a Control of the engraving head;
b Electromechanical cylinder engraving (Hell Gravure Systems)

Areas of Application, Features and Printed Products

Gravure printing is a very good illustration printing technology, achieving very high image quality. When variable-depth and electronically engraved gravure printing cylinders are used, the cells take up different amounts of ink. The different layer thickness produced on the substrate resulting from this corresponds to the tonal gradations of the original. Consequently, a gravure-printed image comes very close to the continuous tonal gradations of an original (e.g., photographic picture). The image effect is improved even more by the fact that, after the ink has been transferred, the liquid ink flows out somewhat in the areas of deeper shades on the substrate, as a result of which no sharply defined screen dots are produced and the cell walls of the printing cylinder are not visible.

The typical *features* of gravure printing are:

- serrated or jagged edge on letters and lines;
- very good image reproduction, similar to continuous tone because the screen cells are of different depths (i.e., different volume of ink);
- with variable-depth gravure printing, square screen dots of the same size are present in all tone values. In light tone values, the cells often print out incorrectly;
- in variable-depth and variable-area gravure printing, screen dots of different sizes and different color saturation levels are produced.

Typical *gravure printed products* are high-circulation, high-quality printed products such as:

- periodicals, magazines, mail-order catalogs;
- plastic films;

Table 1.3-1
Typical gravure printing specifications/numbers

Printing press	
Web width	2.40 m, maximum 3.60 m (illustration or publication gravure printing) 1.20–1.40 m, maximum 1.60 m (packaging gravure printing)
Web speed	10 m/s (2000 ft/min), maximum 15 m/s (illustration or publication gravure printing) 5 m/s, maximum 6.5 m/s (packaging gravure printing)
Cylinder circumference	800–1600 mm (illustration or publication gravure printing)
Screen ruling	40–140 lines/cm (100–350 lpi) typical of illustration or publication gravure printing: 60–70 lines/cm
Gravure (variable area/variable depth, stylus)	
Frequency	4 kHz (4000 cells/s), up to 8 kHz
Number of lines (engraving heads)	8–16 in illustration gravure printing, 1 in packaging gravure printing
Cell geometry	Width (transverse diagonals): minimum 30 µm, maximum 230 µm Depth: 10–30 µm (maximum 50 µm) depending on the angle of the diamond stylus Cell wall width: 3–5 µm
Gravure cell shapes (depending on screen ruling and angle)	
	various, depending on the color separation: compressed: cyan elongated: magenta coarse: yellow (coarser screen) fine: black (finer screen, e.g., type)

- metal foils;
- transparent films, carrier bags;
- security papers, stamps, bank notes.

1.3.2.3 Lithography/Offset Printing

As the currently most important technology, offset printing is explained in detail in section 2.1 with a description of the technology itself as well as printing plate production, examples of machinery, and how the inking and dampening units work.

In *lithography* the printing and non-printing parts are on the same level. The distinctive feature of the printing areas is the fact that they are ink-accepting, whereas the non-printing plate elements are ink-repellent. This effect is produced by physical, interfacial surface phenomena. Lithographic printing can be subdivided into:

- Stone lithography (direct printing process using a stone printing plate),
- collotype (direct printing process),
- offset printing (indirect printing process), and
- di-litho (direct printing process with offset printing plate).

Lithography was invented by Alois Senefelder in 1796. The image to be printed was drawn on the stone with a special ink. The stone was dampened before it was inked up, after which the non-image areas of the stone surface did not take on ink (fig. 1.3-17).

Collotype is another lithography technology. Its beginnings (1856) can be traced back to A. L. Poitevin. Continuous tones can be reproduced without screening. Very high print quality can be achieved (e.g., moiré-free). A light-sensitive layer of gelatin is exposed on a

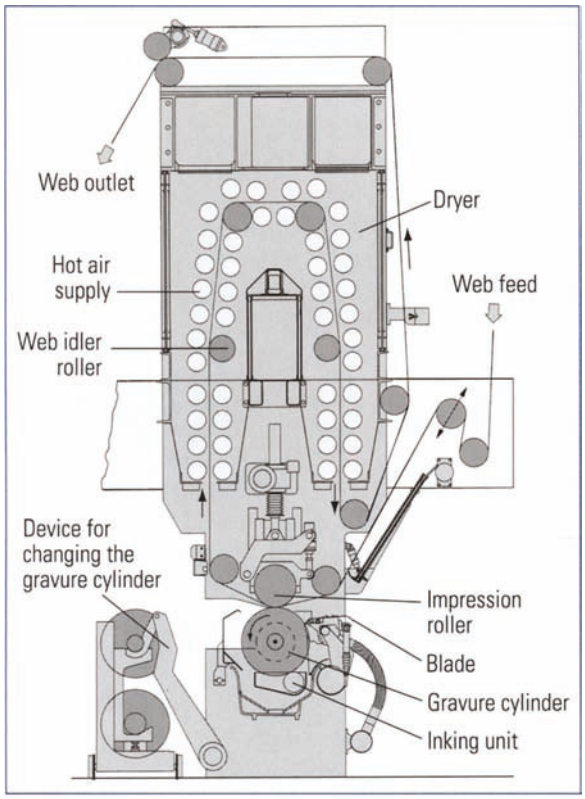


Fig. 1.3-16 Printing unit of a gravure printing press



Fig. 1.3-17 Stone lithographic press (manually operated)

glass base over a negative and then developed. Areas having different swelling properties in relation to water are produced. After the printing plate has been dampened, differentiated color absorption properties are produced. Like stone lithography, collotype is only used for artistic printed products (with very short print runs).

Offset printing is the major lithographic technology. It is an indirect lithographic technology, in which the ink is first transferred from the printing plate onto a flexible intermediate carrier – the blanket – and then onto the substrate. The principle of offset printing is shown in figure 1.3-18.

To achieve an ink-repellent effect on the printing plate (different interaction of printing plate surface and ink), there are two commonly used systems :

- *Conventional offset printing technology:* Dampening of the printing plate with dampening solution (water with additives). The dampening solution is applied to the plate in a very fine film by dampening rollers. The non-image areas of the plate are hydrophilic, that is, water-receptive and the ink-accepting surfaces are oleophilic, and are therefore almost totally unreceptive to water. The film of dampening solution prevents the transfer of ink. Since this technology is by far the most widespread, the repellent effect between ink and dampening solution is generally always associated with "offset printing." Consequently, inking and dampening units are needed for "offset printing." A typical complete printing unit is illustrated in figure 1.3-19.
- *Waterless offset printing technology:* The printing plate surface is basically ink-repellent, for instance, due to an appropriate layer of silicone (fig. 1.3-20b). The ink-receptive base area is exposed by the deliberate interruption of the layer of silicone (approximately 2 µm thick). This procedure is known as "waterless offset" (quite frequently even as "dry offset").

Corresponding printing plates and special inks must be used for both systems.

In a conventional offset press, two different substance flows have to be taken into consideration for the inking up of the printing plate:

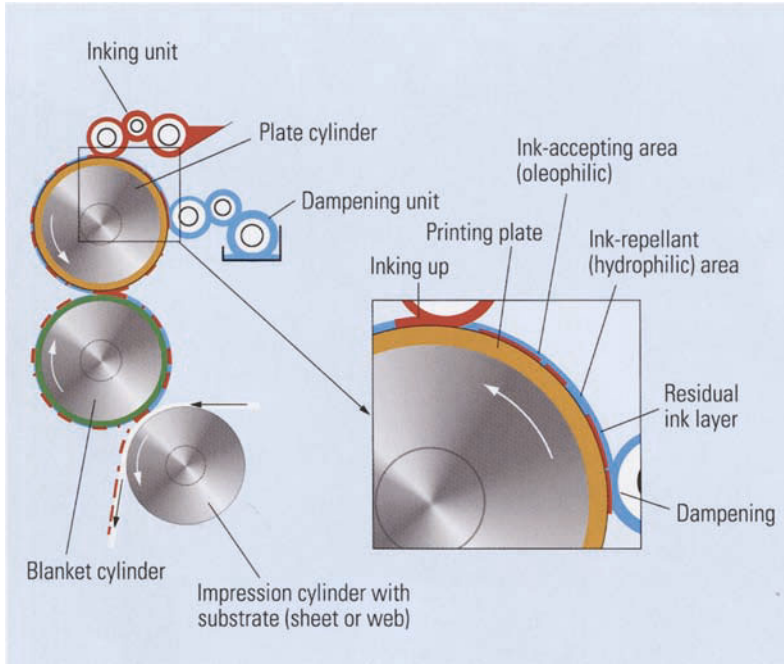


Fig. 1.3-18
Offset printing (lithography, schematic diagram)

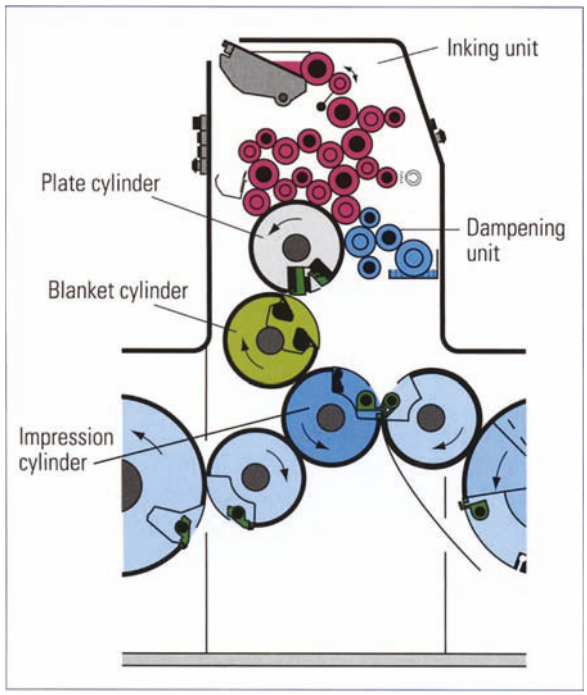


Fig. 1.3-19 Typical sheet-fed offset printing unit

- the ink supply,
- the dampening solution supply.

The *ink supply* over the surfaces is interlinked with the *dampening solution supply* in a complex manner. Typically, the printing plate base material consists of aluminum or polyester. The layer producing the image is then applied to it. Sections of an offset plate are illustrated in figure 1.3-20; figure 1.3-20a shows a conventional offset plate and figure 1.3-20b a waterless plate.

A press diagram of a five-color sheet-fed offset printing press with perfector (for in-line printing on both sides of the sheet) in unit design is given in figure 1.3-21.

The entire range of print media, from an individual brochure to a high-quality catalog, can now be produced to a high standard with the offset printing technology.

The *di-litho technology*, a lithographic technology in which the printing plate prints directly onto the printing substrate, was specially developed for newspaper printing. The advantage of this technology was that conventional letterpress rotary printing presses could be used. The printing units of these presses were modified by the installation of a dampening unit. Printing was done with conventional printing plates, although a special coating had to be applied to them on account

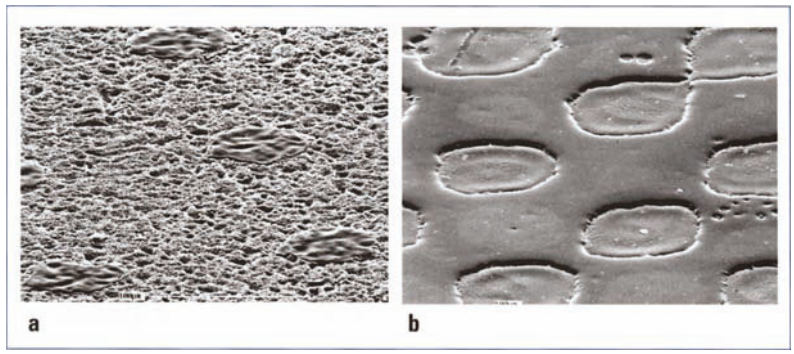


Fig. 1.3-20
Microphoto of offset printing plates (halftone dots on the printing plate).
a Conventional offset, aluminum plate;
b Waterless offset, plate silicone coated: Toray (FOGRA)

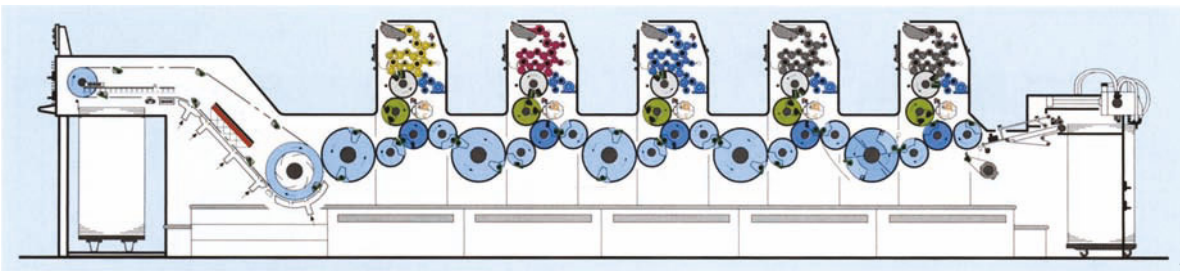


Fig. 1.3-21 Typical example of a sheet-fed offset press (Speedmaster SM 74-5-P-H, Heidelberg)

of the very high stress caused by the direct contact with the paper and the high stability over the entire print run required in newspaper printing. This technology only played a temporary role. When new investment was made in newspaper printing companies, this technology was replaced by web offset presses, which print onto the substrate via a blanket cylinder (see sec. 2.1.3).

1.3.2.4 Screen Printing

(See sec. 2.4 for examples of machinery and other details). Screen printing is a process in which ink is forced through a screen (fig. 1.3-22). The screen printing stencil serves as a printing plate. More often than not, the screen is a fine fabric made of natural silk, plastic, or metal fibers/threads. Plastic or metal fabric is generally used nowadays. Ink is imprinted/transferred through the image-specific, open mesh that is not covered by the stencil. The screen printing plate is therefore a combination of screen and stencil.

It is the material, the fineness of the screen (the number of screen threads per centimeter of fabric length), the thickness of the screen, the distance between the top and bottom sides of the screen, and the degree of opening of the screen (the degree of screen opening areas as a percentage describes the ratio of the total of all mesh openings to the entire surface of the fabric) that determine the printing properties and quality of the fabric (screen).

Fabrics can be obtained in levels of fineness from 10 to 200 fibers/cm. The most frequently used fabrics are those between 90 and 120 fibers/cm. Figure 1.3-23a shows a microphoto of a screen fabric (polyamide fibers), with the non-printing, and therefore covered, sections of the screen. Figure 1.3-23b shows a microphoto of a halftone color print. The notches on the edges of the screen dots come about due to the screen structure.

The screen work and printing of very detailed illustrations necessitate the use of very high levels of fabric fineness that are matched to the resolution requirements of print image reproduction. For screen work, fabric fineness (threads/cm) should be around three to four times greater than the screening of the print image (lines/cm) – therefore nine to sixteen different screen dot area surfaces per screen cell.

The *stencil* on the fabric defines the actual print image. The stencil is on the side of the screen opposite the side on which the squeegee (blade) works, to avoid

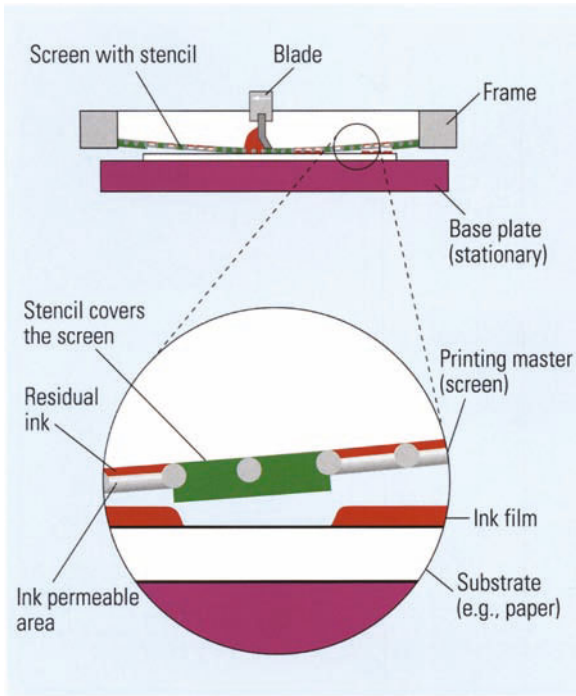


Fig. 1.3-22 Screen printing (schematic diagram)

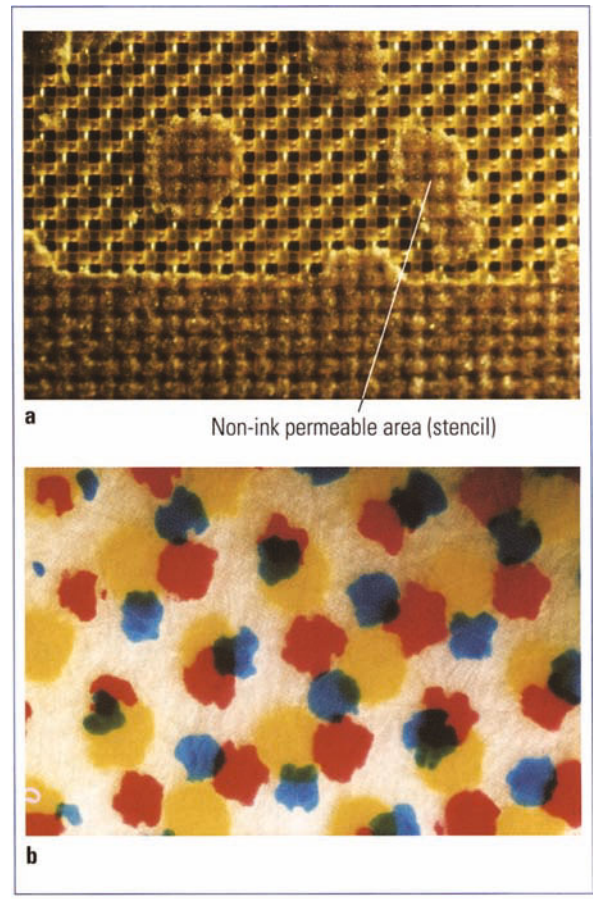


Fig. 1.3-23 Microphoto of screen printing.
a Screen fabric with stencil;
b Halftone dots of a three-color screen print

damage and wear to the stencil. Manual stencils, which can be produced as drawn or cut stencils and transferred to the underside of the screen, are used for simple, solid-area print work.

For sophisticated printed products (halftone prints, multicolor printing) it is almost exclusively screen emulsions with diazo sensitizing that are used (to produce stencils). After coating and drying, a right-reading, positive film copy is exposed on the coated side (the side not facing the squeegee) using UV light. The UV light hardens the film emulsion on all non-image areas (transparent areas of the film copy). The image areas themselves are not hardened and can be removed by a jet of water during developing. This is followed by the drying process. Possible defects can be eliminated with masking lacquer (screen filler).

In practice, three methods are used for screen printing (fig. 1.3-24):

- *The flat-to-flat method (flatbed).* The printing plate and the printing substrate are both flat. The ink is transferred through the mesh apertures and onto the printing substrate by the movements of a squeegee.
- *The flat-to-round method and body printing.*
  - The printing plate is flat, printing onto the printing substrate is done via a rotating cylinder. Printing plate and impression cylinder move synchronously in one direction in the course of which the ink is transferred through the mesh apertures and onto the printing substrate by a stationary squeegee.
  - Printing form and squeegee are adapted to the shape of the printing substrate (curved, arched, round). Printing plate and printing substrate run synchronously in one direction and the squeegee is in a fixed position. This procedure is used for printing on cans and balls, that is, on curved surfaces.

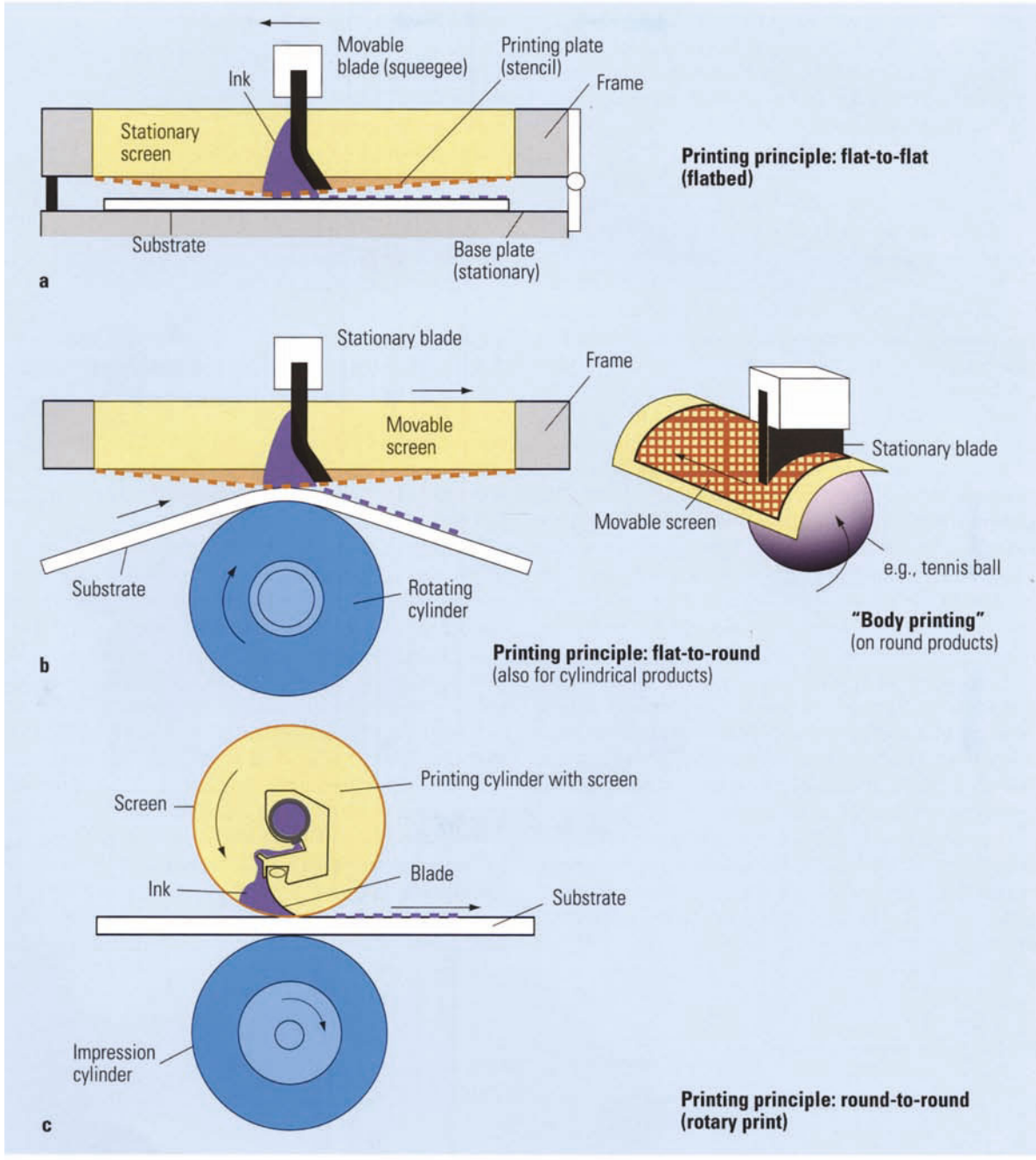


Fig. 1.3-24 Screen printing technologies.

- *Round-to-round method (rotary printing).* The printing screen is cylindrical. Printing plate, printing substrate, and impression cylinder move synchronously; ink is transferred from inside through the cylindrical printing plate and onto the substrate.

The actual printing process can be sub-divided into four different sub-areas (fig. 1.3-25, for greater clarity the screen is shown in a simplified form).

The screen is held by a screen frame. The substrate lies flat on the base plate, which forms the printing body, and is held there securely during the printing process. The volume of ink on the screen is moved like a tidal wave by the squeegee. The ink beneath the tidal wave penetrates the screen. This area is known as the filling zone. Once again the ink in front of the squeegee edge in the contact zone passes through the fabric and makes contact with the printing substrate. Behind the edge of the squeegee, in the adhesion zone, the ink ensures that the printing form adheres to the substrate. The screen's pulling strength pulls ink fibers out of the ink film in the "release zone," meaning that residual ink remains in the mesh of the screen and an even layer of ink remains on the substrate.

It is possible to apply a very thick layer of ink in the screen printing process (normal values are around 20–100 µm, offset printing values are typically around 0.5–2 µm). The thickness of the stencil (the distance that the stencil stands above the screen) determines the thickness of the layer of ink.

The most varied types of ink with the most varied properties are available to the screen printer, depending on the print job and the substrate. There is a larger selection of inks for screen printing than any other printing technology.

Typical *screen printing products* are:

- textiles/materials,
- printed T-shirts,
- printed toys,
- fronts of televisions, radios etc.,
- automobile dashboards, measuring equipment, etc.,
- packaging (plastic bags),
- printed circuit boards,
- large-format advertising posters.

1.3.3 Printing Technologies without a Master (NIP Technologies)

An overview of the various printing technologies is given again in figure 1.3-26, sub-divided into conventional printing technologies (with master) and non-impact printing technologies (masterless).

Printing technologies, which do not require a stable, physical, fixed image carrier and can, in principle, generate a different printed page print per print are explained below with examples. This type of process is referred to as non-impact printing (NIP technology). The term non-impact is based on early digitally controlled printing systems where computing centers would often print out data using dot matrix printers. Typefaces for matrix printers of this kind were controlled electronically and the information transferred to the paper via typeforming pins impacting an ink ribbon. Such impact systems have been superseded by electrophotographic technologies, in which type is no longer transferred to the paper by impact – as was the case with matrix printers. Instead, a laser sends information to an intermediate carrier, a drum with a photoconductive coating, with-

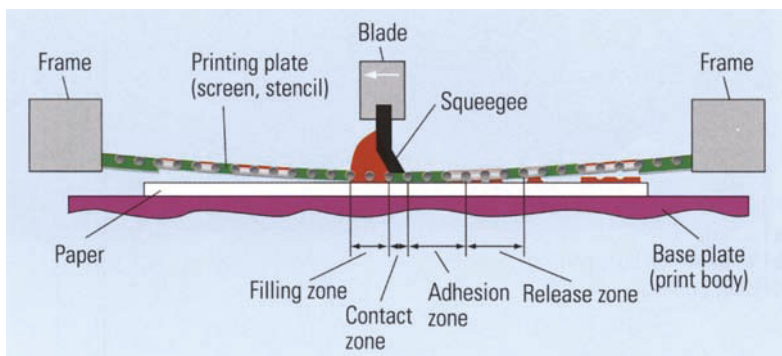


Fig. 1.3-25
Printing process sections (screen printing)

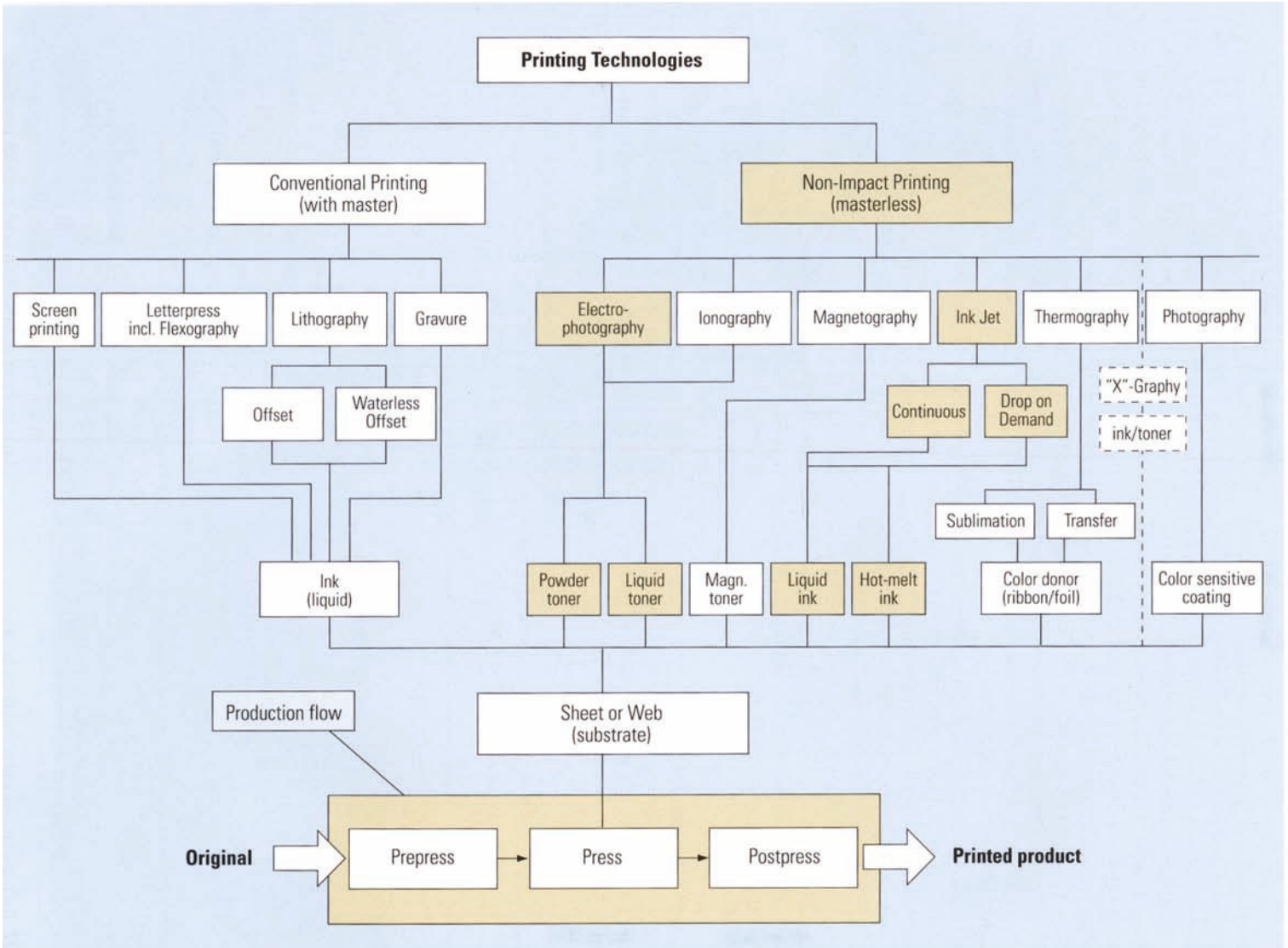


Fig. 1.3-26 Printing technologies for the production of print media

out impact (non-impact) in the traditional sense. The latent (nonvisible), charged image stored on this drum is inked with toner and then transferred to the paper. There is, of course, contact between the inked (toned) information carrier and the paper during printing, but the information is not transferred by impact. This process, therefore, is considered as non-impact printing.

As shown in figure 1.3-26, various physical processes are used to realise, such non-impact printing procedures. The predominating technologies are electrophotography and ink jet printing. Ionography, magnetography, thermography, and photography are, however, also used. New physical processes that could be incorporated in non-impact printing are constantly being discussed and developed in specialist fields. In figure 1.3-26, these new developments are referred to as "X"-Graphy. The masterless printing technologies are described in detail in chapter 5, together with various examples of their practical application. The two most important NIP technologies electrophotography and ink jet printing are explained in the following introduction with examples.

1.3.3.1 Electrophotography

The principle of electrophotography is illustrated in figure 1.3-27. The electrophotographic printing process can be broken down into five steps:

1. *Imaging*
   Imaging is carried out by charging a suitable photoconductive surface (creating a homogeneous charged surface) with subsequent imaging via a controlled light source (this may be scanning laser light or light emitted by an LED array [light-emitting diodes]). The print image corresponds to the positioning of the light signals on the photoconductor drum. The homogeneous charged image on the surface is discharged in parts as a result of exposure and changed in accordance with the desired print image. (Since imaging in electrophotography can be done both by laser light and by light given off by light-emitting diodes, the frequently-used term "laser printer" instead of the term "electrophotographic printer" is misleading.)
2. *Inking*
   Special inks are used for electrophotography. These may be powder or liquid toners, which may vary in structure according to their composition, and contain the colorant in the form of pigments. The ink is the fundamental and decisive element for the impression. Inking is done via systems which transfer the fine toner particles, approximately 8 µm in size, without contact to the photoconductor drum (similar to the example shown in fig. 1.3-27). The toner charge is configured in such a way that the charged areas of the photoconductor surface accept the toner. (As shown in the example, imaging has, therefore, been done with a negative image because the positive charges have been discharged by exposure.) Therefore, after inking, the latent image on the photoconductor drum becomes visible where the toner is applied.
3. *Toner transfer (printing)*
   The toner may be transferred directly onto the paper, although in some cases it may also be transferred via intermediate systems, in the form of a drum or a belt. As shown in figure 1.3-27, transfer mostly takes place directly from the photoconductor drum to the substrate. To transfer the charged toner particles from the drum surface to the paper, electrostatic forces are generated via a charge source (corona) in the nip and it is these forces, supported by the contact pressure between the drum surface and the paper, that transfer the particles to the paper.
4. *Fixing the toner*
   A fixing unit is required to anchor the particles of toner on the paper and create a stable print image. This is usually designed so that melting and consequent anchoring of the toner on the paper takes place by heat application and contact pressure.

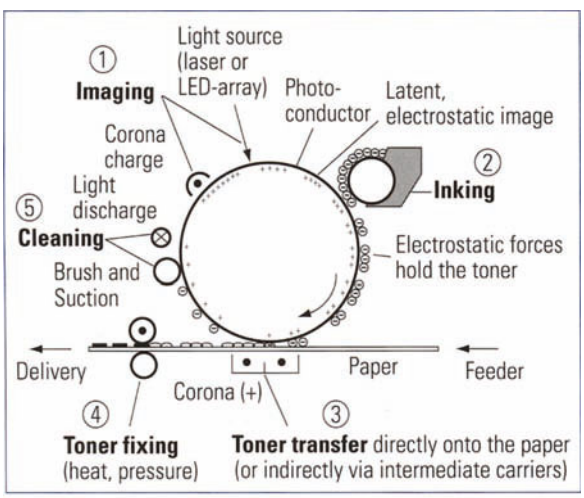


Fig. 1.3-27 The basic structure of electrophotography

5. *Cleaning*
   As shown in figure 1.3-27, residual charges and individual particles of toner remain on the drum after the print image has been transferred from the photoconductor drum to the paper. To prepare the drum so that the next image can be printed, both mechanical cleaning and electrical cleaning of the surface are necessary. The mechanical cleaning, which removes particles of toner, can be done by means of brushes and/or suction, while the electrical "cleaning" (neutralizing) is accomplished by homogeneous illumination of the surface, after which the surface is electrically neutralized and is free from toner particles. The photoconductor drum is now charged again with a homogeneous, charged image via the corona, with subsequent imaging in accordance with the desired print image (as described in step one).

From the procedural steps described, it is easy to see that electrophotography with a fixed, engraved print image operates without a master. A different charged image can be applied to the photoconductor drum after each rotation. This means that it is possible to generate a completely different print image rotation-by-rotation, print by print.

Unlike printing methods that use a fixed image carrier (e.g., a plate), this process (taking a print run of one hundred identical impressions, for example) requires that the same print image be created again and again, rotation by rotation, in the form of a latent charged image. This repetition could lead to process-related variation in the print image. Such fluctuations may be caused by tolerances employed to create the charged image and/or by the tolerances (involved in the technical process) produced during the inking of the photoconductor with toner and the subsequent, electrically-supported transfer of the image to paper. Therefore non-impact printing technologies may produce greater variation within a print run than is the case with technologies requiring a master.

On the other hand, the fascination and the advantage of this technique lie in the fact that a completely different print image can be created rotation by rotation (*variable printing*), thus it is not necessary to generate a mechanical master for each printed sheet. Extremely short print runs (even just one copy) can be produced economically in this way (*print on demand*). Furthermore, each page of a brochure, from the first to the last page, can be produced in succession; the pages for the second copy are not printed until the first book has been completed (*book on demand*). Also, personalizing a part of the print images, for instance by inserting an address or recipient-specific additional information, can be directly carried out copy by copy (*personalization, customizing*).

An example of an electrophotographic printing system for multicolor printing is shown in figure 1.3-28. This system is based on the *unit design principle* like sheet-fed offset presses. The configuration illustrated in figure 1.3-28 comprises four electrophotographic printing units which transfer the usual process colors of black, cyan, magenta, and yellow to the printed sheet in succession.

In the example shown, the photoconductor drum is imaged via an optical system in which the laser light is deflected onto the photoconductor drum by means of a rotating mirror and special optics (fig. 1.3-29). The laser beam is guided over the drum's surface at high speed. Directed by a digitally-controlled modulator, the ray of light is turned on or off depending on the image, that is, the charge is discharged or remains on the previously charged photoconductor drum. The system shown is also known as an ROS imaging system (Raster Output Scanner).

The transfer of paper by means of a transfer belt is an interesting aspect of the example illustrated in figure 1.3-28 where no grippers are used to transfer the sheet. The fact that the paper is held only by electrostatic forces applied over the belt imposes limitations with respect to the accuracy of the color register – acceptable tolerances are usually two to four times higher than with a printing process using conventional technology, such as offset printing. Printing on both sides of a sheet (*duplex printing*) is also possible with the printing system shown in figure 1.3-28a, in which case the sheet is turned automatically after the front side has been printed and fed back to the printing units.

With printing systems of this kind, the content of the print image may be produced in two ways. First, the original can be scanned in with a scanner (that has either been integrated into the printing system or connected via an interface). Secondly, digital data can be used that has either been stored on data carriers or can be fed directly into the production system from a network. The system illustrated in figure 1.3-28 has an integrated flatbed scanner which optically scans and digitizes the print copy. The printing process itself is then carried out. However, with conventional copiers, such

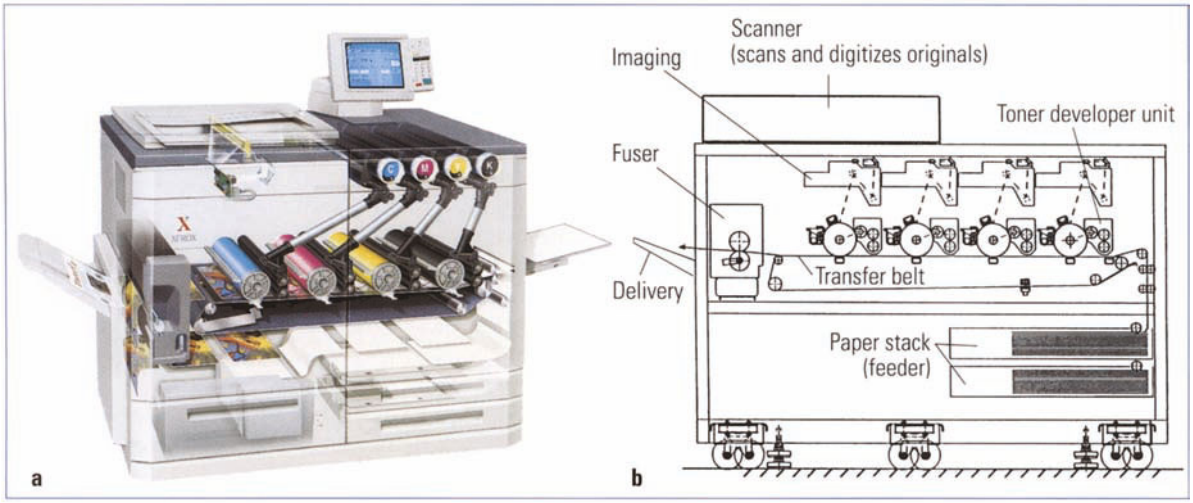


Fig. 1.3-28 NIP printing system (electrophotography) for multicolor printing.
a Unit design for multicolor printing (gripperless sheet conveyance) with sheet transfer for duplex printing and scanner;
b Printing system with modules for imaging, inking, and fixing (DocuColor 40, Xerox)

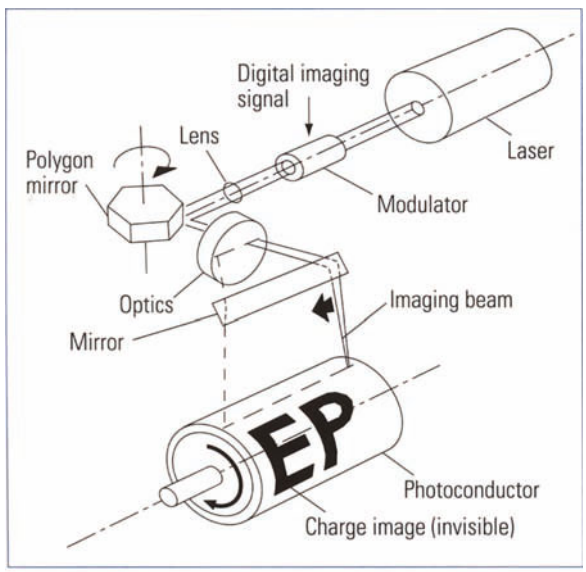


Fig. 1.3-29
Laser imaging system for electrophotography (ROS: Raster Output Scanner)

as those installed in offices for single-color impressions, the copy image is not digitized, but exposed directly onto the photoconductor drum. Printing systems which receive information as analog copy (original) are usually referred to as "*copiers*," whereas the term "*printer*" is used if prepared job data is fed directly to the system in digital form.

There is a considerable difference between the *printing speed* of a NIP printing system and the printing speeds of sheet-fed offset presses. The system shown in figure 1.3-28 (relatively fast because of its unit construction) can produce 1200 A3 pages (impressions) an hour, whereas an A3 sheet-fed offset press normally produces between 10 000 and 15 000 impressions an hour. This difference in productivity results primarily from the imaging technology used – each impression requires fresh imaging, even if the same image is to be printed. On the one hand, the imaging speed is determined by the different digital hardware and software components (which affect costs accordingly) and, on the other hand, the printing speed is also influenced by the physical processes and design of the ink transfer and paper transport systems.

With regard to the precision of modules and components (especially among image systems and cylinder groups), high requirements – like those expected for conventional presses – are absolutely vital. The bearings, for instance, are to be dimensioned similarly in respect to accuracy and resistance. The paper transport must also be supported by high-grade technical systems. Due to a reduced printing speed, the dynamic requirements and loads of such machines are lower – a

fact that allows for a lighter construction needing fewer materials.

Based on the availability of high-quality technological components, the *print quality* generated by electrophotographic systems is at a high level. However, it is clearly lower than the high quality that can be achieved with conventional technologies. The quality-relevant specifications of non-impact printing systems concentrate on *addressability* data (the number of dots/pixels per unit of length), number of *gray values* (or gray levels) per pixel and the *toner technology* used. The system shown in figure 1.3-28 has an addressability of 400 dpi (dots per inch). When imaging one pixel it can generate different charges by varying the intensity of the imaging light ray (e.g., controlled by means of the ON period of the laser), meaning that it is possible to distinguish about ten gray values through the correspondingly varied toner transfer in the printed pixel. As explained in section 1.4.3 and illustrated in figure 1.4-39, the possible reproduction of very fine structures is determined by the addressability and the possible reproduction of tonal values and gamut by the addressability and the gray values per pixel.

The print quality is also affected by the quality of the toner, its particle size, geometric form, and chemical/physical structure. In general, toners with particle sizes of only 6–8 µm and a narrow particle-size distribution are used for high-quality printing so that good image reproducibility is possible. Using powder toners can lead to impaired print quality caused by dusting, that is, portions of the print image that should not carry any ink are inked with "stray" toner particles.

The decisive factor and the guarantee for continuous high quality and optimal reproduction throughout a print run using conventional technologies requiring a master is the fact that a stable image carrier is used that represents the print image as a mechanical master (*mechanical printing process*). In the case of electrophotography (*electronic printing process*) the constant need for re-imaging can produce system-related fluctuations from print to print.

As shown in figure 1.3-26, electrophotographic technologies may operate *with powder or liquid toner*. The use of liquid toners is still not very widespread, although they essentially have the advantage of assuring higher print quality with considerably smaller toner particles (approx. 1 to 2 µm). (Various toner applications for electrophotographic technologies are explained in detail in section 1.5.2.8, and in chap. 5 – in particular sec. 5.1 and 5.2 –, the device-specific inking unit designs corresponding to these toner applications are shown.)

When comparing conventional printing technologies to non-impact printing (especially technologies with a latent intermediate image), it should be noted that in NIP – for instance, with electrophotography – the circumferential length of the photoconductor drum need not be identical to the image length. In many cases the diameters of the drum are smaller than the maximum image length would require, which means that, in order to print a page, the drum has to be imaged over a 360° drum rotation. Therefore, even if the prints are identical, the latent image and the inking by the inking unit do not occur at the same point on the drum surface with every print. Regardless of powder or liquid toner, ink resplitting – such as that occurring (and automatically compensated for) in the sheet-fed offset printing process – is not acceptable in electrophotography.

More detailed information on electrophotography and descriptions of system concepts and examples can be found in sections 4.1.4, 4.5.1, 5.1, and 5.2.

1.3.3.2 Ink Jet

In principle, ink jet non-impact printing technology does not require an intermediate carrier for the image information the way a photoconductor drum does in electrophotography. In the ink jet process the ink can be transferred directly onto the paper. As illustrated in figure 1.3-26, ink jet technologies can be classified as *continuous* ink jet and *drop on demand* ink jet. The ink used for ink jet printing is usually liquid. An alternative, however, is hot-melt inks which are liquefied by heating. The ink is sprayed onto the substrate where it solidifies after cooling.

The main ink jet technologies are illustrated in figure 1.3-30, together with typical specifications. The *continuous ink jet* technology generates a constant stream of small ink droplets, which are charged according to the image and controlled electronically. The charged droplets are deflected by a subsequent electric field, while the uncharged ones flow onto the paper. This means that the imaging signal for charging the droplets corresponds to a negative print image (as was also the case with the example described above for electrophotographic technologies in accordance with figure 1.3-27). Continuous ink jet printing usually feeds only a small proportion of the stream of droplets to the substrate. With continuous ink jet generally only a small part of the drop volume covering

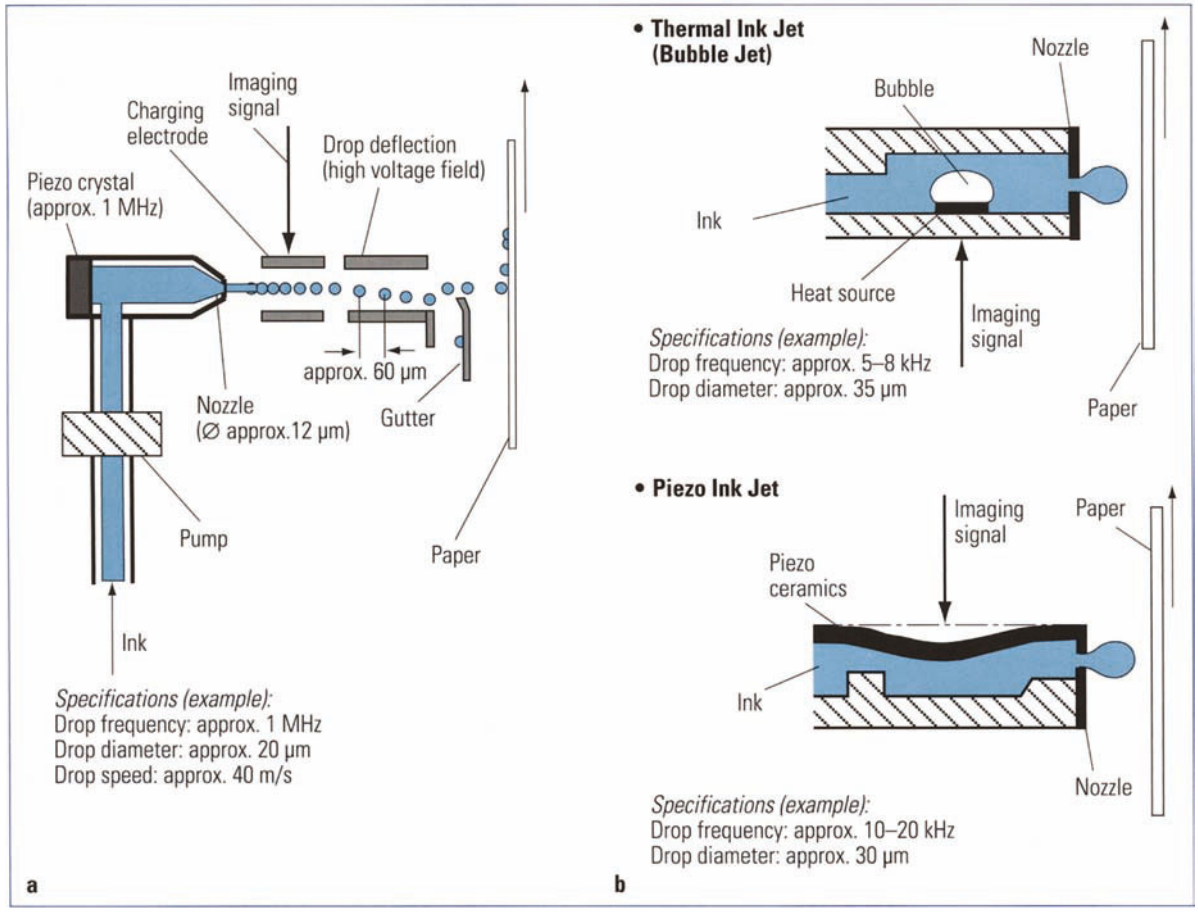


Fig. 1.3-30 Ink jet technologies.
a Continuous ink jet;
b Drop on demand ink jet

the sheet in accordance with the print information is applied to the substrate. The large part is fed back into the system.

With the so-called "*drop on demand ink jet*" technology, on the other hand, a droplet is only produced if it is required by the image. The most important "drop on demand" technologies are thermal ink jet and piezo ink jet printing (other variants are dealt with in sec. 5.5). *Thermal ink jet* (also known as "bubble jet") generates the drops by the heating and localized vaporization of the liquid in a jet chamber. With *piezo ink jet* the ink drop is formed and catapulted out of the nozzle by mechanically deforming the jet chamber, an action resulting from an electronic signal and the piezoelectric properties of the chamber wall. Due to the technical conditions, the possible droplet frequencies are lower with thermal droplet generation than with piezo technology.

Taking a systematic view, ink jet printing represents the most compact technology for transferring information to normal paper in the form of a printed image (comparable to light on photographic paper). It is only necessary to generate a droplet of ink on the basis of image-dependent signals and to spray this droplet directly onto the substrate without an intermediate carrier.

Printing systems based on the ink jet technology are usually slow in comparison to conventional printing technologies with master, that is, they operate at a lower printing speed, especially if imaging is carried out with



Fig. 1.3-31 Multicolor ink jet printing system (continuous ink jet) for proof production (Digital Cromalin, DuPont)

individual nozzles. Figure 1.3-31 shows an ink jet printing system in which a four-color impression is created by four ink jet systems (one for each of the four inks). To do so, the paper is fastened to a drum and the individual ink jet systems (for the process colors cyan, magenta, yellow, and black) transfer the individual color separations to the substrate. This occurs due to the axial scanning motion of the imaging head and rapid rotation of the drum. With the system shown, an A3 multicolor print is produced in approximately five minutes (addressability 300 dpi, approximately 10 gray values per pixel). This type of system is, therefore, mainly employed to produce the proofs necessary in digital prepress before the computer to plate process (digital, filmless exposure of the printing plate, see sec. 4.3) produces a printing plate. Such a proof allows the quality of the data file and the content and visual quality of the subsequent impression to be checked at a preliminary stage (see also sec. 3.2.11).

As previously mentioned, ink jet technologies, which typically operate with a resolution between 300 and 600 dpi, can generate several gray levels per pixel, often depositing several droplets on one pixel. Up to around 30 gray levels are possible with high-frequency continuous ink jet systems.

To increase an ink jet printing system's productivity, nozzle arrays as wide as the printed page have to be used.

Figure 1.3-32 illustrates an example of an ink jet system which prints across the whole width of the web with two ink jet heads (240 dpi). Using the system shown, multicolor printing on the upper and lower side of the web is possible. The system shown in this picture, however, is only applying spot color and not the process colors for multicolor halftone printing.

Ink-drying presents a particular problem in ink jet printing, and the paper surface's ability to carry ink deserves special attention. Special coated papers are usually required for high quality impressions, although specially formulated inks used in conjunction with an adapted drying process can greatly increase the range of suitable papers. Hot-melt inks are primarily of interest because they dry rapidly and allow printing on a variety of papers.

The NIP technology of ink jet printing, system concepts, and examples are dealt with in more detail in sections 4.5.2, 5.5 and 6.2.

1.3.3.3 Printing Systems based on Non-Impact Printing Technologies

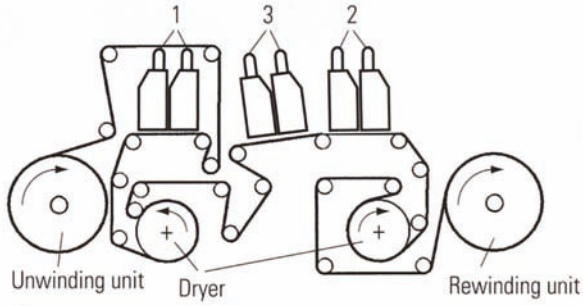
Figure 1.3-33 shows in a system architecture that it is possible to set up print media production systems based on non-impact printing technologies. Such systems enable the entire printed product to be produced in-line. With non-impact printing technologies it is of fundamental importance that the print image is already dry after the print (as described for electrophotography with subsequent fixing or ink jet processes using special



a

Addressability: 240 dpi
Web speed: up to 5 m/s (1000 ft/min)
Ink jet imaging array:
Width: approx. 108 mm
Number of nozzles: 1024

Ink jet imaging:
1 Reverse side printing: e.g., black, page wide
2 Front side printing: e.g., black, page wide
3 Front side: e.g., half page width blue and half page width red



b

Fig. 1.3-32 High-speed ink jet printing system (System 6240/Color Runnar, Scitex Digital Printing/Matti Technology)

Fig. 1.3-33
Block structure of an in-line production system for print media

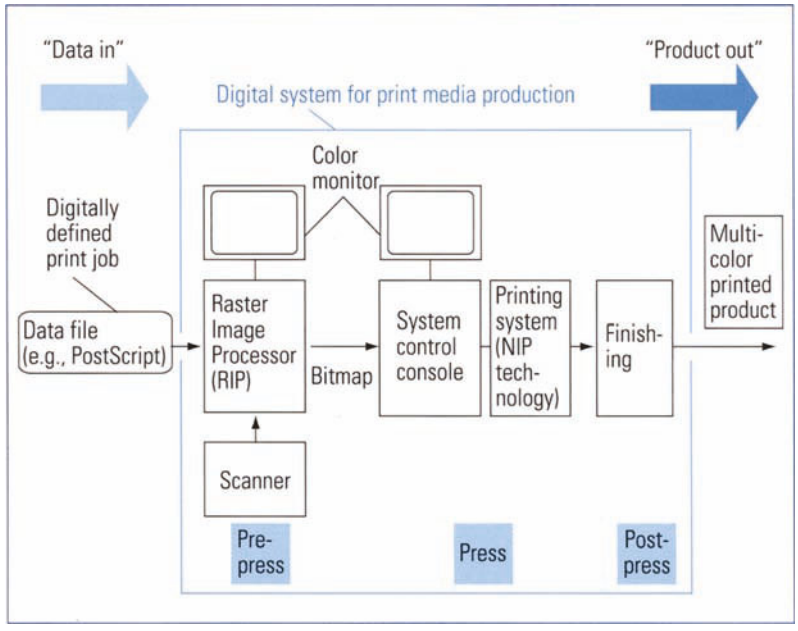


Fig. 1.3-34
Print media production system (electrophotography) for in-line brochure production (Digimaster 9110, Heidelberg)



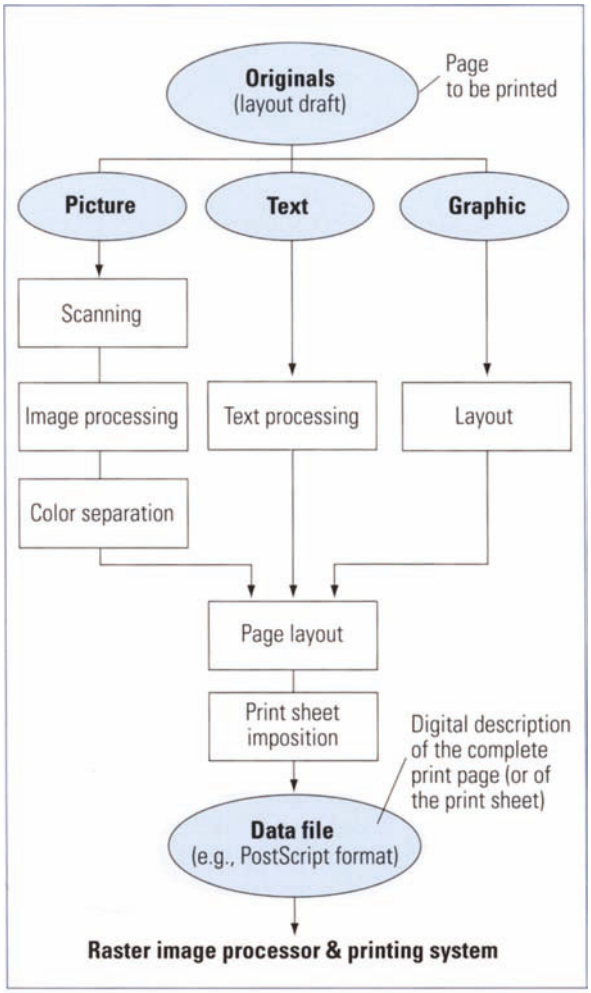


Fig. 1.3-35 Digital composition of a print page

drying techniques or using hot-melt ink). In this way, finishing (collating, stitching and folding) can be done in-line, thereby making the intermediate storage of printed sheets superfluous.

Figure 1.3-34 illustrates an example of a *printing system* that delivers a completely finished brochure copy by copy. The printing process is digitally controlled and a data file contains all the text, image, and graphics information to be printed page by page. Additions or modifications of this file are still possible shortly before printing starts, for example via the connected flatbed scanner. This production system could be summed up as a "data in-product out" system.

If printing systems based on non-impact technologies are to be used, a full description of the *printed product* is required in *digital form*. In a simplified representation, figure 1.3-35 indicates which operations must be carried out in prepress in order to prepare the entire printed page with text, graphics, and illustrations (pictures) in digital form for single or multicolor printing. A detailed description of these processes is given in section 3.2.

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1.4 Print Quality

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1.4.1 Color/Color Theory

Color is an optical phenomenon, a sensory impression conveyed by the eye and the brain. Color is not a physical variable; accordingly it has no physical unit. An object is not colored per se, but the sensation of color is produced as a result of irradiation by light. Sunlight, which appears to be white, radiates onto an object and is partially reflected. Consequently an object that reflects the red area of the visible spectrum appears colored. An object that reflects completely in the entire visible spectrum usually appears to be white and a completely absorbent body appears to be black.

When perceiving and describing colors, physical and physiological effects are always involved. The physical components are measurable, the physiological are not. The physical properties of a color (chromatic stimulus) can be determined with a colorimeter, but how they are interpreted by the human brain (color perception) can only be estimated. Models to describe the measuring instrument "eye" and the perception of color in the brain have been developed by various research groups and organizations, and to date it is the stipulations of the International Commission on Illumination (CIE Commission Internationale de l'Eclairage) that are particularly significant for color description, on the basis of its standard colorimetric observer defined in 1931.

The following explanations are not intended to replace a reference book on chromatics or colorimetry, but to give a brief introduction to the topic. It is primarily the properties of colors that are considered and that are of significance in modern reproduction technology. A detailed overview of colorimetry and its application in the printing industry is given, for example, in [1.4-1].

To help in distinguishing the component parts involved in the description of colors via the "eye and brain" as a perception system

- the *chromatic stimulus* is defined as the physically measurable radiation reflected by the observed body and
- the *color stimulus specification* as the result of the visual perception in the eye of the observer.

Since it cannot be assumed that the brain operates merely as a color stimulus specification "display unit," it is also expedient to define *color perception* as the sensory impression triggered by the color in the brain.

A color measuring instrument (colorimeter, spectrophotometer) primarily measures only the chromatic stimulus, from which the color stimulus specification and possibly also the color perception can then be deduced numerically by means of suitable interpretation models. These may, for example, be the standard color spaces defined by the CIE: CIELAB, and CIELUV.

Color plays an important role in printing and reproduction technology as a descriptive variable for the actual reproduction. A basic knowledge of *colorimetry* on the part of the user is necessary especially since printing quality monitoring has been carried out on the basis of colorimetry color measure-

H. Kipphan (ed.), *Handbook of Print Media*
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ment (sec. 2.1.4.2) and the introduction of color management systems (see sec. 3.2.10).

A color often appears to the human observer in a colored environment. Color perceptions can only be described clearly by means of comparisons and contrasts. Thus, for example, an identical neutral gray tone field appears greenish on a red background and rather reddish on a green background (fig. 1.4-1).

This effect, known as *simultaneous contrast*, and similar perceptive effects can be directly transferred as influencing factors in reproduction technology. Although the practitioner seldom knows the systematic correlations of chromatics, he takes the correct action intuitively and will always reproduce a color image so that, for example, it appears neutral with a certain specified background, even though the colorimeter might indicate a clear color cast. It must be stressed that as a rule the human eye is an excellent instrument for comparing colors, but is virtually unable to give absolute descriptions of the appearance of colors.

Therefore, the aim of color theory in the field of reproduction technology can be clearly formulated: Whatever is used in the way of technical aids or color classification systems must be aligned with the color perception of the "ultimate measuring instrument," the eye of the human observer (a *model on color perception*, in accordance with [1.4-2] is shown in fig. 1.4-14, and the range in the spectrum of electromagnetic waves visible to the human eye is illustrated in fig. 1.4.-15).

Both *additive* and *subtractive color mixing processes* occur in modern color reproduction technology. The building up of luminosity by means of the individual colors involved is known as additive color mixture (fig. 1.4-2). With subtractive color mixing, on the other hand, luminosity is suppressed by the addition of individual colors (fig. 1.4-3). The classification method of additive or subtractive color mixing systems is not produced, as is frequently assumed, as a result of the colorfulness of its individual components (e.g., additive color mixing like RGB or subtractive color mixture like CMYK), but solely as a result of the light-increasing or light-reducing effect of the mixing processes. In other words, with additive color mixing the same points of the retina receive the rays emitted by several colors in the eye simultaneously. The color impressions add up; with, subtractive color mixing no actual color mixing occurs, but the spectral effects of the individual colors/layers of ink are mounted successively, in a comparable way to superimposed optical glass filters with which the spectral transmission characteristics are combined.

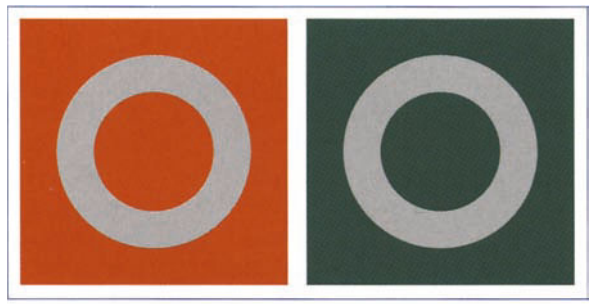


Fig. 1.4-1
Simultaneous contrast. Example of the visual perception of a color shift in an identical gray tone as a result of the surrounding colors

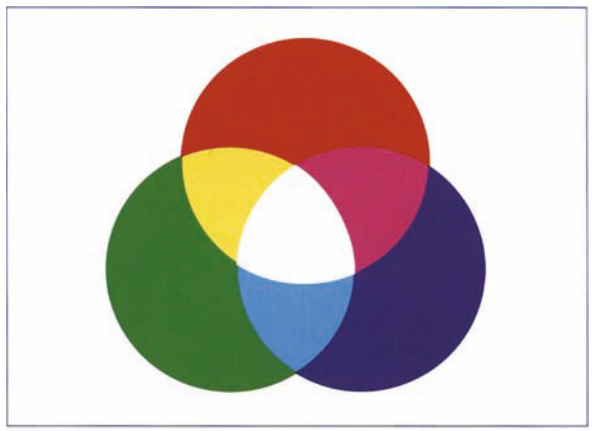


Fig. 1.4-2 Additive color mixing of the basic colors red, green, blue

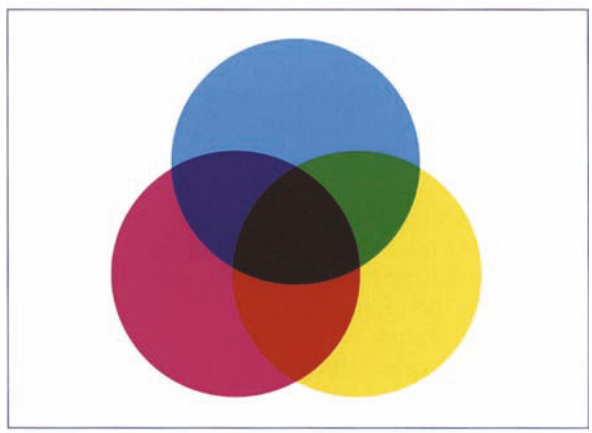


Fig. 1.4-3
Subtractive color mixing of the basic colors cyan, magenta, yellow

Purely additive or purely subtractive reproduction processes are rarely found in color reproduction technology. In multicolor halftone printing, for example, both additive and subtractive color mixing occur (see fig. 1.4-18). Only when colors are presented on a monitor can virtually ideal additive color mixing be observed, virtually ideal subtractive color mixing can be observed with the superimposition of different transparent colored substrates (e.g., optical filters, colored transparencies).

In practice the term *color temperature* is often used to describe the basic setting of a monitor. Of significance with respect to the derivation of this term is the fact that with many artificial sources of radiation, the visible radiation is obtained as a result of the heating up of a material (e.g., a glowing metal filament in an electric light bulb). With these thermal radiators, the radiated energy and its spectral distribution depends on their temperature and absorption properties. Generally valid is the fact that the greater the degree to which a body absorbs visible radiation, the greater is its radiated energy at a specified temperature.

In theory it is an "ideal black body" that has the greatest radiation energy, which can, in turn, be calculated as a function of temperature. This theoretical black body, also referred to as the Planckian radiator, is in practice often taken as a comparison variable for color temperatures, because there are in fact some light sources with radiation distribution behavior very similar to that of the black body. The temperature of the Planckian body at which colors are most similar is called the color temperature or the most similar color temperature. The radiation distribution of the ideal black body is shown in figure 1.4-4. It can be seen that not only does the radiated energy in total increase with the temperature, but its spectral distribution (i.e., "colorfulness") changes, too.

Attempts are often made to describe the color stimulus specification of a light source using the convenient datum of a single number, namely the color temperature expressed in degrees Kelvin. It is generally true that low color temperatures, with a monitor, for example, correspond to a reddish-yellowish (perceptibly warmer) color and high color temperatures tend to appear bluish (perceptibly colder). Of course, the color temperature datum is no substitute for the exact description of a color stimulus specification, but it is in fact a tried and tested, rough model for describing the properties of light sources and primary light sources. It is also true that only a relatively small number of colors can be specified using color temperature.

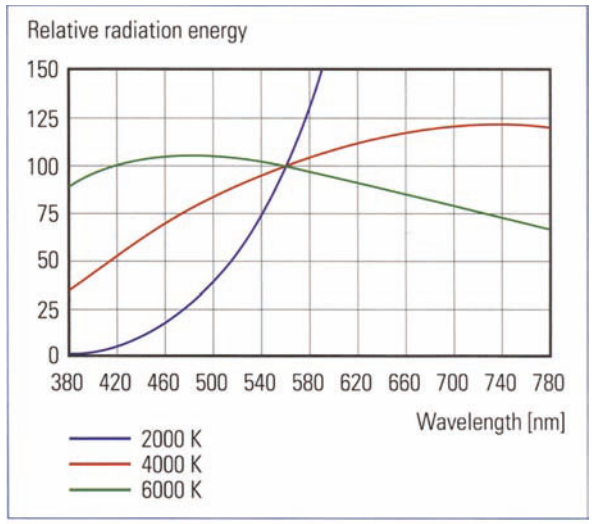


Fig. 1.4-4
Radiation distribution of the ideal black body (Planckian radiator) as a function of temperature (K: absolute temperature in Kelvin)

In order to facilitate a more accurate description of light sources so-called *standard illuminants* were introduced by the CIE. The starting point was the relatively constant electric light bulb, its radiation distribution being standardized as standard illuminant A. A spectral distribution characteristic of daylight, standard illuminant C (artificial daylight), can be obtained from this illuminant using a standardized filter. Because the light of an electric light bulb contains very little ultraviolet radiation, an attribute of the artificial daylight of standard illuminant C is also that only low proportions of UV light (UV = ultraviolet) occur. However, since exactly this proportion of UV plays a significant role in many actual color matching processes (particularly in the printing industry), with D65 the CIE defined an additional standard illuminant (natural daylight), the number 65 signifying in this case that the color temperature is 6500 Kelvin. Since the CIE's standard illuminant D65 has only been specified in theory, it is in fact very difficult to simulate it using actual light media in practice. In printing and reproduction technology another standard illuminant, D50 (5000 Kelvin), is also used, which is intended to describe approximately natural daylight.

As already mentioned, the color temperature datum is not an exact procedure for describing colors. To facilitate a more precise and internationally uniform de-

scription, a system of recognized reference colors, which are also known as *reference color stimuli*, is expedient. In 1931 the CIE specified the color matching functions of the reference color stimuli R, G, and B in accordance with the empirically determined properties of the standard observer. In this system a combination of reference color stimuli is assigned to every wavelength of the visible spectrum. It includes both positive and negative values for reference color stimuli. To obtain only positive values a system of *virtual reference color stimuli* was specified by the CIE, designated by the letters X, Y, and Z, with X corresponding to an imaginary (not actually existing) red, Y to an imaginary green, and Z to an imaginary blue color stimulus specification. The spectral values relating to these standard colorimetry specifications are called *standard tristimulus values* and the color values calculated from them the *standard color values*. The *standard color matching functions* $\bar{x}(\lambda)$, $\bar{y}(\lambda)$ and $\bar{z}(\lambda)$ describe the relative energy radiated over the wavelength and define the spectral sensitivity of the eye of the CIE standard colorimetry observer (fig. 1.4-5 and fig. 1.4.-14).

Certain particular attributes can be derived from the standard tristimulus values specified by the CIE, with an ideal white (under ideal illumination with a spectrum of the same energy and irrespective of wavelength) having the standard tristimulus values X = Y = Z = 100, it being possible to calculate luminance using the imaginary tristimulus value Y.

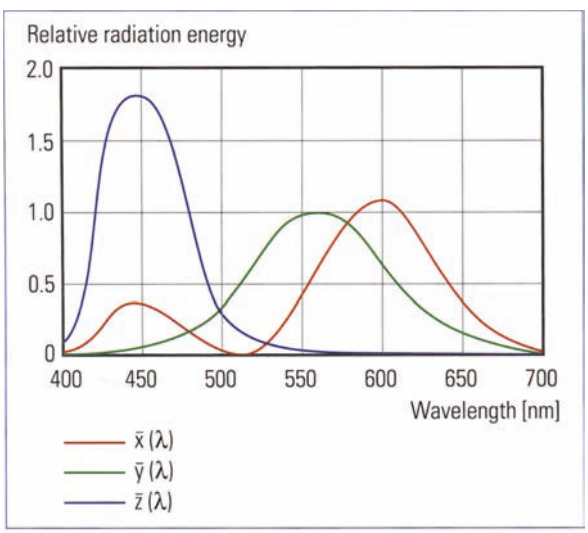


Fig. 1.4-5 Standard color matching functions

The CIEXYZ color system represents an important reference color space in modern reproduction technology. Both the stipulations of the International Color Consortiums (ICC) [1.4-3] and the color definitions of the page description language PostScript [1.4-4] make provision for CIEXYZ as a reference color space under standard illuminant D50, at an observation angle of 2 degrees.

In representing the interrelationship of standard color values, reference is made to the *standard color value ratios* x, y, and z, which when added together always give 1. Accordingly it is not necessary to list all three values, any two values in relation to 1 suffice as an unambiguous value description. The application of this system produces a new representational variant for the unambiguous classification of colors on the basis of the CIE reference color stimuli. Only the standard color value ratios x and y, which constitute a measurement of *saturation* and *hue*, are given instead of the standard color values X, Y, and Z. Also, luminance is described by the additional datum of standard color value Y in the third dimension. The representation derived from this is also known as the *standard color chart*, the CIE color triangle or in practitioner's terms as the "CIE footprint." Marking the actual color stimulus specifications in this visualization diagram (remembering that X, Y, and Z are imaginary and not real reference color stimuli), produces the horseshoe-shaped space illustrated in figure 1.4-6, the outer edge of which is also known as the *spectrum locus*.

The so-called basic stimulus with the standard color value ratios x = y = 0.333 corresponds to the *achromatic point* in the CIE color triangle. The color stimulus specification of the respective light source used is taken as the basic stimulus for surface colors. In the case of standard illuminant D65, for example, the standard color value ratios are x = 0.313 and y = 0.329.

If graphic visualization of the *luminance* is sought, in addition to saturation and hue, another representational axis must be introduced. The Y axis traversed by the achromatic point completes the CIE color triangle for the CIE color solid (fig. 1.4-7). If the maximum attainable luminance is applied to the surface colors in addition to saturation and hue, the CIE color solid has the appearance of an asymmetrical mountain. It must be noted that a markedly greater luminance can be achieved with high saturation in the yellow and green color range than in the blue and red color range. Therefore the CIE color solid is clearly asymmetrical.

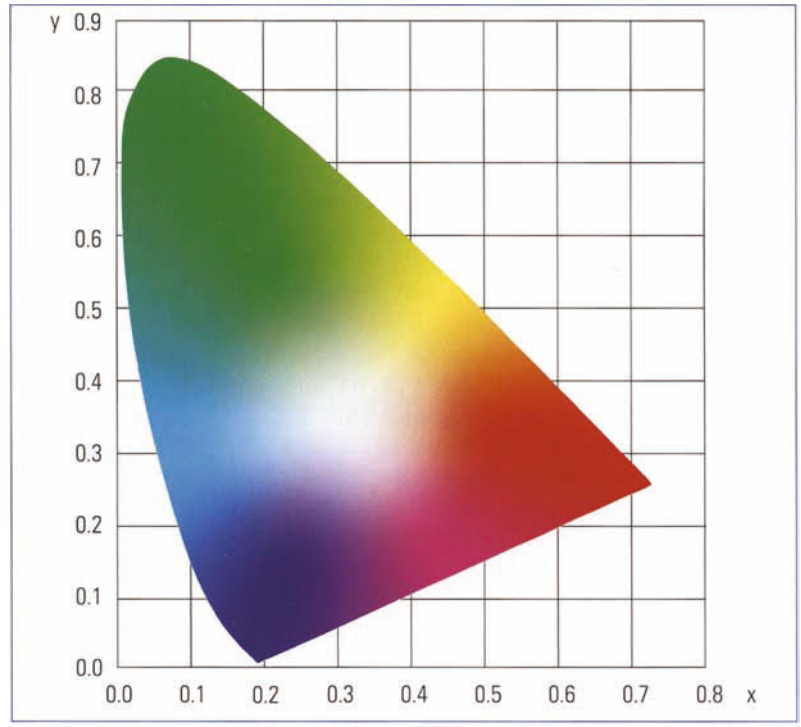


Fig. 1.4-6
CIE (x, y, Y) chromaticity diagram (CIE color space, CIE color "triangle") [1.4-1]

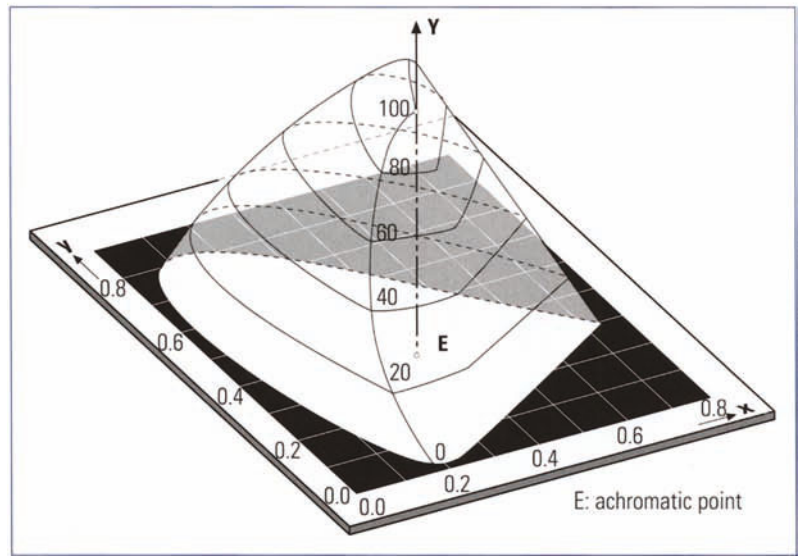


Fig. 1.4-7 CIE color solid [1.4-8]

The CIE color solid in figure 1.4-7 expediently describes all pigment colors that can be perceived by the eye of the normal observer with a specified light source, though the visual difference between two colors cannot be read suitably in this classification scheme.

The numerical value for the difference between two colors in a color classification system is usually indicated by *Delta E* (ΔE). This value per se merely represents a statement of the difference, whereby the classification system and distance formulae with which the

color difference is determined are of fundamental importance. As a general rule, the lower the ΔE value, the lower the *color difference*.

If, for example, the Euclidean difference of two X, Y, Z values (vectors, value triad) is determined by means of a simple difference formula

$$e = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2}$$

(with X, Y, and Z as the coordinates of a three-dimensional coordinate system), it becomes apparent that this numerical value does not agree with the perceived difference between other pairs of colors.

It is for this reason that various attempts have been made to define color classification systems that are better able to meet the criterion of visual uniformity. To solve the problem, on the one hand, as simple as possible a mathematical transformation of XYZ into a new color system, possibly disregarding the ideal visual uniformity criterion, can be used (functional approach). On the other hand, an individual color classification system can be created by drawing up a complex reference system, in which transformation into all individual values is specified that is consistent with the ideal visual equidistance criterion (in table or Look-Up-Table form). The "Munsell Book of Colors" (1915) probably represents the most famous table approach, but this will not be dealt with in greater detail at this point.

Another option consists of an initial improvement of the uniformity criterion being achieved by means of a simple functional approach by introducing a new color system and then obtaining a sufficiently good description of differences using a modified difference formula (e.g., CIE94).

If the CIE color triangle is now transformed (i.e., the chroma specified by x and y) by distortion so that an initial visual uniformity criterion (compensating for the so-called Mac Adams Ellipses) is achieved, the basis of the CIELUV color space (fig. 1.4-8) is produced. This transformation is implemented using linear equations, so that the conversion into u' and v' remains simple, but the criterion of visual uniformity is met only moderately well.

The luminance value Y must then be incorporated into the transformation. This finally produces with

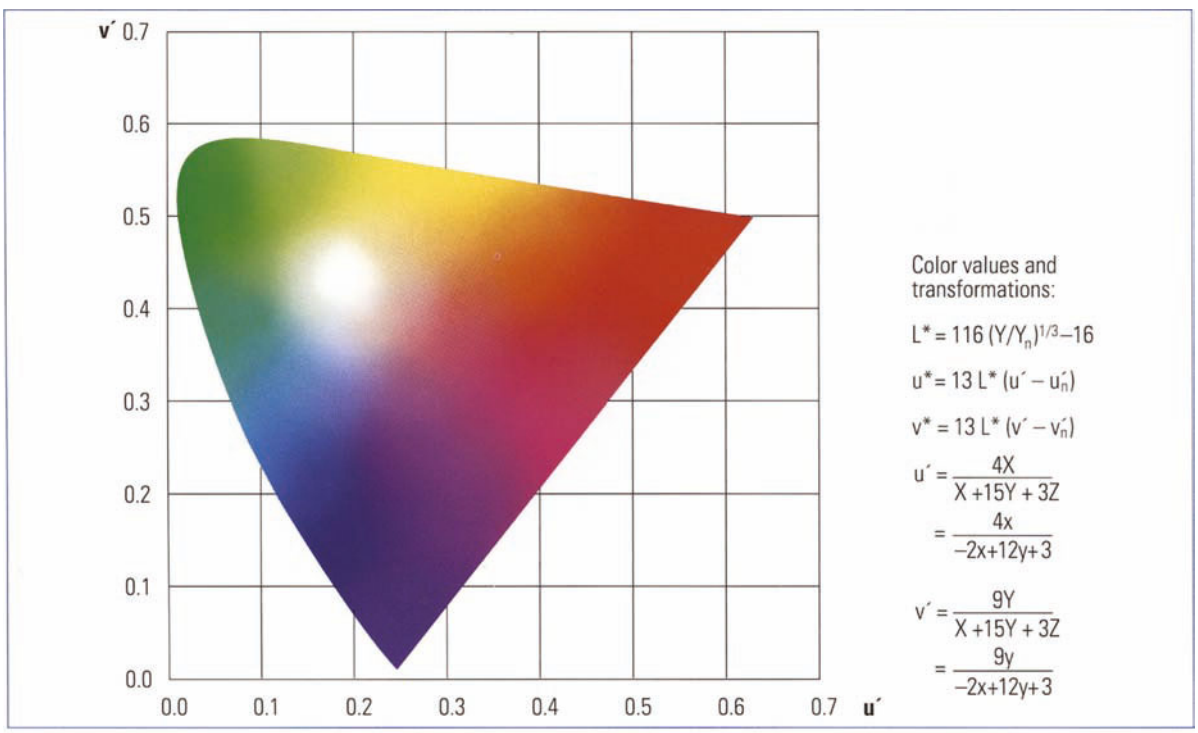


Fig. 1.4-8 CIELUV color space [1.4-1]

L*,u*,v* a value triad for the complete description of color coordinates in the CIELUV color solid in accordance with the equations listed in figure 1.4-8.

The difference between two colors in the CIELUV system is determined by means of the Euclidean difference formula

$$\Delta E = \sqrt{\Delta L^{*2} + \Delta u^{*2} + \Delta v^{*2}}.$$

Differences on the axes or in the levels of the three-dimensional color classification system can, of course, be determined separately (e.g., ΔE_{uv}, ΔE_u, ΔE_v, ΔE_L).

Other ideas for creating equidistant color classification systems and difference formulae have been developed independently of the CIE color triangle classification system using the "complementary color theory" [1.4-5, p. 38].

Probably the most popular and currently the most important color space based on the complementary color theory is known as CIELAB (fig. 1.4-11). The LAB color difference formula defined by the CIE in 1976 was primarily useful for standardizing the different LAB models that had already been developed over the years.

The L*, a*, and b* coordinates can be calculated from the standard color values XYZ, as illustrated in figure 1.4-9. Under the CIELAB color space derivation system, there are no two-dimensional color charts (like the CIE color triangle), in which hue and saturation can be represented. The *CIELAB color solid* is shown in figure 1.4-10 and the cross section for a certain lightness value, the CIELAB color space, is shown in figure 1.4-11. In the *CIELAB color circle* (fig. 1.4-9) the chroma and not the saturation is varied as a parameter from the center to the edge of the circle. This means that no meaningful representation of the spectrum locus outline is possible in the CIE color circle (unlike the u',v' diagram or the CIE color triangle).

The popular representational form LCH is produced from the CIELAB color circle by means of a simple variation. In it *chroma* C* and *hue* h* are determined from the values a* and b* in accordance with figure 1.4-9 and figure 1.4-12.

In figure 1.4-12 the color locations for a blue and green tone have also been entered in accordance with fig. 1.4-13. Calculation was done on the basis of the spectral distributions corresponding to the colors, as il-

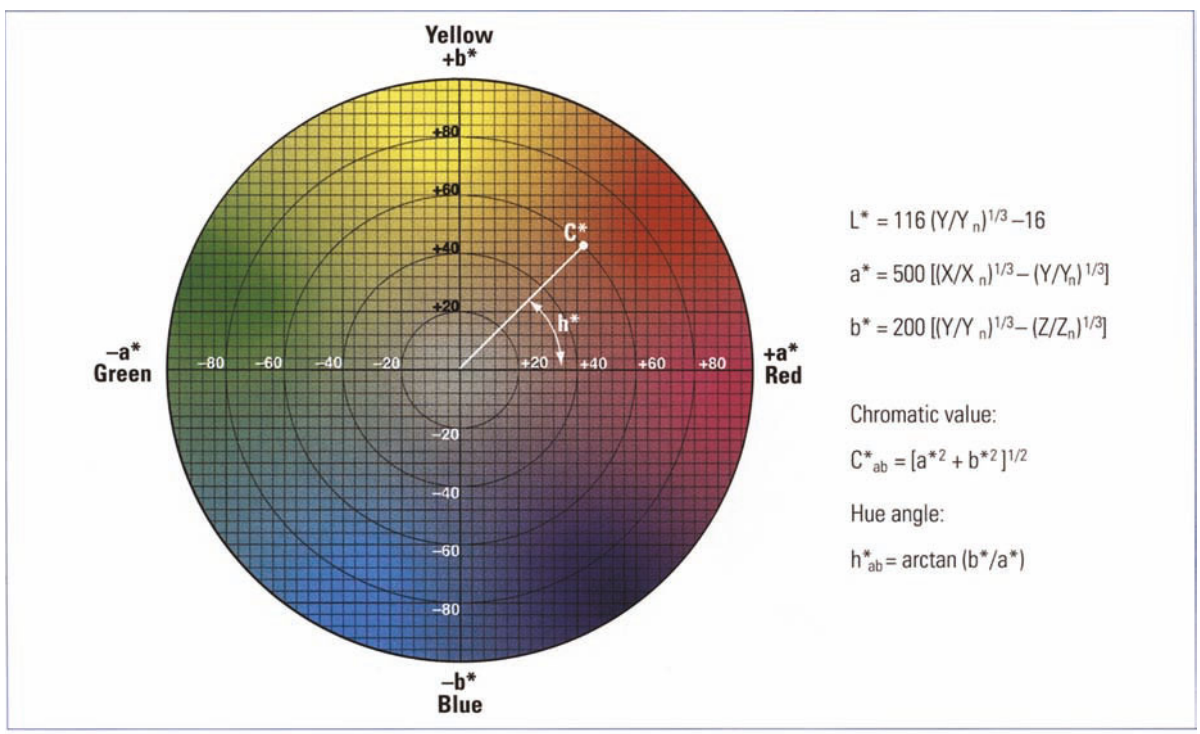


Fig. 1.4-9 CIELAB color circle [1.4-1]

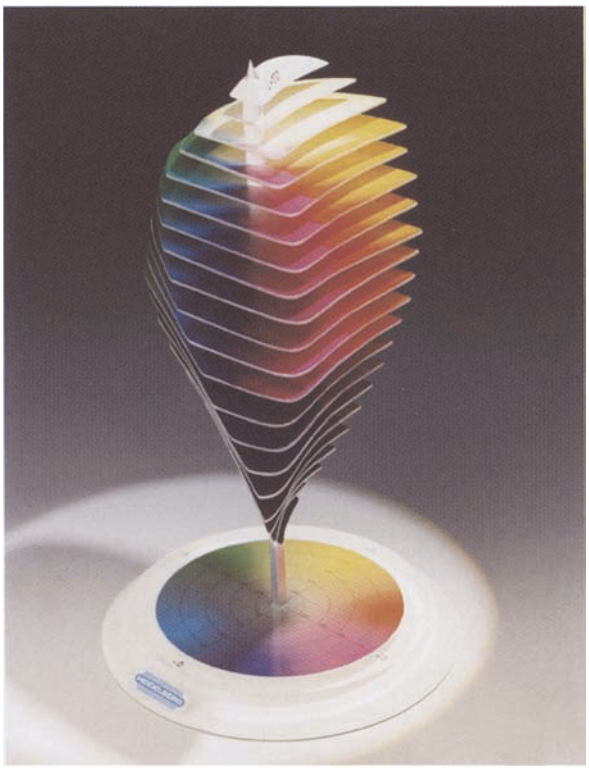


Fig. 1.4-10 CIELAB color solid [1.4-2]

lustrated in figure 1.4-13. These spectral distributions represent the physical "fingerprint" of the colors, from which perception-relevant color coordinates can be calculated by means of colorimetry.

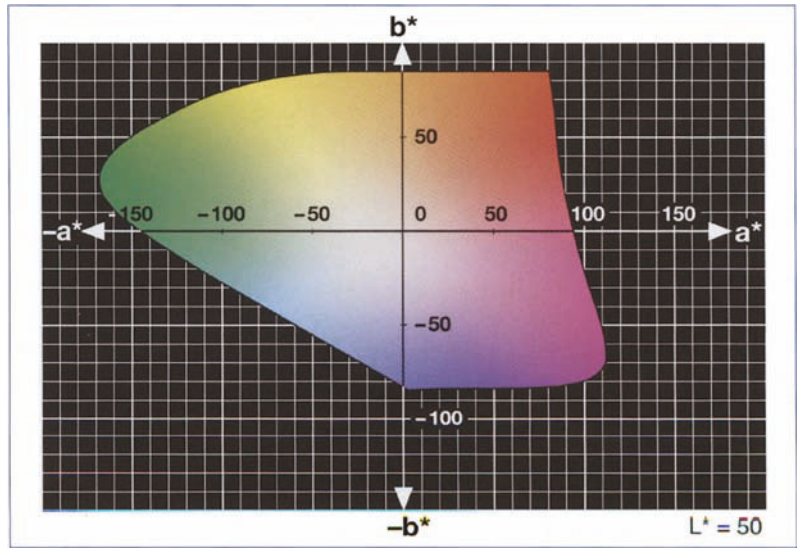
When colorimetrically controlled reproduction systems (color management) are used, it is considerably easier for the inexperienced user to describe and edit the LAB data represented in LCH form. Nowadays, therefore, there is a preference for data to be saved as LAB data and edited in LCH mode.

Figure 1.4-14 shows in summary how human perception of color takes place and how the physical model for the metrological recording and "correct" mathematical description with respect to perception is structured, reference also being made to different color systems.

To sum up, it should be noted that no ideal equidistant color classification system exists to date. It has been attempted in numerous investigations to present the fundamental advantages of CIELAB over CIELUV and vice versa. Subject to a certain "de facto" standardization, conditioned among other things by the stipulations of the International Color Consortium (ICC), the CIELAB color space probably represents the most important colorimetric classification system at present.

Visual uniformity of color differences was optimized further by the introduction of a new color difference formula CIE94, which is based on the parameters of the LCH representational variant of the CIELAB color space [1.4-6].

Fig. 1.4-11
CIELAB color space (cross section of the color solid) [1.4-1]



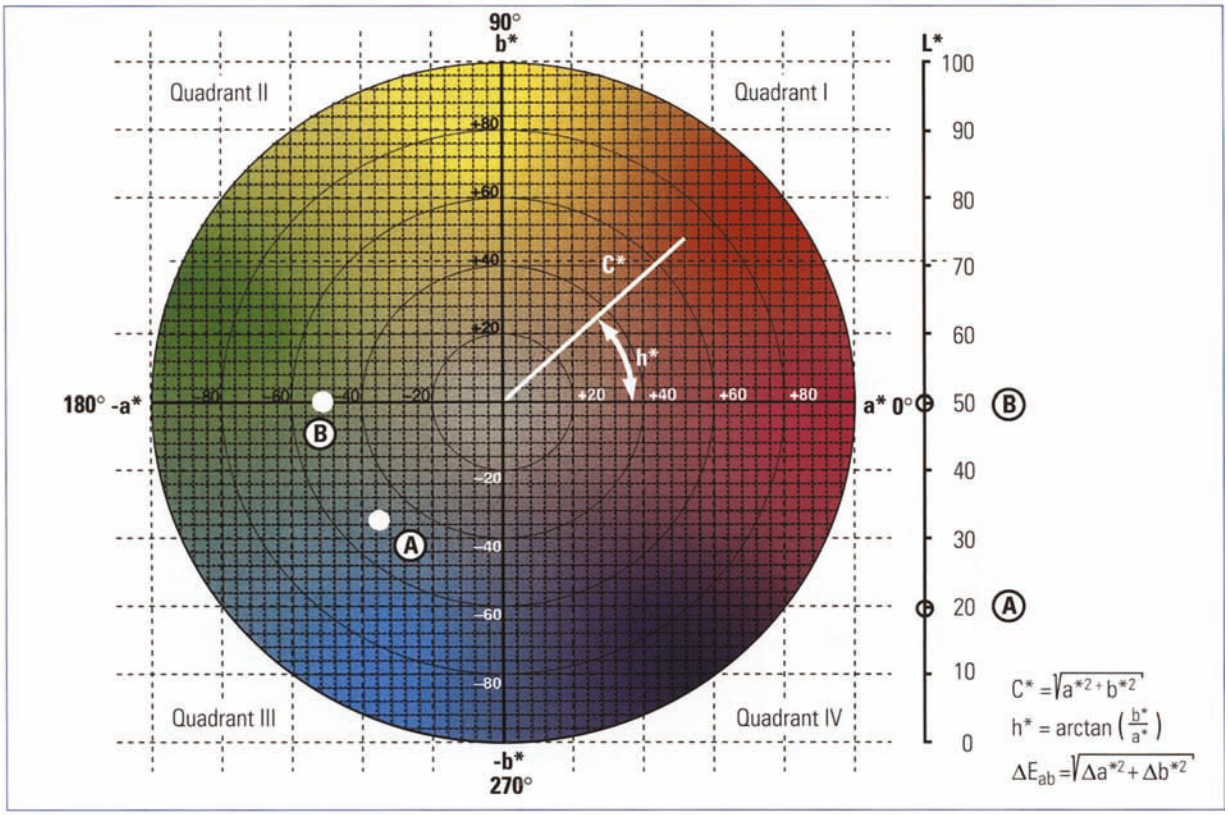


Fig. 1.4-12

CIELAB color circle with chromatic value C* and hue angle h* (color locations Ⓐ and Ⓑ in accordance with fig. 1.4-13) [1.4-2] (Note: The colors in fig. 1.4-12 and fig. 1.4-13 may not be rendered accurately, they should only illustrate the problem in general)

It is primarily the inclusion of color perception effects (e.g., simultaneous contrasts) in the systematic description of colors that represents an actual subject of scientific color research. An attempt is made in so-called *color appearance models* to produce a systematic relationship between color stimulus specification and color perception. A comprehensive summary of the status of discussions is given in [1.4-7].

A special form of color classification systems may be mentioned briefly at this point: *Color sample catalogs* such as Pantone, HKS, or RAL do not serve as a systematic description of all colors that can be perceived by the normal observer. In these cases, a collection of individual colors is merely compiled, which are used for a visual comparison of colors.

A certain Pantone color is, for example, supplied by the manufacturer on the specified substrate of a reference chart, to enable the same color stimulus specification to be copied using a color system appropriate to the output device whereby it could easily be possible that the Pantone reference value cannot be matched in the actual CMYK color space of a printing system. The best approximating solution is usually determined empirically by color mixture trials or by means of a *color management system*.

Spectral measuring instruments (*spectrophotometers*) and tristimulus color measuring instruments (*colorimeter*) are mostly used for color measurement (see also sec. 1.4-4 and figs. 1.4-48–1.4-50). Colors cannot be measured using a densitometer (fig. 1.4-17). This can be explained using the example of the two colors, blue and green, in figure 1.4-13. When measurements are taken using a color filter which produces the maximum measured value, a densitometer gives the same optical density of D = 1.38 for both colors; the measurement based on colorimetry, on the other hand, produces a color dif-

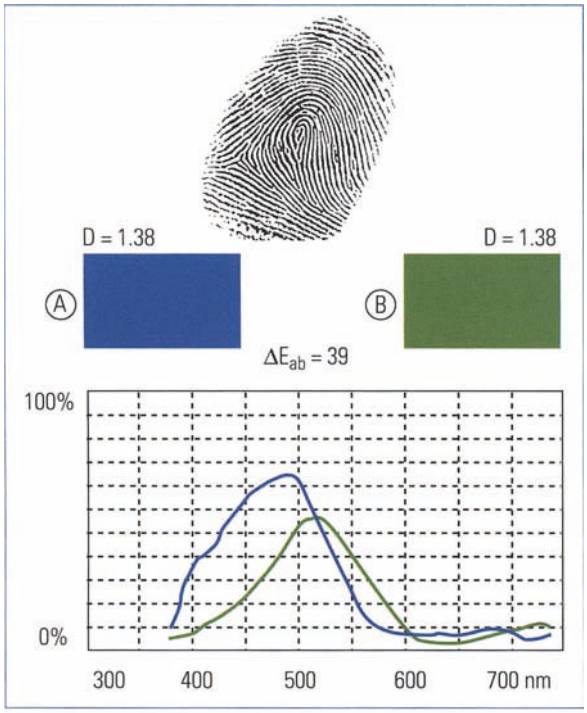


Fig. 1.4-13

Spectral intensity distribution as a "fingerprint" on the example of two colors Ⓐ and Ⓑ (at the same optical density) [1.4-2]
(Note: The colors in fig. 1.4-12 and fig. 1.4-13 may not be rendered accurately, they should only illustrate the problem in general)

ference of $\Delta E_{ab} = 39$, which realistically reproduces the very great difference between the two colors "blue" and "green." Figure 1.4-12 also indicates the location of the two colors in the CIELAB color circle.

The color vision model and the colorimetric measuring system in accordance with fig. 1.4-14 basically encompasses the two colorimetric techniques described below, spectrometric and tristimulus measurement procedures. The difference lies fundamentally in the fact that with the spectrophotometer the intensity spectrum of the color is processed by means of digital filtration using the standard color matching function, whereas with the tristimulus measurement technique filtration is done using optical filters, which have been adapted to the spectral progression of the standard color matching function [1.4-8].

The *spectrophotometer* is based on the principle that any color can be described as an additive mixture of spectral colors. The visible spectrum to be recorded (fig. 1.4-15) is broken down into small intervals and the light intensity in each wavelength interval is measured individually (see also fig. 1.4-50). Most spectrophotometers in general use operate at 10 or 20 nm intervals, so that as much as thirty or more individual light intensities can be determined over the visible range of the spectrum (visible range: 380–730 nm). For special investigations and with technically more sophisticated systems, it is also possible to measure markedly smaller intervals (of up to 1nm).

The spectral intensity data are usually then processed using a mathematical simulation of the three receptors of the CIE standard observer under a specified illuminant and at a specified observation angle. The thirty-channel signal, for example, can be reduced for colorimetric analysis to the defined parameters X, Y, and Z of the CIEXYZ system in this way, and converted from this to other color systems (fig. 1.4-14). The software of a spectral color measuring instrument will typically allow for the direct conversion of the spectral data into the currently relevant color systems, taking the equations of the respective standardization group (e.g., the CIE) into account.

The illuminant, among other things, is taken directly into consideration as a parameter in the reduction of spectral data to CIE color systems, so that subsequent conversions to other illumination conditions (e.g., from D50 to D65 or vice versa) are then quite impossible or at best only possible using mathematical approximations.

The basic concept underlying the *tristimulus color measurement procedure* is that CIE definitions offer a good description of the spectral sensitivity of the three color receptors in the eye. Accordingly, it is also possible to measure colors by means of three sensors, the spectral sensitivity of which resembles that of the eye receptors. Similarly, it is possible to conceive of three color filters, which with a sensor that is ideal over the entire spectrum and with perfect illumination corresponds in transparency to the respective standard tristimulus value curves (figs. 1.4-49, 1.4-5). Therefore the tristimulus color measurement procedure seems particularly attractive because only three measured values must be determined and these values can be immediately converted into CIE standard color values.

In practice there have hitherto been problems in developing color filters that correspond to the precise characteristics of the respective standard tristimulus value curves. Details of the instrument's structure are given in [1.4-2].

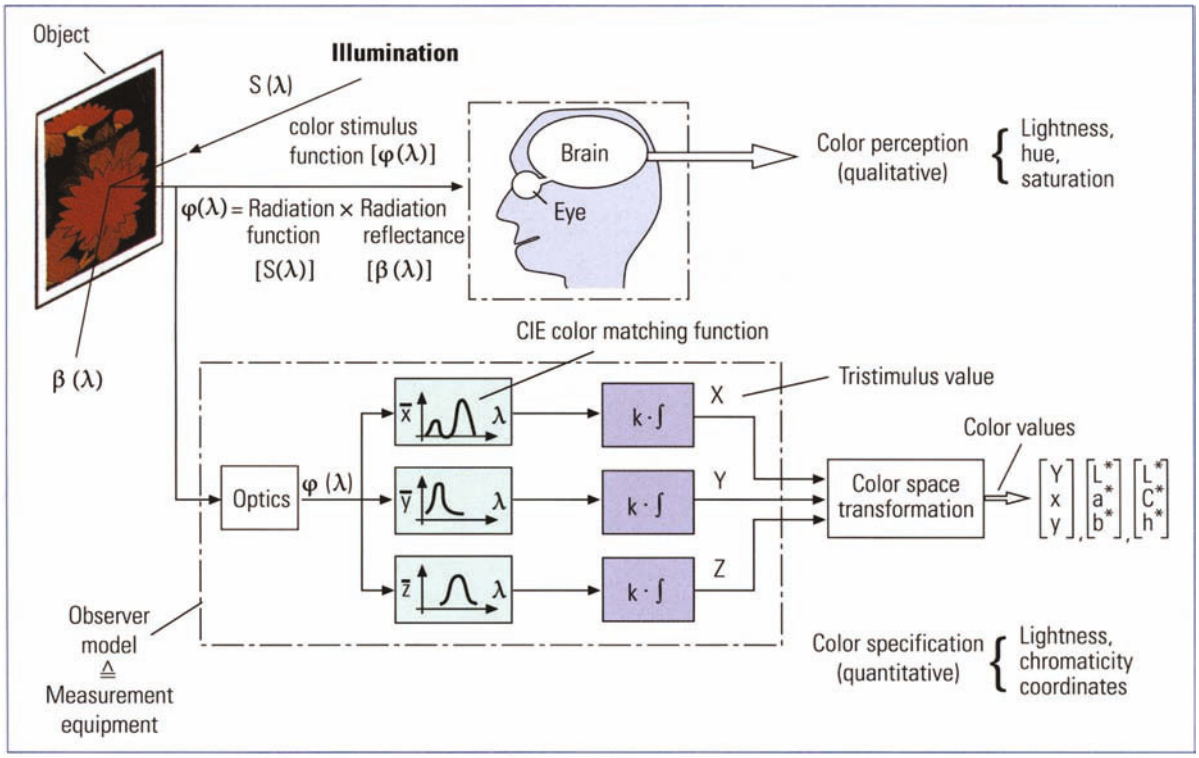


Fig. 1.4-14 Block diagram/model for color perception and the colorimetric description of colors ([1.4.2])

The spectral radiation distribution of the light source used is also a particularly critical parameter because it should be consistent with the specified standard illuminant. Thus tristimulus color measuring instruments are only really perfect if all conditions in the instrument (illumination, color filter, sensor, image geometry) meet the standardized measuring conditions ideally. Only then will the simplification criteria of the direct derivation of CIE standard color values be perfectly valid.

In the interests of completeness in further explaining the properties of a tristimulus color measuring instrument it must be mentioned that the color values resulting from measurement are, of course, only valid under the specified basic conditions (illuminant, observation angle, usually D50 at 2 degrees). Only the integral of light intensity over the spectrum is determined here. With the spectrophotometer, on the other hand, light intensity is determined at small intervals and can consequently be converted in relation to other basic conditions in accordance with CIE stipulations. CIE coordinates for different illuminants and observation angles can only be calculated from the spectral measurement data of a spectrophotometer.

In practice, there are other advantages in using spectrophotometers which arise from the fact that certain, partially disruptive color effects (e.g., *metamerism* – two colors may appear identical under one and different under another illuminant; *fluorescence* – colors may show special radiation effects depending on the illumination) or inadequacy of the measuring optics may frequently be detected from the spectral measurement data. They can then be eliminated in corresponding compensation calculations prior to translation into CIE standard color values. *Optical density* can also be calculated using spectrophotometers; in this case the progression of the optical filters (blue, green, yellow, visual filters) as they are used in densitometers is reproduced digitally.

In terms of a simple comparison, it can be said that a tristimulus color measuring instrument is more suitable for determining color differences than for absolute color measurement. In practice a spectrophotometer is

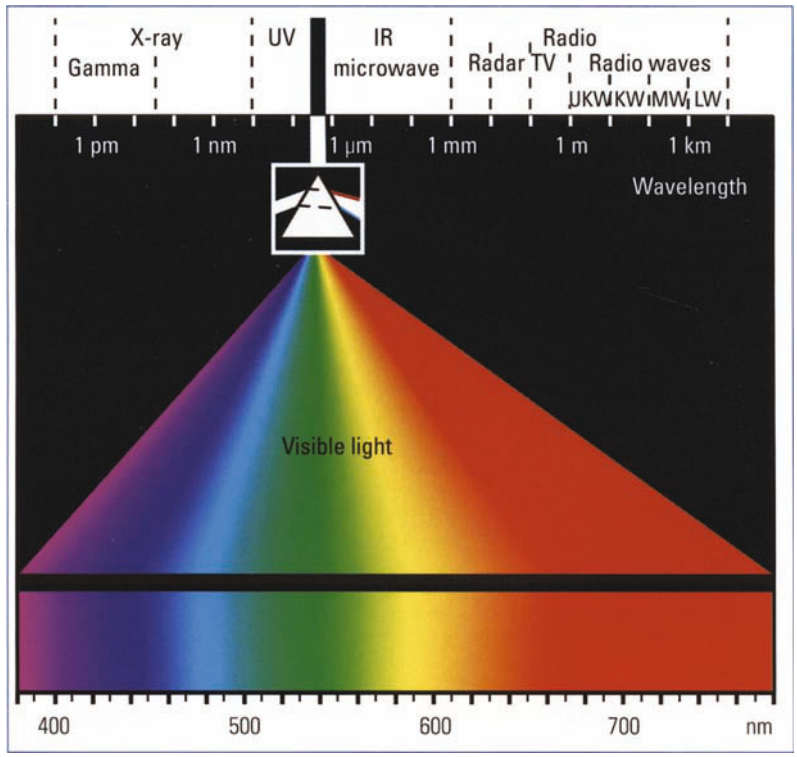


Fig. 1.4-15
Visible range in the spectrum of electromagnetic waves [1.4.-8]

always to be recommended for precise and more flexible color measurement.

1.4.2 Color Image Composition

Color Reproduction

In general terms, printing technology color reproduction is the conversion of a scene or object so that it remains as faithful as possible to the original in order to present it in a printed product via an information transfer chain. In many cases a photograph (bromide or transparency/positive film) is used as the intermediate carrier. The photograph plays its part in the overall reproduction process, as do possible image manipulations, the screen process, materials, transfer characteristics, and many other parameters. What constitutes an "ideal color reproduction" and by what criteria can quality in reproduction technology be measured?

The quality characteristics of modern *reproduction technology* are dependent firstly and decisively on the reproduction intention, that is, on the customer's expectations. For example, in the production of advertisements in newspapers and periodicals, the general rule applies that a printed advertisement should conform as closely as possible to the artwork submitted to the publisher by the advertising agency. The term faithful reproduction can be used here.

[1.4-1] describes in a particularly succinct form that faithful reproduction can even produce "spectrally identical" results, though this can rarely be achieved in practice. In this case it would be ensured that the reproduction looked the same as the original under all lighting conditions. This requirement is especially important in the adaptation of proofs for printing.

In contrast to *faithful reproduction*, in the editorial section of newspapers and periodicals the aim that is frequently pursued is the reproduction of the original images so that they are attractive. The terms appeal or intention-optimizing reproduction can be used here. In this sense the term *appeal-optimizing* can be interpreted in various ways. The transparencies supplied by photographic agencies often have a considerably larger color gamut than the printing technology utilized, so that compromises have to be made during the conversion of the image information into print (fig. 1.4-16).

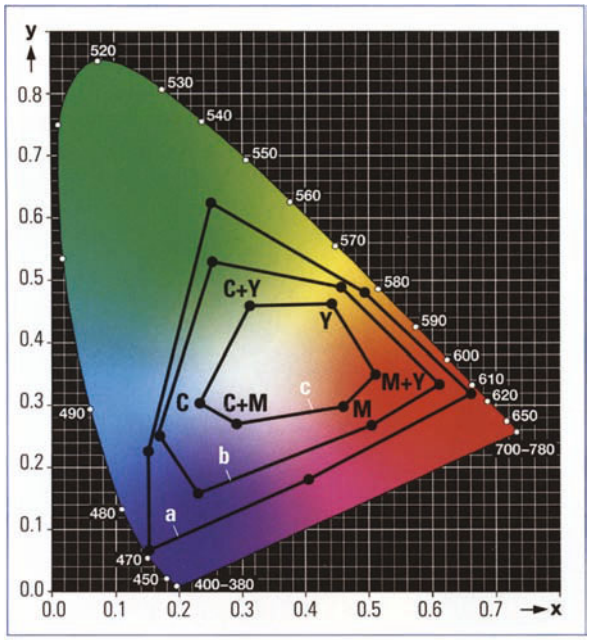


Fig. 1.4-16

Color gamuts in the CIELAB system for different reproduction processes.
a Color photograph (diapositive);
b High-quality offset printing;
c Newspaper printing

The scanner operator decides, after consultation with the customer when necessary, where specific image information (e.g., a drawing) is to be obtained, what is to be omitted and even, if need be, what image content is to be emphasized. Quite major compromises have to made during reproduction for newspaper printing, because in this case there is, on the one hand, a very small color gamut available and, on the other, image data is often supplied (by press agencies, for example) in an inadequately specified color space (more often than not in an undefined RGB). In this example, "attractive images" have to be deliberately created from the unknown color data, the optimization criteria being largely subjective.

With intention-optimizing/faithful reproduction it should be ensured that a company's products displayed in catalogs and advertisements correspond accurately to the manufacturer's color specifications. To comply with the guidelines of corporate design, visual matching with color samples from special catalogues (e.g., Pantone, HKS) is often undertaken. If, for example, a company's corporate color (special color) cannot be mixed sufficiently satisfactorily from the primary colors, an additional color is added, which is also known as a spot color. Spot colors are normally not taken into account in the color separation of image data, but are used solely to create individual elements.

In the case of *faithful* color reproduction, automatic processes can now be used to a great extent ("Color Management," see sec. 3.2.10 in particular). In the case of *appeal-optimizing* reproduction technology, manual intervention by trained image processing specialists is largely unavoidable. Automatic image analysis and optimization methods have only been under development for a few years and have not yet, as a rule, replaced manual image manipulation.

The other factors that determine the quality of a color reproduction depend primarily on the characteristic properties of the ink, the substrate, the printing technology utilized, the printing conditions, the nature of the original, and the separation parameters. The colorimetric properties of the ink utilized and of the substrate have a considerable influence on the reproducible color gamut. For example, it is of importance what magenta pigment is used in the ink. The relatively expensive rhodamin magenta extends the color space, especially in the blue and purple range.

The *substrate*, too, is a major factor in determining the attainable full-tone density, therefore it also affects the reproducible color contrast. Typical full-tone density is around 1.5 density units for uncoated paper when overprinting primary colors and around 2.0 density units for coated papers.

A brief explanation of *densitometry* is given in figure 1.4-17 to supplement the comments on color measurement in section 1.4.1, where the use of spectral measuring techniques based on colorimetrics is explained. In essence, an ink film thickness measurement is being taken here on the basis of the optical absorption of light for a known ink hue using optimal filters to achieve the highest possible measured value and therefore high measuring sensitivity.

Another factor that affects reproduction quality is the nature and definition of the *halftone process* used. The screen ruling for conventional, amplitude-modulated screens depends on the smallest, safely transferable dot structure (around 10–20 µm in offset printing), which is why detail resolution is noticeably better in offset printing than in other printing technologies, such as flexographic or screen printing. Typical screen ruling for high-quality multicolor printing is around

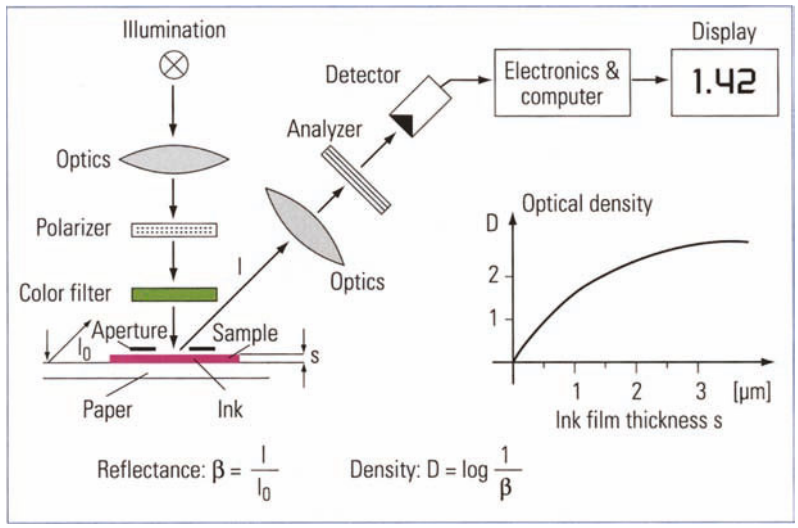


Fig. 1.4-17
Measurement of color density (optical density) by densitometry (measurement method)

60-80 lines per cm (dot spacing, around 125–167 µm), though this screen definition is only the optimal choice where there is a "typical" observer distance of about 25–30 cm (approx. one foot). (Large picture posters are reproduced with noticeably coarse screens, because they are usually observed from a greater distance.)

If the color of an object such as a car is to be reproduced, the lighting of the object during exposure, possible reflections, contrasts, and the color temperature of the light source will naturally have an effect on the overall reproduction. In this case the photograph merely serves as the intermediate information carrier for the overall reproduction task. As a result of the introduction of digital camera technology (cf. sec. 3.2.3) in conjunction with digital printing systems (e.g., NIP systems) it is now possible to have a completely digital reproduction chain, extending from the exposure of the original to the printed reproduction.

A major factor that affects the quality of the color reproduction is the *actual color break-up* or *color separation*. It must be stressed here that multicolor printing is predominantly a trichromatic reproduction process, that is all colors are mixed from three base colors. Even if in practice the fourth "color," black, is added, this does not change the fact that color information for a printed reproduction can generally be composed from three *base or primary colors*. It is of fundamental importance that the filters used for the color break-up carried out during the production of color separations be specially adapted to the inks, in order to achieve the most faithful printed reproduction. If this adaptation is not optimal, additional color transformations will be required (Color Management, cf. sec. 3.2.10).

Color Separation

Color separation for color image composition is based on a subtractive color mixing process, though color image composition in printing essentially involves so-called *autotypical color synthesis*. In multicolor printing the halftone dots are to some extent isolated alongside each other, but they are also overprinted; both *subtractive* color mixing (overprinting of the halftone dot areas by single colors) and *additive* color mixing (integration of the single colors of isolated halftone dots by the eye of the observer) take place on the printed page. In figure 1.4-18a this is shown for three-color overprinting. In figure 1.4-19 the *color separations* are shown together with overprints done on a four-color offset press.

Suitably small, directly adjacent raster dots create a similar additive color synthesis effect to the dot-shaped induced phosphorous coatings in a color monitor (in printing, on the other hand, the halftone dots/color areas are illuminated and the remitted/reflected light reaches the eye of the observer, where the corresponding color stimuli are added).

The ink films applied to the substrate in the printing process have to be transparent, that is, act like color filters, for the physical principles of subtractive color mixing to take effect.

Exclusively subtractive color composition occurs when overprinting fairly large color areas. If there is only subtractive color mixing, the brightness of the

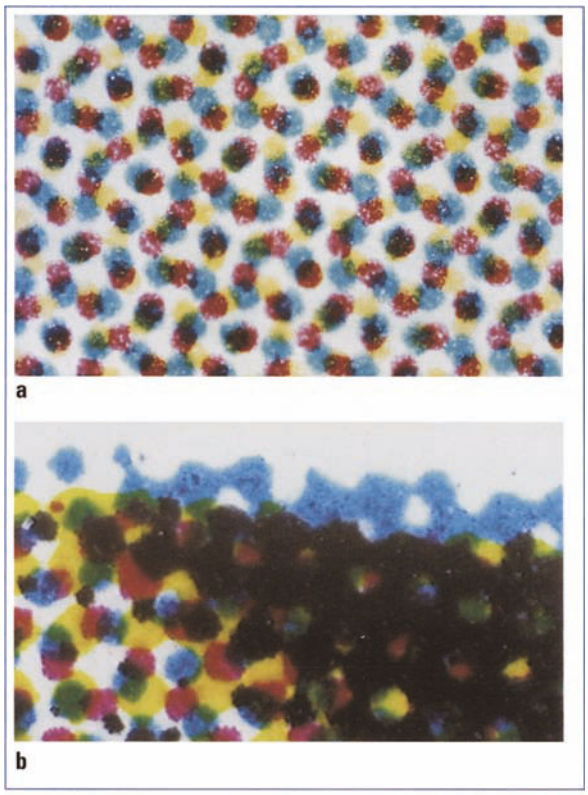


Fig. 1.4-18
Autotypical multicolor printing (microscopic photo of a print image section); scale: cell spacing about 167 µm.
a Image detail with homogeneous color (3-color print);
b Image detail with structured color (4-color print)

mixed color decreases with the thickness of the ink layer.

In screened reproduction processes for multicolor printing the screen structure and the color register adjustment for overprinting inevitably produce a complicated, variable combination of subtractive and additive color mixing. This results in significant demands on the spectral properties of the inks. Both with color mixing through screen dots located next to one another on the substrate (additive), as well as with screen dots above one another (subtractive), the mixing color should be perceived by the observer as the same color.

This requirement on the ideal base colors can only be met if they have rectangular spectral distributions. In addition the discontinuity values must be between zero and one, and there may be no more than two discontinuities (special effects in halftone printing such as light gathering [1.4-9] are not considered here). An additional factor is that it would be necessary to adapt these discontinuities in the spectral distribution of the three primary colors ideally to each other. Furthermore, the discontinuities have to be selected so that as large as possible a range of color is produced for the resultant color solid. Various tests have shown that the first ideal discontinuity would have to be between 489 nm and 495 nm and the second between 574 nm and 575 nm; the corresponding spectral distributions are shown in figure 1.4-20. The base colors resulting from these requirements are also referred to as "*optimal colors*" [1.4-1].

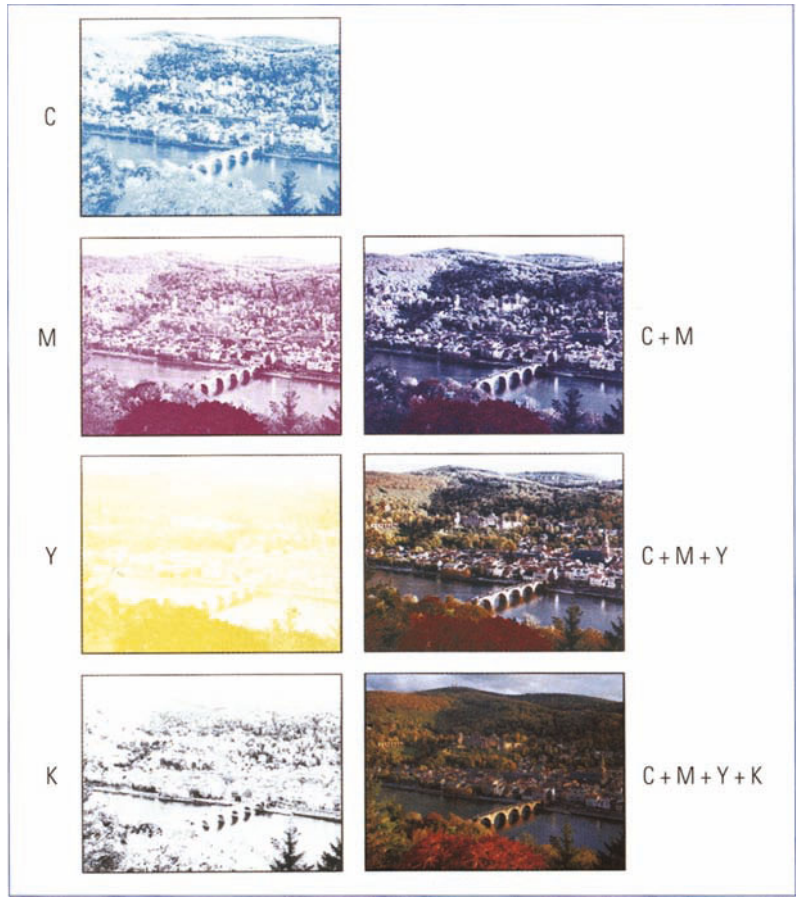
It would be really easy to calculate color reproduction using optimal colors. Magenta, cyan, and yellow are used as the inks and red, green, and blue are produced as the subtractive mixed colors of the first order. If the color locations of the optimal base colors and their first order subtractive mixed colors are entered in the u'v' diagram, it can be seen that the primary colors lie exactly on the connecting line between the mixed colors. The achromatic point (E) is produced by linking up the opposite primary and mixed colors. An ideal neutral gray is produced by mixing the same proportions of primary colors. The color gamut is characterized by the location and size of the triangle in the u'v' diagram (fig. 1.4-21). In contrast to figure 1.4-16, in this case the projection takes place in the u'v' system instead of the x,y coordinate system. (As explained in sec. 1.4.1, the projections are equivalent.)

In this optimal-color scenario, converting RGB and CMY data into each other becomes virtually a minor operation. The color conversion procedures of the first generation in PostScript [1.4-4] page description language were also selected in accordance with this simple model for the spectral distribution of colors:

Cyan = 1.0–Red,
Magenta = 1.0–Green,
Yellow = 1.0–Blue.

It is known that in subtractive color mixing the color "black" (letter symbol "K" for "Key Color") is produced by the superimposition or the overprinting of the colors red (R), green (G), blue (B) or cyan (C), magenta (M), yellow (Y). PostScript's architects had assumed that a combination of the same proportions of the three primary colors would produce an ideal neutral gray and that consequently the largest possible proportion of black in the color separation could be calculated from the largest common proportion of pri-

Fig. 1.4-19
Color separations and overprinting for reproduction in four-color offset printing



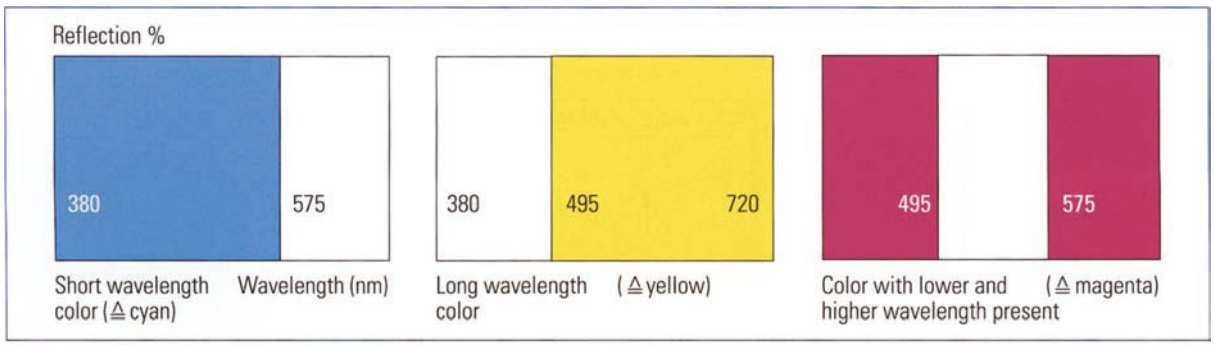


Fig. 1.4-20 Spectral distribution (relative spectral reflections) for "ideal colors"

mary colors [1.4-4]. These assumptions were so far removed from actual practice that during activation of the first generation of PostScript color printing systems unsatisfactory color print results appeared; this was rectified in later versions.

As with the selection of the ideal primary colors, the ideal color separation filters in reproduction systems would also have to be coordinated with the optimal base colors. This requirement would at least apply for analog, camera-based reproduction technology, for which no

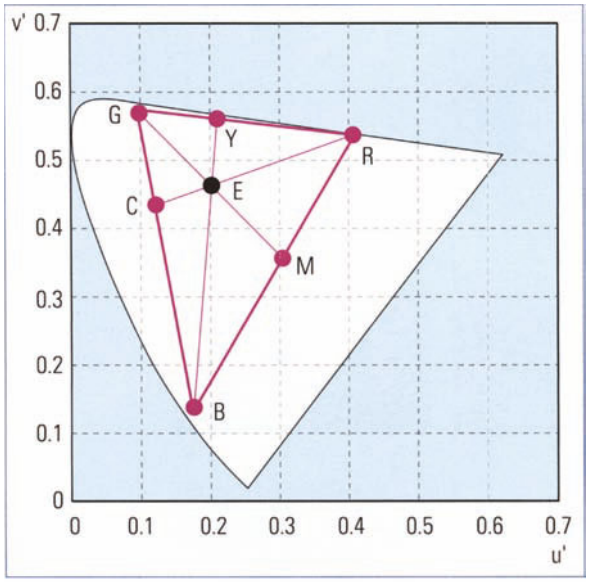


Fig. 1.4-21
Color locations of primary colors (ideal colors in accordance with fig. 1.4-20) and their mixed colors in subtractive color synthesis ("ideal multicolor printing") [1.4-1]

other comprehensive color transformation (via a color management system) is possible. However, since the assumption of ideal base colors cannot be implemented in practice, theoretical consideration of ideal color separations filters will be dispensed with at this point.

In reality, the inks used in actual printing are merely imperfect approximations of the optimal colors. In figure 1.4-22, typical *spectral distributions of real primary colors* in multicolor printing are illustrated together with the discontinuities of the "optimal colors." It can be seen that the real primary colors do not reflect and/or absorb in the ideal section of the spectrum and that a number of unwanted spectral side effects also occur. It follows from this that the color gamut theoretically possible in printing is not being achieved.

Moreover, additive color mixing in printing does not produce the same color impression as subtractive color mixing within color areas, which leads to deviations in the autotypical (screened) image composition. It is a fact that no neutral gray can be created from the same proportions of primary colors (in the color separations) and RGB values cannot be transferred to CMY data merely by "inverting."

It has become apparent in practice that a certain combination of unequal proportions of primary colors will produce a *neutral gray* in standardized offset printing (e.g., tone values for color separations/films for a relatively dark gray value in offset printing: cyan 70%, magenta 60%, yellow 60%; or for a lighter gray value: cyan 24%, magenta 18%, yellow 18%). Such data takes into account the specific colorimetric properties of real primary colors for printing and is useful as a process control tool for specifically determining the *gray balance* (see fig. 1.4-42). However, it cannot be transferred directly to other color scales and printing processes, which would be perfectly possible with ideal inks.

To sum up, the following requirements can be imposed on the ideal set of primary colors for printing [1.4-1]:

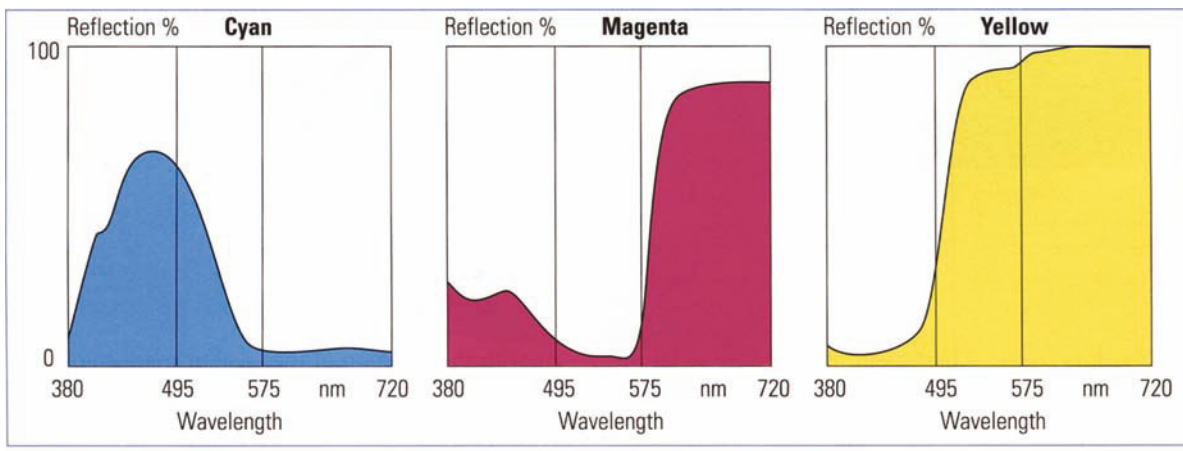


Fig. 1.4-22 Spectral distribution (degree of spectral reflection) of printing inks for multicolor printing [1.4-1]

- The spectral remission (reflectance) and/or absorption properties of the primary colors should be as close as possible to those of the optimal colors.
- The color locations of the primary colors should be selected in such a way that they produce as large a color gamut as possible.
- Equal proportions of primary colors should produce an achromatic tone with additive and subtractive color mixing in printing that is as close as possible to gray (on ideal white substrate).
- The resultant mixed colors of the first order (secondary colors) should, as far as possible, be in the middle between the primary colors in the color circle/color space.

Reproduction Process

Coordination of the process stages and the materials is also of central importance in color reproduction, as well as selection of the ideal base colors and color separation filters. Turning a real scene into a printed product via a photograph involves a multistage *information transfer chain*. The interfaces and parameters of this chain can usually be controlled by purposeful interventions on the part of the operator.

If some image transformation/reproduction properties are, in practice, unchangeable (static), because of machine constants, for example, the other manipulable links in the transfer chain have to be adjusted to the static properties. Consequently, for example, as indicated above only certain real pigments can be used in printing inks, but their spectral properties are very different from those of the optimal colors. Therefore, when they are used for color separation to produce separation films (also sec. 3.1.3.6), the color separation filters should, in an ideal color scenario, be adapted to these properties in an "error-compensating" way.

The technology that has proven its worth in practice in coordinating the partial modules of reproduction technology is the manipulation of *gradations, or gamma curves* (sec. 3.1.3 and fig. 3.1-15). Looked at realistically, the user has virtually no other option for the fine coordination of process components in the analog information transfer chain. It is for this very reason that the use of already color-separated CMYK data is particularly widespread.

Although the processing of image data in RGB or CIE LAB color system brings with it considerable advantages from the information theory point of view (e.g., ensures a wider range of color), an experienced reproduction expert likes to select the color system of the final primary colors for printing (for the most part CMYK) for processing, because he can then intervene directly in the final primary color gradations. On the other hand, it is virtually impossible to exert a specific influence on the reproduction result in the CMYK color system by the manipulation of RGB gradations without using a color management system.

Current reproduction technology practice leads to the assumption that primary color gradations suffice for the representative projection of the reproduction characteristics of an image reproduction system. This assumption is incorrect, at least in the case of many output systems (e.g., offset printing and other conventional printing technologies, but primarily also in the case of non-impact printing systems). In reality the mixed color gradations do not behave proportionately to the primary colors.

To understand the problem it is helpful to enter the *reproduction behavior* of a print reproduction process in a perceptively equidistant, colorimetric reference system (e.g., CIELAB). To do so, the color locations of the solid areas (100% area coverage for a given setpoint color film thickness) of the primary and secondary colors cyan, magenta, yellow, red, green, and blue and the color location of the blank printing paper are determined with a colorimeter and the seven coordinates are projected in the a*, b* plane of the Lab diagram. If the real Lab coordinates of the six individual gradations (halftone value) are now determined, six curves are produced, which start from the white point (the color of the paper) and end in the solid areas. It can be seen from the example of the reproduction characteristics of the example of a thermal sublimation printer (fig.1.4-23) that the primary and secondary color gradations typically do not change linearly in the a*, b*-diagram.

Assuming that the projection of the gradations in the CIELAB diagram is perceptively equidistant, it can be concluded that primary color gradations do not suffice for the representative projection of reproduction behavior. This characteristic is quite typical of output systems (similar gradations are produced in offset printing). The practice of gradation-based image manipulation is correspondingly dubious. Because of the lack of other suitable methods, its use in analog reproduction technology is warranted, in digital image processing scarcely so, however. This finding is confirmed by practical experience which shows that the experts' deliberate interventions in gradations are more likely to be made intuitively, seldom numerically.

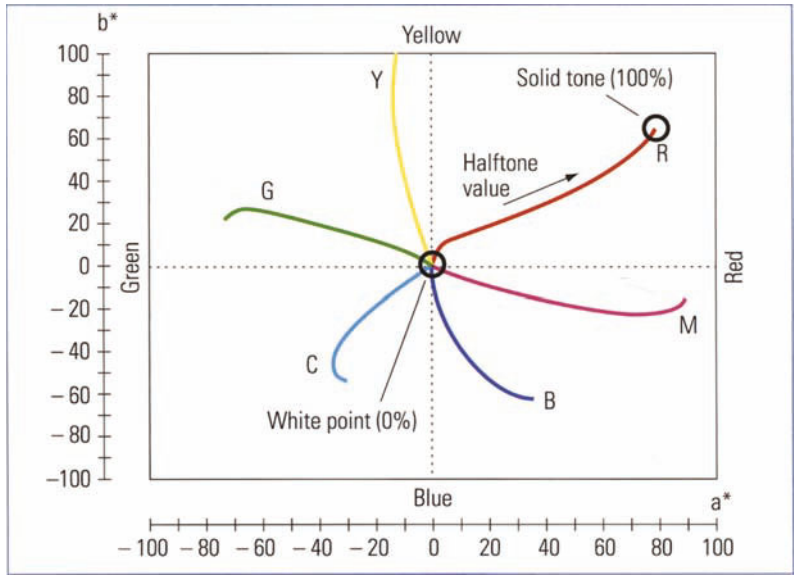


Fig. 1.4-23
Tone value curves (gradation curves) in the color space (0% to 100%) for primary colors CMY and the RGB secondary colors created from them in overprinting in the CIELAB system (Thermotransfer Proof System "Rainbow", Imation)

The coordination of process sub-modules in analog and digital reproduction systems via gradation curves may also be referred to *as characteristic curve communication*. It can be controlled with densitometers or display components similar to densitometers (e.g., in image processing programs) and is strictly speaking only possible where:

- the same color mode is present in both sub-modules (e.g., CMYK),
- the color location of the primary colors is identical, and
- both sub-modules have identical reproduction characteristics.

Only if all the above requirements are met can equipment be adapted solely via gradation curves/characteristic curves. In all other cases more complex color space transformations (e.g., by means of multidimensional tables or functions) must be applied. A colorimeter is usually required to determine the parameters for color space transformations of this kind.

Firstly, it is obvious that gradation curves can only be used for process control if the same color modes (color systems) are being applied. This initial requirement is met in a trivial way in the harmonization of film to printing plate, or printing plate to print, because there are four separate channels involved here and the color conversion to the printing system's CMYK color space has already taken place earlier in the reproduction process. In this case, the color location of the primary colors does not change. In the control of digital printing systems, from PostScript data files, for example, more often than not a different situation exists. If the printer is controlled by means of RGB data, the output can no longer be converted to the CMYK of the printer via gradations alone and the first requirement on characteristic curve communication is not met.

Even if the color modes of both sub-modules of the information transfer chain are identical, characteristic curve communication may not necessarily be possible. There are, indeed, two CMYK-based printing systems available for adapting a color copier (electrophotography with powder toner) to an offset printing process, for example, but usually the color locations of the primary colors differ considerably; consequently requirement two is not met.

During the development of *analog proofing processes* (e.g., Cromalin and Matchprint, see also sec. 3.1.6), colorants for powder toner or overlay color film materials with primary-color locations that correspond to those of the standardized process inks under a given type of standardized illumination were sought. In addition, these colorants should also have the same reproduction characteristics (dot gain, etc.) as a conventional ink. In the absence of suitable colorants (e.g., pigments), in the end only substitute colorants which were as similar as possible were found. Therefore, strictly speaking these

materials also do not meet all requirements on an identical reproduction characteristic, though these interim solutions are to a great extent accepted in practice.

In more recent, *digital proofing systems* based on nonimpact printing technologies (cf. chap. 5), it was no longer even attempted to adjust the colorimetrical reproduction properties to the printing process to be simulated via the selection of particularly suitable colorants. Multidimensional color transformations are used for equipment adjustment here, with the aid of color management systems and colorimetric measurement technique.

The Color Black

The color black has already been mentioned as a constituent of the CMYK color system, but no concrete data was given for *determining the color separation of black*, as it is shown in figure 1.4-19.

Essentially, black is used in multicolor printing to reduce the technological expense of printing three chromatic colors to create black or a gray value by the direct use of black ink, to cut down on the use of expensive high-quality chromatic inks and also, primarily, in order to stabilize the printing process,that is, to make it less sensitive to variations in the individual colors.

There are several methods for controlling the black color separation, that is, for supplementing *chromatic composition* using the colors cyan, magenta, and yellow with the fourth color, black:

- chromatic composition with Under Color Removal (UCR),
- *achromatic composition* (or GCR: gray component reduction), and
- achromatic composition with chromatic color addition (UCA).

These processes will be explained below on the examples of chromatic composition (the projections in fig. 1.4-24 are examples, without claiming to be metrologically accurate and procedurally comprehensive).

Chromatic Composition. In chromatic composition all the hues (color tones) are built up from the chromatic base colors (process colors) cyan (C), magenta (M), and yellow (Y). Black (K) may possibly be used, if at all, to support the image shadows and to improve the contours. Dark hues are created by the appropriate mixing of the three chromatic base colors.

If cyan, for example, is to be printed darker, equal portions (via changing the tone values) of magenta and yellow are added according to the desired blackness value, but these portions must be less than the portion of cyan. These portions of magenta and yellow mix with the correspondingly equal portion of cyan to form black, thus darkening the remaining portion of cyan. This will be made clear by means of an example. The brown shown in figure 1.4-24a was built up in chromatic composition from 70% cyan, 80% magenta, and 90% yellow, a total area coverage therefore of 240%. Black was not used. But because of the high portions of chromatic colors, the color balance is not easy to maintain.

The chromatic composition of the brown shown in figure 1.4-24a comprises a chromatic portion and an achromatic one. The achromatic portion consists of 70% cyan, 70% magenta, and 70% yellow, which create a hue very close to gray when overprinting. Only the remaining 10% magenta and 20% yellow form the chromatic portion.

Chromatic Composition with Under Color Removal. Under Color Removal (UCR) is a variant of chromatic composition, in which a part of the achromatic portion is replaced by black. Assume that in the example (fig. 1.4-24) there is to be a *30% UCR* of the used brown. To this end, the achromatic portion composed from cyan, magenta, and yellow is reduced from 70% by 30% and replaced by the corresponding black portion. As a result of this the area coverage is no longer 240%, but only 180% with the same apparent hue. This greatly simplifies the printer's task, because the danger of offsetting (the printed image is reflected in the pile on the reverse side of the sheet above; see sec. 1.7) is reduced and the color balance is easier to maintain (fig. 1.4-24b).

Achromatic Composition. Unlike chromatic composition, in achromatic composition in principle *all* achromatic portions are replaced by black (GCR: gray component reduction). Therefore, the blackening of chromatic color shades is no longer done by means of complementary color, but solely by black. The brown shown as an example (fig. 1.4-24c) consists in achromatic composition of only magenta, yellow, and black. The area coverage is a total of only 100%. As a result of this, the color portions of cyan, magenta, and yellow can be noticeably reduced in all images and hues; the printing process becomes more stable, the ink acceptance (trapping) behavior noticeably improved.

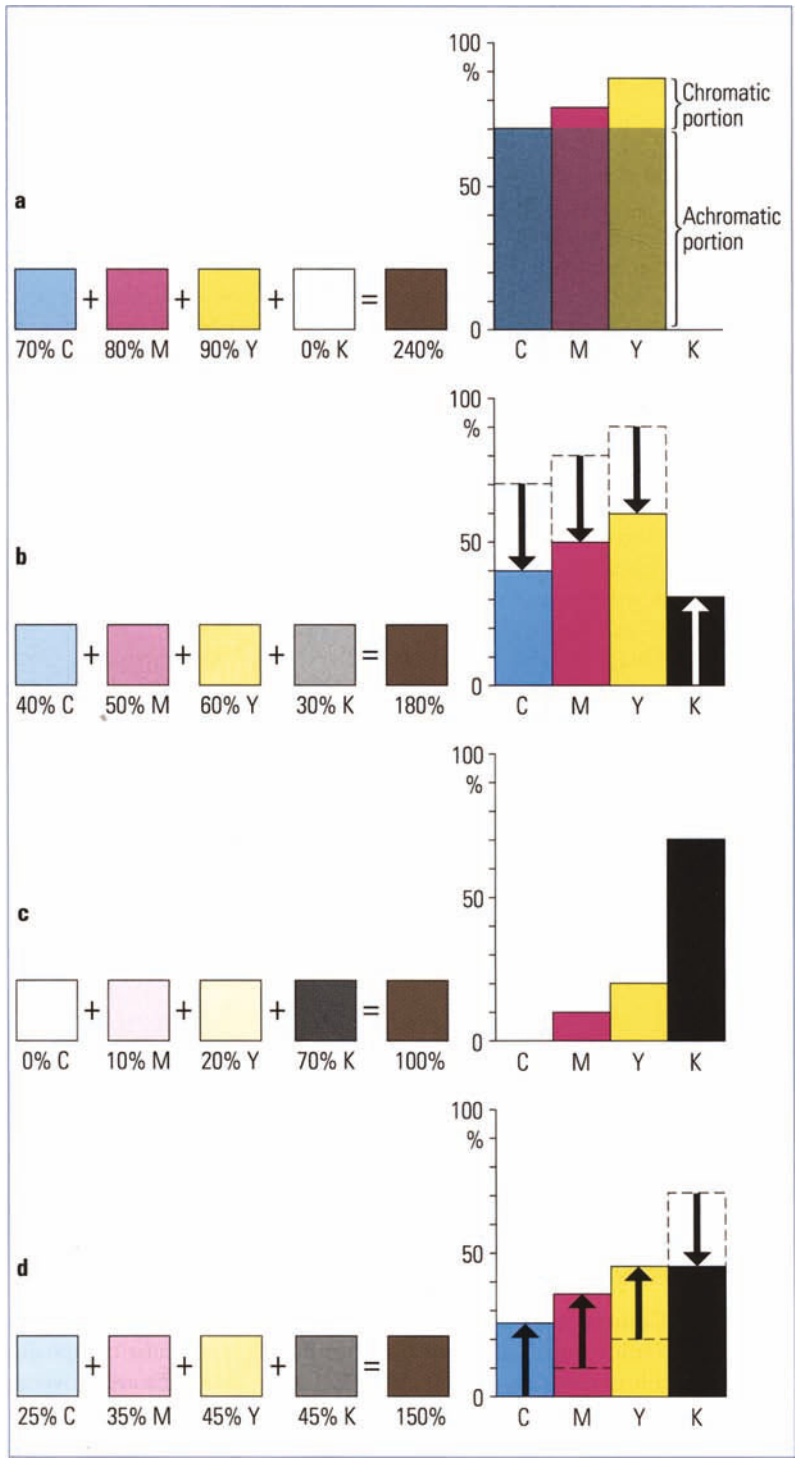


Fig. 1.4-24
Examples of determining the color separation for black using the multicolor printing of brown as an example.
a Chromatic composition;
b Chromatic composition with under color removal (UCR);
c Achromatic composition (or GCR: gray component reduction);
d Achromatic composition with chromatic color addition (UCA)
Note: The chart serves to explain the principle and does not represent a metrologically accurate reproduction [1.4-8]

Achromatic Composition with Chromatic Color Addition. Chromatic color addition (UCA Under Color Addition) is a variant of achromatic composition. To support neutral image shadows, if the density of the neutral black printing ink is insufficient, portions of cyan, magenta, and yellow are again added to the achromatic composition and reduced in the black (e.g., 25% in the example in accordance with fig. 1.4-24d). This type of image composition is widely used now and has proved its worth in practice. Image quality and print quality can be harmonized to each other very satisfactorily by this means.

High-Fidelity Color Printing

To achieve a greater range of color in multicolor printing, with the aim of

- coming as close as possible to the color space that can be recorded by the sensitivity of human visual perception, and at the same time of
- achieving the color gamut of a high-grade color monitor or color photograph,

even more than four colors can be used for special printing jobs (e.g., using the complementary color system red, green, and blue (R, G, B) in addition to the cyan, magenta, yellow, and black (C, M, Y, K) color system).

Printing is then done in sheet-fed offset presses with seven printing units, for example. It is referred to as HiFi (high-fidelity) color printing. In figure 1.4-25 the color gamut attainable by this means is entered for comparison purposes in the CIE standardized color space (as shown in figs. 1.4-6, 1.4-16).

Using six colors, two colors in addition to C, M, Y, and K, also leads to a markedly increased range of color. Consequently in HiFi color printing there are also "Hexachrome" systems in which special colors such as orange and green are printed.

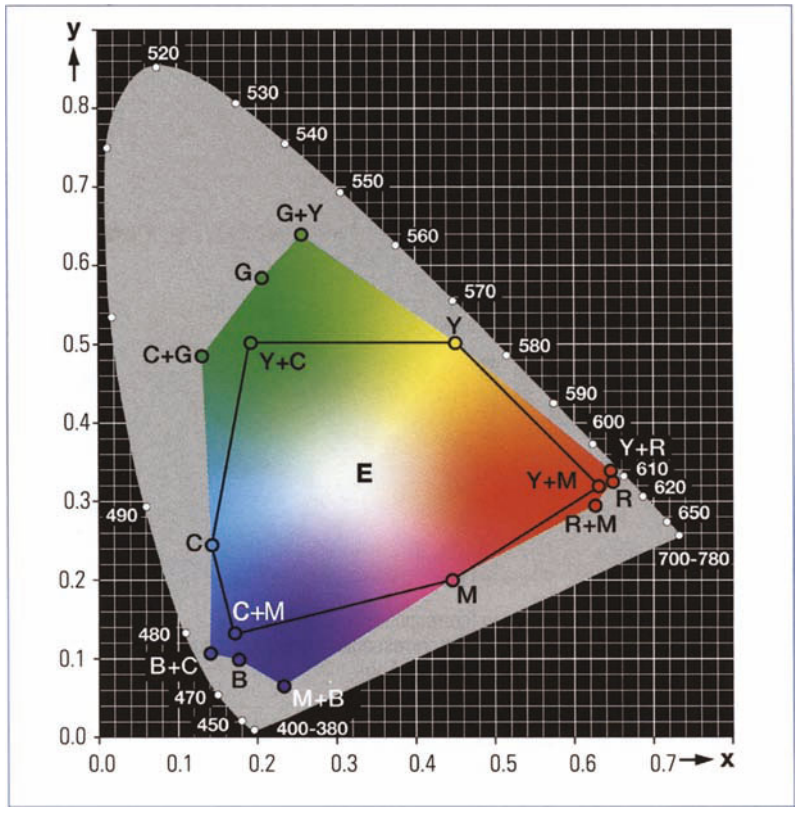


Fig. 1.4-25
Color gamut within the CIE (x, y, Y) chromaticity diagram for HiFi color printing (chromatic color system: cyan, magenta, yellow plus red, green, and blue) compared with conventional multicolor printing
Note: The chart serves to explain the principle and does not represent a metrologically accurate reproduction [1.4-8]

1.4.3 Halftone Process/Screening

The need to illustrate text with pictures is as old as printing itself. Alongside the perfecting of the printing process, a desire to reproduce illustrations in natural *tonal gradations* has also arisen. When printing first began, printers could meet these needs and requirements only to a limited extent. With the woodcuts that prevailed in the middle ages it was only possible to reproduce relatively coarse black or white lines and areas. Subsequent improvements in image reproduction, such as wood and copperplate engraving, enabled much finer elements to be reproduced. Sophisticated copperplate engravings, etchings, lithographs, and collotypes gained ground as artistic forms of expression, but they got no foothold in the industrial printing industry.

After the invention of photography some 150 years ago, there was an ever-increasing desire to develop some form of continuous tone (contone) reproduction in the print, but the technology available in letterpress printing at that time was incapable of reproducing *continuous tones*. This state of affairs did not change until 1881, when Georg Meisenbach laid the basis for screening by inventing the autotypical halftone process that is still used today. Using a structured grid, Meisenbach created repeatable screenings, that is contone reproductions.

Meisenbach's work on breaking up an image was pursued and refined by industrial reproduction technology. Grids in the form of glass screens with evenly distributed grid structures were created for graphic arts cameras. These cameras, using optical photographic means, broke down the contone values of the originals (e.g., photograph or painting) into different-sized screen dots (halftone values), that is, into printable elements (sec. 3.1.3.5).

Screening, therefore, converts continuous tone originals into black and white information (image elements, halftone dots) that is suitable for producing the printing master (film or plate). Depending on the printing process, there are usually only two states of ink transfer (printing or non-printing). For this reason, the varying visual impression of lightness or darkness must be created by varying the *size of the halftone dot*. If the screen structures are fine enough for the viewing distance of the screened image, the integrating effect of the human eye will "smooth out" the image, and the observer, therefore, sees an image that, with its contone gradations, is visually consistent with the original. The greater the number

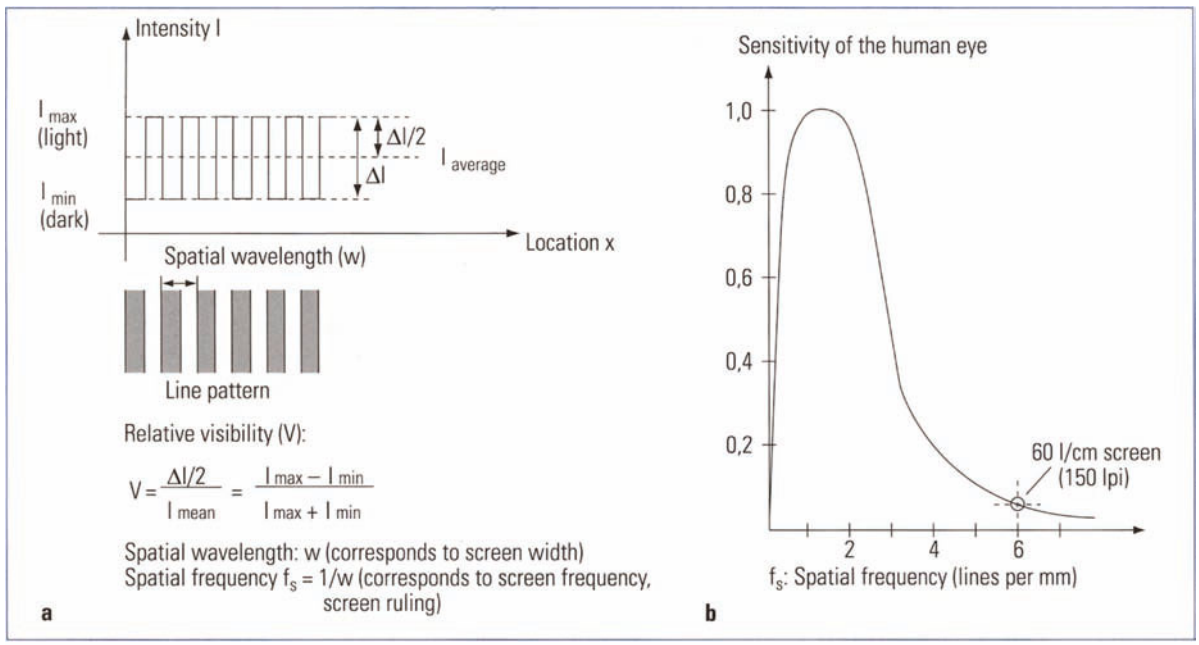


Fig 1.4-26 Visibility of line structures for the visual perception of the human eye at normal observation distance (approx. 30 cm).
a Relative visibility of intensity variations (definition);
b Sensitivity of the human eye to line structures/pattern

of screen dots per image area, the more natural the effect of the image. The term *screen ruling* (or screen frequency) is used to define the closeness of the screen dots to each other. When observing a 60 lines/cm screen (i.e., the *screen frequency*, usually referred to as the screen ruling L = 60 lines per cm, corresponding to a dot spacing w = 1/L = 0.167 mm) at a normal reading distance (approx. 30 cm), the eye is usually no longer able to detect the individual dots (fig. 1.4-26).

Throughout the course of time, screening technology has undergone considerable changes and improvements. With the aid of the computer, the basic, manual screening process has been scientifically and mathematically analyzed in order to develop newer, electronic reproduction processes: Computer-aided screening is now possible. The basic principle of breaking down an image into different-sized screen dots which were equally spaced apart was initially preserved. The first systems capable of electronic screening were output scanners (drum imagesetters) that imaged the films with very finely focused laser beams. The individual, different-sized dots were assembled from several laser spots (picture elements, pixels). Virtually all laser imagesetters now work on this principle.

Screening of Color Separations

When multicolor illustrations are reproduced, the original is broken down into several color separations (see sec. 1.4.2); first into the four basic colors (cyan, magenta, yellow, and black) of the printing process, and then, as described above, into individual printing elements. The screening of the individual color separations is done at different screen angles. This is necessary because the overprinting of different colors will occur without problems only using this procedure. Improper positioning of color separations causes *interference*, or so-called *moiré patterns*, which might severely impair the image impression (fig. 1.4-27).

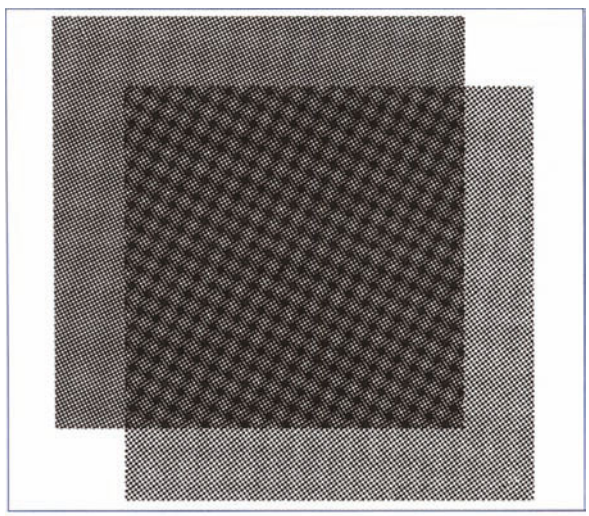


Fig. 1.4-27

Interference effect (Moiré) through overlaying two periodic structures with similar screen angles

With conventional reproduction technology, the color separations for the three chromatic colors (as explained in sec. 3.1.3.6) were each offset at *screen angles* of 30° in relation to each other. With four colors the least distinctive color, yellow, is output at an optimal angle of only 15° in relation to magenta or cyan (fig.1.4-28a). The printer can almost completely prevent the formation of visible moiré patterns in this way, but, because interference is interrelated with the image structure, it is impossible to entirely avoid these visual disturbances.

In spite of the optimal angle formed when attempting to reduce interference effects/moiré phenomena, *rosettes* may form (fig. 1.4-28b) in homogeneous color areas in particular. The formation of a rosette also depends on the relative positioning of the color separations to one another. So color register fluctuations may cause irregular rosette formation during printing. It is also true that the finer the screen ruling, the less detectable the distorting structure. In color reproduction today, most jobs make use of a screen ruling of about 60 lines/cm.

Nevertheless, with originals having a distinctive, fine structure of their own (textile or filigree patterns, for example) *structure-related moiré patterns* may occur and are virtually unavoidable. *Fine screens* with up to 150 lines/cm are sometimes used for the reproduction of extremely fine structure details; although they reduce moiré effects, they do not always prevent them. Fine screens impose exacting technical process-related requirements on reproduction technology and printing.

Dot Shapes

Even in the days of conventional analog reproduction technology, printers experimented with numerous dot shapes in order to reduce incalculable dot gains, optimize color stability, and form an industrial standard. In general terms, one can distinguish between the following basic dot shapes:

- round dot,
- square dot,

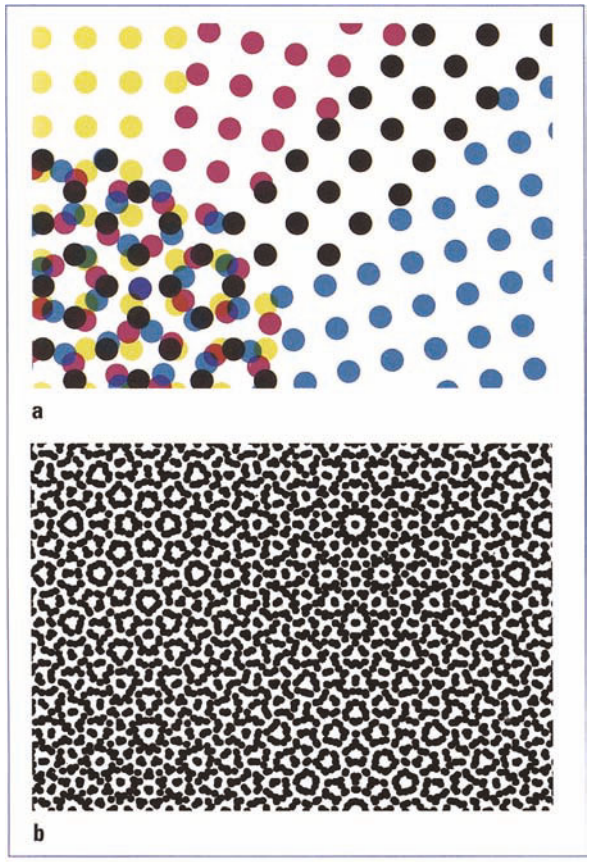


Fig. 1.4-28 Rosette formation in screened multicolor printing.
a Angling of the screened color separations with rosette formation; **b** Rosettes of different structures appearing as special moiré phenomenon (to make the effect more obvious, all color separations are printed with the same color)

- chain dot,
- elliptical dot.

In practice, it has not been possible to establish an ideal dot shape because applications and process techniques are often too diverse. For example, system A, which employs screening with square dots, may produce better print results than the screening with system B; but the latter system may produce a better chain dot than system A. This variation in print quality is attributed not only to the algorithms used for screening (like that in the various software-based, digital screening processes), but also to the technical hardware components for exposing the screened images.

Screening Processes

One can simulate continuous tones with screening in a number of ways.

Amplitude Modulation. In so-called *amplitude-modulated screening* (autotypical screening, periodic screening), the individual dots are spaced the same distance apart, but have different diameters (or different areas, depending on the dot shape). This halftone process, along with its distinct susceptibility to moiré patterns, has already been described.

Frequency Modulation. In the case of *frequency-modulated screening*, the individual dots have the same diameter but are different distances apart (non-periodic screening). When using the frequency modulation screening process to convert continuous tones of the original into a quantity of dots in a so-called *screen cell*, the dot spacing must be specified for a known dot size. This can be done according to various algorithms. Usually the distances for a certain tone value differ from individual dot to individual dot (which would lead to susceptibility to moiré patterns), but are distributed randomly. For this reason, frequency-modulated screening is also referred to as random or *stochastic screening*.

Figure 1.4-29 illustrates both screening processes, amplitude-modulated and frequency-modulated. The *single-color* image in figure 1.4-30 shows that, when using identical dots of the smallest possible size, FM screening produces better reproduction of detail in printing than AM screening; it must also be possible to repeatedly reproduce each of the small dots in print.

Figure 1.4-31 gives a comparison of amplitude modulation with frequency modulation for the continuous-tone reproduction of a *multicolor image*. One can clearly see that the FM screening produces a higher resolution and that its stochastic, random screening prevents rosettes.

Figure 1.4-32 gives a physical description of the terms amplitude and frequency-modulation. In halftone screening, the image information is basically contained in the amplitude, that is, the dot size (therefore amplitude modulation, since the image information is coded by the amplitude of a periodic spatial frequency). On the other hand, in random or frequency-modulated screening, the image information is coded in the frequency ranges, that is, the dot spacing.

Hybrid Screening. There are also *hybrid techniques* for screening continuous-tone originals: both AM and FM

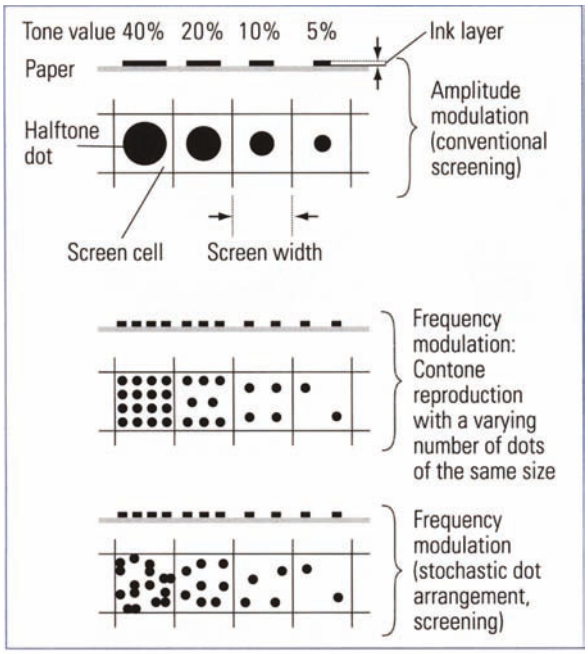


Fig. 1.4-29
Continuous-tone (contone) reproduction with amplitude-modulated (AM) screening and frequency-modulated (FM) screening

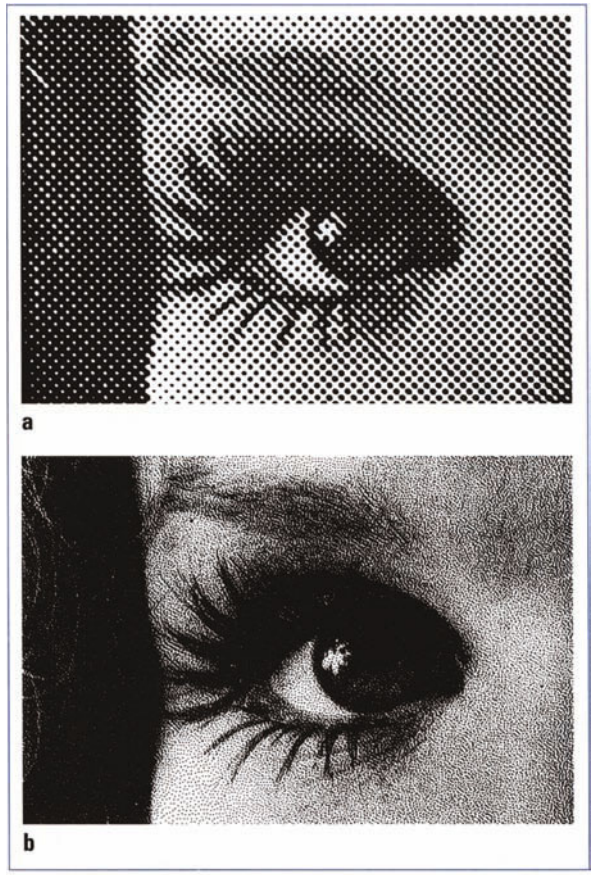


Fig. 1.4-30. Comparison of AM screening and FM screening.
a Amplitude-modulated (autotypical) screening;
b Frequency-modulated (stochastic) screening
(IFRA [1.4-11])

screening are used, depending on the image. A possible algorithm is based on the approach of using FM screening for very light and very dark tones and AM screening for the remaining tone value range (fig. 1.4-33).

A comprehensive representation of various dot arrangements and combinations is given in figure 1.4-34.

Intensity Modulation. So far we have assumed that tone values for printing are reproduced merely by varying the dot area and/or the dot spacing and that the ink film thickness on the substrate/paper is identical for all dots (apart from slight technical, printing-related deviations). With printing technologies in which the ink can be transferred to the paper in varying amounts from dot to dot, a tone value is created by modulation of the ink film thickness; optical density modulation is achieved. The change to the tone value can be done three-dimensionally: through the area of the dot and the thickness of the ink film. This is possible in gravure printing with varying cell depths, or non-impact printing technologies such as electrophotography or ink jet. This is shown in figure 1.4-35 corresponding to figure 1.4-29.

A larger color gamut can be reproduced in the print through the combination of density modulation with amplitude or frequency-modulated screening. Hence, the combination of FM modulation with density modulation aims to optimize the reproduction of detail and color.

Digital Screening

Digital screening is considered an algorithmic process that creates the illusion of contone images from an arrangement of small, binary dot elements. As a result of the current "computer to ... technologies" such as computer to film, computer to plate and computer to press/print (see sec. 4.1), there are virtually no limits to the practical application of vari-

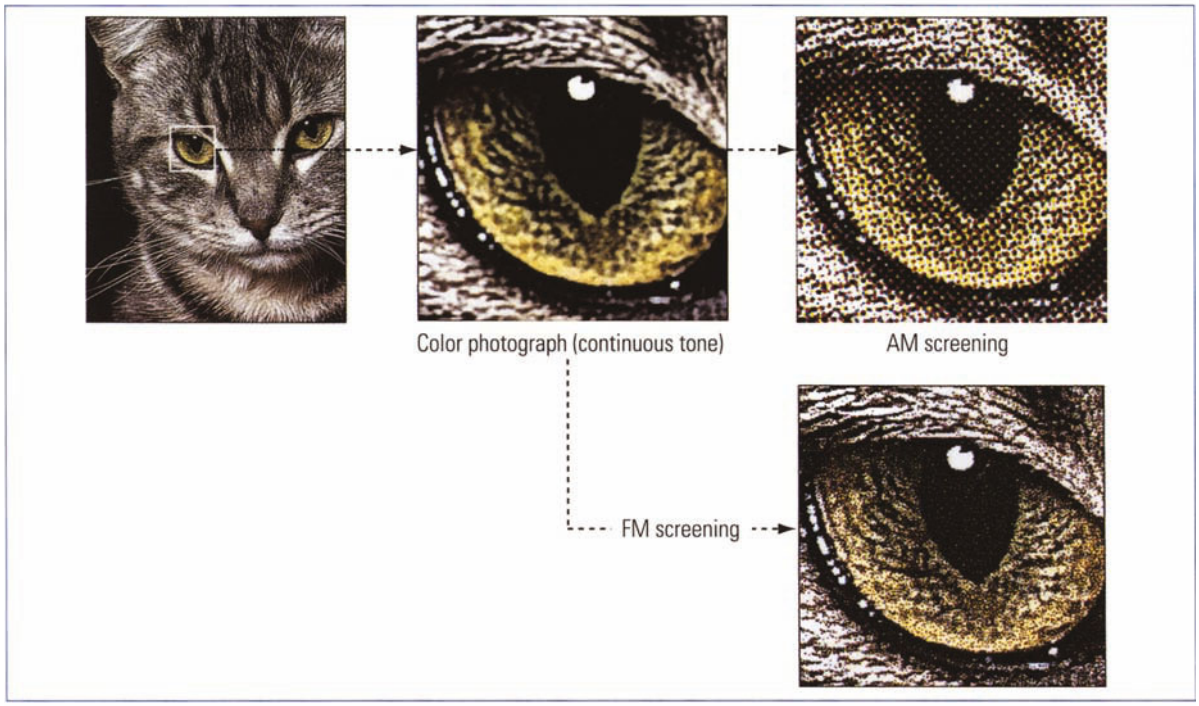


Fig. 1.4-31
Detail of a color photograph (continuous tone) for reproduction using conventional (AM) screening and stochastic (FM) screening for creating halftones in multicolor printing (AGFA)

ous halftone processes. Digital screening simulates the tone values of the originals with dots assembled from individual, small image elements (pixels: picture elements). Figure 1.4-36 illustrates the process of digitally reproducing a conventional analog dot. The higher the addressability (dpi: dots per inch) of the output device (film imagesetter, computer to plate equipment or computer to press/print system), the more accurate the reproduction of the dot shape of the analog AM screening.

Only with the advent of digital imaging technology has the widespread use of FM screening been made possible. The smallest reproducible pixel that an imagesetter can generate and position is, for example, the dot for frequency-modulated screening. The tone values are then simulated by varying the dot distance in the spacing of the pixel cell size/pitch (fig. 1.4-37). Individual dots of varying numbers and shape are then combined into groups (clustered) in accordance with the algorithm for FM (stochastic) screening.

Another example for comparing AM and FM screening is given in figure 1.4-38. In both illustrations the dots have been built up digitally from individual pixels with the same adressability/resolution.

In the case of conventional screening with an analog dot, the number of *gray levels* (or *gray values*) per screen cell depends on the reproducibility of different-sized dots. For a 60 lines/cm screen, one can assume that there will be approximately 70 to 100 different dot sizes/areas (this means that a dot's diameter may vary in a range from approximately 1 to 2 µm).

If the dot is then built up from individual picture elements (pixels), the number of different tone values is determined by the size of the screen cell – in which a tone value of the original is to be simulated (screen ruling L in lines per centimeter or lines per inch) – and the addressability A (in dpi, i.e., dots per inch), at which the individual pixels can be positioned.

As figure 1.4-39 shows, the number of picture elements N per screen cell *(gray levels)* results from the screen ruling L and the addressability A, where $N = (A/L)^2$ (e.g., $N = 64$ for $L = 150$ lpi and $A = 1200$ dpi).

Since a screen cell can contain a maximum of N pixels and include the value for the "blank" (unprinted)

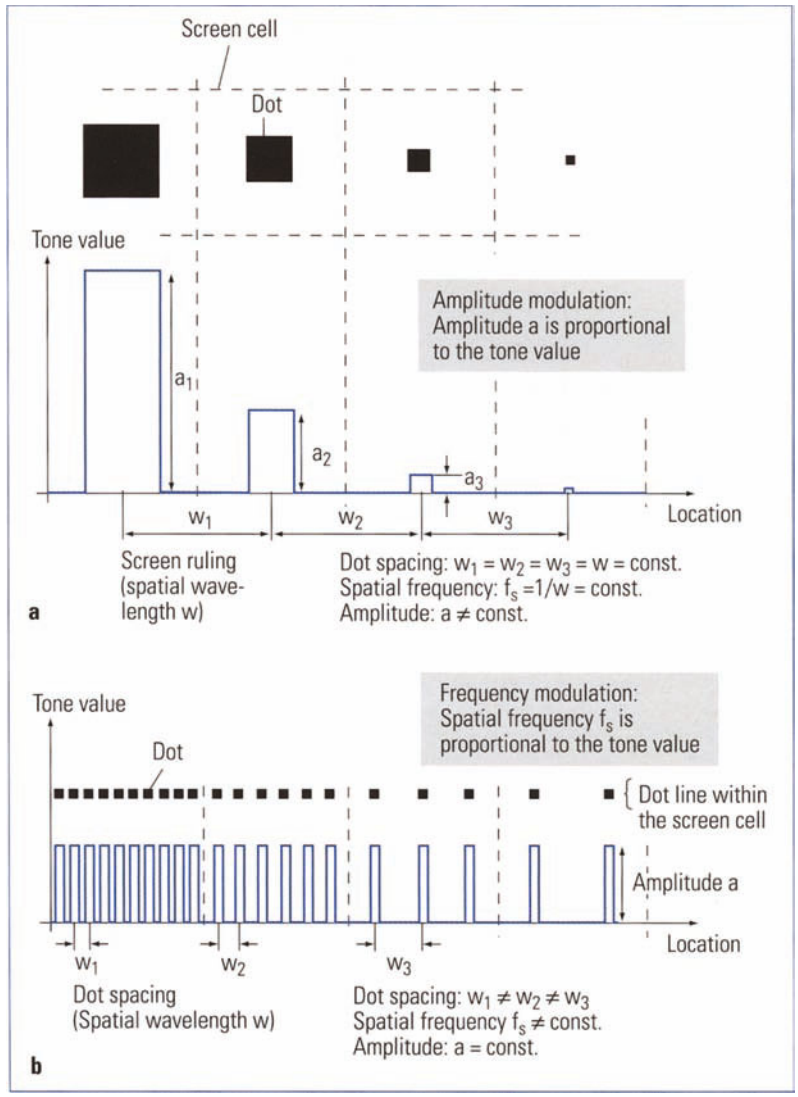


Fig. 1.4-32 Spatial tone value gradation.
a Amplitude modulation;
b Frequency modulation

screen cell N+1, possible *gray values* for a range of 0% to 100% in N levels (e.g., with N = 64 in levels of 1.56%) result. For this it was assumed that the individual elements of the screen cell have been covered completely and can have only two states, covered or not covered, that is, black or white.

If a printing process is used in which the individual dot can be printed with varying optical density (fig. 1.4-35), not just two, but five gray values per pixel can be reproduced (g = 5) (see the example in fig. 1.4-39). Consequently, the number of reproducible gray levels per screen cell increases considerably. For binary assignment of the pixel elements (g = 2) with screening of 150 lpi and addressability of 1200 dpi the resulting number of gray values is 65 (G = 65). But if five different gray values per pixel can be inked, the resultant number of gray values is 257 per screen cell – a considerably improved reproduction of the tone value ranges. If the structures in the image are not particularly fine, reproduction at a lower resolution is possible. In the example (g = 5) a reproduction at only 600 dpi with the same number of gray levels per screen cell (64) can be achieved as with 1200 dpi and just two gray levels (g = 2) per pixel.

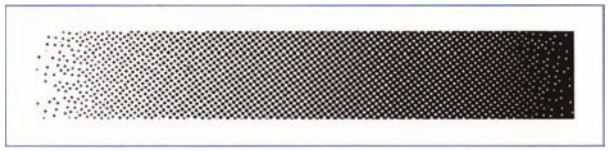


Fig. 1.4-33
Hybrid screening: a combination of AM and FM screening (Samba-Screen, Barco)

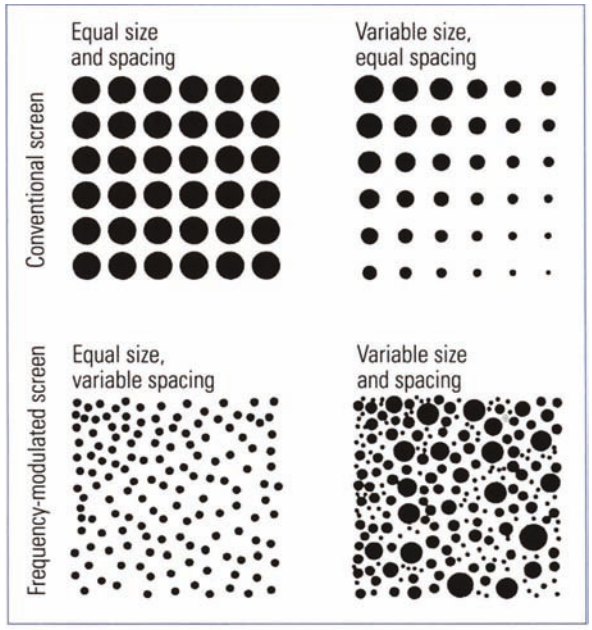


Fig. 1.4-34 Dot structures for the reproduction of tone values

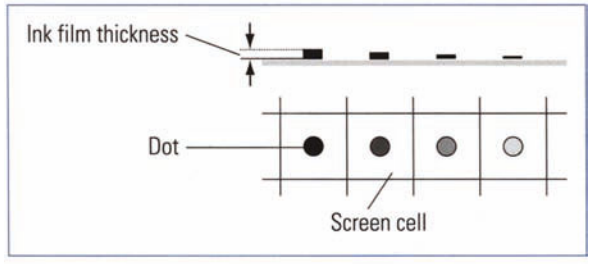


Fig. 1.4-35
Optical density modulation by changing the ink film thickness

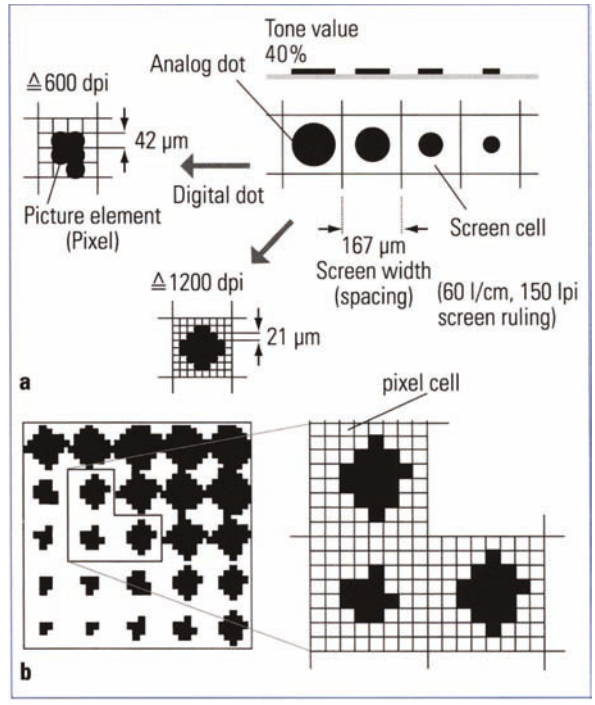


Fig. 1.4-36 Digital dot structure.
a Reproduction of an analog dot from picture elements with digital technology of varying addressability (resolution: dpi);
b Reproduction of a tonal value gradation

In the operations set of the *PostScript* page description language (which is the dominant standard in the printing industry; cf. sec. 3.2.9) the three parameters described above – screen ruling, alignment of the screen lines, and dot shape – that are specified in the "setscreen" operator to create an *amplitude-modulated screen* are fixed. The dot shape is described by the "spot function" and is ideally round in its original form.

A frequency-modulated image format should, in theory, be carried out throughout the entire image without segmentation. For practical reasons, screen cells are often defined with frequency-modulated screening in computer systems; the arrangement of the individual dot elements in the individual cells, however, is random. To avoid complex, mathematical analyses of the surroundings and thus save on computing time, screen cells with random dot distribution are formed. Nonetheless, there is always a risk that moiré-type patterns will form because of the periodic use of a screen cell structure [1.4-10].

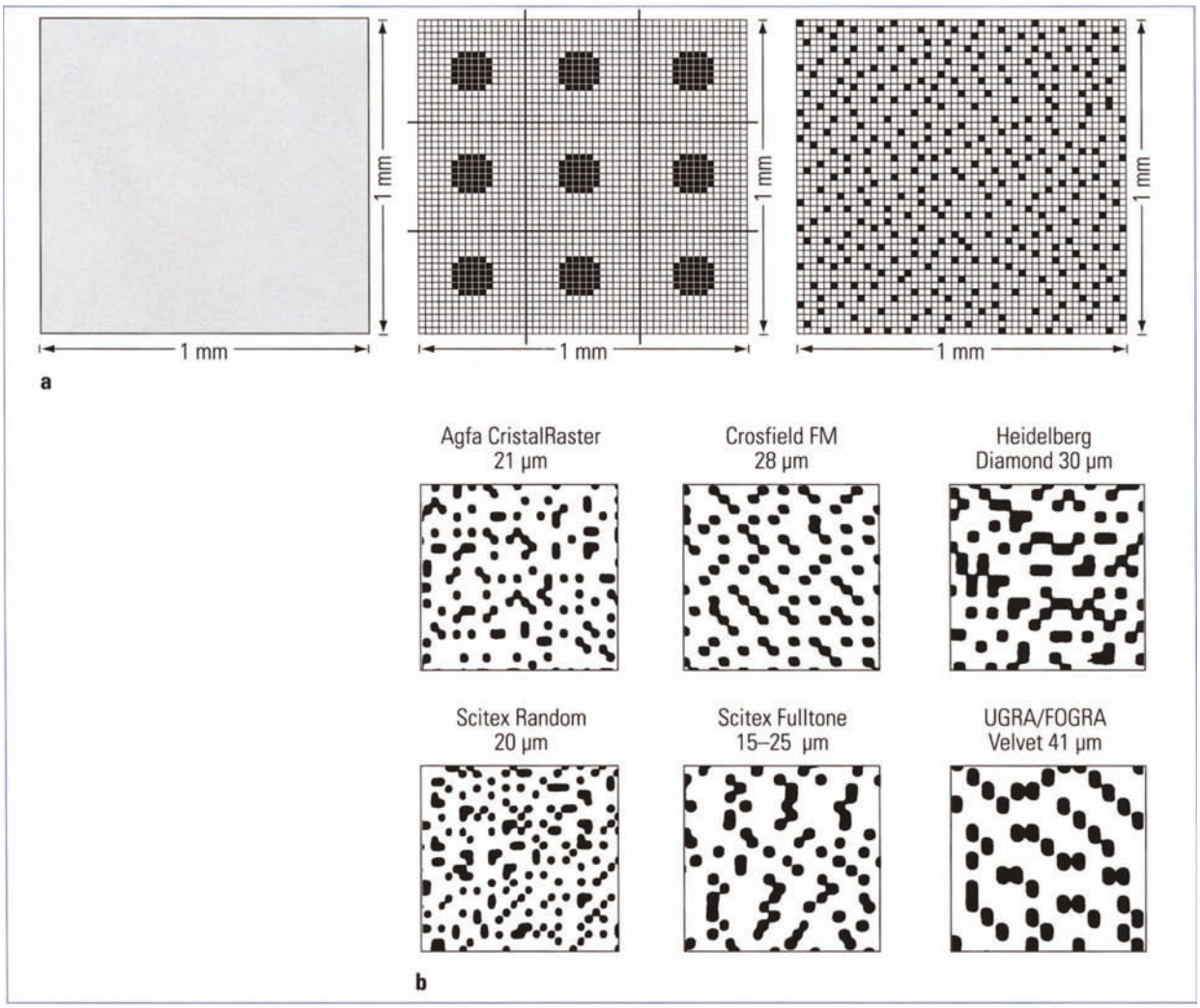


Fig. 1.4-37 Digital screen structure.
a 12.5% tone value with AM and FM screening (resolution of 1200 dpi);
b 25.0% tone value reproduced with different algorithms for FM screening (manufacturer and product name are given, and the diameter of the individual dot) (IFRA, [1.4-11])

The most harmonious, uninterrupted tone value structure possible embodies the most important quality parameters for a frequency-modulated halftone process. When randomly assigning individual dot elements, one must ensure that no unwanted dot conglomerations form that the observer's eye could perceive as disruptive. The individual dot elements are, in fact, sufficiently small for typical viewing distance and normally not recognized by most observers. In contrast, isolated dot conglomerations will usually be noticed immediately and may be registered as interference patterns.

Especially in terms of amplitude-modulated screening processes, the reproduction of larger dots with small, individual dot elements in an age of digitally addressable exposure devices can be considered a relic from the world of analog, photographic reproduction technology. In principle, frequency-modulated screening seems to be the ideal process for present-day digital reproduction technology. In practice, however, the amplitude-modulated image structure is still



Fig. 1.4-38 Comparison of amplitude-modulated (AM) screening with frequency-modulated (FM) screening (AccuTone, R. R. Donnelley)

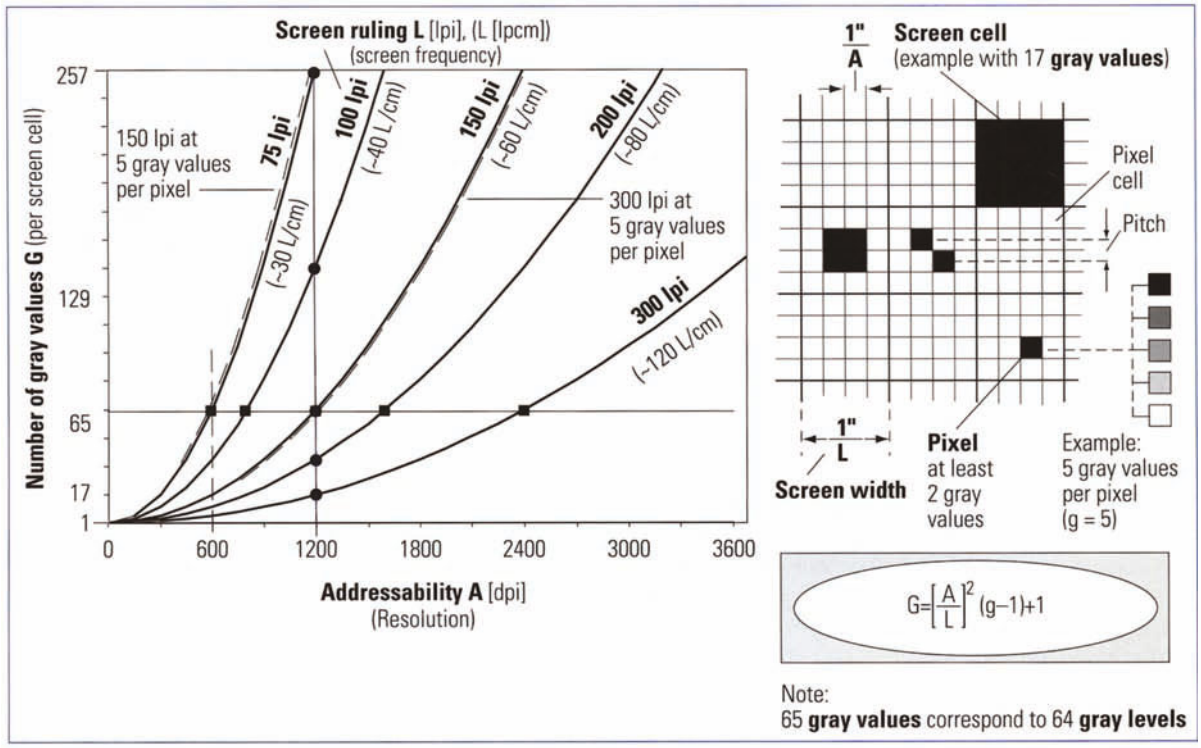


Fig. 1.4-39 Correlation between screen ruling, addressability and gray values in the case of digital screening and image structure

predominant. In platemaking, for example, it is possible to work with the largest possible dots, offering much greater production tolerances. Because of smaller dot sizes, the gradation behavior of frequency-modulated reproductions reacts more sensitively to interference factors. Frequency-modulated image structure variations usually improve the continuous-tone simulation, but as a result of using smaller, individual dots, there may be a detrimental effect on the stability of transfer characteristics curves. An advantage of FM screening is that color register variations – especially in homogeneous color areas with multicolor structures – prevent color variations or make them less obvious.

1.4.4 Quality Control/Measurement Techniques

The quality of the print depends greatly on the preparatory work done in prepress, the printing process, the machine engineering employed, and the materials used for creating the printed product such as paper and ink. The quality of the final printed product itself is affected by the finishing processes and equipment.

The quality of the print (i.e., the single or multicolor print image with pictures, text, and graphics) can be specified through the quality of the coloring, the reproduction of fine structures and the range of tone values, the precision of the multicolor overprinting and the surface properties of the print image and the entire printed page or sheet.

Quality-determining factors and selected specification used for defining quality are given in figure 1.4-40.

These specifications must be definable and measurable. Appropriate measuring instruments are available for metrological quality control. Most of these work on the basis of specific test elements (measuring targets/patches) which are printed together with the print image.

In addition the printing quality is checked visually. To perform a visual quality control the illumination and viewing conditions must fulfill some minimum requirements (ISO 3664). The subjective visual inspection brings a psychological element into the assessment of the image. Depending on the image message, the image structure, and the intended use for the prints, different assessment criteria will be applied.

Only measurability provides the possibility for objective and, to a certain extent, automated quality control in printing. One of the most important quality characteristics in printing is the quality of the color reproduction. The color effect of the printed image is measured in order to correct slight deviations between original, proof, and production, or to ensure consistent quality throughout the entire print run.

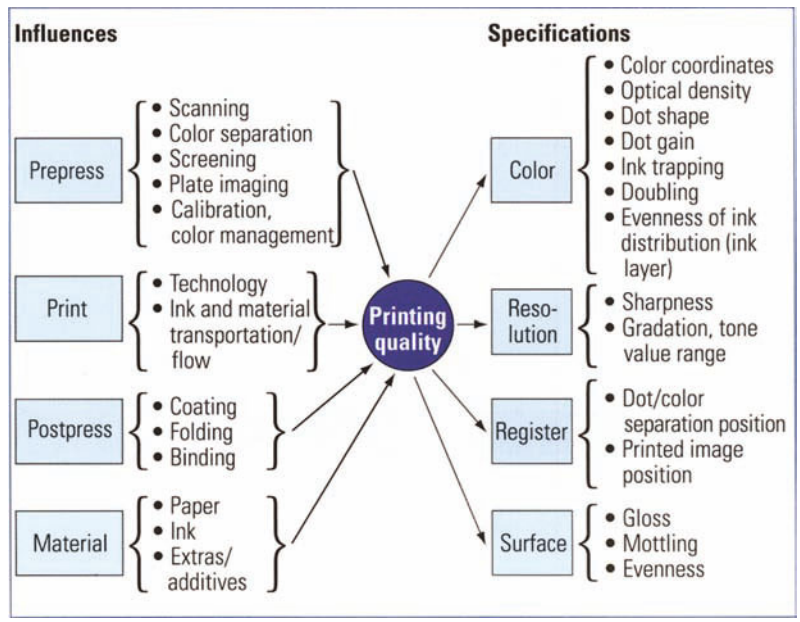


Fig. 1.4-40
Factors of influence and specifications determining the quality of the print

1.4.4.1 Color Measurement

Both densitometric and, increasingly, colorimetric processes and instruments are used for color measurements on the print. While colorimetric measurements are based on techniques where colors are measured as they are perceived by the human eye (as described in sec. 1.4.1, fig. 1.4-14), densitometric techniques are basically a measurement of ink film thickness that has been adapted to the inks used in the print, and where the processing of the measuring values is adapted to human perception/sensitivity in relation to changes of lightness/saturation with varying ink film thicknesses.

Measuring optical density is a common process, and there are tried and tested measuring instruments available. Such densitometers can determine not only the optical density, but also the parameters that characterize halftone printing, such as dot gain and relative printing contrast; the fact that ink acceptance/trapping can also be measured is an important feature in multicolor printing.

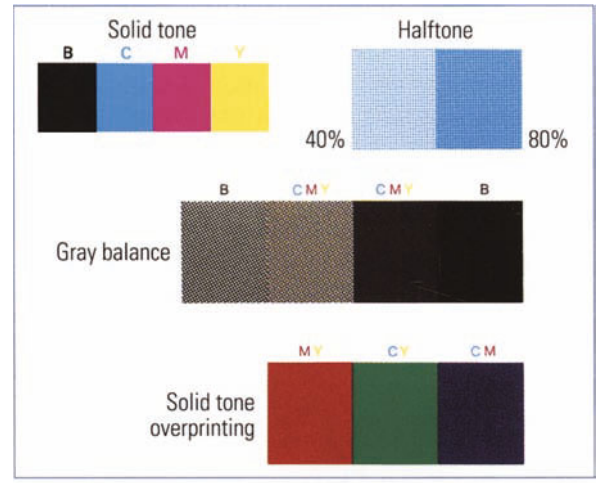


Fig. 1.4-42
Typical examples of color measurement patches (size of measuring patch, e.g., 5 mm × 6 mm)

Densitometry

On multicolor presses, the application of ink in each printing unit must be monitored and adjusted individually. The fact that several colors have to be printed together in a halftone image makes both visual assessment and measurement of the individual inks in the image relatively difficult. The measuring accuracy is limited because the measuring signal is partly superimposed by the other inks. Printing a so-called *color control bar* with measurement patches in the individual colors in the trim-off alongside the image has proved good practice (fig. 1.4-41). Color control bars of this kind are usually printed over the entire sheet width, and the individual patches are positioned so that they are assigned to the ink zones of the ink fountain. This enables targeted adjustment or control of the color/ink flow. Density can be monitored at the patches in a print image using a densitometer. Changes in the inks can be detected easily by means of the density value. As shown in figure 1.4-42, elements for solid tones, halftones, gray balance, and solid color overprinting are contained in the color control bar.

Optical density D is defined in the form of a logarithmic ratio (fig. 1.4-43):

$$D = \log \frac{1}{\beta} = \log \frac{I_0}{I}$$

Reflectance factor β is the ratio of the light intensity I of the light remitted by the ink film in relation to the intensity of light I_0 remitted by the blank paper. Reflectance factor β decreases as the film thickness increases. To obtain a measured value proportionate to the change of film thickness, the reciprocal value $1/\beta$ for calculation of the optical density is established first, then the logarithm for reproducing values corresponding to non-linear human

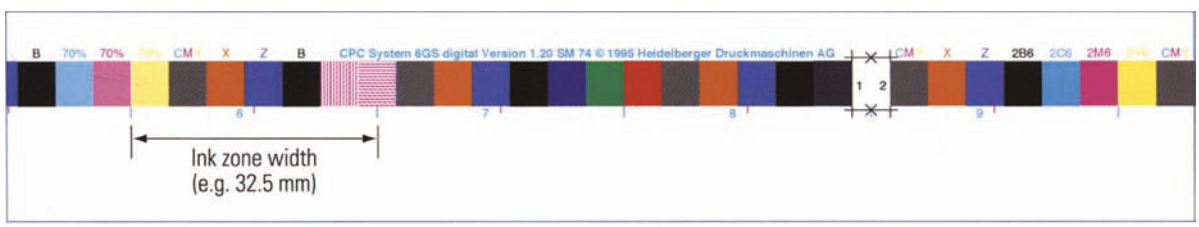
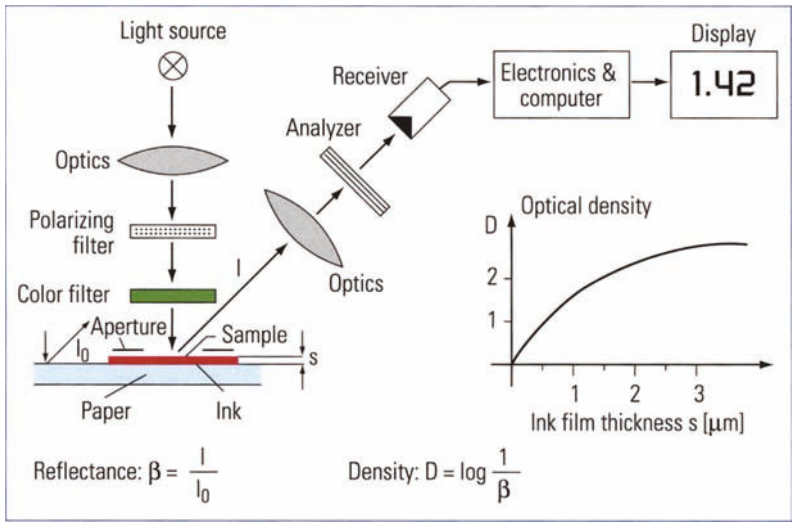


Fig. 1.4-41 Color control bar with color measurement patches

Fig. 1.4-43
The basic principle of a densitometer for optical density measurement



visual perception. Figure 1.4-43 presents the density characteristic in relation to the ink film thickness.

Prior to taking measurements, the measuring instrument is normally calibrated to the substrate (paper white) – to the densitometric value "0." (A special, standardized calibration white, e.g., barium sulfate, can be used for absolute calibration, so that substrate-independent devices can be compared with/adjusted to each other.)

To measure printing inks of different color with the same light source, color filters are fitted in the beam path of the densitometers. The color filters are matched to the process inks of common color sets (C, M, Y, K) for four-color printing. The color filter should have the maximum transmission in the minimum reflectance of the color to be measured, that is, it should possess the complementary color to the color intended for measurement (e.g., blue filter for yellow, green filter for magenta, red filter for cyan) which results in high measured values and an optimal sensitivity of the changes of ink film thicknesses (the filters are standardized and installed in the various measuring instruments). The term "color density" was introduced because of this assessment of the color in the density measurement (in contrast, general optical density without special filtration is mainly used to measure black inks; however, very often a so-called visual filter or the green filter for the measurement of magenta is used here, too). Densitometers have no adapted filters for *special colors*, and so a preferable alternative is to take a measurement with the filter that can obtain the highest density values.

The density curves for the common inks are given in figure 1.4-44, together with the ink film thicknesses typical of multicolor offset printing.

In order to measure *spectral density*, the appropriate densitometers are fitted with special narrow-band filters (e.g., bandwidth of 30 nm). This spectral density measurement resulted from the need to improve the comparability of various measuring instruments. When making a densitometric reading, the typical *measuring aperture/spot* has a diameter of approximately 3 mm.

The Effect of Polarizing Filters. Both wet and dry ink can be measured with a densitometer. Wet inks have a relatively smooth, glossy surface. To some extent, the ink adapts itself to the structure of the paper surface during drying and loses some of its gloss in the case of an irregular, rough structure. Measuring the ink when still wet will produce a different result to when it is dry (the measured density value for a wet ink is higher than that for a dry ink).

To compensate for this, two crossed linear polarizing filters are placed in the beam path (fig. 1.4-43). Of the light waves emitted in all directions, polarizing filters only allow those moving in a certain direction to pass through. Part of the light rays polarized by the first polarization filter are reflected by the ink surface specularly, that is, without altering their direction. The second polarizing filter is aligned at an angle of 90° to the first so that the reflected light waves cannot pass through (fig. 1.4-45), thus suppressing the specularly reflected light for this measurement. However, light beams that penetrate

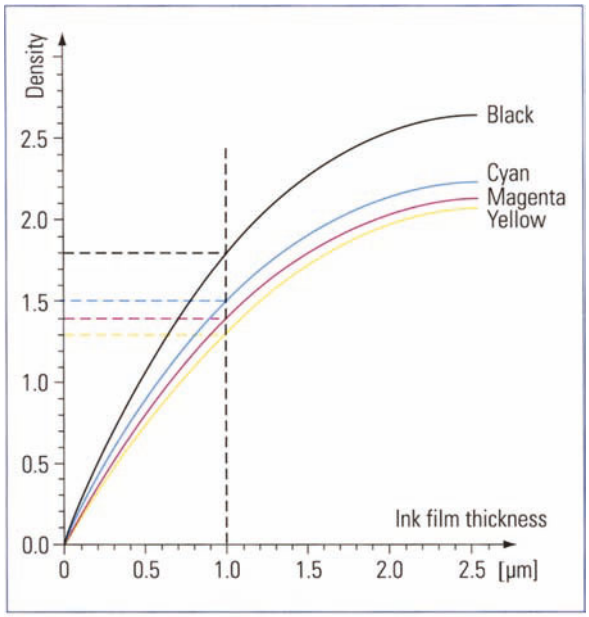


Fig. 1.4-44
The optical densities of inks with different ink film thicknesses

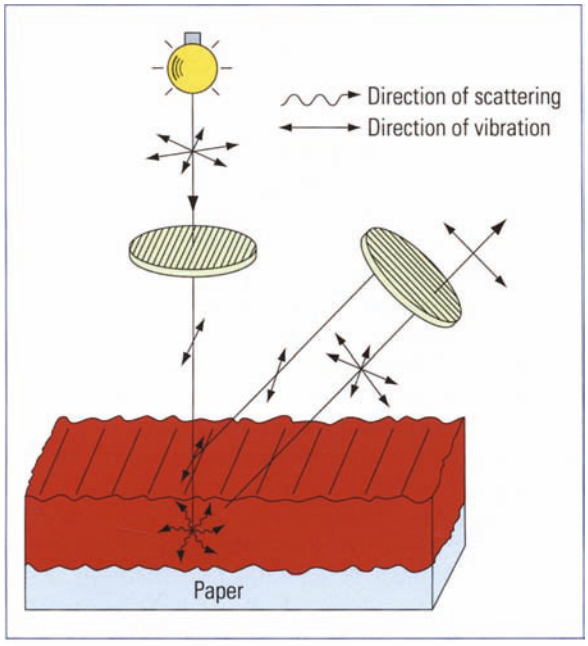


Fig. 1.4-45
The effect of polarizing filters for avoiding specular reflection on smooth surface structure when measuring optical density

into the ink film and are reflected either by the ink or by the substrate lose their uniform polarization. Therefore, they are, in part, allowed through by the second polarizing filter and reach the receiver (fig. 1.4-43). Consequently, by blocking the portions of light specularly reflected by the wet ink, one can obtain approximately identical readings from wet and dry inks, that is, the wet printing ink with more gloss is measured as if it were already dry. Due to the absorption by the polarizing filter, in principle less reflected light reaches the receiver, which leads to slightly higher measured values.

Area Coverage (Tone value)

For true-to-color reproduction of halftone images in the print, the change in dot diameter is the critical factor for the print image transfer, as these changes lead to tonal and color shifts. There are various factors which affect the halftone value transfer and need to be monitored in the interests of standardization. During printing, the simplest control parameter for halftone value transfer is the measurement of the dot percentage in the halftone patches of the color control bars printed along with the image (fig. 1.4-41 and fig. 1.4-42).

The area coverage in the print (F_D) (i.e., the portion of the area covered with ink within a control patch covered with halftone dots in relation to the entire area of the control patch) can be measured with a densitometer.

Using the "Murray-Davies" equation, the area coverage percentage is calculated from the remitted light intensity of solid and halftone areas as follows:

$$F_D[\%] = \frac{1-\beta_R}{1-\beta_V} \cdot 100\%$$

where β_R: Reflectance factor, measured in the halftone patch
β_V: Reflectance factor, measured in the solid tone patch

In this case it is assumed that the halftone and the solid tone have been printed with the same ink film thickness.

Accordingly, the area coverage is calculated from the measured density values, as follows:

$$F_D[\%] = \frac{1-10^{D_R}}{1-10^{D_V}} \cdot 100\%$$

where D_V is solid tone density
D_R is halftone density

When screens are measured with a densitometer, it is not the geometrical area coverage, that is, the ratio be-

tween dots and paper white on the measuring patch, but the "optically effective area coverage." The difference between geometric and optically effective area coverage is due to the fact that in visual observation and in densitometric measurements, part of the arriving light penetrates into the paper between the dots at the unprinted areas, but is trapped under the dots during reflection and thus absorbed (fig. 1.4-46).

Called "*light gathering,*" this effect causes the dots to appear optically larger than they are in reality. For this reason, the optically effective area coverage consists of the geometric area coverage and the optical area gain. Mathematically this is interpreted, for instance, using the "Yule-Nielsen" equation, an expanded "Murray-Davies" equation.

Dot Gain

For an assessment of the printing process in conjunction with the materials used, the area coverage in the print constitutes the key measured and reference quantity.

Dot gain/tone value increase (Z) is calculated from the area coverage of the film (F_F) as a master for platemaking and the tone value (F_D) is transferred to/printed on the substrate via the printing form, printing process, and printing units as follows:

$$Z[\%] = F_D[\%] - F_F[\%]$$

Using the color control bar (containing measuring patches as shown in fig. 1.4-42) the area coverage value (e.g., 55%) can be determined for cyan by measuring the solid and halftone patches (e.g., 40%). Based on the known area coverage of the film for the halftone patch of 40%, the resulting dot gain is 15%. Dot gain is usually positive because the blanket enlarges the dot upon transfer to the paper (given that the tone value of the film does not change significantly from film to plate – which is generally the case; and depending on whether the printing plate is made with a positive or negative working plate). The change in tone values resulting from the printing process must be considered for the color separation and film making.

In the standardised positive copy during the manufacture of printing plates, the dots are copied from the film to the plate somewhat smaller for practical reasons, because when printing under standard printing conditions the dots expand.

Figure 1.4-47 gives a typical print characteristic curve. Dot gain essentially depends on the paper's surface and its absorption/ink setting behavior, the ink rheology, the blanket, printing pressure, and so on.

In the attempt to standardize offset printing, standard values have been specified for the dot gain from film to print. It is the printer's job to achieve the standard for dot gain by appropriately selecting materials and making suitable press adjustments.

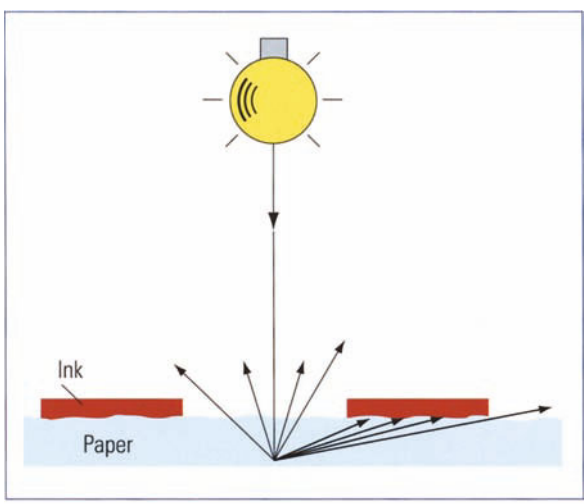


Fig. 1.4-46 Light gathering in the area of the inked paper surface

Derived Quality Parameters

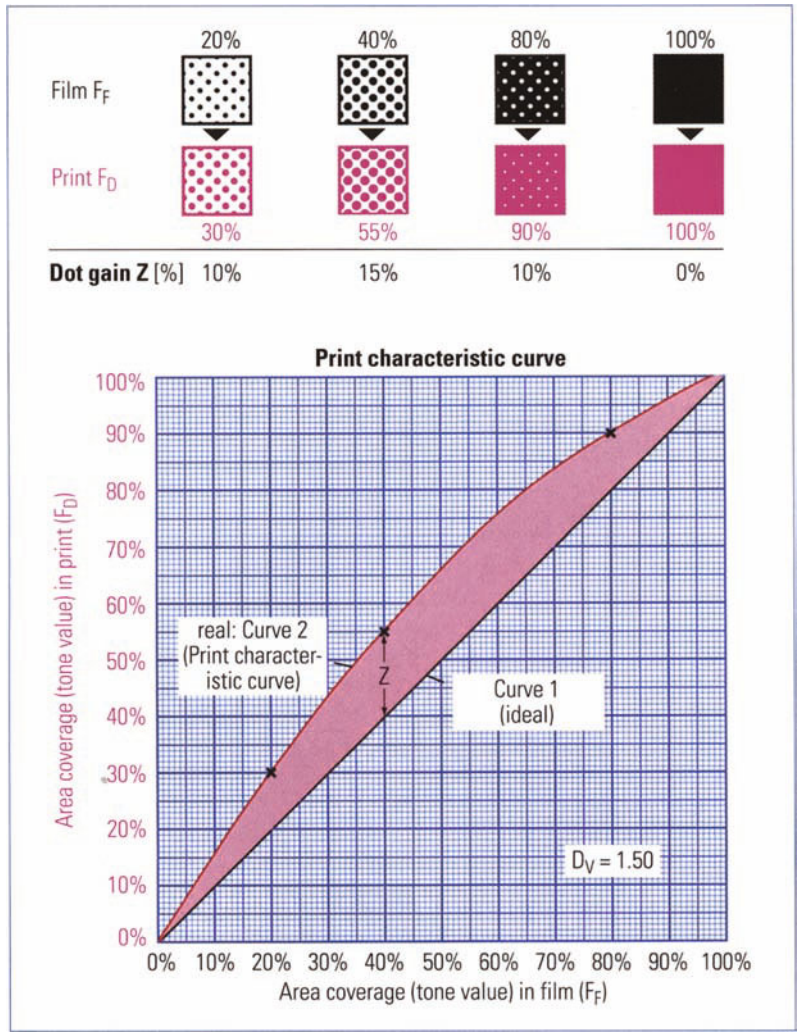
Other parameters that characterize the print can be derived by means of density measurements, particularly in relation to the ink transfer for printing halftone and solid areas (relative printing contrast or, in short form, contrast) and the overprinting of solid tone color areas (ink acceptance/trapping).

Contrast. From the measured values of the ink density in the solid D_V and the ink density in the halftone screen D_R one can calculate the relative printing contrast. In doing so, it is preferable to measure the D_R value in the three-quarter tone; for instance 70% as indicated by the color control bar in figure 1.4-41.

$$K[\%] = \frac{D_V - D_R}{D_V} \cdot 100\%$$

Ink Trapping. The ink trapping is calculated from the ink densities of solid overprint patches with one, two, or three colors and in consideration of the color sequence. Examples of corresponding measuring patches are given in figures 1.4-41 and 1.4-42.

Fig. 1.4-47
Print characteristic curve and dot gain



The ink trapping calculated on the basis of the following formula states by how many percent one ink lies over another and where the ink printed by itself onto the paper (for which the ink trapping is 100%) is used as the comparative quantity.

The following applies for *two-color overprinting*:

$$FA_{\underset{1}{2}}[\%] = \frac{D_{1+2} - D_1}{D_2} \cdot 100\%$$

where:

D_{1+2} is the ink density of the two overprinted colors,

D_1 is the ink density of the color that was printed first,

D_2 is the ink density of the color that was printed last.

All ink densities must be measured using the filter for the second color.

Accordingly, the following applies for *three-color overprinting*:

$$FA_{\underset{1}{\overset{3}{2}}}[\%] = \frac{D_{1+2+3} - D_{1+2}}{D_3} \cdot 100\%$$

where:

D_{1+2+3} is the ink density of the three overprinted colors and

D_3 is the ink density of the color that was printed last.

All ink densities must be measured using the filter for the third (last) printed color.

Densitometric Measurement Systems

Hand-held densitometers are suitable for quality control, provided that only a few measurements are required on a sheet. Random checks undertaken in the interest of offset printing standardization and random checks of tone values represent typical examples of the use of the hand-held densitometer. However, the constant monitoring of a print run or the continuous adaptation of the ink feed in the press requires an abundance of additional measured values. Automated measurement systems have been developed for this purpose.

Scanning densitometers were primarily developed for offset printing in order to be able to scan the control bars that are printed at the sheet tail, for instance, and span the entire width of the printed sheet.

In print run control, it is helpful to set the ink zones in the printing units of multicolor presses according to density values. Because separate measurements are required in each ink zone, a scanning densitometer must move along the control bar, scanning the sheet at right angles to the direction of travel.

This task can be performed off-line by a densitometer that scans the sample sheet previously removed from the delivery of the press. The control bar is usually printed in the trim area at the sheet tail. The necessary measuring targets (solid, halftone, additional control patches) are arranged in a set sequence in the control bar (see also fig. 1.4-41). Since automatic patch recognition cannot be done with an adequate level of certainty, the type of control bar (and therefore the target sequence) is entered in the measurement system prior to evaluation. The geometric alignment in relation to the guidance of the printed sheet in the press is also stipulated (e.g., center of press), so that each separate measurement on the printed sheet can be assigned to the correct ink zone.

In packaging printing, in particular, color areas are often printed with special color tones (decorative colors) for which narrow tolerances apply. Normally there is insufficient space on the printed sheet for a continuous control bar, but it is possible to arrange it in sections between the individual copies on the sheet. Special scanning densitometers with a *two-coordinate measuring system* permit the measuring head of the densitometer to be moved automatically to any measuring point on the sheet; measurement coordinates, however, must be programmed in prior to printing.

Numerous, *more recently developed color-measuring systems* (whether they are simple hand-held instruments or automated systems) that scan the entire printed sheet are based primarily on spectral metrology. In addition to determining the colorimetric parameters (sec. 1.4.1), such instruments can also calculate the optical density as a derived quantity following the measurement of the spectral reflectance (by digital filtration, for example). There is little difference in the external appearance of the instruments; figure 1.4-51 shows hand-held measuring instruments and figure 1.4-52, a scanning measurement system.

For *in-line color measurement*, especially for printing with web presses, there are measurement systems which make possible the continuous monitoring and, to some extent, even control of the production process. Generally speaking, these types of systems are not economically feasible for use with sheet-fed presses (sec. 2.1.4 includes additional information).

Spectral Color Measurement

The correct comparison of solid tone colorings on different prints based on density measurements is only possible if, for the specification of reference values, prints have been used for which the same paper and the same ink were used as for the job. For this reason, density measurement is very effective for quality control within a print run. However, it is less suitable for a comparison between proof and production since different materials are employed for each of these processes. These problems in densitometry have been overcome with the help of color measurements. The measuring of colors as they are perceived by the human eye has made it possible to start-up a production press in accordance with suitable colorimetric values of a proof, and to adjust the press to the specified color values within narrow tolerances.

As described in section 1.4.1, color measurement is based on colorimetric techniques. The basic structure of a color-measuring device is given in figure 1.4-48.

Spectral color measurement itself can be done either by means of three special filters that have been adapted to the visual perception of the human eye (*tristimulus filters*), (fig. 1.4-49, colorimeter) or primary measurement of the spectral reflectance factor distribution and subsequent *digital filtering* by the methods illustrated in figure 1.4-50 (spectrophotometer).

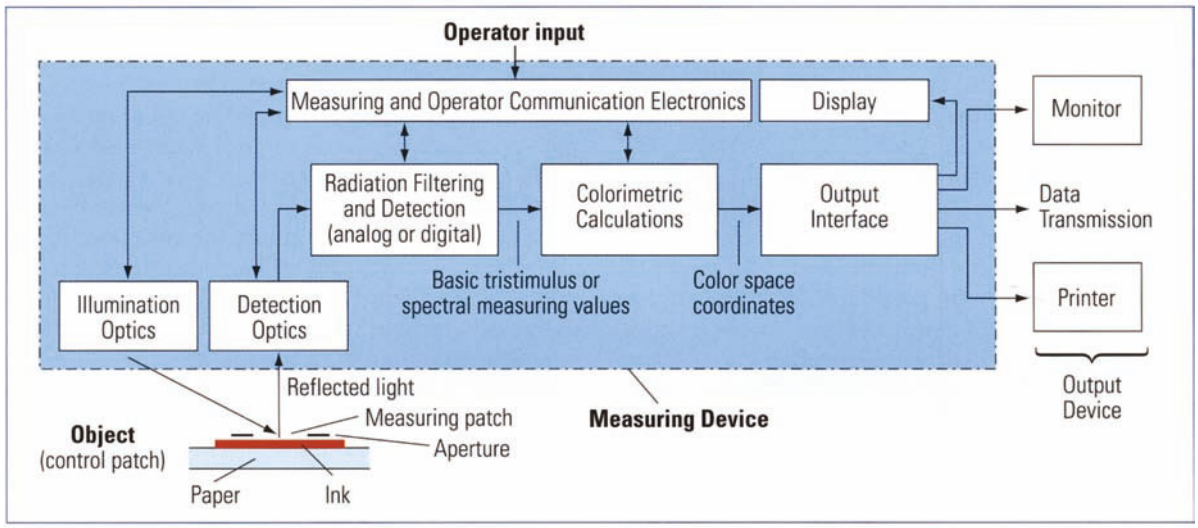
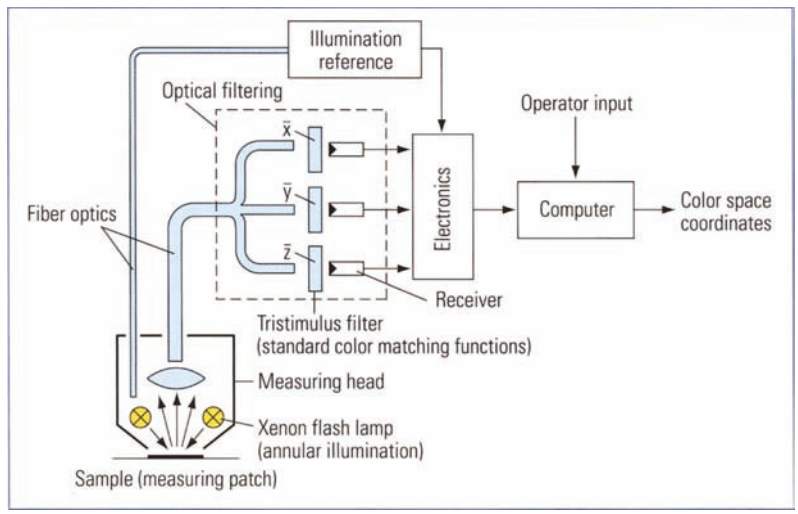


Fig. 1.4-48 Basic structure of a color-measuring device

Figure 1.4-51 shows some typical *hand-held measuring instruments* for color measurement. The *scanning spectrophotometer* integrated in the color measurement and control equipment shown in figure 1.4-52 is based on the diffraction grating principle (fig. 1.4-50c).

The *color measurement and control system* illustrated in figure 1.4-53 records the entire printed sheet in one measuring run at a local resolution of approx. 2×3 mm^2. An optical multiplexer scans the entire printed sheet. The spectral measurement itself for the individual measuring areas is also based on the diffraction grating principle, much like that of the system illustrated in figure 1.4-52. In addition to measuring the control bar patches and the decorative colors, a system of this type can also take measurements directly from the image. The possibility to take *measurements in the image* has always been every printer's wish because in the end it is the quality of the image that is decisive for the customer's satisfaction with the print job. With the overall measurement of a sheet, it has become easier to eval-

Fig. 1.4-49
Photoelectric colorimeter; optical filtering with tristimulus filters



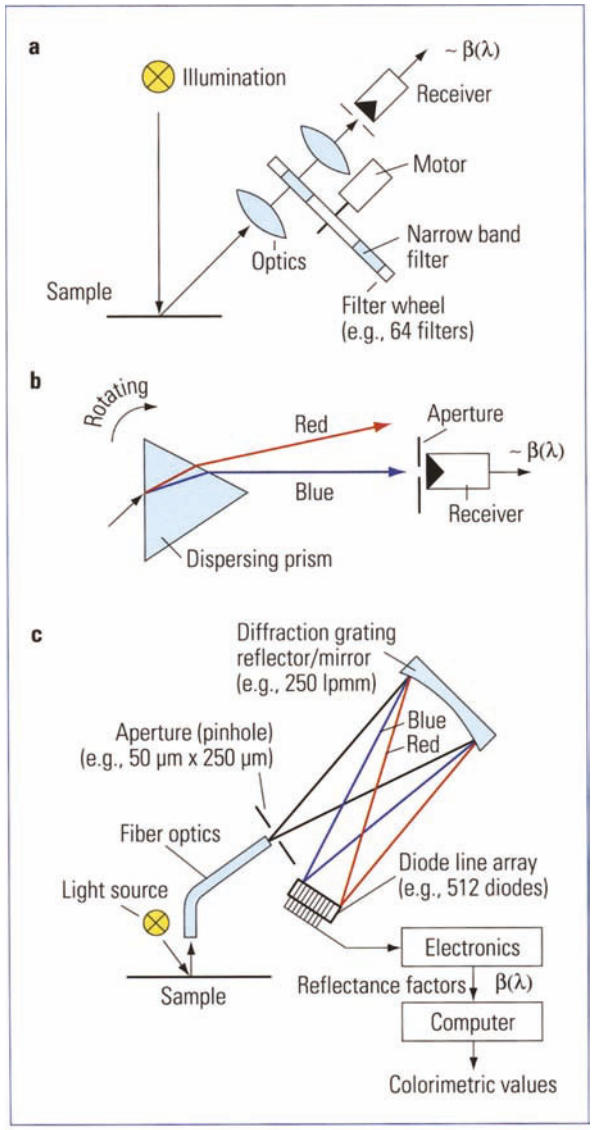


Fig. 1.4-50

Spectrometer principles for measuring spectral reflectance factors.
a Filter wheel principle;
b Monochromator principle;
c Diffraction grating principle

uate mixed forms using different criteria and measurement references. The evaluation of the control bar, the assessment of multicolor images produced by overprinting, the evaluation of decorative colors in solid areas, and so forth are now possible. Special software algorithms automatically detect suitable measuring areas on the printed sheet. This considerably simplifies makeready, especially in packaging printing. Moreover, the *inspection* of the entire print image for damage and defects on the basis of the scanned sheet can take place via the monitor or in an automated process.

All *density values* and derived quantities such as area coverage, ink acceptance, and so forth can also be determined from the *spectral measuring values*. This means that all traditional control methods can be supported metrologically on the basis of color measurement. On the other hand, however, color measurement during printing is a prerequisite for the efficient use of color management methods.

Density measurement is based on measurement of the ink film thickness, and therefore density variations are direct measuring variables for controlling the ink feed in the individual printing units. Colorimetric measurements and their comparison of measured and reference values indicate color location deviations which need to be calculated to adjust the inking units for changing the ink film thicknesses for the process colors in the press. Section 2.1.4 provides further information about this topic.

Inspection of the Image

In gravure, flexographic, and rotary-screen printing the webs are usually printed in a continuous printing process; the web is rewound again after the dryer section (in web offset, continuous printing is, by and large, still the exception). If quality control cannot take place on the running web, the press needs to be stopped in order to do so. However, since faults can occur at any time during production, web inspection devices have been developed for in-line monitoring.

The specifications of *web inspection systems* vary considerably depending on the task to be performed. Most devices are suitable for visually detecting faults in the print image, gross fluctuations in the color, or fairly large deviations in the register. Reliable color control throughout the entire print run can only be ensured by a densitometer or colorimeter that take measurements on the web during printing. The stroboscope provides the simplest means of *visually inspecting* the running web. The *stroboscope* uses a periodic flash of light that is synchronized with the press speed, making it seem to the observer as if the web were standing still. Optical systems incorporating a rotating mirror enable high-quality image inspection. The quality of the static image also enables the press operator to detect bigger changes in color.

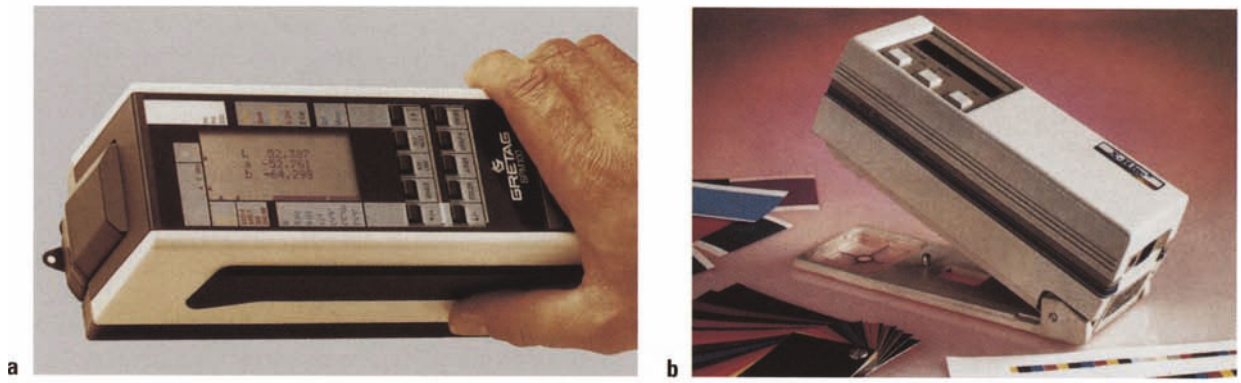


Fig. 1.4-51 Examples of hand-held color measuring instruments.
a Spectrophotometer SPM 100 (Gretag);
b Spectrodensitometer 938 (X-Rite)

Fig. 1.4-52
Scanning spectrophotometer for print quality measurement and control (CPC 21, Heidelberg)



Video web inspection systems are used to an increasing extent because these systems can detect structural defects as well as fairly large color variations. Video monitoring has the advantage of offering digital image analysis with automated fault detection. The accuracy of color detection is limited by the camera's technology and quality, which do not usually allow density measurement or even color measurement. Therefore, systems of this kind are suitable for computer-assisted image inspection, but not for binding color measurement and control within the narrow tolerances of the required printing quality.

1.4.4.2 Color Register

Register is traditionally the exact superimposition of the print images on the front and back side of a substrate with no geometric differences. Accuracy requirements are approximately 1/10 mm. A much higher level of accuracy in the overprinting of the separate color separations for cyan, magenta, yellow, and black (color register) is essential for quality multicolor printing. The ac-



Fig. 1.4-53 Measurement and control system for color measurement and image inspection on the printed sheet.
a Measuring equipment;
b Monitor (CPC 24 ImageControl, Heidelberg)

curacy of the color register must lie within a range of a few hundredths of a millimeter. For setting the colors in a color set to one another on a printing press, register adjustments with increments of $^1/_{100}$ mm in circumferential and lateral direction are used. The adjustment of minor register differences can be initiated from the control desk. By turning and moving the individual plate cylinders, one can make register corrections in a circumferential and lateral direction. Diagonal register adjustments (rotation of the image) are possible on some press designs which is achieved by shifting the plate cylinders (the ideal solution would be to rotate the printing plate on the plate cylinder surface). Register measurement and control systems – the majority of which analyze special register marks printed on the substrate – have been developed to bring the press more quickly and easily into register during set-up.

The easiest way to check the color register is to examine a section of the image with a *magnifier*/optical magnifying glass (fig. 1.4-54a). If this magnifier is fitted with an additional measurement scale, the printer can assess by how much the circumferential and lateral register needs to be adjusted, should it be necessary.

Special *register marks* printed along with the image make this process easier. These marks are positioned on the plates in such a way that, if the overprinting is done correctly, all the lines/marks for the inks/color separations concerned lie one on top of another or form

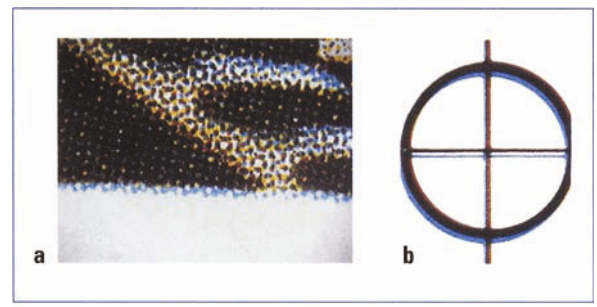


Fig. 1.4-54 Color register deviations.
a Halftone multicolor image;
b Register measuring mark

specified structures (register marks, register crosses – fig. 1.4-54b). Deviations, when enlarged with a magnifier, are identified and used for press adjustment.

Automated *color register measuring instruments* can automatically detect, quantitatively evaluate, and display deviations for the operator. Additionally, these instruments may even initiate adjustment directly in the press.

A *hand-held measuring instrument* of this kind is illustrated and described in figure 1.4-55. Figure 1.4-56 shows a special magnifier that consists of a camera system which displays the halftone image on the monitor.

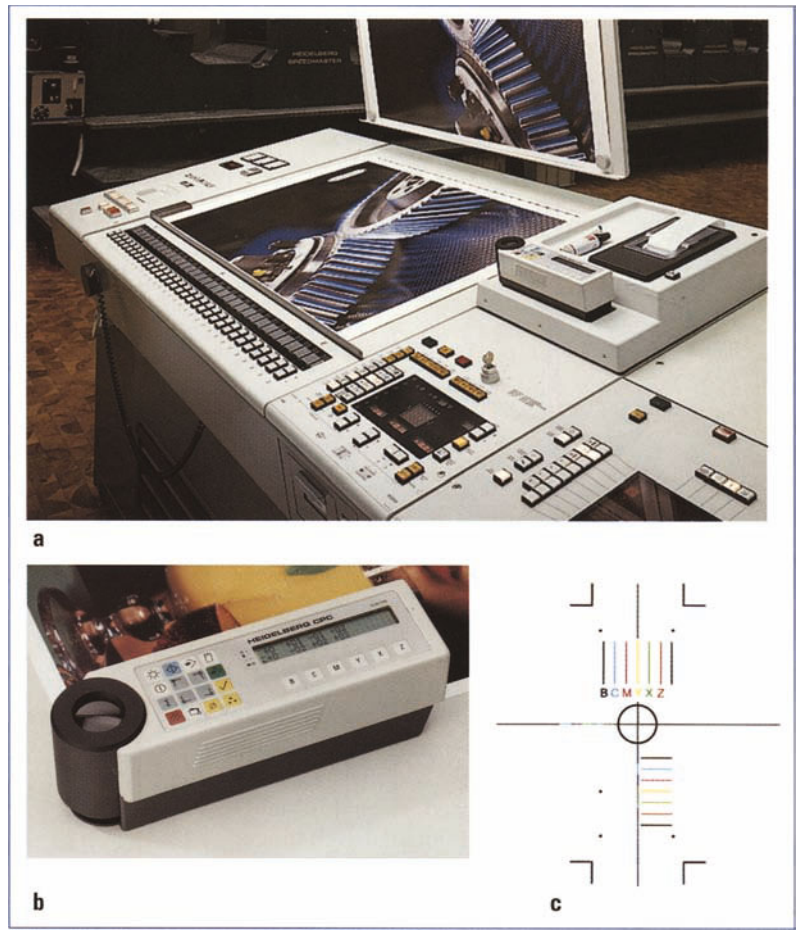


Fig. 1.4-55
Hand-held instrument for the measurement of color register deviations and automatic adjustment of the press by means of infrared signal transmission.
a Register mark reader on the control desk of a sheet-fed offset press;
b Hand-held instrument ("electronic" magnifying glass with display for color register adjustment);
c Register mark for six colors for register mark reader on the printed sheet
(CPC4 register mark reader, Heidelberg)



Fig. 1.4-56
Video magnifying glass for assessment of the color register in multicolor printing (MAN Roland)

There are measurement systems that can be installed on both sheet-fed and web-fed presses for *in-line measurement of the color register*. The measurement is usually carried out on the basis of special measuring marks which are printed along with the image (sec. 2.1.4 for further information).

1.4.4.3 Measurement of Gloss

A gloss of a surface can be specified by means of its reflection behavior. The measurement is based on the varying scattering angles of light in accordance with the surface structure (specular or more or less diffuse reflection). So-called goniometers can take three-dimensional measurements of the directional diffusion of light in great detail (indicatrix of diffusion, see fig. 1.4-57a). This complicated measuring technique, however, is only suitable for laboratory tests and not for assessing printing quality during production. Glossmeters

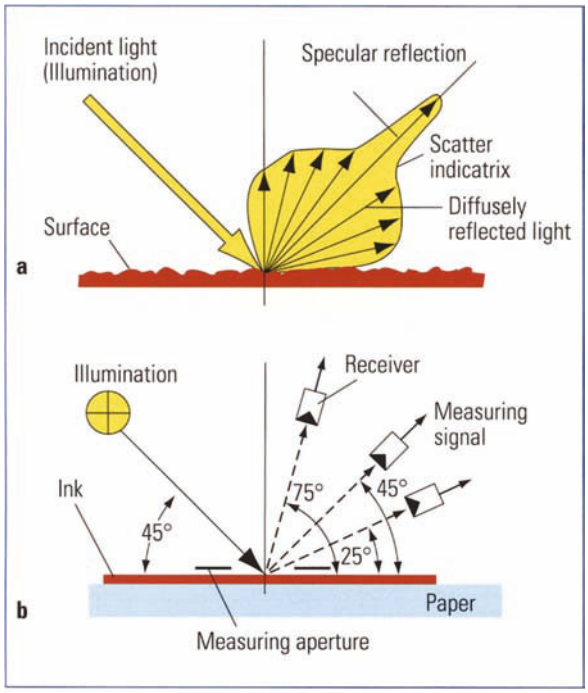


Fig. 1.4-57
a Reflection behavior of a rough surface;
b Gloss measurement at specified measuring angles of a glossmeter

are limited to measuring reflected light in a few selected directions, as figure 1.4-57b shows (for example: 25°, 45°, and 75°, with illumination at an angle of 45°).

1.4.5 Surface Finishing

Coating printed sheets in-line in sheet-fed or web-fed presses or in a downstream finishing process has become increasingly important for many printed products. The following are the basic objectives of coating of printed products:

- increase visual effects, particularly gloss,
- protect the substrate from mechanical factors such as abrasion and scratches,
- protect the substrate from penetration by liquids and gases,
- optimize subsequent finishing processes.

In sheet-fed offset there is a growing tendency for presses to be fitted with coating units, since the value of the print can be significantly increased by applying a coating. A much greater degree of gloss can be achieved with coating than with printing inks alone. Virtually photographic quality is achieved with high-gloss coating. The visual impression of the print image is essentially affected by contrasts, so that matte varnish can produce the desired effects for many layout designs as well as high-gloss varnish.

For many print jobs, however, it is not the gloss that is of prime importance but rather the mechanical surface improvement, namely protection from abrasion and a defined coefficient of friction. Printed products such as folding boxes or book covers are exposed to a particularly high degree of abrasion and scratching. Appropriately formulated varnishes that offer protection from abrasion make the printed sheet surface very resistant.

The properties of the coating film, such as a sealing effect against water and grease and, to a certain extent, steaming are particularly exploited in food packaging.

Coatings with defined coefficients of friction play a significant part, particularly in the production of folding boxes, since they optimize the conveyance of the folding boxes to the subsequent finishing stations. Coated prints also need less powdering in the delivery to prevent offsetting. This also contributes to speedy finishing as well as to obtaining the desired glossy effects.

1.4.5.1 Characteristics of Surface Finishing

Optical Effects/Gloss

Gloss provides printed products with a better overall look. It increases the attention paid to the product. The color of high-gloss prints appears more intense (greater depth of color), that is, more chromatic and at the same time somewhat darker. The colorful glossy effects can be expressed more succinctly: a glossy black appears to be blacker than a matte black and a glossy red darker and more intense than a matte red.

Gloss is the light reflected from the surface, whereby the angle of incidence of the light is the same as the angle of the greater part of reflection. Gloss is a characteristic of the surface of a material. The surface reflex of a pane of glass, for example, superimposes on the color image behind it, thus intensifying the color impression. The gloss reflex of an ink film or a coating has the same effect on the color appearance of a print.

On an absolutely smooth surface all the gloss is reflected below the glazing angle and is only visible in this

direction of angle. When looking at glossy print copies or packaging, the objects must be held so that the gloss does not strike the eye. Semi-matte coatings, where the light is reflected diffusely, are less dependent on the angle of observation and the potentially disadvantageous effects of specular reflection.

An ideally glossy ink surface is not achieved in sheet-fed offset. The film of ink is more or less semi-matte. The surface may be treated with a coating or film lamination in subsequent finishing operations.

Figure 1.4-58 outlines the specular and diffuse reflection which can occur on printed and coated surfaces.

Protection from Abrasion

The quality of high-grade printed products can be considerably impaired by scratches on the substrate. The higher the density of the color areas in a printed image, the more noticeable scratches become. Surfaces may be subject to just as much stress in subsequent finishing processes as during transportation. Protective varnishes can be enriched with suitable abrasion protection waxes. Abrasion marks on a coating are considerably less conspicuous than scratches in the ink film.

Resistance

For some applications, such as packaging, labels, and banners, particular properties are required with respect to protection from environmental influences. Folding boxes, cardboard products, pouches, and paper bags are often exposed to considerable humidity. All composite fiber materials tend to absorb moisture and to lose their strength and stiffness as a result. Varnishes that lie on the surface of the substrate actually inhibit permeation of the moisture into the substrate but are penetrated if subjected to the constant effect of moisture. Longer-lasting resistance to water can only be achieved with varnishes that penetrate the fiber material.

Many packaging materials need to have barrier properties against water vapors to prevent the exchange of moisture with the atmosphere. Cookies, for example, must not become soft as a result of water absorption.

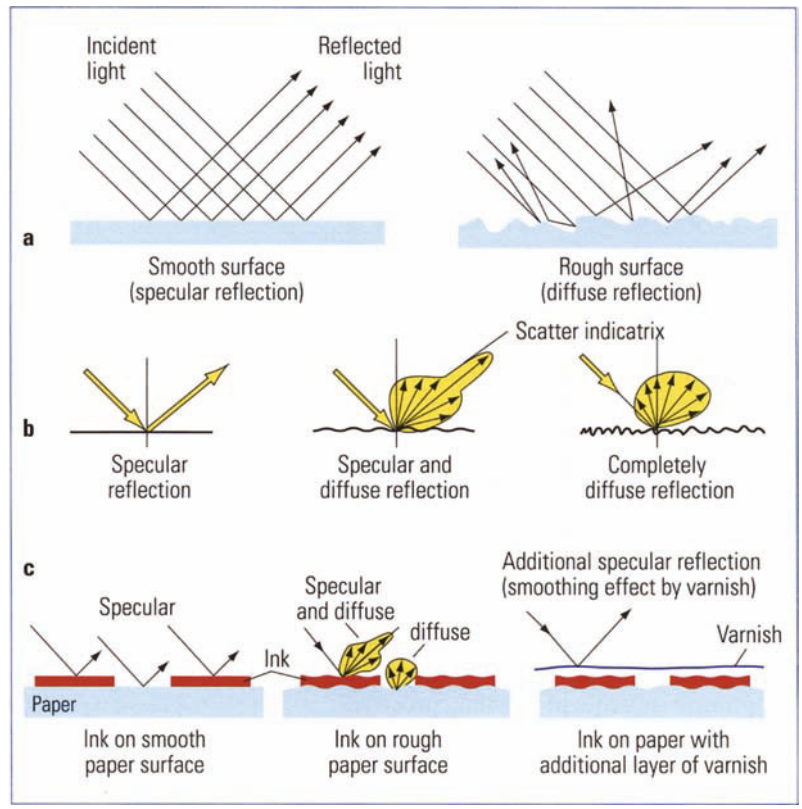


Fig. 1.4-58
Reflection properties of different surfaces in printing.
a Reflection/Scattering of light on reflective and rough surfaces;
b Scatter indicatrix on various rough surfaces;
c Scatter behavior of printed papers: smooth and rough paper and varnished print image

Varnishes applied to fiber materials can often provide adequate protection from water vapor diffusion for a certain period of time. However, absolute protection can only be achieved with film packaging (or glass, metal) or by using film-laminated fiber materials.

Varnishes are used to protect the surfaces from soiling, which is particularly important in the case of packaging, labels, and paper tablecloths, among other things. Grease, oil, and water-based dispersions are more prone to penetrate fibrous substrates of this kind and form disturbing, blotchy discoloration. Varnishes of different formulations protect the cardboard, paper, or corrugated board. Cardboard packages for cakes and pastries are usually protected from the penetration of grease by the application of a coating film.

Decorative articles, such as banners and streamers, must not actively aggravate any fire which might occur. Papers can be made far less inflammable when they are treated with special varnishes.

Enhancement for Finishing

The coefficient of friction of a substrate is an important factor in all finishing machines, both for conveyance and for the machine settings. Die-cut boards for the production of folding boxes are frictionally engaged for the transportation on gluing machines between conveyor belts. Printed areas usually have different coefficients of friction than non-printed areas. A uniform coefficient of friction is achieved over the entire surface with the application of coating. The travel behavior of coated substrates is considerably easier to adjust on finishing machines than the behavior of printed products with varying surface characteristics. Production reliability is therefore increased and the quality improved.

The powder applied to the printed sheet in sheet-fed offset presses for better sheet delivery and drying results may soil subsequent finishing machines. Coated sheets can be stacked in the sheet delivery without powder or with only a minimal application of powder. Many sheet-fed offset jobs are therefore only coated so that the application of powder can be to a large extent avoided and the job can be finished more quickly.

With flexible packaging, the extremely smooth surfaces of special foil materials may be undesirable for further use. Plastic bags, for example, can easily slip around in the pile. The surface friction can be increased by overprinting with special varnishes (silicates) to offer good stacking properties.

1.4.5.2 Surface Finishing Techniques

Coating

Amongst the most important types of varnish, especially in conjunction with the offset printing technology, are:

- water-based varnish (dispersion varnish),
- print varnish, and
- UV varnish.

The different varnishes are described in detail in section 1.5.3.

Varnishes are applied directly to the substrate by rollers or coating forms in coating units or indirectly via intermediate carriers (e.g., print varnish from the printing plate via the blanket onto the paper). Roller and blade systems (usually chambered doctor blades in conjunction with anilox rollers) are used to meter the quantity applied (see fig. 2.1-63). The various coating units, and in-line and off-line applications, are dealt with in section 2.1.2.7.

Varnish Application. The varnish should produce a smooth and even film directly after application. The surface is still rough after the varnish has been applied and needs a short time to run smooth. On absorbent substrates the varnish will begin to penetrate the surface and lose some of its gloss as absorption progresses during this process. In many cases the gloss can be optimized by determining the most expedient time to allow between printing and drying.

Differences in quality occur, depending on whether the varnish is applied to an ink film which is still wet or to a dry one. In gravure and flexographic printing, drying takes place after each printing unit, meaning that there is no fundamental difference in the product whether coating is done in-line or off-line. In sheet-fed offset, however, the oxidatively drying inks have still not dried when the sheets reach the delivery. In-line coating is therefore always performed on ink which is not yet dry.

Water-based varnishes (unlike oleaginous print varnish, they are based on water) do not moisten a damp ink film as well as one that has been dried. A homogeneous, high-gloss coating of the highest quality is therefore only obtained on a thoroughly dry ink film (and substrate). This is possible if the ink is dried in-line (UV inks) or coating is done off-line.

Print varnish basically consists of unpigmented offset ink. It can be applied either by special coating units or the inking unit of an offset printing unit, that is, via ink fountain, inking roller system, offset printing plate

and blanket cylinder. The quality of the gloss is not as high with in-line coating because the print varnish mixes with the ink which is still fresh to some extent. Print varnishes tend to turn yellow and are therefore not suitable for long-life print products where water-based varnishes are preferable.

Water-based varnishes can also be applied via the inking unit and an uncoated, that is, normally hydrophilic, offset plate (e.g., aluminum surface) although the quality is limited compared to the quality achieved with a separate coating unit since only a thin coating can be applied via the inking unit of an offset press. Moreover, the varnish might build up on the rollers when it runs through the roller train creating extra cleaning work.

In sheet-fed offset the desired coating quality cannot be achieved with the application of varnish alone (e.g., subject to the paper quality). The quality can usually be markedly improved by the *application of a primer.* The development of double coating units in sheet-fed offset made it possible to apply a primer first, dry the surface in between, and then finally apply the actual varnish (see fig. 2.1-64). One sector of application involves water-based varnishes. The capillaries in absorbent papers can be closed by the application of a primer. Extremely high gloss values are then achieved with the subsequent coating process on the sealed, already-smoothed paper surface. *UV varnishes* represent the second area of application. In sheet-fed offset it is necessary to be able to overprint UV varnishes on conventional, oxidatively drying inks. This can be done in a second pass (off-line), after the ink has already dried. With an optimally equipped production installation, however, UV coating should be done in-line, that is, in one pass directly after multicolor printing on the not yet dry sheet-fed offset ink. To achieve a good coating result special bonding agents are needed. They increase the surface tension between the UV varnish and the oil-based ink. The drying of the ink on the substrate is not affected by the varnish film above it.

UV Varnishes. Compared to other types of varnish, UV varnishes have the advantage that very thick overcoating can also be applied in-line and a film of varnish produced that is scarcely distinguishable from film lamination. (Unlike water-based varnishes, UV varnishes do not contain any volatile constituents, so that the coating thickness of the liquid film of varnish is the same as the dry one. Also, absorption into the paper is so low as to be negligible.) In sheet-fed offset, UV coating has replaced film lamination to a great extent. Due to the high coating thickness (up to approximately 8 µm), UV varnishes attain gloss values never achieved before with water-based varnishes (coating thickness approximately 3 µm).

Special Effect Varnishes. The use of varnishes for special effects is not limited merely to surface effects. Unusual designs can be achieved with inked varnishes, especially with pale background color tones. Alongside the absorbent color pigments, reflective pigments in the varnish have become a factor. The group of metallic pigments for gold (bronze pigment), silver (aluminum pigment), and metallic inks, embedded in a water-based varnish, has achieved high gloss values that could not previously be attained with varnish inks. With pearlescents the inkfilm may be given the luster characteristic of mother-of-pearl (different colors depending on which direction they are viewed from) that stand out from conventional color prints in their appearance.

In *screen printing* it is possible to apply coatings which are so thick that the imprinted structures can be felt when touching the printed image. Special *relief codes*, such as Braille lettering or security features in security papers, can be imparted in this way. Applications with strong surface structures/reliefs are particulary interesting for decorative printing. The relatively expensive embossing tools used to produce the structure were replaced by much more economical application of varnish. In wallpaper printing, for instance, there are widespread examples of so-called "embossed wallpapers," for which special screen printing inks are foamed in a hot air dryer whereby a profile is produced without embossing equipment.

Cut-Outs/Spot Varnishing. Spot varnishing is used to highlight image elements by the contrast between gloss or matte varnished and unvarnished areas, which produces special color effects. Glossy items such as jewelry and accessories can be highlighted very effectively in illustrations using high-gloss coatings around matte surroundings. The surface elements of print and varnish must lie exactly over each other. In spite of there being only a slight contrast effect with highly glazing varnishes, the slightest register errors are perceived as very disturbing. The register demands on the coating forms are therefore comparable to those on printing forms. The accurate positioning of the coating plates register is not a problem with print varnish, because the same printing plate can be used as for the offset print-

ing. Water-based and UV varnishes need a flexographic printing plate, that is, a flexible letterpress plate, which can become deformed when it is mounted onto the cylinder in the coating unit. All-round exposed plates (i.e., where the plate is mounted on a cylinder) increase the dimensional accuracy. To improve the stability the forms are stuck onto metal base plates.

With commercial print jobs coating is usually applied over the entire surface without cut-outs. With folding boxes, on the other hand, some areas must stay free of coating so that the water-based adhesive can penetrate the fibrous material faster at the places where the boxes are to be stuck together. The cut-outs in the coating plates (e.g., blanket, full tone flexographic plate) required here are usually cut manually.

Scented Varnishes. Alongside the visual response generated by the multicolor print with varnish coating, the sense of smell can also be stimulated. Micro-encapsulated fragrances are embedded in the varnish and reach the customer with the printed product. Once with the customer, the fragrances of the scented varnish can be activated by rubbing or just by touching, the capsules burst and the fragrances are released.

Hot-Calender Varnishes. Each type of varnish (with the exception of UV varnishes) can only be applied in a limited (3–8 µm) coating thickness, meaning that varnish can never achieve the gloss values and protective properties of film lamination (film thicknesses of up to approximately 200 µm). On the other hand, film-laminated print products are not as easy to recycle and their production is more complicated and expensive. Hot-calender varnishes achieve surface smoothness that is scarcely distinguishable from that of film lamination. At the same time, the products are absolutely recyclable. The varnish (thermoplastic) can be applied and smoothed out between heated, polished calender rollers. It forms a considerably thinner film than can be obtained by lamination. In spite of all their advantages in terms of quality, hot-calender varnishes have only gained general acceptance in a few applications. Hot-calendering takes place off-line and its production costs are therefore clearly higher than those of in-line varnishing.

Film Lamination

Film lamination provides the highest possible gloss values and protection. Laminated films with structured surfaces are occasionally applied to create special effects. The film lamination is not dependent on the printing process, that is, it requires no special matching of the ink with the laminating material, that is necessary to a certain extent with varnishing (the cover of this book is film-laminated).

Film-laminated materials frequently offer further functions in addition to enhancing appearance. The stiffness of cardboard makes it especially suitable for packaging drinks and liquids in combination with a liquid-resistant film that can be designed especially so that the aroma is not lost.

Embossing

Embossing is one of the most demanding yet most effective of all types of surface finishing. The embossed effect is achieved solely by deformation of the materials by means of a block or die, that is, the formation of a relief; that can be superimposed in film lamination after the film has been applied. The reflection on the varying structures of the embossed image changes depending on the incidence of the light.

In the sheet-fed printing sector, embossing plates can be produced at a manageable cost. In web printing the production of embossing cylinders is very costly and time-intensive. Rotary embossing is therefore only done on regularly recurring products with high print volumes (e.g., wallpaper).

Hot-Foil Stamping. Perfectly smooth surface elements in gold, silver, copper, aluminum and metallic colors can be transferred to the substrate by hot-foil stamping. A base film is coated with a layer providing the color and a hot-melt glue (adhesive coating layer). The image can be transferred under pressure and heat using a heated block (letterpress block). Suitable presses are letterpress machines and flat-bed die-cutters. Hot-foil stamping is primarily used for products such as packaging for cosmetics, sweets, and drinks as well as for brochure covers.

In narrow-web flexographic presses embossing is often done in-line.

Holograms can be transferred in the same way with conventional hot foil stamping machines. The holograms are first embossed into the foil and then applied with a coating. This foil can then be applied like a gold foil, for example, using the hot-foil stamping technique with a repeat length control.

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1.5.1 Substrates

History

The forerunner of paper (c. 2600 BC) was papyrus, a material made out of the papyrus plant, which grows in Africa. Thin strips cut out of the inside of the plant were laid down next to each other, pressed, beaten, and smoothed out. The actual invention of paper produced from plant fibers such as bamboo fibers or cambric grass dates back to about AD 105; recent literature refers to paper production actually dating much further back. Tsai Lun from China is accredited as the inventor. The main feature of his invention was that a new wire mesh was not required for each sheet to be molded, but that the sheet molded with a wire mesh of fine bamboo rods could be couched for drying.

In AD 610, the Buddhist priest Dolyo brought it to Japan, and in AD 710 it first came into Arab hands. The Arabs mainly distributed it in Asia. Paper production started in Europe in around 1150 in Spain, 1276 in Italy, and 1338 in France.

In 1990 the German paper industry celebrated its six-hundred-year anniversary of papermaking in German-speaking countries. Ulman Stromer (1329–1407), a Nuremberg tradesman and councilor, began making paper by hand for the first time on 24 June 1390 in a mill he had set up, called the "Gleismühle," in front of the city gates.

Manual paper production by craftsmen in Europe lasted for a long time – around 650 years. It was not until 1799 that Nicolas Louis Robert (1761–1828), a French mechanic, received a patent for the fourdrinier paper machine which he had invented. This machine was a wooden washing vat with which it was possible to produce paper 12–15 m in length. In this process the pulp was not molded, but moved to the rotating surface of the wire screen using a rotating centrifugal wheel. It was driven manually by means of a handwheel.

Basic Materials for Paper Production

Whereas the Chinese, almost 2000 years ago used bast, bark, hemp, rags, and rice grass as raw materials, wood is the primary raw material in use today. In terms of volume it is also the most widely available natural product on earth. Approximately a third of the land is covered by forest. For over one hundred years wood has been the most important raw material for chemical and groundwood pulp for paper production. Table 1.5-1 gives an overview of the raw materials and fibers required to produce paper, card, and board.

Wood is mechanically and/or chemically prepared for paper production.

To process wood to *groundwood pulp (mechanical pulp)* for paper production, it must be mechanically treated by grinding (fig. 1.5-1). The bark is stripped from the wood trunks and during the subsequent grinding process they are continually pressed against a revolving grindstone under pressure (stone groundwood pulp). While water is being sprayed on simultaneously, the individual fibers are ripped out of the wood and are crushed, scored, pressed, torn off, and sheared by the grindstone surface. During a second phase of the grinding process they are further fibrillated (reduced to fibers) and ground down. The result is mechanical ground-

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Raw materials	Wood			Annual plants (straw, reed, cotton, etc.)	Rags (linen, hemp, etc.)	Waste paper	Fillers (kaolin, calcium carbonate, titaniumdioxide, etc.)
Processing	mechanical: log	mechanical: shavings	chemical: shavings	chemical	chemical/ mechanical	recycling process	
Fiber product	groundwood pulp	refiner pulp	chemical pulp		pure cellulose fiber	recycled fiber	
	primary fiber					secondary fiber	
End products with dominant proportion of fiber	newsprint, magazine paper, folding box card/board, writing/printing paper (medium fine paper and paper containing wood)		writing paper, printing paper (coated, uncoated), sack paper (woodfree paper)		banknote paper, document paper, magazine printing paper, bank paper	newsprint, simple boards, folding box card	(proportion of filler up to 30%)

Table 1.5-1 Raw materials and processing to create paper, card and board

wood pulp. *Refiner groundwood* is obtained by grinding chips, a waste product of timber mills.

Chemical pulp is the fiber material obtained from wood (chips) and other vegetable raw materials (e.g., annuals including hemp, jute, esparto, straw, cotton) by chemical digestion. Chemical pulps differ from groundwood pulp mainly in the fiber characteristics (they have more fibers and firmer, more supple ones) and a higher degree of whiteness. Depending on the chemical solution used for treating, the following are differentiated:

- Sulfate pulp: digestion of chips in a caustic soda lye (alkaline process);
- Sulfite pulp: digestion in acid (acidic process).

Approximately 85% of the chemical pulp produced worldwide is sulfate pulp. It is firmer than sulfite pulp, but has a lower degree of whiteness and is produced with a lower yield. Sulfite pulp needs a longer digestion time. Chemical pulp washing, bleaching, draining, drying, and packing follow after the actual digestion process.

Chemical pulp, which is bleached entirely without chlorine, is designated "TCF" (Totally Chlorine Free). Instead, most common oxygen and hydrogen peroxides are used.

Groundwood pulp and chemical pulp fibers are referred to as *primary fibers*. *Waste paper* also has always played an important part in paper production. Back in 1774 Justus Claproth, a Göttingen scholar, published a brochure printed on paper, for which printed paper had been used as a raw material. Today paper is manufactured using up to about 60% of waste paper in its production. However, special paper can consist of up to 100% of these so-called *secondary fibers* (e.g., for newspaper printing). Thus waste paper has become the most important raw material source in paper production.

However, the use of these recycled fibers obtained from waste paper is limited. On the one hand, their quality must meet the requirements of the paper quality to be produced, on the other, the chemical and technical expense and the high production costs involved in this must be taken into account. In the process of obtaining secondary fibers from waste paper, a work-intensive cleaning process and suspension, as well as deinking, that is removing the printing ink, and fractionating (structuring according to fiber lengths) are required.

In addition it must be noted that there are limits to the reuse of waste paper fibers. According to current research and development one can assume that the fibers are unusable after being recycled 3–5 times. A continual supply of fresh wood or primary fibers is essential for paper production [1.5-1].

Paper Production

Pulp Preparation. Material preparation is required before the pulp suspension is fed to the paper ma-

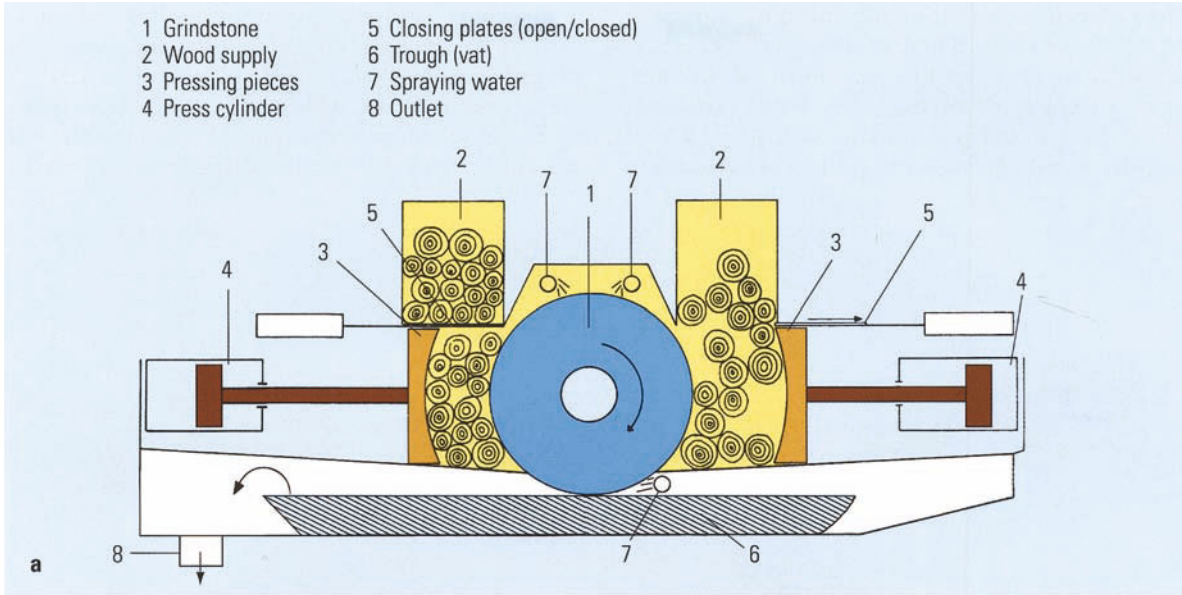


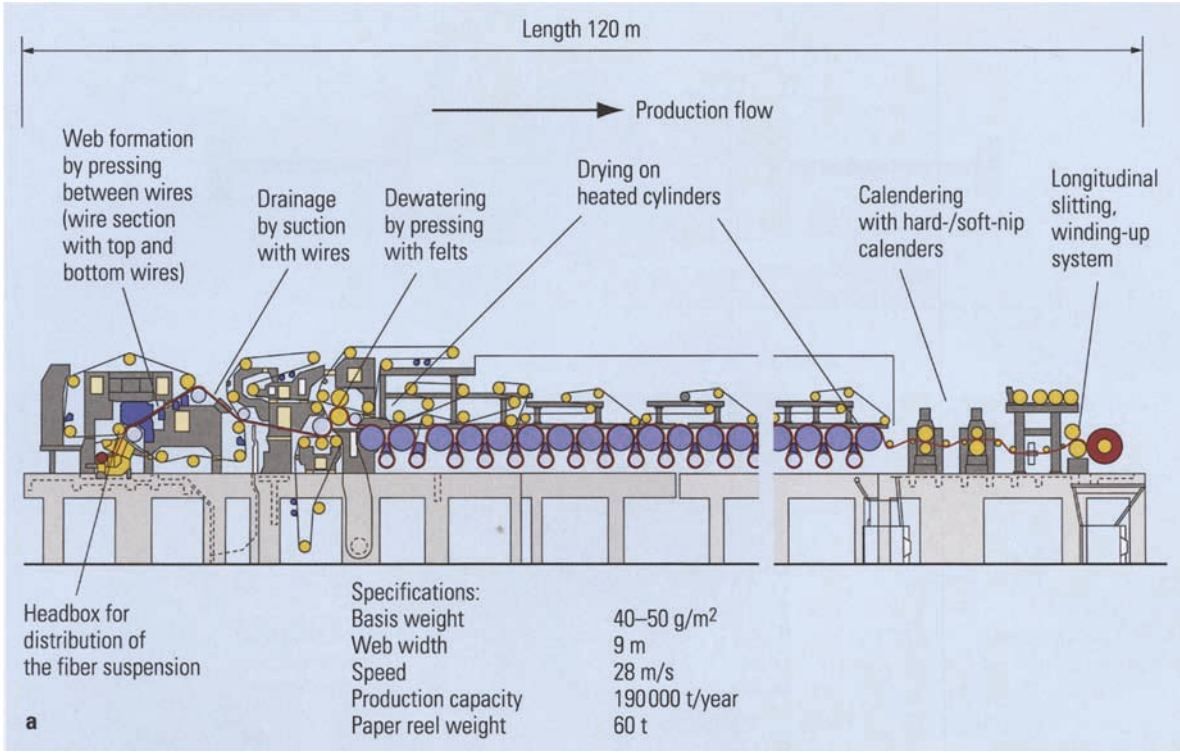


Fig. 1.5-1 Production of groundwood pulp.
a Principal structure of a magazine grinding unit;
b Production plant (Stora Feldmühle)

chine for paper production. This includes a wide range of processes starting with preparation of the pulp, additives, and paper auxiliary agents and ending in front of the paper machine headbox. This includes the pulp grinding treatment and the supply of fillers (kaolin and calcium carbonate) and additives. The basic properties and quality characteristics of the paper are substantially determined in this way. The final composition of the ready pulp suspension takes place in the so-called paper stock vat where the required fillers and additives are also supplied. The paper machine is supplied for paper production with the ready "material" (material suspension) from the paper stock vat.

Paper Machine. Production of paper and card mainly takes place on modern high-speed paper machines today. In Germany alone there are about four hundred very different types of machines, which continually manufacture in different working widths and various speeds in so-called continuous operation. Machines for producing higher paper quality are available for working widths of 6.60 m and above, and speeds of 1300 m/min (21.7 m/sec).

Paper machines are at the heart of every paper factory. The so-called *fourdrinier paper machines* with endless wire are the most widespread. Figure 1.5-2 shows the



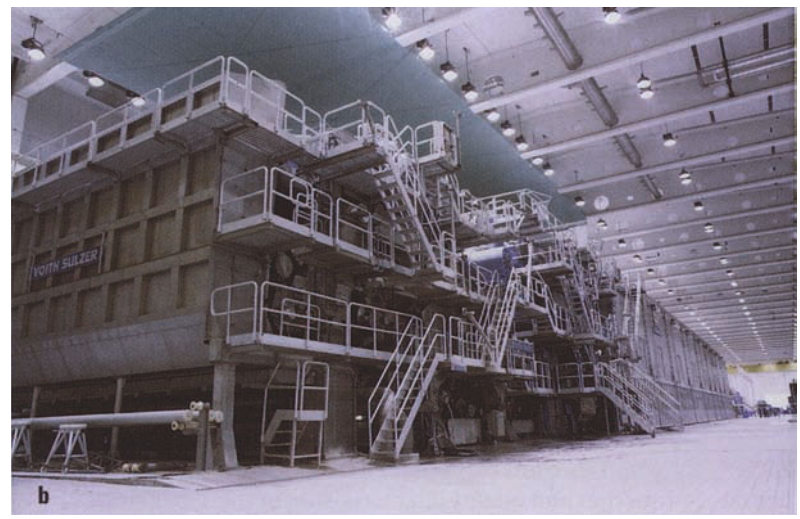


Fig. 1.5-2
Fastest paper machine for the production of newsprint in 1997, example of a fourdrinier paper machine (Voith Sulzer Paper Technology, Germany, 1997).
a Diagram showing production stages;
b Picture of the paper machine. Basis weight 40 to 50 g/m², web width 9 m, speed 28 m/s, production capacity 190000 t/a, weight of the paper reel 60 t.

production of newsprint with the following machine components (for other types of paper, additional components must be supplied according to requirements):

- headbox,
- wire section,
- press section,
- dryer section,
- calender,
- winding unit with longitudinal slitting.

The pulp is routed through the headbox to the endless wire. The paper web is formed at the wire section. This happens by draining (filtration), that is, by separating water and solids. As soon as the fiber suspension of water, fibers, fillers, and additives has run uniformly from the headbox to the wire (mesh net) at a high speed, the water flows off through the wire due to gravity. The fibers remain on the wire and become felted into a continuous web. This process is referred to as "drainage." A slight jogging motion is exerted on the wire. In this way the longitudinal orientation of the fibers parallel to the direction of flow, which causes the characteristic *grain direction of the paper*, is somewhat reduced and at the same time supports the draining and felting.

Sheet paper is cut out of web material. Differentiation is made between *long grain* (fiber orientation parallel to the length side) and *short grain* (fiber orientation parallel to the narrow side of a sheet). The running direction of the completed paper (fig. 1.5-3) is particularly important for a lot of printing work in view of the stability of the paper, as the individual fibers expand more in width than in length (up to a ratio of 7:1) when moistened. This characteristic must be taken into account for printing and finishing. Additionally the stiffness and strength of the paper are greater in the fiber direction than across it.

The function of the *dandy roll* (not shown in the paper machine depicted), which is a screen mesh cylinder running on the fourdrinier wire, is to evenly form the upper side of the wet web. Marks that are embossed or soldered into the dandy roll wire leave an impression – *watermarks* (see also fig. 2.5-10) – while rotating into the wet web. Elevations result in light watermarks, and sinks (from compaction of pulp) in dark watermarks, also referred to as "light shade watermarks".

At the end of the *wire section*, the bridging of the paper web, which is still wet, takes place over the couch press into the so-called *press section*, also referred to as wet pressing. This is where further mechanical draining and compaction of the paper web takes place.

In the *dryer section*, the paper web undergoes a long gentle drying process against drying cylinders heated by steam. The type of drying has an effect on the strength of the paper and how it stretches.

Before the last third of the dryer section there is a *size press* (fig. 1.5-4), with which surface sizing (increasing the wet-strength) or also light pigmentation (coloring) of the paper web can take place, if this is required for the paper type. Modern size presses are referred to as "film presses", and they provide a precise dosage of the volume of coating.

The *calender* is part of the end section of a paper machine. Its function is to mechanically even out or reduce slight irregularities and the roughness of the paper. With a dry calender, such as one that consists of five to ten ground steel rollers arranged above one another, "machine finished", matte, or slightly machine finished paper can be produced.

A *cooling system* is located after the drying section. Production of the paper ends with the winding of the paper web onto a steel core referred to as a reel drum.

Whereas on fourdrinier paper machines the fiber suspension is deposited on the fourdrinier wire for paper formation, on *cylinder paper machines* it is "molded" by circular calenders rotating in the pulp. In this process drainage takes place by the water running off into the inside of the circular calender. Cylinder paper machines are used for producing multi-ply paper or card which can consist of up to ten individual layers. In this process the individual layers are transferred and brought together (couched) by aligning several circular colanders within the cylinder paper machine on the revolving endless couch felt (fig. 1.5-5).

Paper Finishing

The most frequently used processes for paper finishing are:

- coating,
- impregnating,
- parchmentizing,
- laminating.

The most important finishing process for paper today is *coating* (fig. 1.5-6). This means machine coating of a base paper with one or several layers of a white pigment coating that consists of:

- pigments,
- vehicles (binders),
- additives (e.g., optical additives).

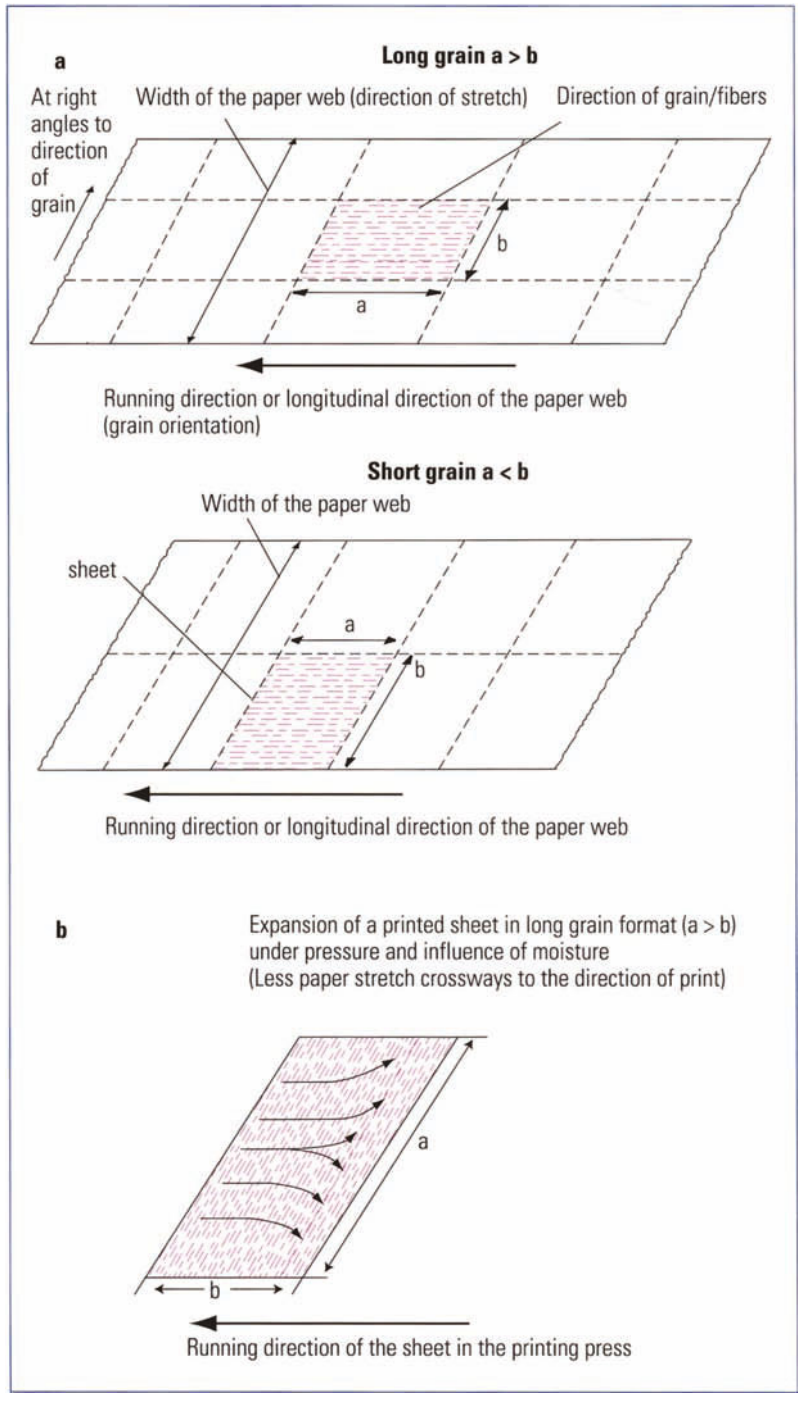


Fig. 1.5-3
Running direction of paper during production.
a Sheet cut from the paper web (indicating direction of grain/fibers);
b Position/running direction of the sheet in the offset printing press showing the stretch-direction (less expansion under influence of moisture in direction of grain, preferred folding in direction of grain)

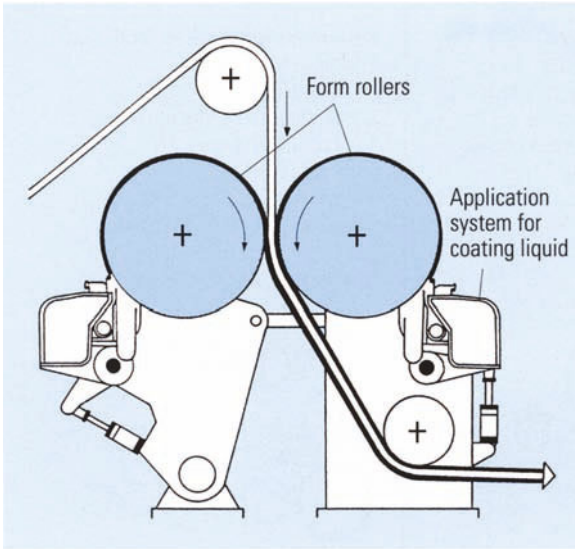


Fig. 1.5-4
Functional diagram of a size press for online surface sizing of paper or card on both sides in a paper machine. Special application systems meter the size on the rollers. The size is transferred to both sides of the web in the roller nip (the point of contact between rollers and paper web). [1.5-1]

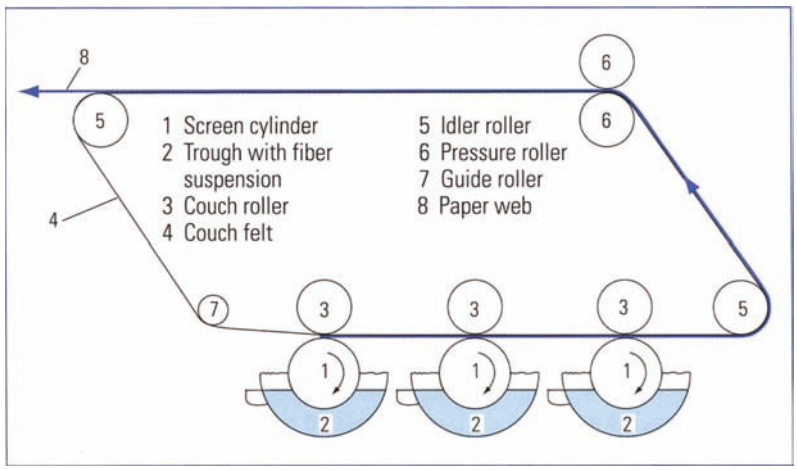
The function of the vehicles of a coating color is to finely distribute pigments in the coating color and to bind them to the paper. Depending on the printing process for which the type of paper is to be used and the printing quality to be produced, there are many different vehicle formulae.

The paper coating is used deliberately in order to influence the paper surface with regard to lightness/color and structure/roughness – for example, to produce *glossy, half-matte* (satin gloss) or *matte* surfaces for better printability. Printing results can be achieved that are not possible on uncoated natural paper. The base paper is matched to the different requirements of the printing process through the composition of the coating material.

After coating the paper, *calendering* can take place (giving the surface a satin finish). This is how the paper obtains its final surface structure (gloss and glaze) and thus also its visual impression as well as printability properties. Calendering takes place in a calender in which the paper web is mechanically routed between rollers that are located above one another under pressure, friction, and warmth. Paper or card obtain special structures, that is, fine and coarse or hammertone embossing in an embossing calender.

Today such a large variety of coated and cast-coated paper of very different properties is available for use in all printing processes that it is hard to obtain an overview. With *cast-coated* paper the mirror finish surface is not produced by calendering, but after the coating by contact drying which follows immediately against a hot chrome cylinder. In this way the coating undergoes plastic deformation and the surface structure of the extremely smooth chrome cylinder is transferred to the paper or card surface [1.5-1, 1.5-2].

Fig. 1.5-5
Functional diagram of a cylinder paper machine for manufacturing multi-ply board [1.5-1]



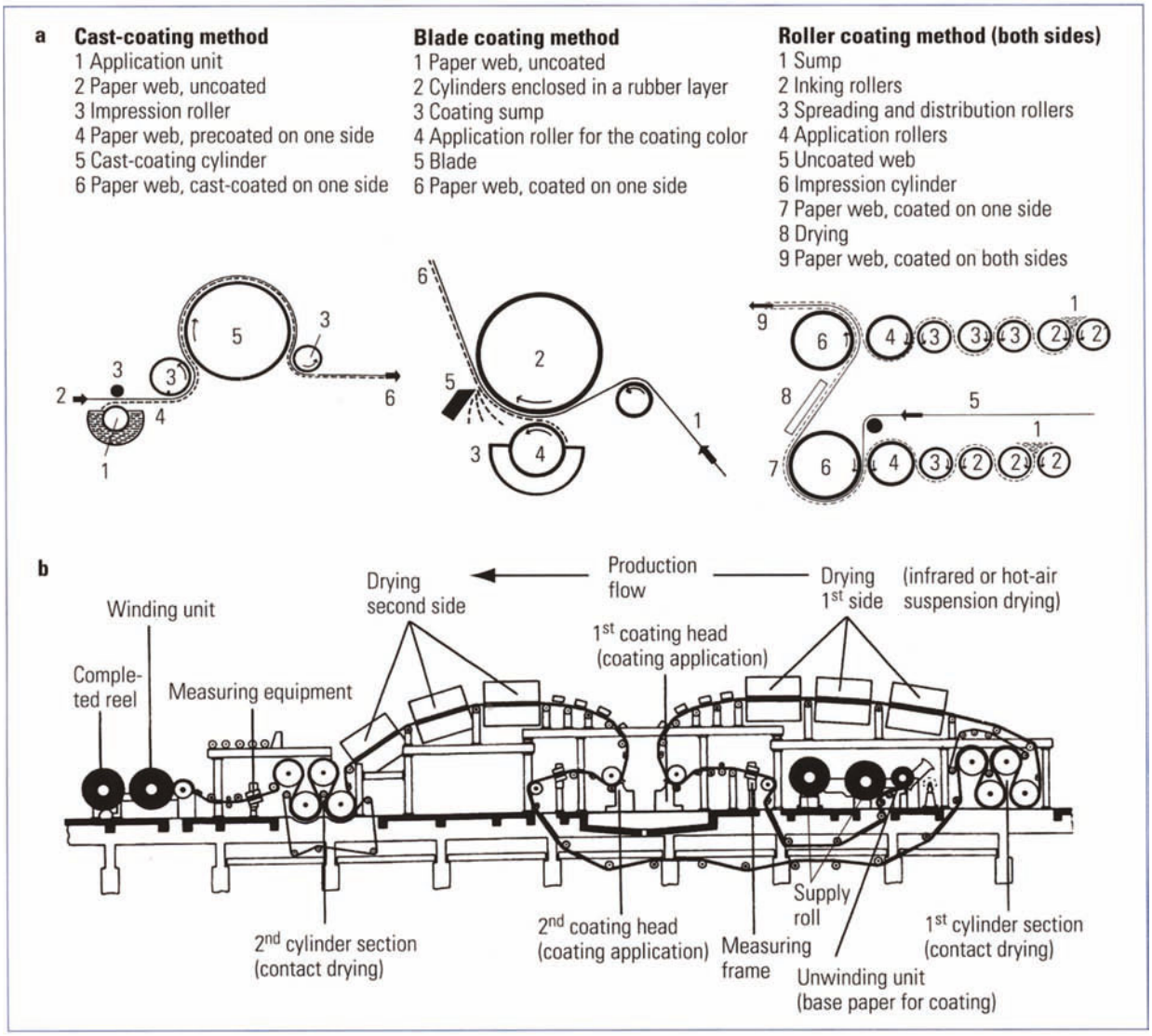


Fig. 1.5-6 Paper finishing by coating.
a Principles of the coating process;
b Functional diagram of a modern coater for paper coated on both sides (blade coating process). Production speed: 500–1000 m/min

Structure Type

Paper is a flat material produced from plant fibers that are mechanically or chemically treated or thermo-mechanically treated with chemicals. It is a tabular structure generated by natural agglutination and felting of fibers and having a grammage (surface related mass) of 7 g/m² up to about 150 g/m². The following are differentiated: *uncoated paper*, *coated paper*, and *cast-coated paper* (high finish gloss).

The pulp composition of paper gives information about its quality determined by the raw material (see also table 1.5-1).

Paper is divided into:

- woodfree,
- containing wood,
- containing waste paper,
- containing rag.

Woodfree paper is mainly produced from chemical pulp fibers and must contain a maximum of 5% groundwood pulp. For example, a lot of printing and writing paper as well as uncoated paper and finished paper with a coated surface is woodfree paper.

Paper containing wood is produced by using a high proportion of mechanical pulp (groundwood pulp). Paper containing wood still contains a large proportion of lignin (lignified and robust part of the wood) so that it yellows relatively quickly. Examples of paper containing a lot of wood are newsprint and magazine paper which are increasingly produced by using waste paper (secondary fibers/deinked fibers). In general the proportion of mechanical pulp is not always precisely indicated. For this reason the designations "containing some wood" or "almost woodfree" are used.

Paper containing waste paper (recycled paper) is increasingly available today. For example, newsprint is produced from nearly 100% secondary fibers [1.5-1].

Uncoated Paper

The names "paper," "card," and "board" on the one hand depend on the grammage, but on the other are also related to their application. The following reference values and typical applications apply to:

- Paper < 150 g/m² (sometimes up to 400 g/m²), (thin paper up to cover);
- Card 150–600 g/m² (cardboard for folding boxes);
- Board > 600 g/m² (cardboard and corrogated board for heavy packaging).

The types and quality features of uncoated *reel paper* (natural paper rolls) for web-offset and gravure are stated in table 1.5-2. Additional types of uncoated paper of varying composition and character that are printed partly in *sheet-fed printing* as well as in webs for continuous form printing [1.5-1] are as follows:

- offset paper,
- recycled paper (consisting of up to 100% secondary fibers),

Table 1.5-2
Types of uncoated paper for web offset printing and gravure printing – general properties and application [1.5-1]

Designation	General quality characteristics and application
WSOP paper	Web Special Offset Paper containing wood, uncoated, calendered paper.
SC-A paper	Super Calendered: Uncoated paper (containing wood) with a lot of glaze from calendering.
SC-B paper	Newsprint paper with surface glaze produced by Soft-Nip-Calender. Also referred to as "improved newsprint paper."
B pulp paper	Uncoated, calendered paper for web offset printing. Pulp composition: chemical pulp, groundwood pulp, and filler. The whiteness is fixed.
NP paper	Uncoated paper mainly produced from secondary fibers (waste paper). "Standard" and "improved" are differentiated. Grammage: 39 – 50 g/m². The glaze, absorbency, dyeing, and opacity are particularly important for printability. Continuous paper: From woodfree to thatcontaining some wood, and also with a more or less high proportion of secondary fiber, worked, uncoated paper for text and data processing. The properties are defined in DIN 6721 (German Industry Standard).
SC-HSWO paper	Super Calendered Heavy Special Web Offset Paper: calendered, uncoated paper with a large grammage

- thin letter paper (air mail paper/onion skin paper),
- watermark paper,
- letter paper (bank paper/typewriter paper),
- book paper (usually with large volume/thickness),
- banknote paper (mostly with watermarks),
- transparent paper,
- ink jet paper (specially for ink jet printers),
- special papers for electrophotography.

Coated and Cast-Coated Paper

Table 1.5-3 gives an overview of the classification of paper coated on both sides for sheet fed offset printing, for web offset and rotogravure printing (the terms correspond generally to common technical everyday language; official or standardized definitions are not available). The paper thickness can be derived approximately from the paper grammage normally given: 100 g/m² corresponds approximately to 0.1 mm thickness.

Card. Card (cardboard) is a tabular material consisting mainly of plant fibers. As regards its grammage it can be classified as paper as well as board. Grammage of card: 150 g/m²–600 g/m². The most important uncoated card qualities can be surface-treated and/or pigmented.

Folding Boxboard. Folding boxboard is the generic term for all types of card which are suitable for producing folding boxes. Folding boxboard must have defined quality characteristics for printability, finishing,

Table 1.5-3
Papers coated on both sides which are suitable for sheet-fed, web-fed offset and web gravure printing – general properties and application [1.5-1]

Designation	General quality characteristics and application
Cast-coated paper	Paper with a mirror or glossy finish surface and large volume. Mainly white on one side and colored. Used especially for labels, envelopes, and high-quality folding boxes. Grammage 70–400 g/m².
Original coated art paper	Best quality coated paper. Thick coating layer gives high degree of uniformity. Excellent printability and pressroom runnability.
Specially coated illustration printing paper	Coated paper for demanding and high-quality printing jobs. Glossy, half matte, or matte on both sides. Quality is very consistent. Best printability and pressroom runnability.
Standard illustration printing paper	Good quality paper coated on both sides.
Ordinary illustration printing paper	Paper coated on both sides for simple printing work, limited quality with regard to gloss and evenness of the print image.
MWC/HWC paper	Medium Weight Coated Paper/Heavy Weight Coated Paper Paper containing wood with grammage range of 80–130 g/m².
LWC paper	Light Weight Coated Paper. Paper widely used for mass print runs in web offset printing. LWC paper range goes up to 72 g/m².
LLWC/ULWC paper	Light Light Weight Coated Paper Ultra Low Weight Coated Paper Ultralight coated paper below 45 g/m², used in particular in web offset printing and gravure for printing international magazines and mail-order catalogs.
FC paper	Film Coated Papers. Paper which is coated or pigmented on both sides in a super size press (film press) within the paper machine with a coating volume metered on rollers, thus avoiding swamping.

and subsequent processing. All types of folding boxboard are produced on the card-making machine from several pulp webs (plies) in one operation:

- the front cover ply,
- one or several single layers/or plies,
- the back cover ply.

The thickness ratio of the layers to one another is approximately as follows: front cover 25%, single plies (55%), back cover 20%.

Cast-coated folding boxboard *(CC)* is a card with a mirror finish and closed surface. Coated folding boxboard (C) is a card with a coated, usually gloss surface, which in contrast to uncoated card permits a significantly better print and coating result. *Uncoated* folding boxboard (U) is a card with an uncoated, but nevertheless relatively smooth matte surface with good printability [1.5-1, 1.5-3].

Board. The dividing lines between card, folding boxboard and board, are blurred. *Board* (mill board) is the generic term for all single-layer (i.e., processed and couched, multi-layer) solid board. Wet machine board and machine-made board are differentiated. The term board is usually used if the product was produced from simple raw materials (groundwood pulp and secondary fibers) and has a grammage of over 600 g/m².

Corrugated board consists of one or several layers of corrugated paper that is stuck onto one ply or between several plies of another paper or card. The most frequently used type of corrugation worldwide is the sine wave, also called round corrugated form. The corrugation can be produced in different ways. To determine the size of a corrugation, the corrugation pitch – corrugation width – and corrugation height have to be measured. The corrugation pitch is the measurement in the horizontal plane, the corrugation height is the measurement in the vertical plane from apex to apex. The different designations for corrugated board are determined by the different sizes of the corrugations [1.5-1].

Special Paper – Carbonless Copy Paper

Carbonless copy paper has a special place among print media papers. It is referred to as chemical reaction paper or autocopying paper. It is very important in business form production. Production of today's autocopying paper is based on a patent granted in 1938 in the USA for the micro-encapsulation of fluids (Mead Corp.).

Carbonless copy paper is supplied in various formats in white and color for sheet offset printing and in different roll widths and lengths for processing on continuous-form printing presses. Carbonless copy paper is available for producing multi-part forms set with the following designations:

- CB paper (upper sheet): Coated Back. The back page of this type of sheet is coated with a layer made of micro-capsules, vehicles, and spacers.
- CFB paper (middle sheet): Coated Front and Back. This type of sheet is coated both on the front and the reverse side.
- CF paper (under sheet): Coated Front. This type of sheet is only provided with coating which removes the color on the upper side.
- SC paper (one-sheet type): Self-Contained. The upper side of this paper is coated both with coating transferring color as well as coating which removes the color.
- SC-CB paper (intermediate sheet type): Self-Contained/Coated Back: with this paper the upper side is coated with coating transferring color as well as coating which removes the color, the rear side with micro-capsules.

Printing Characteristics of Paper

The printing characteristics of paper and card/cardboard are differentiated according to printability and pressroom runnability. There are also paper characteristics, however, that can jointly affect the printability and pressroom runnability. In the case of *printability*, these are characteristics that primarily affect the optical quality of a printed product. With *pressroom runnability*, it is those characteristics that have an effect on the running and speed at which the sheet or web runs through the press when printing the job. Several specifications for the printability and pressroom runnability are listed in table 1.5-4 [1.5-1].

Measuring and Checking Paper and Card

For checking and measuring paper and card there is a plethora of test devices, test inks, and test procedures corresponding to the specifications for printability and pressroom runability. The tests are partly standardized. Many processes have been developed by the individual paper manufacturers in order to incorporate continuous inspection of the special characteris-

Table 1.5-4
Paper properties, in particular with effect on printability and pressroom runnability

Printability	Pressroom runability	Paper characteristics
Accepting printing ink	Tear resistance	Drying of the printing ink
Ink (color location/coloring)	Moisture expansion	Picking resistance
Gloss	Breaking load	Absorption time
Glaze	Reel tightness	Quality of cut (e.g., cavity cut)
Evenness of the surface	Blistering	Creasing
Incandescent residue (ash)	Tearing resistance (tensile strength)	Calluses/flatness
Compressibility	Micro-blistering	pH value
Light fastness	Tendency to web breaks	Holes
Absorption capacity	Mechanical stretching (transversely and longitudinally)	Moisture content
Coating quantity		Free of dust
Whiteness		
Cloudiness (mottling)		

tics of their products. Above all, the countless inspection criteria and regulations concern the constitution of the type of paper and card. This does not, however, necessarily make a statement about the characteristics of a specific product for a printing process or about the later application or usage of a printing product, for instance, for labeling, forms, or folding boxes. Therefore, sample test printing devices have been developed over the years which inspect the interaction of paper with printing ink or varnishes and printability in general. By this means, the possibility exists to inspect paper and card with regard to their behavior patterns regarding printing inks, test oils, or dampening solution under precisely defined and reproducible conditions.

Detailed instructions for carrying out the many inspections of paper and card are conveyed by the various norms of the German Institute for Standardization (DIN), the information leaflets of the Association of Chemical Pulp and Paper Chemists and Engineers (Zellcheming), and, increasingly, the international standards such as ISO (International Organization for Standardization) and EN (European Norms). Furthermore, there are the recognized inspection and testing methods of the FOGRA (German Research Association for Printing and Reproduction Technology e.V.) and PTS (Foundation for Paper Technology), both based in Munich. In the United States inspection is carried out in accordance with the TAPPI standards (Technical Associations of the Pulp and Paper Industry, Atlanta). The most important inspection methods in the paper industry are listed in table 1.5-5.

When inspecting and testing paper and card, it is necessary to maintain the standardized environment in accordance with DIN EN 20187/ISO 187 and also to ensure that the taking of samples is in accordance with DIN/ISO 186 [1.5-1].

With *test-print presses* special stresses on the paper and characteristics corresponding to the real printing process can be simulated. Under defined and reproducible conditions with low material consumption, test prints can be produced in the laboratory. There are a multitude of test-print presses that find usage in practice. In the following, two devices are shown as an example:

- Multi-purpose test printing device (fig. 1.5-7). A pre-dampening unit (for dampening the paper), a hot-air dryer, and a dryer with IR and UV device are available as modules for this testing press.
- Printability test device A 1-3 (fig. 1.5-8).

This offers the possibility to study the interaction between printing ink and paper and to simulate the multitude of influences of an offset printing press, also taking the dampening solution into account. On multicolor testing devices it is also possible to simulate wet-on-wet printing.

In addition to the standard checks and comparison options, test prints are carried out to inspect a number of other parameters, such as:

Table 1.5-5
Testing criteria, regulations and equipment for paper and cardboard (selection)

Inspection criteria	Inspection regulations/Inspection device
Wettability	FOGRA contact angle projector or inspection inks
Bursting resistance	DIN 53113 or DIN 53141*
Bending strength	Various inspection methods and regulations
Bending resistance	DIN 53112
Abrasion	DIN 53109* and DIN 6723*
Cobb test	DIN 53132
Cobb-Unger test	FOGRA
Density (weight by volume)	DIN 53105
Thickness	FOGRA thickness measuring device or paper thickness measuring device
Pressure folds	DIN 53112
Initial tear resistance	With tensile strength inspection device
Fold resistance	TAPPI T 423m-45, ISO 526
Coloring/ink	With Elrepho 2000 in accordance with DIN 53145 or ISO 2469
Moisture expansion (%)	DIN 53130*
Grammage	DIN 53104/DIN ISO 536
Gloss	ISO 2813; ASTM D523 and DIN 67530* information leaflet Zellcheming V 22/72
Incandescent residue (ash)	DIN 53136
Direction of grain	Moisture test; tear test; finger-nail test; bending test
Air permeability	ISO 5636 / TAPPI 460 m-46 and others
Wet elongation	FOGRA
Opacity	DIN 53146/ISO 2471
pH value	DIN 53124*; Zellcheming information leaflet V/17762; FOGRA
Tear length	DIN 53112
Scoring	DIN 55437; scoring tester
Curling	FOGRA; buckling height in accordance with Brecht DIN 6023
Absorption capacity (Degree of bonding)	Various methods and devices including DIN 53126 and Zellecheming information leaflet V/15/60 and others
Suction height	DIN 53106
Interlaminar strength	FOGRA
Secondary tear resistance	DIN 53115

Remark: *engl. version available

- the drying time of a printing ink,
- the abrasion resistance of a type of paper or the combination of paper/ink,
- the gloss of a printing ink,
- the color density or the color tone and yield of a printing ink,
- the picking resistance of a type of paper,
- the wet picking resistance of a type of paper in connection with a dampening solution,
- the absorption time of the printing ink with a specific type of paper,
- the blistering of the ink when drying in web offset printing,
- mottling (uneven density of solids).

Furthermore, there are manual and special printability tests. In particular refer to the relevant ISO and DIN standards.



Fig. 1.5-7

Multi-purpose test printing device. A dampening unit is placed as a module on the left-hand side, and a hot air dryer on the right-hand side. Test print format: 40 mm wide × 200 mm long. Testing can take place at a constant speed (0.1 to 12 m/s) or with acceleration. Both the contact pressure and the printing sequence interval are variable. (prüfbau Dr. Dürner GmbH)



Fig. 1.5-8

Printability testing device used for testing special interactions of certain paper/ink combinations e.g. picking tests and absorption tests. Printing disk width: 10, 20 and 32 mm. The device is comparable with a single-color printing press. Speed: 125 cm/s. (Model: A1-3, IGT)

1.5.2 Printing Inks

1.5.2.1 Structure and Requirements

Structure and Components

Printing inks are principally made up of:

- colorants (pigments, dyes),
- vehicles (binders),
- additives,
- carrier substances (solvents).

Depending on the type of printing process, inks have a largely variable flow properties which ranges from extremely thin (watery), through highly viscous, up to dry (powder-like). The ink transfer mechanism and the type of drying/fixing of the ink on the substrate principally determine the structure and the components of a printing ink (fig. 1.5-9).

Colorants. They are divided into:

- pigments (organically or inorganically colored, white, or black substances that are insoluble in the ink vehicle.) These are solid particles and/or molecular agglomerates that must be held in suspension in the base liquid;)
- dyes (organic compounds that are dissolved in the system during application), which are present in molecular form.

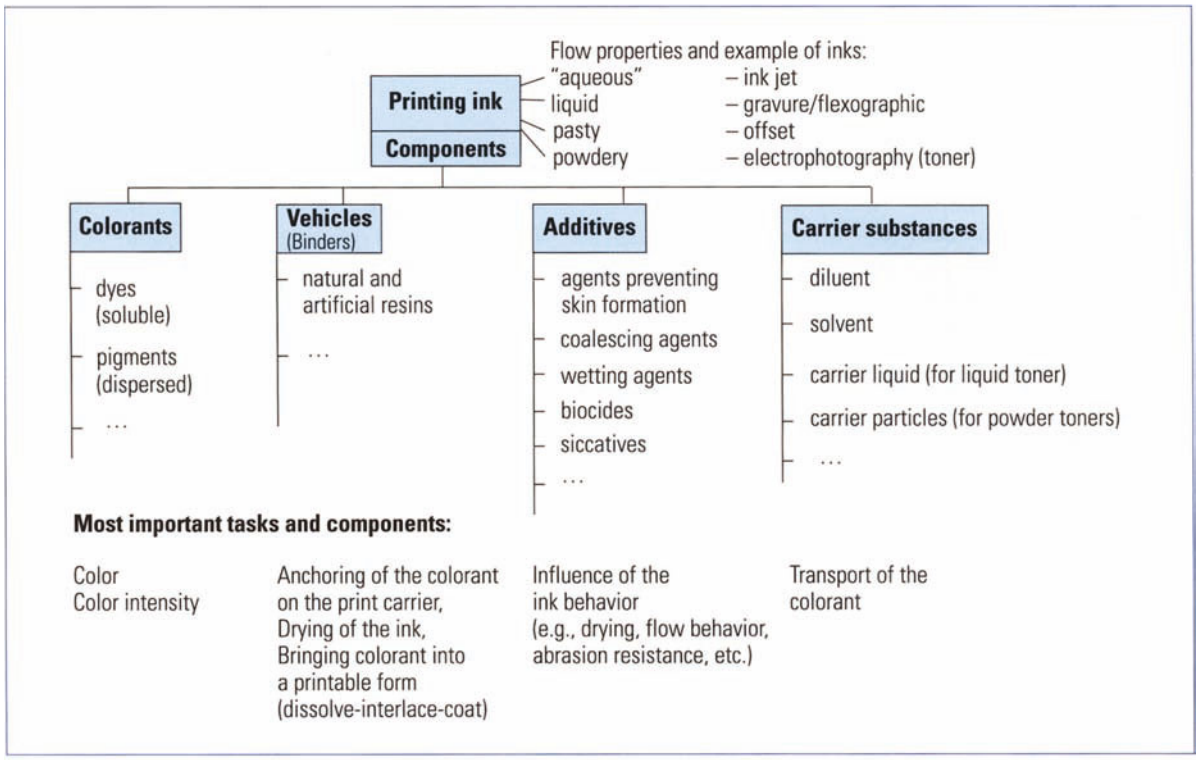


Fig. 1.5-9 Composition of printing inks

Pigments consist of molecules that are cross-linked with one another as crystals. Normally pigments have a particle size of 0.1–2 µm. A pigment particle can consist of several million molecules. Only around 10% of the molecules lie on the surface, and it is only these molecules and a few underneath that can absorb light. Pigments disperse light and, as such, are opaque. They have a wide absorption band and are therefore not as "pure" as dyes, which possess an extremely narrow absorption band.

Dye molecules are surrounded by solvents (base liquid), so that almost every molecule can absorb photons, which leads to higher color intensity and more luminous colors. Dyes have a larger range of colors. They are naturally transparent since the molecules are significantly smaller than the visible wave length of 380 nm.

Pigments always require a vehicle for binding them to the substrate while dyes in most applications connect themselves directly to the substrate surface. The disadvantage with most dyes is their limited light-fastness (oxidation leads to bleaching). With respect to light-fastness and stable ink impression, pigment-based inks are advantageous.

Pigments as base materials are basically cheaper than dyes yet require greater expenditure when being processed into ink: dispersing agents must be added to pigments so that they do not agglomerate. Dyes are, in contrast, dissolved and do not deposit themselves in the liquid.

Printing inks normally contain pigments. The most important exception is currently still those inks used in ink jet technology, but even here the trend is towards pigments (better light-fastness, less bleeding on the paper). The pigment content, depending on the color tone, is between 5% and approximately 30%.

Those *organic pigments* which give the printing inks (process inks) the desired color (hue) are most important for the printing industry. They can be grouped into the two main categories of chromatic pigments and black pigments.

The main *inorganic pigments* are:

- white pigment (e.g., titanium dioxide),
- metal effect pigment (gold and silver bronzes),
- pearlescent pigment,
- fluorescent pigment (for daylight luminous colors).

Binders. In conventional printing processes, binders are normally resins dissolved in mineral oil. The pigments are finely dispersed in the binder. The pigment particles are then enclosed by a binder shell. The shell protects the finely dispersed particles from associating into agglomerates and being deposited. The binders dry (harden) on the substrate and thereby bind the pigments.

Additives. The type of additive is dependent on the respective printing process. Additives are added to the ink in particular to influence drying, flow behavior, and abrasion resistance.

Carrier Substances. Carrier substances for the colorants in conventional printing processes are on the one hand thinning agents such as mineral oils and on the other, insofar as available, solvents (e.g., toluene in gravure printing). The special features of non-impact printing technologies such as electrophotography and ink jet are dealt with in greater detail in section 1.5.2.8.

Requirements for the Printing Inks

Printing inks must be transported from a reservoir and then in a printing-process-specific manner onto the substrate. The *ink transfer* can take place through:

- ink splitting (offset, gravure, and letterpress printing): inking rollers, printing plate, and blanket (in offset) transfer/transport the ink film;
- direct ink film transfer from a base foil onto the substrate (hot embossing, thermotransfer);
- pressing the ink through openings (screen printing);
- spraying on the ink in the form of droplets without making direct contact with the substrate (ink jet).

The inks must *dry* or cure on the substrate. Here, differentiation is basically made between physical (absorption, evaporation) and chemical drying (oxidation, radiation curing) procedures. Very often a combination of the drying processes is applied. Solidification drying represents a special characteristic whereby inks are fluid in a hot state and then solid after cooling, for instance, hot embossing (details on drying in sec. 1.7).

The ink must have good *adhesion* to the substrate. Several methods are common (also combinations):

- The ink anchors mechanically to the substrate surface (penetrating into pores, encasing paper fibers); here, a certain pressure between ink carrier (e.g., blanket for offset printing processes) and substrate is required and/or
- The ink penetrates into the substrate surface by capillary action (e.g., ink jet).
- In the case of extremely smooth surfaces, the ink is held by means of polar interaction (chemical/physical effects) between the ink and substrate.

Manufacture of Printing Inks

Taking the *example of a sheet-fed offset ink*, the manufacturing process of the printing ink is depicted roughly in figure 1.5-10.

Rheological Characteristics of Inks. The setting of the "consistency" of a printing ink has a decisive influence on the productivity and quality of a print job. The "consistency" can be classified into various individual properties and should be adjusted to match specific printing presses, substrates, printing subjects, speed, and so forth, as optimally as possible. The most important terms are:

- Dynamic viscosity η (tackiness) which can be termed as the inner resistance to the flow of the ink. The more viscous an ink, the less easily it flows and the more difficult it is for it to spread into a film. The unit of mass is Pa · s (Pascal second) or cP (centi Poise) = 1 mPa · s (milliPascal second). See also table 1.5-6 with information on the viscosity of individual inks.
- Thixotrophy is the characteristic of changing viscous inks from a high viscosity (in the case of non-moving ink) into a significantly lower viscosity (when stirring).
- Tack of an ink characterizes the splitting property of an ink film, for instance, between two inking rollers. The greater the tack, the more heat is produced in the roller inking unit, and the greater the tendency for fibers/particles to pull out from the paper surface. On the other hand, a higher level of tack improves the adhesion of the ink to the image elements of the printing plate or the blanket (printed image sharper).

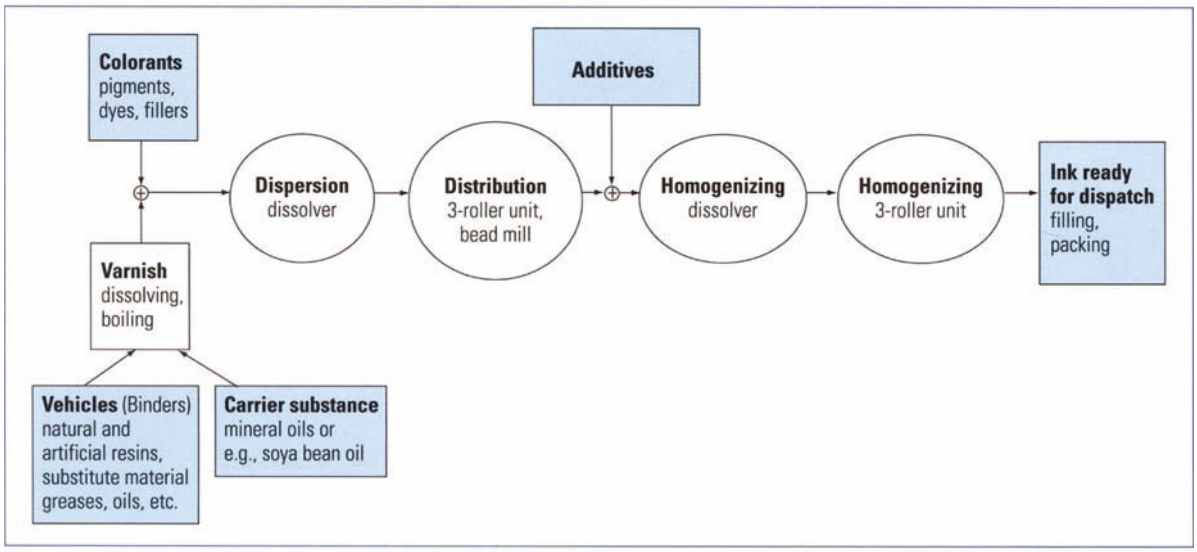


Fig. 1.5-10 Producing ink for sheet-fed offset printing

- "Shortness" is understood to be the flowability of an ink when a certain shearing force acts upon it. The physical forces between pigment particles and the higher molecular vehicle components determine whether an ink is "short" or "long." Very short inks cannot easily be pumped or exhibit bad flow characteristics in the ink fountains. However, they have little tendency to drip and contribute to a sharper print image and less ink misting.

Radiation-Curing Inks (UV, electron beam). The *advantages* of these inks are essentially

- "abrupt" (1–100 ms) drying or curing so that immediate finishing of the print is possible,
- free of solvents,
- no drying in the inking unit or on the rollers (thus less need for cleaning of the inking units),
- zero or only minimal heating of the substrate,
- high mechanical stability and chemical resistance.

The *disadvantages* are that

- these inks cost more than conventional printing inks,
- dryer design is at a high technical level,
- increased ink handling demands for reasons of health and safety.

The drying of these inks is dealt with in more detail in section 1.7.

UV Inks (curing through ultraviolet radiation, wavelength approximately 100–380 nm). UV curing printing inks have a completely different structure than conventional printing inks. They are predominantly used in the printing of non-absorbent materials such as plastics and metal sheets, but also for high-grade card products and labels. There are UV inks for all conventional printing technologies as well as for the ink jet technology. UV curing printing inks are made up of:

- monomers,
- prepolymers/oligomers,
- pigments,
- additives,
- photo-initiators/synergists.

UV inks therefore contain no volatile substances.

The monomers are liquid and are used for adjusting the processing viscosity. Together with the prepolymers they form the binder system (fig. 1.5-11). During UV exposure, prepolymers/oligomers react with the monomers, becoming three-dimensional cross-linked polymers. The photo-initiators decompose to radicals during UV exposure and trigger the polymerization. The radicals create further radicals in a chain reaction and

Printing process (Ink type)	Transfer mechanism in the printing process	Drying	Dynamic viscosity*(η), layer thickness on the substrate	Proportion of ink to be cured on the substrate	Comments
Offset					
• Oil-based	Ink splitting Pressure about 1 MPa in contact zone (nip)	Physically: Absorption, Chemically: cross-linking/ oxidation	40–100 Pa · s (pasty), 0.5–1.5 µm	90–100%	Slow drying, high print quality
• UV/EB (curing)		Radiation cross-linking		100%	Rapid drying
Gravure printing					
• Solvent	Ink splitting, emptying of cells Pressure approx. 3 MPa in the contact zone	Evaporation of solvents (H_2O/Toluene),	0.05–0.2 Pa · s, 0.8–1 (2) µm	25%	Absorbent paper Solvent recycling
• UV (curing)		Radiation cross-linking	5–8 µm	100%	Thick ink layers possible
Flexographic printing					
• Solvent	Ink splitting Pressure approx. 0.3 MPa in the contact zone	Evaporation of solvents (H_2O, alcohol, etc.)	0.05–0.5 Pa · s, 0.8–1 µm	20–30%	Medium quality Solvent recycling
• UV (curing)		Radiation cross-linking	Up to 2.5 µm	100 %	High ink layer thickness possible, Better quality
Letterpress printing	Ink splitting Pressure approx. 10 MPa in the contact zone	Absorption and cross-linking	50–150 Pa · s, 0.5–1.5 µm	90–100%	Slow drying
Screen printing					
• Solvents	Pressing ink through holes in the screen	Dependent on ink type	Dependent on the mesh width up to about 12 µm	Dependent on ink type	Versatile application, Low quality
• UV (curing)					
Electrophotography					
• Dry/Powder toner	Electrostatic (powder film)	Melting (+ pressure)	Powder, 5–10 µm	100%	High layer thickness
• Liquid toner	Electrostatics extracts toner particles from base liquid	Anchoring, melting (+ pressure) Evaporating base fluid	10–20 mPa · s (dispersion), 1–3 µm	2–5% in ready-for-use mixture, 25 % concentrated	Elimination of of the base fluid

* Dynamic viscosity η: Pa · s (Pascal seconds) or 1 mPa · s (milliPascal seconds) (For example: water = 1 mPa · s; honey = 1 Pa · s)

Table 1.5-6 Properties of different types of ink in the printing process (continued on next page)

Printing process (Ink type)	Transfer mechanism in the printing process	Drying	Dynamic viscosity*(η), layer thickness on the substrate	Proportion of ink to be cured on the substrate	Comments
Ink Jet					
• Thermal technolgy (DoD) (dyes/ pigments in base fluid, water)	Pressure impulse Drop volume 6–30 pl	Evaporation/absorption	1–5 mPa · s, < 0.5 µm	3–5%	Avoiding bleeding in the paper by means of special coating
• Piezo technology (DoD) – conventional (dyes/ pigments in base fluid, oil or water)	Pressure impulse ("diaphragm/pump") Drop volume 4–30 pl	Evaporation/absorption	5–20 mPa · s, < 0.5 µm	5%	Avoiding bleeding in the paper by means of special coating
– Hot-melt (Pigments in melted polymers/ wax, 80–100 °C)	Pressure impulse Drop volume 20–30 pl	Hardening through cooling	10–30 mPa · s, 12–18 µm	100%	Thick ink layer, sensitive to scratching
– UV (Pigments in liquid monomers, etc.)	Pressure impulse Drop volume 10–30 pl	Radiation cross-linking	15–30 mPa · s, 10–20 µm	100%	Thick ink layer on non-absorbent substrates
• Continuous-technology (dyes in solvent, water, MEK, etc.)	Ink drop jet, splitting up into drops of 5–100 pl for printing	Evaporation/absorption	1–5 mPa · s, < 0.5 µm	< 5%	Avoiding bleeding in the paper by means of special coating

* Dynamic viscosity η: Pa · s (Pascal seconds) or 1 mPa · s (milliPascal seconds) (For example: water = 1 mPa · s; honey = 1 Pa · s)

Table 1.5-6 (continued) Properties of different types of ink in the printing process

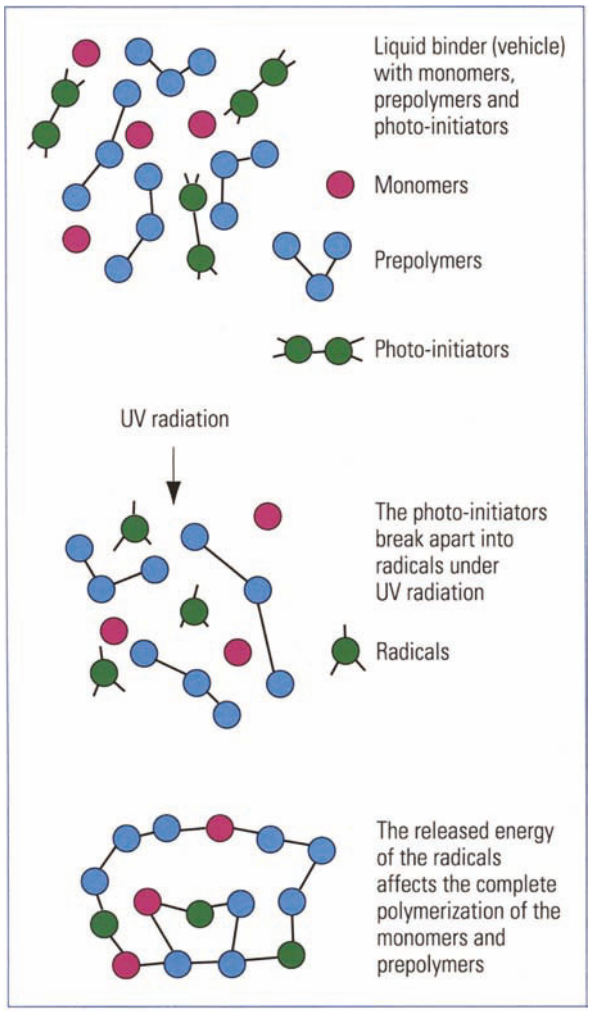


Fig. 1.5-11 UV ink curing [1.5-8]

react with the monomers and prepolymers under formation of a cross-linked structure. The colorants and additives used in UV curing printing inks correspond approximately to those of other printing inks.

In general, when processing UV inks and varnishes, care must be taken so that no so-called aerosol droplets (ink mist) form during splitting of inks or varnishes. The droplets can soil the press and leak into the air of the surrounding area. Among other things, ink fogging is dependent on the printing velocity, the binder, the design of the inking and coating units, and the temperature. Due to the photo-initiators, the UV ink has a specific odor that recedes strongly after the hardening of the ink. However, the odor is trapped in the image. Systems based on cationic curing are more favorable than radical systems in terms of odor produced, but also take longer to dry. It is better for varnish since there is less tendency to fissuring.

EB Inks (curing by electron beam). With EB inks, photo-initiators can be omitted since the electron beams act directly upon the reactive binder. High ink film thickness can be cross-linked since the electron beams penetrate deeply and the influences of the pigments on curing are minimal.

Special Inks: Metallic/Pearlescent. A special position among the printing inks has been earned by those printing inks manufactured using metal pigments, iridescent pearl effect pigments, or interference pigments. These printing inks are also called gold and silver printing inks, or inks that demonstrate a metal-like character. Gold bronze pigments are obtained from ground brass alloys with a varying proportion of copper and zinc. The higher the copper content in the alloy, the redder the gold bronze.

The technology used in the manufacture of bronzes enables the particle sizes of the metal pigments to be adapted to the respective printing technology. For offset printing this is 3.5 μm; for gravure and flexographic printing 8–9 μm (the ink film thickness is therefore considerably higher than is usual with conventional inks/pigments (0.1–3 μm).

For the manufacture of silver pigments, aluminum with a purity of 99.5% is assumed. After melting in induction furnaces, the liquid molten mass is lacerated by a compressed air stream. The end product is a metal granulate with a metallically polished surface.

These inks dry like a normal offset printing ink by absorption and oxidation.

The latest developments are gold and silver printing inks which are built up on water-dilutable dispersion varnishes and are transferred via coating units with a chambered blade system (sec. 2.1.2.7). These inks dry by absorption into the substrate and evaporation of the water contained in the ink. They have a clearly higher brilliance than the normal gold and silver printing inks which are based on varnish.

Inks with pearlescent effect pigments enable a characteristic gloss of the printed image comparable to the iridescent gloss of pearls. These pigments possess a mica core which is encased by one or more metal oxide layers.

Printing inks with metal pigments are also used in gravure and flexographic printing. The structure of these inks is identical to that of organic or inorganic color pigments. Silver-metallic printing inks which are mixed with colored inks in any proportion are classified as satin inks. Color metal gloss inks are the result [1.5-5 to 1.5-7].

1.5.2.2 Offset Printing Inks

For offset printing, highly viscous, pasty inks are necessary (dynamic viscosity $\eta = 40–100$ Pa · s). The ink must be structured in such a way that the drying components in the ink do not harden while being spread over the rollers in the inking unit or at the subsequent transfer stations such as the printing plate and blanket. Furthermore, the printing ink for conventional offset printing (with dampening solution and ink) must be able to "store" a certain portion of dampening solution which is taken up via contact with the plate or directly via the dampening unit. (In waterless offset printing on the other hand, silicone oil can be added to the ink to ensure that the non-printed image areas are not inked.) In offset printing extremely thin ink films of approximately 0.5–1.5 µm thickness are transferred onto the substrate.

Offset inks are made up of the following components (weight proportions):

- The varnish (binding agent) consists essentially of hard resins (20–50%) with a high proportion of colophon, alkyd resins (0–20%), and proportions of vegetable oils (0–30%) such as linseed oil, soya bean oil, and wood oil, as well as mineral oils (20–40%) and various drying agents (< 2%).
- Depending on color, the proportion of pigment (coloring agent) lies between 10 and 30%.
- Additives have a proportion of up to about 10%. The following are classed as additives:
  - drying catalysts (combinations of cobalt, manganese and other metals),
  - waxes for improving the abrasion resistance and slip properties,
  - agents for preventing premature drying and skin formation on the surface in the can or in the ink fountain,
  - silicone oils for printing inks used in waterless offset printing.

Due to the multitude of requirements on the finished printed product and the nature of the substrates, the percentage content of the individual ink components varies considerably. Furthermore, the particular printing requirements of offset printing must be taken into account when composing the printing ink. With offset printing inks, the following are of particular significance:

- high transparency (due to the subtractive mixing of inks with overprinting);
- characteristics for printability and pressroom runability such as flow properties, drying, brilliance/gloss, emulsification (combined effect of ink and dampening solution), pile behavior, abrasion resistance;
- ink acceptance of the substrate, and, in overprinting, the suitability to wet-on-wet printing.

Based on these requirements, an entire range of ink classes is offered for offset printing. They can be classified as shown in table 1.5-7.

1.5.2.3 Gravure Printing Inks

The essential difference between gravure and offset printing ink is the viscosity. Gravure requires a liquid ink ($\eta = 0.05–0.2$ Pa · s, even as low as 0.01 Pa · s in publication gravure printing), which can fill the image forming cells of the gravure cylinder at high print speed.

The gravure inking unit is the "shortest" inking unit (shortest path for the ink from the ink fountain onto the paper) of all inking units used with conventional printing technologies. It consists only of an ink feeding chamber that supplies the printing plate directly with ink, and a doctor blade. This is a closed system, which permits the use of a very low viscosity ink (fig. 2.2-14 in sec. 2.2.1.5).

Gravure inks are simpler in composition and manufacture compared to offset inks from a process point of view. The range of workable inks is very large, for instance, inks for obtaining a coating thickness greater than 2 µm, or inks with special metal pigments. The chemical composition of the inks permits greater variation in principle due to the direct ink transfer.

Solvents are particularly important in gravure – they ensure the low viscosity of the ink and they also change the pigment concentration/optical ink density. The following factors are important for selecting solvents:

- boiling point,
- evaporation number,
- flash point,
- explosion limit,

Table 1.5-7
Ink categories in offset printing – their properties, areas of application and drying methods involved [1.5-4]

Ink class	Characteristics, usage, and type of drying
Universal or standard inks	Can be used universally on single or multicolor sheet offset presses. They are in line with normal demands with respect to brilliance and abrasion resistance and dry-through absorption (physically) and by oxidation (chemically). Usage on uncoated paper and coated qualities. With IR radiation and hot air, the oxidation and absorption of the inks can be accelerated.
Glossy inks/ high gloss inks	Printing inks that attain a high gloss on coated paper. Prerequisite is the use of glossy or highly glossy coated paper. The drying occurs through absorption and oxidation. With IR radiation and hot air, the oxidation can be accelerated.
Printing inks with good abrasion resistance	Abrasion-resistant printing ink ranges are especially used for printing packaging and matte coated paper. Drying is through rapid absorption and oxidation. With IR radiation and hot air, the oxidation can be accelerated.
Printing inks for waterless offset printing	Printing inks that are used if the prerequisites for waterless offset printing are met by means of special inking unit temperature control, and where suitable printing plates are available. Inks should be used without additives since viscosity changes can cause scumming. The inks are very similar to normal offset printing inks in their composition.
Low-odor printing inks	Printing ink ranges for printing food packaging. They have a special vehicle structure, but their properties are comparable with conventional printing inks.
Foil inks	Printing inks that dry purely through oxidation and have to be used if the substrate has no absorption capacity, such as metallic papers and plastic foils.
Heat-set inks for web offset printing	Printing inks for web offset printing with predominantly hot air drying. The mineral oils contained in the vehicle are of a special type that vaporizes through the heating effect of the dryer. Drying takes place physically. The correspondingly adapted ink type is offered for the most diverse kinds of paper.
Web offset newspaper printing inks (cold-set inks)	Special printing inks for printing on newsprint. They consist of a combination of various mineral oils and/or vegetable oils, the pigment (especially carbon black), and various additives such as waxes, cross-linking agents, mineral fillers, and oil-tolerant, gel-forming agents. These are to meet special quality demands such as flowability and to prevent setting-off and show-through as much as possible. Web offset newspaper printing inks dry physically by absorption into the paper.
UV inks	Frequently used in packaging and label printing. The material of the inking rollers must be adapted in order to avoid disadvantageous changes of the roller covering through the special components of UV inks, especially also for hybrid operation or just UV. Suitable wash-up fluids must be used. Hardly any restrictions to the printing plates. For waterless offset printing, UV drying inks are also available.

- odor,
- work safety,
- ecological compatibility.

Completely different solvents have to be used for publication gravure and gravure package printing. This is mainly because of the very varied requirements of individual packaging. The most important solvents for publication gravure are:

- toluene (pure toluene with a benzene content of <0.3%),
- xylene,
- petroleum spirits (not permitted in many states due to its inflammability).

Toluene is a petrochemical product and a colorless, flammable liquid, which is an ideal solvent. It does an excellent job dissolving the binding substances (which surround the pigments) can be regained to a great extent in reclamation systems, dries with comparatively little expenditure of energy, and is available at a reasonable price in large volumes. Xylene is closely related to toluene from a chemical aspect. Since it dries more slowly it is seldom used today in illustration gravure printing.

The most important solvents for gravure package printing are:

- ethanol (ethyl alcohol),
- ethyl acetate (acetic ether),
- water (also in connection with organic solvent, generally alcohol).

The use of printing inks that can be diluted with water plays a subordinate role in publication gravure with today's technology.

Due to the many different requirements of gravure package printing (e.g., no reaction with the contents or change in odor) the most varied organic solvents for printing ink production are used, although to a lesser extent than the main solvents listed.

1.5.2.4 Flexographic Printing Inks

Flexographic inks are very similar to gravure inks in their viscosity, they are in the viscosity range of 0.05–0.5 Pa · s and form an ink layer of up to about 1 µm. Flexographic inks are transferred onto the flexible printing plate via an inking unit which consists of a chambered doctor blade with anilox (screen) roller, especially when high quality is required. The setting of the ink viscosity is particularly important for attaining good printing quality. The following are requirements: no squeezing away of the ink on the edges of the raised image areas, sufficiently good ink thickness, good ink splitting and filling of the cells on the screen roller. The number of different pigments for inking is very high with flexographic inks, which results in a wide range of usage.

As in gravure printing, the type of solvent also plays a critical role in flexographic printing. The solvent is evaporated after transfer to the substrate through the application of heat, and the dry ink film remains. Intermediate drying has to take place with color printing, since wet-on-wet printing would result in ink residue transfer in the next inking unit. The following solvents are predominantly used in flexographic printing:

- ethyl acetate,
- alcohol,
- water (alcohol is usually added to promote better adhesion to the substrate).

Pigments are mainly used as a coloring agent. Inks containing water (i.e., water as a solvent) are used in package printing. For label printing UV inks are most frequently used.

1.5.2.5 Letterpress Printing Inks

In letterpress printing, which is only occasionally practiced, viscous inks (η = 50–150 Pa · s) are used whose principal components are organic and inorganic pigments and varnishes. On paper and card they dry like offset printing inks, both physically through absorption and afterwards chemically by oxidation. When printing on non-absorbent materials such as transparent paper or metallic paper, the drying takes place solely through oxidation when using "foil inks."

For newspaper web printing based on the letterpress printing technology (not very widespread) printing inks of medium viscosity are used whose principal components are cheap carbon black pigments and mineral oils. Here, the drying takes place solely physically through absorption of the inks into the very absorbent newspaper printing paper [1.5-7].

1.5.2.6 Screen Printing Inks

In comparison with other printing technologies screen printing has the most varied range of application with regard to possible substrates. It is divided into four production areas:

- commercial screen printing for different advertising media;
- silk screen printing, referred to as serigraphy;
- industrial screen printing, for instance, for bottles, tubes, cups;
- special processes such as textile printing, or printed circuit boards for electronic circuits and so forth.

Along with paper and card, possible substrates are plastics, glass, metal, textiles, and so forth. The very varied chemical and physical properties of these materials are the reason why a very large variety of ink types are available for screen printing. When printing on plastic material, screen printing inks are similar to gravure inks and flexographic inks in their composition. The viscosity must be matched to the desired ink, layer thickness and the fineness of the mesh. Drying takes place by evaporating the volatile solvent and is speeded up by supplying warm air. For paper and card, however, matte and glossy printing inks of an oil or varnish basis are used. These inks mostly dry in an oxidative process. UV inks are sometimes also used in screen printing.

It is characteristic for screen printing that it is possible to transfer a thick ink layer of up to 12 µm and more.

1.5.2.7 Pad Printing Inks

Pad printing is referred to as an indirect gravure printing technology and is used especially for printing non-even and difficult surfaces (see sec. 2.5.4). The printed image is transferred to the elastic tampon via a gravure plate which then puts the print onto the substrate. The inks are quite similar to those used in screen printing, although the viscosity is reduced.

The inks have a very high pigmentation (approximately 30%) since only very thin ink layers can be transferred. They are usually fast-drying due to the solvent evaporating. However, depending on the type of substrate, inks with chemical drying are also used. Special inks are required for each individual substrate since, like with screen printing, a wide range of materials such as wood, rubber, plastics, leather, imitation leather, glass, porcelain, and coated surfaces are printed on. Usually the printer must carry out some tests to check the adhesion of the inks.

1.5.2.8 Inks for Non-Impact Printing Technologies

Electrophotography

In electrophotography (the principle is shown in fig. 1.5-12), the coloring substances are referred to as *toners*. Toners can be differentiated as shown in figure 1.5-13 into powder and liquid toners. The toner particles are charged electrostatically in the developing unit and are attracted to the drum by the oppositely charged image portions of the photoconductor. The transfer from the photoconductor onto the substrate takes place via electrostatic forces (sec. 1.3.3.1 and 5.2).

The most frequent application is in copiers and electrophotographic printers. *Powder toners* are generally fixed by means of heat (heated rollers, IR radiators) and pressure on the paper. In today's two-component systems, the toner is brought via so-called carriers (magnetic carrier particles), which are held on the developer roller by a rotating magnetic roller. The toner particles are charged and therefore adhere to the carrier. The mixture of toner and carrier is called a developer.

The toner is a consumable, while the carrier (an expendable material) remains in the ink feeding system. Toners are adapted to the individual process parameters of the copier/printer models. Colored dry toners (powder toner) cannot be mixed with one another for a new color tone (e.g., a special color). Dry toners are usually produced in a melting-grinding process, where the toner particles obtain a more or less regular shape (fig. 1.5-14). A more modern method is chemical direct synthesis (polymerization process), which ensures spherical particles with very even diameters. The layer thickness of dry toners on the paper is 6–15 µm per ink after fixing/fusing. The variety of material for printing is limited in comparison with offset printing.

Magnetic one-component toners are basically structured like the toners described above in two-component systems, except the toner particle itself contains the magnetic developing part (iron oxide). These toner particles are larger, about 12–20 µm. Suitable color toners can only be produced in a limited number for multicolor printing. If the (dark) iron oxide has a large proportion of the volume, light and translucent colors are difficult to achieve.

Electrostatic one-component toners do not require carrier particles. The toner particles are transported by controlled electrostatic fields. These toners can only be used at relatively low speeds.

In the case of *liquid toner*, the coloring agents – usually pigments – are contained in a base liquid. The transfer of the loaded particles on the imaging cylinder takes place via electric forces acting in a field. The concentration of toner particles is only about 5% and

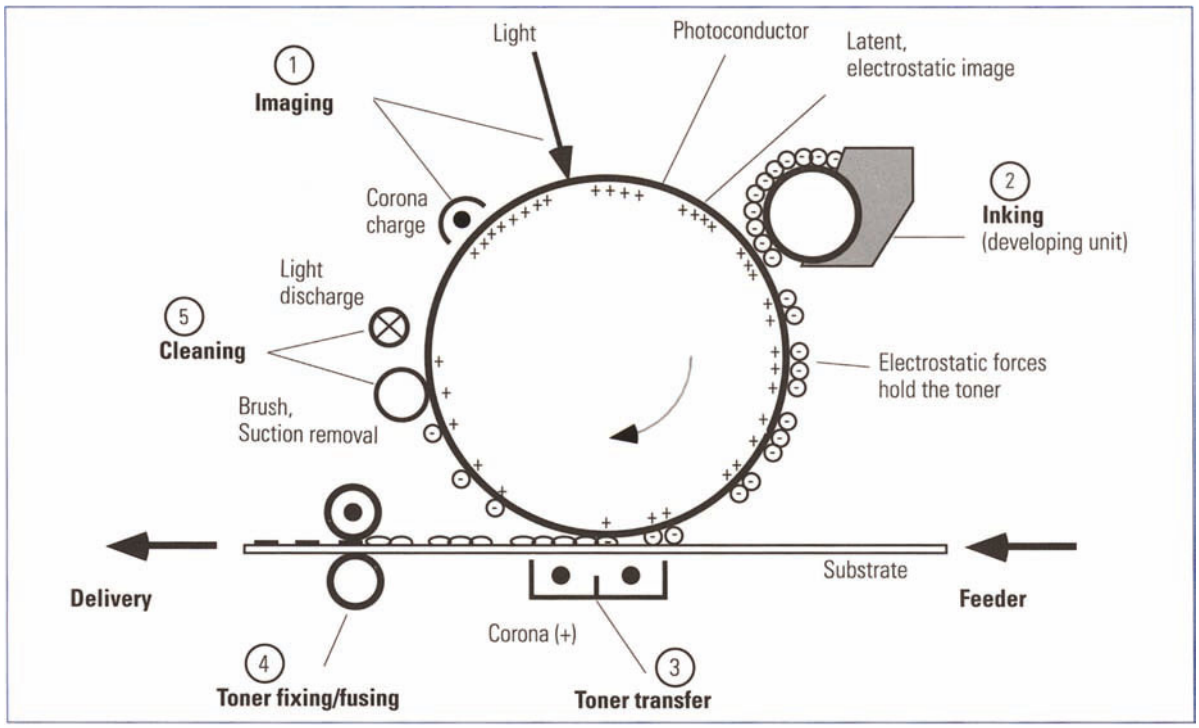


Fig. 1.5-12 Electrophotography (basic principle of the process)

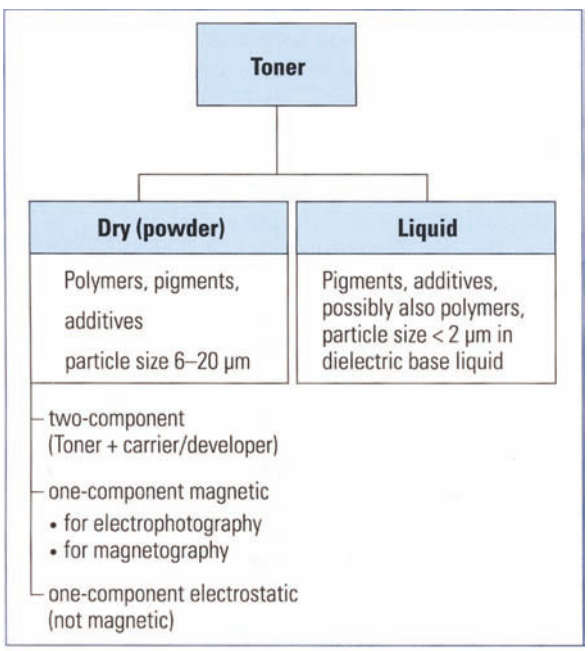


Fig. 1.5-13 Toner systems

must be increased for printing, as ideally only the toner particles should reach the paper; so the base liquid must be removed from the mixture. The liquid toner particles are smaller (about 1–2 µm) than dry powder toners, which is their big advantage. The smaller particles allow for a thinner ink layer and higher resolution enabling an offset-like image quality. Special colors can be produced by mixing. Liquid toners are less common compared to dry toners. In comparison with dry toners they are not as easy to produce and to process. The viscosity is typically about 15 mPa · s.

Ink Jet (see also sec. 1.3.3.2 and 5.5)
Ink jet inks have a low viscosity (η = 1 to 30 mPa · s). Dyes and increasingly pigments are used. The inks must be well-filtered so that pigment agglomerates or impurities do not block the small channels and nozzles of the print head.

Depending on the technology and the material to be printed, different carrier liquids are used:

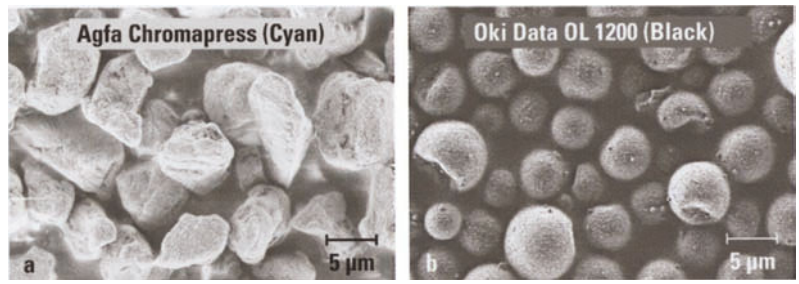


Fig. 1.5-14 Toner for electrophotography.
a Manufacture in the melting-grinding process; toner particles have an irregular shape;
b Chemical manufacture (polymerization process); toners are spherical

- Drop on demand ink jet:
  - Thermal ink jet: water
  - Piezo ink jet: water, oil
    melted waxes for hot-melt inks (solid at room temperature) liquid plastics for UV inks;
- Continuous ink jet: water, MEKs (methyl ethyl ketone).

Because of the low viscosity of the inks, the printing result is very dependent on the substrate surface. The inks tend to bleed and penetrate, or, with non-absorbent surfaces (e.g., transparencies), to marble. Drops of different colors can run into one another. Furthermore, the substrate changes its geometrical shape (formation of waves) due to the high proportion of liquid (90–95%). The problems described are solved for the most part by special surface coatings of the substrates. These coatings store the liquid and prevent it from bleeding.

Ink layers with water-, oil-, or MEK-based inks are very thin (<0.5 µm). Hot-melt and UV inks on the other hand form relatively thick ink layers (<10 µm), since they contain hardly any fluid.

1.5.3 Varnishes

Overprint varnishes are to enhance and protect the printed substrate. They are applied with special coating units that are predominantly coupled in-line to the printing press; that is to say, after single or multicolor prints, the varnish application takes place inside the printing press (sec. 2.1.2.7). Various varnishes are used, depending on the requirements for the coating, and the transfer technology used.

Oil-based Varnishes

Oil-based varnishes can be compared to colorless offset printing inks. The main components are resins, drying oils, mineral oils, and drying agents. The oil-based varnishes are transferred onto the paper with offset inking units. They dry on the paper by absorption and oxidation. Oil-based varnishes are used to:

- increase printing ink brilliance (glossy varnishes),
- achieve specific matte effects (matte varnishes and satin finish varnishes),
- improve abrasion resistance (protective varnishes).

Oilprint varnishes tend to turn yellow. For web offset printing, special heat-set varnishes are used.

Water-based/Dispersion Varnishes

Today, dispersion varnishes are widely used and offer diverse technical possibilities in offset printing. The principal components of dispersion varnishes are:

- polymer dispersions,
- hydrosols (resins dissolved in water),
- wax dispersions for grinding and abrasion resistance,
- film-forming aids,
- cross-linking agents and antifoaming agents.

Dispersion varnishes dry extremely quickly. They are therefore not used in standard offset inking units but in special coating units that only have few rollers or work with a chambered doctor blade system.

The drying takes place purely physically by evaporation of the water, often supported by hot air application. As soon as a part of the water contained in the varnish is removed, the surface becomes non-tacky. The most significant advantages of these modern varnishes are:

- odor free,
- rapid film formation (drying),
- no yellowing,
- zero, or only slight, powder spraying in the delivery on sheet-fed printing presses necessary,
- high processing speed,
- smooth surface,
- dilutable and washable with water.

The following qualities of the printed product are achieved by coating with a dispersion varnish:

- abrasion protection, scuff resistance in a wet condition (labels),
- high gloss, silk finish, or matte effects,
- hot-seal resistance,
- gliding quality,
- deep freeze resistance,
- fixing of metallic inks.

Other special *functional varnishes* that fulfill an additional task alongside surface finishing are:

- blister varnishes to enable adhesion for blister packaging (compound packaging with plastic foil),
- primer (bonding agent), for instance, for further UV varnish finishing,
- varnishes that can be ultrasonically welded for special finishing methods,
- scented varnishes (varnishes with micro-encapsulated aromatics),
- label varnishes,
- two-component varnishes (varnish and hardener).

Dispersion varnishes are also used for surface finishing in *gravure printing*. They are essentially identical to the dispersion varnishes used for offset printing. The principal difference lies in the typically much lower viscosity of those varnishes used in gravure printing. The following categories of aqueous dispersion varnishes are offered for gravure printing:

- preprint and intermediate print varnishes,
- high gloss and matte finishing varnishes,
- special varnishes, for instance, calendar varnishes (high gloss after calendering), and varnishes with gliding properties for special finishing techniques, as well as varnishes with barrier properties, for instance, for drink packaging.

Solvent-based Varnishes

Varnishes containing solvents are varnishes in which resin components are dissolved in organic solvents. The hardening takes place through evaporation of the solvent. The varnishes are called nitro varnishes, or nitro combination-varnishes, and are applied in a separate process with coating machines. They are declining in importance in connection with ecological issues (e.g., inflammability). Furthermore, equivalent varnishing results are achieved using water dilutable dispersion varnishes in in-line operations with printing presses.

Solvent-containing gravure printing varnishes are of similar composition to solvent-containing gravure printing inks. The drying of these one-component varnishes takes place purely physically. Two-component varnishes for gravure printing consist of the actual varnish and a hardening component. The cross-linking reaction begins the moment the hardening agent is added to the varnish. When running through the hot air dryer of the press, the two-component varnish receives an energy feed, which induces the further cross-linking reaction in the film. In the course of five to seven days the varnish layer hardens fully. It is then heat-resistant and resistant to many chemicals.

UV Varnishes

UV varnishes are varnishes cured under UV radiation. They have a similar composition to UV inks – and are therefore completely different to oil-based and dispersion varnishes – and thus contain no volatile substances. Principal components are:

- acrylic oligomers – material to be cross-linked and decisive for viscosity,
- acrylic prepolymers for brilliance, hardness, and abrasion resistance,
- photo-initiators for the curing (drying).

Under the influence of hard UV radiation, abrasion resistant, hard, glossy, or matte surfaces result in a matter of seconds. They can cope with high mechanical stresses.

UV varnishes can be adapted to many different applications. They are processed both in-line in special coating units in offset, screen printing, and flexographic printing presses as well as off-line in special coating machines.

Radiation-curing varnishes are categorized into two different product groups:

- radically-curing UV varnishes: the drying process is complete when the product leaves the drying zone;
- UV cationically-curing UV varnishes: the drying process is only complete after a post-hardening phase (which can take hours or even days).

With radically-curing UV varnishes the photo-initiators break down into chemically reactive compounds that initiate the cross-linking of the monomer and prepolymer vehicles to a solid plastic-like ink film. Cationically-curing UV varnishes contain photo-initiators which split off acids under the influence of UV radiation. These act upon the vehicle and initiate the curing mechanism [1.5-7].

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1.6 Printing Presses and Printing Systems

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1.6.1 General Structure

Printing presses fulfill a central role in the print production process (see sec. 1.2). They transfer ink to parts of the substrate/paper during a printing process in which text and image information are reproduced. In conventional printing presses the visually perceptible contrast between the printed and non-printed image elements is created using process-specific printing plates (sec. 1.3.2).

Since, in the case of this printing process, the text and image information stored in a printing master cannot be changed, special plates have to be made and mounted in the press for each printing job.

Process-specific *contact pressures* or forces (force per unit of area) have to be applied to transfer the ink from the master to the paper or other substrates (sec. 1.5). These *pressures* (reference values) are:

- for letterpress printing 5–15 MPa,
- for flexographic printing 0.1–0.5 MPa,
- for offset printing 0.8–2 MPa,
- for gravure printing 1.5–5 MPa.

(1 Pa = 1 N/m²)

Figure 1.6-1 shows the main three printing methods used to transfer ink to the substrate in conventional printing presses.

The impression is created in the press in the "printing nip." This consists of two surfaces that are pressed against each other, between which are the substrate and the inked plate. Technical development has progressed from the flat to the cylindrical impression surface and from the flat to the cylindrical master.

In printing method 1.6-1a, a plate (printing surface) that is moved in a vertical direction presses the paper against the plate. This principle was applied in the Gutenberg press and then later in *platen presses* (sec. 13.1.1). This principle is still used in flat-bed die-cutters and vertical embossing machines.

Printing method 1.6-1b with an engaged impression cylinder that is rotating and a plate moving to and fro, was used in flat printing presses (sec. 13.1.1). Because of the rolling motion, these presses, which are also known as "*automatic cylinder presses*", enable higher printing speed to be achieved in comparison to platen presses. This method is still used in die-cutting and embossing machines and also in proofing devices.

The on-going development of the printing nip with cylindrical master and impression cylinder led to the high-output rotary printing method (fig. 1.6-1c) employed in all *rotary printing presses*.

Since both sheet and web substrate have to be printed, *sheet-fed presses* and *web-fed presses* were developed. In the printing couple of rotary presses there is a radial flexible layer for all printing processes, and this compensates for the variations in thickness of the plate and run out of the cylinder, and also makes it possible to print on rough paper. The configuration of the various layers is shown in figure 1.6-2.

In *letterpress printing*, a cylinder jacket of several layers of paper and cardboard is mounted on the impression cylinder. Its thickness of 1.25 to 1.75 mm enables compensating radial indentation to occur.

In *flexographic printing*, the soft, flexible *rubber* or *photopolymer* plate enables radial deformation to occur. More recent developments have resulted in harder and thinner plates (<1 mm) that are glued onto a compressible packing (film or sleeve).

In *offset printing*, an additional blanket cylinder is configured between the plate cylinder and the impres-

H. Kipphan (ed.), *Handbook of Print Media*
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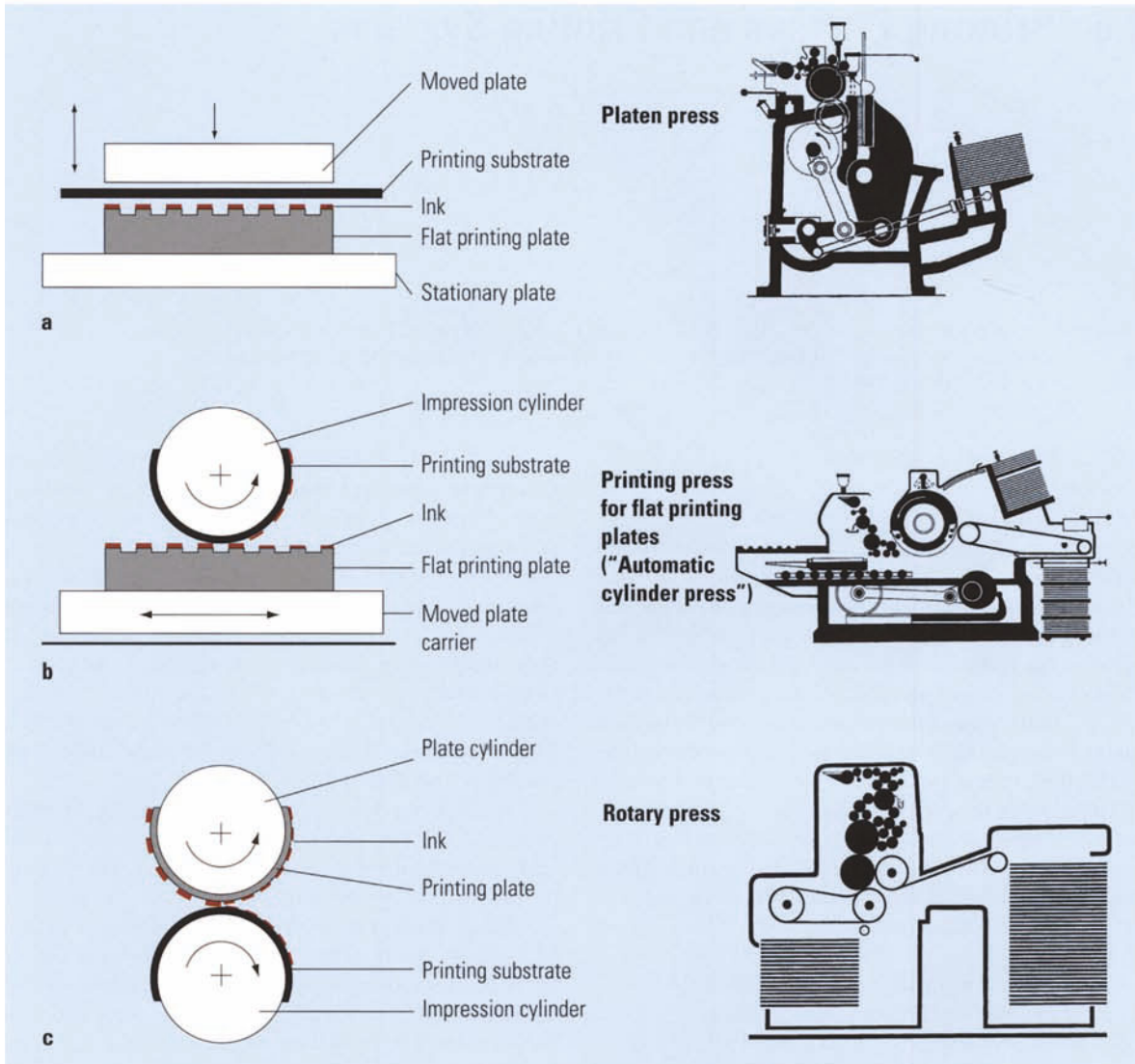


Fig. 1.6-1 Printing methods (with examples of presses).
a Platen press (platen);
b Flat printing press (automatic cylinder press);
c Rotary press

sion cylinder, on which the radial flexible *blanket* is mounted.

In *gravure printing*, a thick-walled rubber layer on the impression roller presses the paper onto the ink-filled cells of the form cylinder.

Printing presses belong to the group known as *processing machinery*. Figure 1.6-3 shows the functional structure. Processing machines include the following areas of function:

- materials processing (e. g., inking, printing, substrate transportation),
- drive (motors and transmission elements),

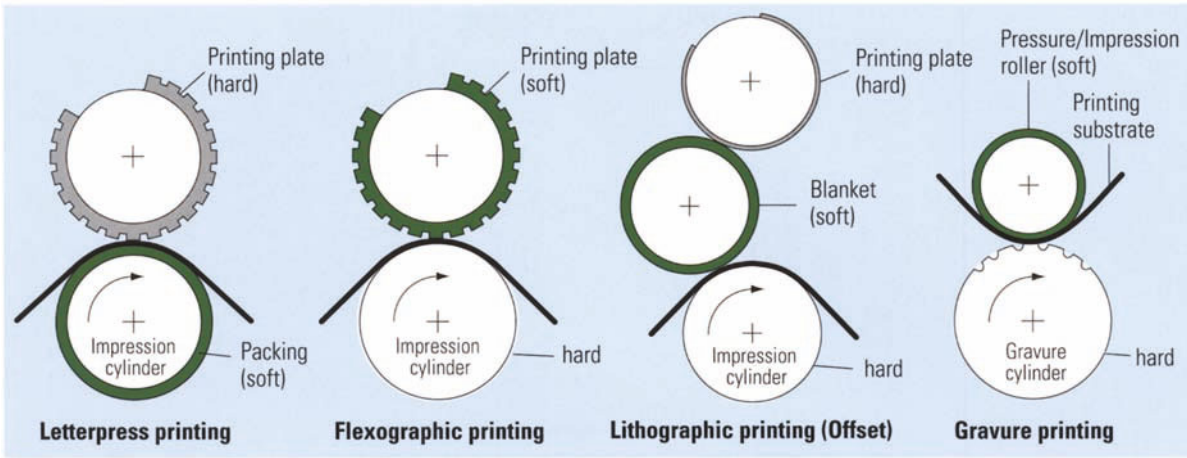


Fig. 1.6-2 Printing unit cylinders with radial flexible layers

- control system (e. g., sensors, actuators, and control processors),
- support and covering area (frame, bearings, guides, guards).

All but the first of these operational areas ensure the functioning of the active elements that process the paper, ink, varnish, and other materials. Direct imaging presses feature input facilities for text, graphics, and image information.

To carry out their function, printing presses comprise the following *sub-assemblies* or units:

- Equipment for *feeding* the substrate
  - sheet feeder to separate sheets from piles of paper,
  - unwinding stands for reels of paper;

- Equipment for *conveying* the substrate
  - alignment, acceleration, and transport elements for sheets,
  - draw and idler rollers for webs;

- Equipment for *metering*, evening out and applying the coating substances
  - inking units,
  - dampening systems,
  - varnish application systems;

- Equipment for *transferring* the coating substances,
  - printing units,
  - coating units;

- Equipment for *drying* the coating substances,
  - dryers;

- Equipment for *finishing*
  - folders in web presses,
  - cross cutters for open sheets (unfolded sheets from webs),
  - slitters for *dividing* sheets or webs;

- Equipment for *storing* printed sheets or webs,
  - sheet delivery unit (individual sheets to the pile),
  - rewind unit (webs to reels),
  - winding of folded sheets onto storage reel.

Configured in the *printing units* are:

- the printing cylinders (printing unit), (see secs. 2.1.1.3 and 2.1.3.3),
- the inking unit,
- the dampening system (only in offset printing),
- the wash-up devices (sec. 2.1.5.1).

Each maximum *printing format* depends on the dimensions of the plate cylinder. Smaller formats are also possible

- using narrower webs and sheets and
- for sheet-fed presses by using shorter sheets in a circumferential direction.

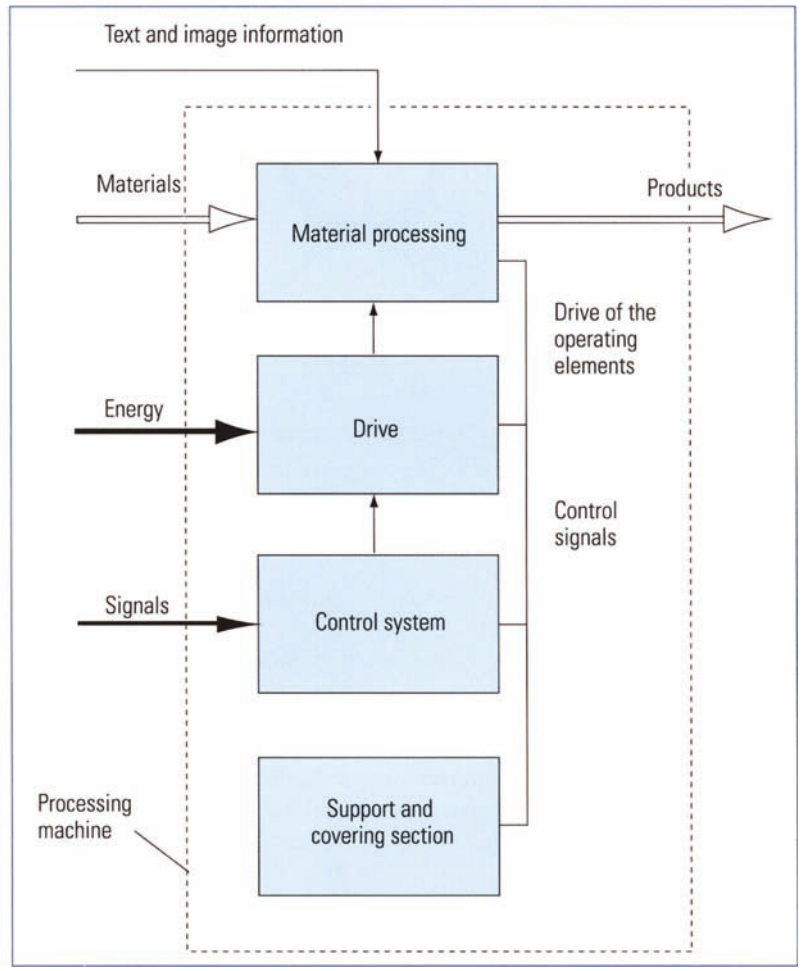


Fig. 1.6-3
Function structure of processing machinery

Web presses have a constant print length in accordance with the circumference of the cylinder, and this can only be varied by changing the diameter of the cylinder. Variations of format in gravure and flexographic presses are mainly achieved by changing the plate cylinder, but this option is not usually available in offset and letterpress printing. The terms *fixed format* printing press and *variable format* printing press always refer to the print length, not to the print width which can always be changed.

The process-specific cylinder configurations shown in figure 1.6-2 allow for the transfer of *one* ink to the substrate.

Multicolor printing requires a configuration of several printing units in one press (sec. 1.6.2).

To print the front and reverse side of sheets or webs (*perfecting*), blanket-to-blanket printing units are often used in web printing, whereas sheet-fed presses (with a few exceptions) have perfecting equipment (sec. 2.1.2.4) especially for this purpose.

The basic configuration of presses (for sheet offset, web offset, and web flexographic printing) can be seen in figure 1.6-4 and is explained below.

Sheet-fed Printing Presses

In example 1.6-4a the pile of sheets is put in the sheet feeder and lifted with a pile hoist until the top sheet is seized by the separator elements and passed on to the feed table. The sheet grippers of the swing unit grip the front sheet after it has been aligned (positioned) at the front and side edge, accelerate it to the circumferential speed of the printing unit cylinders, and then transfer the sheet during the rotating motion to the grippers of

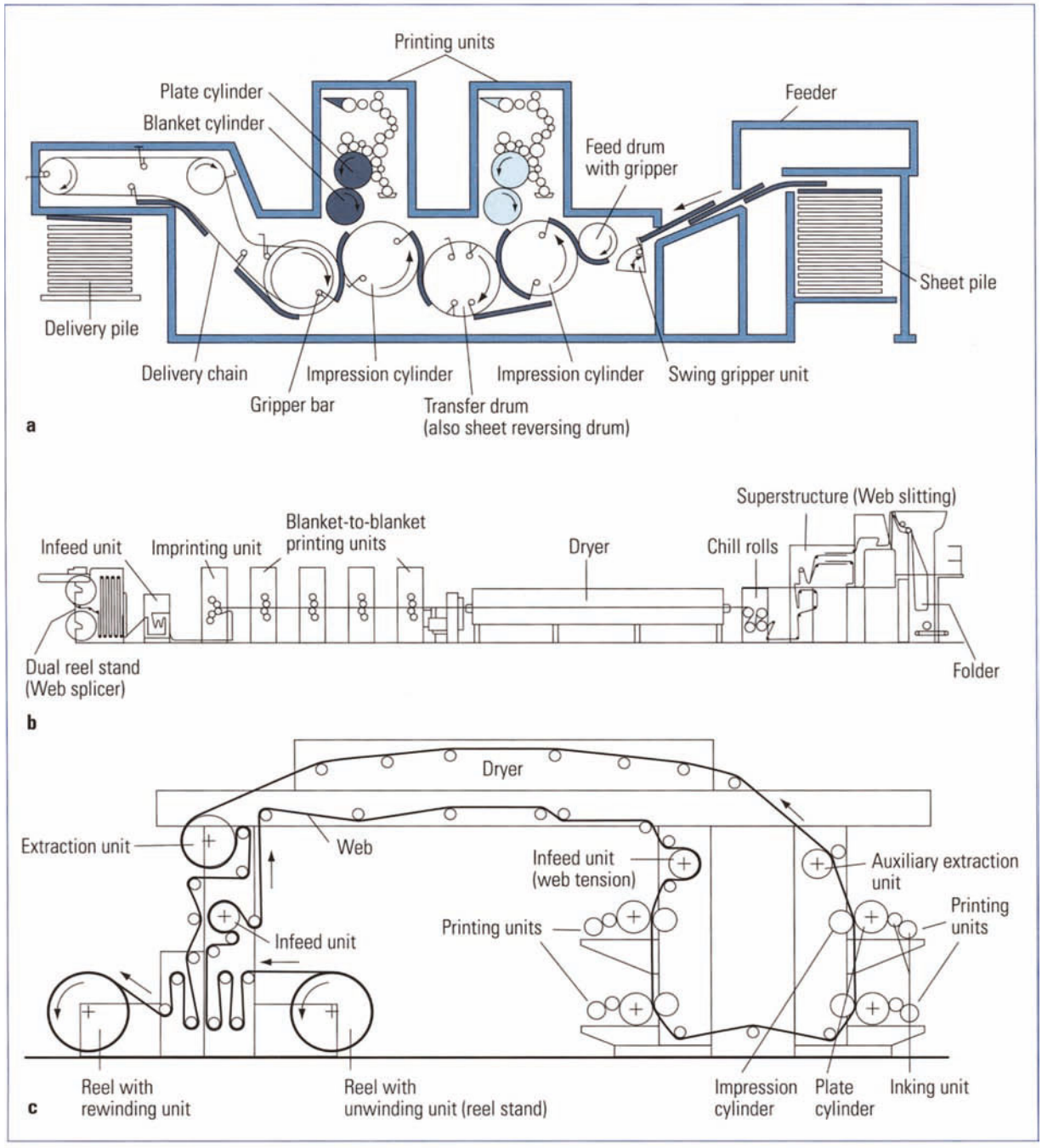


Fig. 1.6-4 Basic configuration of rotary presses.
a Schematic diagram of a sheet-fed press (see also fig. 2.1-18);
b Commercial web-fed offset printing press;
c Multi-cylinder flexographic printing press

the feed drum. The subsequent transfer of the sheet to the first impression cylinder, to the transfer drum, storage drum, and perfecting drum, as well as to the second impression cylinder always occurs by means of gripper systems. This ensures that multicolor printing is in accurate register in the printing unit area.

The two offset printing units shown comprise the blanket cylinder and the plate cylinder in addition to the impression cylinder, the plate mounted on the plate cylinder being dampened by the dampening unit and inked up by the roller-type inking unit. The grippers of the final impression cylinder transfer the now printed sheet to gripper systems, which are attached to the delivery chains and transport the sheets to the delivery unit. After the sheet transfer, the sheets are released from the grippers in the direction of motion, slowed down and pressed down vertically by air-blowing devices and deposited on the delivery pile.

Web-fed Printing Presses

They are classified depending on their use as:

- commercial printing presses,
- newspaper printing presses, and
- packaging printing presses.

The *commercial web printing press* shown in example of figure 1.6-4b consists of the dual reel stand with vertical festoon storage that provides for automatic reel change without interrupting the printing production (see sec. 2.1.3.2). The infeed unit peels the web off the slowed-down reel at a certain tension, allows the web to be aligned laterally and, as a result of the slight speed variations, enables the web tension to be adjusted before it enters the printing units. Commercial printing presses usually have horizontal web travel. For example, the web is printed on both sides with four colors by the four blanket-to-blanket printing units. With the imprinting unit (imprinter) varying text imprints can be printed on the substrate during operation. The inking and dampening units of a web offset press are not shown here. To avoid smearing of the freshly printed ink when finishing in the folder, the web passes through a dryer, in which the fresh ink is hardened by drying (see sec. 1.7 and 2.1.3.1).

The chill roll assembly cools down the web that has been heated in the dryer (to about 130 °C) and at the same time serves to adjust the tension of the web upstream of the folder. The web can be cut lengthwise in the superstructure upstream of the folder and the resultant web sections are guided over each other by turner bars. In the folder (see sec. 2.1.3.4), the web can be folded longitudinally and crosscut, glue strips are applied to glue the fold if necessary, and/or longitudinal and cross perforations are made, as well as the multiple fold of the web section into the folded product.

In a *newspaper printing press*, it is typical for the webs to be fed in a vertical direction with several webs being printed at the same time. The configuration of a newspaper printing press is explained in detail in sections 1.6.2.2 and 2.1.3.5.

The example of a multi-cylinder flexographic printing press in figure 1.6-4c serves to show the configuration of *packaging printing presses*. The first infeed unit draws the web off the reel that is revolving mounted and slowed down in the reel stand. The second infeed unit determines the web tension of the web fed to the four printing units. Flexographic printing units consist of the impression cylinder, the plate cylinder, and the inking unit. The web, which is printed on one side, is guided by the extraction unit through the dryer via an auxiliary extraction unit, before the web is rewound in the rewind unit onto the printed web reel.

1.6.2 Designs for Multicolor Printing

1.6.2.1 Sheet-fed Printing Presses

The vast majority of all sheet-fed printing presses use the offset printing technology. Printing press manufacturers supply these presses principally for sheet sizes between 37 cm × 52 cm (14½ × 20½") and 72 cm × 104 cm (28⅜ × 40⅛"). The maximum sizes are 120 × 162 cm (see also table 2.1-4).

Production speeds lie in the range of 10 000 to 18 000 sheets/hour, depending on the format, the substrate properties, and the sheet feeder in use. Single-sheet feeders can produce up to 10 000 sheets/hour on small-format presses, whereas stream feeders can produce up to 18 000 sheets/hour in medium-size format (72 cm × 104 cm).

Various cylinder configurations are possible in *multicolor printing presses*. The *three-cylinder configuration* unites the plate cylinder, blanket cylinder, and impression cylinder in one printing unit. The number of printing units arranged in a series, also referred to as unit configuration, determines the maximum number of colors that can be printed in one machine pass. Figure 1.6-5a shows the configuration of a four-color printing press with a single-sized impression cylinder

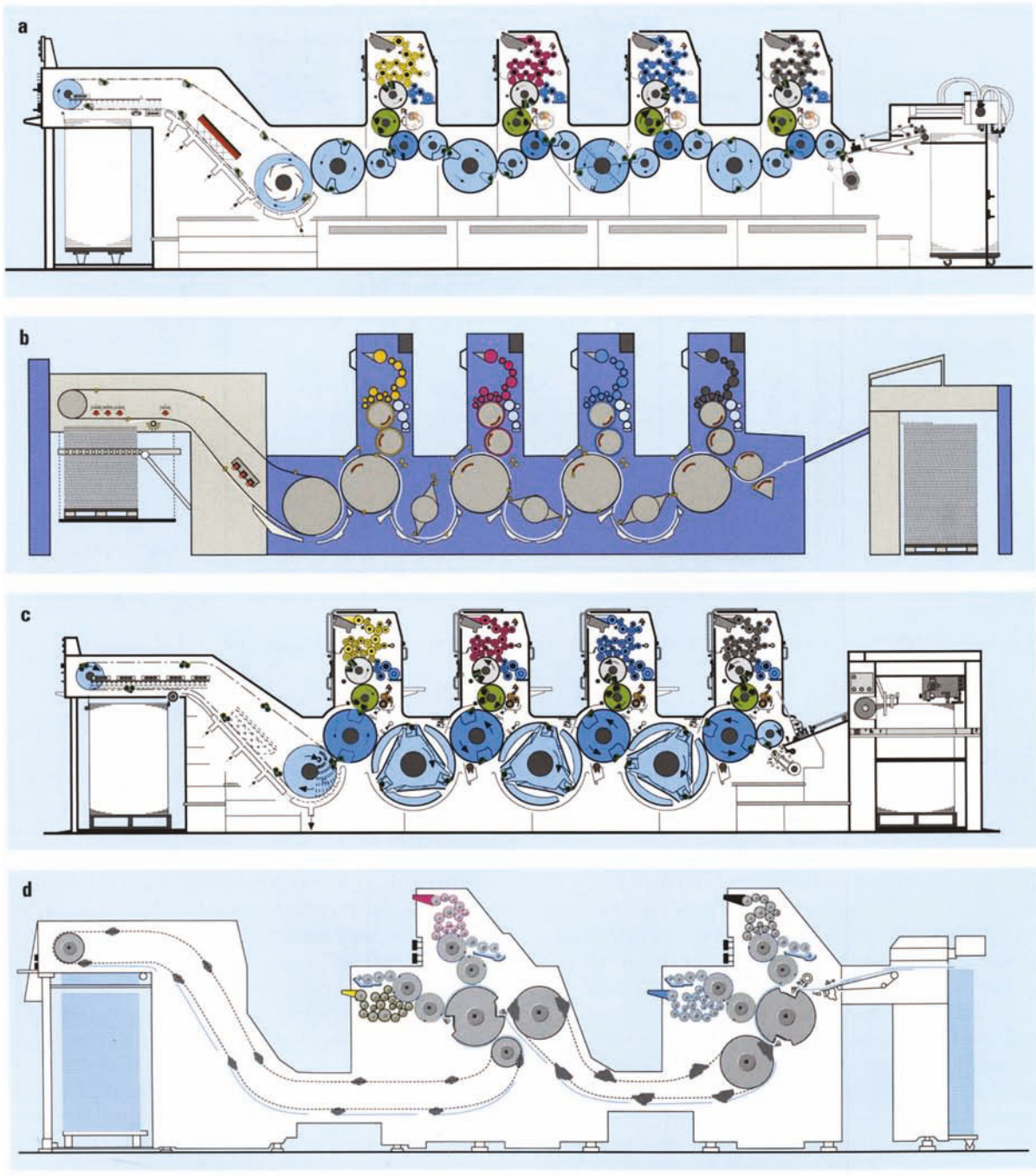


Fig. 1.6-5 Design concepts and cylinder configurations for multicolor sheet-fed offset printing presses.
a Three-cylinder configuration with three transfer drums (Speedmaster 74-4-P-H, Heidelberg);
b Three-cylinder configuration with one transfer drum (Rapida 105, KBA);
c Three-cylinder configuration with a triple-size transfer drum (Speedmaster CD 102-4, Heidelberg);
d Five-cylinder configuration with chain transfer systems (MAN Roland)

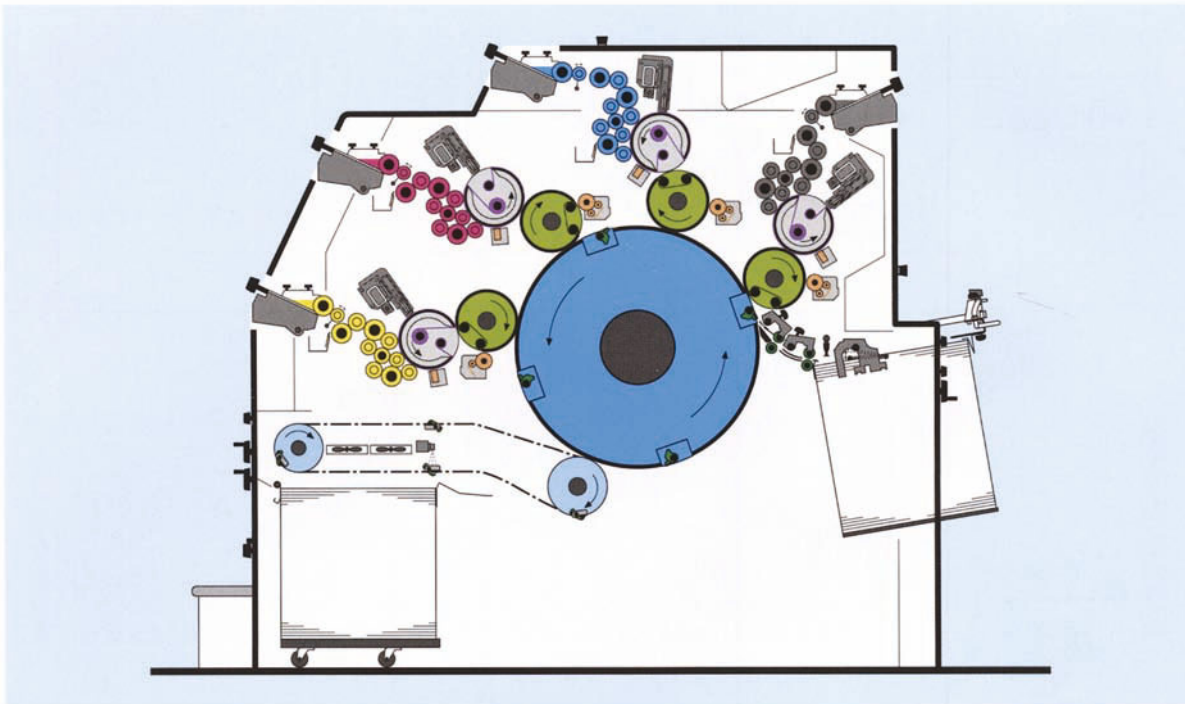


Fig. 1.6-6 Satellite configuration of a sheet offset printing press with direct imaging technology (Quickmaster DI 46-4, Heidelberg)

and three transfer drums between the printing units. The middle drum is double-sized, and has two gripper systems; together with a special reversing drum it can be used for sheet reversal.

Figure 1.6-5b shows a four-color printing press with double-sized impression cylinders and double-sized transfer drums. Because of the requirements of the direction of rotation, one or three drums must be located between the impression cylinders for sheet transfer. Double-sized impression cylinders and transfer drums are advantageous in the printing of cardboard and metal sheeting, since the materials will be subject to less deformation by the cylinders. Presses specially optimized for cardboard printing (fig. 1.6-5c) have double-sized impression cylinders and even have triple-sized transfer drums.

Figure 1.6-5d shows the *five-cylinder configuration* of a four-color printing press with chain transfer. Each printing unit has one plate and one blanket cylinder for each two colors and a joint impression cylinder. The two colors are transferred onto the printing sheet in register one immediately after the other, the sheet being held on the impression cylinder by grippers. The sheets are transferred from the first to the second printing unit in this press by gripper systems attached to circulating chains. The chains provide the means to overcome a relatively large conveying distance so that the distance between the printing units is sufficient for a convenient operation. The chain system makes an alignment of gripper systems using special alignment elements on the impression cylinder necessary in order to achieve the required accuracy of transfer for the color-to-color register.

An example of *satellite configuration* is demonstrated in figure 1.6-6 by a four-color printing press with direct imaging for digital printing (see sec. 4.4). It shows a quadruple-sized impression cylinder with the four plate and blanket cylinders configured around it. The four colors are transferred onto the printing sheet one immediately after the other in one gripper bite.

Figure 4.4-14 shows a sectional drawing of a four-color printing press with a special *five-cylinder configuration* for digital printing and direct imaging technology. (The special type of direct imaging press is dealt with in detail in sec. 4.4.). What is shown is two double-sized plate and blanket cylinders, working

with a triple-sized impression cylinder. The short inking units, which can be cyclically engaged and disengaged to ink one of the two printing plates, are mounted on the plate cylinder, and they then transfer the ink to the corresponding blanket. The transfer and assembly of the four colors on the printing sheet take place during two revolutions of the impression cylinder. Two transfer drums then pass on the freshly printed sheet to the delivery chain.

A special feature for two-color printing is the *four-cylinder configuration* illustrated in figure 1.6-7. Two plate cylinders transfer their ink to one blanket cylinder which then transfers both inks to the printing sheet on the impression cylinder simultaneously.

Sheet-fed gravure presses, like the one shown in figure 1.6-8, have been developed for packaging printing with two to seven printing units. With this press, the sheets are fed via a feed drum to the first impression cylinder, ink is applied there by the bottom gravure cylinder, which is inked up by means of an inking roller and a doctor blade (see fig. 1.3-16). There are conveyance chains with grippers installed between the printing units; they take over the printed sheets from the impression cylinder grippers, guide them through the dryers and pass them on to the grippers of the next impression cylinder. At the end of the drying cycle the conveyor chain system behind the last print unit transports the sheets to the delivery unit.

The multicolor sheets printed in sheet-fed printing presses are mostly processed into books, stationery, or packaging media off-line on special machines or flow-lines (system of finishing units). *In-line finishing operations* (in sheet-fed printing presses) are, for example:

- sheet reversal for perfecting (see sec. 2.1.2.4),
- coating the sheets (see sec. 2.1.2.7) for the most part in special coating units and extended delivery for the drying units (see sec. 2.1.2.6),
- use of rotating cutting blades in delivery to split large sheets and adapt them in this way to smaller-format folding machines,
- configuration of special numbering boxes (see fig. 2.1-66) with a separate inking unit on the impression cylinder of the final printing unit; this enables consecutive sequences of numbers to be imprinted (e.g., for entrance tickets or lottery tickets).

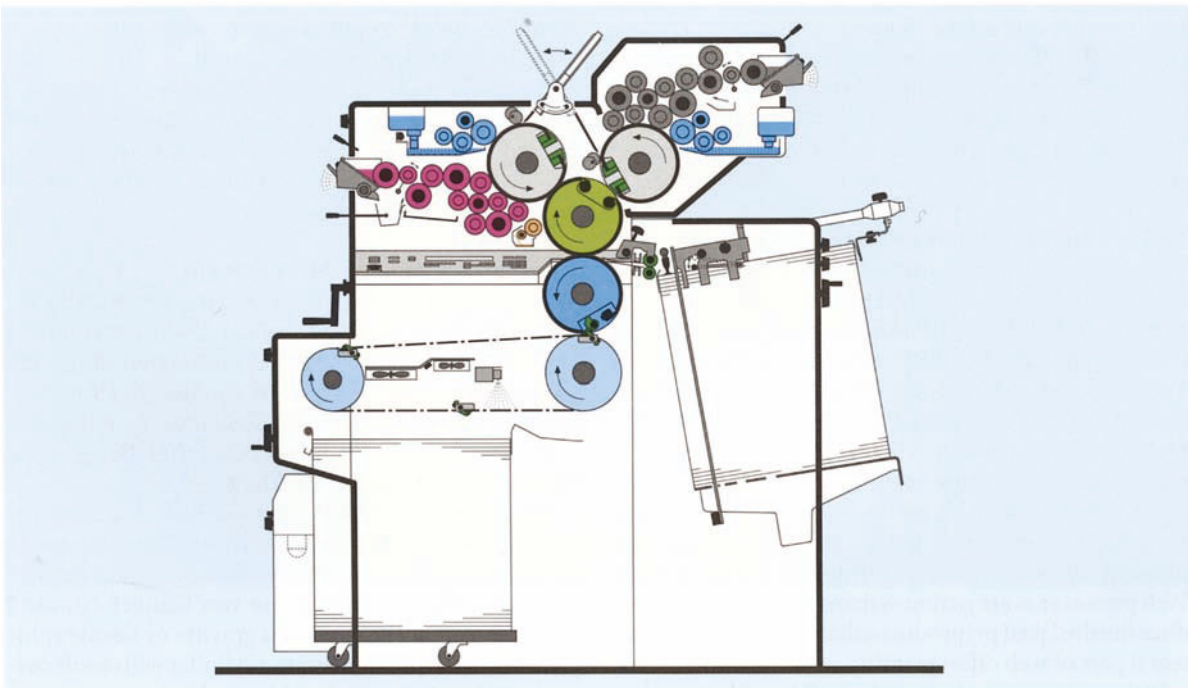


Fig. 1.6-7 Four-cylinder configuration of a two-color sheet offset press (Printmaster QM 46-2, Heidelberg)

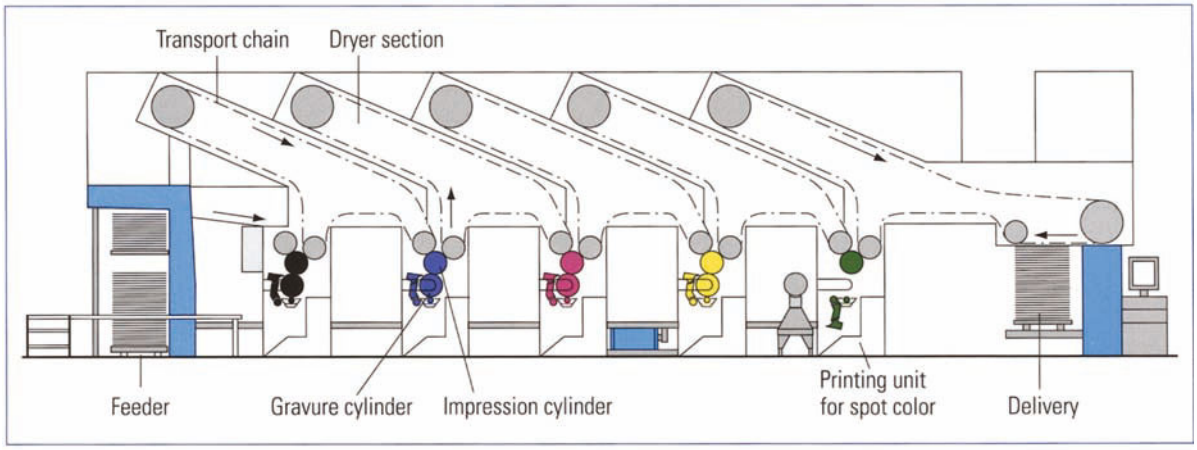


Fig. 1.6-8 Sheet-fed gravure press (REMBRANDT 142, KBA)

Non-stop equipment (sec. 2.1.5.3) is used in the feeder and delivery units so that the sheet-fed press does not have to be stopped for the piles of paper to be changed. It supports a small residual pile in the feeder, making it possible for a new pile to be run up that takes over the residual pile after removal of the supporting elements and then gradually raises the merged pile. Once a pile has been filled up in the delivery unit, a special device moves into the pile area and supports the subsequently delivered sheets to form a partial pile. After the full pile has left the delivery unit, the pile board moves upwards with a pallet and takes over the partial pile after the supports have been removed.

1.6.2.2 Web-fed Printing Presses

Web-fed printing presses differ less from sheet-fed presses in the configuration of their printing and inking units than in all the machine elements actually transporting the substrate. In principle it is much easier to transport a web through the various press units than a sheet. The continuous web to a great extent guides itself, because the start of the web is pulled and the web is held under tension in a stabilizing, defined way. Therefore web presses are more suitable for higher printing speeds than sheet-fed presses (sheet-fed printing up to approximately 4 m/s, web printing up to approximately 15 m/s). Web presses are production systems that are able to produce finished printed products, that is, finishing is an integral part of web offset printing.

Web presses are relatively inflexible with regard to format variation compared to sheet-fed presses, only the web width is variable. The format is defined in the circumferential direction of the printing plate and in the direction of web travel by the cut-off length. The advantage is here that, depending on the printing process, there is no printing gap (or at least almost none). In flexographic and gravure printing the cylinder circumference can, within certain limits, be adapted to the cut-off length, whereas on web offset presses the cylinder diameters are invariable.

Figure 1.6-9 shows a schematic representation of a web-fed offset press and its various components. Web offset printing is explained in detail in section 2.1.3, gravure and letterpress in sections 2.2 and 2.3. Only a general description is given below.

Transport Elements of the Web Press

Web transport through the web press begins with the reel of paper or any other substrate on a reel; this is clamped in reel arms. To avoid production stoppages, the reels are almost exclusively changed in a fully-automated process by *splicers*. A separate *infeed unit*, also called pre-tensioning unit, is located after the reel stand for keeping web tension constant.

The *printing unit* itself serves also as a transporting element, because the web is transported under pressure between two cylinders. In the blanket-to-blanket unit of a web offset press these are two blanket cylinders (blanket-to-blanket mode), in gravure or flexographic printing (letterpress) they are a cylinder with a soft covering and a steel cylinder. Multicolor prints are produced by printing units arranged one after the other,

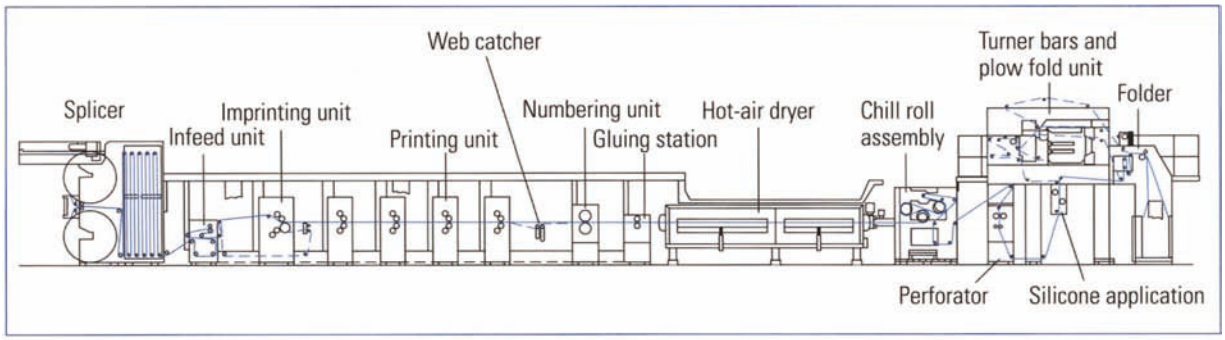


Fig. 1.6-9 Print line of a web-fed offset printing press with the individual units (IFRA/KBA)

which print the color separations onto the web. The web behavior during transport varies according to the cylinder surfaces, which requires a special dimensioning of the diameter of the steel cylinder and/or adaptations of the blanket cylinder packing.

Various *finishing equipment* is connected to the printing unit, such as the numbering unit, gluing station (for partial coating), dryers, chill roll assembly, slitters, turner bars, and perforators, as well as the formers and the folding unit, which all have some effect on web travel. To compensate for this the web travel is stabilized by driven draw rollers. In many applications (e.g., newspapers, magazines, catalogs) the folder with its cylinder section acts as a tensioning mechanism at the start of the web. Draw rollers acting on both sides are fitted at the entry of the folder, but it is the tucker blade cylinder of the jaw folder that exerts the actual tension. It is equipped with height-adjustable, curved plates or with circular shaped segments that correspond to the cylinder radius. The press does not need to be stopped for readjusting the tension, as it is equipped with a mechanism that allows adjustment during paper run. After the web or the ribbon bundle has been cross-cut in the folder, the sheets are transported and delivered by means of pins or grippers in the cylinder section of the folder. The web can also be cut into individual sheets after printing using "sheeters", and then stacked in a delivery like with sheet-fed presses.

Various Printing Unit Configurations on Web Presses

Web presses can be designed for all of the three main printing technologies: lithographic printing (offset printing), gravure printing, and letterpress/flexographic printing, as well as for non-impact printing technologies (sec. 1.3.3 and chap. 5). It is mainly the printing unit configurations of web presses for letterpress and offset printing that are explained in this section.

The *image carrier* (printing plate) in web-fed letterpress printing presses was, and to a certain extent still is, a round form (stereotype plate, electrotype plate, or wrap-around plate), which is mounted on a plate cylinder. This is brought into contact with an impression cylinder, a cylinder covered with a blanket. The paper web to be printed is routed through the two cylinders and the impression cylinder presses it against the plate cylinder to transfer the ink onto the web.

When lithographic printing (the di-litho method) was introduced into web printing, the only change to the above printing unit was that the letter press plate was replaced by a lithographic plate. At the beginning zinc plates were used. The dampening unit supplemented the inking unit, to enable the process of separating ink-accepting and non-ink-accepting, that is, ink-repellent, image areas on the flat form.

It was only with the invention of *offset printing* that a third cylinder was used as an intermediate image carrier. Accordingly the main elements of an offset printing unit therefore consisted of a plate cylinder, a blanket cylinder (a cylinder with a blanket covering), and an impression cylinder. The latter no longer needed to be coated, that is, covered with a blanket. Only with the invention of blanket-to-blanket printing could one of these additional cylinders be dispensed with again. Here two blanket cylinders are in contact with the web, which runs between the cylinders and is printed on the front and reverse side simultaneously (perfecting). This was a considerable improvement in rationalization.

Vertical Blanket-to-Blanket Unit

Nowadays virtually all printing units on commercial web offset presses (fig. 1.6-9) are designed in such a way that two blanket cylinders are arranged on top of one another with the web guided between them in a horizontal direction. The plate cylinders, the inking units, and the dampening units belonging to each printing unit are arranged at the top and bottom respectively. This printing unit configuration is referred to as a *vertical blanket-to-blanket unit* (fig. 1.6-10) with horizontal web travel. Four-color printing on both sides is produced by arranging four such blanket-to-blanket units in sequence (fig. 1.6-11). (Figure 1.6-10 shows a printing unit with a double-sized blanket cylinder and the possibility of printing two webs in printing units arranged in line.)

There are various options for installing and coupling presses for *multi-web production*. It is, for example, possible to install an identical but inverted production line on the other side of the folder. Another variant is to choose a two-level hot air dryer where both print lines are arranged behind each other and reroute the web via the second section (as illustrated in fig. 1.6-10). Double-deck configurations can also be found, as can parallel configurations with cross transfer of the second web to the common folder via turner bars. Of

Fig. 1.6-10
Printing unit of a web offset press (vertical blanket-to-blanket unit) with horizontal web travel and possibility of a web over-run (IFRA)

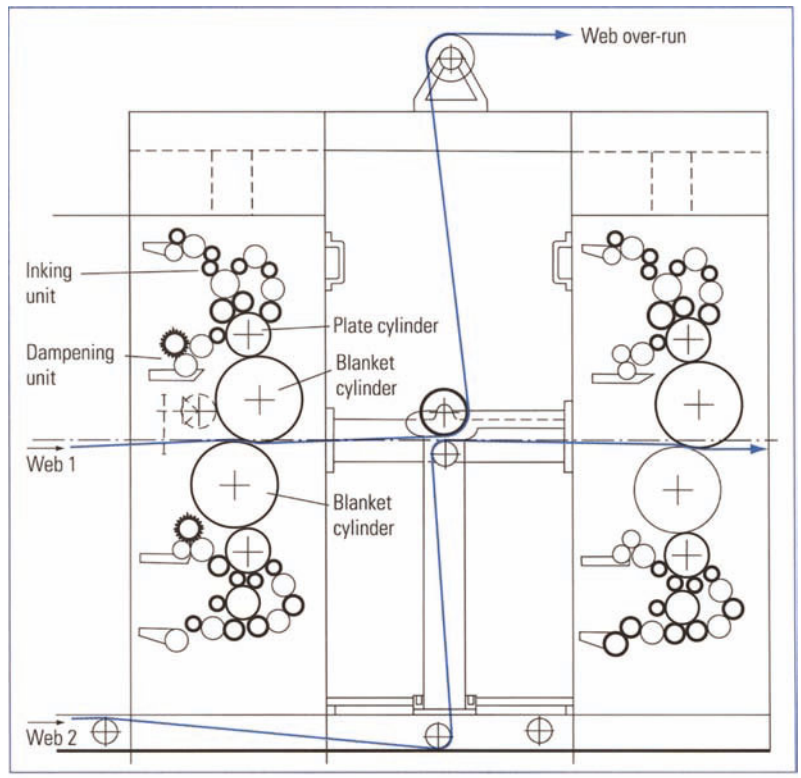
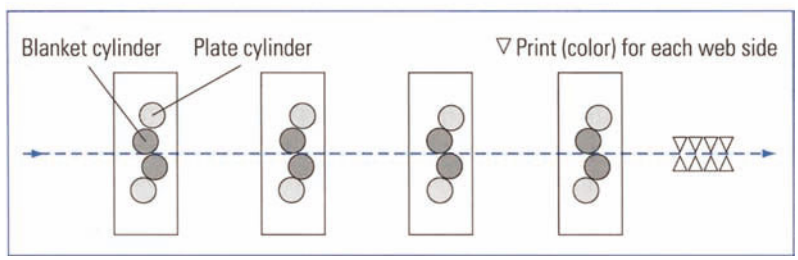


Fig. 1.6-11
Printing unit configuration for four-color printing on both sides of the web; vertical printing units for horizontal web travel



course it might be necessary to arrange more than four printing units in a row, for instance, when using spot colors or coatings. In addition the press can be equipped with "in-line finishing units", for example, for plow folding, punching, perforating, and applying adhesive (see sec. 2.1.6.2).

Horizontal Blanket-to-Blanket Unit (Arch-Type Printing Unit and Four-High Unit)

In newspaper printing multiple web operation is usually required. With the vertical blanket-to-blanket unit configuration described above this is very difficult to achieve. This led to the development of another basic design – the *arch-type printing unit*. Here, both blanket cylinders are brought into contact with each other in a horizontal direction and the web runs between them in a vertical direction. The plate cylinders, inking units, and dampening units are arranged to the sides of each blanket cylinder in a downward slanting direction. This results in an arch shape, giving the design its name.

Single-color printing on both sides in *multi-web operation* can be achieved by arranging several such arch-type printing units (printing towers) alongside each other with the reel stands in the basement of the building and the webs being fed through slits in the floor. For multicolor printing the arch-type printing units need to be stacked in a vertical direction. This means that for four-color prints on both sides of the web, four arch-type printing units are arranged on top of each other, producing the so-called *four-high unit* or *tower* (fig. 1.6-12).

To save on overall height, the vertical *U-type printing unit* was designed. This is arranged inverted to the arch-type printing unit, and placed on top of an arch-type unit to form an *H-type unit*. Two of these stacked on top of each other will form *a four-high unit*. The majority of applications now utilize this compact four-high design (fig. 1.6-13). The web has to travel the shortest distance between printing nips through this four-high configuration to produce a 4/4 print. Cylinders and web are easily accessible for the operator.

Initially, it was sufficient in newspaper printing to introduce individual spot colors and not to have them on all pages. So-called "*Y-shaped printing units*" (fig. 1.6-14) were quite adequate for this application, using blanket-to-blanket printing twice on one side to manage without a separate impression cylinder. There were also attempts to let two plate cylinders run in contact with one blanket cylinder. However, this only produced satisfac-

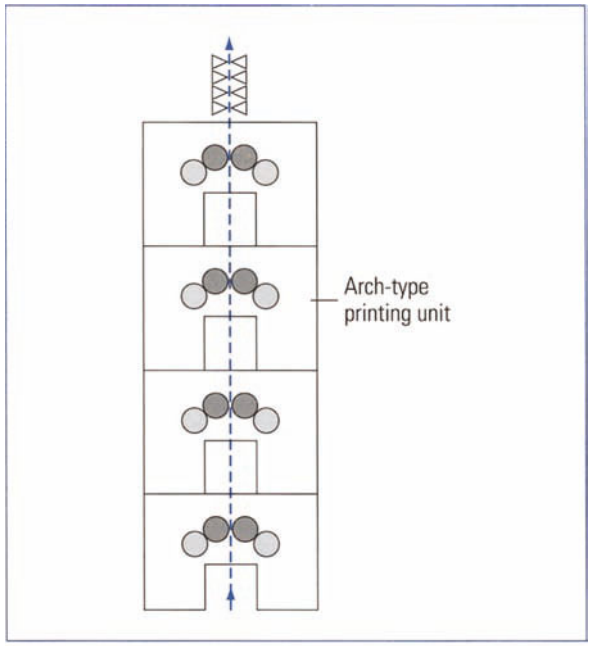


Fig. 1.6-12
Vertical web guidance in a "four-high unit" (four arch-type printing units stacked on top of one another for multicolor prints)

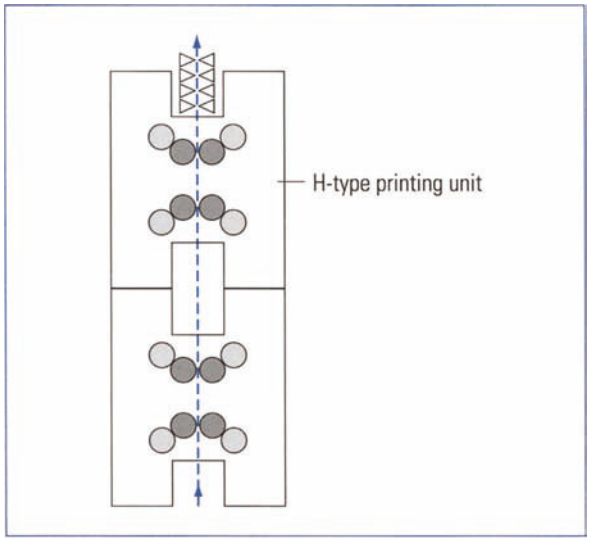


Fig. 1.6-13
Four-high unit for four-color printing (consisting of two H-type printing units)

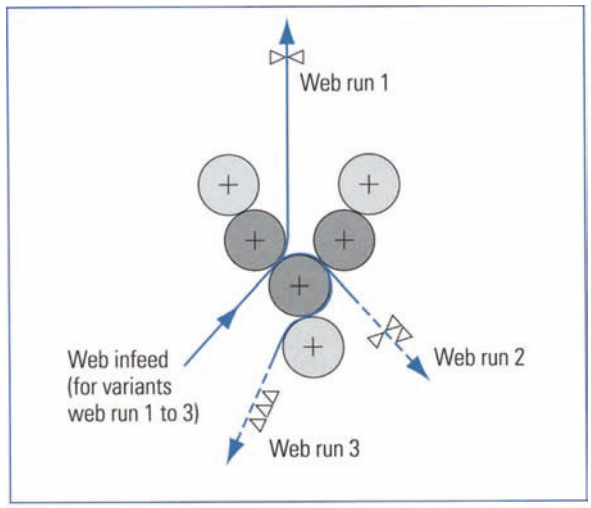


Fig. 1.6-14
Y-type printing unit for printing with up to three colors, three different web routes are possible

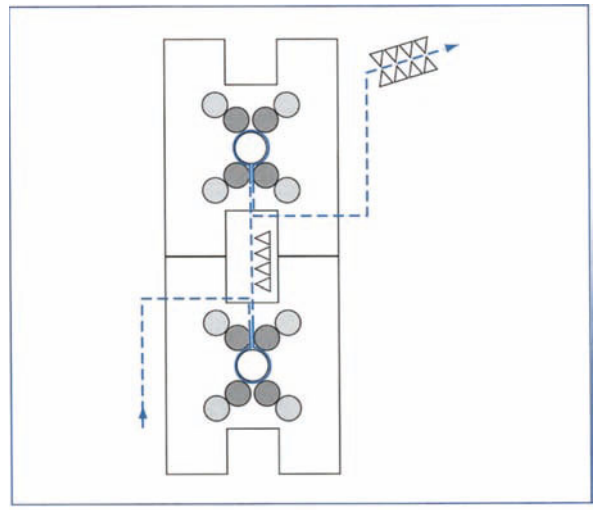


Fig. 1.6-15
Satellite printing units for four-color printing on both sides of the web; nine-cylinder satellite

tory results if the spot color was used completely separately and no overprinting of two colors was required.

Satellite Designs

The fear of not being able to print in accurate register in four-color printing where the web had to travel over a relatively long distance between the individual printing nips was the incentive for a design based on the *satellite construction*. Here, the four blanket cylinders are installed around a common impression cylinder (fig. 1.6-15). The advantage in terms of register accuracy results from the fact that the web is in contact with the common impression cylinder during the entire printing cycle. The four colors are printed very quickly one after the other, which gives the web little time to change its geometry due to the repeated application of dampening solution. In four-high units special measures have to be taken to compensate for changes in the web geometry (using so-called anti-fan-out rollers or buzzle wheels, etc., see sec. 2.1.3.2).

There are basically two different satellite configurations, the nine-cylinder satellite (fig. 1.6-15) and the ten-cylinder satellite (fig. 1.6-16). The latter is also called a *semi-satellite*. The most important designs are explained in greater detail in section 2.1.3.5.

Figure 1.6-17 shows a satellite (central cylinder) printing unit, as used in flexographic printing (for further information refer to sec. 2.3.3). Figure 1.6-18 shows

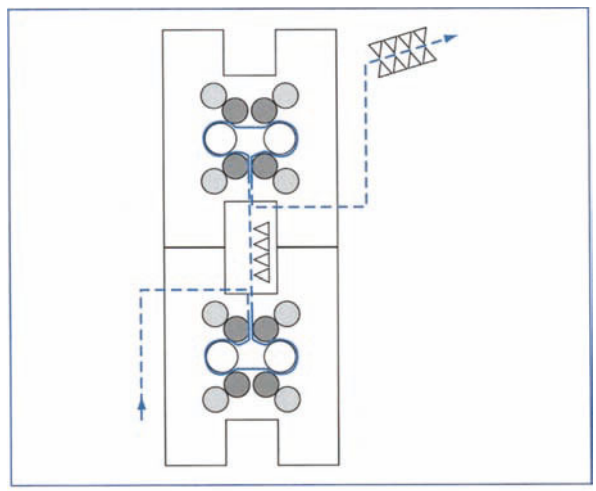


Fig. 1.6-16
Semi-satellite printing units (two ten-cylinder satellites, stacked) for four-color printing on both sides of the web

the printing units of a rotogravure press (for details see sec. 2.2).

Web Processing in the Folder

The web is cut and folded in various ways in the folder. This is done to create the end product (e.g., leaflet, newspaper) or at least an intermediate product partial

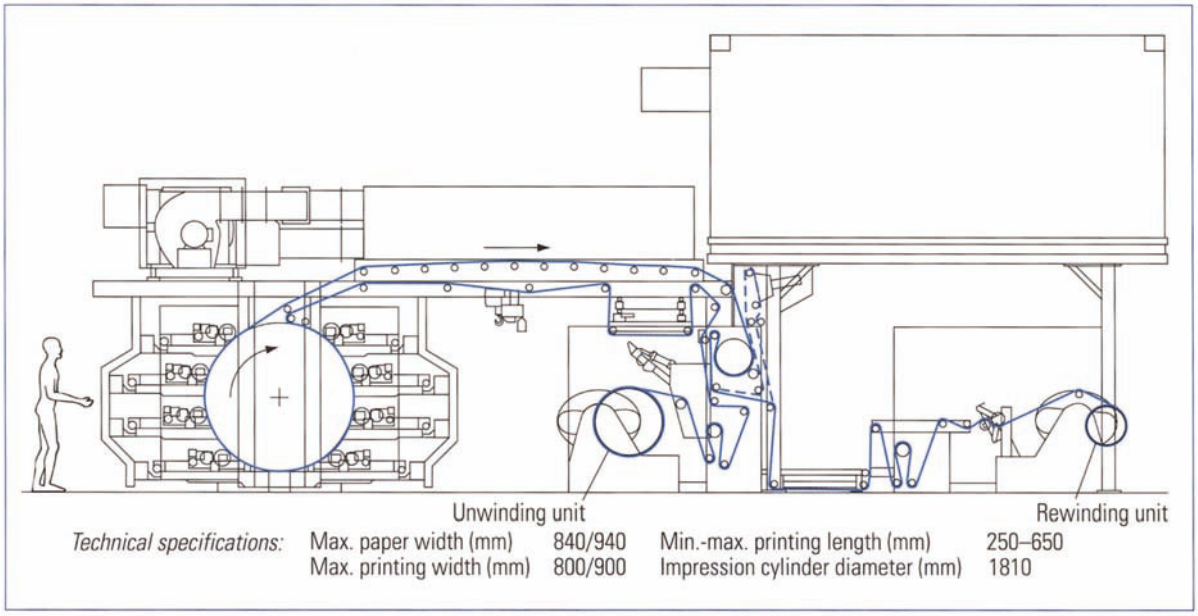


Fig. 1.6-17 Web guidance in a flexographic printing press, central impression cylinder design, eight colors (Fischer & Krecke)

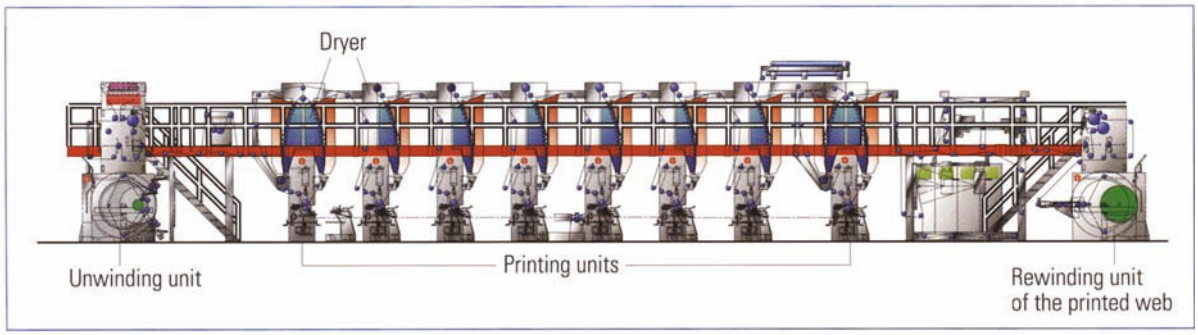


Fig. 1.6-18 Gravure printing press, eight printing units, unit design (W&H)

signature for books or magazines. Figure 1.6-19 shows a folder which is able to produce folds of the types illustrated in figure 1.6-20. Folders are explained in greater detail in section 2.1.3.4.

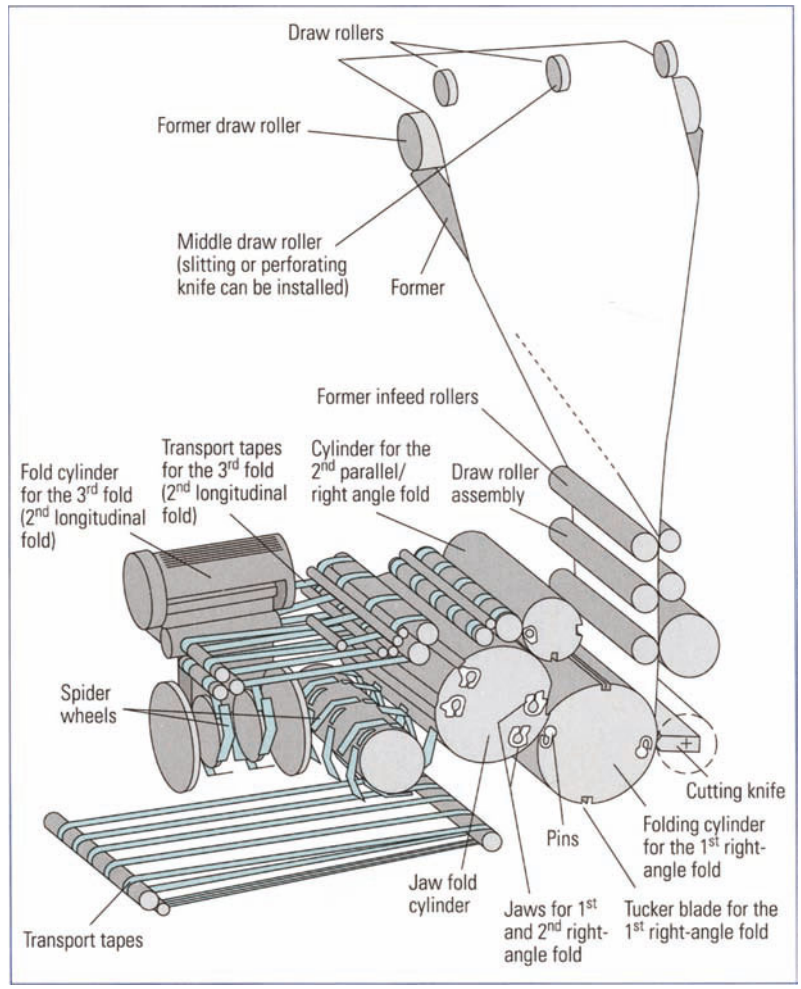
1.6.2.3 Packaging Printing Presses

The printing technology of letterpress (flexographic printing), offset, and gravure have also been used for printing packaging material for several decades. Key factors in packaging printing are the very diverse demands made on packaging, such as:

- stability and functionality, which means that substrates, such as card, board, plastic film, aluminum foil, and compounds are used;
- neutrality with respect to odor, which is especially important in food packaging;
- external appearance ranging from "purely utilitarian" to very high quality.

Because quite specific demands are also made on substrate, color, and press design, the result is that the assembly and design of individual units may differ to a

Fig. 1.6-19
Folder to produce different types of fold (in accordance with fig. 1.6-20) (IFRA)



relatively great extent from the traditional printing presses used to print books, newspapers, periodicals, or other print products.

Even before the turn of the nineteenth century, letterpress printing presses available at the time were used to print simple bags, sacks, and packaging papers. At the beginning of the twentieth century firms were engaged in developing a new printing technology for packaging materials, called *aniline printing* (inks containing aniline were used) and brought the first aniline printing units on the market (1905). The process using flexible rubber forms as printing plates from which flexographic printing (sec. 2.3.3) developed, works with elevated and somewhat soft image carriers and low-viscosity ink (aniline dye dissolved in alcohol) and is therefore very suitable for printing on rough packaging paper surfaces and for rapid drying.

Flexographic Printing (see secs. 1.3.2.1 and 2.3.3)
Though initially it was often only three- and four-color presses (fig. 1.6-21) that were required, a greater demand for six-color stack type presses soon developed. These presses, with web widths of about 60–100 cm for multicolor printing on different packaging papers, were fitted with a simple unwind unit and a rewind unit with carrier rollers for a reel diameter of 60–80 cm (fig. 1.6-21). When *cellophane* entered the market as a new packaging material, the ink drying in the presses had to be modified and intensified, and sensitive web tension control systems and center driven winding units (shaft-

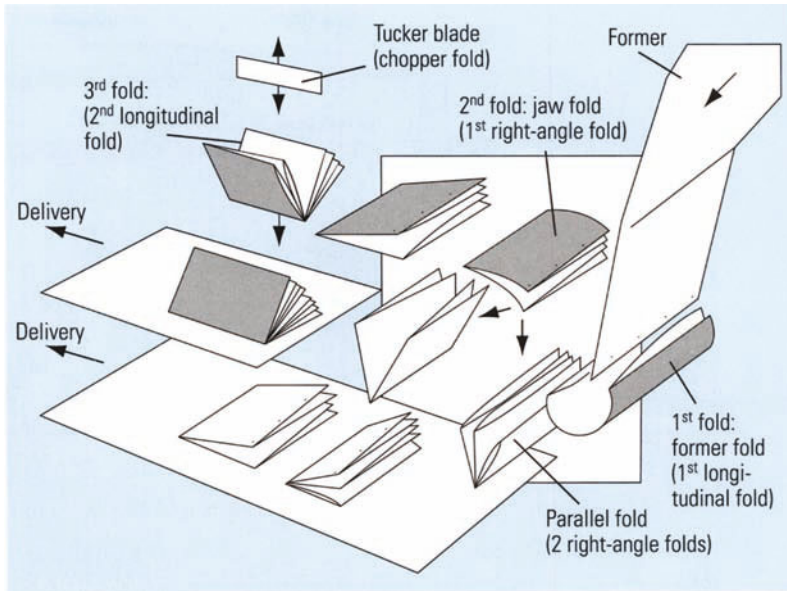


Fig. 1.6-20
Types of fold (produced with the folder illustrated in fig. 1.6-19) (IFRA)

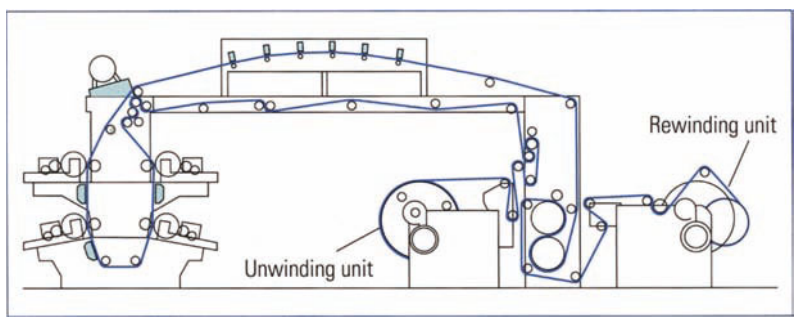


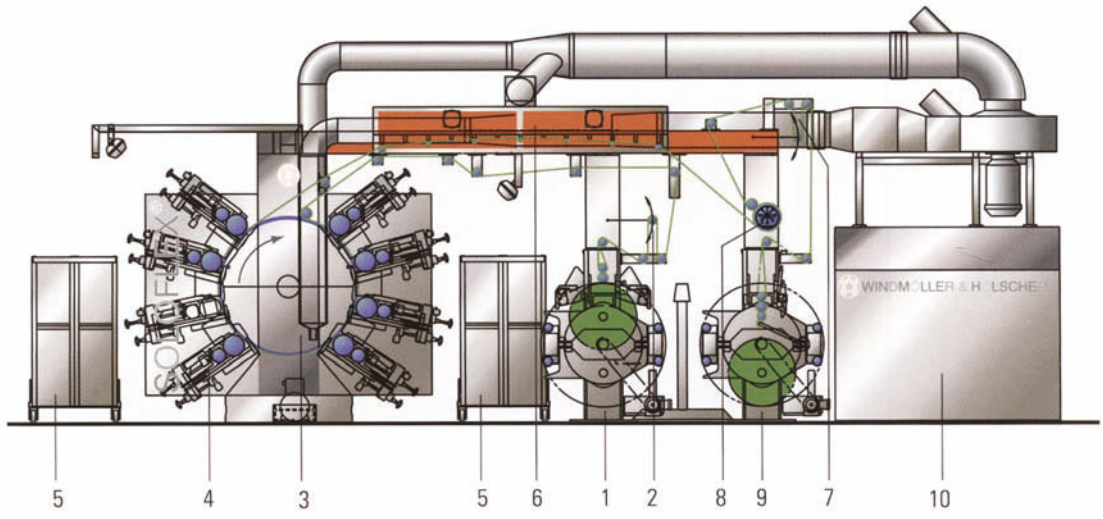
Fig. 1.6-21
Web guidance of a four-color stack type flexographic printing press for packaging printing (production from reel to reel)

ed winding units) were required. Apart from other fairly small press modifications, the major requirement was that new inks with suitable adhesion to the non-absorbent substrate be developed.

With the development and the use of thinner, more flexible plastic films in some areas of the packaging industry, new printing solutions were found. Consequently, at the beginning of the 1950s the first multicolor flexographic printing presses with a central impression cylinder (fig. 1.6-22) were produced. This was the decisive step in flexographic printing press design, because in these presses, flexible and even very thin webs can be held and guided accurately during the entire printing process. This was and remains the prerequisite for achieving a high level of register precision and results in improving overall flexographic print quality as well.

Since *polyethylene* was increasingly used to make the most varied flexible packaging products, such as bags, carrier bags, and food packaging in particular, the demands placed on flexographic printing continued to increase as well, especially as it emerged during many trials that printing on fairly thin polyethylene webs with existing gravure printing presses was virtually impossible because of the difficult web guide between the individual gravure printing units, which is why more and more packaging was produced by flexography.

The basis for the eventual breakthrough of flexographic printing was created in 1972/73 with the introduction of *photopolymer printing plates*. The preliminary requirements for flexographic printing to come closer to the high quality of offset and gravure printing had now been met.



1 Non-stop unwinding unit
2 Web tension measurement and control systems for the unwind
3 Eight-color central impression unit/system with hard-chromed steel impression cylinder, with a diameter of 1257 mm and temperature control unit
4 Doctor blade inking unit with form cylinder and anilox roller in sleeve technology
5 Ink circulation for four inking units on a transport carriage
6 Single-circuit drying system
7 Web tension control system for the rewind
8 Chill roller
9 Non-stop rewinding unit
10 Control cabinet

Fig. 1.6-22 Eight-color central impression cylinder flexographic printing press, reel to reel operation (W&H)

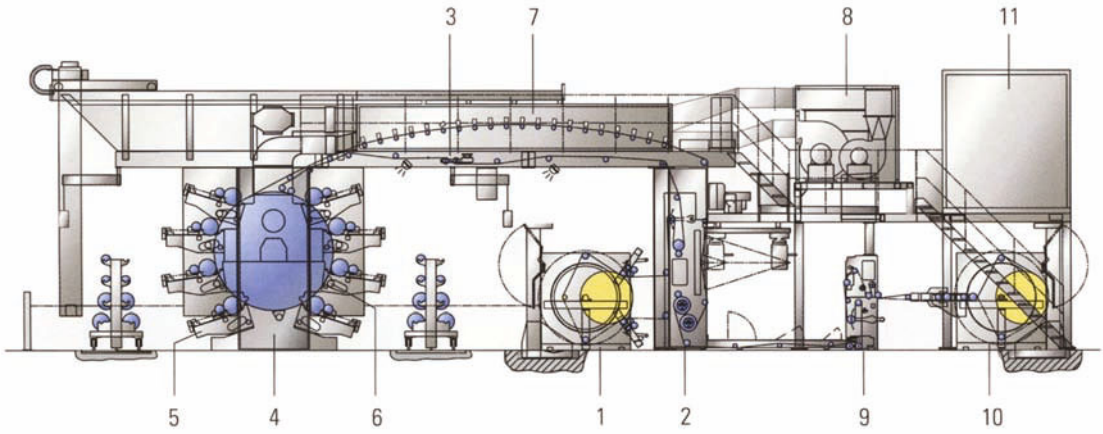
Flexographic printing units have also been used for many years in the corrugated board industry for the direct printing of *sheets of corrugated board or solid board*. At first only single-color alphanumerics were needed as imprints. In the meantime many improvements have been made to these flexographic printing units for printing on corrugated board and development results from flexographic web presses have been integrated. Modern high-capacity presses are now available for corrugated board packaging with which good quality, multicolor printing is achieved.

Despite the improvements in quality that have been made, and the various advantages of printing corrugated board sheets, especially for small print jobs, printing companies and corrugated board manufacturers world-wide have decided in favor of the preprinting of liner board on *central impression cylinder flexographic printing presses*. These presses are constructed in working widths of approximately 200–300 cm and for a maximum production speed of 400 m/min (1320 ft/min).

As a result of the many new developments and constant improvements, the entire flexographic printing technology has in recent years become increasingly important as an industrial printing technology worldwide, with disproportionately large market growth in some fields. The continued development of printing inks has also contributed greatly to the rise in quality of flexographic printing. Thanks to this it was possible to print folding boxes on flexographic printing presses. Figure 1.6-23 shows a modern high-capacity flexographic printing press. High-quality printing can be done economically on folded boxes with narrow-web, flexible, and relatively inexpensive central impression cylinder flexographic printing presses.

Offset Printing

Offset printing (secs. 1.3.2.3 and 2.1) was used from the outset in place of letterpress printing in the packaging industry. The offset printing domain in package printing is still paper, cardboard, and board. Printing is done mainly on *multicolor sheet-fed printing presses*. Multi-



1 Non-stop unwinding unit
2 Web tension measurement and control systems for the unwind, infeed stand
3 Automatic web guiding system with web monitoring prior to printing
4 Central impression frame for attaching eight printing units, with temperature-controlled impression cylinder
5 Doctor blade inking unit
6 Inter-unit drying
7 Drying tunnel
8 Recirculating air drying system
9 Web tension measurement and control system for the rewind
10 Non-stop rewinding unit

Fig. 1.6-23 High-capacity central impression cylinder flexographic printing press with eight inking units (W&H)

color printing in accurate register on the front and reverse sides of the sheets is possible with such presses.

The highest printing quality for packaging is achieved with offset printing. Consequently printing of expensive luxury packaging for special spirits, chocolates, perfumes, and cosmetics, and even embossing in accurate register is always done on sheet-fed offset presses. The printing of many other cardboard products and folding boxes for the packaging of frozen food, ice cream, cigarettes, drugs, and cosmetics, as well as many other products in the food and non-food areas remains the almost exclusive domain of offset printing technology (fig. 1.6-24).

Added to these are special packagings made of thick board (up to approximately 600 g/m²), high-quality gift paper and a multitude of exclusive paper and secondary packagings, such as hand-made bags and carriers. Printing thick and consequently relatively stiff materials presents sheet-fed presses with a special challenge. Sheet guides that do not require much bending of the material (e.g., large cylinder diameter) must be used here. Figure 1.6-25 shows a printing press specially designed for printing on cardboards.

In some instances *web offset presses* are also used to print packaging materials. This applies mainly to drink cartons and the outer packaging of drinks. Only a few cut-off lengths are required in this range; this means special presses with slide-in printing units are used for different cylinder diameters.

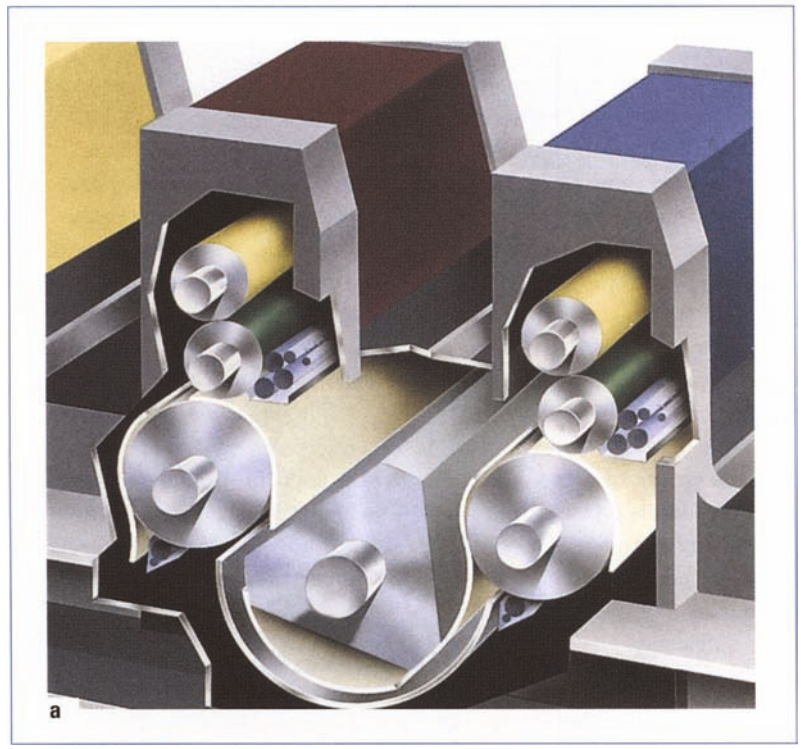
Gravure Printing

Like flexograhic and offset printing, gravure printing (sec. 1.3.2.2) also profited from the increasing demand for packaging. A *high-capacity gravure printing press* for packaging printing is illustrated in section 2.2.3 (fig. 2.2-36). Gravure printing processes and presses are dealt with in detail in section 2.2. Especially with long print runs, the big brand-name product manufacturers demand the constant, high print quality that only the gravure printing process can achieve on the most diverse substrates, such as high-quality coated paper, cellophane, aluminum foils, polypropylene foils, and other plastic films. This printing quality is achieved by the special inks and the gapless gravure cylinder.

This technology, in particular, enables good-quality reproduction on the various substrates mentioned,



Fig. 1.6-24
Various packaging products produced in offset printing (Heidelberg)



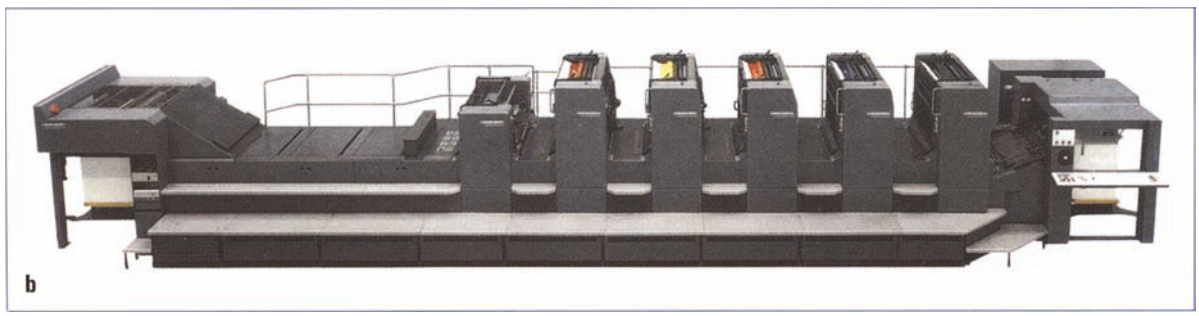


Fig. 1.6-25
Multicolor sheet-fed offset press specially designed to print on cardboard.
a Sheet guidance between the printing units (double-size impression cylinders, triple-size transfer drum);
b Multicolor sheet-fed offset press with coating unit and extended delivery for installation of different types of drying systems (see also fig. 1.7-2; Speedmaster CD 102, Heidelberg)

with the required properties, such as abrasion resistance, light-fastness, and gloss and sealing capabilities. Thus, the golden age of gravure printing in the packaging industry began around 1955. The gravure printing technology was especially used for long print runs on paper, light card, cellulose film (cellophane), and sometimes aluminum foil, mainly for brand-name product manufacturers to pack items such as cigarettes, candy, coffee, cookies, butter, and cheese. Carrier bags and high-quality gift-wrap were added to this.

Some press manufacturers offer easily convertible, inexpensive presses, mostly with slide-in and cassette systems for the printing unit. These printing unit cassettes can be prepared for the next job away from the gravure printing press without tools, and inserted quickly in the press. So it is possible to produce even small jobs cost-effectively and to compete with flexographic printing. Energy-saving and efficient drying processes also contribute to the high economic efficiency of modern gravure printing presses.

Presses can be fitted with drying units that can be individually adjusted to the substrate. Sensitive web tension measurement and control systems, taper tension facility, and web edge guide systems ensure the winding of optimal, straight-edged reels, thus providing mastery of the widespread application of operating from reel to reel. Brand-name product manufacturers and end users of packaging materials often decide in favor of gravure printing, in spite of the somewhat higher costs, due to considerations of prestige and quality. In some printing companies sheet-fed gravure printing presses (fig. 1.6-8) are also used for printing varied, high-quality packaging.

Outlook

The future in the packaging industry of the three printing technologies mentioned – flexographic, offset and gravure printing – depends primarily on the further demands made on packaging, future statutory provisions, the changeover from various types of packaging to other packaging materials, the consumer's wishes, the manufacturing costs of the entire packaging, and the development of new, even of digital, printing technologies. A salient fact, compared to other printing media, is the worldwide rise in the entire packaging market. It can be assumed from this that flexographic printing will gain an ever greater share of the market because of the quality already achieved and the increase in quality expected in future.

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1.7 Drying Methods

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The term "drying" includes all processes taking place after the ink transfer, for instance, from the blanket or printing plate onto the substrate, thereby providing a stable linkage between the substrate and the printing ink. The printing ink solidifies during the course of this process, creating a prerequisite for reliable print finishing and later use of the printed products.

Depending on the ink build-up, drying is effected either by chemical reaction (oxidation or polimerization) or by physical processes (penetration, evaporation) or by a combination of both. Figure 1.7-1 shows an overview of the drying methods and their primary fields of application.

Figure 1.7-2 shows a sheet-fed offset press with several drying systems integrated into the delivery. Different drying methods for inks and varnishes often require different systems – also in the form of combined systems – for an optimum drying process. It can be useful to install both an IR and a UV dryer to ensure a variable capability of the printing press (see also figs. 2.1-58 and 2.1-60).

The structure of the printing inks has to meet two opposing requirements with regard to the drying properties:

- no drying on the rollers during press operation or short standstill periods,
- fast drying and anchoring on the substrate after printing.

The following factors are the most crucial ones for the drying properties of the printing inks:

- the ink's composition, above all with regard to the vehicle used, the carrier and relevant additives,
- characteristic features of the material to be printed (penetration capacity, etc.),
- printing conditions (ink quantity transferred, pile height, printing speed),
- climatic conditions (humidity, room temperature),
- dryer construction (air stream on the ink surface, reaction period, type of energy supply, etc.).

The temperature is a decisive factor – in general, higher temperatures are beneficial:

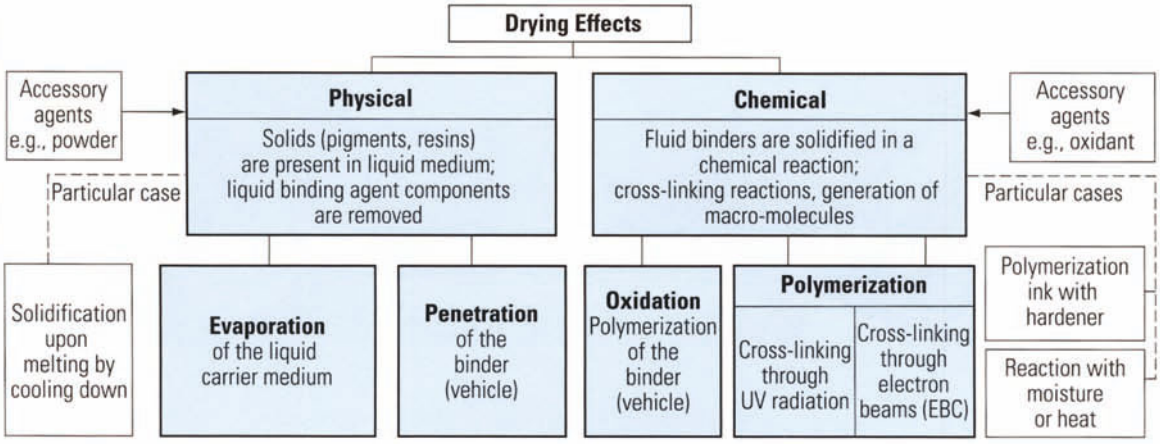
- the polymerization speed is accelerated,
- the ink viscosity is reduced to support penetration,
- there is faster evaporation of the solvents.

The degree of bonding between the inks and the substrate varies after the drying process is finished. As for the possible stress of the prints, there is a classification by the following characteristics: abrasion resistance, scratch proofing, scratch resistance, pile resistance, and wiping stability against wiping (see also sec. 1.7.4).

1.7.1 Physical Drying (Absorption)

Penetration is achieved by the interaction of printing ink and substrate (see also sec. 1.5.2). It depends above all on the carrier viscosity of the printing ink, the vehicle (binder) and the absorption capacity of the substrate.

H. Kipphan (ed.), *Handbook of Print Media*
© Springer-Verlag Berlin Heidelberg 2001



a

Drying methods	Drying Effects						Use (mainly)
	Evaporation	Penetration	Oxidation	Polymerization	Solidification	Two-component polymerization	
Hot-air drying	**X**	x	(x)			x (Polymerization is accelerated)	Web offset (heatset) Gravure printing Flexo printing Screen printing Ink jet Dispersion varnish (water-based)
IR drying		**X**	(x)			x (Polymerization is accelerated)	Sheet offset
UV drying		(x)		**X**			Flexo printing Sheet offset Screen printing Varnishes
Excimer				**X**			Flexo printing
EBC				**X**			Web offset
Cooling (Hot-melt inks)					**X**		Ink jet

b

Symbols: **X** main effect; x, (x) further effects of less importance

Fig. 1.7-1 Drying processes.

a Overview of drying types and effects;
b Overview of drying methods, drying effects and fields of application

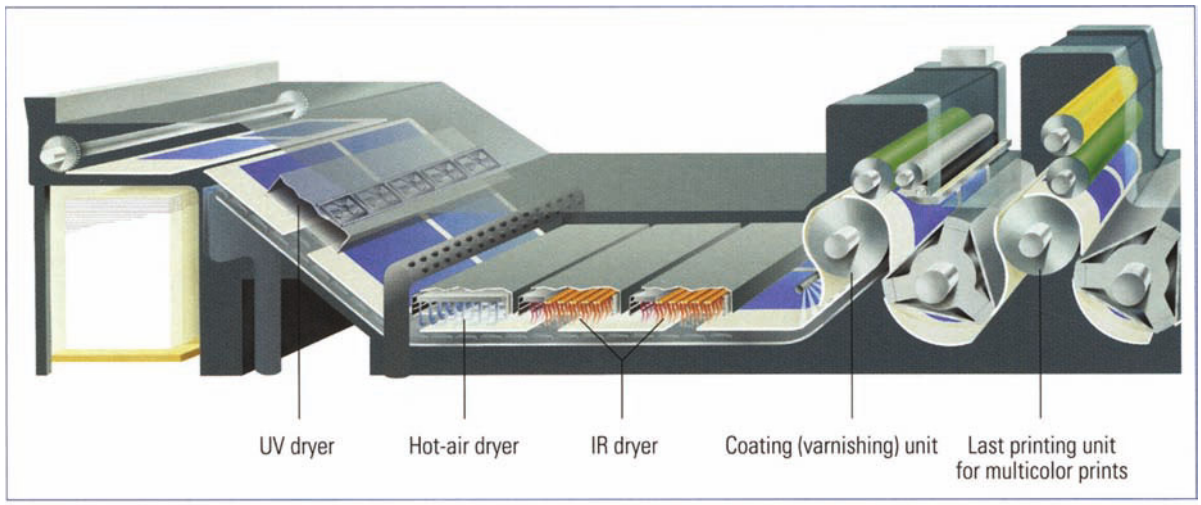


Fig. 1.7-2 Installation of different types of drying systems in a sheet offset press (Speedmaster CD, Heidelberg)

The printing ink components start *penetrating* with the transfer of the printing ink onto the paper and are sucked up into the paper by paper capillary tubes.

Consequently, penetration in the substrate depends on the *absorbency* and the *absorbing speed* of the substrate. The absorbing speed is determined by the porosity and the wetting quality. Porosity is characterized by the number of pores per area and the average pore diameter. Moreover, the absorbing speed is greater, the lower the viscosity of the printing ink.

Figure 1.7-3 explains the dependency of the ink penetration behavior on the absorption capacity of the substrate. In a test, the optical density of the ink film transferred on the counter sheet is measured relative to the drying period. (A counter sheet is an unprinted sheet unrolled defined on the freshly printed image. The optical density of the image reproduced on the counter sheet is measured, providing a value for the degree of drying.) Figure 1.7-3 shows that the non-absorbing substrate 1 still displays a very high counter print density after 120 minutes – it has not yet fully dried. Penetration is improved by smaller substrate pore sizes.

Too high an absorption capacity of the substrate can cause the printing ink to deplete vehicles. The ink loses brilliance and abrasion resistance and pigments can be wiped off. That is why papers with a good separation effect, that is, papers with a high *density of small pores*, are usually the optimum substrate for fine print results and for drying (e.g., art paper).

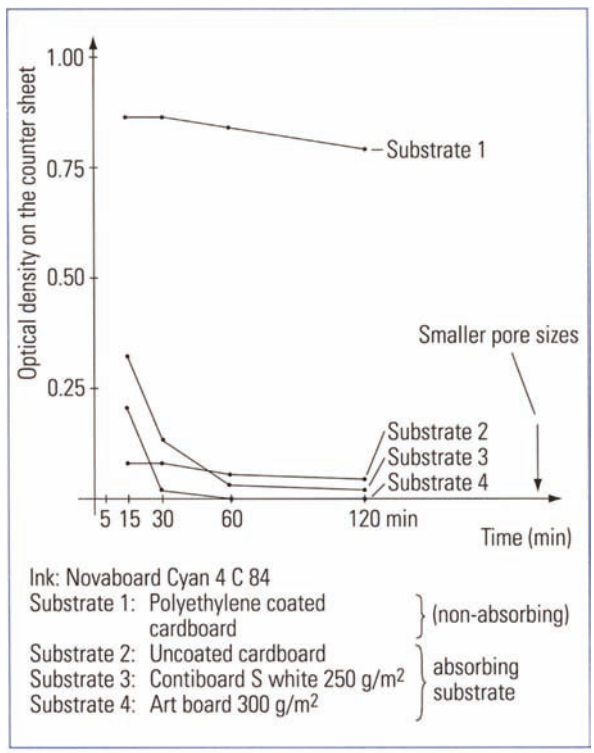


Fig. 1.7-3
Penetration behavior of ink (counter-print density) relative to substrate and time

Penetration depends on the absorption capacity of the substrate, but also on the viscosity (fig. 1.7-4) of the printing ink [1.7-1]. Absorbing speed also depends on the wetting behavior between the printing ink and the substrate.

In newspaper printing, *drying is effected by mere penetration* (coldset). The penetration process is carried out in a split second and the drying process is finished. Usually, printing inks used in newspaper printing do not contain drying oils (mineral oils). In cases where printing inks are used whose vehicles consist of drying oils, chemical drying by oxidation is triggered after penetration (see sec. 1.7.2).

1.7.1.1 Infrared (IR) Drying

Penetration of a printing ink is faster if the viscosity is low. Viscosity decreases when the temperature is raised. The transferred ink film can be heated up together with the substrate by using an IR radiation source (fig. 1.7-2). The IR drying effect in offset printing can be described in the following way:

- Lowering of the ink oils' *viscosity* by heating results in faster penetration.
- *Oxidation* in the warm pile is faster.
- Oxidation is accelerated by smaller *proportions of water* in the ink layer applied.

The chemical drying process (oxidation) following the physical drying process is also accelerated by a rise in temperature (see sec. 1.7.2).

The above processes are detectable in almost any kind of offset ink. Harmonizing IR radiation ranges and vehicle components absorbing within these frequency ranges helps to improve the effect of the radiators. Optimum effect of an IR radiator is achieved if maximum energy of the radiator and maximum penetration of the printing ink (or the varnish) coincide.

Wave ranges of the IR spectrum within the electromagnetic radiation spectrum are shown in figure 1.7-5. Infrared radiators are used in the following ranges of wave length:

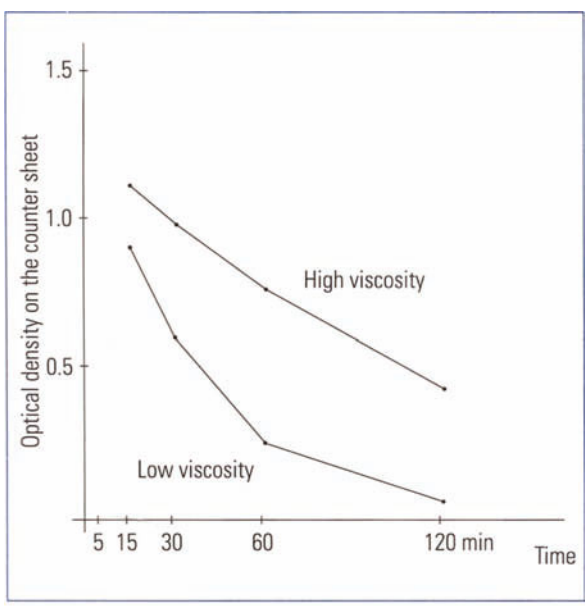


Fig. 1.7-4
Penetration behavior of ink (counter-print density; see also fig. 1.7-16) relative to ink viscosity and time

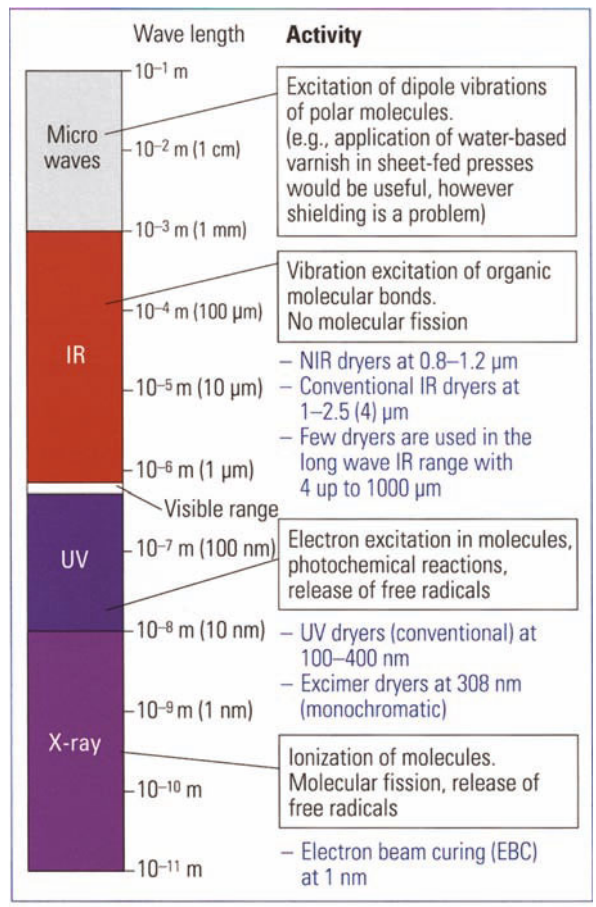


Fig. 1.7-5 Electromagnetic radiation spectrum for ink drying

- *short-wave* (0.8–2 µm, corresponding to a spiral-wound filament temperature of 2700–1500 °C), radiation penetrates mainly into the paper;
- *medium-wave* (2–4 µm, corresponding to 1500–750 °C), the air is heated mainly above the ink layer.

Experience has shown that optimum *absorption of ink* is achieved with short- or medium-wave IR radiators. Moreover, the short-wave radiator has a higher G-value (radiation efficiency). The so-called NIR dryers (near infrared, 0.8–1.2 µm) work in the lower short-wave range. Due to low efficiency, long-wave radiators (4 µm to 1 mm) are not suitable for offset drying.

As penetration is particularly important for fast drying, IR drying is most effective only if absorbent substrates are printed on. Figure 1.7-6 gives a description of the *IR radiation effect* on the penetration behavior.

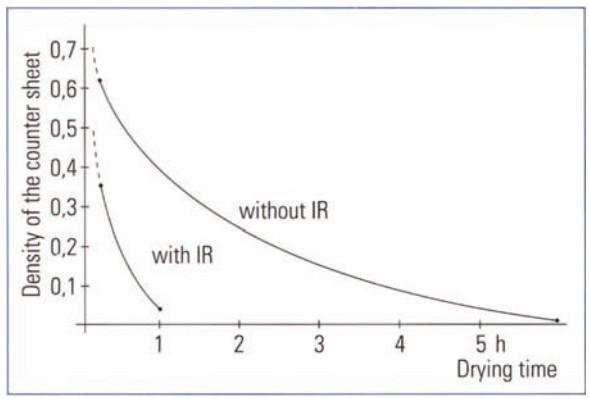


Fig. 1.7-6
Influence of IR radiation on penetration behavior (sheet-fed offset ink on coated paper)

The IR radiator heats unprinted areas in the paper, too, which results in an increase in the *pile temperature* (up to 40 °C) and an advantageous faster polymerization (see sec. 1.7.1). The pros and cons of IR drying are summarized in table 1.7-1.

1.7.1.2 Evaporative Drying

The printing ink consists of several components such as resins, pigments, and solvents, the drying of which is achieved partly by *evaporation*. The following processes take place:

- conversion from liquid (solvent) into vapor state and
- eduction of steam generated or steam-loaded air.

As a rule, only as much heat should be supplied as is dissipated in the generating steam, regardless of the type of heat supply and bearing in mind the economic efficiency and the careful treatment of the product to be dried. This rule is to be followed particularly when designing a dryer for printing presses since the substrate should be heated as little as possible for known difficulties such as register inaccuracy, variations of the visco-elastic properties of the substrate, and warping. The solvent evaporates when a printing ink is dried by evaporation. The drying process is determined by the *heat and material transport* in the boundary film on the surface of a liquid (printing ink).

The surface temperature, and above all the air speed along the substrate surface as well as the partial pressure difference are the main parameters for the *drying speed* [1.7-2, 1.7-3]. Drying by evaporation is accelerated by additionally enforced convection. Therefore, heating via heat radiators and/or hot air is to be com-

Table 1.7-1 Pros and cons of IR drying

Pros	Cons
Faster penetration of the printing ink resulting in more favorable pile behavior with respect to ink set-off	Higher investment leading to a higher hourly rate of the press due to the installation of the IR system
Considerably faster final drying	Higher energy consumption
Lower powder consumption for spraying the printed sheets before they are delivered in the pile, resulting in better print quality and less dirt accumulation in the press	Increased temperature in the machine as well as in the press room
Print finishing is made easier by less powder application	

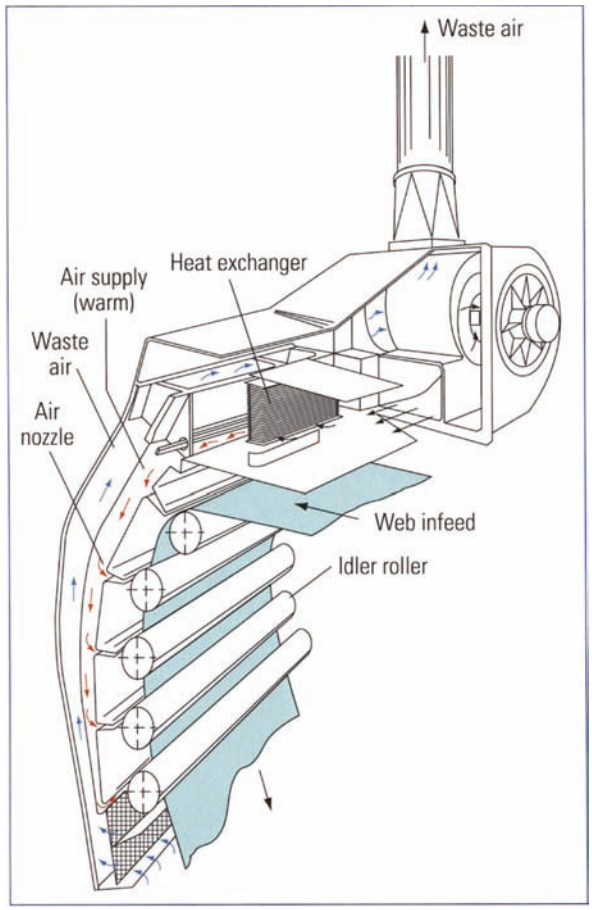


Fig. 1.7-7
Vertical blast dryer (with single-sided drying) in a web-fed gravure press

bined with optimum air conduction. Figure 1.7-7 shows a *vertical blast dryer* used for gravure printing.

This dryer is optimized with regard to aerodynamics. Such vertical blast dryers are used for drying printing inks containing low-boiling solvents mainly used in gravure and flexographic printing. The organic vapors generated are taken up via adsorption on activated carbon in solvent recuperative systems.

The supersorbon method (fig.1.7-8) for *solvent recuperation* [1.7-4] includes the following processes:

- *Charging (adsorbing).* Air containing solvent is extracted by a fan at the evaporation points (e.g., gravure printing press, vertical blast dryer) and conveyed from the bottom upwards by one or several adsorbers filled with activated carbon. The solvent is adsorbed by the activated carbon. Solvent-free air penetrates at the top (fig. 1.7-8). Charging of the adsorbers is continued until it "breaks through," that is, until the vapors are no longer sufficiently adsorbed.
- *Regenerating (desorbing).* Extracted activated carbon is regenerated in reverse exhaustion flow direction by way of desorption with water vapor. The activated carbon is heated to a little over 100 °C; the solvents – including higher-boiling point solvents – are vapor-expelled. They condense in the water of the container and can now be separated from the water and become reusable.

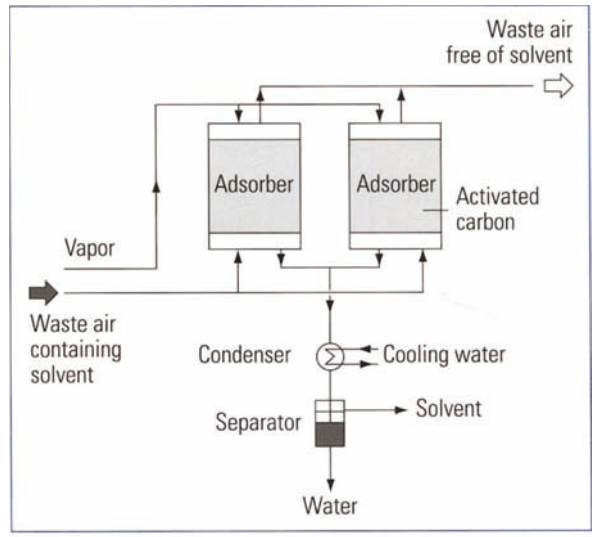


Fig. 1.7-8
Flow chart of the Supersorbon method (simplified representation) (Lurgi [1.7-4])

Heatset Dryer

Unlike gravure printing, printing inks used in *web offset* contain a high portion of high-boiling point mineral oils (heatset oils). Low-boiling point oils cannot be used as such printing inks become dry on the rollers while the ink is transferred in the roller-type inking unit. Heatset inks used in web offset contain between 20% and 40% high-boiling point mineral oils. Therefore, appropriately adapted evaporative dryers are to be used in web offset.

"*Suspension dryers*" (fig. 1.7-9) are mainly used as drying units in web offset (see also sec. 2.1.3). The web is routed contact-free through those dryers without guid-

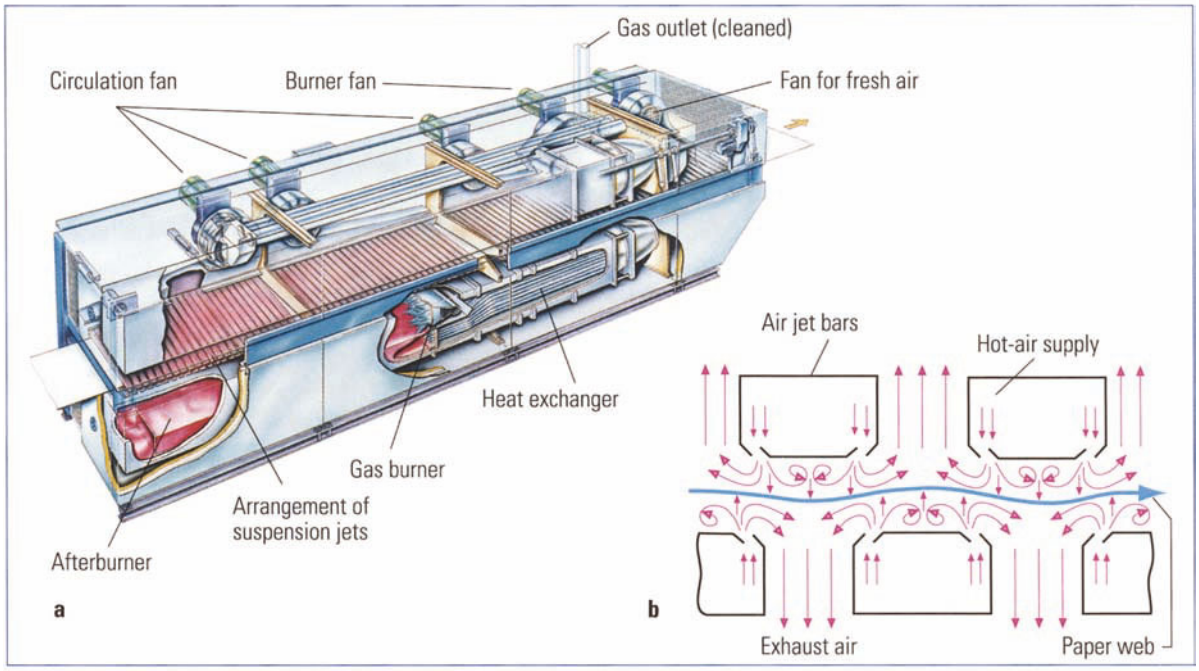


Fig. 1.7-9 Suspension dryer for web offset presses.
a Sectional drawing;
b Web guidance with suspension jets (Ecotherm, Heidelberg)

ing elements. This is achieved by a well-directed blower stream in the hot-air dryer. Floating dryers are roughly classified according to the type of air stream applied to the surface of the web of fabric. They all have in common that the web is conveyed at high speeds through the dryer without it contacting any surface. A web that is transported in such a way demands high standards regarding method, mechanics, and control engineering in order to achieve optimum and economic drying and a smooth production flow. The waste air is directed via an after-burner. The heat generated during combustion is used again to heat the dryer.

1.7.1.3 Problems in Practical Operation

In general, physical drying is influenced by various parameters. The following examples will illustrate this:

- Drying becomes more critical if the *penetration speed* decreases, or if the ink application increases in the image, or if the grammage of the substrate increases.
- *Blistering* may occur with high grammage, double-coated, and heavily calendered papers. Water vapor penetration capacity is reduced to a minimum due to the surface densification. High ink application might cause the temperatures to rise so high – particularly with short dryers – that the water vapor generating in the paper partly splits the paper, which in turn results in blisters and a large number of waste sheets. The temperature of the dryer and the print speed are then reduced.
- Drying is dependent on the speed at which the paper web passes through the dryer. The temperature of the dryer should be set according to the paper grammage: the higher the *grammage*, the higher the temperature. In order to achieve sufficient drying, the paper web needs to remain in the drying area for 0.8 to 1 second. If the paper web is conducted at a speed of 8 m/s, the dryer needs to be at least 8 m long. Drying systems therefore require considerable space. Due to dehydration, the paper web can become fragile and wavy and starts shrinking. Print finishing thus becomes more and more difficult. For this reason, *remoistening* with water is recommended for web offset printing presses. The water can either be sprayed onto the web or applied by rollers.

1.7.2 Chemical Drying/Curing

1.7.2.1 Oxidation

In offset printing on absorbing substrates, inks first dry by penetration (see sec. 1.7.1) and then by oxidation and polymerization. Final drying of the printing ink film is effected only by oxidation and polymerization of the drying oils and resins. The printing ink film receives appropriate cross-linking and consistency against rubbing-off and abrasion, it has, however, to preserve adequate elasticity for the product to be used.

Oxidative drying of offset inks containing drying oils is effected without additional units by molecular linkage with oxygen from the air. For that, the ink layer on the sheet to be linked should be supplied with sufficient oxygen in the delivery pile. The necessary space between the sheets can be increased by *powdering*, and oxygen can then diffuse in the piles. Powdering serves to support drying in the pile, and also to avoid smearing the image on the underside of the top sheet.

Even though accelerated by *catalysts* in the printing ink, drying by oxidation takes quite a while. Metallic soaps, that is, cobalt or manganese combined with oil-soluble acids, are used as catalysts.

Cobalt driers in the ink are "surface driers", that is, the drying process is started on the ink surface and slowly proceeds to the substrate. *Manganese* functions as a through-drier. Frequently, *compounds* are used as driers guaranteeing a straightforward drying process. There is an optimum quantity of *drier additive* for every ink/substrate combination. Adding too much additive can cause the ink to dry on the rollers of the inking unit. Transfer of ink onto the substrate is then likely to be disturbed.

Parameters influencing printing ink drying are:

- in the printing ink: pigment, vehicle, drying agent;
- in the substrate: pH value, coating composition, penetration behavior, water absorption, temperature in the delivery pile;

and in offset printing:

- dampening solution with: pH value, water salt content, water hardness, alcohol percentage.

Figure 1.7-5 shows the relevant spectrum of electromagnetic waves specific to ink drying. The IR radiation is of no direct significance for chemical (oxidative) drying. It is merely the elevation of temperature that brings about increase in reaction speed. However, UV radiation and ionizing radiation (electron-beam) in comparison produce radiation-linking chemical ink drying.

1.7.2.2 UV Drying/Curing

UV drying of printing inks (and varnishes) is based on radical polymerizable vehicles. UV inks with appropriate UV dryers are suitable for sheet-fed printing presses and web presses. Drying between the print units – inter-unit drying – (fig. 1.7-10) can be used to prevent a reversal of the ink splitting in the following inking unit. In flexographic and gravure printing, drying has to be carried out after each inking unit (e.g., straight (recto) printing and perfecting) because of the ink properties (ink trapping, etc.). Very often an overall drying becomes necessary after the last inking unit, possibly at a higher output rate.

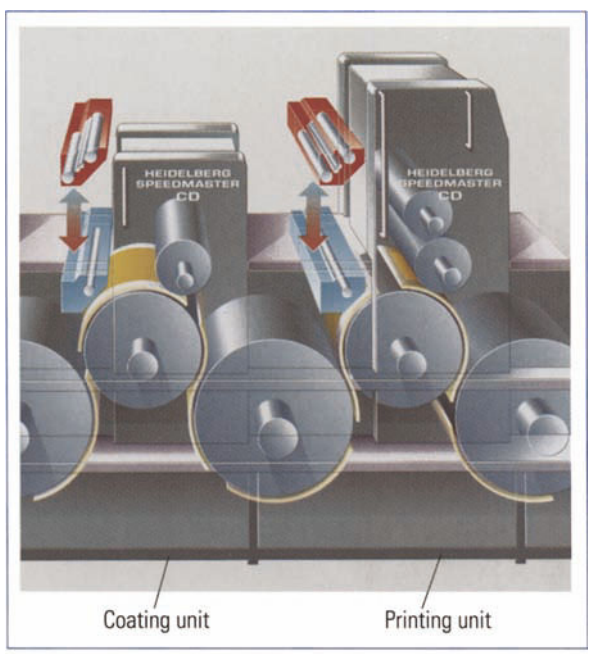


Fig. 1.7-10
UV inter-unit dryers for sheet offset printing press after printing unit and coating unit; UV dryer (blue) can be replaced by IR dryer (red), (IST Strahlungstechnik metz)

In case of UV drying, the ink film polymerizes and dries completely as soon as radiation occurs. Polymerization takes fractions of a second. The UV drying method, however, requires *special inks* containing completely different binders (vehicles) and additional photoinitiators (see sec. 1.5.2). The color black prevents UV radiation from penetrating in the ink layer and the curing effect is less than with chromatic colors or varnishes.

Conventional UV dryers work with one or several *mercury vapor lamps* (fig. 1.7-11, see also fig. 2.1-61). The wave length range lies between 100 and 380 nm. The system is enclosed by a reflector housing. Optimum cooling and extraction of generated ozone is necessary for the complete system. The units are designed in such a way that the permissible threshold limit value of 0.1 ppm (parts per million = one millionth of the volume of the substance in question, e.g., air) is not exceeded and damage (e.g., irritation to the mucous membrane) to one's health is prevented.

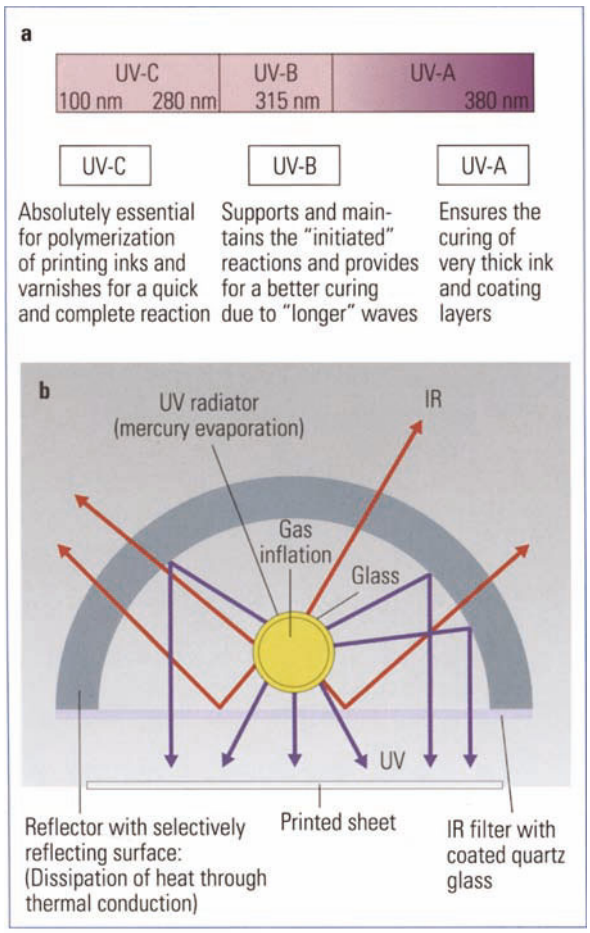


Fig. 1.7-11 UV drying system.
a Ranges of the UV spectrum and their effect;
b UV radiator reflector system (Dr. Hönle)

Excimer

The excimer radiator is a special type of UV lamp (fig. 1.7-12) with monochromatic light (mostly used with a wave length of 308 nm). Advantages of this radiator include:

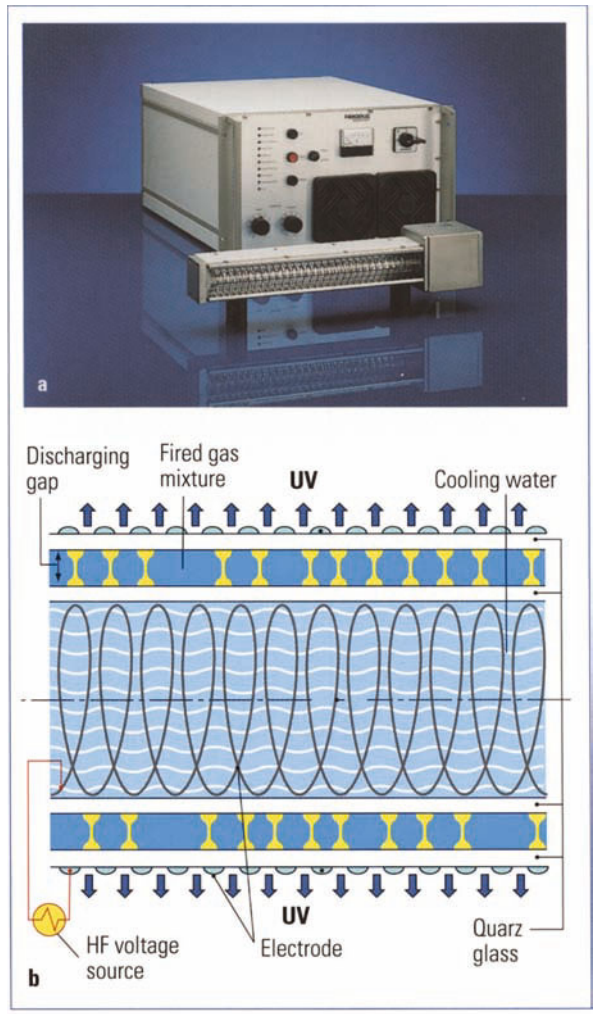


Fig. 1.7-12 Excimer radiator.
a Excimer system with radiation unit and ballast;
b Structure of an excimer radiator (Heraeus Noblelight)

- no heating of the paper as radiation does not involve any IR,
- no ozone generation at 308 nm,
- better utilization of electrical susceptibility for the drying process.

The disadvantages are:

- The power (up to 50 watts/cm radiator length) of today's excimer radiators is still considerably lower than the power density of mercury vapor lamps (up to 250 W/cm). If radiation takes place in an inert gas atmosphere (e.g., nitrogen), it will still result in the desired drying performance.
- The ink photoinitiator system needs to be adapted to the particular wave length. Conventional UV lamps are polychromatic and therefore cover a greater bandwidth of photoinitiators.

Excimer dryers are particularly interesting for flexographic printing in association with the printing of heat-sensitive substrates (e.g., foils). The pros and cons of UV drying are summarized in table 1.7.2.

1.7.2.3 Electron Beam Drying/Curing (EBC)

Electron beam is an *ionizing radiation* of such high energy that molecules in the vehicle of a printing ink are ionized, thus causing the release of free radicals. Today, electron beam drying is used with particular print products (e.g., food packages, due to the absolute drying of ink and the destruction of any micro-organisms in the substrate). Appropriate drying systems and inks are comparatively expensive.

In principle, the same vehicles and inks can be used for EBC and UV drying. Owing to high energy, a sufficient number of initial radicals are released in the vehicle itself; therefore there is no need to add expensive photoinitiators (resulting in better storage stability of the inks). It is, however, absolutely essential to use radiation in an inert gas since the presence of oxygen not only considerably impedes curing, but also leads to a radiation-induced, oxidative degradation of the ink layer and, possibly, of the substrate. If oxygen is excluded, the dose of radiation required for drying the ink layer only causes minimal damage.

With electron-beam drying no unwanted high heating of the substrate or the printing ink layer occurs. Figure 1.7-13 shows the possible arrangement of radiators.

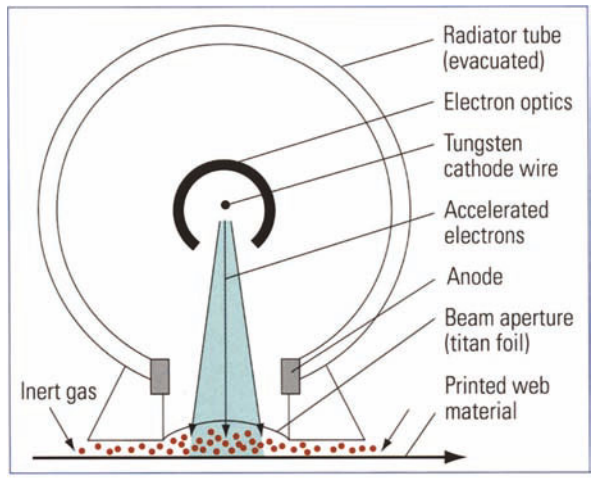


Fig. 1.7-13 Principle of electron-beam tube (MEC)

Table 1.7-2 Pros and cons of UV drying

Pros	Cons
UV inks are completely dry upon radiation	Higher capital investment due to accessory equipment
No damage to the prints by ink set-off or sticking	Higher costs for printing inks, washing agents, etc.
Immediate print finishing is possible (e.g., trimming, scoring, stamping, punching, etc.)	Relatively short service life of UV lamps
Printing on non-absorbent substrates (metal, foils) is not difficult	Less suitable for absorbing substrates
	Fogging/misting (due to the rheological properties of ink, e.g., tack) with UV offset inks results in a limiting of the printing speed

Table 1.7-3 Pros and cons of EBC drying

Pros	Cons
Immediate drying Radiated product stays cold	High investment costs X-radiation shield is a "must"
Simultaneous drying of both sides in recto/verso (perfecting) printing and radiation only from one side of the substrate (not possible for tin or metallic foils)	Radiation inside a protective atmosphere (e.g., nitrogen)
	Substrate is likely to get damaged if the radiation dose is too high
	Higher cost for printing inks

An electrically heated tungsten ribbon serving as an electron-beam source is admitted to the web.

The pros and cons of EBC (electron beam curing) drying are summarized in table 1.7.3.

1.7.3 Auxiliary Drying Techniques

As described in section 1.7.1, the drying process in conventional letterpress or sheet-fed offset takes place in two steps: penetration, followed by oxidative polymerization of the printing ink.

The penetration process is effected immediately on ink transfer in the printing zone. Penetration provides higher viscosity for the ink film lying on the substrate. Quite often, however, this hardening effect is not enough to avoid set-off effects and, in extreme cases, complete blocking (sticking) of the paper in the delivery.

1.7.3.1 Powder Spraying

The printed sheets in the delivery are *powdered* to avoid set-off or blocking effects (fig.1.7-14). The fine powder layer is distributed by compressed air, thereby preventing the ink of the freshly printed sheet from getting too close to the reverse side of the top sheet (fig. 1.7-15, see also fig. 2.1-56 for powdering on both sides with perfecting jobs). The colorless (white) powder grains serve as "spacers" ensuring oxidative drying by inclusion of air. These grains lying on the printed sheet provide an air cushion between the individual printed sheets. Grain sizes vary from 15 to 75 µm (material: colorless mineral or vegetable based substances). As a general rule one can say that

- the rougher the substrate, the more coarse the grain should be,
- the thicker the ink layer, the more powder is needed.

Incorrect powdering can seriously affect the usually good print quality, in particular with regard to gloss.

Mineral and vegetable based powder types are classified as:

- *Calcareous* (mineral-based) spraying agents available in different graining. They are essential for cardboard printing.
- *Starch-containing* (vegetable-based) products based on corn. They are available in fine graining only and therefore suitable for processing papers of up to around 100 g/m² only. Since they are not as hard as calcareous agents, ink abrasion is considerably less.

The printing plates, too, are less affected by abrasion through soft (vegetable) powders. In multicolor printing, calcareous (mineral) powders deposit on the rubber blanket in the form of dust acting like sandpaper against the printing plate, thereby considerably reducing its service life.

1.7.3.2 Silicone Application

Coating the web in a commercial web offset press with a thin film of silicone oil-in-water emulsion prevents the products getting smeared in the folder. After printing, the ink beneath the silicon layer is not fully dry even after a few days and may still be smudged after the silicon layer has been rubbed off.

1.7.4 Measuring Techniques

The finishing of freshly printed sheets in particular requires sufficient abrasion resistance and pile resistance (no offsetting and blocking of sheets). For basic balancing between ink and substrate regarding ink

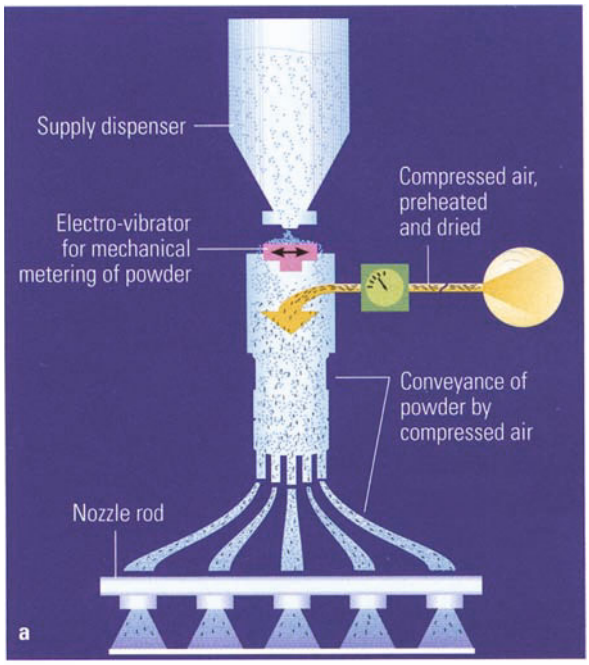




Fig. 1.7-14 Powder sprayer.
a Spraying principle, vibration metering system (Grafix);
b Installation of a powder sprayer in a sheet-fed offset press (see also fig. 2.1-56) (Heidelberg)

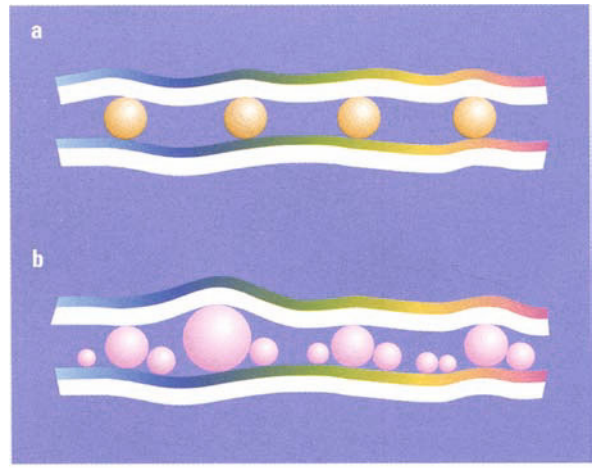


Fig. 1.7-15
Anti set-off powder as a spacer between sheets lying on top of each other.
a Perfect, almost mono-disperse distribution of granular sizes: even application;
b Spread distribution of granular sizes resulting in dust production and uneven sheet set-off

absorption and drying behavior, testing presses are used before the job is produced.

The test printing system as shown in figure 1.7-16 is especially suitable for systematically determining the drying behavior of a printing ink/substrate combination. The test printing system is equipped with two printing units. Printing on the test paper takes place in the first unit. The second unit is designed in such a way that the freshly printed sheet is passed through the "printing zone" together with an unprinted counter sheet; in this process the freshly printed and not yet dry ink is reproduced on the unprinted paper strip. This action is repeated several times.

The optical ink density of the counter sheet is measured after counter printing. The drying process is regarded as finished when the optical density tends towards zero, that is, when no ink is transferred from the printed sheet onto the counter print sheet in the printing zone of the second print unit.

Drying tests. There are numerous methods that can be applied to test the drying behavior. However it is not easy to infer actual drying behavior in an offset printing press by means of tests. Laboratory test methods are therefore mainly suitable for predicting long-term drying behavior.

A test method has been developed to determine the *degree of drying* in a running web offset press [1.7-5]; however, it has not yet been accepted in practical operation. This test method serves to record short-term drying behavior. The principle of measurement is based on a consistency test of the printing ink transferred onto the substrate.

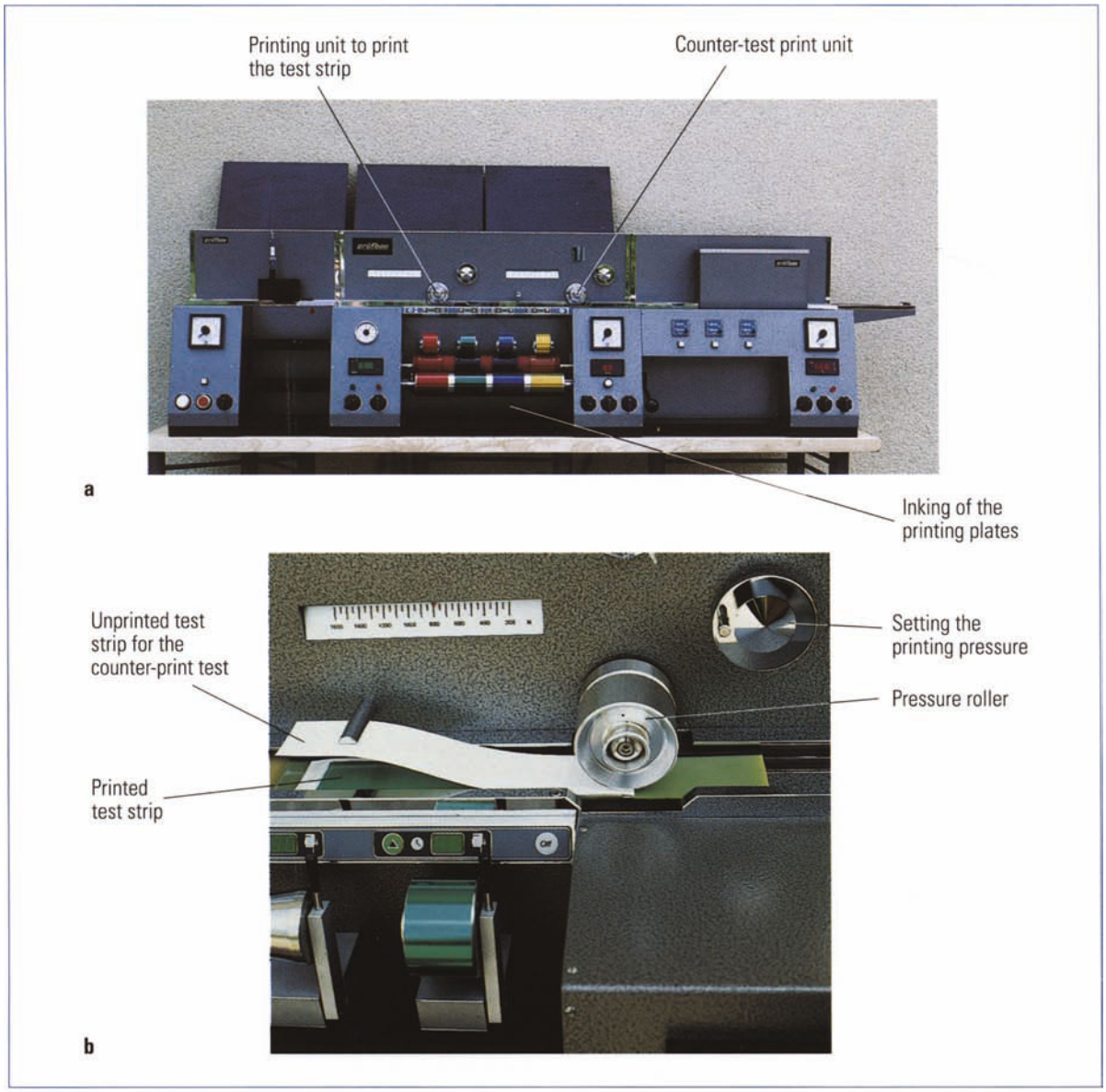


Fig. 1.7-16 Test printing system.
a Structure of the system;
b Unit for counter-print test (prüfbau Dr. Dürner GmbH)

The *consistency test* is done on a web offset press idler roller (fig. 1.7-17). A transparent plate is pressed against the paper web. The web is printed with small solid tone patches, for instance, on the image-free margin. If the ink film is not dry enough, each solid tone patch reveals a little smudging tail (that means the print would be damaged). This effect is detectable with electro-optics.

Electro-optical scanning records the translucency of the transparent plate at the point of contact between the plate and the paper web. If the ink film resists the

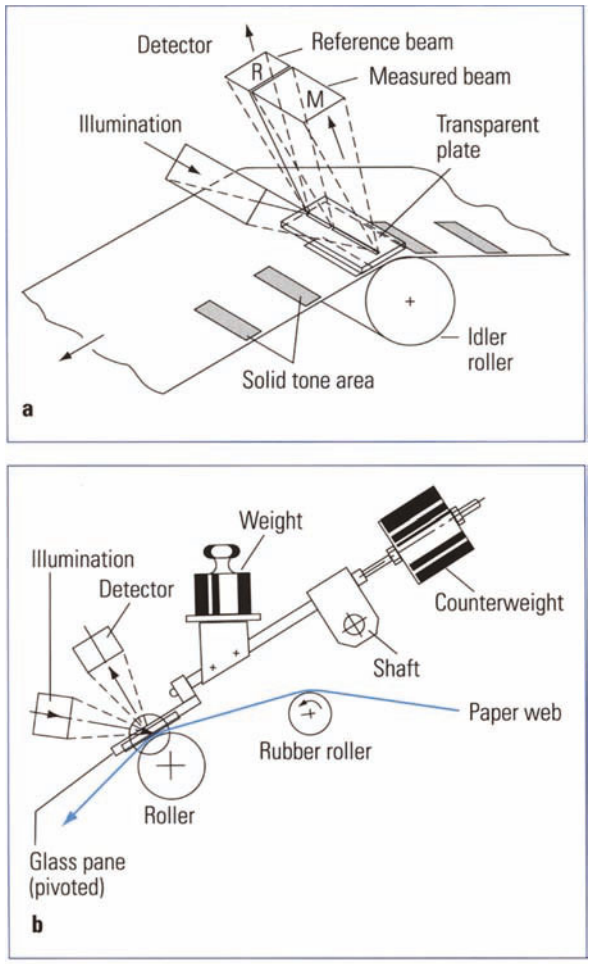


Fig. 1.7.17 Dynamic drying test device.
a Principle of measurement;
b Diagram of an optical measuring head

strain, the clean paper surface serving as white background area becomes clearly visible without loss of light between two succeeding test marks. Luminous reflection is then 100% (total reflectance). If the ink film does not resist the strain, the ink is transferred onto the contact area of the transparent plate thereby diminishing translucency and measured luminous reflection. The temperature of the dryer can be adjusted according to the measuring signal.

There have been no satisfactory solutions found yet for practical online measurement of the drying. For the most part, drying is controlled by visual and manual inspection carried out by the operator. Developments regarding measuring techniques are to be expected in future. It is essential to optimize/harmonize the substances involved.

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1.8 Products of Print Finishing

During print finishing and converting operations, printed webs, sheets, or any other substrate are given the shape and properties required for their use. (The term "converting" also comprises the production of products made of unprinted materials, which are then normally further processed in finishing.)

From the late Middle Ages to the beginning of modern times, written and printed works were bound into books by monks and later by craftsmen within their own trade. The splendor and craftsmanship in these books is as impressive as ever, as is their durability (if they have been looked after properly) and the variety and effectiveness of binding techniques employed. Besides converting printed paper into books, the bookbinders constantly utilized their processing skills and knowledge of materials to turn the materials they were used to working with into other goods.

Nowadays printing companies produce printed products that, to a great extent, are in no way intended to be "bound" into books. But they all still require make-up work before they can be presented to the customer. Therefore finishing ranges from simple sheet trimming, via diverse folding variants, simple completion operations and most versatile binding methods to the production of brochures and hardcovers. The latter products (among others) are classified in publishing terminology as "books," because it is the content and consumer group that is being considered rather than the actual structure of the product itself.

The variety of printed products in all areas of society is shown in table 1.8-1, which lists basic product groups by functional aspects and processing criteria. The table gives an impression of the abundance of products that are covered by the term "print finishing." This overlaps in some areas with the term "paper finishing" as such. Figures 1.1-1 and 1.1-2 also give an impression of the huge diversity of printed products. Besides printers, the main associates of the finishing industry are:

- *book publishers*, who undertake the preparation, planning and marketing of literary works (in short: published products);
- *newspaper and magazine publishers* as the publishers of short-lived, periodically published information and advertising (in short: periodicals);
- *trade and industry* as consumers of printed organizational materials and as distributors of promotional material and product descriptions as well as packaging material made from substrates;
- *public authorities and professional associations* as users of organizational materials and distributors of documents, securities, and so forth;
- *private households* as consumers of goods that have been produced by the finishing industry (in short: family products).

In printshops the term "job (commercial) printing" is usually applied to the sundry processing orders which do not require a special printing press, such as would be needed to print newspapers or packaging. In chapter 7 the products and their variants are categorized under technical aspects in product groups.

The end products of printed paper (or perhaps some other suitable substrate), which are briefly described below, are produced in finishing firms such as:

- "classical" binderies,
- finishing companies,
- packaging companies,
- finishing departments of multistage printing companies,
- mailing rooms and in-house printshops of large companies.

Sheets/Trimmed Sheets

A range of printed products with a small volume of information such as

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Table 1.8-1
Print finishing products (Examples)

	One-piece products	Gathered products	Bound products	Other products
Published products	Art reproductions	Music (notes) Loose-leaf compilations	Books (hardcovers) Pocketbooks Paperbacks Wall calendars	Art prints Maps Street maps
Family products	Postcards Patterns Boards Envelopes	Games Playing cards Sets of recipes Coasters	Coloring and handicraft books Exercise books Writing pads	Jokes Stamped figures Garlands Sanitary items Pop-up products
Organizational materials	Business stationery, Information sheets, Security papers Card files	Sets of forms Registers Official gazettes Manuals	Blocks of forms Calendars Telephone directories Cash books	Folders Files
Advertising products	Advertising sheets, Posters Placards	Mailings Brochures	Catalogs Company booklets, Operating instructions, Schedules	Large-scale advertisements
Periodicals		Daily newspapers, Advertising journals	Mass-circulation magazines Trade journals Hobby magazines Magazines	
Packaging materials	Labels Wrapping paper, giftwrap Blanks Covers			Boxes Cans All kinds of bags

- information sheets, note-paper, business cards, labels, but also
- banknotes, security paper, sets of stamps (possibly with consecutive numbering)

are given their final format by cutting the printed sheet on paper cutters (see sec. 7.2.1). One print sheet mostly contains several copies of the same end product. When producing with "collect-run", copies from different customers (mostly of different sizes) are printed on one sheet.

In cutting lines, the printed sheets are aligned in stacks (with 500 to 1500 sheets/stack) at the lay edges and processed in a (programmable) cutting sequence into end-product stacks. Processing modules/process elements which count the sheets per stack, wrap bands around the stacks, and which sort the end-product stacks into trays (folding boxes without lids) may be incorporated into the cutting line.

Folded Products

Folding (see sec. 7.2.2) is a very effective method of converting printed products, such as brochures, advertising sheets, and information sheets into a user-oriented end format.

Folding is the sharp-edge bending of webs or sheets of paper in accordance with specified dimensions and a pre-determined pattern (e.g., parallel and right-angle folding sequences). The folding layout (which is the basis for the imposition pattern) determines the posi-

tion of the pages on the sheet or on the web. Printed webs are folded in folding units incorporated in web-fed presses and printed sheets are folded in stand-alone sheet folding machines.

The structural design of the folding units/folding machines allows a large number of different folding layouts. Processing components that perform operations such as creasing, perforating, cutting, and gluing may be incorporated into folding units. This increases the use-value of the folded product. A banding unit to gather and pack products may, among other things, be installed in the delivery unit of folding machines.

Forms

Form processing plays a special role in finishing since these products sometimes require special units and production lines because of the features required by the bureaucracy/organization. The various types of forms are listed in table 1.8-2.

Continuous blocks of forms are usually finished in a separate process. After the printed sheets (and a bottom cardboard sheet) have been cut, the stacks are bound into blocks by gluing or in rare cases bound in a lateral wire stitching operation. Snap-apart sets have to be collated prior to gluing.

Continuous forms are finished in a web form printing press, which incorporates units for sprocket hole perforation, longitudinal and cross-slitting perforation, and accordion folding, as well as various additional functions (such as numbering, die-cutting, labeling). To produce sets of continuous forms, the webs have to be gathered and possibly attached together. Forms are usually packed and dispatched in folding boxes.

Newspapers

From the finishing point of view, newspapers are gathered products produced from folded signatures and usually different-sized inserts. They are characterized by the (mostly) daily publication of editions, high circulation, extremely short production times and splitting of editions into regional sub-prints. It is these conditions that define the mailroom technology (see sec. 7.3.2.3) as this print processing is called in the case of periodicals.

The newspaper's core products – several simultaneously printed "folded signatures" completed in a multi-web configuration in the folders (separating, gathering, and folding the web) of the newspaper printing press – are transported in a stream to the mailroom by chain conveyor systems. Here they are brought together with the preprints (also folded newspaper signatures) and inserts (in inserters) to form the newspaper. The newspapers might be addressed and stacked in bundles in compensating stackers. A packaging slip is added to each bundle or roll, which specifies the delivery modalities. These mailing units are distributed to the appropriate delivery channels and loaded directly into vehicles from there.

The core products (folded signatures) arriving in the mailroom have to be finished immediately into newspapers ready for dispatch. To this end,

Unit forms (blocks of forms)	**Snap-apart sets** (sets of forms)	**Continuous forms**	**Forms on carrier tapes**
Cash payment blocks and receipt blocks can be quoted as examples. The form consists of one page. The forms printed in multiple-ups are converted into blocks.	A set of forms means that the form has several sheets for the same transaction but the sheets have different uses (internal and external documentation of the transaction). Autocopying paper is used to copy the information onto the pages underneath. The sets are again bound into blocks.	Continuous forms are used in printers for DP systems. They have sprocket holes, so that they can be transported by a tractor mechanism into the printer. The paper web, which is formed into a continuous stack by accordion folding, is determined by the purpose. Continuous forms can be designed as sets of forms.	These forms are also used in printers for digital printing/ data output systems.They consist of a continuous, accordion-folded paper carrier on which various types of forms (e.g. snap-out sets, unit forms) and other printed matters (self-adhesive labels, identity cards etc.) are dispensed. A carrier tape set may comprise several consecutive sheets.

Table 1.8-2 Types of forms

- the units installed there must have a high capacity or
- several mailing units must be installed in parallel (mailroom cells);
- there must be emergency delivery sections and short-term buffers in the mailroom cells in case of stoppages during production;
- there must be an effective intermediate storage system for preprints and inserts (e.g., on the basis of folded signature reels [see 7.3.1.2]);
- production must be controlled by a powerful process computer that controls the sequence of the sub-editions (with various preprints and inserts), the volume, the distribution of the mailing units, as well as the allocation to the delivery channels.

Sheet Brochures

Sheet brochures, such as operating instructions, advertising brochures, wall calendars, and college notebooks consist of sheets collated into blocks, which are bound along the spine. Printing of the sheets is mainly done in sheet-fed offset presses. Binding is done:

- as perfect binding on small-scale perfect binders (see sec. 7.2.5.3 for information on perfect binding);
- by means of single-sheet binding systems, such as plastic comb binding, wire comb binding, or spiral binding (see sec. 7.2.5.1). For this kind of binding the block is trimmed to final size prior to binding;
- or by putting the punched blocks in files or folders (binding mechanism).

Single-layer Brochures

Single-layer brochures (see also table 7.2-11) are produced by insetting folded sheets which are then bound into a block. Mass-circulation magazines (see sec. 7.3.2.4), catalogs, and exercise books or even simple booklets/brochures (see sec. 7.3.2.7) printed in short print runs are examples of single-layer brochures. They are produced on production lines known as "gatherer-stitchers". The folded sheets are placed into one another. The block is bound by wire staples through the back margin (spine). This is followed by trimming the product (most commonly on three sides). The simple and at the same time safe procedure means this binding method is used for many product groups.

With production lines for mass-circulation magazines, equipment has to be incorporated for inserting and gluing small individual sheets, for instance, for tipping in postcards or inserting machines for advertising inserts, addressing units and so forth. Similar requirements to those of a newspaper mailroom apply for distribution of the magazines in the mailroom in the minimum period of time.

Single-layer brochures can also be bound by thread-stitched bindings, such as straight stitching or knotted thread-stitching (see sec. 7.2.5.1). However, these procedures are of only minor importance at the present time.

Multi-layer Brochures

To bind multi-layer brochures (see sec. 7.3.2.5), the individual folded signatures (or even already finished single-layer brochures) are placed on top of each other to form a block, collated (see sec. 7.2.4.2), and then bound. Mass-produced paperbacks, mail order catalogs, telephone directories, trade journals, and hobby magazines are typical representatives of multi-layer documents, as are operating instructions and company brochures, which are mostly processed in short runs.

The widespread use of this product group can be attributed to the simple and economical binding method. Production of these brochures ends with trimming. The predominant binding process is perfect binding. In perfect binding (see sec. 7.2.5.3) the spine of the collated and aligned block is ground away. Adhesive with good adhesion properties and a high level of elasticity is then applied. The back of the cover (which is to protect the block) is glued to the adhesive surface. After the adhesive's stabilizing period, the brochures are trimmed and packed.

Perfect binding lines with a nominal rated capacity of between 3000 and 18000 products per hour as well as manually operated small-scale perfect binders with nominal rated capacities of between 100 and 1000 products per hour are used, depending on the structure of the print job.

Thread-stitching and thread-sealing are alternative binding processes for multi-layer brochures that have to be very durable, as is the case with travel guides and specialized books.

Hardcovers

Hardcovers (see sec. 7.3.2.6, fig. 7.2-45) consist of a book block and a book cover. The book block is produced by binding several folded signatures. The cover (see sec. 7.2.8) is made up of several materials (cardboard, covering material).

Book production is a process in which printed webs of paper or printed sheets are converted into conven-

ient folded signature format. The folded signatures are gathered, bound into blocks, and given a binding in the form of a sturdy book cover, in the interests of practicality and in order to achieve an aesthetic form appropriate to the content. The separately produced cover serves primarily to protect the block but also as a carrier of information and advertising. The connection of block and cover and the finishing with inserts and/or a protective cover occur within the book assembling process. Hardcovers are mostly produced in editions of 3000–30 000 products/print run. Industrial processing is done in flowlines.

Mailings

Mailings (see sec. 7.3.2.2) are usually personalized advertising letters from mailing organizations or associations, which are dispatched by mail on a massive scale (sometimes by the million) to potential customers or members. The letters vary in content and mostly consist of several separately produced sub-products, such as sheets, folded products, back-stitched booklets, and samples.

To produce these mailings, pre-printed pages with identical content must be personalized (digital printing with computer to print systems), sheets have to be folded and if required wire-stitched, cards or items on sheets gathered, sub-products collated and put into envelopes, and the envelopes sealed. For economic reasons, mass production necessitates that the finishing equipment has a high level of automation. Since the nature of mailings can vary a great deal, the installation of invariable systems as used for the production of books is not always practical. In addition to the standard processing system, there has therefore been a tendency in these production fields to set up job-specific, flexible production lines with variably interlinking modules that can be separated again once the print run has been completed.

Packaging Materials

Table 1.8-1 gives an overview of common packaging materials produced during a print finishing process; in particular these are folding boxes, wrapping paper, labels, bags, and pouches. They are mostly produced on special finishing systems from sheet or web material. Both off-line and in-line systems are used.

The making of bags, pouches, and sacks and in addition the production of boxes in varying shapes are important. Production takes place on production lines, which can process different formats but are usually not able to process different types of packaging material. In some cases the packaging material produced on these production line machines will only receive its final shape in the actual packing machine (when making a folding box).

Summary

The most varied types of end products are produced in print finishing processes. On the one hand after the printing proper there is the print media in its manifold variations (books, magazines, brochures, etc.) and on the other there are commodities that can contain printed information (packaging, securities, forms, etc.).

The printed product in its final form is produced within the process chain of prepress, press, and postpress. This requires a variety of different processes, methods and production equipment, with the addition of further components such as book cases.

1.9 Aspects of Management and Business Models

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1.9.1 Production Options and Business Models

Creating *print media* is a diverse and often complicated process with very different information and material flows in the production process. Just as diverse are the demands on print products. As in other industries, such as the automobile industry, a distinct core function can be defined for the print media: applying permanent structures to material objects with the purpose of visualizing information. However there is a broad overlap with other industries and keeping the print media distinct will not be possible in the long term. It is above all the new opportunities arising from the use of computer technologies that open up completely new ways of mixing media. Figure 1.9-1 shows three important related industries that share certain market segments with the print media industry.

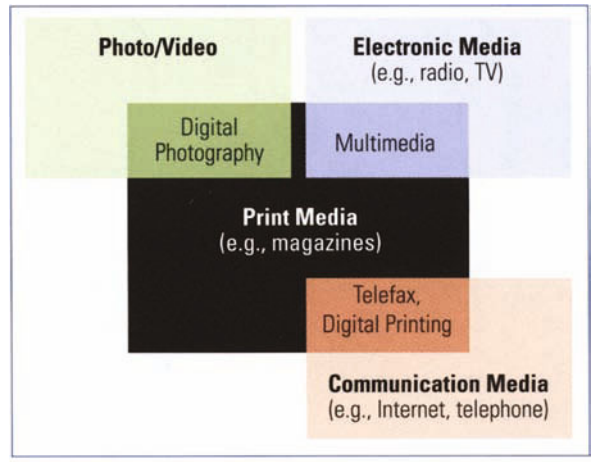


Fig. 1.9-1
Print media in the surrounding of information and communication industries

The assimilation of information has become a central function of human society. The *information* that people require is manifold and results in a broad diversification of print media. Print media can be classified by production technologies (e.g., gravure printing, sheet-fed offset, etc.), by distribution channels (e.g., newspapers on subscription, street sold newspapers, etc.), by customer groups (children's books, specialist books, etc.), by financing strategies (advertising literature, in-house printed matter, etc.) and many other criteria. Figure 1.9-2 shows a categorization of print media by the *function of the information*; there is on the one hand the type of information that may be purely graphic-oriented or character-oriented (mainly text) and, on the other, information having a direct functionality, or it may be more of a decorative character, that is, it can only be perceived as a pattern. *Product segments* and their market situation are shown in figure 1.9-3.

This extreme *product diversity* – scarcely found in any other industry – is reflected in the structures of the market. Unlike the car manufacturing industry, where

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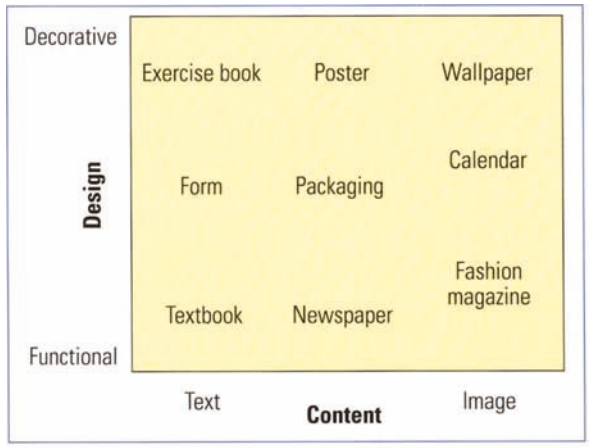


Fig. 1.9-2 Function of print media information

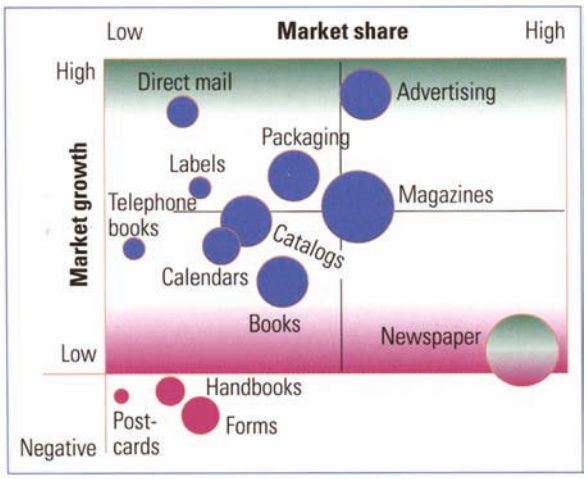


Fig. 1.9-3 Market portfolio of print media (MAN Roland)

most automobile factories are of a similar structure and only differ in the size and fittings of their products, companies producing print products are to a large extent heterogeneous: there are many small- and medium-sized companies in all the world markets (see also fig. 1.1-4) who have specialized in their own product portfolio and are holding their ground in the market with very individual concepts. When comparing the big media concerns with one another, it becomes apparent that these clearly differ with regard to market presence, financing strategies, value-added chain, and media-wide diversification.

Thus only a few basic aspects of *business models* in the print media industry can be recapitulated in the following. The combination of these models might differ from case to case in practice.

1.9.1.1 The Value-added Chain (Production Depth and Product Range)

The question of the position within the *value-added chain* (fig. 1.9-4) is of fundamental importance for the organization of print media companies. Positioning depends for one thing on the technical needs; however it is also a strategic decision. It is possible to specialize in a certain segment of the value-added chain and to cover a wide product range within this segment. The company will develop technology and market competence to distinguish itself through cost and quality leadership, capacity reserves, and so forth. An alternative is to cover several segments along the value-added chain. Such a strategy bears the potential of eliminating interface costs and of having a better influence on the degree of utilization of those production stages that are very cost-intensive.

The individual segments of the value-added chain are characterized by very different cost structures. Paper processing production is shaped by technical costs, which are characterized by other parameters at every stage of production.

The *printing segment* is characterized by high one-time investments in machinery. Here, too, the success of a business very much depends on sensible investment planning. Special attention must be paid to the tie-up of capital and the capital costs arising from this, alongside market development and availability of new machine technology. It might be beneficial for a company to use modern machinery that brings it productivity benefits, or it can meet requests for certain product variants. If the rate of innovation in new machines is not too steep, a production strategy with machines that are already depreciated may, however, be sensible too.

Production labor costs are the dominant cost factor in *finishing* due to the still relatively low level of automation. At this stage successful value-adding depends on cost-conscious use of labor and a sensible organization of production.

The *prepress sector*, which is nowadays mainly influenced by computer equipment, is characterized by the high rates of technological innovation in information technology. These result in very short depreciation cycles and require continual adaptation of the work

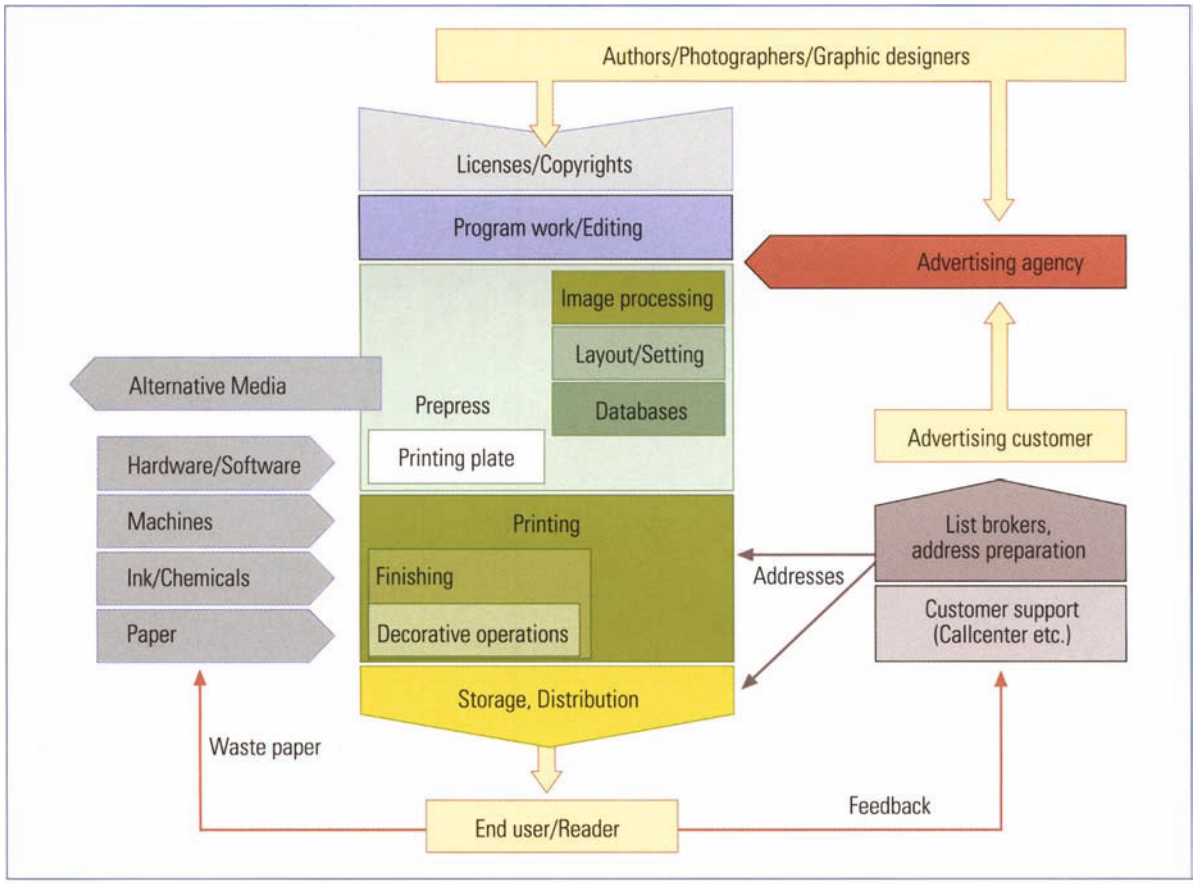


Fig. 1.9-4 Principal value-added chain for print media

processes to new systems, data format, storage media, and so forth.

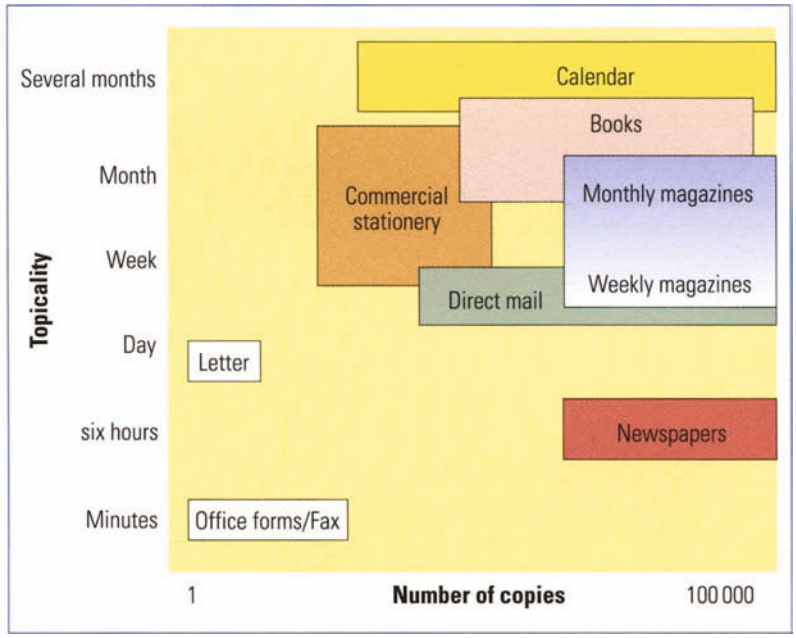
Program work, editorial work, and the *advertising agency* are segments of the value-added chain that are very much dependent on the creativity of the staff involved. Many technical innovations such as digital cameras and the Internet have certainly changed the way of working for staff here too, but the quality in terms of content of the respective print media, as well as the concepts regarding innovative forms of distribution continue to be critical to business success.

The processing and marketing of *licenses* and *rights* is gaining in significance in many product groups. This is reflected in the development, where information is gradually changing from a general cultural asset to a product, such that the value of the contents becomes a factor relevant to cost in the value-added chain.

For print media financed by advertising, the *feedback from customers* to the advertisers is becoming increasingly significant. Customer addresses are the most important vehicles of the value-added segments of this feedback channel. They are increasingly developing into qualified customer profiles.

One specific basic condition for decisions on the integration of value-added segments emanates from the *demand for topicality* on the respective *media segment* (fig. 1.9-5). The trend in all segments is for quicker publication, shorter runs, and thus shorter throughput times in production. Modern technologies certainly provide the means for faster production times; however, a multitude of system limits can also cause a delay in the production flow due to the coordination and correction processes required. Owing to the high demand in topicality of most newspapers, the whole pro-

Fig. 1.9-5 Topicality of print media



duction flow from editing to distribution is integrated within one system, while with books the value-added stages can generally be separated.

1.9.1.2 Financing and Distribution Models

Circulating *information* creates work and costs. For *distribution* all media can make use of the same basic routes of information, which are:

- The reader/customer seeks information, and is generally prepared to spend money.
- A person offering information (generally with information about products) seeks customers for whom his information may be of use. The supplier is prepared to pay to distribute his information (advertising).
- A special situation arises when supplier and reader form a unity (in-house media).

Since opportunities for technical product innovation are very limited in the established print media market, new *financing concepts* make up the bulk of new print media developments. Often the above-mentioned basic forms are mixed. They differ greatly according to region and are very dependent on the prevailing competitive situation. Just as in other media markets, print media is also undergoing progressive diversification as regards quality of information, where the reader is offered free products financed by advertising and high-priced products.

Figure 1.9-6 compares the costs per copy dependent on run length for different printing technologies.

The *cost structure* for the individual print products is of course decisive for the financing concepts, too. Above all in conventional print media, a reduction in cost is very much dependent on the run length. Alongside non-recurring costs such as machine makeready time and platemaking, material is an important factor in the costs. In the case of long print runs, the production costs for print media are defined by the price of paper: 25% for small book editions (fig. 1.9-7), up to 70% for advertising. For short print runs, especially when digital printing technologies are used, machine costs in relation to material costs (paper and ink costs) play a role (fig. 1.9-8). Unlike electronic media, print media cannot make use of financing models in which part of the technical costs is directly borne by the end consumer. With television, for example, the user himself bears 90% of the overall technical investment required.

The high proportion of material costs in the overall cost of print media means that in the case of high print volumes, there is a substantial *burden of advance financing*, as the printed products are only sold gradually

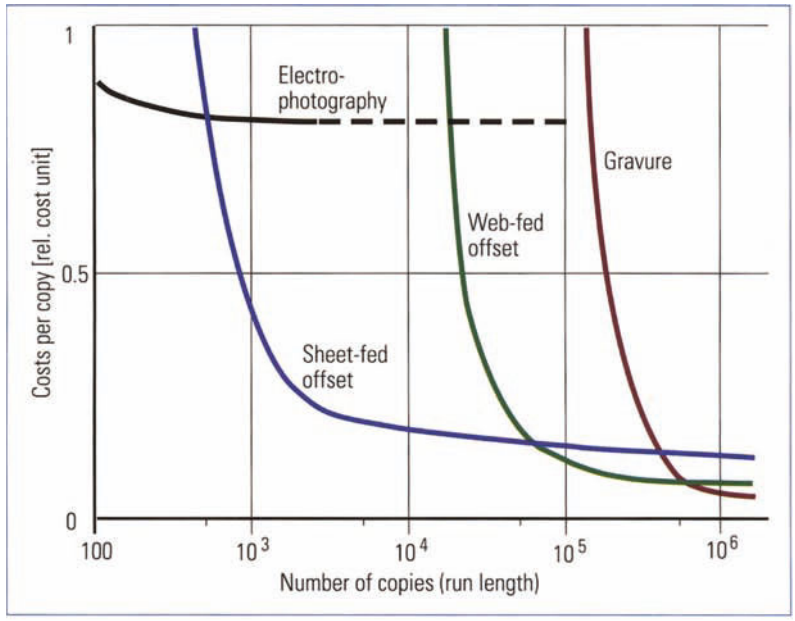


Fig. 1.9-6
Comparison of costs per copy (dependent on run lengths) of different printing technologies, multicolor prints (rough trends)

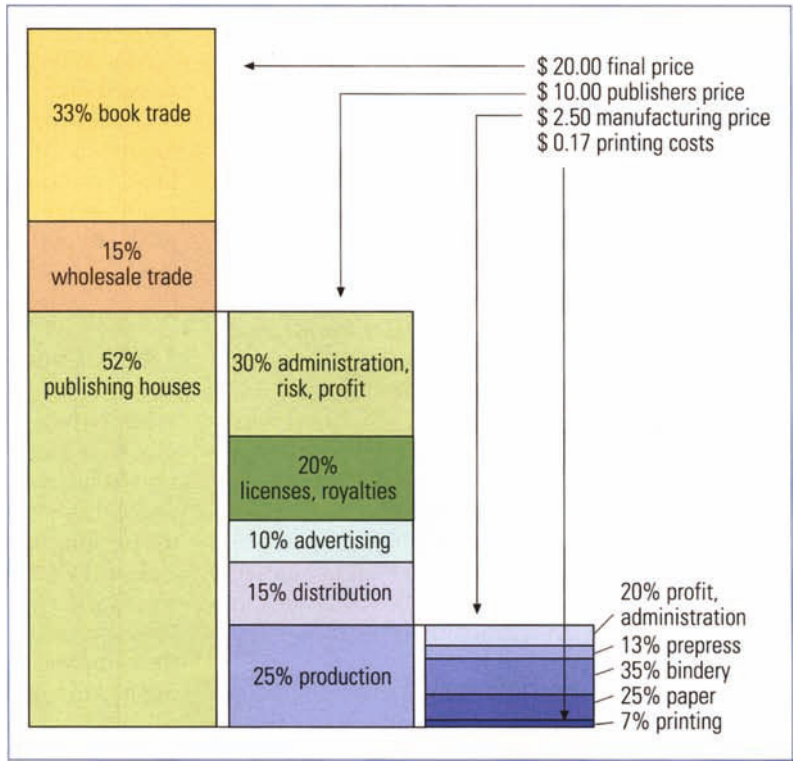


Fig. 1.9-7
Example of cost structure for books (typical B/W book with hard cover, run length 5000, 380 pages, cover, A5 size)

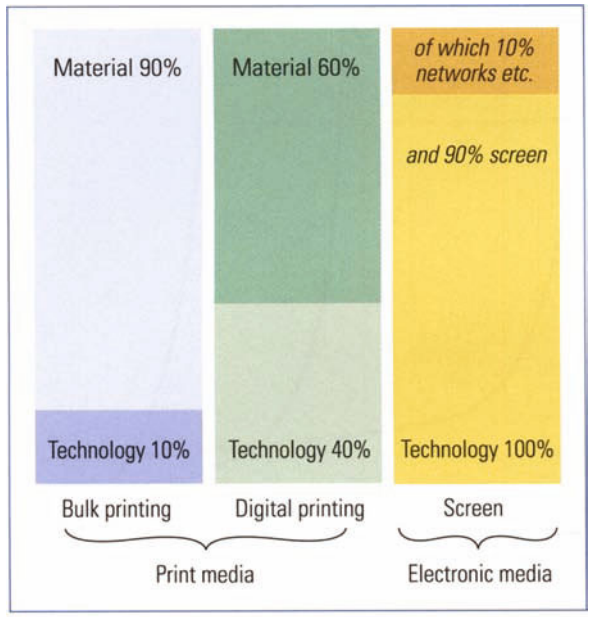


Fig. 1.9-8
Cost structure for media production (investment in material and equipment)

and in the case of books it might take years. Besides the program work and editing, this function of advance financing and risk coverage has remained one of the main tasks of publishing houses. This represents an essential door-opener for digital printing technologies, which provide the means for printing on demand (see sec. 9.1.3).

For the reasons given, the *distribution scheme* for the share of the cost borne by the reader has a decisive influence on the financing model. Traditionally independent forms of distribution have developed for individual print media groups, for example retail selling via newspaper kiosks or the book trade and subscription systems for newspapers and magazines. The distribution costs represent a considerable proportion of the final sales price (fig. 1.9-7). The final sales price is mainly determined by the amount of capital tied into the book trade and in general by the risk of slow-moving articles.

To work around these problems there are book clubs in the book trade that can significantly reduce the entrepreneurial risk and the amount of tied-up capital by means of their balanced program policy and limited product range, as well as their direct approach and link to the customer. Further forms of distribution are the mail order book trade and, increasingly nowadays, the Internet book trade. General magazines and lately also standard book titles are marketed as consumer goods through alternative regional distribution organizations such as gas stations and supermarkets.

1.9.1.3 Media Business as a Technical Service

Although print media are not directly driven by technological development to the same extent as electronic media, there are many potential ideas, particularly in the areas dependent on computer technology, for offering print media business mainly as a *technical service*. The opportunities with desktop publishing, digital photography, and so forth, enable totally new customer groups to generate and layout information themselves. Although this makes some business fields in the traditional publishing and prepress segments of the value-added chain redundant, there is on the other hand a totally new requirement for technical services such as graphics databases, address and dispatch services, as well as so-called "Internet-Printshops," where print jobs arrive via the Internet and are then printed digitally.

As a consequence the content and design aspect of printed matter is increasingly being handled separately and independently from the actual technical implementation, for which the respective specific technological competence is then sought. The requirement for multiple processing of data in very different output media in particular requires completely new business models and divisions of work (see sec. 1.2.6, Premedia).

1.9.2 Coordination of Workflows

With the increasing complexity of internal production processes and of external customer and supplier relations it has also been necessary to develop systems and concepts for coordinating and handling workflows in the printing industry. Some of these concepts were taken over by other sectors of industry and have led to a large variety of similar established models. In the following you will find a description of a few examples of these approaches that have to some extent been implemented in the printing industry.

1.9.2.1 Lean Production and Lean Management

The organization of the internal production processes of a printshop should primarily ensure high productivity, short throughput times, and maximum product

quality. These requirements can only be attained by motivating and leading employees adequately. In particular, the Japanese industry has developed an approach which can be summed up in ten basic principles:

1. the continuous improvement process called "Kaizen";
2. the team's own sense of responsibility;
3. immediate error tracing and elimination;
4. simultaneous product and process development;
5. short in-house channels and "Just-in-Time";
6. identification with customers' needs;
7. the engagement of sub-contractors;
8. product flexibility in spite of automation;
9. the improvement of work tools in small steps;
10. standardized working with "Kaizen".

The Japanese word "Kaizen" means nothing more than striving for continuous improvement (*kai* = change, *zen* = good, for the better). It must be looked on as a kind of "scout's promise" to do a good deed for the community every day, the community in this case being the company. Of course, this requires identification with the company, which the Japanese have to a high degree, possibly supported by a guarantee of lifelong employment. "Kaizen" has little in common with the suggestion schemes common in the West, because it is based on a sense of moral obligation and not financial remuneration. It is the unspoken minimum obligation for an employee to become accepted in the company.

As far as the team's own responsibility is concerned, the following core ideas for team work in the group apply [1.9-1, 1.9-2]:

- The team thinks more in terms of the collective than the individual.
- Teams put pressure on and increase motivation.
- The team absorbs more information, identifies more problems.
- The problem-solving capacity is greater than the sum of skills of the individuals.
- Increased communication output from the team as a result of increased two-way communication.
- The team saves the cost of support through self-management.
- The team instantaneously balances output surplus and uncovered demand.
- The team gives personal support in the event of failures, but also requires that personal reputation be secondary to group benefit.

Teamwork can be considered the organizational work core of the Lean Production concept, when it is said: "In the end it is the dynamic working team that emerges as the heart of a lean factory. Building up an efficient team of this type is not easy. First of all the members of the team must learn numerous skills through job rotation – in fact, all the work tasks within the team, so that the job allocation can be changed and the workers can stand in for each other. They also have to acquire other additional skills such as simple machine repair, quality inspection, cleaning, and material provision. They must be stimulated in the direction of active, even forward-looking thinking, so that they are able to find solutions before problems become serious."

Another feature of Lean Production is the shortened development and process planning time achieved through overlapping work of otherwise successive departments (fig. 1.9-9).

The technical term for this is: "Simultaneous Engineering." It requires that all information on the development situation in connected departments be made transparent, because everybody's task is focused on the end-product and not on semi-finished part-products. As far as the engagement of subcontractors is concerned, the Institut für Angewandte Arbeitswissenschaften (Institute of Applied Work Sciences) in Cologne has drawn up a list showing four essential features that characterize the relationships between a "lean" company and its suppliers:

- *Reduced number of suppliers*
  - vertical structure: the manufacturer alone contacts the main, or level-one, suppliers, who in turn contact the level-two suppliers, and so on;
  - allocation of orders for entire component systems.
- *Information exchange*
  - exchanging personnel in the development section;
  - joint cost analysis and fixing of supply prices (Value Engineering);
  - disclosure of production methods;
  - the manufacturers announce production volume changes in good time;
  - feedback on supplier performance (quality).
- *Partnership relationship*
  - outline agreements on business relationships;
  - joint responsibility for costs;
  - agreement on cost reductions to be achieved annually, savings achieved by additional effort on the part of the supplier remain with the supplier;

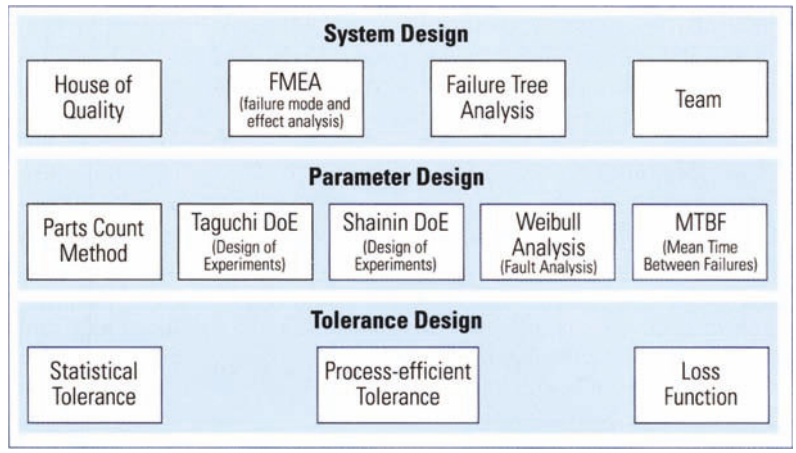


Fig. 1.9-9
The Simultaneous Engineering tools (Steinbeis-Transferzentrum Qualitätssicherung Ulm, [1.9-6])

  - freedom in design changes within the scope of the function specifications;
  - support with production problems;
  - mutual financial participation.
- *Effective production*
  - just-in-time-supply to the assembly line;
  - adaptation of component manufacture to fluctuations in requirement at the manufacturer's level;
  - classification of manufacturers according to performance (quality, delivery, deadlines);
  - continuous improvement process.

Therefore Lean Production must result in the same rationalization effects with the subcontractors and the guarantee that these cost advantages are passed on to the manufacturer of the end product. This should be achieved through partnership-like collaboration, disclosing cost accounting and the hierarchical structuring of subcontractors [1.9.-3, 1.9-4].

1.9.2.2 Tracking

Another important task in the coordination of internal workflows in a printshop is the securing of deadlines and order tracking. Keeping within tight time schedules set by customers requires a strict monitoring of deadlines, which is referred to as tracking. Frequent last minute changes with respect to content also call for transparent organization, by means of which the current production status of each printed product can be checked in the printshop at any time.

Previously, job tickets were used which followed the product throughout the entire production process. Duplicates were kept in the production control department and put up on a display wall for a better overall overview of production progress. Computer technology has made it possible to provide this overview solely by means of computer programs and visual displays on the monitor. Below you will find a description of a "Production Tracking" process explained through the example of producing a newspaper.

Example: Newspaper Production Process

It is characteristic of newspaper production that at the start of production the final form of a product is not yet definite. Its content and structure may be changed considerably "at the last minute" due to external circumstances. The product changes from day to day. Productions plans must nevertheless be adhered to, so that readers receive a complete product on time.

The newspaper production process can be sub-divided into two clearly definable production stages:

- The objective of the first stage is to create a master copy (fig. 1.9-10). In this creative process the pages of the newspaper are put together consisting of their own editorial content as well as advertisements. Each newspaper has two main prepress departments, working in parallel on the production of master copies: the advertising department sells available space for advertising in the newspaper or creates them itself. The editorial staff collects information, with which it fills the pages of the newspaper, subject to a complex selection and preparation process.
- This is followed by the rapid production and distribution of the "copies" of this master copy (fig. 1.9-11). Production of these copies, the actual newspapers, is

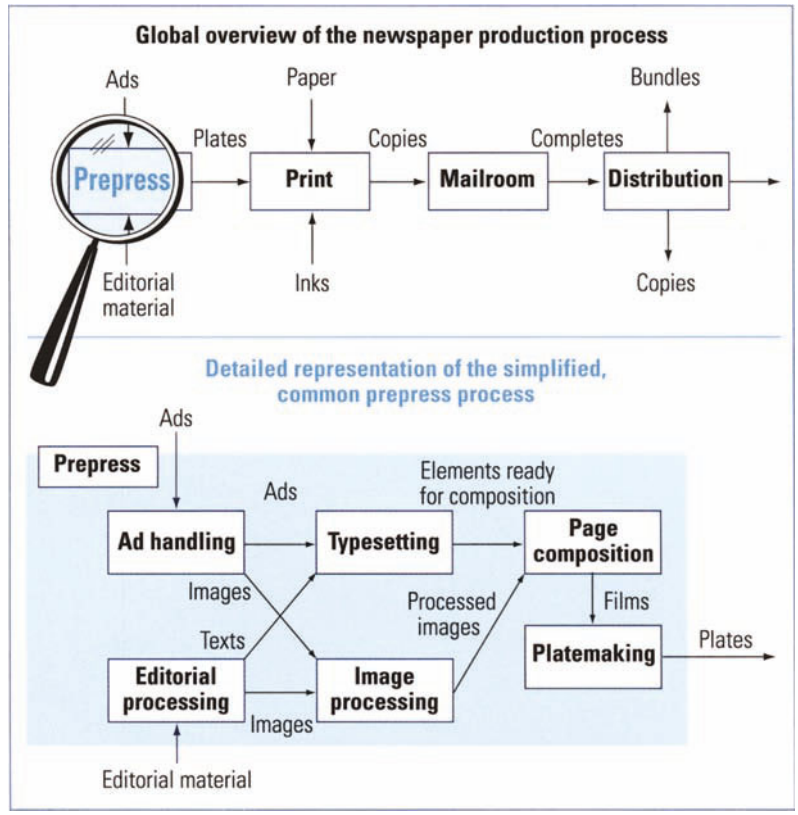


Fig. 1.9-10
Global overview of the newspaper production process showing prepress in detail [1.9-7]

a linear production process. It comprises production stages of platemaking, printing, insertion of preprints, addressing of copies sent by post, stacking, packing, transporting, and distributing. This represents a traditional production process that can be planned, monitored, and optimized using resource management methods and systems [1.9-5, 1.9-6].

Production Management in the Newspaper Business

The problems involved in newspaper production come from the fact that the production process must not exceed the time frame and the budget. Nowadays the production management of most newspaper companies is done by a small team of employees who store the necessary information "in their heads" and make sure that the newspaper is completed on time.

Especially for prepress, this type of production management is becoming more and more difficult due to increasing computerization. The advent of more economical and efficient text-, image- and page-processing software for standard computers has given many newspaper publishers the opportunity to transfer to digital production of the newspaper's pages. Organizational structures are aligned with technical and functional requirements. In the future the digital material flow will be monitored electronically, since there is no actual physical material that can be checked mechanically or visually.

Events and objects in newspaper production will now be tracked by function-related, local tracking systems, if tracking is done at all. Individual system solutions are available from different manufacturers for mailroom control, press control, page output, and printing plate tracking. Apart from advertisement tracking, system suppliers only recently started to focus on production tracking in the prepress sector.

The Need to Exchange Production Tracking Data Between Systems

The tracking of the entire processing path of a page from composition to platemaking and mounting of the printing plates is only possible if the various individ-

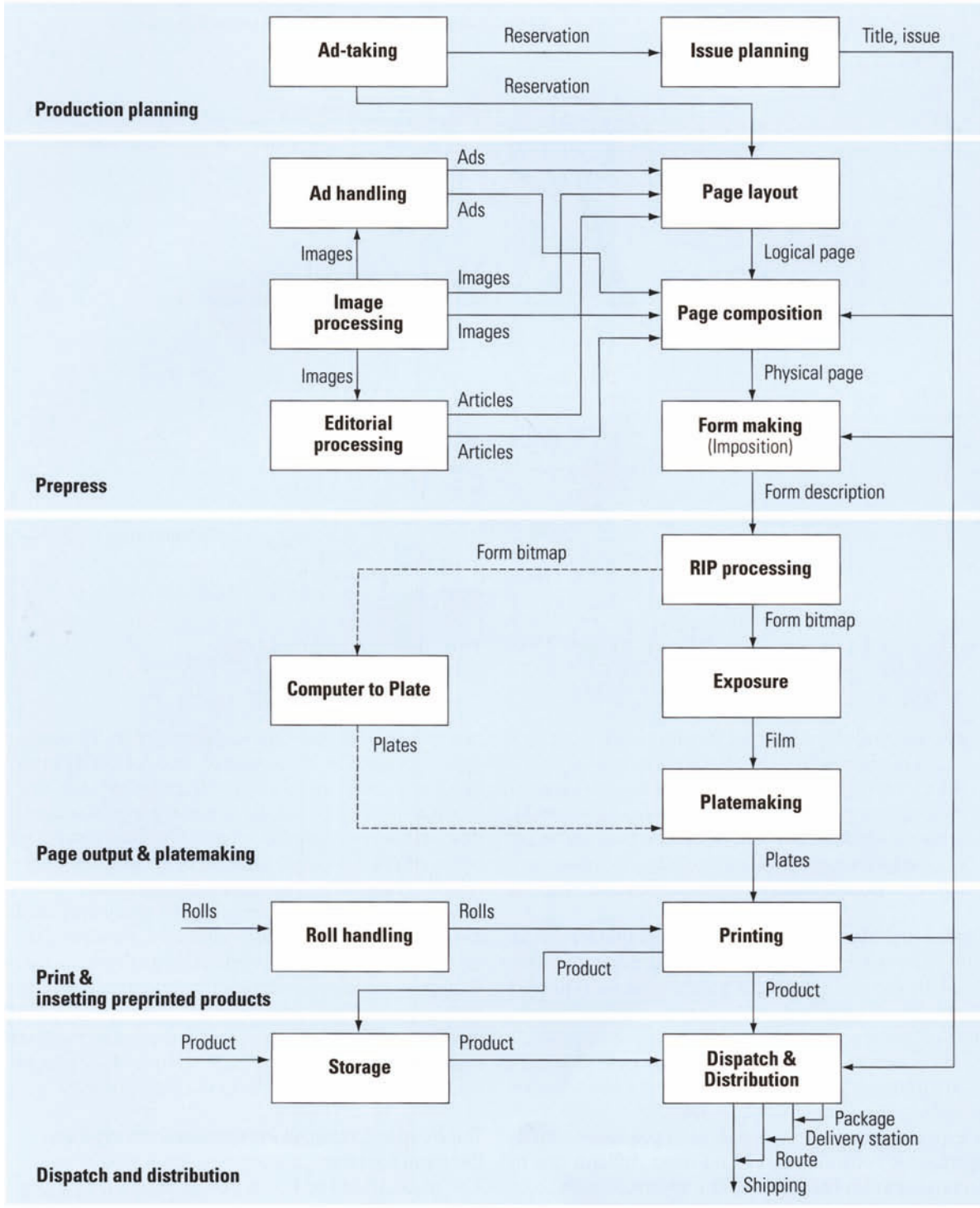


Fig. 1.9-11 Basic workflow model in newspaper production (IFRA)

ual systems are able to exchange tracking data with each other.

Therefore production tracking requires a process that enables the printing press tracking system to communicate with the mailroom system. It is even more important that on the basis of this process, a superordinate global level (company-wide production tracking system) is created allowing management to track production flows.

In newspaper printing operations there is a specific need to extend production tracking and production management over the entire production process, from the drafting of reports and ad-taking to delivering the newspapers. A global production tracking system must fulfill the commercial requirements and should be furnished with the necessary tools to obtain the parts of information that are relevant for planning and decision-making on a superordinate level from the various local systems. It should also take on the function of communicating information between the different areas of responsibility within the newspaper production process [1.9-7].

Ability of Local Systems to Communicate

It would be relatively easy to implement a global management system if all the tools used were part of one and the same system from one manufacturer. In that event, production monitoring could be undertaken from a common database. This is not the case in the newspaper industry, where various systems from various manufacturers have to communicate with each other. Therefore the implementation of a global management system calls for a standardized approach.

IFRA, the International Service Organization for Newspaper and Media Technology has therefore created a standard or a recommendation that is called IFRAtrack, which establishes the form of messages that must be transmitted from the local tracking systems to a superordinate, global tracking system [1.9-8, 1.9-9]. The recommendation is based on three fundamental points:

- *Semantics*: the scope and content of the tracking messages to be transmitted are defined.
- *Syntax*: the method is specified by which the tracking messages are to be described and encoded. The systems transmitting and receiving the messages must be clearly designated. The objects to which the messages refer must also be clearly identifiable. All this information must be encoded and presented in readable form for the user.
- *Message exchange procedure*: The procedure for exchanging tracking messages is also defined.

1.9.2.3 Quality Assurance

The assurance of product quality has a long tradition, especially in the printing industry. Whereas previously the principle of quality checking took center stage, nowadays the most effective form of quality control is a company-wide quality assurance. Therefore in 1985 the ISO (International Organization for Standardization) drafted an internationally applicable standard, which it published in 1987 and in which the requirements for an internal quality assurance system were established. This system was given the easily remembered name of "ISO 9000."

ISO 9000 does *not* specify product quality, but a company's ability to generate quality (fig. 1.9-12). In practice the conclusion is often mistakenly reached that the ISO 9000 certificate is a guarantee of product quality. This was also a reason why the industry and its associations initially somewhat disapproved of the standard, especially as it did not address fundamental elements of product liability at all. Common terms that the test should focus on are not included; for example, risk reduction, damage analysis, the state of the art, the accepted rules of technology and the state of science and technology [1.9-10].

ISO 9000 Standards

The reference work of the ISO 9000 Series of Standards is certainly not easy reading for anyone wanting to become familiar with the field, because it is written in very abstract terms, using a kind of official language similar to laws. It requires additional comments and concrete examples of the type that many relevant organizations provide. The work consists of five substandards with the abbreviated names ISO 9000 to ISO 9004 (fig. 1.9-13). As European standards they had been given the designation EN 29000 to EN 29004. With national standards often only the respective country code is prefixed – in Germany "DIN". In the United Kingdom they are the British Standards (BS) 5750 Part 0 to Part 3.

Part standard ISO 9000 precedes the others and provides a guideline to the selection and application of part standards ISO 9001, 9002, and 9003. ISO 9001 describes a system that includes the entire production line from design/development to customer services and is therefore of relevance for newspapers, which produce their own product. ISO 9002 deals only with production and is applied in the printing sector when outside products

Fig. 1.9-12
The quality loop as per ISO 9000

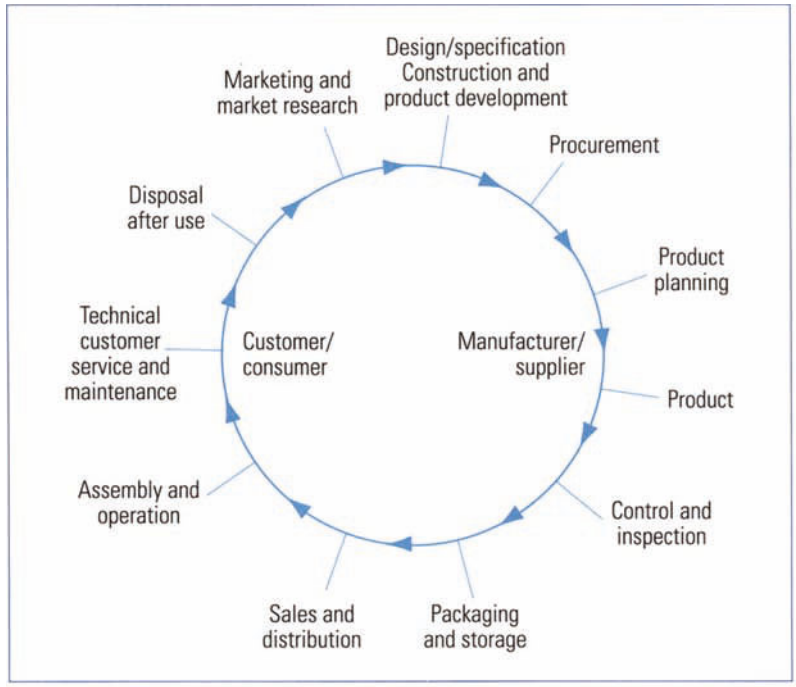
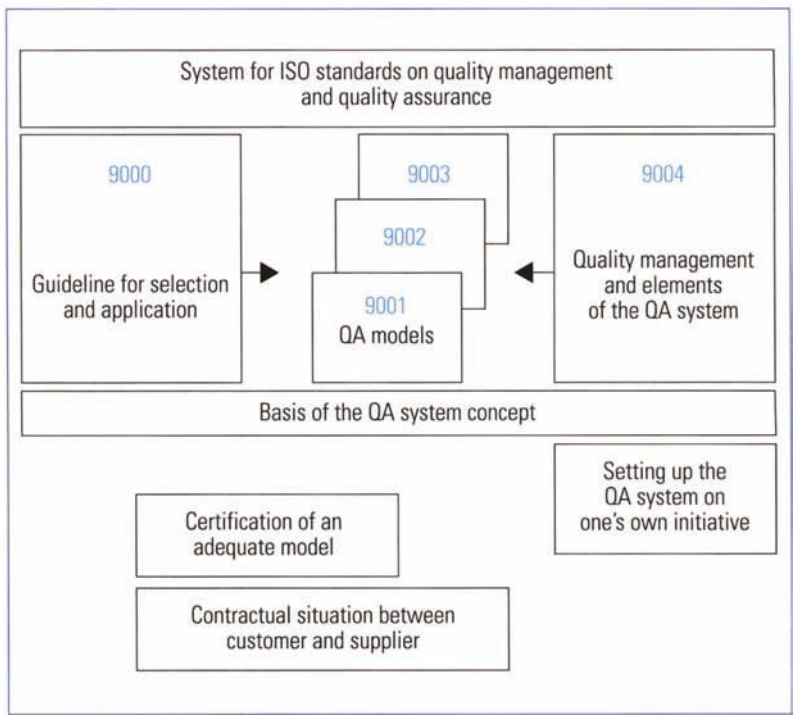


Fig. 1.9-13
The structure and application of the ISO 9000 standards



such as packaging materials, labels, continuous forms, books, leaflets, and commercial printed products are involved. ISO 9003 is actually only applicable for service-providers in a narrower sense (without their own product manufacture), because it only implements final inspection and is therefore not used in printshops.

1.9.3 Production Layout

For efficient work in the production department, production layout is of crucial importance, since it involves defining for a long period of time an environment for the entire manufacturing process that cannot easily be changed. Most printshops have a past history and are not entirely planned anew from scratch, which means that a multitude of given restrictions must usually be taken into account when planning the production layout of a printshop. In sections 2.1.3 and in 8.1, examples are provided of production layouts and of logistics/material transportation. In figure 1.9-14, the layout for a new packaging printing company is shown by way of example.

1.9.3.1 Material Flow

An important requirement for the layout of a printshop is that it must ensure an optimal material flow. For the general planning of a printshop, it is necessary to provide for the basic functions shown in figure 1.9-15.

The delivery of paper is organized in the incoming goods department; it is usually brought to the printshop by truck and sometimes by train. In large printshops the daily throughput of paper can amount to 500 tons. Although production is supposed to be "just-in-time" today, a storage site is necessary for the *temporary storage* of paper before it is printed. Production sequence delays, unforeseeable production times, and scheduling bottlenecks at the paper supplier must be absorbed here, which means that today an average storage time of one to two weeks is normal for the print-run paper. As a rule, the delivery of *ink* is organized in an independent circuit, since here specific transport container systems are used that differ according to the level of ink consumption (tanks, ink containers, drums, etc.).

Pressroom and *paper store* should be optimally linked, so that in-plant transportation costs remain minimal. Ideally, the printing presses should be positioned during installation so that the paper in-feed links up with the paper storage site or is already a part of the paper storage site. Here thought should be given not only to the regular transportation routes but also to situations in which an interruption of the production sequence makes it necessary to return the paper from the printing press to storage. Such situations are not infrequent.

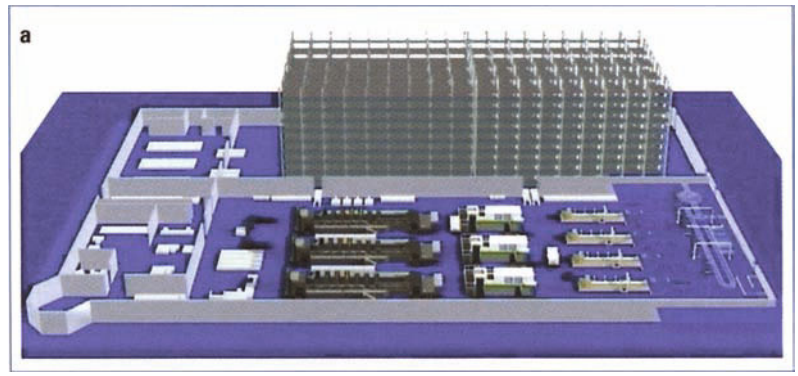
If the production process includes the finishing of printed sheets, these must be stored at a *buffer storage site* because, as a rule, the various print products cannot be printed simultaneously, but finishing can only begin when all product parts are available. In sheet-fed offset printing, the storage of freshly printed sheets is also necessary because the sheets take longer to dry: The intermediate storage site can consist of open areas, a shelf system, or an automated high rack store. It should be situated as close as possible to the product delivery of the printing presses.

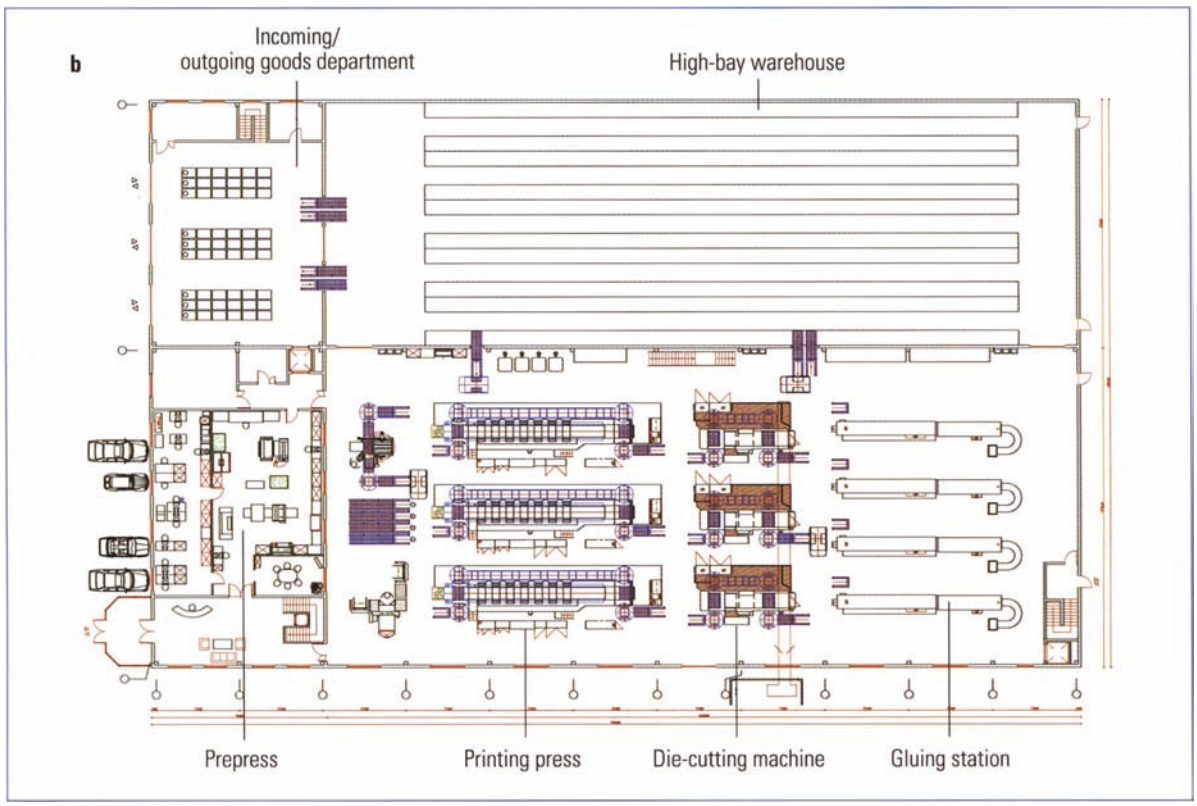
From the buffer storage site the preprinted product parts are conveyed to the product finishing area. In *finishing*, depending on the type of product to be finished, there is not always a linear production process. Moreover, in individual stages of production, intermediate products (e.g., book blocks and book covers) are mostly produced that must be stored temporarily again in each case. In a complex finishing process it is therefore practically impossible, as a rule, to perfectly harmonize the layout with the material flow in the production process. Accordingly, the optimization potential in many shops whose finishing area has increased gradually over the years is often large.

As a rule, the *shipping department* will be located directly downstream of the finishing area. If required, it must also be coupled with a small buffer storage site. As a rule, however, an effort is made to ship finished products immediately. For reasons of traffic management, the incoming and outgoing delivery departments are often concentrated at the same place in the company, so that a U-shaped layout results (fig. 1.9-15).

Alongside the main product flow through the print shop there is a multitude of secondary flows that are to be taken into account in the layout of a printshop. Thus, it should be ensured that the printing press is supplied with *printing plates*. An additional supply of printing plates must be secured in order to reduce to a minimum costly printing press down-times, especially in unforeseeable production situations – for example, when printing plates are faulty. Therefore, a nearby printing plate production site needs to be included in the planning. In modern printing companies the printing plate imaging area is already located directly next to the printing press. The storage and transport of

Fig. 1.9-14
Plant of a package printing company.
a Computer animation;
b Layout (Heidelberg)





other *production materials* such as printing chemicals, auxiliary materials used in finishing, and packaging material must also be taken into account.

Furthermore, the *disposal* of waste paper is to be incorporated in the layout of a printshop. Sheet spoilage in the printing area above all, as well as sheet spoilage and final trimming in the finishing section, result in paper waste that, depending on the print job, can amount to 20–25% of the paper used. This paper waste must be collected – after having been separated as far as possible into unprinted and printed material – and fed into the paper recycling system. In large printshops, paper waste can be removed by suction at the spot where it is produced and conveyed pneumatically to a paper disposal center where it is then pressed into bails.

In addition to this, in some printshops additional material-flow components are to be taken into account

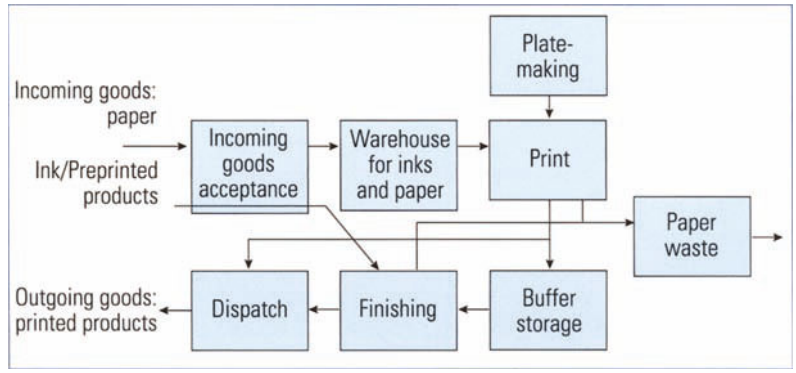


Fig. 1.9-15
The basic functions in the layout of a print shop

when, for example, products preprinted in other printshops are included in finishing or a part of the print production is not finished in the plant.

1.9.3.2 Capacity Planning

Alongside optimal material flow, *capacity planning* is of decisive importance for the layout of a printshop. For economic reasons, optimal utilization of the machines used is to be aimed at. On the basis of factors such as seasonal variation, the failure risk for individual aggregates, and so on, it is possible to determine an optimal *machine capacity* for the planned output volume. In figure 1.9-16 an example of output volumes in a web offset printing system is shown. From this it is possible to derive the necessary *transport capacities* for removal of the finished prints. These volumes are to be taken into account in the layout of the transport routes and in the organization of storage in the buffer storage facility.

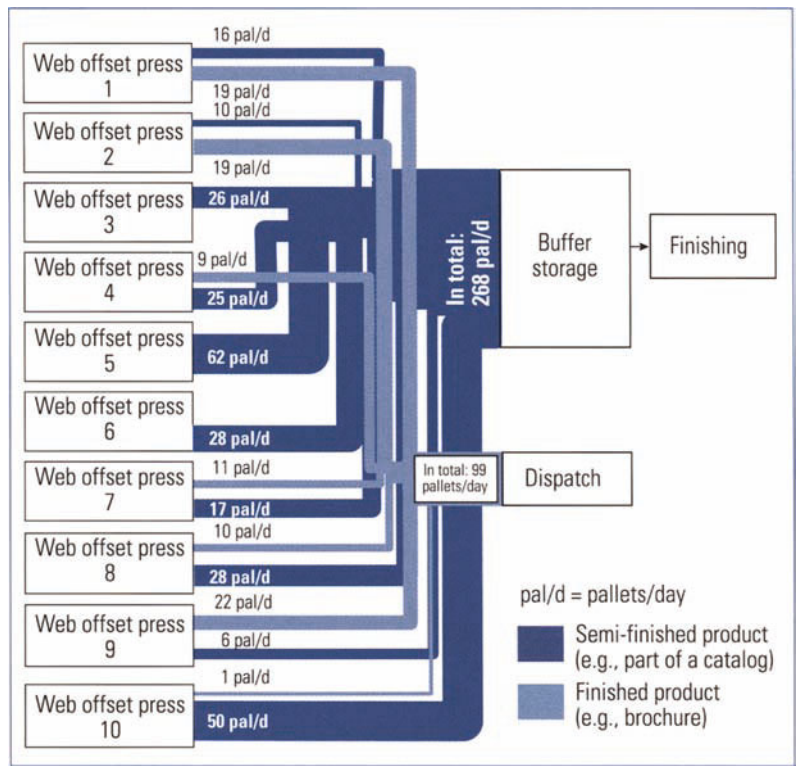


Fig. 1.9-16
Production volumes of a large web offset printing system

Furthermore, by considering the relations between personnel costs, capital costs, and the local regulations for shift, night, and weekend work, it is possible to determine a least-cost machine loading. As a rule, capital-intensive production lines such as web presses must be used as continuously as possible, while steps requiring large numbers of staff, such as finishing, are most economical without night shifts.

Thus, there is a suitable number of machines in each stage of production whose utilization, of course, is also harmonized with the planned production variants. It is precisely in the case of complicated, multistage production in the finishing process that the *ideal capacity* is determined by a large number of product parameters. For example, the process speed of thread-stitching depends on the number of pages per book (see sec. 7.2.5.2); if books with a large number of pages are produced, the number of finished books is correspondingly smaller. In the alternative perfect binding process, however, book output is independent of book thickness. In figure 1.9-17, a block diagram for book production in which the important parameters of individual stages of production are specified, is shown by way of example.

For layout planning, flexibility with regard to increasing the number of machines is also called for when deciding how many machines are necessary (for example, installation of another thread-stitching machine should be possible if market trends turn in favor of books with many pages). Moreover, a personnel adjustment or the operating of various machines by two employees is also to be considered when planning the arrangement of the machines.

1.9.3.3 Personnel Deployment and Supply of Utilities

The third important factor in optimization is *personnel placement*. Machines should always be installed so that they can be operated with the minimum amount of work. Accordingly, control desks, product delivery, supply points, and so on, are to be positioned so that, as far as possible, they can be accessed centrally and monitored from one point. If, for individual machine sets, these parameters are predetermined by their design, there exist optimization possibilities when installing the machines in linked production lines or when forming machine groups. In particular, the monitoring of several machines by one employee requires that the machines are arranged in a suitable way.

Alongside the actual operating of the machines, the *ancillary activities of the employees* are also to be taken into account in the layout. Particularly long access ways that cause an employee to be absent from the machine to be actually operated affect total productivity. This is to be taken into account in the positioning of storage and service rooms, toilets, refreshment areas, and so on.

The *supply of machines* with utilities is particularly relevant to the layout of a production facility. Alongside the power supply, thought must be given to the supply of compressed air and cooling water in a large printshop. Furthermore, *after-burning* of the solvent near the dryer is to be provided for in the case of web offset printing systems, while in gravure printing a reprocessing of the solvent is necessary. Here the particular conditions of the site are always decisive for the optimal solutions.

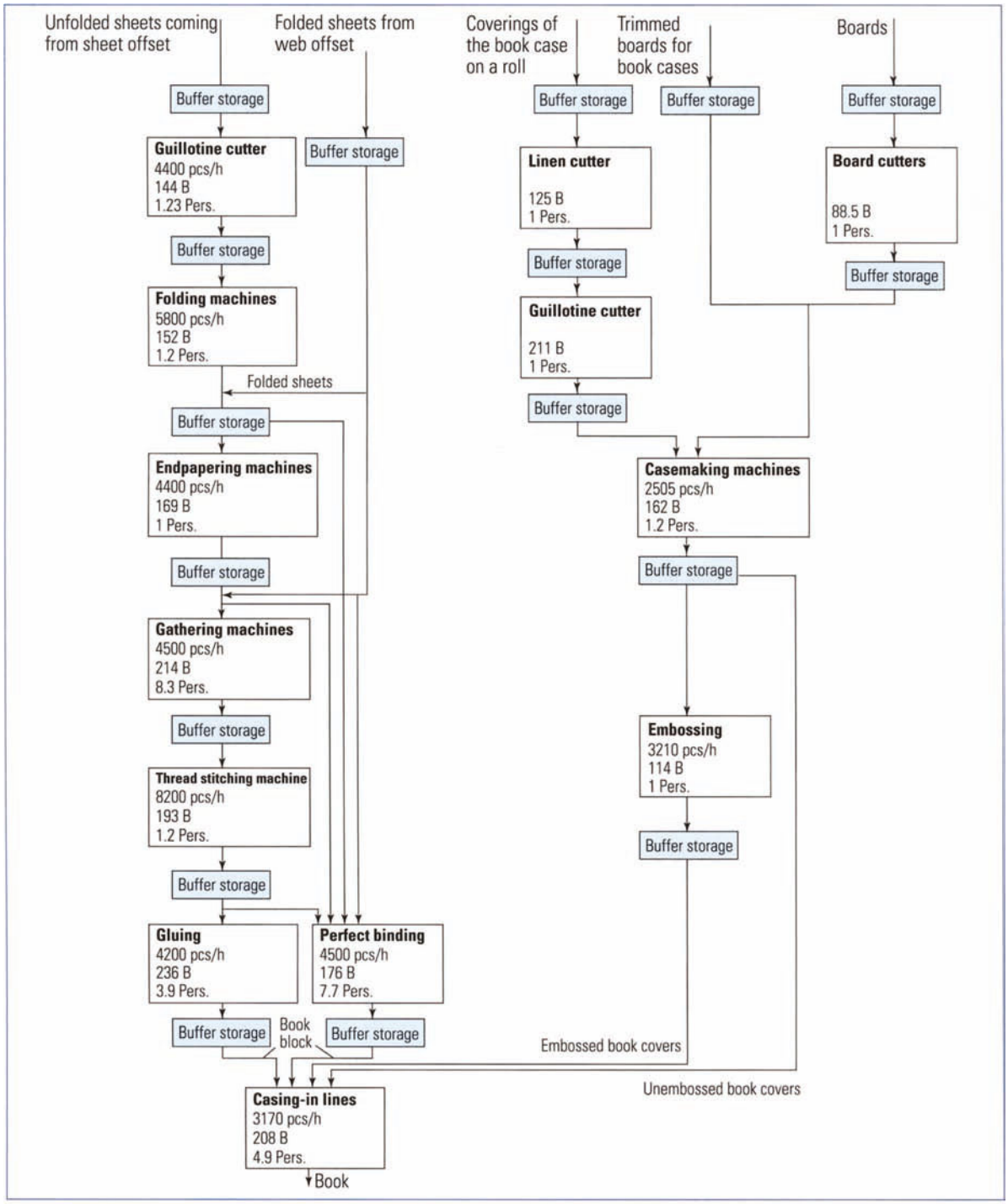


Fig. 1.9-17

Block diagram for book production (example with various material flows): Explanation of the figures: Productivity in pieces per hour [pcs/h]; average printshop index B = 100 for one-shift or B = 200 for two-shift production; Pers.: average manpower for operating the unit.

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Offset printing is an indirect lithographic printing technology (see also sec. 1.3.2.3). Offset printing has spread markedly since approx. 1970 and has, to a great extent, ousted the letterpress printing technology which prevailed until that time. The offset printing technology is now the major printing technology.

2.1.1 Basic Principles

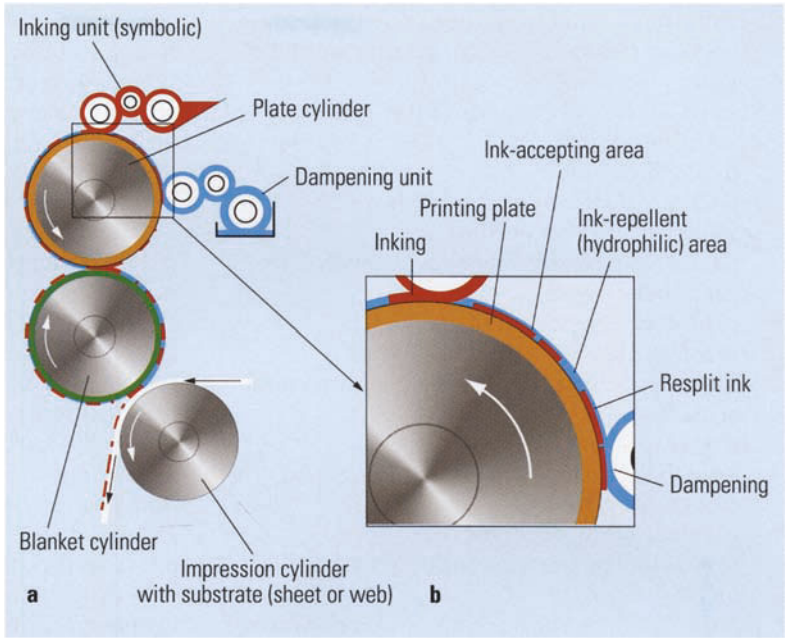
2.1.1.1 Process

In the offset printing process the printing and non-printing areas of the plate are practically on one level. The printing areas of the printing plate are oleophilic/ink-accepting and water-repellent, that is, hydrophobic. The non-printing areas of the printing plate are hydrophilic, consequently oleophobic in behavior. This effect is created by physical phenomena at the contact surfaces (figs. 2.1-1 and 2.1-2).

The dampening system covers the non-printing areas of the printing plate with a thin film of dampening solution. This dampening solution (water plus additives) spreads over the non-printing areas. To achieve good wetting, surface tension has to be reduced by means of dampening solution additives. In extreme cases, reducing the surface tension of the dampening solution too much can result in too great an emulsification of printing ink and dampening solution, leading to a situation

H. Kipphan (ed.), *Handbook of Print Media*
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Fig. 2.1-1
Offset printing (lithography).
a Components of a printing unit;
b Basic principle
(see also fig. 2.1-8)



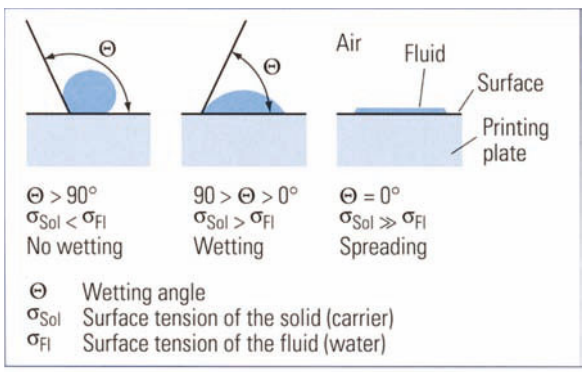


Fig. 2.1-2 Wettability of surfaces and wetting angles

where an exact separation of printing and non-printing areas on the plate is not achieved when inking.

The perfect offset printing process depends on many chemical and physical specifics of the materials and components involved in the process. The most important are given in the following list:

- *Influence of the printing plate*
  - surface tension of the ink-accepting areas,
  - surface tension of the dampening solution-accepting areas,
  - surface roughness, especially of the ink-free/non-image surface,
  - capillary attraction, microstructure of the non-image surface,
  - type of materials,
  - production methods in making the offset plate (mechanical or electrolytic graining, etc.);
- *Influence of the inking rollers*
  - characteristics of the roller coverings,
  - surface tension of the roller material,
  - surface roughness,
  - viscoelastic properties of the rubber coverings,
  - throw-on (pressure in the nip), adjustment,
  - concentric running;
- *Influence of the blanket*
  - surface tension of the blanket,
  - surface roughness,
  - compressibility,
  - ink acceptance and ink transfer behavior,
  - tone value transfer behavior,
  - setting/swelling, release behavior, hardness, dimensional stability;
- *Influence of the ink*
  - surface tension, contact surface tension in relation to the dampening solution,
  - rheological properties (viscosity, tack, etc.),
  - temperature behavior,

  - dampening solution absorption/emulsification behavior (leeway between smearing limit and water vanes),
  - running clean behavior during start-up,
  - ink composition,
  - drying behavior;
- *Influence of the dampening solution*
  - water hardness/impurities,
  - dampening solution additives (alcohol, detergents, buffer agents),
  - pH value, surface tension,
  - rheological properties (viscosity, tack),
  - dependence on temperature of the rheological characteristics;
- *Influence of the substrate*
  - printability properties (smoothness, absorption capacity, wettability),
  - pH value of the substrate,
  - workability properties (tension/stretch behavior, picking, tearing);
- *Influence of the printing press* (on print quality and process stability)
  - design of the printing unit (accurate, stable, vibration absorbent, etc.),
  - design of the inking unit (front-heavy, back-heavy, free surface, little retroaction),
  - design of the dampening unit (contact dampening, non-contact dampening),
  - design of the ink feed system (ink metering),
  - temperature control.

This short overview shows that the offset printing technology must be viewed as a multiparameter system. Changing just one of the parameters can have an immediate effect on the printing process.

Offset printing is a technology that is clearly determined by interfacial processes, of both a physical and a chemical nature. The fact that homogeneous phases (e.g., pure water) are hardly ever involved in this process, and that more often than not it is a matter of mixed phases (e.g., water in which other substances have been dissolved) or even compound phases (e.g., printing ink, a dispersion of solid and fluid content) makes the understanding of how the various "partners" involved in this process interact more difficult.

To understand the actual mechanism of ink transfer in offset printing it must be taken into account that the contacting liquid films are always split in addition to the wetting process. Therefore, if a film of ink and a film of water come into contact with each other, the decisive factor in the transfer of ink is not whether there is some sort of repulsion, but in which liquid cross-section splitting occurs. Splitting depends to a great extent on the cohesion of the liquid film. Offset inks have higher cohesion properties compared to water, which in turn means that splitting always takes place in the water film and not in the ink film.

Since it is always the water film that splits, any contact between printing ink and water has the effect that water remains on the ink film (and may consequently also penetrate the ink in an emulsified form). The spread coefficient determines whether the water spreads over the ink surface or not.

So that water is not repelled by the ink, the contact surface tension between ink and water must not be too high. Studies have shown that the contact surface tension primarily affects the water adsorbed on the ink surface, whereas the proportion of emulsified water depends on the cohesion of the ink.

As there is water on the ink film surface of the printing plate, the ink must also be able to displace the water from the image areas during inking (the water film reaches the image area first via the dampening unit). This does not cause problems, provided that the image area has already been inked.

Both the printing plate with its special properties and the ink and dampening solutions play a fundamental role. In *conventional offset* printing the interaction of surface tension between printing plate and ink is achieved by the addition of dampening solution. The same basic principle is applied in *waterless offset* printing, but with different surface/materials combinations. Consequently the surface of the waterless printing plate is made up of a highly ink-repellent silicone coating. Silicone oil is mixed into the printing ink, so that a separation layer forms when the ink comes into contact with the plate. Ink is only accepted on areas of the printing plate in which the silicone coating has been removed.

Waterless offset printing requires ink of comparatively high viscosity. Due to the milling operation in the inking unit, the inking form rollers get too hot (up to 50 °C); and the cooling effect offered by the dampening solution is also not present, which causes scumming effects. The temperature of the inking unit must therefore be stabilized. This may be done either by means of distributor rollers with water flowing through them or by an air current (very often in conjunction with plate cylinder cooling). The temperature of the inking form roller should not exceed 28–30 °C. Waterless offset printing is particularly suitable for fine

and very fine screens (low dot gain). The absence of dampening solution in this process simplifies the printing unit set-up, meaning that the desired production run quality is achieved more quickly. The absence of the cleaning effect provided by the dampening solution is a disadvantage and hickeys and paper dust deposit easily on the blanket and printing plate. The potential of waterless offset printing is dealt with in greater detail in section 2.1.7.

2.1.1.2 Printing Plates, Printing Ink, Dampening Solution

Printing Plates

The plates used in offset printing are thin (up to about 0.3 mm), and easy to mount on the plate cylinder, and they mostly have a monometal (aluminum) or, less often, multimetal, plastic or paper construction. Aluminum has been gaining ground for a long time among the metal-based plates over zinc and steel. The necessary graining of the aluminum surface is done mechanically either by sand-blasting, ball graining, or by wet or dry brushing. Nowadays, practically all printing plates are grained in an electrolytic process (anodizing), that is, electrochemical graining with subsequent oxidation (fig. 2.1-3).

The imaging, ink-accepting coating (light-sensitive coating, thickness around 1 µm) is applied to the base material. This material is usually a polymer, or copper in the case of multimetal plates (bimetal plates). Light-sensitive, diazo (photopolymer) pre-coated aluminum printing plates are now the predominant plates in printshops. The image transfer is produced via the different properties on the surface of such plates after they have been exposed and developed. The remains of the original light-sensitive coating or the light-sensitive coating changed by the effect of light are the ink-accepting (oleophilic) elements that create the image.

The thin coating of aluminum oxide created by the special treatment of the aluminum base material a particularly stable water-attracting (hydrophilic) surface with special retention properties. In processing a pre-coated offset printing plate the essential task lies in achieving surface differentiation using two basic steps, exposure and developing.

Chemical changes occur as a result of the penetration of photo-effective (actinic) light (light containing UV rays), causing the light-sensitive coating to react differently depending on its type and structure. There are two types of photochemical reactions when developing the printing plate:

- hardening of the light-sensitive layer by light (negative platemaking),
- decomposition of the light-sensitive layer by light (positive platemaking).

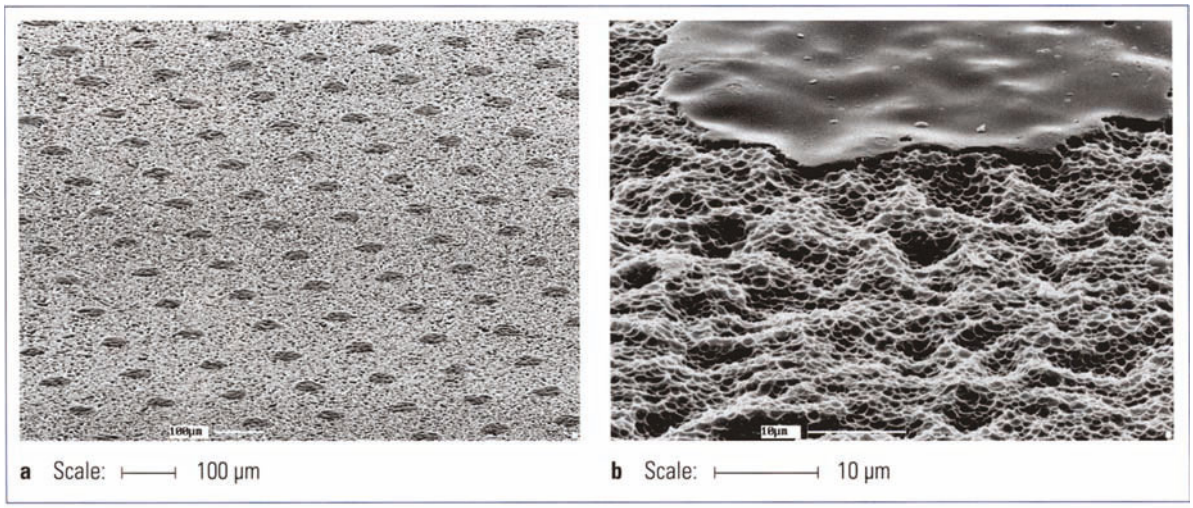


Fig. 2.1-3 Aluminum printing plate with halftone dots.
a Magnified a hundred times;
b Magnified 2000 times

If the light-sensitive coating is hardened photochemically, it becomes insoluble for the developer in the exposed areas. If, on the other hand, the light-sensitive coating is decomposed photochemically, the developer removes the exposed light-sensitive coating from the base (e.g., aluminum). These two different platemaking processes (positive and negative platemaking) require different exposures to create images,that is, different types of films that are produced in advance (fig. 2.1-4).

With *positive platemaking* and conventional printing plate production, a positive film is used as the original, that is, the non-translucent, blackened sections of the film correspond to the ink-accepting surface elements on the plate. As illustrated in figure 2.1-4a, if light falls on the ink-free areas during exposure, the light-sensitive layer "decomposes," which results in the non-image areas being uncovered (in this case aluminum) during the developing process. This process has the disadvantage that film edges and dust, that is, the darker areas on the film compared to the translucent image areas on the film copy, are sometimes reproduced on the printing plate as ink-accepting surface elements.

In the case of *negative platemaking* with "negative plates" a negative film is used as an original, that is, the ink-accepting image areas of the printing plate correspond to the translucent, light areas on the film. As shown in figure 2.1-4b, the light-sensitive coating is hardened on the printing plate by light, so that it stays in place after the developing process, as opposed to the unexposed areas, which are removed.

The developed plates are then gummed up to protect the plate surface and preserve the plate. The finished printing plate will, of course, be identical in informational content regardless of whether positive or negative platemaking is used. Only the kinds of film used for production are different. Different characteristic curves between the tone value of the film and that of the plate must be taken into account in prepress.

Whether to use positive or negative working plates is a fundamental decision to be made by the printshop. Many printing plates can be heat-treated (baked) after developing to increase their service life.

For smaller formats, single-color or multicolor jobs on medium-quality, *polyester-based plates* are for reasons of cost preferred over aluminum plates as their dimensional stability is lower.

For quality assurance and monitoring during platemaking, *control elements* are copied onto the plates. Standardized elements are available, for instance, in accordance with FOGRA's standardization concept [2.1.-1] with a wedge, such as the PMS or the UGRA offset test wedge (see sec. 3.1.7.2 and 4.3.7).

Thermal Plates

Alongside conventional printing plate systems, thermal plates have been developed for digital imaging.

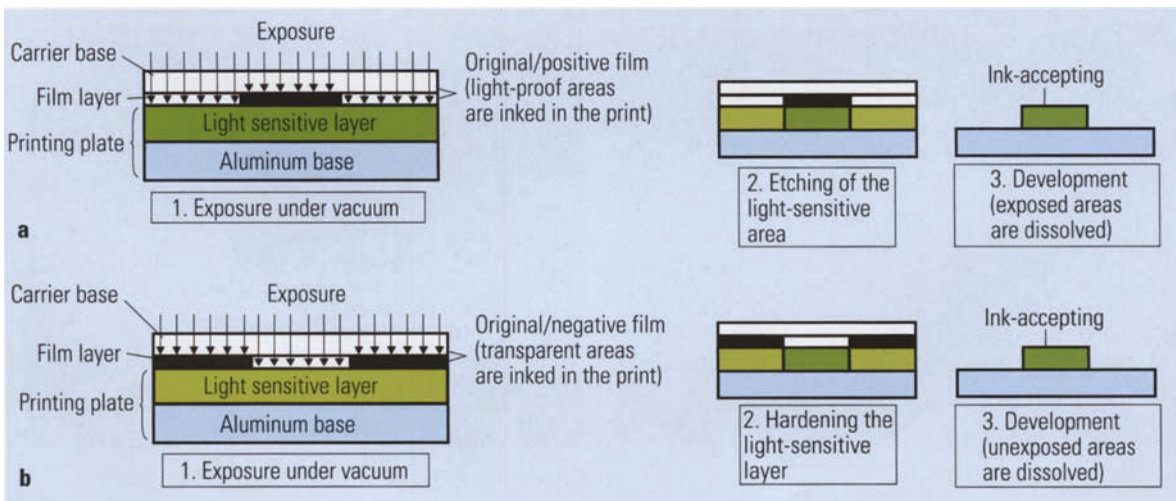
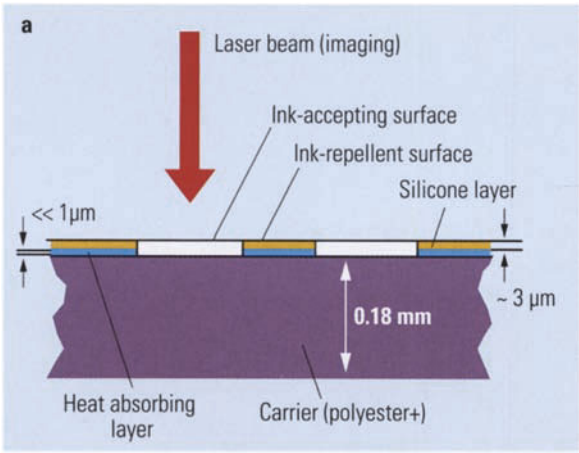


Fig. 2.1-4 Platemaking.
a Positive platemaking;
b Negative platemaking

(These plates are described in sec. 4.3.9 in connection with computer to plate technologies.) A polyester-based waterless offset plate is shown in figure 2.1-5 as an example of a plate that is imaged by thermal ablation using laser light. Platemaking processes are described in detail in section 4.3.9.

Printing Ink

The ink used in offset printing is usually a highly viscous mixture having the basic components of ink pigment, vehicle (binder), additives, and carrier substance (see also sec. 1.5.2).



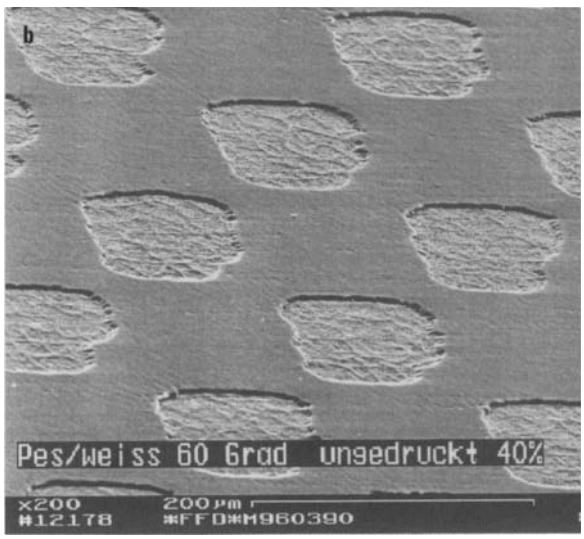


Fig. 2.1-5
Waterless offset plate with digital imaging by thermal ablation (Heidelberg/Presstek).
a Plate structure with imaging;
b SEM shot of the plate surface

Ink pigments can have either an organic or inorganic nature. The pigments determine the hue of the printing ink. They consist of solid, irregularly-shaped particles that are about 0.1–2 µm in size.

Vehicles (binders) are needed to bind the pigment, which is supplied in powder form, to the substrate. Vehicles also form a protective film around the pigments so that they are protected from mechanical abrasion. The composition of the vehicles depends on the printing technologies and substrate to be used. The vehicles used in the production of printing ink are also called "varnishes". The real know-how of the printing ink manufacturer lies in the creation of the formula and the preparation and combination of the individual raw materials which make up the vehicle.

Additives can be mixed into the ink to achieve specific properties and to overcome specific printing problems. The additives and their specific uses are listed with examples in table 2.1-1.

Mineral oils are used as *carrier substances* for offset inks. They fulfil the function of transporting the ink and are removed again in the drying process (evaporation, absorption). Conventional offset inks dry by absorption, evaporation and, depending on the type of ink, oxidation (see secs. 1.7.1 and 1.7.2). In addition to these most commonly used inks, there are inks that cure by radiation cross-linking (see sec. 1.5.2.1 for UV and electron radiation). The structure of these inks is completely different than that of conventional inks. UV inks are available for both conventional (with dampening solution) and waterless offset printing.

Dampening Solution

In the conventional offset printing process the dampening solution is used to separate the image and non-image areas, that is, to prevent the transfer of ink onto non-image areas of the printing plate. The dampening solution consists mainly of water. Experience has shown that in conventional offset printing the dampening solution should have a pH value between 4.8 and 5.5 and the water used in the dampening solution should have a hardness level of between 8 and 12° dH (1.43 and 2.14 mmol/liter; 1 mmol/litre = 100 mg $CaCO_3$ per 1 liter water). Dampening solution usually contains plate preservative agents, wetting agent, isopropyl alcohol (IPA), buffer substances, and anti-microbe additives.

Additives		Areas of use in the case of printing problems													
Types	Interaction and effect	Setting off	Chalking	Repelling	Drying	Piling	Hickeys/Dusting	Curling of the sheet ends	Picking	Increasing the abrasion resistance	Badly printing areas	Sticking in the ink fountain	Scumming	Unsatisfactory drying results	Ink too "short"	Ink too sticky
Linseed oil varnish—highly viscous	Thick varnish, tacky, increases viscosity.		•			•					•				•	
Print oil	Linseed oil and other drying oils. Weak varnish, reduces stickiness, makes the ink shorter and thinner. For oxidative drying.					•		•	•		•	•				•
Diluent	Low-viscosity mineral oils, partly combined with drying oils. Reduces tack, makes the ink shorter and thinner					•		•	•			•				•
Print paste	Waxes and similar substances which are dissolved in oils. Reduce the tackiness like liquid thinner, but without changing the viscosity.							•	•		•					•
Print gel	Jellied thinning agent: thickened mineral oils and other oils with different additives with thixotropic properties.							•	•		•					•
Drying agent – Siccative (liquid) – Drying substance (solid)	Metallic compounds dissolved in solvents or oils. – Cobalt = Surface dryer – Mangan = Internal dryer	•								•				•		
Alumina hydrate	Binder with transparent pigments. Increases tackiness, lightens up.		•	•		•							•		•	
Abrasion resistant paste	Wax with oxidative drying oils; makes the surfaces smoother to reduce friction.	•								•						
Antistaling agent	Spray. Highly volatile solvent.				•		•	•	•							•

Table 2.1-1 Additives for inks and their areas of application

Gum arabic is used as plate preservative. Wetting agents and IPA are used to reduce surface tension. Figure 2.1-6 shows the effect of reducing surface tension by a dampening solution additive. Admixed buffer agents are used to stabilize the pH value.

Antimicrobe additives are essential if the dampening solution is prepared for several offset printing presses in a central additive metering unit. Without these additives the pipes would become clogged due to the growth of algae. Alcohol-free dampening solutions contain alcohol substitutes such as glycol, instead of isopropyl alcohol.

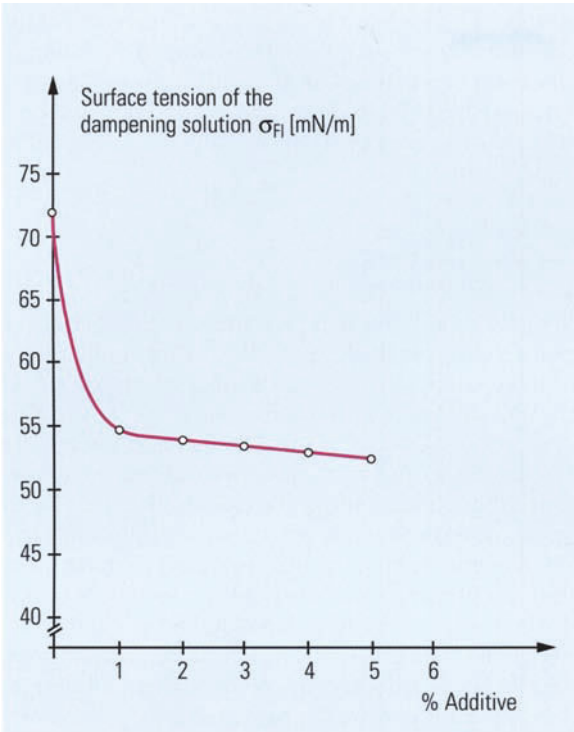


Fig. 2.1-6
Dependency of dampening solution's surface tension on the concentration of a dampening solution additive

2.1.1.3 Inking Unit, Dampening Unit, Printing Unit

Inking Units

During the printing process, a thin film of ink is transferred from the image areas of the plate to the substrate (ink film thickness on the substrate around 1 µm). The inking unit's function is to provide a constant supply of fresh ink to the image areas on the plate to maintain a constant inking process. The amount of ink "used up" must be fed back to the system. There must be an equal balance between ink fed and ink dispensed in order to avoid variations in the ink density on the printed image.

Another important factor for the print quality is the uniformity of the ink film thickness on the image areas of the plate or the image areas of the substrate. (It is a postulate of offset printing that the film of ink should be of the same thickness across the entire printed sheet. Reproduction technology for the creation of color separations is based on this principle). Consequently, the criteria determining quality are:

- temporary fluctuations of the average ink film thickness (quantity balances) and
- uniformity of the ink film thickness on the image areas of the plate or the printed areas of the substrate.

These parameters are dependent on the structural design of the inking unit. The quality of the microscopic full-tone density and the individual dots on the substrate depend primarily on the roughness of the substrate, the microgeometry of the plate and blanket, and the rheological properties of the ink.

In an inking unit like the one shown in figure 2.1-7, ink is fed intermittently via the oscillating vibrator roller H. The vibrator roller H receives a relatively thick ink stripe from the ink fountain roller and transfers part of this stripe to the first roller SO of the inking unit. The quantity of ink supplied via roller SO is determined by the ink zone aperture a, the rotary motion of the ink fountain roller (in most cases intermittently), the vibrator roller frequency, and the speed of the inking rollers. In addition to these *vibrator-type* inking systems there are also *continuous/film-type inking* systems (see fig. 2.1-15).

All the rollers of the inking unit (apart from rollers D and H) have the same circumferential speed as the plate and/or blanket cylinder. Apart from a negligible stretch slippage [2.1.-2] caused by deformation between stiff and the flexible rollers, the system works virtually without slippage. The applied ink stripe is split and transferred several times. The quantity of ink in the inking unit depends on the number of inking rollers and/or the size of their surfaces. With an optimal design the inking form rollers A1–A4 will produce a relatively constant ink film on the image areas of the plate cylinder rather independent of the printed image, that is, after the last ink form roller A4, the oleophilic areas are inked with a practically even ink film.

Part of the ink film is applied to the substrate in the printing zone (between blanket and impression cylinder). A distinctive feature of offset printing plates is the fact that the printing and non-printing areas are on one level. To separate these areas a very thin (approximately 2 µm) dampening solution film is applied to the plate by the dampening unit. Part of the dampening solution is printed, part emulsifies together with the ink, and part evaporates.

The mass balance of the quantity of ink "printed" and the quantity of dampening solution consumed must correspond to the respective quantities fed. If

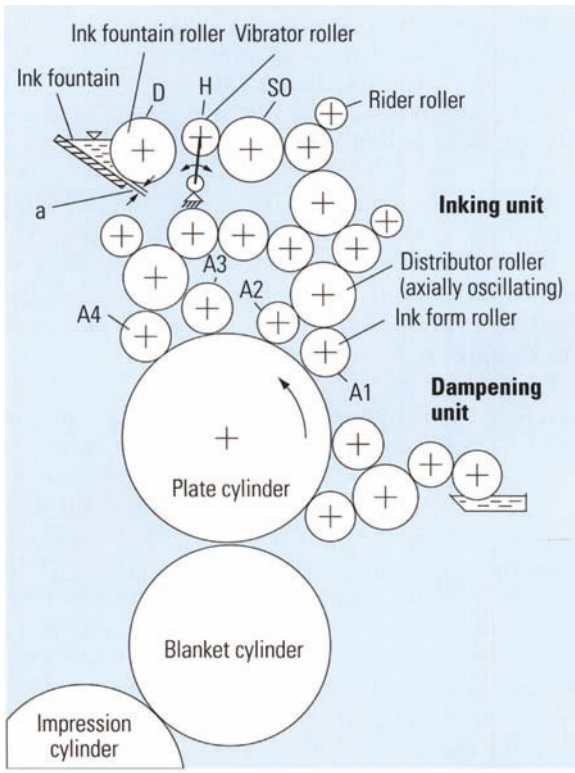


Fig. 2.1-7

Diagram of an inking unit and dampening unit of an offset printing press

this is not the case, temporary variations in average ink-film thickness arise.

Intermittent ink supply (vibrator and ink fountain roller) and the intermittent transfer of ink onto the substrate (non-printing and printing elements on the plate) imply that in reality there is no such thing as a precisely continuous, constant ink flow. The ink-splitting processes between the individual contact sections (nips) and the splitting in the inking unit need to be taken into consideration.

Figure 2.1-8 shows a simplified model of an inking process with an ink form roller to illustrate the creation of retroactive disruptive effects [2.1-3] during the application of ink (fig. 2.1-8). The layer of dampening solution is not to be taken into account for this model. Before the inking process starts there is a film of ink with thickness S_1 on the ink form roller. The printing elements on the plate carry a residual ink film with thickness S_2. This means that after inking, the printing element on the plate has the new ink film S_4 and at the relevant location on the ink form roller the ink film of thickness S_3 remains. Using the ink-splitting factor α (given that the ink films are closed, and not as shown in fig. 2.1-8 in segments) the ink film thicknesses of S_3 and S_4 turn out to be

$$S_4 = \alpha\,(S_1 + S_2)$$
$$S_3 = (1-\alpha)\,(S_1 + S_2).$$

Figure 2.1-8a shows that directly before and after the point having the thickness S_3, the ink form roller has a film thickness S_1. This means there is an irregularity in the film thickness with the difference $\Delta s = S_1 - S_3$. This difference is reduced by the turning distributor roller (see fig. 2.1-7) and by feeding new ink via the inking unit although it is not completely eliminated. This difference then becomes apparent in the printed areas on the substrate so that the ink film is not perfectly even over the printing elements but there is a more or less distinct relief in the film that could impair the printing quality to a greater or lesser extent (ghosting, see also fig. 2.1-17), depending on the inking unit design.

Figure 2.1-8b shows the basic ink-splitting processes and film thickness ratios from plate cylinder up to the printed sheet. This representation was based on an ideally constant ink-splitting factor $\alpha = 0.5$ and a constant film thickness on the plate of S_4.

There are two approaches to developing/designing offset inking units:

- the experimental approach and
- the theoretical or computational approach (further information on inking unit design can be found in sec. 13.1.3.2).

The experimental approach requires the construction of several offset printing unit prototypes or one very variable prototype used for printing tests. So that utilizable results can be achieved, the technical printing parameters must be kept constant.

The theoretical approach simulates the transportation of the ink and dampening solution in the inking unit using computers and a corresponding computer program.

The ink-transfer functions constitute the basic elements of a theoretical model for computing the ink and dampening solution transport. Distinction has to be made between two types of ink transfer in an offset inking unit. In the actual printing process, ink and damp-

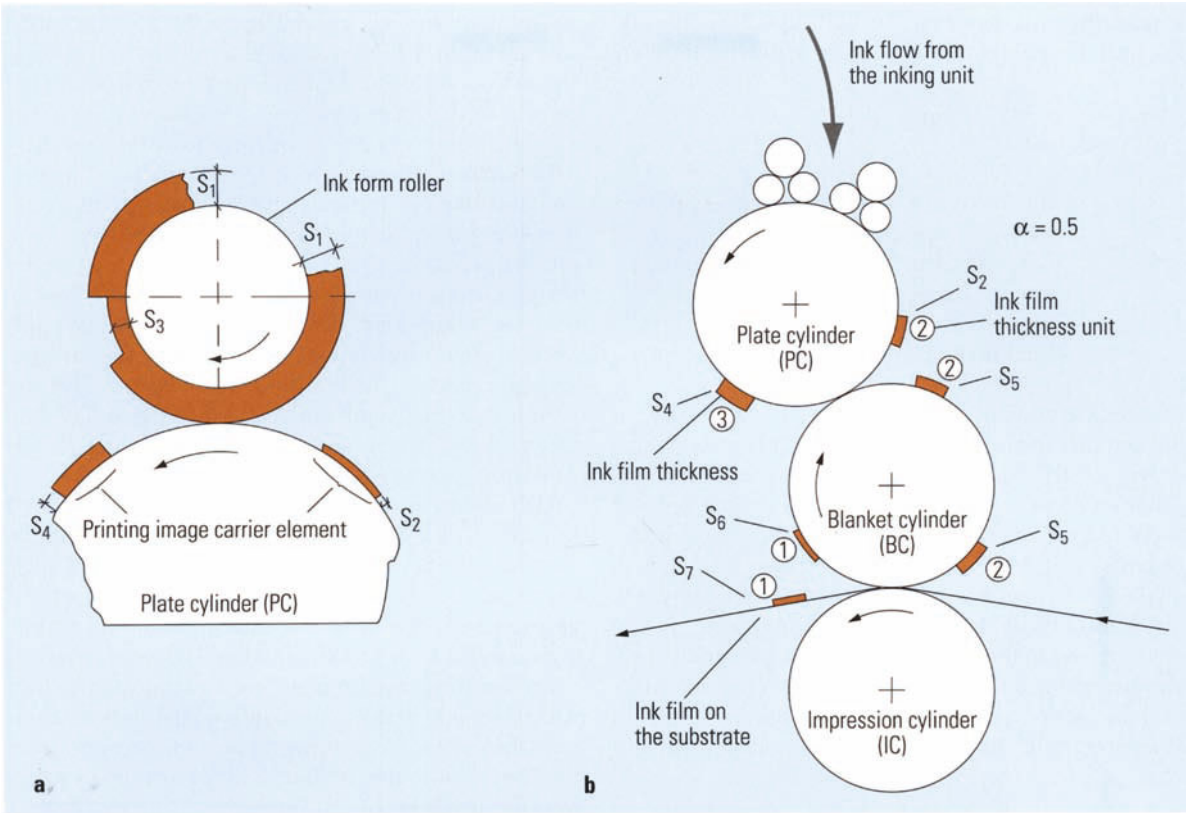


Fig. 2.1-8 Ink transfer in the inking unit.

a Ink transfer from the ink form roller to the plate cylinder;
b Ink transfer from the printing plate to the substrate (the numbers for the "ink film thickness units" correspond approximately to µm)

ening solution are transferred to a surface on which no printing has yet taken place (for the printing of further color separations, the ink is usually transferred onto an already preprinted paper surface). The surface properties of the substrate (such as wettability, porosity and roughness) play a decisive role here.

The first instance, that is, the correlation of ink transfer from the printing plate to the substrate, has been examined in detail by Walker and Fetzko [1.3-3]. They found that the ink transfer process can be expressed by the relationship described in section 1.3.2.

The second kind of ink and dampening solution transfer exists when a dampened surface that is already ink-accepting is in contact with another ink- and dampening-solution-carrying surface.

Ink splitting cannot be described by a constant ink splitting factor if dampening solution is present. The ink splitting factor is dependent on the dampening solution feed. Suggestions with respect to a functional correlation of this kind were made in [2.1.-4].

The inking unit system given in figure 2.1-7 shows a typical front-heavy configuration. The main flow of ink is fed to the printing plate via the first ink form rollers A_1 and A_2. Rollers A_3 and A_4 only transfer a small quantity of ink to the printing plate and essentially perform a smoothing role. (A computational estimate produces the following percentage ratios for the final film thickness of S_4 (fig. 2.1-8) fed by the individual plate rollers (fig. 2.1-7): A1 = 45%, A2 = 38%, A3 = 10%, A4 = 7%.) This means that fluctuations in film thickness present on the printing elements of the plate are reduced. Ideally, all the printing elements of the plate should have ink films of the same thickness. In reality, however, fluctuations of film thickness do exist. The

smaller they are, the better the inking quality of the inking unit. This is defined by the degree of irregularity η.

$$\eta = \frac{S_{max} - S_{min}}{S_{average}} \cdot 100\,\%$$

S_{max}	the maximum ink film thickness on the plate printing elements,
S_{min}	the minimum ink film thickness on the plate printing elements,
$S_{average}$	the arithmetic average of the ink film thickness of all plate printing elements.

Theoretical and practical experiments [2.1.-5] have indicated that the inking behavior of front-heavy inking units is clearly better than that of back-heavy systems. Therefore modern offset inking units in web-fed and sheet-fed presses are usually designed as front-heavy systems.

Another option for increasing inking-up quality is to install additional rider rollers, which smooth the ink film on the rollers in the main ink flow (figs. 2.1-7 and 2.1.-9). Various inking unit designs are shown in figure 2.1-10.

These roller-type inking units consist of a number of alternating stiff and flexible coated rollers. The stiff rollers (hard surface) generally perform a reciprocating movement in a transverse direction (they are also referred to as "distributor rollers") to smoothen out the ink profile on the roller surface and the scores/lines in the ink which appear in the travel direction of the sheets.

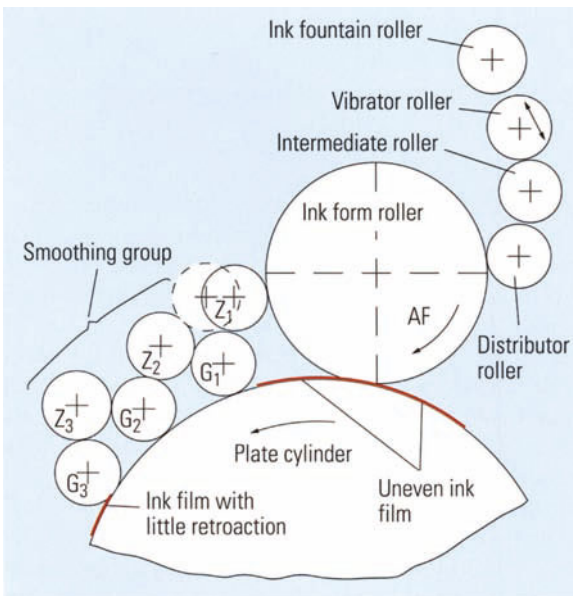


Fig. 2.1-9
Inking unit with film-thickness smoothing system on the plate cylinder

Newspaper presses, which have lower print quality demands than commercial presses, also use ink-zone-free short inking units or "*anilox inking units*" (fig. 2.1-11, see also sec. 2.1.3.5). These inking units have a simpler design than conventional inking units and offer the great advantage that the inking unit is in stable equilibrium after only a few revolutions due to the low ink storage capacity. The main disadvantage of these systems is that they require inks with lower viscosity than conventional inking units, which leads to a high dot gain during printing.

Like a gravure cylinder, the anilox roller (fig. 2.1-11) has cells. These cells all have the same filling volume. Wear is an important consideration as the excess ink is squeezed off the roller, although adequate service life is ensured with the materials used nowadays (ceramic screen roller, blade made from high-alloy material).

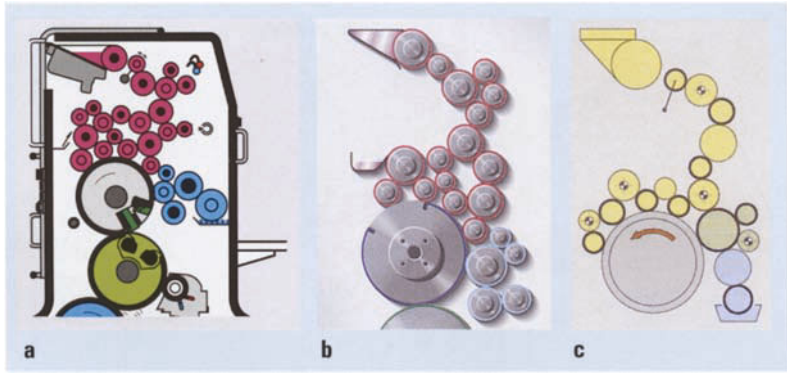
Dampening solution metering is particularly critical with short inking units, the dampening solution that is not taken up by the printing plate cannot evaporate on its short path to the ink fountain, which means it collects in the ink fountain. The main advantage of short inking units is the ink-zone-free ink feed, especially with "anilox inking units".

Conventional roller-type inking units need special ink feed systems with the option of metering the ink in the *ink zones*. Examples include fountain roller blades and fountain roller, ink zone systems.

As illustrated in figure 2.1-12, a flexible ink blade can be adjusted at varying distances to the ink fountain using ink screws to adjust the amount of ink taken out of the ink fountain. This ink blade system is not without side effects (cross talking). The ink blade can be designed to rest as a beam on n supports (n the number of ink screws). Adjusting a single ink screw may affect not only the zones right next to it, but the entire system. Therefore printing press manufacturers have developed various solutions for ink zone systems free from side effects.

The following is a short description of the ink zone system from Heidelberger Druckmaschinen AG (fig. 2.1-13). The ink film defined in thickness is created by the interaction of ink fountain roller and adjusting cylinder. The adjusting cylinder has an eccentric section which ends just in front of the cylinder so that rings are produced that rest on the fountain roller. As

Fig. 2.1-10
Inking unit designs for offset printing units.
a Speedmaster 102 (Heidelberg);
b Roland 700 (MAN Roland);
c Rapida 104 (KBA)



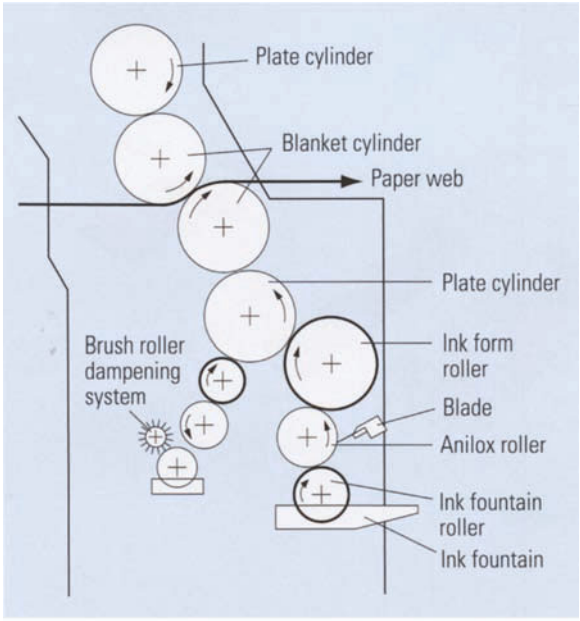


Fig. 2.1-11
Example of a "short inking unit" in an offset printing unit for newspaper printing

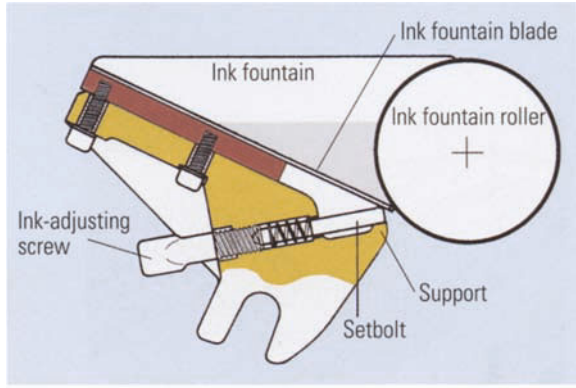


Fig. 2.1-12
Ink fountain with continuous ink duct blade and ink fountain screws

shown in figure 2.1-13b, ink-free areas are produced that on the fountain roller as a result of supporting the adjusting eccentrics. This is compensated for by the axially oscillating distributor rollers in the inking unit so that the plate is covered in an evenly closed ink film in line with the print image. A cover foil is inserted between the ink fountain roller and the adjusting cylinders, which also facilitates cleaning the ink fountain. Due to its structural design the system automatically compensates for both inaccuracy in the concentric running of the fountain roller and expansion due to heat and, as such, can be described as a self-stabilizing design.

Other ink zone systems with no side effects have also been developed, such as ink slides or slotted ink duct blade and doctor blade systems (fig. 2.1-14).

Conventional inking units (as shown in fig. 2.1-7) therefore require adjustable ink feed systems since ink consumption varies across the width of the press in accordance with the image. The ink zone elements and/or the ink fountain blade have to be adjusted accordingly (see also fig. 2.1-13).

Dampening Units

Conventional offset printing requires a dampening system to supply a very thin film of dampening solution (approx. 2 µm) to the non-printing elements of the printing plate. Since part of the dampening solution is printed via the ink, plate, and blanket and another part

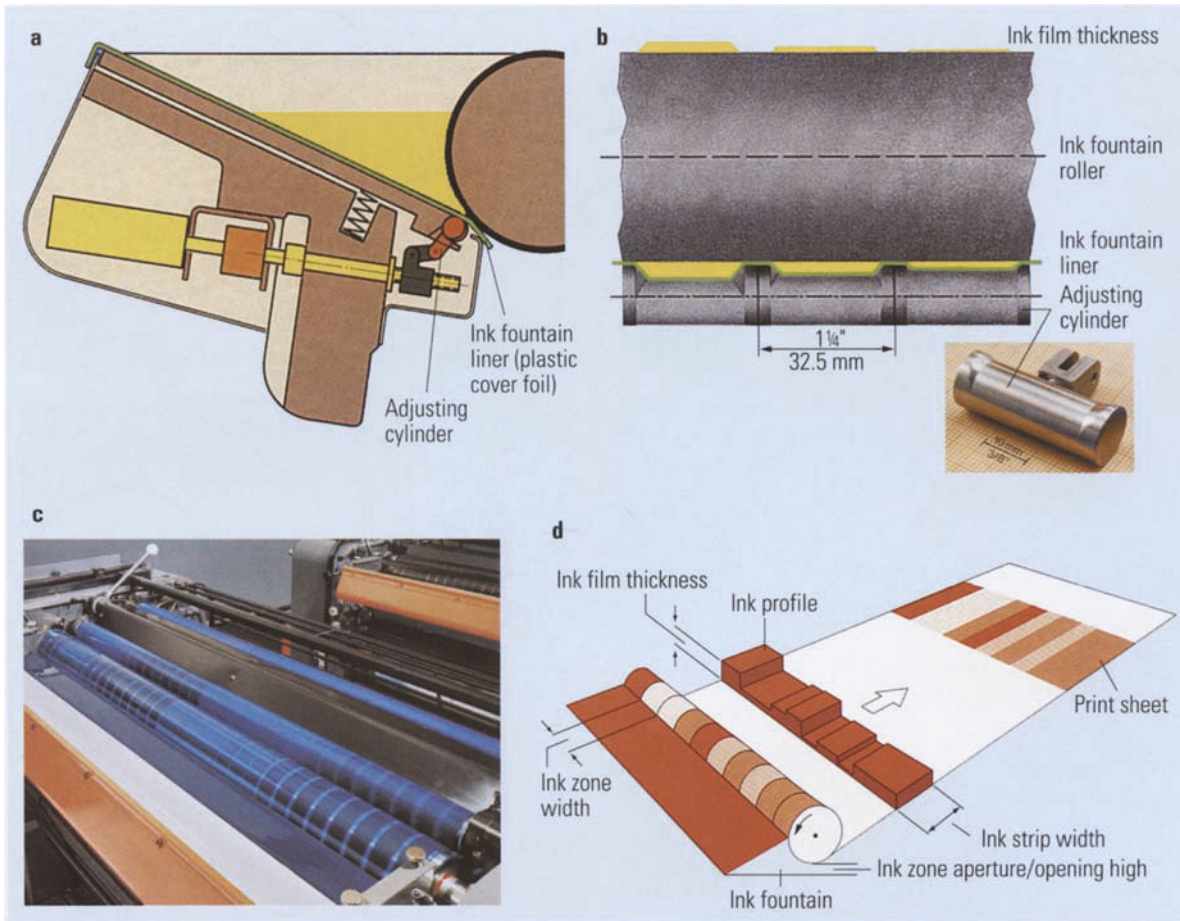


Fig. 2.1-13 CPC ink fountain with zonal ink feed adjustment free from side effects.

a Ink fountain;
b Adjustment eccentric (adjusting cylinder);
c Ink fountain in the printing unit;
d Diagram of zonal ink feeding (Heidelberg)

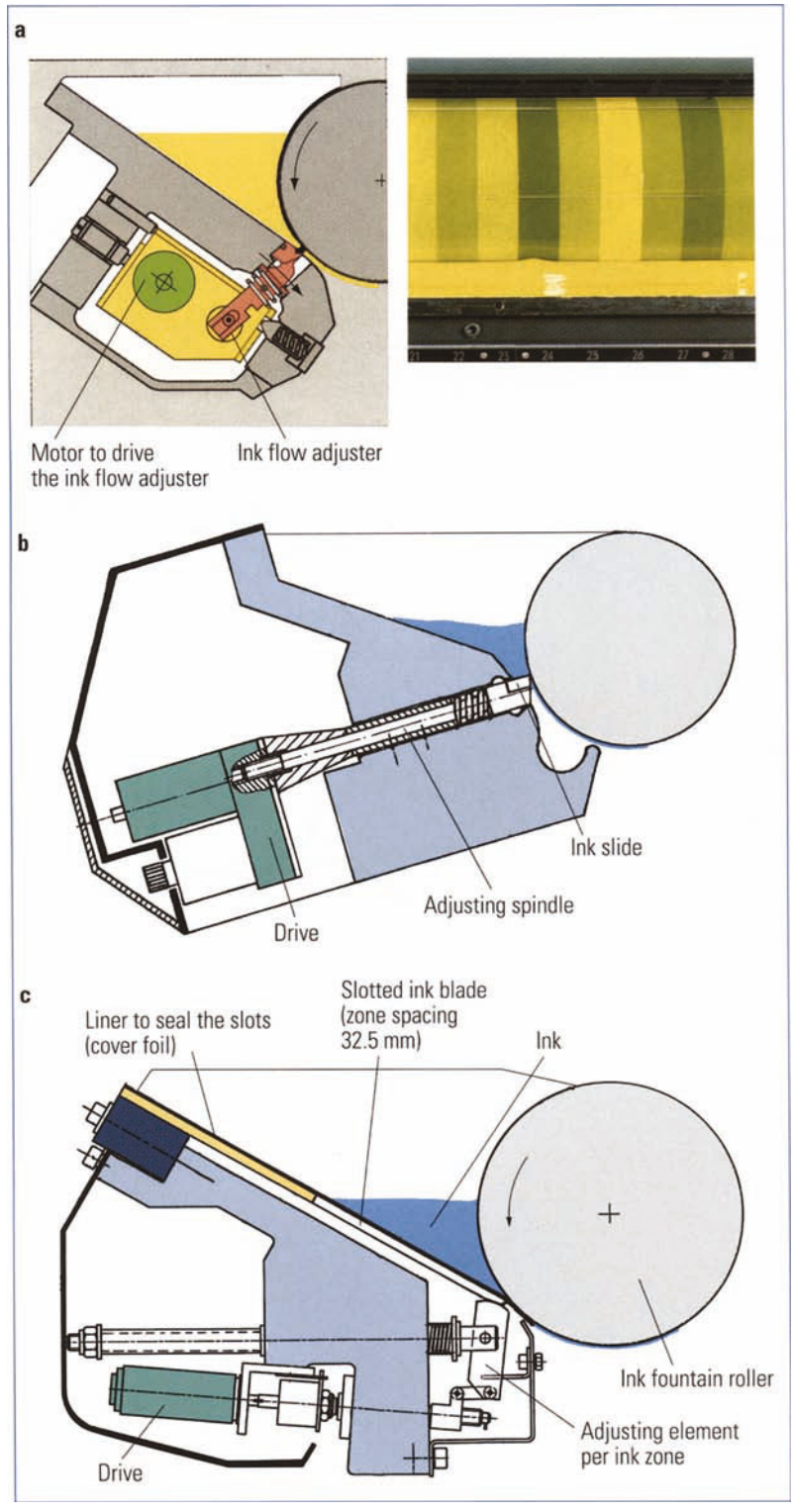
evaporates, it is necessary to have a constant supply of dampening solution. Continuous/film-type dampening units are shown in figures 2.1-7 and 2.1-10, and a contact-free brush-type dampening system is shown in figure 2.1-11. Other dampening system designs are shown in figure 2.1-15.

Dampening units have developed from the "dampening roller" used to dampen the lithographic stone. Vibrator-type dampening systems and continuous-flow dampening systems are systems with contact between the dampening solution pan, the dampening vibrator, and the printing plate. The disadvantage of these dampening systems lies in the fact that substances (e.g., particles of ink, paper dust) can get from the printing plate into the dampening solution pan and can lead to contamination. This problem does not occur in dampening systems that are contact-free or where there is no feedback from plate or ink flow. The amount of dampening solution has to be metered very accurately, as excess dampening solution cannot flow back from the printing plate into the dampening system with these systems. The systems are known as "brush-type and centrifugal dampening systems" (fig. 2.1-15d and e).

Vibrator-type dampening systems (fig. 2.1-15a) often have dampening rollers covered with absorbent mate-

Fig. 2.1-14

Ink fountain systems with zonal adjustment (free from side effects).
a Metering lever system (Model: Colortronic, KBA);
b Ink slide system (Model: RCI/CCI, MAN Roland);
c Ink knife system (Model: CPC/Web, Heidelberg)



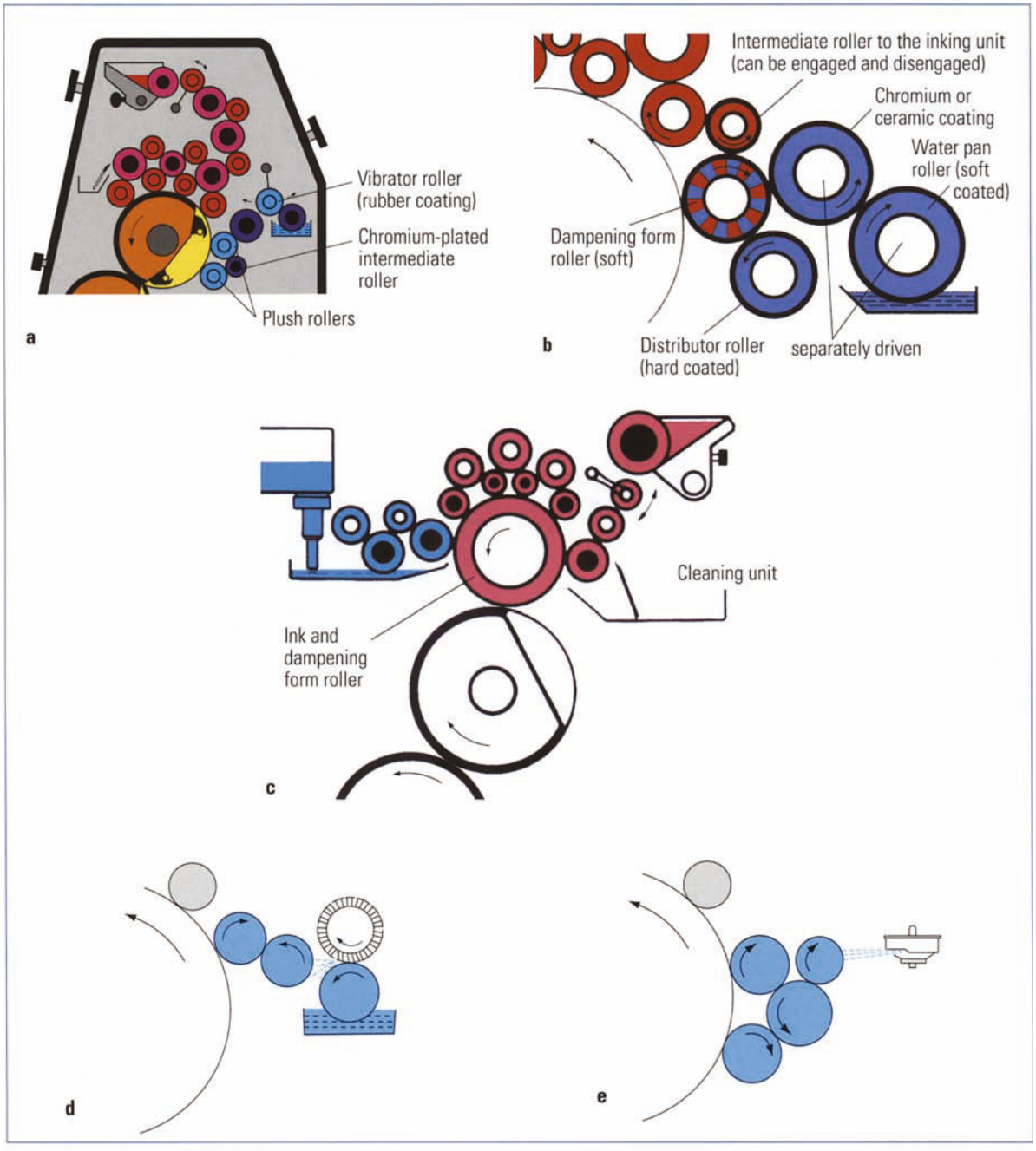


Fig. 2.1-15 Dampening system designs.

a Vibrator-type dampening system;
b Continuous-type dampening system;
c Indirect dampening solution application through the ink roller;
d Brush-type dampening system;
e Centrifugal dampening system

rials (e.g., molleton, plush). The inertia of these systems with respect to necessary changes with the amount of dampening solution to be fed is very great because the cover absorbs a great amount of dampening solution. The fabric covering also has other disadvantages with regard to the printing process:

- high maintenance,
- high paper waste rate because the required ink/dampening solution balance is reached very slowly,
- frequent malfunctions due to coverings becoming fluffy (mainly with new covers),
- often uneven distribution of the dampening solution,
- high risk of excessive supply of dampening solution.

Continuous-type dampening systems (fig. 2.1-15b) work without ductor/vibrator roller and fabric-coverings yet do usually need alcohol additives or special dampening solution additives. Dampening systems acting directly on the plate use dampening form rollers to transfer the dampening solution onto the plate.

In the case of *indirect systems* the dampening solution is fed to an ink form roller which then transfers ink and dampening solution to the plate in dispersed form (dampening solution also in the form of "surface water"), (fig. 2.1-15c).

Contact-free dampening systems are known as *centrifugal, turbo* or *brush-type systems* (figs. 2.1-15d and e). Here, dampening solution is catapulted onto the printing plate as finely dispersed droplets. Adequate surface tension ratios must then ensure a rapid spreading of the droplets. Droplets have essential disadvantages compared to the continuous-type application and it is therefore continuous-type dampening systems that prevail in the commercial printing sector. The main advantage of catapult (centrifugal) dampening systems is that the quantity of dampening solution can be metered in axial direction of the roller/plate (this is an advantage since different quantities of ink and dampening solution are needed to achieve an even emulsion throughout the ink zones).

Printing inks absorb dampening solution to a certain extent. Printers refer to this as an "emulsion". In physical/chemical terms it is an ink/water dispersion. The dampening solution is contained in the ink in the form of droplets and some of it also sits on top of the ink film.

If the dampening solution droplets fall below a certain size, the offset printing process immediately breaks down, that is, the transfer of ink onto the plate is no longer even or in accordance with the image. The tiny droplets of dampening solution mean that separation of the printing and non-printing plate elements is no longer possible. Scumming is the result, that is, the non-printing areas on the plate also print.

As with inking units, there are dampening system designs that allow the path and the distribution of the dampening solution application to be changed. This can be achieved using intermediate rollers that can be engaged and disengaged from the inking unit (fig. 2.1-15b). The quantity transferred can be changed and the cleaning effects achieved at the printing plates by using variable drive ratios of the dampening rollers (slippage).

Printing Unit

The structure and action of an offset printing unit is described below using the example of a typical sheet-fed printing press in unit-design (fig. 2.1-16). Presented in a simplified form, a printing unit of this type consists of inking and dampening units (already described), the plate cylinder with the printing plate, the blanket cylinder with the blanket fixed to it, and the impression cylinder. The plate cylinder with the inked printing plate rolls over the circumference of the blanket cylinder. The blanket cylinder, in turn, rolls over the circumference of the impression cylinder, on which the sheet of paper is held by grippers. The contact line between the blanket cylinder and the impression cylinder is called the printing nip.

The printing plate – an up to 0.3 mm thick sheet of metal or a foil – carries the image elements of the respective color separation. The blanket is an approximately 2 mm-thick, exchangeable cylinder cover made from flexible material and layers of fabric.

As can be seen in figure 2.1-16a, the plate cylinder's circumference is interrupted by an axial recess, the cylinder gap. This recess holds the plate clamping mechanism. The blanket cylinder, likewise, has a gap to hold the blanket clamping mechanism, and the impression cylinder has a gap to accommodate the gripper system for paper transportation.

To ensure perfect transfer of the print image from plate to paper, all three cylinders must have the same circumferential speed at the contact line/printing nip. Due to the recesses in the cylinder's circumferences, the relative rolling motion necessary for continuous pro-

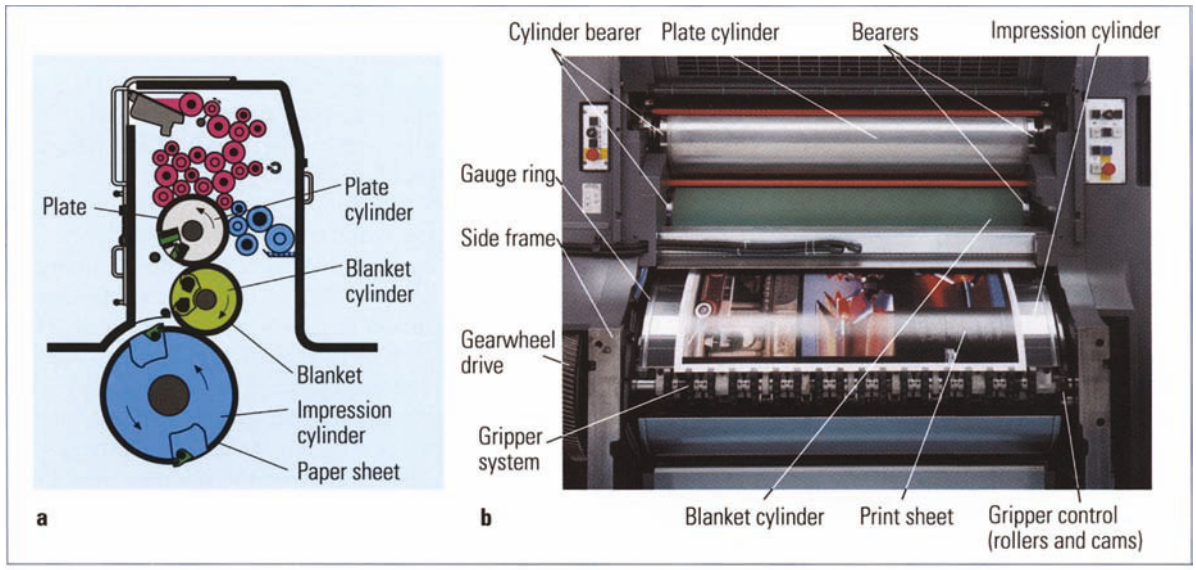


Fig. 2.1-16 Offset printing unit.
a Cylinder configuration;
b Bearers, gearwheel drive and gripper control in sheet offset (Heidelberg)

duction cannot be achieved simply by friction between the cylinder surfaces. Along with the frictional connection via the cylinder surfaces, the cylinders are also connected via a gear train for this reason.

The printing unit is driven by the impression cylinder via a gear train. The printing unit in turn transmits the necessary drive power for the inking unit. Printing problems arising from the gear train (the unwelcome "gear marks" in particular) are avoided by the narrow tolerances specified for the design of gearwheels and thanks to tried and tested production technology and quality control.

An important aspect of gearwheel design is to provide for an adjustable spacing of cylinders, so that certain operating conditions can be met (engaging and disengaging of the cylinders). When setting the paper thickness, the variable spacing between blanket and impression cylinder shafts must be given particular consideration when going to impression on. For operational reasons changes in shaft spacing are achieved by using helical toothing with an appropriate tooth profile. This type of toothing is, to a large extent, insensitive to changes in the shaft spacing.

It must be ensured that even at the smallest shaft distance there is enough backlash and that at the largest shaft distance the teeth still mesh perfectly. For this reason, "full-depth teeth" are used for printing presses. Moreover, the synchronized operation of the cylinders is optimized by the helical gearing. This increases the contact ratio of the gears.

For the proper transfer of ink between plate and blanket and between blanket and paper, a sufficiently high contact pressure between the cylinders as well as the same circumferential speed of the cylinders are necessary. To adjust the contact pressure between plate cylinder and blanket cylinder, which move towards each other at a fixed axial clearance, the plate or the blankets are underlaid, a process which results in a 0.05–0.15 mm radial deformation of the blanket. The printing pressure between the blanket and the impression cylinder is set according to the nature of the substrate.

The gearwheel-drives produce slippage between the surfaces. The slippage means that, in addition to the radial deformation of the blanket in the contact zone, the cylinders also undergo tangential deformation. The forces cause the deformation of the blanket to die down abruptly during the rotation of the cylinders at the start of the gap and are just as abruptly built up again when the cylinders come into contact again. This fluctuation of the contact pressure between zero and the maximum value is also referred to as "cylinder gap shock." It caus-

es vibrations in the printing unit which impair the printing result.

Bearer rings, also called "cylinder bearers", made from hardened steel with high rolling strength are inserted on the sides of the plate and blanket cylinders to minimize the effect of this vibration. They are of approximately the same diameters as the working pitch diameters of the gears and roll upon one another at high initial tension. The initial tension of cylinder bearers is approximately 15000 N on presses for the 70 cm × 100 cm (28" × 40") printing format. The basic task of the cylinder bearers is to prevent the rotational vibrations that would normally be generated between the cylinder and gears. In addition, the rigidity of the cylinder couples is increased by the cylinder bearers. This shifts the resonant frequency into non-critical ranges and reduces bending vibrations, which are caused when the cylinders roll over the gaps. Furthermore, by choosing varying cylinder bearer diameters, which are slightly smaller on the plate cylinder than on the blanket cylinder, it is possible to create initial tension in travel direction between cylinder bearers and gears. This ensures an optimal groove angle with well defined flank contact of the gears even if there is a long torque impact during overrunning of the gaps.

As previously stated, for the proper interaction of plate, blanket and impression cylinders it is essential that they be connected to each other so that no relative motion takes place in a circumferential or radial direction, that is, as little vibration as possible is produced. Thus the cylinders have to be fixed to each other with a minimum of oscillation. Therefore, the structural design of cylinder bearing and printing unit frames takes on considerable importance. For all three cylinders the bearing assemblies must be dimensioned for high forces. Moreover, to ensure an accurate ink transfer, the cylinders must be very rigid and rotate with zero backlash.

Due to the diagonal register adjustment (see sec. 2.1.2.3), the plate cylinder must also allow for an angular adjustability of the bearings and the blanket cylinder bearing must allow for complex switching motions. Due to the diverse requirements, printing presses are practically always equipped with almost zero-backlash needle bearings or pretensioned tapered roller bearings. They are supplied by roller bearing manufacturers with factory set pre-tension.

As can be seen in figure 2.1-16b, the cylinders with their bearings are supported between two vertical side frames which are mainly made from high-quality casting material. Since the exact parallel alignment of cylinders is of vital importance, the side frames are machined in pairs to make the holes which are to take up the cylinder bearings. To give the printing unit the necessary rigidity against vibration and distortion, the side walls in the lower area are screwed to a rigid, box-type base frame. In some designs the base frame also serves as a machine foundation. Cross bars are used in addition to reinforce the printing unit frame as well as the base frame.

Alongside supporting the cylinders, the press frame has the task of absorbing the forces and torque that occur during operation of the printing unit. The gripper systems, for example, are supported by rollers and cam followers revolving along with the cylinder on gripper opening cams. These are firmly connected to the press frame and control the opening and closing of the grippers depending on the printing unit's angle of rotation.

There are many components that move against one another in a printing unit. In the interests of continuous functional performance and the service life of these components, adequate lubrication is essential. The bearings and gears, in particular, place high demands on the lubricant. From a technical point of view, oil lubrication is the most suitable. However, leakage can be a problem. Therefore, for presses of small- to medium-sized formats liquid grease is also used. When selecting lubricants, factors such as their compatibility with different solvents, their effect on non-ferrous metals and plastics, and their durability must be considered. When using liquid grease in central lubrication systems, the flowing qualities also play an important role.

Quality control and corresponding measurement technique are dealt with in detail in sections 1.4, 2.1.4, and 3.2.2. Only an overview of the parameters that define quality will be given at this point. The quality characteristics of printed products are described in [2.1.-6]. One or another quality criterion (quality characteristic) may become more important, depending on the print job and the subject. The most important *quality criteria* are:

Evenness of the Optical Density of Halftone Areas

If, for example, a halftone area in a printed image has a constant tonal value, small differences in the order of $\Delta D = 0.02$ can be perceived by the human eye (see also sec. 1.4.1). Fluctuations in the print are noticed in the form of cloud formation or streaks. If the optical density fluctuates from copy to copy these fluctuations are immediately apparent when comparing the prints.

Evenness of the Optical Density of Solid Areas

Fluctuations within a printed product or even from copy to copy can be also perceived easiliy by the human eye in this case.

Halftone Value Transfer

Considerable differences in tone value can occur during both platemaking and printing and have a detrimental effect on print quality. However, constant halftone value transfer can be achieved in platemaking and in printing by standardization of the offset process [2.1.-1]. The blanket and the press setting exert the greatest influence on the transfer of tone values during printing. A change in the contact pressure acting between the plate and the blanket cylinder causes considerable changes in the transfer of tone values. A change in the contact pressure acting between the blanket and the impression cylinder tends to produce only small tone value deviations.

Deformations of the halftone dots in the halftone image can very easily lead to dot gain and color shifting. Slurring and doubling are the two most important influential factors when printing (fig. 2.1-17a).

In the case of *slurring*, the print ink is squeezed over the edge of the halftone dots. This is caused by relative movements between the surfaces of the printing plate and the blanket cylinder or between the blanket cylinder and the substrate, meaning that the surfaces then no longer fit precisely on top of one another. Slurring in the direction of print is known as circumferential slurring and slurring at right angles to this as lateral slurring. It is usually caused by the pressure between two adjacent cylinders being too great. Since the blanket has hardly any area to give way in the lateral direction, the deformation occurs predominantly in the direction of print. In this case, a round dot is deformed to become an ellipse. An insufficiently tensioned blanket or excessive inking can often also be the cause. Slur-

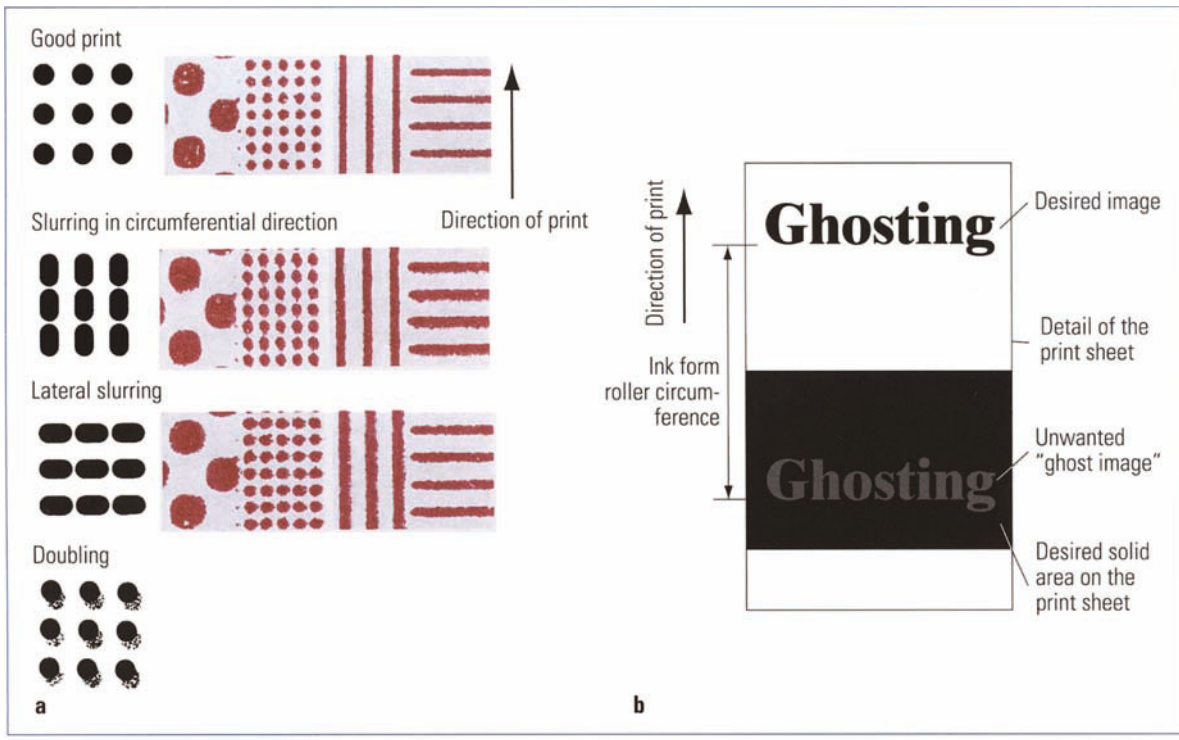


Fig. 2.1-17 Quality attributes of printing.

a Dot deformation caused by slurring and doubling;
b Ghosting effect in the print image caused by the feedback of the ink on the plate to the ink form roller for the image to be printed and the subsequent inking of a further ink-accepting area on the printing plate

ring can also occur in the lateral direction. Directional errors can be clearly seen on color control strips with line fields (fig. 2.1-17a). Lines which are at right angles to the direction of print become wider due to slurring in a circumferential direction; the halftone becomes darker while the lines remain unchanged in the direction of print.

Doubling is when a halftone dot increases in size and the desired dot of the print image has a double (or multiple), shadow-like contour. This lightly offset color impression increases the halftone values, that is, leads to dot gain. Doubling is caused by register deviations during the printing process (caused by press vibrations and/or paper deformation, feeding variations). In multicolor presses the print sheet with the fresh ink, for instance, from the first printing unit, is pressed against the blanket cylinder of the subsequent second printing unit. Due to ink splitting an impression of the halftone structure is produced on this blanket which is then printed again on the subsequent sheet (or section on a web-fed printing press). This means that the image must be printed precisely onto the freshly printed image as the image elements are otherwise enlarged by doubling. The film thickness of this enlarged area is less than the actual print, in accordance with the ink film on the blanket of the subsequent unit. As little as 10 µm misalignment leads to tonal shifts.

Ghosting

Ghosting is when image elements overlap onto subsequent image areas in the direction of print (fig. 2.1-17b). The inking rollers are generally smaller than the plate cylinder in a roller inking unit. After inking the plate, an ink profile remains on the inking roller due to the ink splitting and can appear in the print image as a "ghost image" after one roller revolution. Several ink form rollers of various diameters (on sheet-fed offset printing presses normally four form rollers) and a correspondingly dimensioned inking unit regarding the number of rollers and the points of contact as well as the effect of the lateral distribution, usually ensure that the ink film is smoothed out sufficiently on the printing plate. However, with an unfavorable color combination on the printing plate with regard to the geometry of the inking unit, visible ghosting effects can occur.

Mottling

Mottling is the spotty and cloudy appearance of the ink on the substrate. An uneven absorption of the printing inks by the substrate between the printing units of a multicolor press leads to uneven re-splitting on the subsequent blankets.

Unevenness in absorption causes uneven ink acceptance, which becomes visible, particularly in overprinting with potentially increased severity of the mottling effects. The faster and more evenly the ink is absorbed the better and more even the ink acceptance of the subsequent ink. The mottling effect can be counteracted, in particular by altering the absorption characteristics of the inks, by changing the sequence in which the inks are printed, or by using a different kind of paper. Mottling is influenced significantly by the characteristics of the paper with regard to the homogeneity of its structure and its coating.

Trapping

Trapping is the acceptance behavior of the ink in wet-on-wet overprinting of several inks. The ink splitting is mainly dependent on the rheological properties (e.g., tack) of the inks. So that the ink adheres well to the already printed inks, the subsequent ink must have a lower tack.

Absolute Value of Optical Density and Color Location

The absolute value of the optical density together with the colorimetric specifications of the color used also determines the color location. Colorimetry based on spectral values is primarily used for multicolor prints where separated colors are overprinted.

The optical density or color location value must be kept within the tolerance limits by means of suitable measuring and control systems. This applies both for halftone areas and solid areas. While a densitometer reading will often suffice for measurements during production, a spectrophotometer reading is necessary for efficient makeready and color analysis.

Register

The register (the accurate overprinting of the individual color separations) has a crucial influence on print quality. The sharpness and cleanness of a four-color print is greatly affected by the accuracy of the color register.

Register refers to the accurate positioning of the printed image on the substrate in relation to the sheet edges or the web cut-off length; mostly we also talk about colour register with our printing of color separations.

Gloss

The gloss of the printed image, and above all the evenness of the gloss, has a subjective effect on the print quality, although the legibility of extremely glossy

printed products decreases. Visually, a high gloss is often associated with high print quality.

Type of Screening

The finer the screen, the higher the resolution achievable for the print, but also the greater the dot gain. To avoid moiré and rosette effects in multicolor printing, non-periodic screening has often been used. With these screens it is also possible to reproduce fine details of the original, and register fluctuations have a less pronounced effect on color fluctuations (see also sec. 1.4.3). Further improvements to the print can be achieved with hybrid screens (combination of period and non-periodic screening technologies).

Whiteness and Uniformity of Substrate's Whiteness

Whiteness plays a decisive role in determining the colors produced in four-color printing. Art papers have coatings that enable a very high level of whiteness. This produces brilliant multicolor prints. The hue of the blank paper has a decisive effect on the color reproduction.

Measuring Techniques

Specific measuring techniques and measuring instruments for print control can be employed to measure the described quality parameters. The primary measuring techniques used for determining quality are:

- densitometry,
- colorimetric measurement,
- gloss measurement,
- measurement of register differences,
- measurement of whiteness (whiteness meter, spectrophotometer),
- determining the screen frequency,
- determining the sharpness of contours (measuring microscope).

There are a large number of control elements that can be integrated in the printed image. They support metrology, but are also used to visualize the deviations affecting the quality of the print. Measuring techniques are explained in greater detail in sections 1.4.1, 1.4.4 and 2.1.4.

2.1.2 Sheet-fed Offset Printing

Sheet-fed offset printing has impressive economic and qualitative advantages over other printing technologies. Fundamental attributes of sheet-fed offset are flexible production options and the relatively economical production of printed products of a very high quality for a wide range of print volumes. The color combination ranges from one to four-color prints up to twelve-color prints (with perfecting). In sheet-fed offset printing, substrates of different sheet sizes and grammages are processed and these can generally be obtained off-the-shelf at short notice.

Just as important for the client as the free choice of format is the range of special substrate qualities. The great variety of standard substrates for sheet-fed offset necessitates well-organized stock-keeping in the paper industry. In-line or off-line finishing operations, such as coating, imprinting, numbering, perforating, and punching are popular technologies used in sheet-fed offset. And finally the sheet finishing variants available are virtually inexhaustible.

A sheet-fed offset press must basically perform the following tasks:

- provide a high-precision conveyance of the flexible substrate at high speeds, under very dynamic, process-specific strains;
- enable a complicated printing process, involving several material flows (of dampening solution, ink, paper, air), to run in a controlled and reliable way.

2.1.2.1 Paper Travel

High-precision conveyor systems, guide elements, and monitoring systems are necessary in order to route the sheet from the feed pile via the feeder, through the printing units, and finally to the delivery, where the printed sheet is stacked in a pile again (fig. 2.1-18). In the *feeder area* the sheet is mostly conveyed by suction and friction, whereby the top sheet of the feeder pile is lifted by suckers (the so-called suction head) and routed to the feed table where it is guided between rollers, belts, and brushes. Each sheet is aligned with great precision before it is fed to the printing units. For this purpose it must be slowed down to be aligned to the front and side guides, which usually takes place when the sheet is completely stationary. It is then taken over by grippers, accelerated to production speed and transferred to the printing units. In presses of the 70 cm × 100 cm format class that typically produce 15 000 sheets an hour, the sheet is transported at speeds of approximately 3.5 m/s. Gentle acceleration to printing speed is achieved by suitable sequences of movement of the feed drums or swing gripper systems.

In the *printing units* (fig. 2.1-18) the sheet is fed to the impression cylinder. Held by gripper systems (fig. 2.1-19), it passes under the blanket cylinder as the cylinders continue to revolve and the image is transferred onto the sheet. It is then passed on to the transfer drum to be conveyed into the next printing unit or into the delivery. The printing process necessitates a certain contact pressure between the plate cylinder and the blanket cylinder and between the blanket cylinder and the impression cylinder in order to transfer the ink. The contact pressure must be set according to the surface structure and thickness of the paper. This is usually

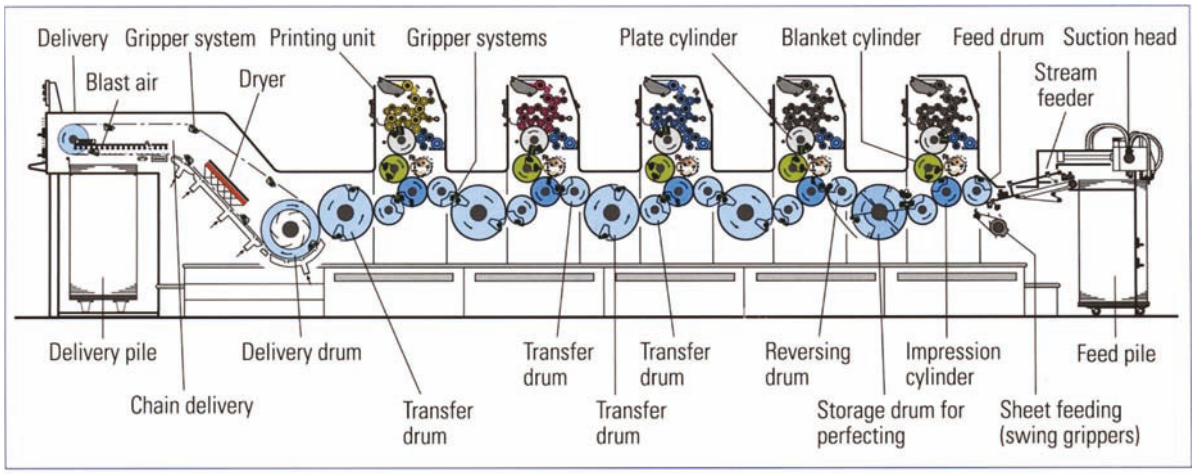
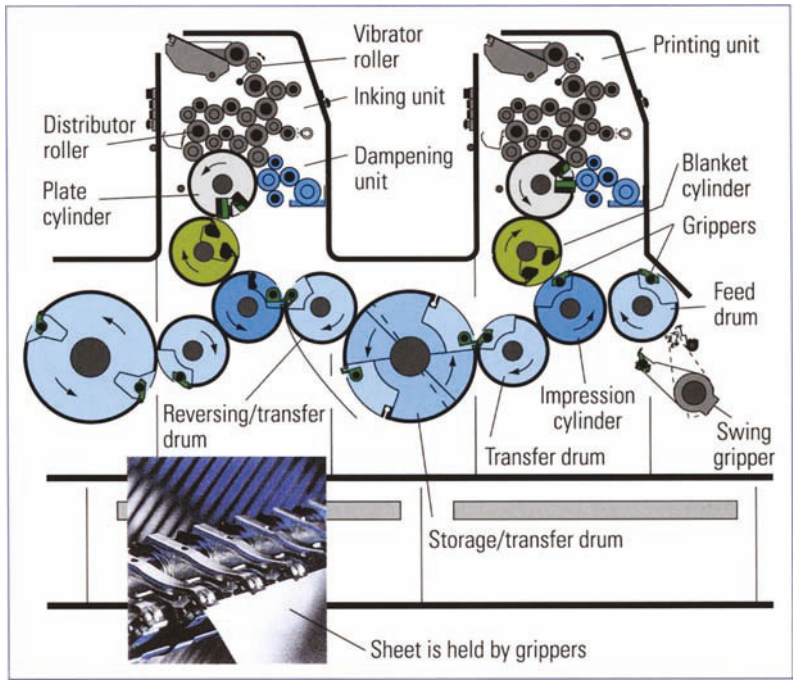


Fig. 2.1-18 Sheet conveyance in a sheet-fed offset press in unit design (Speedmaster SM 74-5-P-H, Heidelberg)

Fig. 2.1-19
Sheet conveyance between printing units for perfecting or straight printing (Heidelberg)



done by suitable adjustment of the blanket cylinder in relation to the impression cylinder, which does not affect the contact pressure between plate and blanket.

Offset inks are stiff, highly viscous, and consequently sticky. So that the paper does not stick to the blanket at the areas to be printed, the grippers have to pull the sheet with such a great force that it can come free of the blanket cylinder. To release the paper from the blanket, it needs to be pulled off by the grippers; this means the grippers must operate with the appropriate clamping force. In spite of the considerable gripper closing force that needs to be applied, the gripper pads should leave as few marks as possible on the print and should also be resistant to wear and tear. To ensure that the sheet is held reliably in position, appropriate gripper covering materials are used (e.g., polyurethane, ceramic) and the gripper pads have a special surface structure (grooved, roughened). Nevertheless, for physical reasons there is a certain overtravel of the substrate on the blanket cylinder, as illustrated and explained in greater detail in figure 2.1-54 and section 13.1.3 (fig. 13.1-51).

After printing, the sheet is transferred to the next cylinder. This transfer from cylinder to cylinder, from gripper system to gripper system, must be concluded after a cylinder rotation of only a few degrees of angle. In this angle range the sheet is held for a short period by two gripper systems on the two cylinders at the same time ("synchronous movement"). If this synchronous movement takes too long, the sheet will tear at the gripper edges. The cam control, which brings about the opening and closing of the grippers, needs to operate in an extremely accurate way and must be optimally adapted to the motion sequences as well as the acceleration and deceleration forces (deceleration torque) present. Gentle and scarcely audible gripper closure can be ensured by suitable design of the cam control in relation to the dynamic behavior of the gripper system's components during the closing process. The movement of the grippers and the location of the front edge of the sheet are illustrated in figure 2.1-20.

The sheets lie on the *transfer drum* (fig. 2.1-18) of the next printing unit with the freshly printed ink directly on the drum surface. Since the ink is not yet sufficiently dry, ink may be transferred to the surface of this drum during contact. Ink may collect there and smear subsequent sheets. A simple way of avoiding smearing is to position support wheels instead of closed surfaces in the image-free strips between the print pages. However, the necessary repositioning of these support wheels for each new print job is tedious and time-con-

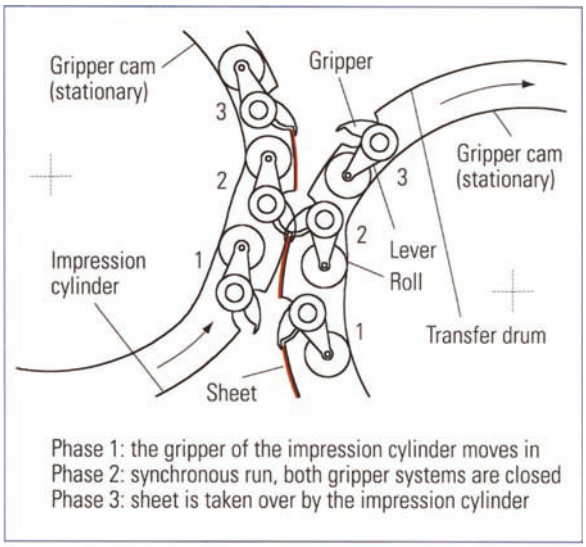


Fig. 2.1-20
The different gripper control stages up to the sheet transfer

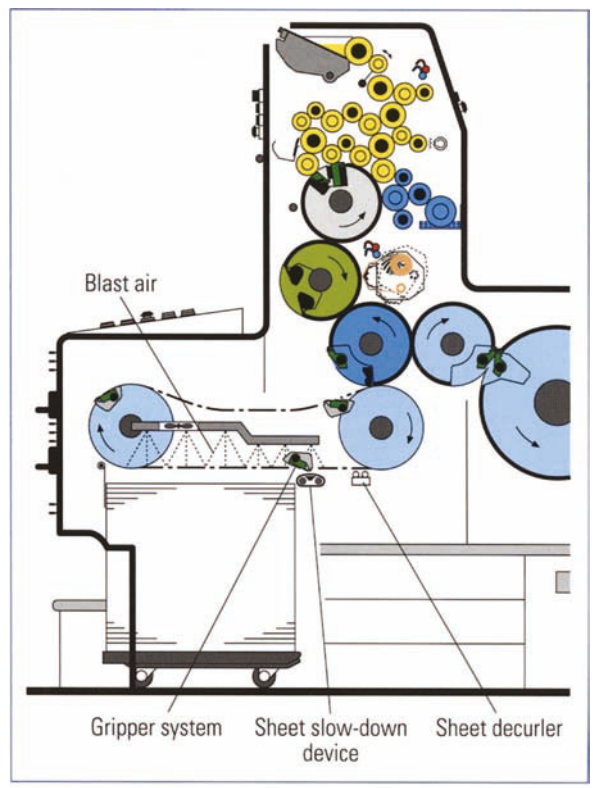


Fig. 2.1-21 Chain delivery for standard pile delivery (Heidelberg)

suming, and more often than not there are no suitable image-free zones on the sheet where the wheels could be positioned. Other solutions had to be found. Solutions currently in use to prevent smearing of the freshly printed sheet by selecting suitable materials and surface structures are described in section 2.1.2.4.

The other inks are printed on the sheet when it passes through the following printing units. The sheet transport from printing unit to printing unit has to be extremely accurate and in register and the print images of the individual color separations must be accurately aligned – for high quality jobs at an accuracy of 0.01 mm to one another. These demands on sheet transport, in addition to the high production speeds, impose considerable requirements on the press drive and on the synchronous operation of all printing units.

Before the sheet is stacked in the *delivery pile* (figs. 2.1-18 and 2.1-21) after it has left the final printing unit (fig. 2.1-22), most press configurations involve other process steps such as coating, drying, or at least powder spraying and sheet decurling. On its way from the final impression cylinder to the delivery pile, the sheets are conveyed at production speed in chain systems and held by grippers. When the sheet arrives in the delivery it needs to be slowed down so that it can be gently dropped down on an air cushion onto the delivery pile in a stationary condition. The drying and solidification of the ink (by absorption and oxidation) that is required for the further processing steps of the printed sheets usually takes place in the pile.

2.1.2.2 Feeders

There is a great variety of constructive solutions for feeder variants used in printing and print finishing machinery. *Single-sheet feeders* (fig. 2.1-23) or *stream feeders* (fig. 2.1-24) are found on sheet-fed offset presses. The single-sheet feeder has the advantage that it is easier to adjust to the sheet size and the paper quality. High-speed presses processing large formats, on the other hand, are exclusively equipped with stream feeders, so that the highly dynamic processes and the accurate sheet alignment can still be mastered in accordance with quality requirements.

The *feed system* has the task of picking up the sheets from the feed pile, separating them, conveying them to the feed table via a feed system, and aligning them at the feed guides. Since each sheet is individually aligned at the feed guides (fig. 2.1-25) the print image can be positioned on the sheet with an adequate degree of accuracy (position in relation to the paper

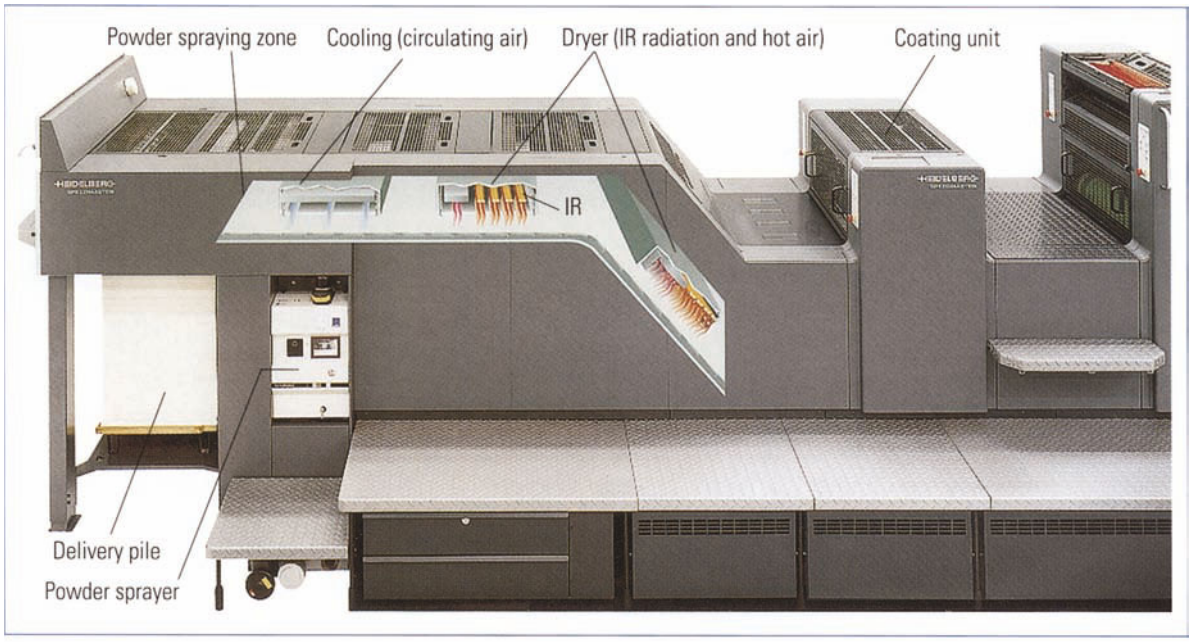
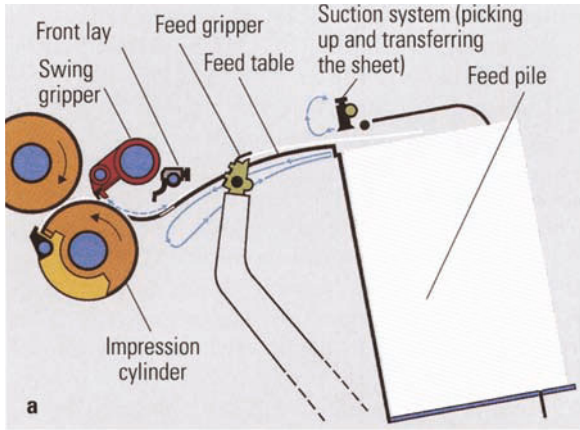


Fig. 2.1-22 Press components after the printing units: coating unit, various dryers, powdering unit, high-pile delivery (Heidelberg)



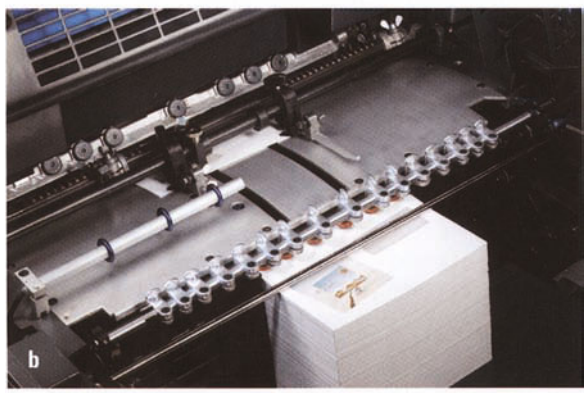
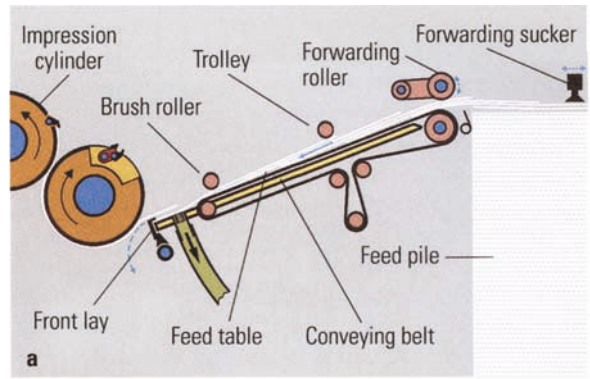


Fig. 2.1-23 Single-sheet feeder.
a Diagram of the sheet transportation;
b Example of a single-sheet feeder (Heidelberg)



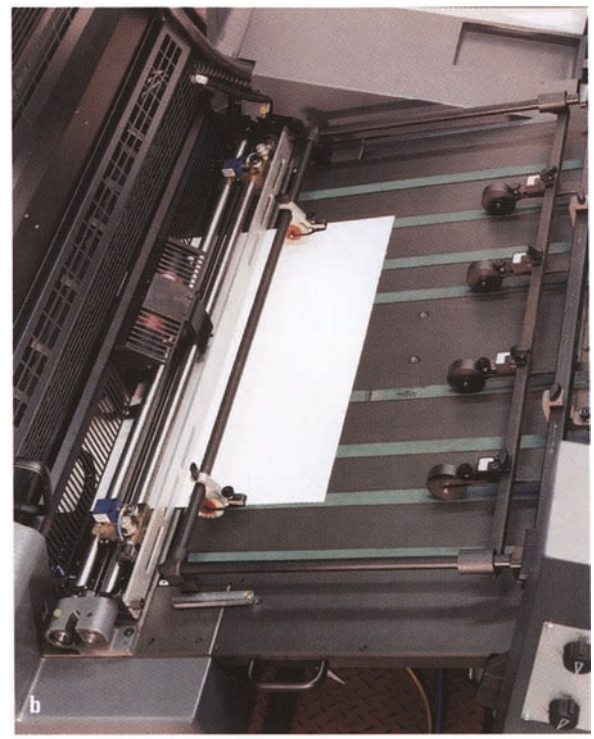


Fig. 2.1-24 Stream feeder.
a Diagram of the sheet transportation;
b Example of a sheet stream feeder (Heidelberg)

edges and, if applicable, to a preprinted image on the front or reverse side). No inaccuracies at all should be recognizable on the finished product with the naked eye. Poor sheet feeding might result in register errors during a second pass to print another color, therefore an extremely high level of feed accuracy is called for here. Alignment inaccuracies associated with the position of the print image in relation to the sheet edges are often only noticeable during finishing and/or have a visible detrimental effect on quality after trimming, folding or punching.

Single-Sheet Feeder

A single-sheet feeder feeds the sheets to the feed table. While this is happening, the sheet is usually lifted near the front edge by several suckers (fig. 2.1-23) and taken to a position at which either the feed gripper or the conveyor belts can take over the sheet. From there the sheet is then transported to the *front and side lays*, where it is aligned.

The separation of the top sheet from the feed pile in order to transport it to the feed table is a difficult task, which is basically solved by the interaction of suction

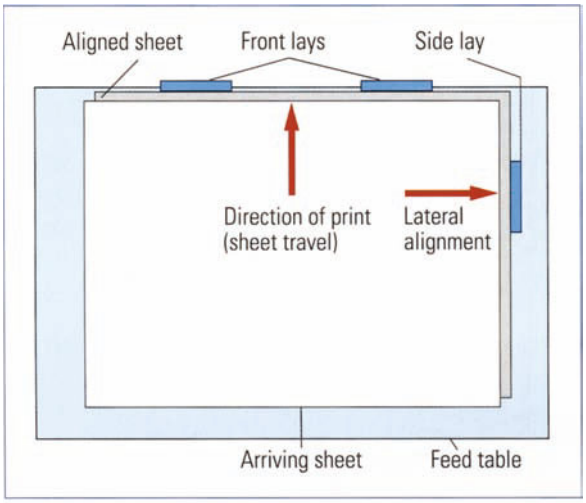


Fig. 2.1-25 Sheet alignment on the feed table at front and side lays

and blower systems. Two sheets occasionally stick together as a result of electrostatic charges or get caught at the cut edges. To prevent these "*double sheets*", separators and blast air are used to support the safe separation of sheets. Undetected double sheets might, under certain circumstances, damage the blanket and the grippers in the press. Unprinted sheets in the delivery pile can also trigger malfunctions and spoiled products as a result of undetected double sheets. The clean separation of the sheets is monitored in the feeder area by a *double sheet detector*.

The separation of sheets picked up from the pile is supported by suitable measures. Air blowers that blow against the front and rear edge of the pile fan the upper sheets. As each individual sheet is being lifted, mechanical sheet separators separate any sheets sticking to the top sheet. In simple systems (fig. 2.1-23) separation takes place at the front edge of the pile by means of an adjustable tilting motion. While this is happening, the sucker bends the front edge of the sheet, as a result of which adhering sheets are pushed slightly apart and can be separated much more easily. Another factor supporting this separation process is the stiffness of the substrate (fig. 2.1-26). With single-sheet feeders, the following sheet can only be lifted by the suckers when the previous one has completely left the feeder pile. This affects the conveying speed in the feeder area, being approximately the same as the production speed, making the time available for sheet alignment correspondingly short.

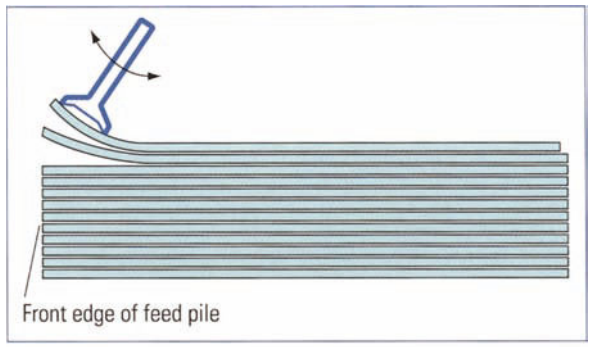


Fig. 2.1-26 Sheet separation by sucker tilting

Stream Feeder

With stream feeders (fig. 2.1-24) the sheets are separated initially by a *suction head* (figs. 2.1-27 and 2.1-18) at the rear edge only. Lifting suckers lift the rear sheet edge, and here again sheet separation is supported by blast air and sheet separators. Cycled blast air is now blown between the sheets and causes the entire sheet on the feed pile to float on an air cushion. In another movement sequence the sheet is fed to the stream of sheets on the belt table using forwarding suckers. The next sheet is lifted from the pile when the preceding sheet is about a third of the way along the feed pile. The rate of motion of the sheet stream is in this example approximately a third of the production speed, as a result of which it is in fact possible to achieve high production speeds while at the same time maintaining high sheet-alignment accuracy.

A *forwarding roller* on the belt table, which runs synchronously with the press, clamps the sheet upon its entering the belt table, thus placing it into synchronous movement with the sheet stream. The time of arrival of the sheet in the feed guides is determined by the moment the sheet is clamped on the forwarding roller. Slight variations in the sheet stream may lead to early or late sheets. The arrival of the sheets at the feed guides is subject to a certain variation. To avoid press stoppages and ensure a proper sheet alignment at the *front and side lays*, the sheet arrival is set to a mean value of the optimal feeding time and the range of variation optimized by adjustments at the feeder.

The sheet separation process and the feeding of the sheets into the sheet stream essentially depend on the substrate. Differences in surface properties, paper thickness, grammage, porosity, electrostatic charges and so on affect the sheet travel. Therefore, it must be

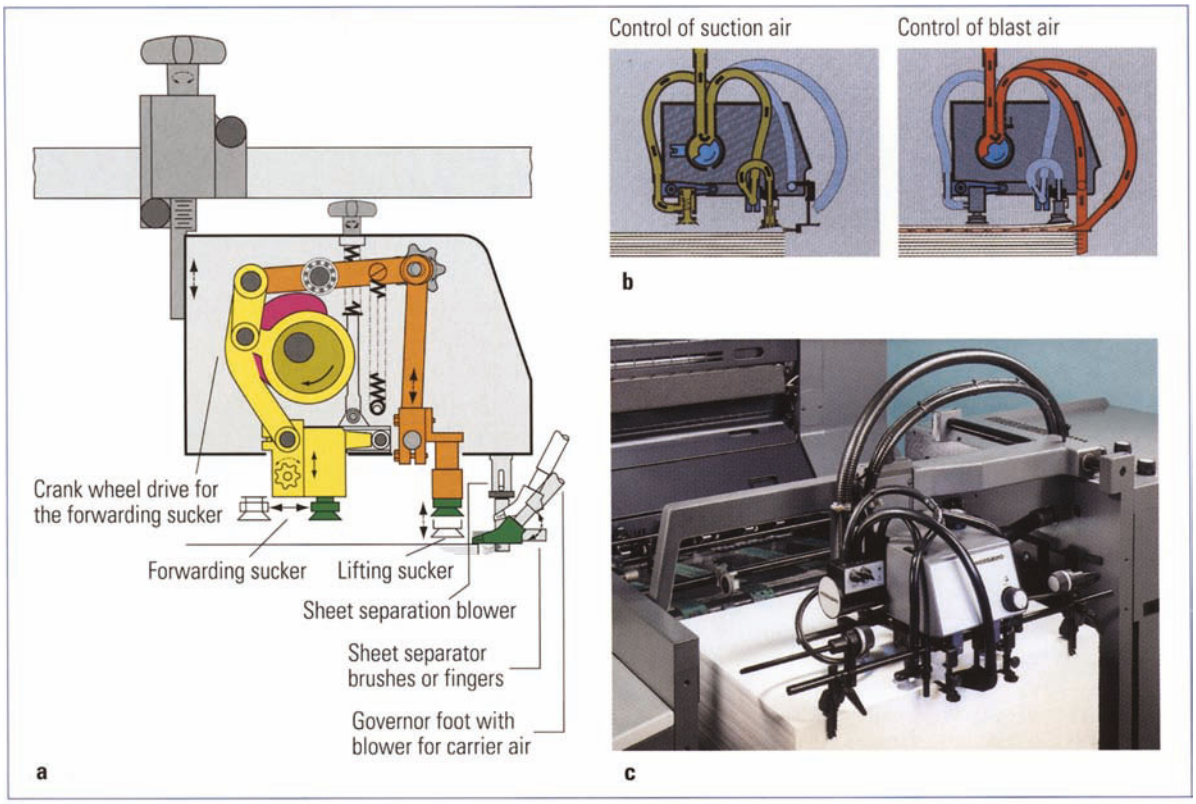


Fig. 2.1-27 Suction head.

a Diagram of sucker, blower and conveying system;
b Suction and blast air control;
c Suction head on a stream feeder (Heidelberg)

possible to adapt the entire feed system to extremely varied paper qualities. Since with high-speed presses the feed behavior of the sheet cannot be followed by the naked eye alone, state-of-the-art accurate measuring, display and control systems are used to monitor the sheet travel from the feeder through to the delivery.

The two feed systems, the *stream feeder* and the *single-sheet feeder*, are very different in their structural design, the way they are set, and their application. The single-sheet feeder has the advantage that its structural design is comparatively simple, which makes the operation uncomplicated. The single-sheet feeder requires significantly shorter set-up times for a change of format but is, in principle, only suitable for smaller formats and lower printing speeds. Using a single-sheet feeder on a high-speed, large-format press would lead to erratic movements. It was also necessary to have sheet transport that is free of scratches and abrasion for stream feeders. This is resulted in a feeder table using stream feeders which are easy to adjust. This led to the development of a *suction tape feeder table* (fig. 2.1-28) which operates without pressure rollers acting from above upon the sheet. The transport of the sheets is only assisted by brushes when necessary.

Double Sheet Detectors

Any double or multiple sheets (i.e., two or more sheets are picked up together and guided to the feed table) must be detected in good time if subsequent damage is to be ruled out. As soon as a double sheet is detected in the feeder, the feeder stops the conveyance of this double sheet and any following sheets. The press control usually ensures that the preceding sheets are printed and transported to the delivery. As can be seen from table 2.1-2, the

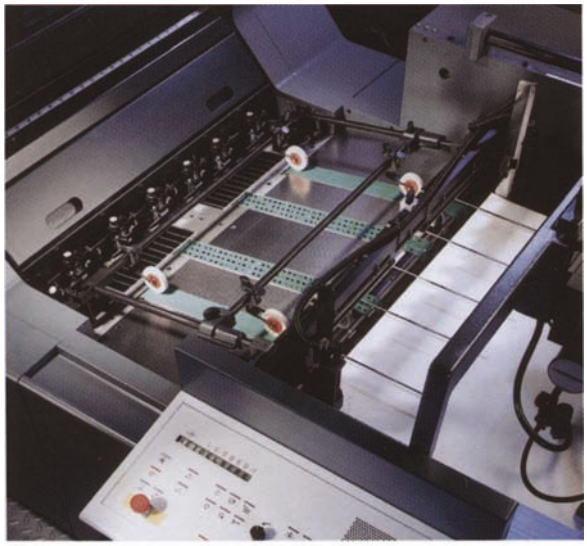


Fig. 2.1-28
Stream feeder with suction tape feed table (Speedmaster SM 74, Heidelberg)

different double sheet detection systems all have certain limitations in the identification of different substrates.

In many cases double sheet detectors still operate mechanically and usually have to be adjusted to the substrate thickness. They have certain limits with respect to their sensitivity, as in the case of light-weight papers. The operation of optical double sheet controls is very much easier, as they adjust themselves to the material thickness at the start of the sheet travel. In addition to position sensing systems, double sheet detectors mainly use radiation intensity damping with infrared or ultrasonic systems to measure the sheet thickness. The capacitive measuring system is particularly suitable for thick substrates but its application is severely limited for substrates containing moisture.

Sheet Alignment on the Feed Table using Three-Point Alignment

Alignment precision has to be met within sufficiently narrow tolerances wherever a sheet has to run through the press a second time. This applies for the front and reverse sides with straight printing and perfecting, it applies for finishing at the paper cutting unit, at the folder, and also for punching, embossing, or creasing. It also applies for a second sheet pass when imprinting other colors such as decorative colors for multi-

System	Systems with contact		Systems without contact		
	mechanical	inductive	optical	acoustic	capacitive
Measuring principle	Distance measuring		Damping the output signal (the intensity of the signals is lower with double sheets)		Changing the capacity
	Lever system acting on a switch	Lever system acting on inductive distance sensors	Transmitted light	Ultrasound	Measuring the capacity between sensor and sheet guide plate
Suitable for substrates such as: paper/board with grammages of about	> 60 g/m²	> 40 g/m²	28 (Bible paper) up to 170 g/m²	> 28 g/m²	> 120 g/m²
Metallized substrates	X	X		X	
Foils, credit cards	X	X		X	(X)
Envelopes (made of 2-ply paper)	(X)	(X)			X

Table 2.1-2 Double sheet detection systems and their applications (selection); remark: (X) with limitations

color printing, and for spot coating or hot foil stamping.

To align the sheet on the feed table with the required accuracy, it is usually aligned at two *front lays* and one *side lay* (fig. 2.1-25). On large format presses, which are equipped with six front lays, unneeded front lays are disengaged when smaller formats are processed, so that only two front lays are used for the alignment. To be able to align the printed sheets at the same side for the finishing operation, the alignment points have to be marked in the printed product (e.g., manual marking in the delivery pile). Whether these alignment points must then be used in finishing depends on the product and the required tolerances. Since there are different alignment systems in printing and finishing, it is very important for the front edges of the sheets to be cut as straight as possible and within narrow tolerances, as well as for the angle between the front and side edges to deviate as little as possible from an exact right angle.

The accurate position of the print image on the sheet can only be achieved if each sheet is aligned individually before it enters the press. During the actual alignment process, the sheet is pushed or pulled with light force against the alignment guides. Guide elements, such as belts, brushes, rollers, pulling segments, or the suction plates of the side guides, slide gently over the sheet and, assisted by sliding friction, take it to the correct final position. It must be possible to adjust the sheet feeding systems to allow for the great variety of sheet sizes, the variable sheet thickness, and the different sliding friction of the different sheet surfaces. Exact alignment is made more difficult if the sheets do not lie completely flat and have a certain waviness at the edges. With suitable components in the feed area (e.g., pull lays and rotary suckers) the lead edge of the sheet can be tensioned so that it lies flat.

Side Lay. The side alignment of each individual sheet takes place at the side lay, by means of push or pull lays (figs. 2.1-29 to 31). Pull and push lays are press elements that ensure the exact lateral alignment of the sheet before it is transferred to the printing units.

Push lays (fig. 2.1-29) are of simpler design and are easier to adjust than pull lays. They should be used when processing smaller sheet sizes. The functionality of push lays has certain limitations with large formats and insufficiently stiff substrates. To align the sheet, it is pushed a few millimeters sideways against a stop (side lay) by a pushing piece acting at a right angle to the direction of travel. Consequently, the push guide exerts an accelerating force on the sheet, which may buckle and bend it. The higher the speed of the press, the bigger and less stiff the sheet, the greater the risk that the sheet will be deformed and cannot be fed accurately. Some feed tables are slightly bent in the direction of sheet travel, which gives the sheet greater stiffness for the lateral alignment. To feed stiff cardboard, on the other hand, a flat feed table is required, otherwise the cardboard will buckle and/or lift.

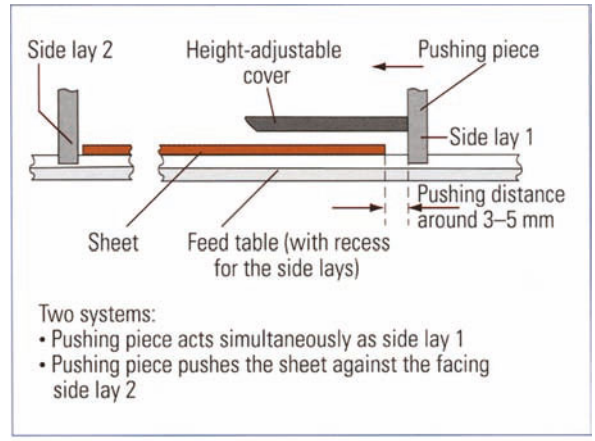


Fig. 2.1-29 Push lay

High-speed, large-format presses are usually fitted with *pull lays* (fig. 2.1-30). Pulling the sheet from one

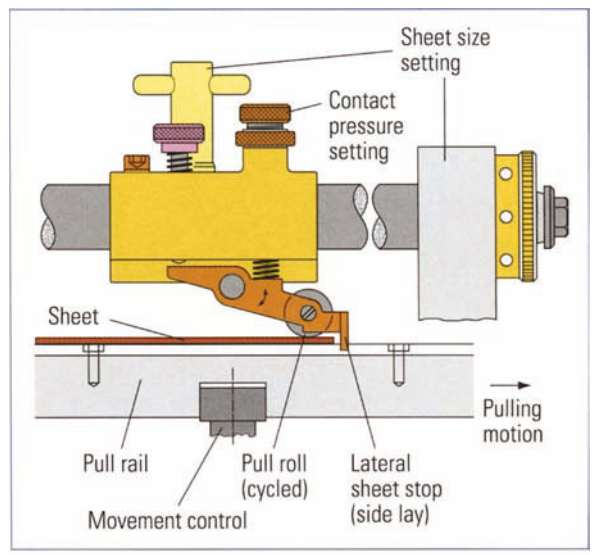


Fig. 2.1-30 Pull lay for lateral sheet alignment

side tensions the front edge. Waviness at the edges of the sheet is smoothed by the pulling action. A sheet tensioned crosswise to the direction of transport at the front edge can be transferred from gripper system to gripper system considerably more accurately than a wavy sheet, especially in multicolor presses. Doubling effects (see sec. 2.1.1.4) contingent on the substrate are also avoided in this way. The pull lays work in two ways: The sheet is pressed against a pull rail (fig. 2.1-30) or is sucked onto a suction plate (fig. 2.1-31). This pulling segment tracks the sheet until the edge of the sheet touches the side guide. The pulling segment starts to slide over the sheet as a result of this increased resistance. This transition from adhering to sliding has to be adjusted in accordance with the substrate. The contact pressure of the pulling segment on the substrate is set mechanically via an adjusting screw and contact spring or via the vacuum when using a suction plate (fig. 2.1-31).

Front Lay. The two front lays act as stops for the sheet, which is usually fed at low speed by conveyor belts via the feed table. The aim of this is the exact alignment of the sheet in the travel direction (direction of print). The front lays remain in their start position/alignment position until the swing-arm grippers close (fig. 2.1-33). They are then moved out of the travel line of the sheet, before the swing gripper moves along with the sheet in the direction of the print. The front lays then return to their alignment position. When the sheet makes contact with the front lay it has a tendency to bounce back slightly. To compensate for this effect and to align the sheet perfectly for its further transportation, it is pressed lightly against the front lay with the help of suction tapes, rollers, and/or blower/suction nozzles. Another option for accurate alignment is to swivel the front lay back slightly toward the sheet after the sheet has touched it.

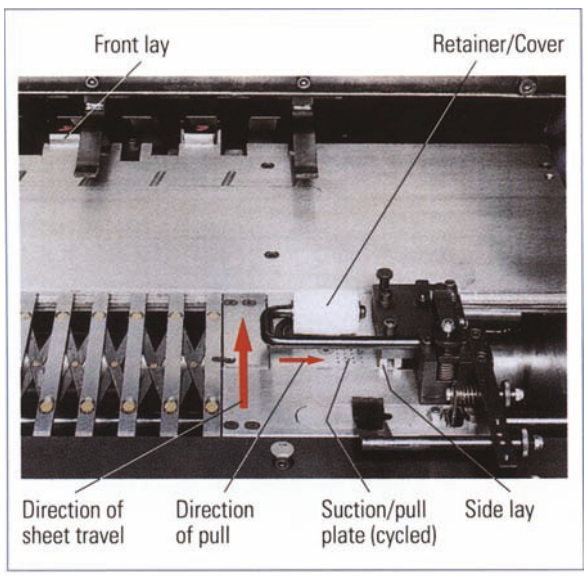


Fig. 2.1-31 Pneumatic pull lay (KBA)

Sheet Reversal

Sheets are usually printed on both sides. To achieve this, they have to pass through the press a second time, unless a perfecting press is being used, in which straight printing and perfecting can be done in one pass.

Work and Turn. For the second pass (verso printing) the sheets are usually turned over before being prepiled again. This means that the pile is turned so that the side edges are changed over (fig. 2.1-32a).

So that the sheet can always be aligned at the same three points, the sheet-fed offset press needs a second side lay on the opposite side from the first side lay. After work and turn, the second side lay has to be used to ensure an accurate register alignment. The change of side lay after work and turn only becomes unnecessary if all sheets in the pile are of the same size. Only then can the accurate register alignment be ensured for the front and reverse sides without having to change the side lays.

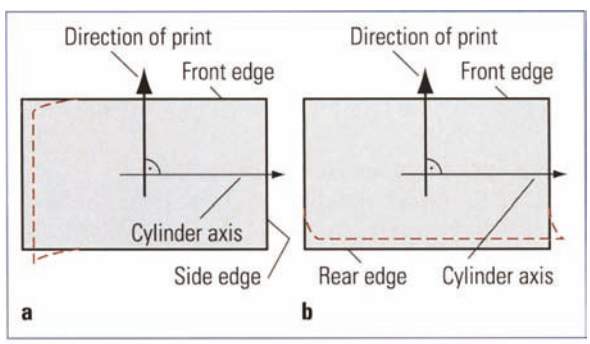


Fig. 2.1-32 Turning the sheet pile.

a Work and turn: Turning the sheet round the axis of the direction of printing, the right edge becomes the left edge, the front edge remains the same;

b Work and tumble: Turning the sheet round the axis perpendicular to the direction of printing, the front edge of sheet becomes the rear edge of sheet. The side edges stay the same

In practice, however, there are sheet-size tolerances in the production print sheets, meaning that the individual sheets differ in size slightly within a pile. The knife on the guillotine cutter can deviate (under or over-cutting) or the sheet "works" and changes its size due to moisture absorption and ambient temperature. The problem here is that the change in sheet sizes can differ considerably from section to section within the pile. Already in the first sheet pass, the sheets in the pile are not equally dimensioned and the differences from section to section are even greater in the second pass. However, since the side guide is changed after work and turn, so that the sheet is aligned at the same three feed points for straight printing as for verso printing, an accurate register can be maintained throughout the print run for both sides. This production accuracy for the finished product can, however, only be achieved if the same alignment points are used throughout all finishing operations.

Work and Tumble. The pile can also be inverted to print the second side, which means that the edge of the sheet that was the front edge for the first side becomes the rear edge for the second side (fig. 2.1-32b). In this way the lead edge of the sheet becomes the rear (trailing) edge. With work and tumble, exact straight printing and verso printing register can only be achieved if the distance between the front and rear edges of each individual sheet is exactly the same throughout the entire print run. As already explained, the paper's dimensions may change and this makes it necessary for all four sides of the sheets to be trimmed shortly before printing. Work and tumble layouts must include two *gripper margins*, whereas with work and turn one gripper margin suffices. It is on account of these complexities that work and tumble is only rarely used.

Infeed Systems to the First Printing Unit

Between the feeder and the first printing unit a section is needed where the sheet is accelerated. The sheet is stopped on the feed table and the sheet is aligned at a complete standstill. The impression cylinder moves constantly at printing speed. The infeed system now has the task of bringing the sheet, guided accurately in grippers, up to production speed and passing it on to the grippers of the impression cylinder.

In many presses this task has been solved by *swing grippers* (fig. 2.1-33). Distinction must be made between *swing grippers* that lie above the sheet and *swing grippers* arranged under the sheet.

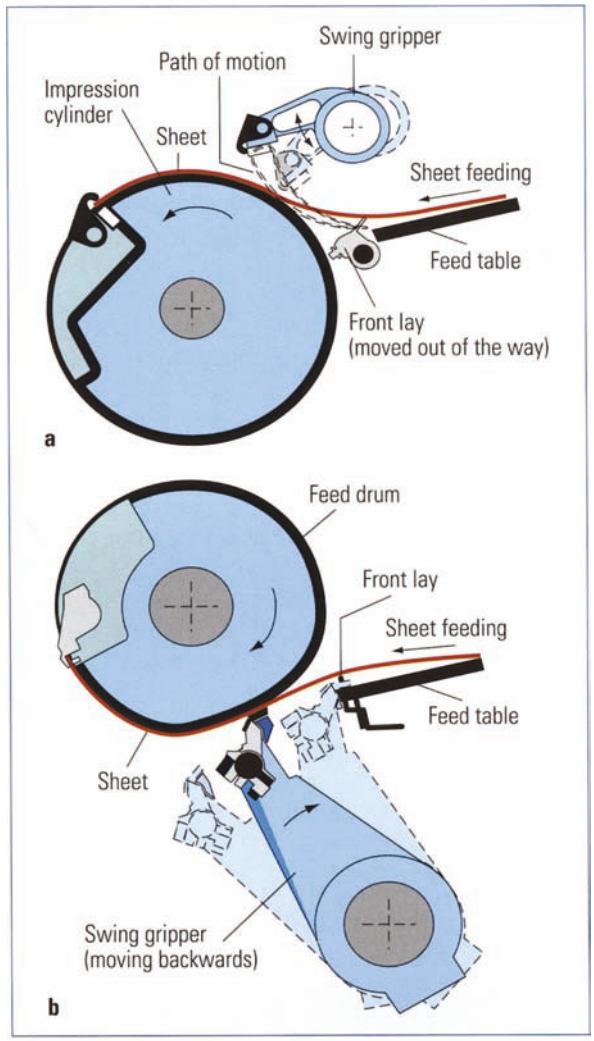


Fig. 2.1-33 Swing gripper.
a From above;
b From below

With the "*Ranger drum*" (fig. 2.1-34), named after the English inventor, Ranger, a constant, circular motion of the feed drum was achieved. Here, it is only the group of grippers that performs a relative motion opposite to the uniform rotation of the drum. Before reaching the feed table, the grippers move slightly faster than the rotation of the drum. During transfer of the sheet they remain stationary at the feed table for a short moment, pick up the sheet, and then accelerate to printing speed again on their way to the impression cylinder. This se-

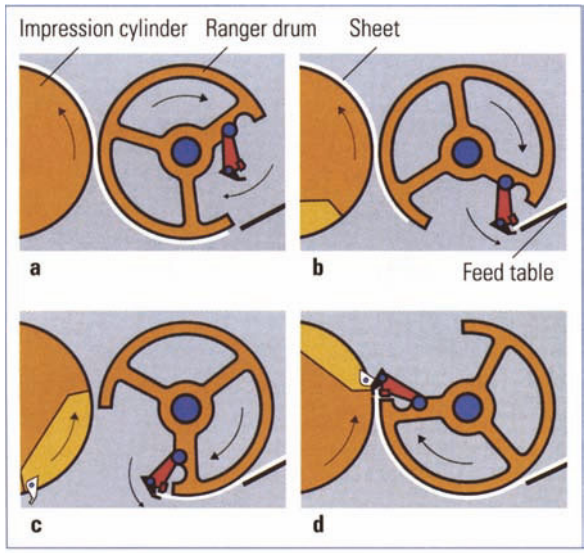


Fig. 2.1-34 Ranger drum, sequence of functions.
a Initial position;
b Gripper swings towards the stationary sheet and grasps it;
c Sheet is slowly accelerated up to printing speed;
d Transfer of the sheet to the impression cylinder with synchronous movement (Heidelberg)

quence of movements is controlled by a special cam control system.

The *stop drum system* (fig. 2.1-35) represents another option for picking up the stationary sheet from the feed table, accelerating it, and transferring it to an intermediate drum, from where it is transferred in true register to the impression cylinder.

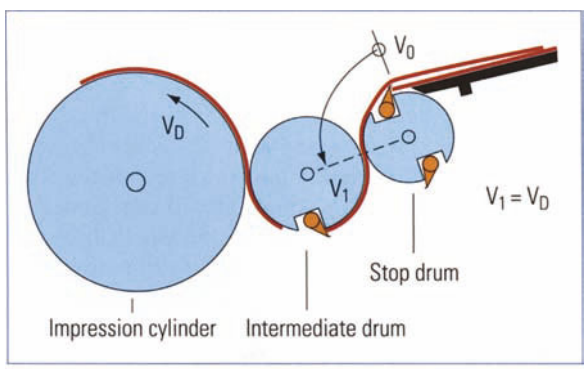


Fig. 2.1-35
Stop drum system; stop drum accelerates the stationary sheet up to printing speed (KBA)

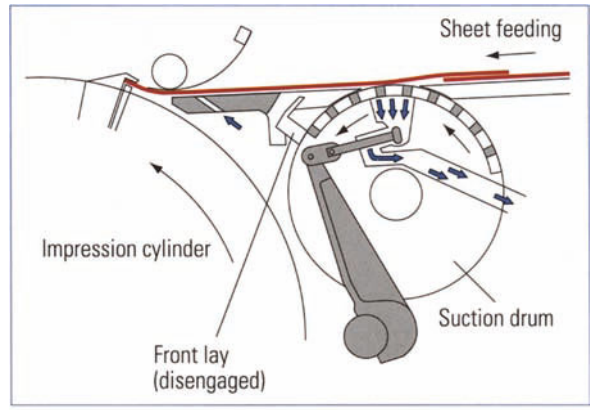


Fig. 2.1-36 Suction drum system (KBA)

With the *suction drum system* (fig. 2.1-36), the aligned sheet is transferred directly to the impression cylinder grippers via suction drums (e.g., four), which are arranged next to each other.

2.1.2.3 Printing Units

The printing unit is a sub-assembly of the press (see figs. 2.1-18 and 2.1-19) that consists of a plate, a blanket, an impression cylinder, an inking unit, and a dampening unit. Transfer drums that transfer the sheet to the next printing unit can also be classed as part of the printing unit. Printing units can also be equipped with wash-up devices and automation systems just as for feeding the plate.

The *inking unit* in a sheet-fed offset press (fig. 2.1-19) is designed as a roller-type inking unit with numerous rollers to evenly ink the printing plates with an area coverage and corresponding ink requirement. The quantity of ink required by the printing plate is mostly supplied from the ink fountain to the inking unit via a fountain roller and a vibrator roller. Zonal setting of the ink feed depending on need of printing plate, at right angles to the direction of printing, is done with ink-adjusting screws or ink-adjustment segments (see sec. 2.1.1.3). Makeready times are considerably reduced by using automated ink key presetting systems. To do so, the necessary data for the color combination is determined from digital prepress or by means of a printing plate scanner by measuring (plate image reader; see sec. 2.1.4.1). The inking unit also has inking rollers that perform an axial oscillating movement (see fig. 2.1-19). This *lateral distribution* ensures that the ink profile set is evened out slightly at the transition points and that

even inking occurs. It is, above all, the *distribution rollers* (especially those close to the ink form rollers) that break down or smooth out the resplit ink profile in the circumferential and axial direction of the rollers. Due to the cylinder gap on the plate cylinder there is no continuous flow of ink from the inking unit. In connection with the ink accepted by the printing plate in accordance with the image and the generally discontinuous supply of ink from the ink fountain into the inking unit via a vibrator roller (fig. 2.1-19), there is a variation of the ink film thickness on the printing plate in the circumferential direction. This is referred to as "*gradual fading.*" The profile of the ink film thickness on the plate in the circumferential direction can be influenced by the phase position of the axially reciprocating distributor rollers in relation to the plate cylinder gap (starting point of lateral distribution). With high-grade inking units it is possible to adapt this phase position to the printing plate. More recent inking unit developments enable remote adjustment. The color setting data from prepress can be used to calculate the optimal starting point for lateral distribution.

The *dampening unit* can be designed as a continuous-type dampening system for the application of minimal quantities of dampening solution. A dampening unit is not required in waterless offset printing; that is, when plates and inks are used for waterless offset printing, the dampening unit is switched off (for waterless offset printing, the printing unit is fitted with a temperature control unit and/or cooling unit).

The ink flows from the inking unit via the plate, the blanket and the impression cylinders. This group of cylinders operates with considerable reciprocal interaction. These three cylinders form a unit within the printing unit. There are various cylinder configurations. One blanket cylinder may, for example, be inked by two plate cylinders or the sheet may be printed by several blanket cylinders on one impression cylinder (see sec. 1.6.2.1). The most important configurations are discussed in detail below.

Three-Cylinder System

The three-cylinder system (fig. 2.1-37) has become the most widely-used in sheet-fed offset printing. Presses for multicolor printing are put together in *unit construction* (as shown in fig. 2.1-18), which are connected by sheet transfer systems. The fact that all the printing units in a multicolor press are identical has many advantages in manufacturing terms and also regarding operation. There are also process-related advantages,

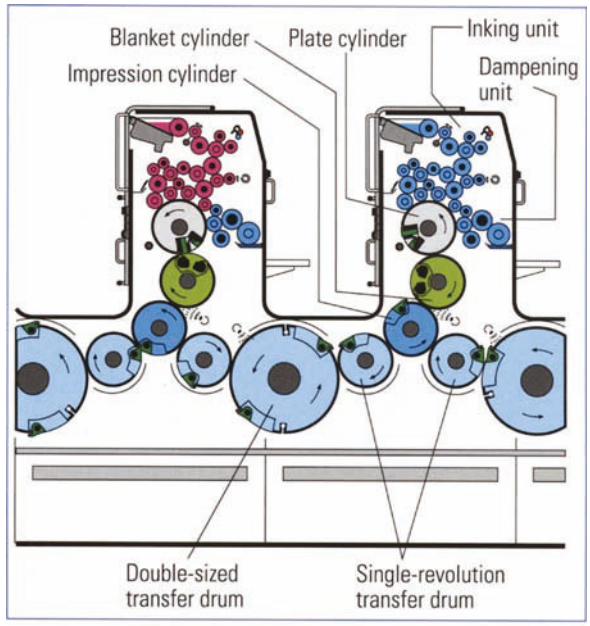


Fig. 2.1-37
Printing unit in a 3-cylinder design with single-revolution transfer drums

such as the same drying periods for the color separations that are printed in sequence.

Most components and operating elements are identical from printing unit to printing unit throughout the entire press. In virtually all presses in the three-cylinder group, the bearers of plate and blanket cylinders run in direct contact, which means that the distance between the plate and blanket cylinders cannot be adjusted by the operator. The printing pressure between plate and blanket is determined by the cylinder packing (the thickness of the plate, blanket, and underlay). The distance between the blanket and impression cylinders can be adjusted via a cam control system attached to the side frames. To adapt the blanket pressure to the quality and thickness of the substrate, the blanket cylinder is adjusted during make-ready to the impression cylinder on which the substrate is located, without changing the pressure ratios to the plate cylinder. Multicolor presses in unit construction using the three-cylinder systems are usually equipped with single-sized (single-revolution) impression cylinders. However, there are some press configurations that use double-sized (half-revolution) impression cylinders.

Double-sized impression cylinders (fig. 2.1-38) were initially developed for printing on cardboard. Due to the quite considerable bending involved, very thick, multilayer, couched cardboard would be subjected to considerable stress on single-revolution impression cylinders with a relatively small diameter, which would lead to bending marks on the cardboard. On double-sized (half-revolution) impression cylinders the bending radius is twice as large as with single-revolution cylinders, the cardboard is subjected to less stress and can be guided through the press with fewer sheet guiding elements.

The "straighter" sheet guidance also has mechanical advantages even for paper as thin as Bible paper. Less force is required to separate the sheet from the blanket cylinder with larger cylinders. There is another even more important advantage, namely the absolutely smear-free conveyance of the sheet on the transfer drum. With double-sized impression cylinders it is actually possible for the printed sheet not to be taken over by the transfer drum until it has left the nip between the blanket and the impression cylinders. As a result of the centrifugal force, the sheet is pushed outwards on the transfer drum. The unprinted outer side can be aligned at a stationary arched guide plate.

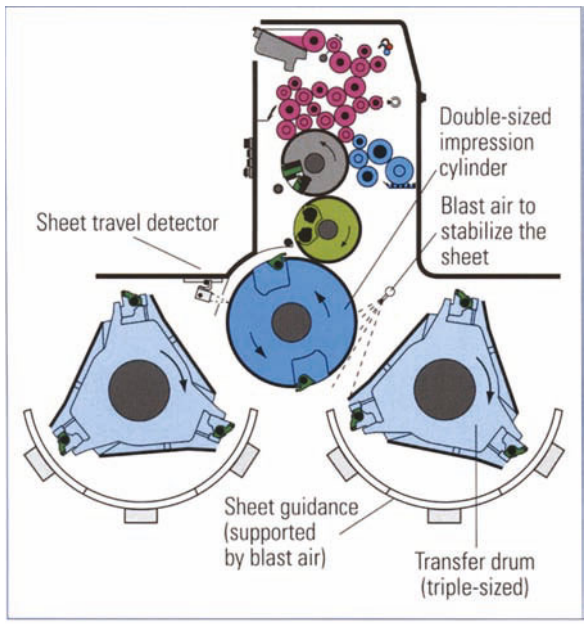


Fig. 2.1-38
Printing unit in a 3-cylinder design with double-sized impression cylinder and triple-sized transfer drums (Heidelberg)

The design of the *transfer drums*, various versions of which are illustrated in figures 2.1-37 and 2.1-38, is of fundamental importance for the further conveyance of the sheet. Double-sized drums are also used instead of single or triple-sized drums. The inner side of the sheet with the wet ink must not come into contact with the transfer drum. In presses with single-sized impression cylinders, the sheet is already clamped by the grippers on the transfer drum while it is pulled off the blanket. The sheet is pressed against the surface of the transfer drum by this tensile force.

Many methods are used to prevent the ink from offsetting on the cylinder surface and the consequent ink build-up during production. The cylinders and/or the sheet guiding elements are coated with a variety of surfaces or substances, mostly in conjunction with microroughening/structuring. There are also special cloth coverings coated with glass beads or silicone rubber. Another very successful method is to mount a special, movable fabric jacket (fig. 2.1-39). The air cushion drum represents a relatively expensive solution.

The double-sized impression cylinder in conjunction with "contact-free" sheet guidance on the transfer drum has proved to be particularly advantageous. The triple-sized transfer drum shown in figures 2.1-40 and 2.1-38 together with the air currents provide contact-free sheet transfer from impression cylinder to impression cylinder.

Five-Cylinder System

The five-cylinder system (fig. 2.1-41) is a more compact variant than the unit construction version. Two blanket

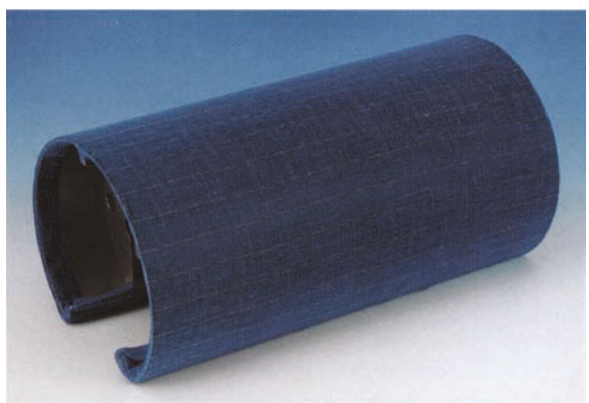


Fig. 2.1-39
Fabric jacket on a delivery drum ("Super Blue", Printing Research)

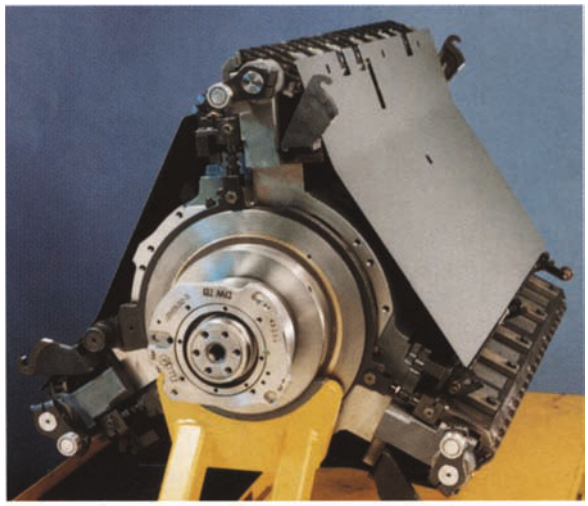


Fig. 2.1-40
Triple-sized transfer drum (see also fig. 2.1-39; Speedmaster CD transfer drum, Heidelberg)

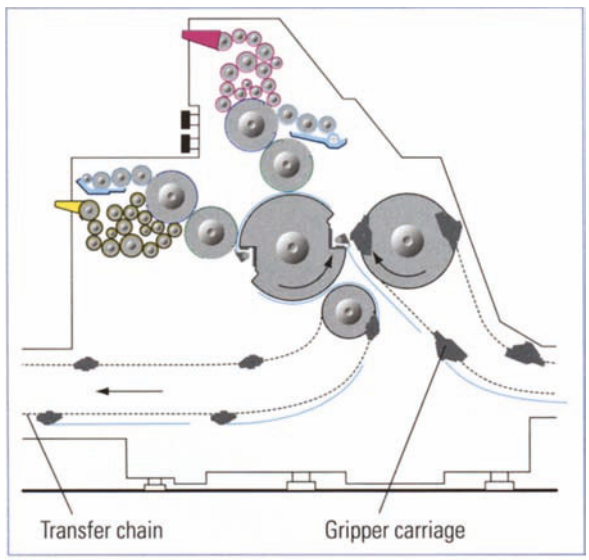


Fig. 2.1-41
Printing unit in a 5-cylinder design, with transfer chain (Roland 204 H, MAN Roland)

cylinders print onto a common impression cylinder, whereby five cylinders form one printing unit. With appropriate sheet transfer systems, compact two to ten-color presses can be built as five-cylinder systems. This type of press has marked advantages if the space in the printshop is limited. With two-color presses there is good accessibility to the inner cylinders for cleaning and maintenance work. With longer presses, however, additional space is required at the impression cylinder for sheet transfer and accessibility is limited.

The fact that the sheet passes through the five-cylinder system with just a few gripper transfers is a distinctive feature of sheet travel in five-cylinder systems. On the other hand, there are considerable tensile forces acting on the sheet since the sheet is often printed with two inks at the same time. A disadvantage when using five-cylinder systems for multicolor printing is generally the differing lengths of time taken to convey the printed sheet from one nip zone to the next and the different drying times arising from this (see fig. 1.6-5d).

A cost advantage of the five-cylinder system is the saving of every second impression cylinder and further sheet transfer systems. Chain systems as illustrated in figure 2.1-41 are used as transfer systems from the first double printing unit to the next one, but transfer drums (see fig. 2.1-186) are also found in some five-cylinder presses. Special catch arms have been designed for chain transfer systems by means of which the gripper carriages are aligned very accurately for in-register transfer of the sheet to the impression cylinder in spite of chain play.

Transfer Systems

The cylinder groups on which the sheets are transferred from printing unit to printing unit can be arranged in various ways: mostly using three transfer drums or only one transfer drum between the printing units (figs. 2.1-37 and 2.1-38). Since accessibility to the printing units has to be maintained with one-revolution impression cylinders, i. e. there must be a certain clearance, these presses are usually equipped with three transfer drums. Presses with half-revolution impression cylinders can also operate perfectly well with a single double-sized transfer drum. A triple-sized transfer drum can also be used to optimize sheet transfer in such a way that the sheet is not taken over by the impression cylinder until it has left the nip between impression and blanket cylinder and there is sufficient intermediate space available between the printing units for operational purposes.

Plate Cylinder

Significant advances have been made in the area of *printing plate change-over* in recent years, achieving very short change-over times. In spite of the obvious

advantages of technologies employable for reducing set-up times, such as automatic plate loading and special register and clamping systems, traditional working methods are still widely used for plate change-over.

The printing plate is clamped in the plate cylinder gap (fig. 2.1-42) by two clamping bars. The cylinders on sheet-fed offset presses usually have a wide gap, thereby offering good accessibility for manual mounting of the plates.

Thanks to modern set-up technology, register errors occurring during assembly, platemaking, and plate clamping are so minor that accurate positioning can be achieved by *circumferential, lateral, and diagonal register* adjustments via the control console (see sec. 2.1.4.3) without stopping the press. The remote-controlled register setting systems have an adjustment accuracy of up to approximately 0.01 mm depending on the press concept. Printing-plate-sized film imagesetter or computer to plate systems achieve notably higher precision in prepress than is achieved with manual stripping operations, especially if this work is done under time pressure. In order to fully exploit the precision achieved in prepress, the accuracy with which the plate is clamped on the plate cylinder regarding the clamp bars and register systems, must be correspondingly high. It is important here that the front clamping mechanism be fixed on the cylinder to create a solid base. More recent press models offer fixed front clamping bars of this kind as part of the standard equipment. Fixed clamping bars are also available for fully or semi-automatic plate change.

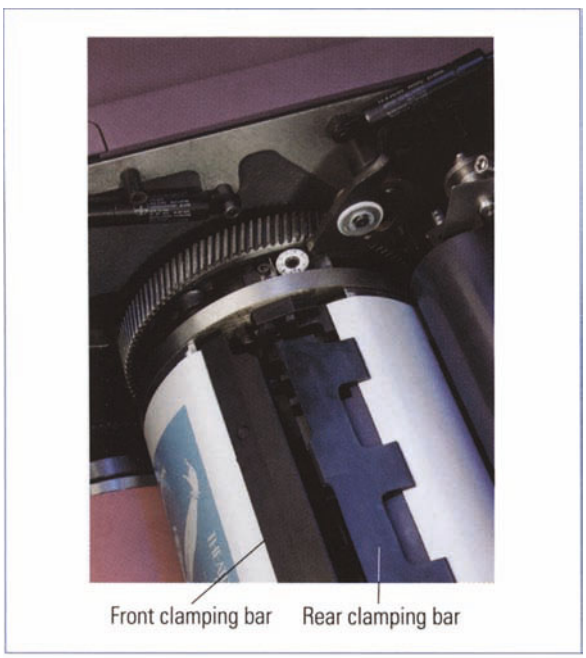


Fig. 2.1-42 Plate clamping (Printmaster QM 46, Heidelberg)

Manual plate change and registering of the individual colors take up a large proportion of time in the overall makeready process. With *automated plate change* (fig. 2.1-43), it is possible both to speed up the plate change and to clamp the plates more accurately. Even the first sheet is printed with good color register and only minor fine register corrections are required. The printer can therefore run the press up to production speed and start the fine color corrections immediately after the plate has been clamped in position. The positioning of the color separations is done by circumferential, lateral and diagonal register adjustment on the plate cylinder.

Fully automatic plate change from a cartridge/cassette with a supply of five to ten plates (see sec. 2.1.5.2) has not succeeded in gaining widespread acceptance. The cost of the plate guidance in the cartridges is relatively high and the advantage over semi-automatic plate-change comparatively slight. Cartridge systems of this kind are rarely used, since it is rare for sets of plates for several jobs to be available in advance and the presses that would be necessary to fill the cartridges cannot be reserved in advance.

The plates are usually aligned in relation to the plate cylinder at their *register holes* (see also sec. 3.1.5.2). If the

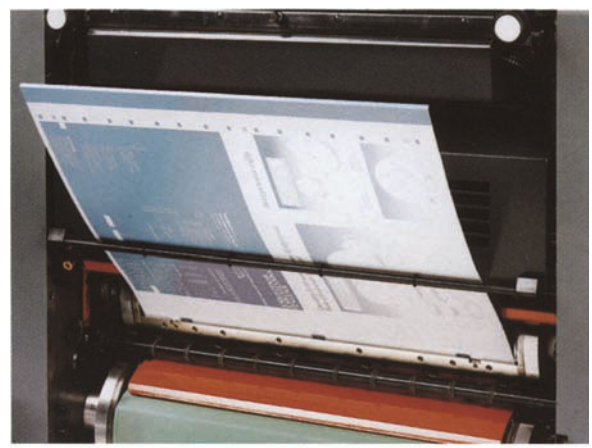


Fig. 2.1-43
Automatic plate loading (Speedmaster SM 52, Heidelberg)

print image is copied at an angle onto the plate or the plate is clamped at an angle on the cylinder, this cannot be compensated for by adjusting the lateral and circumferential register; the plate needs to be realigned on the cylinder surface. On many presses, the plate cylinders can be cocked to achieve this. There are other solutions for moving the plate, where the clamping bars in the cylinder are repositioned (fig. 2.1-44).

The plate cylinder must roll very accurately on the blanket cylinder. Slight inaccuracies of only a few microns could lead to clearly visible streaks in homogeneous halftone tints at right angles to the direction of printing, which is why there is cylinder bearer contact between the plate and blanket cylinders.

Cylinder Bearer, Gauge Ring

In bearer-contact presses, the bearers located at each end of the plate cylinder and the blanket cylinder are in direct contact with each other. The *cylinder bearer* is of the same diameter as the pitch diameter of the driving gear. The blanket is usually underlaid with packing sheets (fig. 2.1-45) so that the printing plate exerts a contact pressure as a result of a 0.1 mm interference, in order to level out certain surface unevenness and to build up the necessary surface pressure. It has proved expedient to mount printing plates 0.1 mm above the bearer level and to underlay sheets below the blankets at the cylinder bearer level. The bearers also serve as a reference height for verifying the packing height on the

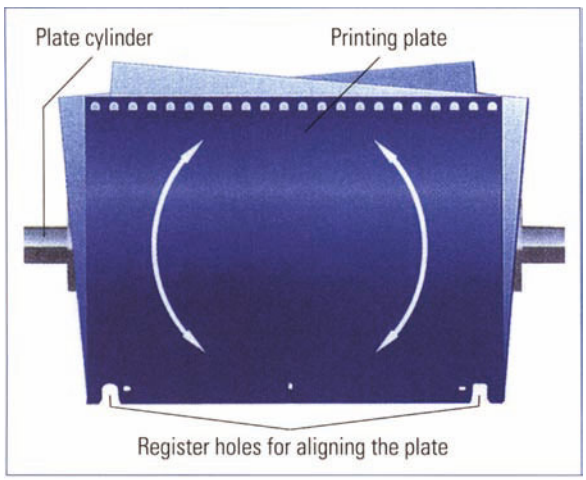


Fig. 2.1-44

Register adjustment by twisting the plate on the cylinder surface by changing the clamping rail position (MAN Roland)

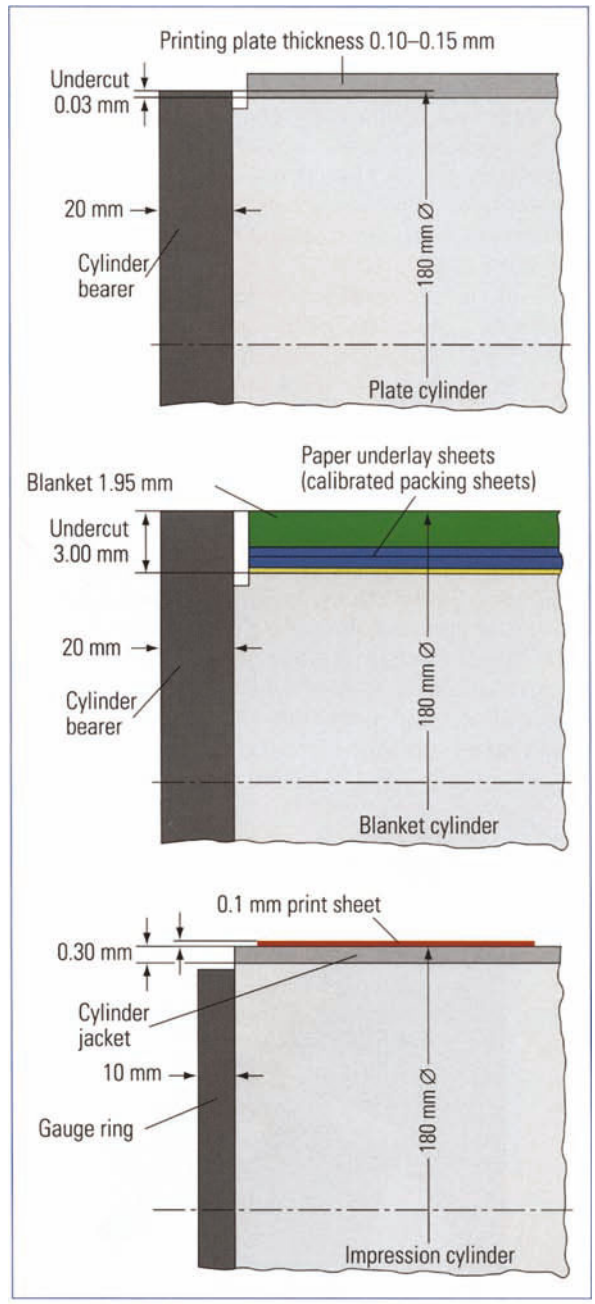


Fig. 2.1-45

Example for adapting the cylinder diameters in relation to one another

cylinders. However, the primary task of the cylinder bearers is to ensure smooth running of the cylinders, which is achieved through the initial tension applied during mounting; they also help to prevent the quality-impairing and noise-producing effects of load variations as a result of overrunning the cylinder gap. Variations in bearing force may cause quality-impairing streaks in homogeneous, fairly large screen areas due to slightly varying dot gain.

There is no bearer contact between the blanket cylinder and the impression cylinder. On each side of the impression cylinder there is a *gauge ring*, the diameter of which is less than that of the bearer.

Gauge rings (measurement rings), which are fitted at each side of the plate and blanket cylinders instead of the bearers, have a slightly smaller diameter than the pitch diameter of the driving gear, so that the plate and blanket cylinder gauge rings do not touch. As the term gauge ring implies, these rings are used merely as a reference to measure the packing height. Since, in the case of non-bearer-contact presses, smooth running has to be ensured by the bearing application alone, some presses are still fitted with sliding bearings instead of roller bearings to guarantee smooth running even without bearer contact.

Blanket Cylinder

The ink is transferred from the printing plate to the substrate indirectly via the blanket (fig. 2.1-46). Distinction is made between *compressible* and *incompressible* blankets, whereby compressible ones are more common. On account of its surface properties, the flexible blanket retains water in the non-printing areas (less transfer onto the paper) and is able to compensate for unevenness of the substrate in the printing areas. Both solid areas and halftone dots are practically transferred as though the substrate had have an ideally even surface. Since, with respect to their physical and chemical properties, blankets age and may also become damaged, they have to be replaceable. Blankets are usually fastened onto the blanket cylinder with clamping bars and clamping systems. Pre-railed blankets, which are widely used in web offset presses, are also being used more frequently in sheet-fed offset presses and can be changed quickly (fig. 2.1-47).

Calibrated packing sheets (fig. 2.1-45) are used to adjust the blanket surface to the pitch diameter of the gear wheel. There are variants where the packing material is already attached to the blanket cylinder yet underlay sheets are still inserted here between the blanket and the packing material to balance out minor inaccuracies in thickness and ink transfer.

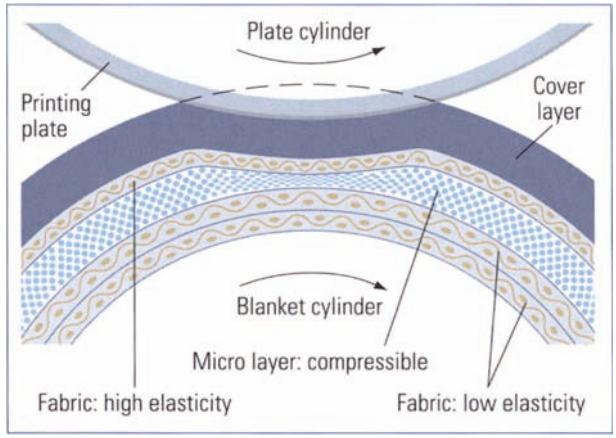


Fig. 2.1-46 Structure of a compressible blanket (ContiTech)

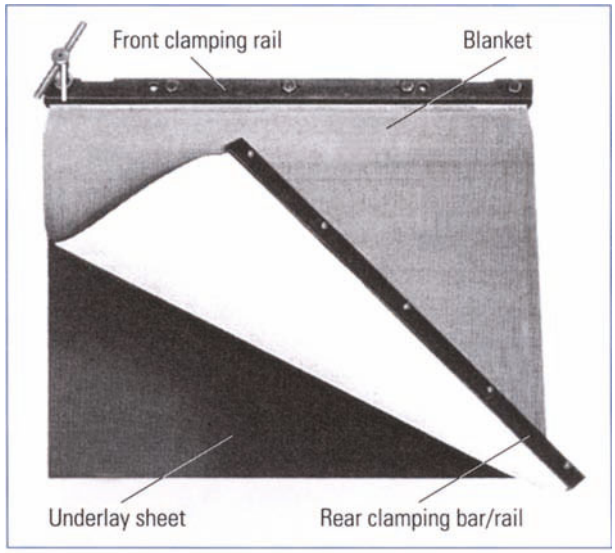


Fig. 2.1-47 Fixing the blanket (pre-railed blanket)

Rolling Length

In offset printing the printing or rolling length of the print image in the direction of printing can be shortened by slight amounts in relation to the size of the image on the printing plate by packing the plate (not included in fig. 2.1-45). In multicolor printing, register

differences may occur, especially if the sheet is subjected to considerable tensile forces. This can be compensated for by printing the first color separation slightly shorter, for which a sheet is placed under the plate in the first printing unit. A 0.1 mm packing under the plate produces an approximately 0.4 mm shorter print image with standard cylinder geometry.

But this contradicts the wish for ever shorter make-ready times. Packing the plate simply takes too long. Especially with short print runs this is no longer practicable. It is more efficient to make allowances for any potential distortion of the paper in the digital prepress stage when producing the film or plate. It is also still perfectly possible to print the first color rather shorter and to mount the first plate cylinder permanently with the attached packing minimally higher than the next cylinder.

2.1.2.4 Sheet Reversal/Perfecting

The ability to switch over the sheet travel from straight printing to *perfecting* necessitates a sheet turning device (perfector) between the printing units, where the sheet is reversed ("work and tumble", see fig. 2.1-32b) at full production speed for printing in-line on both sides of the sheet. These types of presses are called "perfecting presses". In figures 2.1-48 and 2.1-49 two structurally different sheet reversal designs are illustrated, a "*single-drum system*" and a "*three-drum system*".

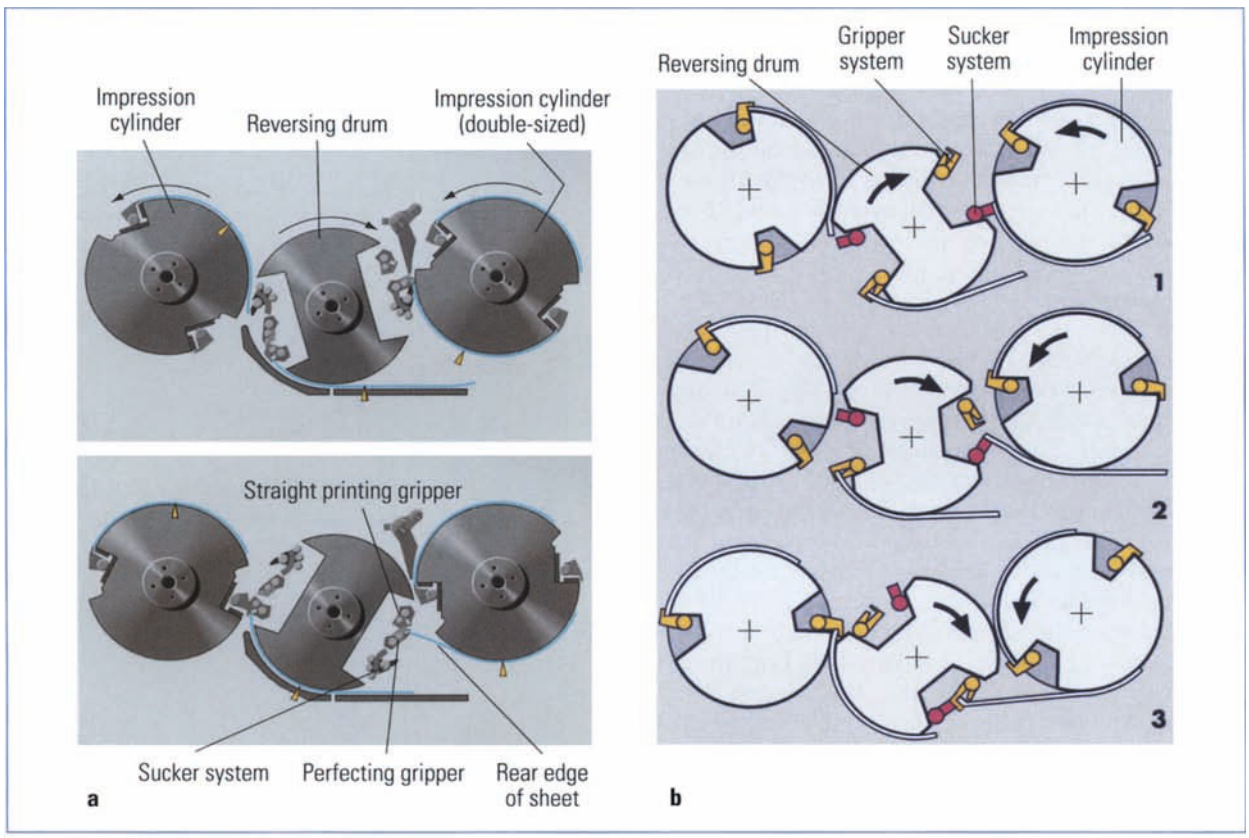


Fig. 2.1-48 Sheet turning devices (single-drum system).

a MAN Roland system: The sucker system picks up the rear edge of the sheet, transfers it to the perfecting grippers which then transfer it to the straight printing grippers. The front sheet edge is released first (Roland 700, MAN Roland);
b Koenig & Bauer system: The rear sheet edge is gripped by the sucker system of the sheet reversing drum and the front edge is then released. Sucker and gripper system in the sheet reversing drum move towards each other and the sheet is transferred to the grippers (Rapida 72, KBA)

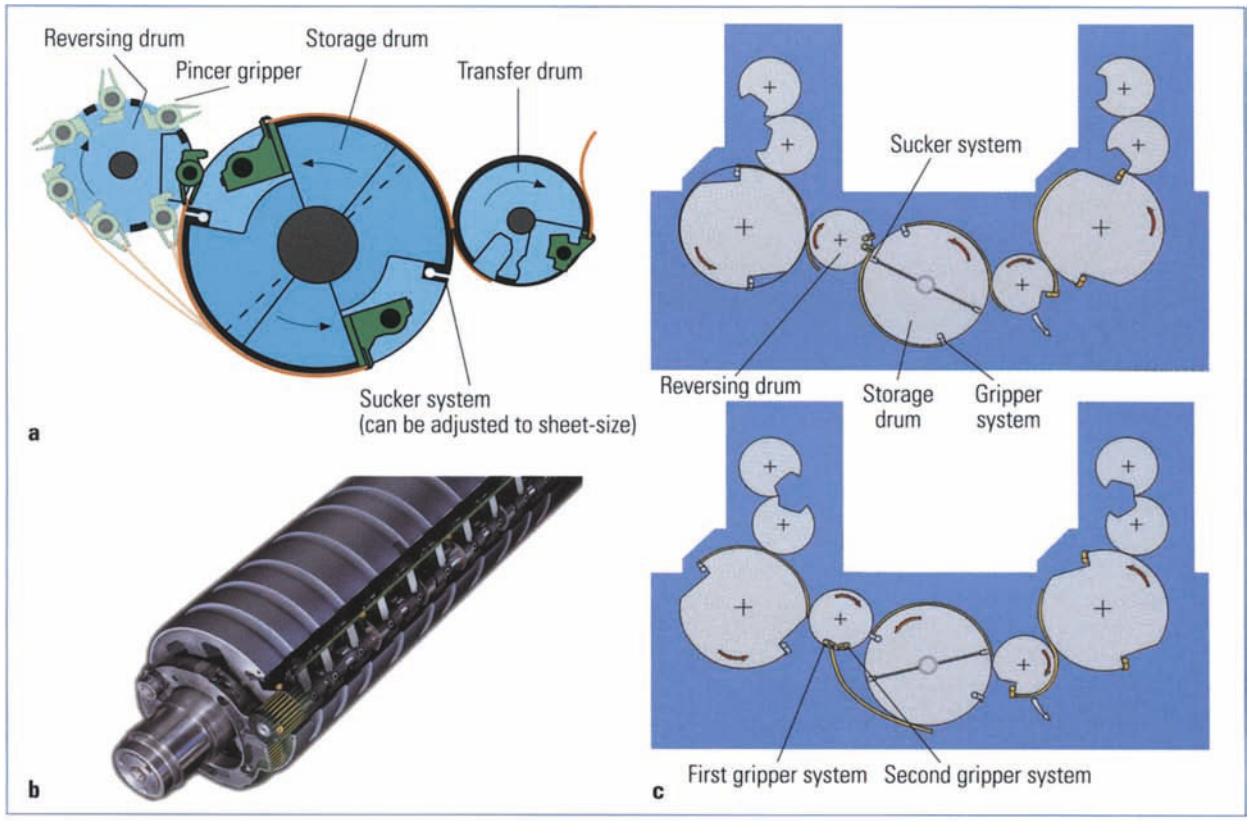


Fig. 2.1-49 Sheet reversing systems (three-drum system).
a Heidelberg system (basic principle): The pincer grippers of the reversing drum take over the sheet at the rear edge in a single gripper closure from the storage drum (Heidelberg);
b Reversing drum with pincer grippers controlled via gear wheel and toothed segment (Heidelberg);
c Koenig & Bauer system: Suckers in the storage drum grasp the rear edge of the sheet and transfer it to the first gripper system in the sheet reversing drum. This gripper system then transfers the sheet's rear edge, which in the meantime has become the sheet's front edge, to the second gripper system (Rapida 104, KBA)

The sheet is turned in the perfector by transfer grippers grasping the rear edge of the sheet. After the sheet has been turned, the rear edge of the sheet then becomes the new front edge for the following print on the reverse side. For the sheet assembly of perfecting jobs it is important that there is a gripper margin on the front and the trailing edge of the sheet. A quite considerable simplification and increased productivity on the part of perfecting presses is obtained with this "in-line turning" because the sheet needs to be aligned only once in the press; it is not necessary to re-align the sheet to the second gripper margin after sheet reversal.

On purely straight printing presses, four-sided trimming is usually required for work-and-tumble jobs, to ensure that all sheets are of exactly the same size for the second sheet pass, or the side guides must be turned and the direction of pull needs to be changed when using the work-and-turn method. On the perfecting unit the sheets are pushed into the grippers in proportion to the length of the individual sheet. In this way the sheet remains properly aligned at the infeed edge.

Striving for a more cost and time-effective print production has lead to the development of perfecting presses that allow printing on both sides of a sheet in one pass. It is more cost and time-intensive to run a sheet through the press a second time to print the reverse side than it is to print both sides in a single pass. In the early stages of perfecting technology, perfecting presses

were only able to produce single-color prints on the reverse side. A single ink layer is much easier to monitor than a full-color set. The ink is absorbed into the paper very quickly and virtually without resplitting on subsequent impression cylinders. With single-color perfecting there is hardly any risk of smearing or doubling.

There are special perfecting units for single-color perfecting, as shown in the example in figure 2.1-50. Perfecting can also be done by printing from underneath directly against the transfer cylinder (see figs. 2.1-74 and 2.1-75).

4/4 Printing

On modern presses which can produce four-color prints both on the front and reverse sides in one pass and at the same quality on both sides, the distinction between the side printed first and the one printed last no longer plays a role. Technical developments have made it possible to construct eight-color presses with extremely high sheet travel precision and series-produced special impression cylinder surfaces for perfecting, making it possible to turn the sheet after four colors. In this way 4/4 color prints can be achieved in a single pass. After the sheet reversal the freshly printed inks are pressed against the impression cylinder at full contact pressure when the sheet passes through the subsequent printing units.

Any attempts to solidify the ink enough to prevent any ink splitting have proven to be unsuccessful with all known offset inks other than UV inks used in combination with *inter-unit dryers*. Consequently, the other route has been followed and the inks are kept fluid until the final printing unit. Fresh, resplittable ink has a lower tendency to pile, but the press becomes somewhat more prone to doubling if the reversed sheets are not transferred with a great degree of accuracy. Each dot that has been resplit on the impression cylinder must be perfectly superimposed dot by dot on the next sheet. On a 60 lines/cm screen, an offset of only around 10 µm causes doubling that is recognizable to the naked eye as tonal shift.

With suitable structural measures it has become possible to guide the sheet smear-free through the press just as accurately after the sheet reversal as is the case with long presses with no perfecting unit. Figure 2.1-51 shows technical details on the design of perfecting presses: Figure 2.1-51a shows a suction device on the storage drum (see also fig. 2.1-49a), which keeps the rear sheet edge in position and smoothens the sheet. Figure 2.1-51b depicts the surface structure of the cylinder jacket fitted on impression cylinders that are arranged after the perfecting unit to prevent smearing of the freshly printed image. Surface coatings such as silicone are also used, where setting off or resplitting of the ink can be prevented merely by physical interfacial processes without the need for any geometrical fine structuring of the surfaces.

Although the inks have to remain fresh on their way though eight printing units, after the final printing unit the inks should dry very quickly. The more the ink has solidified on the sheet, the more likely it is that the sheets can be piled without offsetting. Since these two requirements on the drying behavior represent conflicting characteristics, it is impossible to fulfill them both to the same degree at the same time. Consequently, heavier powdering has to be applied on high-speed eight-color presses than on shorter printing

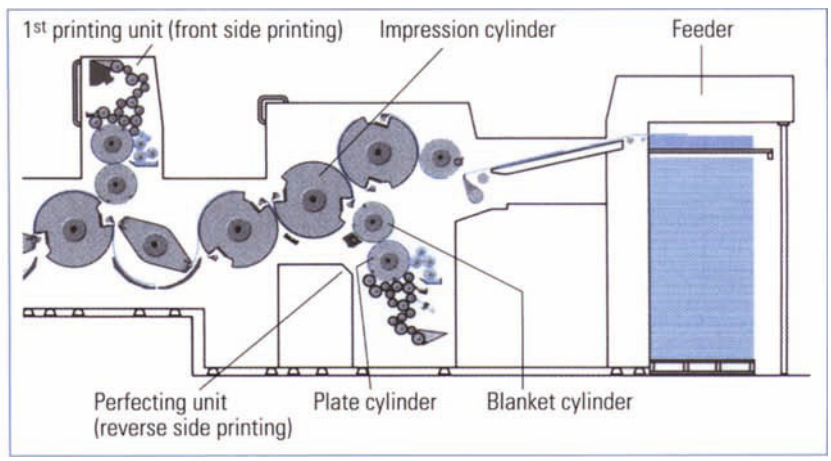


Fig. 2.1-50
Perfecting unit for packaging printing (Roland 900, MAN Roland)

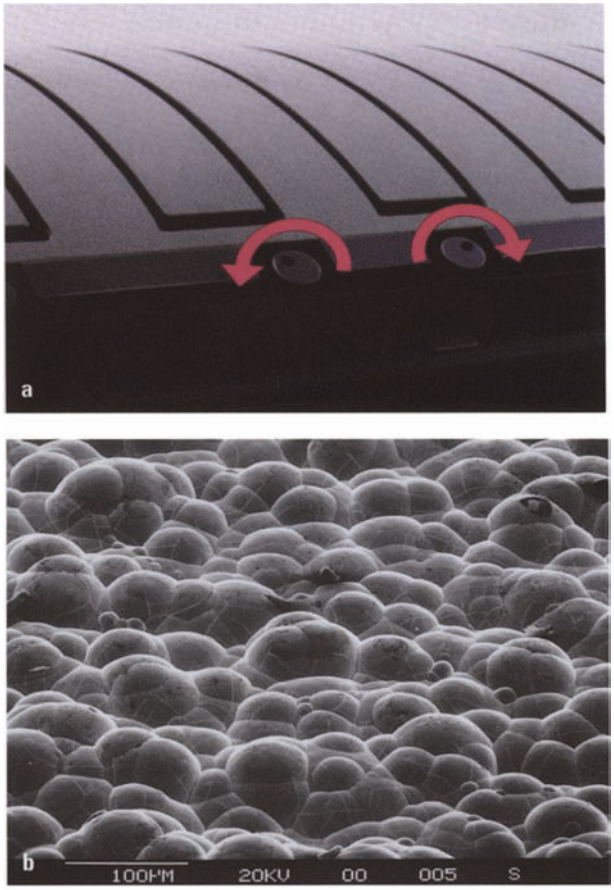


Fig. 2.1-51
a Smoothening of the rear sheet edges by fixing the sheet on the storage drum using rotary suckers (up to 20 for large sheet size); **b** Refined impression cylinder surfaces arranged after the sheet reversing unit, specially-chosen material and surface structure to avoid the offsetting of freshly printed ink (Heidelberg)

presses. The trend in press engineering is towards even longer presses (6/6) so that meanwhile additional spot colors can be printed. Coating units are also used to apply an even coating layer over the entire image surface or to do spot coating, and all this is integrated with special drying units in front of and after the sheet reversal.

Variants in 4/4 Printing

A special structural variant of 4/4 printing is a perfector that prints the sheet in one pass alternately from above and below (see figs. 2.1-74 and 2.1-75). The impression cylinders of the lower printing units simultaneously perform the function of transfer cylinders for the upper printing units. The upper units, on the other hand, print against the transfer cylinders of the lower printing units. As in web offset, four blanket-to-blanket printing units are arranged in a line, and two operating levels are required for the upper and the lower printing units. This results in shorter presses for multicolor printing on both sides, albeit with increased overall height. With this design the sheet does not need to be turned and consequently no second gripper margin is needed. On the other hand, this press does not have the flexibility required for the most diverse color combinations, as is achieved on presses with convertible perfecting units.

In conventional production, eight-color presses are not only used as 4/4 perfectors, but also for 8/0 print jobs. To meet exacting demands in quality, decorative/spot colors are printed with a special ink rather than with color mixing with the basic colors of cyan, magenta, yellow, and black. This separation between decorative color and multicolor halftone image enables well-directed control of the respective image sections, which ultimately leads to shorter makeready times.

2.1.2.5 Delivery

After printing, the sheets are fed to the delivery pile. The simplest technological solution is the *chute delivery* (fig. 2.1-52), which is used in some small offset presses, where the sheets are transported on the delivery table by rollers.

A straight-edge delivery pile is usually required, where each of the delivered sheets is jogged one by one to produce a neat pile. The deliveries of sheet-fed offset presses are equipped with *sheet joggers*, which take every sheet to the same position on the pile. Exact pile formation is essential to avoid a manual or automated sheet alignment before subsequent finishing operations can be performed.

The standard *chain delivery system* (fig. 2.1-18) conveys the sheet from the final impression cylinder to the delivery pile. A distinction is made between presses with high-pile delivery (fig. 2.1-18), standard delivery and extended delivery systems.

The *standard delivery* (fig. 2.1-21) is the most compact and economical design. The short chain delivery unit carries the sheet directly (generally horizontally) from the impression cylinder to the delivery pile. This means that the pile is only about 50 cm high, depending on the press model. For standard short print runs this delivery pile height (approximately 1000 to 5000 sheets) is usually sufficient.

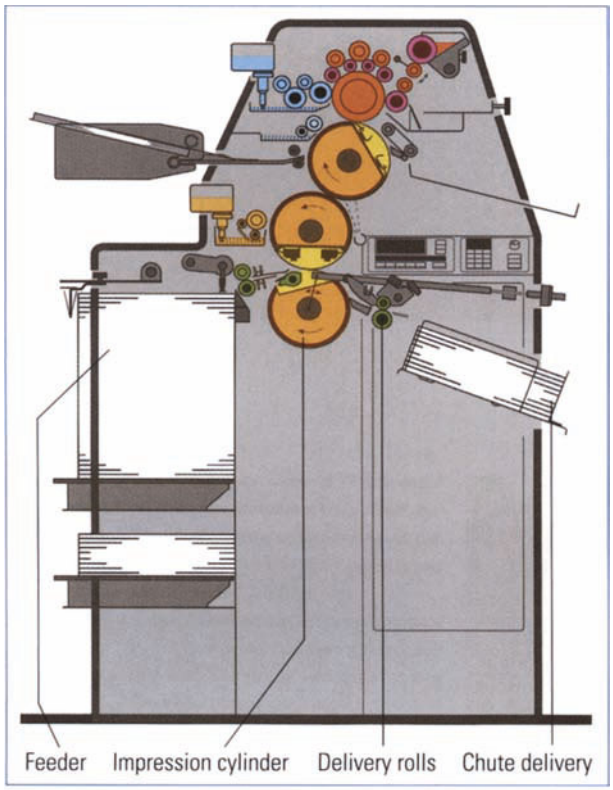


Fig. 2.1-52
Chute delivery on a small single-color offset press (TOM, Heidelberg)

With longer print runs, faster presses, and thicker substrates, the time between pile changes should be as long as possible, therefore *high-pile deliveries* with a *pile height* of more than 1 m are preferred. For papers with grammages of 100 g/m² (approximately 0.1 mm thick) this is equivalent to 10 000 sheets, which is usually printed in barely an hour. Cardboard printers tend to raise their presses, so that correspondingly higher piles can be processed in feeder and delivery. In a high-pile delivery (fig. 2.1-18) the sheet travels a correspondingly longer distance from the impression cylinder to the pile.

At fairly high press speeds lightweight sheets tend to flutter, and in the course of this the fresh ink may smear on contact with press elements in the area of the delivery. Turbulences generated by the gripper bars when releasing the sheet induce the sheet fluttering. Aerodynamic tests with the aim of optimizing sheet guidance and installing special *sheet guidance elements* have resulted in smooth sheet guidance. An air current, generated between the guide plate and the printed sheet (figs. 2.1-18 and 2.1-56a), holds the sheet at a specified distance from the guide plate. This sheet guidance in the delivery is a fundamental constituent of completely smudge-free sheet delivery (see also sec. 13.1.3.4 and fig. 13.1-53).

The distance to the delivery unit can be used to accommodate *drying units* such as IR dryers, UV dryers, hot air blowers, air circulating blowers, or *powder spraying devices* and extraction systems. This space is often not adequate to accommodate all units, in which case an *extended delivery unit* (figs. 2.1-57 and 1.7-2) may be necessary for the installation of dryers. An extended delivery unit has the additional advantage of allowing more time for the ink to solidify without any special drying equipment. On high-speed presses in particular, the time between the final printing unit and the delivery pile is very short, in the region of less than one second. Time extensions of almost a second can bring the solidification of the ink or vanish application into a range in which offsetting is avoided, or the necessary powder application can be reduced.

Since the sheet arrives in the delivery at high speed, it is necessary to slow down the sheets using braking systems. The gripper opening cams can be adjusted so that the grippers are already open a certain distance before reaching the end of the pile. At this same moment the rear sheet edge is drawn in from below by *braking suction rollers or belts* (figs. 2.1-53 and 2.1-21). The sheet arrives with so much kinetic energy that it would normally continue to travel. The braking rollers, with a cir-

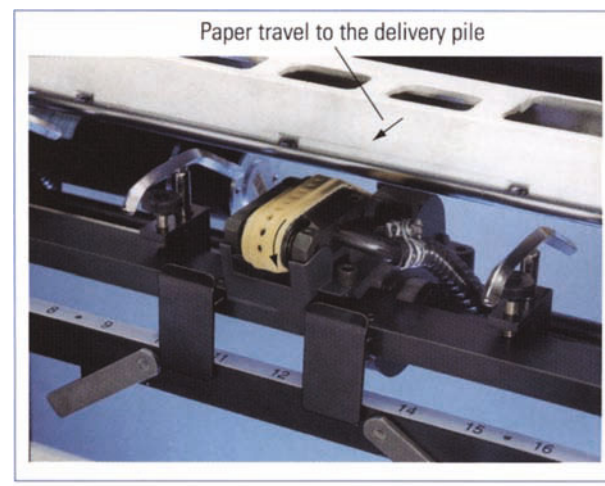


Abb. 2.1-53
Sheet slow-down device (Speedmaster SM 74, Heidelberg)

cumferential speed lower than the printing speed, hold the sheet firmly at the rear sheet edge and stretch it, so that the sheet is laid out virtually flat.

In *convertible perfecting presses* the underside of the sheet is also covered with fresh ink, so the braking rollers must be positioned only on non-image areas. Sufficiently wide non-image areas can often be found between the trim of the individual pages printed on a sheet (e.g., eight pages on one side of the printed sheet). Generally speaking, however, with 4/4 print jobs, possible traces of the braking rollers should also be taken into account in the sheet layout.

The flatter the sheet lies in the delivery, the better the air cushion between the sheets will be maintained, and the more evenly the contact pressure in the pile will be distributed over the surface of the printed sheet. All these things help to avoid the risk of ink offsetting.

To achieve a satisfactory and sufficiently fast delivery, the dropping down of the sheets is *supported by blowers* located between the top and bottom chain guides (see fig. 2.1-21). The *blast air* must be regulated according to the paper quality, grammage, sheet size, direction of travel, and printing speed in order to achieve an optimal effect. The sheet should show (in its direction of run) a slight downward bend at its center, so that the air between sheet and pile can escape at the sides and the sheet remains stable in the direction of travel. A sheet-fed offset press in the 70 cm × 100 cm format class (see also fig. 2.1-64), is equipped with fifteen fans above the delivery pile (in the direction of travel, three rows of five fans). The blowing power of these fans is adjustable in several zones.

Sheets printed on one side often have such a strong tendency to curl in the delivery pile that it is difficult to form a smooth pile. This *curl formation* in the paper also increases the risk of offsetting and blocking (freshly printed sheets sticking together). Curl formation is encouraged by the rheology of offset inks: the sheet sticks to the blanket so firmly that the grippers have to remove the sheet with a great deal of pulling force. The paper stretches somewhat in the course of this action, and is rotated on the blanket cylinder at a certain arc. When the sheet is released from the blanket a slight bending radius is produced (fig. 2.1-54). The *sheet decurlers* (figs. 2.1-55 and 2.1-21) in the delivery area bend the sheet in the opposite direction, so that a good flat position is regained. (The sheet decurler is not needed for perfecting jobs.)

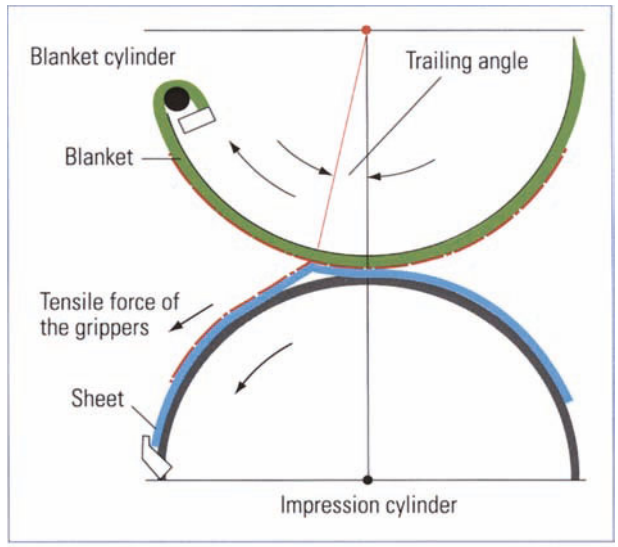


Fig. 2.1-54 Releasing the sheet from the blanket (trailing effect)

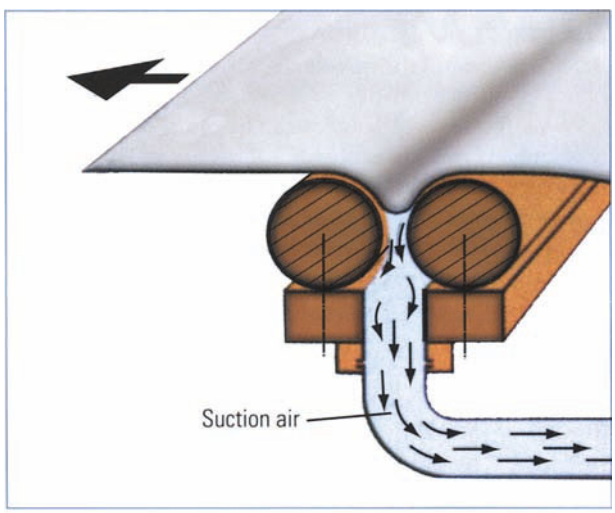


Fig. 2.1-55 Sheet decurler

Powder Application

In sheet-fed offset, the conventional ink is still not thoroughly dry when the sheet arrives at the delivery pile. Consequently one of the major requirements in sheet-fed offset is the avoidance of *smearing, offsetting* (transfer of ink onto the following sheet), and *blocking* in the pile (sheets lying on top of each other sticking together). The application of powder offers a remedy (fig. 2.1-22 and sec. 1.7.3.1) yet brings many negative consequences, such as soiling of the press, quality defects in the print area (reduced gloss), and finishing problems.

Due to the powder layer between the sheets, the wet ink surface does not come in contact with the following sheet. Only a small proportion of the delivered powder actually arrives on the sheet. The faster the press runs, the smaller the powder yield that actually reaches the sheet, the remainder contributing to soiling of the press in the delivery area. The longer the press, such as an eight-color press for straight printing and perfecting (4/4), the longer the ink has to remain fresh to avoid build-up on the impression cylinders, and the more crucial the pile formation in the delivery becomes. Consequently, with long, fast-running sheet-fed presses, powdering has to be intensified. Powder extraction systems in the delivery actually remove large quantities of powder, though a residue still remains, which necessitates cleaning work in the press, though considerably less often.

Both-sided powder spraying (fig. 2.1-56) from above and below brings obvious savings in the quantities of powder used. The major saving is made with verso powder spraying. The gripper bars carrying the sheet into the delivery are shaped so that the sheet is guided on an air cushion at a minimal distance above the guide plates (fig. 2.1-56a). Due to the small distance between the substrate and the powder outlet nozzles in the guide plates very little powder is lost, so the powder metering is very effective and powder can be reduced accordingly. Conventional top powder outlet nozzles are at a much greater distance from the sheet on account of the gripper bars, and so the air eddies behind the gripper bar swirl up the powder stream and the powdering is ultimately much more liberal in order to compensate for losses (see also fig. 2.1-59). For virtually all print jobs it is adequate to powder sparingly from the rear side, even if it has not been printed on.

Another way of optimizing the sheet's behavior in the delivery pile lies in improving the drying process by accelerated absorption (see sec. 1.7.1). Absorption can be accelerated using *IR drying* if the ink and paper are well-matched to one another.

Another option for optimizing delivery behavior (together with improvement of the print image quality/the image appearance) is the *application of varnish* (see sec. 2.1.2.7). Water-based dispersion varnish dries so quickly that powdering can, to a large extent, be dispensed with. Nevertheless, dispersion varnish is only used to improve delivery in exceptional cases, since a separate printing unit has to be incorporated for its application. The increased use of water-based dispersion varnish would improve gloss, give increased protection from abrasion and also improve delivery behavior.

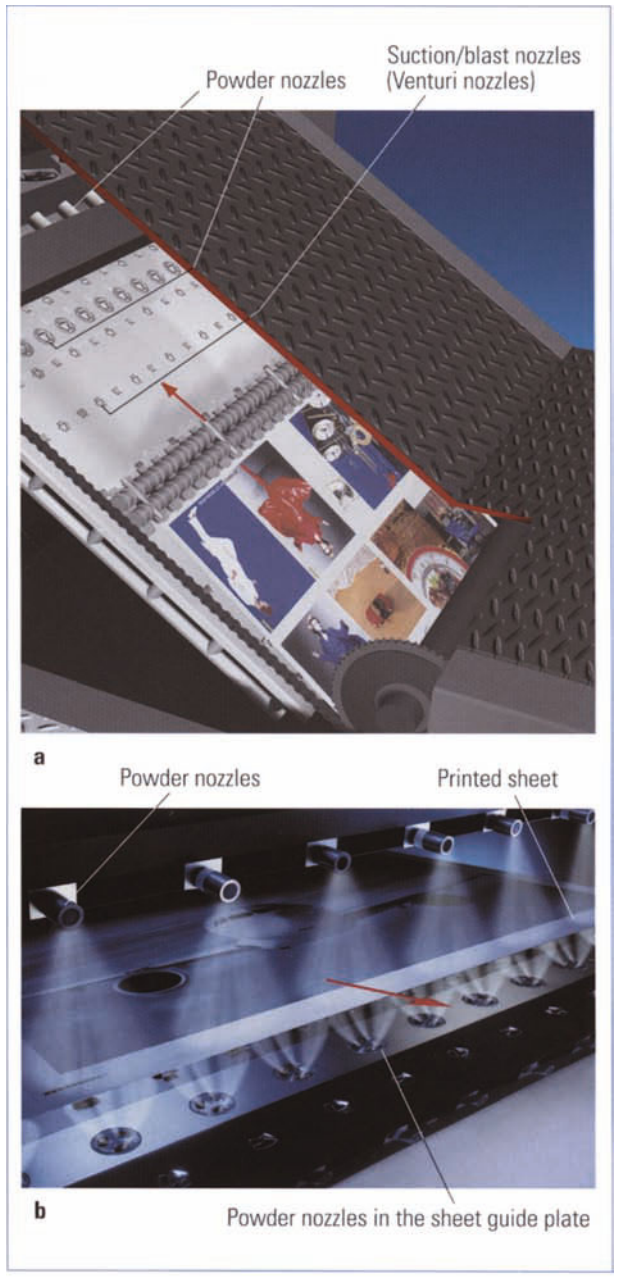


Fig. 2.1-56 Powder application in the delivery area.
a Sheet guide and powder application;
b Powder spraying on both sides (Heidelberg)

2.1.2.6 Drying

The drying processes possible in sheet-fed offset, such as

- IR drying,
- hot-air drying, and
- UV drying/curing

are described in detail in section 1.7 and therefore only a few specific designs and special features in sheet-fed offset will be dealt with in this section.

The following two requirements are of particular importance in multicolor sheet-fed offset:

- Drying in the delivery pile after printing should be done as quickly as possible so that the printed sheets can be finished without delay.
- The drying of the ink on the printed sheet between the printing units must guarantee sufficiently good ink acceptance in the subsequent printing unit so that doubling, color shifting over the print run, and/or soiling are avoided.

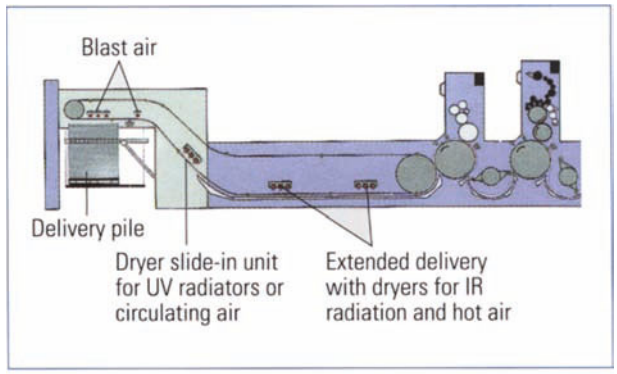


Fig. 2.1-57 Extended chain delivery with dryers (KBA)

IR and Hot-air Drying

The ink is usually chosen and possibly modified by the printer on the basis of its drying characteristics on the paper quality to be printed on, the technical process-related requirements, and the desired print quality. There are different drying systems available to enable optimal drying of a great variety of inks:

- *IR dryers* accelerate absorption and oxidation (cross-linking) of the ink.
- *Hot-air dryers* with ambient air blowers provide a higher exchange of air and, as a result, they vaporize the water (dampening solution) contained in the ink and paper faster. Hot-air dryers are also particularly effective in the drying of water-based dispersion varnishes.

Additional ambient air blowers with cold or warm air may be expedient for better drying and for "gentle treatment" (waviness, drying-out) of the paper.

Present-day sheet-fed offset presses for multicolor printing are also available with *extended delivery*, into which the most varied dryer modules can be fitted. Figures 2.1-57, 2.1-64, 2.1-22, 1.7-2, and 1.7-10 show examples of modular dryer installation.

Particularly efficient is a dryer design featuring a *combination* of IR radiator and integrated hot-air blower as illustrated below in figures 2.1-22 and 2.1-58. The sheet is stabilized (no fluttering of the sheet) by means of the sheet guide plate fitted with specially formed air nozzles (venturi nozzles) and held at an optimal and safe distance from the radiators (figs. 2.1-56a and 2.1-59). The floatation guidance is of great benefit, especially for sheets with print on both sides, in avoiding damage (scratches) on the print as a result of the surrounding components.

Another special feature of this dryer is the fact that the IR radiators are cooled/temperature stabilized by blast air fed to the radiator on both sides by fine nozzles. Flow detectors monitor the air current, ensuring that the radiators are quickly up to operating temperature when they are turned on, and that overheating during operation is signaled immediately and the radiator power reduced as necessary. If only fairly small format printing is being done, the width of the radiator can be reduced by the removal or addition of IR radiator components, as illustrated in figure 2.1-60.

Both chemical and physical balance reactions can be accelerated by heat radiation in the infrared range. However, the drying period required before it is possible to finish the sheets will still be several hours, depending on process conditions. Both oxidative drying and drying by absorption proceed faster at increased temperatures than at ambient temperature. Absorption is an exponentially convergent diffusion/equalization process. The warmer the substrate surface, the faster the final balanced situation is reached. The higher the ink absorption ratio during the drying process, the greater the contribution the heat radiation makes to the improvement in delivery and pile behavior.

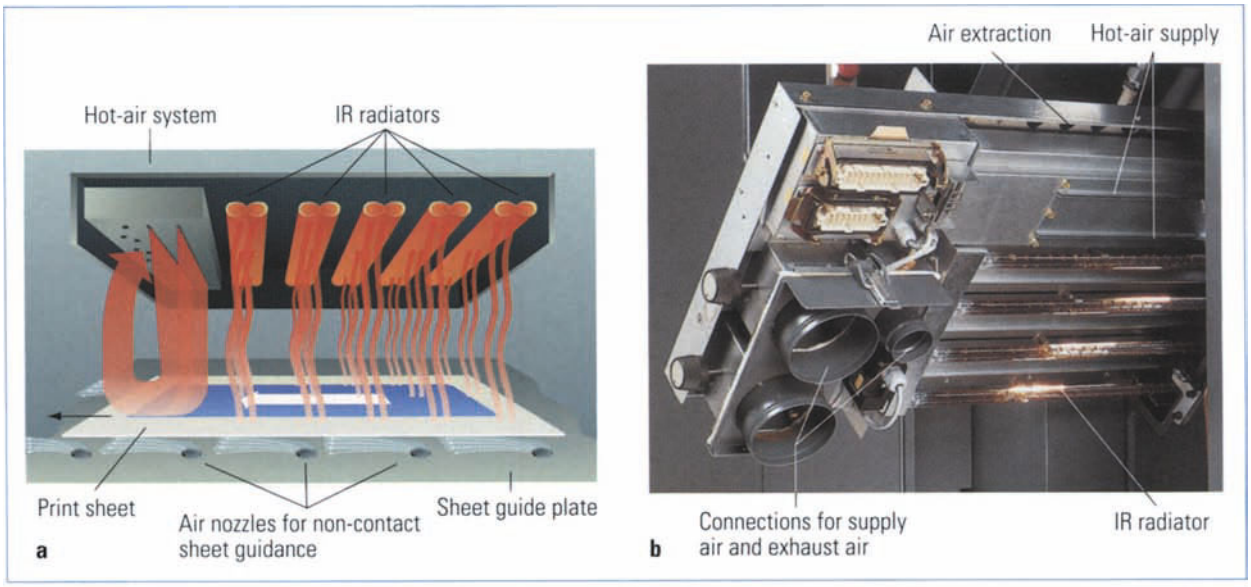


Fig. 2.1-58 Dryer module for the combination of IR radiation and hot air.
a Diagram of the drying module: Non-contact guidance of the sheets in the delivery;
b Combined dryer (Drystar, Heidelberg)

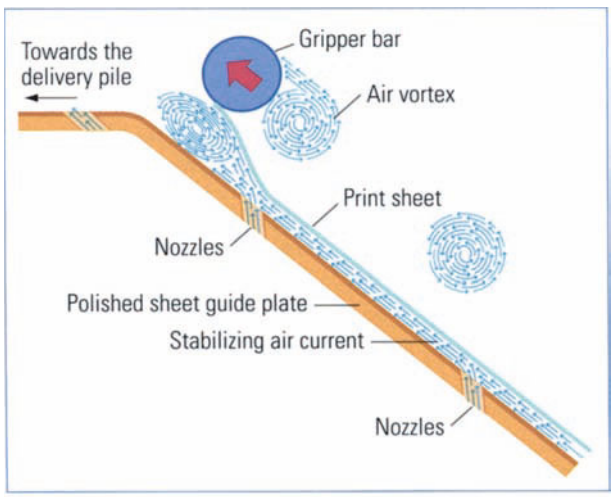


Fig. 2.1-59
Stabilization of the sheet by special air guidance, venturi nozzles in the sheet guide plate

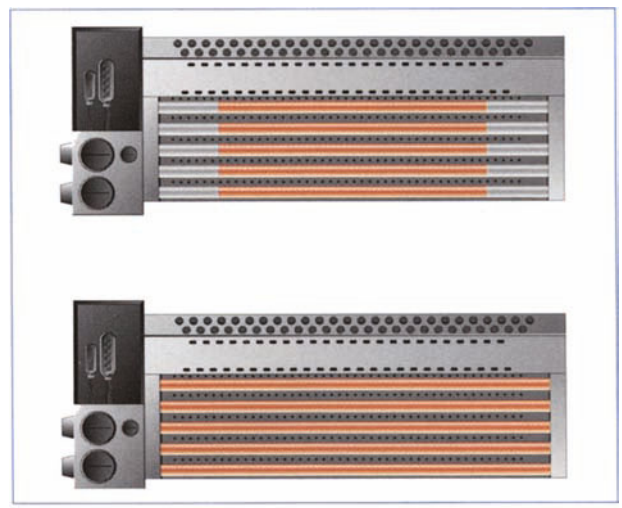


Fig. 2.1-60
Adapting the radiation width to the print format (Drystar, Heidelberg)

The piles can be run higher without the fear of blocking (sheets sticking together).

Oxidative cross-linking of the ink film is also accelerated under the influence of heat, as well as absorption. Compared to cross-linking under UV radiation, oxidative processes proceed slowly. The drying period of usually several hours (depending on the paper and ink, from five to twenty hours with-

out special drying measures) can quite easily be halved.

Drying by the application of heat between the printing units (inter-unit drying) would lead to poorer ink splitting in most cases and is therefore only rarely used. The absorption of the oleaginous constituents of the ink into the paper between printing units at ambient temperature is sufficient for good absorption of the next ink film. In perfecting, as already described, attempts are even made to keep the ink film fresh on the substrate until the final printing unit, to ensure ink splitting on the second side when printing the first side and thereby avoid ink build-up on the impression cylinder. Therefore there is no point in introducing inter-unit drying.

To minimize the problem of ink resplitting from the previous to the subsequent printing unit, it is also possible to adapt the rheology of the ink, and here in particular to graduate the tack of the inks accordingly (higher tack in the preceding printing unit).

UV Drying

A reactive binder/vehicle system will be cured in a very short time (almost instantaneously) under the influence of UV radiation. In sheet-fed offset, the use of radical inking systems predominates and mercury gas discharge lamps with an output of 100 to 120 W per cm printing width are usually used for drying. Since the UV radiator converts only approximately 25% of the consumed power into UV light (the balance is almost 50% in IR radiation and 25% in visible radiation), the radiators become very hot and have to be adequately cooled over the housing and the reflector (see also sec. 1.7.2.2). The thermal load of the substrate is considerable, and it increases with substrate thinness – that is to say,with reduced thermal capacity. To prevent the sheet from touching the radiator and becoming overheated, for example during a paper jam, the UV dryers are equipped with safety devices such as closable reflectors (fig. 2.1-61).

UV dryers can be used both in the delivery after wet-on-wet printing and also for *inter-unit drying* (drying between printing units). In wet-on-wet printing the tack of the UV inks is adapted by the ink manufacturer according to their sequence during printing. This is also usually the case with oil-based inks. Printing with UV inks is often done in conjunction with very high requirements on print quality and special printing features. To be able to fulfill these requirements, multicolor presses are more often than not equipped with inter-unit drying (see fig. 1.7-10). Inter-unit drying must be done if the layers of ink are extremely thick, to improve ink acceptance and gloss. A thick and evenly printed ink film is then dried before another color is applied in the next printing unit (e.g., black type on a silver background).

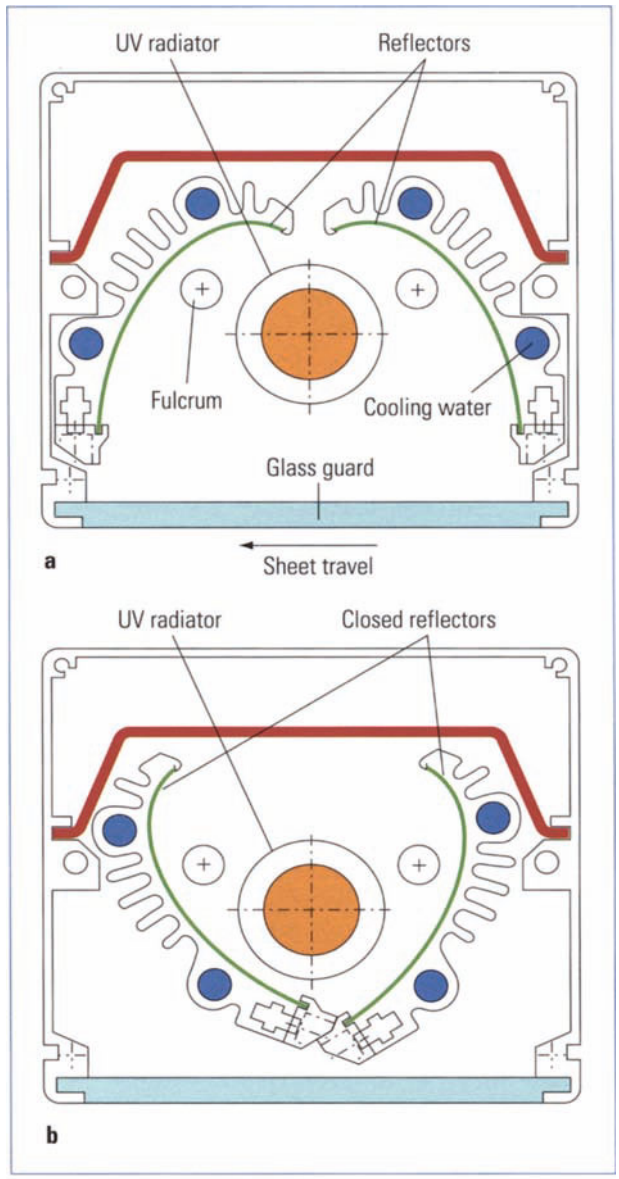


Fig. 2.1-61 UV dryer with shuttable reflectors.
a Open reflector;
b Closed reflector (Dr. Hönle)

As already described, mercury gas lamps, with the disadvantage of high proportions of IR radiation as well as ozone formation, are usually used in sheet-fed offset. Drying devices with excimer radiators (see sec. 1.7.2.2), which do not suffer from this disadvantage, are under development for sheet-fed offset. These radiators are (still) limited with respect to output, so inert gas (nitrogen) has to be used between sheet and radiator to support initialization. Using a chamber filled with nitrogen, as is the case with web presses, is virtually impossible in sheet-fed offset presses on account of the gripper bar that would have to be used. Much of the nitrogen is carried off without being used.

2.1.2.7 Print Enhancement and In-line Finishing

Print Enhancement and in-line finishing processes are widely used in sheet-fed offset, the following being the fundamental processes:

- *coating* to improve the visual impression and/or to protect the printed surface;
- special additional printing with *metallic inks*;
- *numbering* and simple *imprints*;
- *surface treatment*, such as perforation and punching, cutting, creasing and embossing.

Print Enhancement/Surface Finishing

It is mainly coating units that are used today for *coating* or the application of metallic inks (fig. 2.1-62). However, some varnishes can also be applied using standard printing units (e.g., water-pan varnish via coated offset plates).

Coating units should always be considered as a system operating in combination with a dryer (hot-air, IR, UV). The demands on surface finishing determine the nature and characteristics of the varnish to be used and the type of drying. In sheet-fed offset, dispersion varnishes (water-based varnishes) and UV cured varnishes predominate. Oil-based varnishes are rarely used because they produce very little gloss. Very glossy surfaces are achieved with both dispersion and UV varnishes. Annual reports, brochures, catalogues, wine labels, cosmetics and food packaging are typical products. Special effects can be achieved with metallic varnishes such as gold and silver.

Besides enhancing the product, coating has the positive effect that printing can be done with reduced quantities of powder, therefore the delivery and subsequent finishing machines become less soiled. The composition and properties of varnishes are explained in sec. 1.5.3.

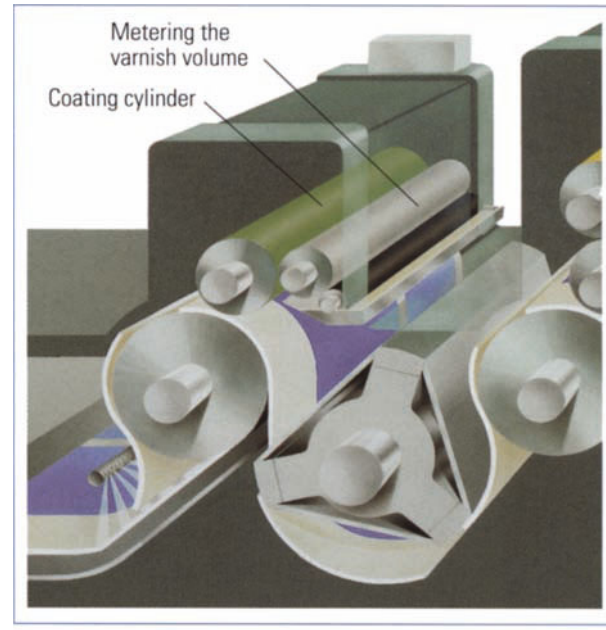


Fig. 2.1-62 Coating unit (Speedmaster 102, Heidelberg)

Coating units are very similar to flexographic printing units: a soft image carrier, in its simplest form a blanket for full-surface coating, is "inked" by a hard application roller and the varnish is transferred directly onto the substrate. Two types of systems (fig. 2.1-63) are used for applying the varnish ("inking unit"):

- *Roller system.* The varnish is scooped from a pan by a roller. The coating is metered by a second roller acting as a squeeze roller or by using differential speeds. The quantity of varnish can be varied. Two or three rollers may be needed, depending on the configuration and the direction of rotation.
- *Chambered-type doctor blade system.* The varnish is applied and metered to an anilox roller by means of a chambered doctor blade. A better, more even application of coating can be achieved with this system throughout the print run even at varying production speeds. The quantity of varnish applied depends on the total volume the anilox roller can hold (cell depth, number of cells/cm), that is, the anilox roller has to be changed if the requirements on the coating film thickness change. (A standard value for the total volume of an anilox roller for coating application is 20 cm^3/m^2, which produces a solid coating application of about 8 µm, 8 g/m^2 on

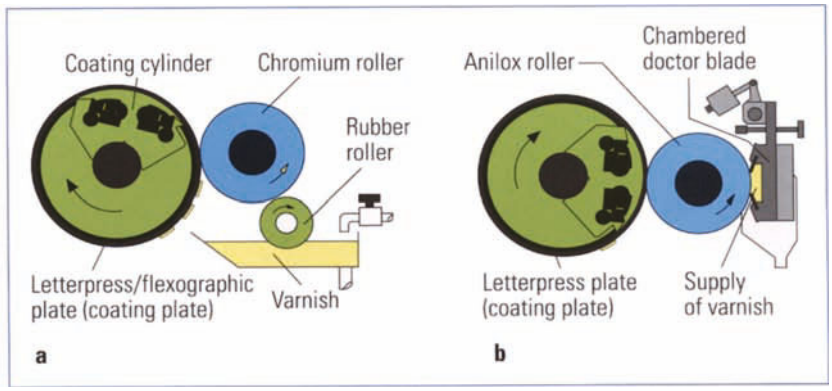


Fig. 2.1-63
Varnish application and metering systems.
a Open system with metering roller (roller system);
b Closed system with chambered doctor blade and anilox roller (Heidelberg)

the substrate.) In practice, it is usually enough to have two to three anilox rollers with different cell volumes, which can be used alternately.

The *printing plates* (coating plates) may consist of:

- blanket for full-surface application of varnish,
- letterpress image carrier (see sec. 1.3.1) made from cut-to-size blanket or strip plates for spot coating (polyester/rubber),
- letterpress/flexographic printing plate (photopolymer with polyester, or an aluminum base due to the greater dimensional stability) for high-quality spot coating or for printing with high-gloss metallic varnishes.

There are quick-action clamping systems available for clamping the coating plate, and the plate cylinder is adjustable in circumferential and lateral direction for positioning the plate in accurate register.

To apply thick layers of dispersion varnish, in conjunction with very high gloss, *double coating units* with inter-unit drying must be used (fig. 2.1-64). The first application of coating seals the surface of the paper, so that after the second application in the second coating unit the varnish can be distributed evenly, resulting in a high-gloss film of coating.

Double coating units are also required to achieve the best results when using UV varnishes. A *primer* is applied as the first coat (mostly an aqueous varnish) and then dried. Only on this base coat will the actual UV coating produce the desired quality.

Special Effects. Certain effects can be achieved with varnish that are not possible with conventional offset printing. Printing with gold and metallic pastes can be done in offset printing using conventional methods, but the quality suffers as a result of the low coating thickness to be applied and as a result of the dampening solution and the additives. Better *metallic effects* are

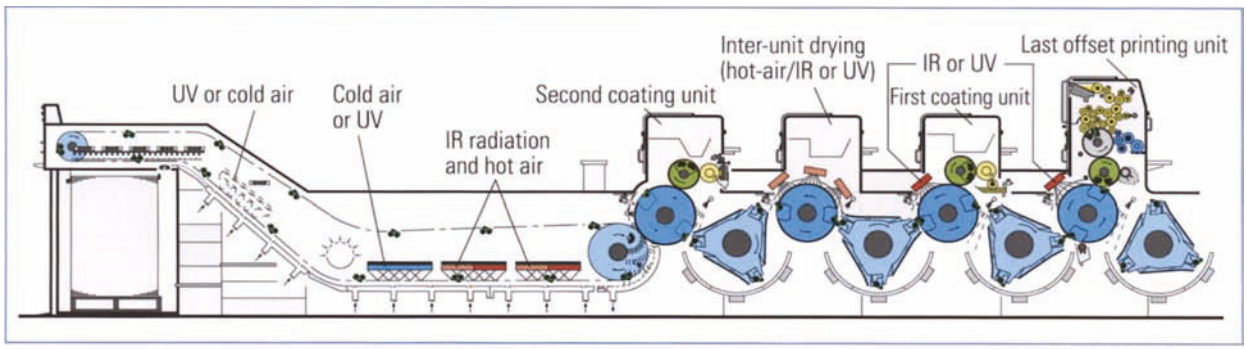


Fig. 2.1-64 Double coating units with inter-unit drying and extended delivery with several dryers (Speedmaster SM 102 CD, Heidelberg)

achieved by using a coating unit. Gloss effects can be achieved with gold and metal pigment inks in conjunction with aqueous varnishes, which are markedly better than those achieved with oil-based inks. Special effects, for instance, gold effects, of a good quality can be created with pearlescent pigments ("metal-free" gold). Another variant for creating special effects with varnish is to apply scents using scented varnish. *Scents*, microencapsulated in the varnish, can be printed on the substrate via the coating unit. The scent takes effect as soon as the capsules are broken open by rubbing.

There are special enhancement machines in use, particularly for coating sheets that have already been printed and whose ink has dried. Figure 2.1-65 shows an example of such a machine. It is designed for high-quality products yet at the same time offers great versatility in terms of the types of varnishes that can be used. UV varnishes (gloss and matte), dispersion varnishes (likewise gloss and matte), combinations of both varnishes, and also combinations in conjunction with metallic varnishes are possible and ensure a wide range of applications for this machine. The prerequisites, in addition to the universally applicable coating units with a doctor blade, are smudge-free (virtually contact-free) sheet conveyance as well as inter-unit and final drying units. The type of drying, the number of drying processes (dryers), and the drying time can be optimally adapted to the qualities of the substrate and the varnishes used.

In-line Finishing

Numbering, Imprinting. Many sheet-fed offset presses are equipped for the installation of special numbering boxes. Figure 2.1-66 shows the place of installation and an example of a numbering box shaft with mounted numbering boxes. The numbers are inked by a simple inking unit (letterpress process) and are then printed on the sheet at the final impression cylinder before the sheet is taken over by the chain gripper system. The numbers are indexed with each revolution of the cylinder, mostly by mechanical means. Letterpress plates can be mounted instead of numbering boxes to imprint logos, for example. Depending on the application, a hard or soft packing (sheet metal, cork, plastic film, etc.) must be mounted on the cylinder to protect the surface of the impression cylinder and to achieve the appropriate counter-pressure.

Perforation, Cutting, Punching, Creasing, Embossing. The perforating, cutting, creasing, or embossing tools can be attached to a cross bar with millimeter graduations for easier positioning (figs. 2.1-67a and 2.1-66a). As is the case with numbering units, these tools, for instance, slitting wheels, work on the impression cylinder, which therefore has to be equipped with the special cylinder jacket. Perforation, creasing, and so forth, can usually only be done in the sheet's direction of travel and not at right angles to it. It must also be taken into account that the tools can only be fitted in the areas between the grippers. A device for cross perforation is shown in figure 2.1-67b.

So-called "perfostrips" offer another easy method of perforation and cutting. These strips with integrated blades are exactly fixed onto the impression cylinder or cylinder jacket and cut the sheet from underneath

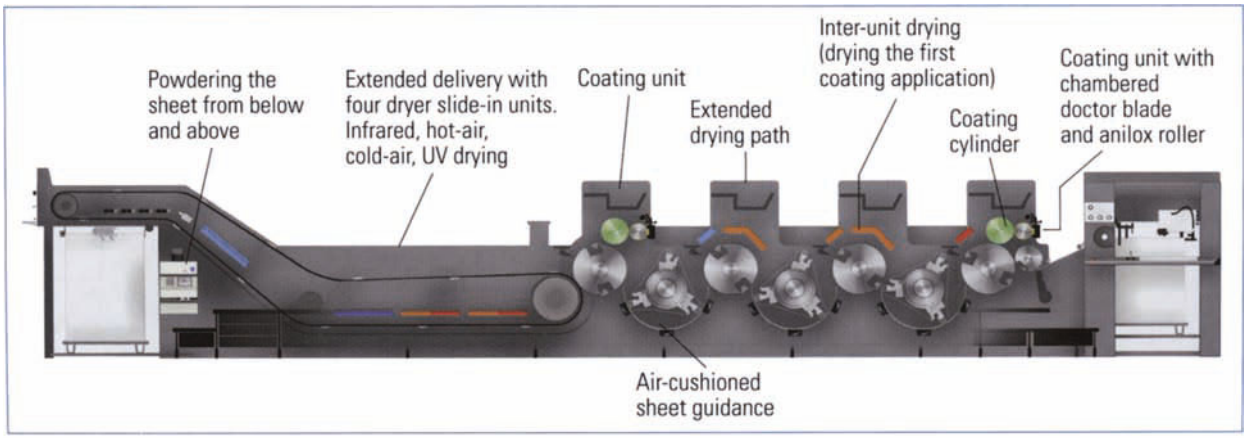


Fig. 2.1-65 Off-line surface finishing system (Speedmaster CD 102 LYYL, Heidelberg)

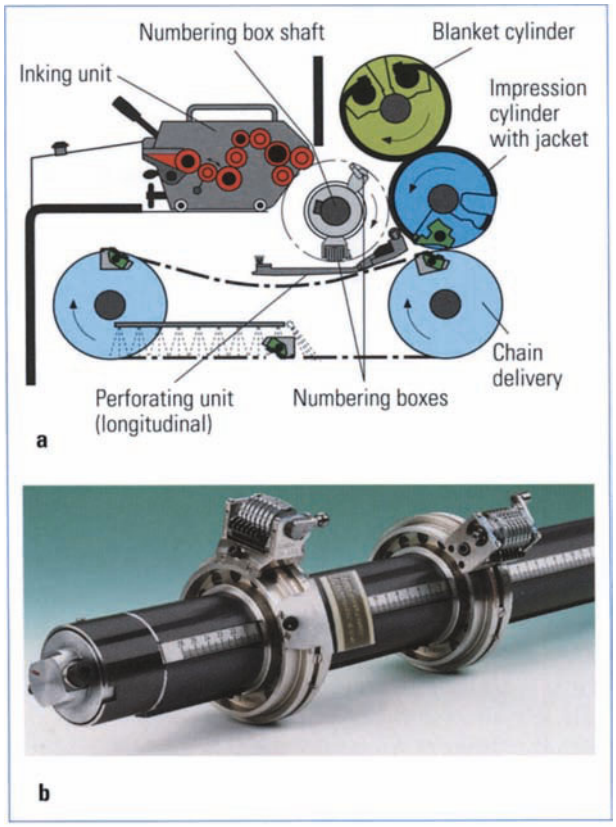


Fig. 2.1-66 Numbering unit.
a Numbering box in a single-color press;
b Numbering box shaft with longitudinal and transverse numbering boxes (Speedmaster SM 52-1, Heidelberg)

against the blanket. With this configuration, printing and perforation/cutting can be done simultaneously in the printing unit, although the possibility of damage to the blanket cannot be ruled out.

The sheet can be perforated, cut, creased, or embossed lengthways or at right angles to its direction of travel with specially shaped metal sheets (fig. 2.1-68). These sheets are mounted either in place of the blanket or the cylinder jacket on the impression cylinder. The respective impression cylinder must be fitted with the appropriate cylinder jacket (soft or hard). The diameters are usually adjusted by means of plastic underlays. These metal sheets are used to pre-punch adhesive labels or decals. Cartons are grooved and sheets are cut into strips in this way. It is also possible to produce embossed textures.

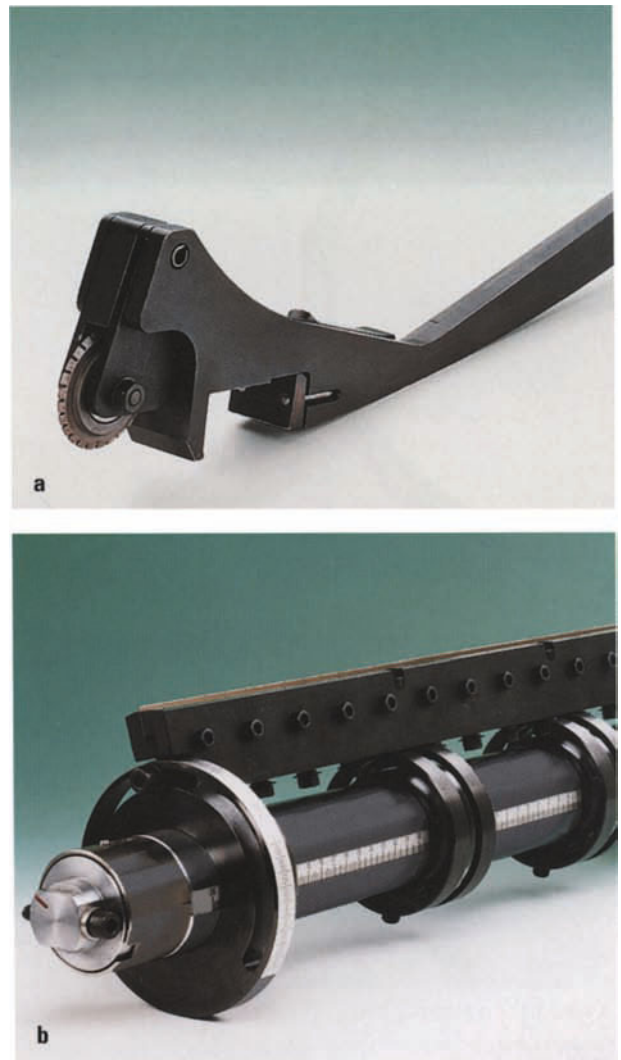


Fig. 2.1-67 Perforating tools.
a Perforating wheel (longitudinal direction);
b Perforating knife (at a right angle to the direction of travel)

2.1.2.8 Press Architecture (Special Designs)

Non-stop Sheet Feeder

The supply and removal of paper in sheet-fed presses are of crucial importance for productivity and a uniformly high print quality, especially if there is a high throughput of materials. Equipment for non-stop pile change, that is, where the piles are changed without machine stoppages and therefore no new start-up

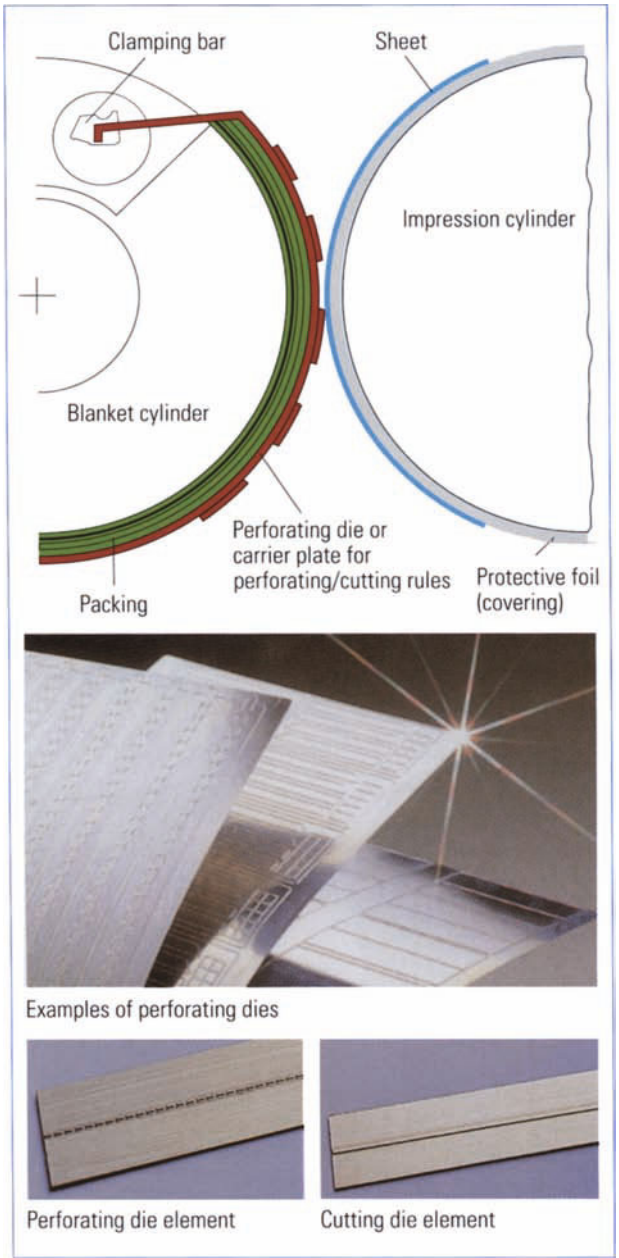


Fig. 2.1-68
Perforating plate for use on the blanket cylinder with perforating and cutting rules to be fitted on the base plate (Perf Print Plus)

waste is created, are essential for a smooth production flow. Figure 2.1-69 (see also fig. 2.1-161 and sec. 8.1.1.5) shows a device for automatic changing of the pile at the feeder and figure 2.1-70 shows the different stages involved in the pile change.

The pile of paper lies on special pallets that have longitudinal grooves (in the direction of travel of the sheet). Once the height of the residual pile reaches approximately 300–500 sheets, a rake is pushed automatically into the grooves beneath the paper pile (fig. 2.1-70a). The rake takes over the pile (residual pile) at full printing speed, the empty pallet is lowered and moved away from the feeder area. A new pallet is transported to the exact insertion position by means of special logistics systems and lifted up. As soon as the new pile is underneath the rake (fig. 2.1-70b), the latter is withdrawn and moved up into parking position (fig. 2.1-69). This rake method can be applied accordingly in the delivery.

Non-stop Delivery

Figure 2.1-71 shows another solution for holding the residual or auxiliary pile when changing the pile in the delivery. The printed sheets are deposited on non-stop rollers, while the main pile is lowered and removed from the delivery. An empty pallet is inserted and the rollers retract as soon as the pallet is beneath the rollers.

Figure 2.1-72 shows a press where two delivery locations are arranged one after the other in the chain delivery. The second delivery can be used for pile changes or for stacking waste sheets.

Waste Diverter

In figure 2.1-72 an image inspection unit can be seen between the delivery and the final printing unit, which detects faults in the print image during production. The fault is signaled to the operator, or the waste sheet is directly diverted to the waste sheet pile.

Sheeter

A reel-to-sheet device (sheeter) is used instead of a feed pile as shown in figure 2.1-73. There are two advantages of this device. Firstly a considerably larger amount of printing material can be stored at the feeder, and secondly the reel material is less expensive. The web is cut into sheets, which are then fed to the feed table board in a sheet stream.

Straight Printing and Perfecting

Figures 2.1-74 and 2.1-75 show two 4/4 perfector presses on which the printing units are not all arranged in a line

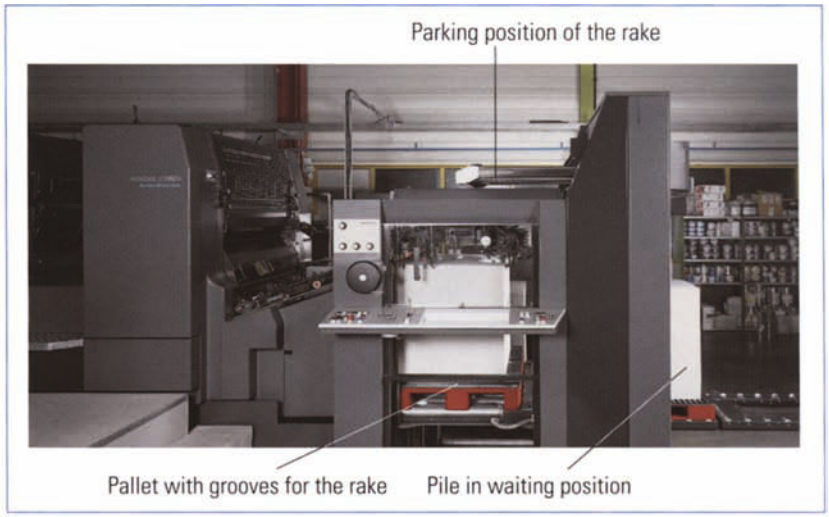


Fig. 2.1-69
Non-stop pile change at the feeder (Heidelberg)

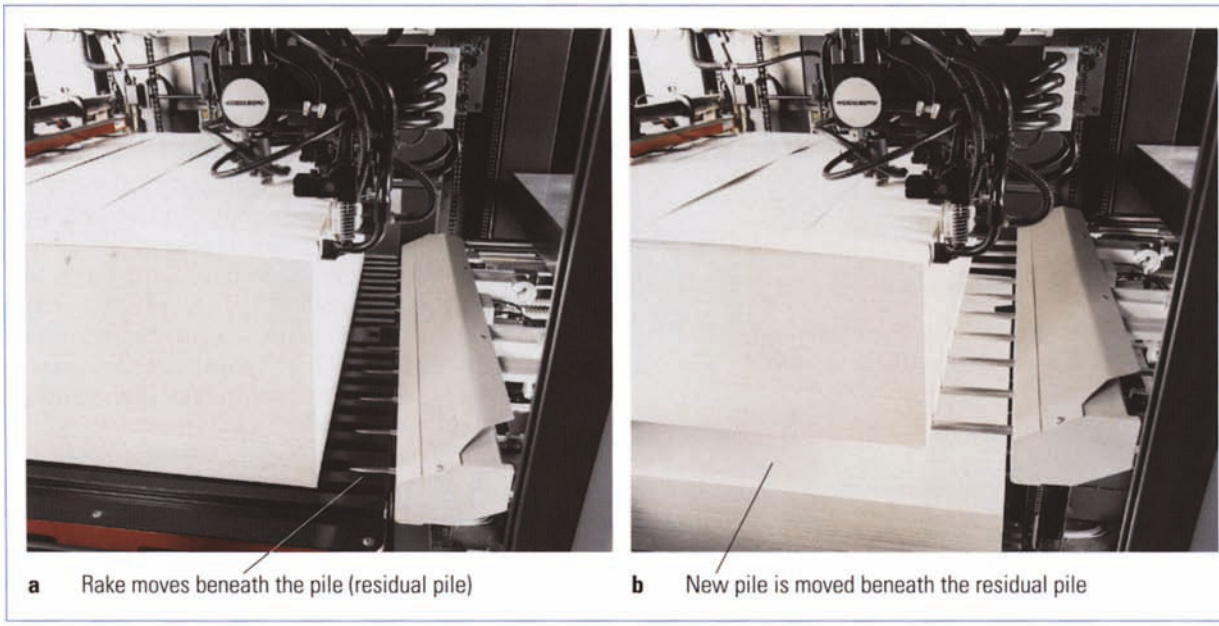
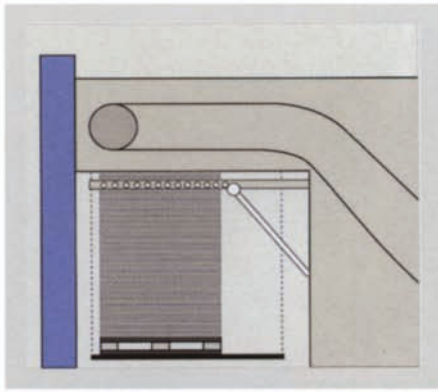
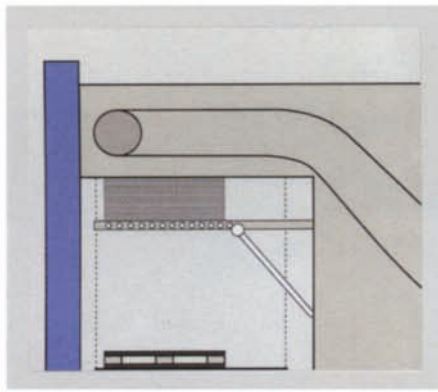


Fig. 2.1-70 Stages during pile change with a rake.
a The rake is moved under the residual pile;
b The new pile is moved up to the rake beneath the residual pile, the pile is aligned and the rake is removed (Heidelberg)

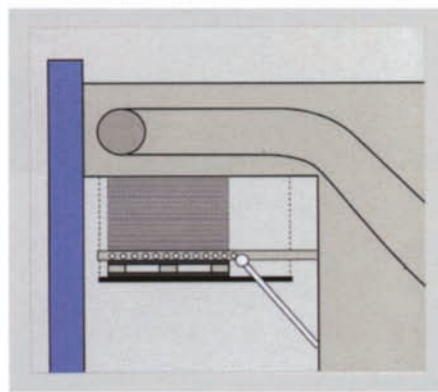
but also on top of each other. The sheet is printed alternately from above and below in multicolor. These types of presses are of a more compact design compared to presses with printing units arranged in a line and equipped with a sheet reversing unit, yet the printing units are somewhat less easily accessible and the press is less versatile (e.g., 6/0 or 8/0 is not possible). The press in figure 2.1-74 is equipped with single-revolution cylinders and three transfer drums, one of which acts as an impression cylinder for the perfector. Figure 2.1-75



The inserted rollers take on the sheet



The rollers move downwards gradually as the auxiliary pile gets heavier



The empty pallet is beneath the rollers which now move back

Fig. 2.1-71 Pile change at the delivery using rollers (KBA)

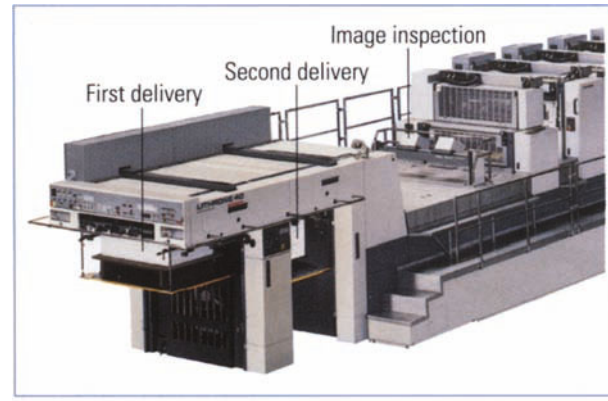


Fig. 2.1-72
Dual-stream delivery and image inspection (Lithrone 40, Komori)

shows a press with double-sized impression cylinders and a two-revolution transfer drum between the printing units. The transfer drum acts simultaneously as the impression cylinder for the perfecting unit.

Rainbow Printing

Figure 2.1-76 shows a special ink fountain. Ink fountain dividers separate the ink fountain into several segments crosswise to the direction of printing. Each segment of the ink fountain can be filled with a different color, meaning that several inks can be printed on the sheet (side by side) in one printing unit. This ink fountain variant is used for special applications such as rainbow printing (printing of securities). Deliberate use of lateral distribution allows the inks to run into each other in the intended areas to produce special color effects during printing. The application of this in newspaper printing is illustrated in figure 2.1-211c. The printing plate is inked in different colors through ink fountains which are arranged next to each other.

2.1.3 Web-fed Offset Printing

2.1.3.1 Press and System Concepts (Components)

Web-fed offset presses are production flow lines where the product is also a means of transportation. Therefore, it makes sense to describe these lines by following their production cycle, that is, to start by describing the feeding-in of the unprocessed material – the paper reels. Web offset presses are usually categorized into either press types operating on the *heatset* principle for

Fig. 2.1-73
Reel-to-sheet equipment with sheeter for cutting the web instead of a feed pile, and feeding system (KBA/MAN Roland)



Fig. 2.1-74
Perfecting (4/4) without sheet reversal with single-sized impression cylinder (JPrint 40, Akiyama)



Fig. 2.1-75
Perfecting (4/4) without sheet reversal with double-sized impression cylinder (Lithrone 40 SP, Komori)

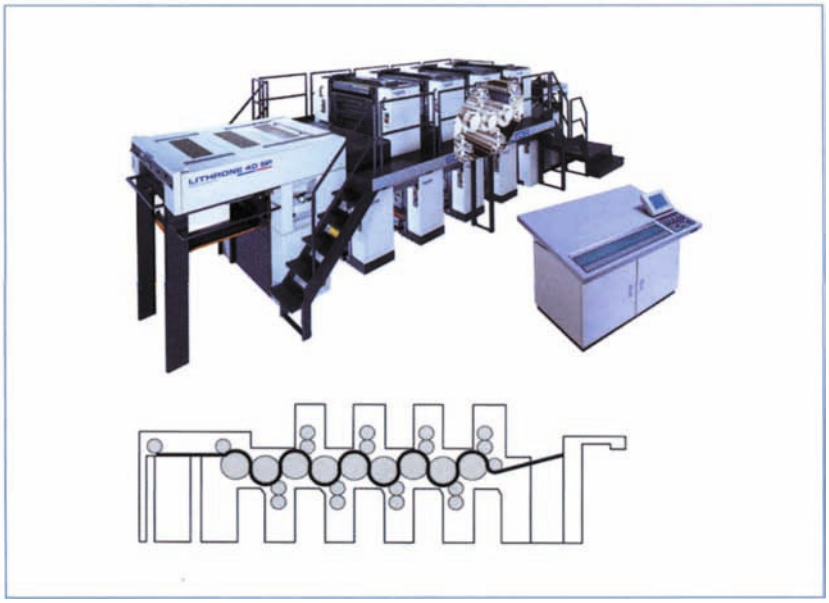




Fig. 2.1-76
Ink fountain with ink fountain dividers for printing different colors (rainbow printing) in one printing unit (KBA)

the production of commercial print jobs, magazines, and publications (fig. 2.1-77) or newspaper offset presses operating on the *coldset* principle. However, both press types are described together in this chapter. The fundamental differences will be dealt with in a separate section (2.1.3.5).

Paper Reel Store

Due to a high level consumption, stocking up and storing the paper reels is an important aspect for web offset and newspaper printing companies. Great emphasis is placed on unloading and handling the paper reels, as the printing company can keep useful statistics and give proof of damage caused during transport only if the reels are also monitored upon receipt. If damage has been caused and the printing company wishes to make a claim for compensation with the insurance company, the following details need to be recorded while an employee of the shipping company is still present:

- the number of reels,
- the type of damage (edges, reel body, front sides, noncircularity, packaging damage, or damage caused by water),
- the extent of the damage,
- the possible cause.

The importance of reel inspection still holds even if unloading is to be carried out automatically, as the reels may have been damaged before being accepted.

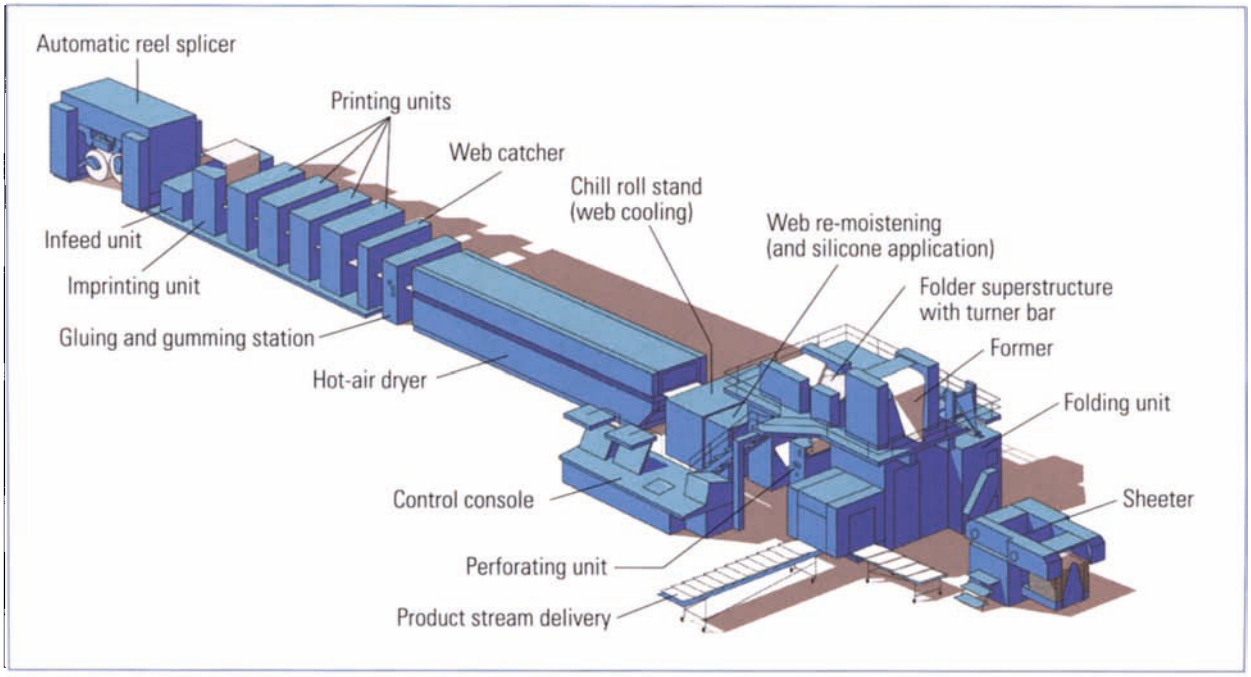


Fig. 2.1-77 Web offset press components (M-600, Heidelberg)

AGV Transport

Figure 2.1-78 shows the connection between paper storage and pressroom. In order to avoid losses, rather than to cut staff, further transportation of the paper reels in the printing company is now carried out by *Automated Guided Vehicle (AGV) Systems*. A paper reel is picked up on v-blocks (or on an arbor) by small transport vehicles powered by rechargeable batteries. These vehicles are controlled by a central computer via radio signals and directed by an induction wire which is installed in the floor. This results in higher flexibility and lower overall costs compared to chain-driven, floor-mounted conveyors. Besides induction wire-directed vehicles, there are also vehicles in use today which steer themselves by means of an integrated optical sensor system and prominent location marks in the warehouse. For reasons of safety, the vehicles are equipped all around with proximity sensors and flexible bumpers to avoid injuring any staff in the vicinity.

Unpacking Paper Reels

Upon removal from the storeroom, the paper reels are taken to the unpacking station by the AGV, where they are unpacked by a semi-automated or automated process, or else manually. For unpacking the reels manually, a knife is used for the side caps and a plow blade knife to open the belly wrapper; however, over the last ten years, semi-automated devices have been developed where the reels are turned by motor, and the packaging material is disposed of by a shredder which is within easy reach above the head. Inspired by examples from Japan, there are also systems with a fully automated unpacking process, where circular knives cut away the side caps, slit open the packaging on the circumference and transport the packaging material to the shredder via a conveyor belt.

If the reel identification is not carried out by the AGV, a barcode label (peel-off label) must be peeled off the reel label (fig. 2.1-79) before the reel label is destroyed and stuck on to the reel core so that the unpacked reel can still be identified.

Preparation for Pasting

After the reel unpacking section there is a station for preparing the pasting. This sets up the flying reel change, that is, the front end of a new paper reel is glued to the tail piece of the expiring reel while the press is running. Here again, a distinction can be made between manual, semi-automated and automated devices. Auxiliary devices range from a ruler or stencil to



Fig. 2.1-79 Reel label with barcode and peel-off-label (IFRA)

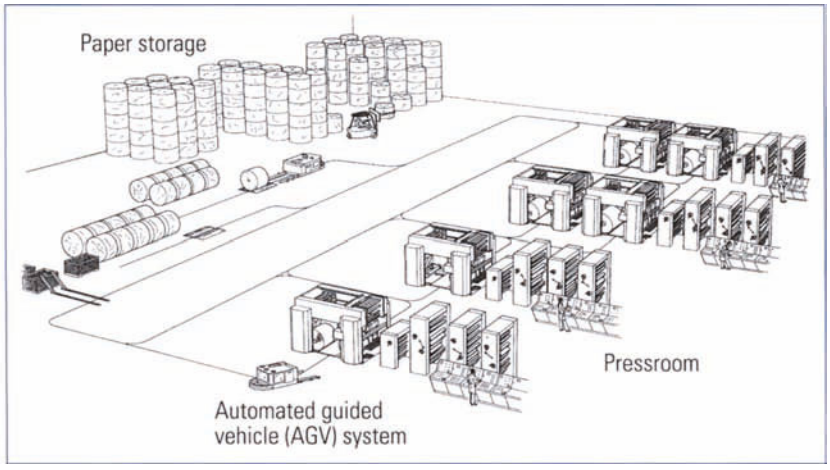


Fig. 2.1-78
Material transportation from the paper store to the pressroom using driverless transport systems (IFRA)

a splice preparation robot for fully automated execution of such operations as outer layers alignment removal, V- or W-shape trim of the web, application of the glue or the double-sided adhesive tape, and putting on the splice tap (metal or black marking) and the adhesive seal. The paper reel is prepared by the robot alone. In Japan, a large number of robots of this kind are already in use, but other countries are still a little hesitant to install such automation systems. Occasionally there are devices integrated in the reel stand. This requires two back-to-back reel stands.

Reel Stand/Reel Splicer

The main tasks of a reel stand or a reel splicer are

- to unwind the paper reel,
- to tension the paper web and keep it at constant tension, and
- to change the reel fully automatically (depending on the types of paper reel).

There are a large number of different paper reel stands available, ranging from the simple unwinding frame to high-performance autopasters for fast-running newspaper web offset presses. Features of reel stands are:

- simple unwinding with supporting axe clamping or shaftless,
- bud splicer,
- flying reel change with one-arm, two-arm, or three-arm reelstand.

Another design feature is the type of reel drive with or without a belt (core-driven).

The *"flying" reel change* (fig. 2.1-80) is carried out in the following automatically executed sequences:

- Clamping the new reel in the chucks.
- Moving the new reel into working position (the new reel is moved to a distance of 1 cm from the expiring web, which is protected against fluttering by a support roller).
- Acceleration of the new reel to the circumferential speed of the expiring web.
- On passing the splice marking, the expiring web is pressed down to the circumference of the new reel by means of a foam roller (formerly a brush). The adhesive end of the new reel sticks to the expiring reel and at the same time the paste seal is broken.
- Swinging in the separating knife to cut off the remaining piece of the expiring web.
- Braking and ejection of the expired reel while the new reel is active.

The expired residual reel is placed in a carriage and removed; the carriage is moved onto the sliding platform – in most cases by the AGV and the chain-driven hunt (a transport vehicle for the paper reel, which is guided on rails). The full carriage is moved to a waste disposal store, where the waste paper and the printshop waste come together to be compressed in presses into space-saving bales. The waste disposal store has an approach ramp to transport the bales and bulk goods to the recycling plant.

Reel change in *zero-speed web splicers* – frequently used in commercial web offset presses – is carried out in a completely different way (fig. 2.1-81). The paper reels are not carried on tilting brackets but solid in the frame – one reel on the top and one reel at the bottom of the frame. The paster device (paster head) is placed in-between, and the web storage (festoon) is located behind the reel stand in the form of meandering paper loops running between two batteries of idle rollers. The new reel is mounted in the frame by a ceiling crane and roll-down rails.

For reel change, the front end of the new reel is mounted in the paster device (paster head), and the speed of the expiring reel is reduced by braking. When braking down to a standstill, the web storage is emptied proportionally by moving the idle roller batteries together, thus keeping the web offset press running. A paster tab is inserted between the pinched front end of the new reel and the idle expiring web (after the latter has been bled-off horizontally with a knife), thus providing bud-splicing without the tail pieces overlapping.

When pasting occurs at a standstill the new reel is accelerated by a belt drive up to production speed and momentary overspeed, in order to fill up the web storage by moving the idle roller batteries apart. Later versions of this zero-speed web splicer put the web storage in a horizontal position above the reel stand (fig. 2.1-82) and use brackets instead of a ceiling crane to mount the new reel more easily.

For *newspaper web offset presses*, two or three-armed reel stands are used for the flying reel change. In general, three-armed versions are in use in North America, whereas in Europe two-armed versions are preferred. The three-armed version is advantageous only

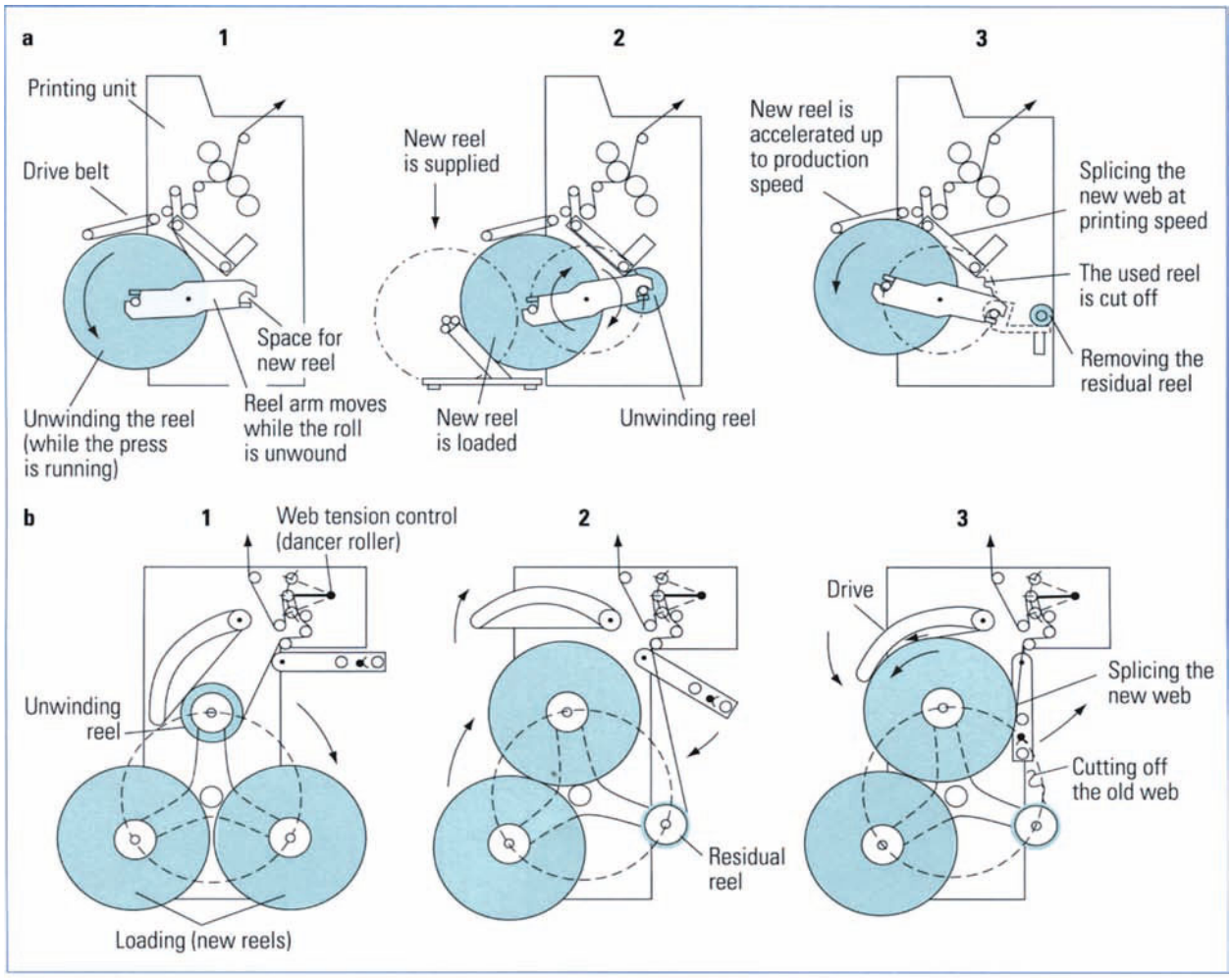


Fig. 2.1-80 Automated reel change.
a Reel splicer, two-arm version (simple version, integrated in a printing unit);
b Reel splicer, three-arm version (IFRA)

if no more than three reels are required for one shift. The paper reels can then be preloaded and are not in the way. Since two-armed and three-armed versions operate in the same cycle time, neither offers advantages over the other under normal operation.

To trigger the reel change process automatically, the web sequence has to be electronically monitored. Paper consumption is measured continuously, for instance by tachogenerators, and the expiring reel diameter is calculated accordingly. Once the expiring reel has reached a certain diameter, the signal for turning in the new reel, accelerating it and so on, is transmitted. Naturally, operational data evaluations and statistics on web tear can be compiled for the reel change. For this purpose it is necessary to identify the individual paper reels before mounting, for instance, by barcode, either by inserting peel-off labels from the reel label in protocols, or by central assignment during goods inward inspection and AGV transport. In this way, the status of individual paper reels in the workshop can be clearly defined and monitored.

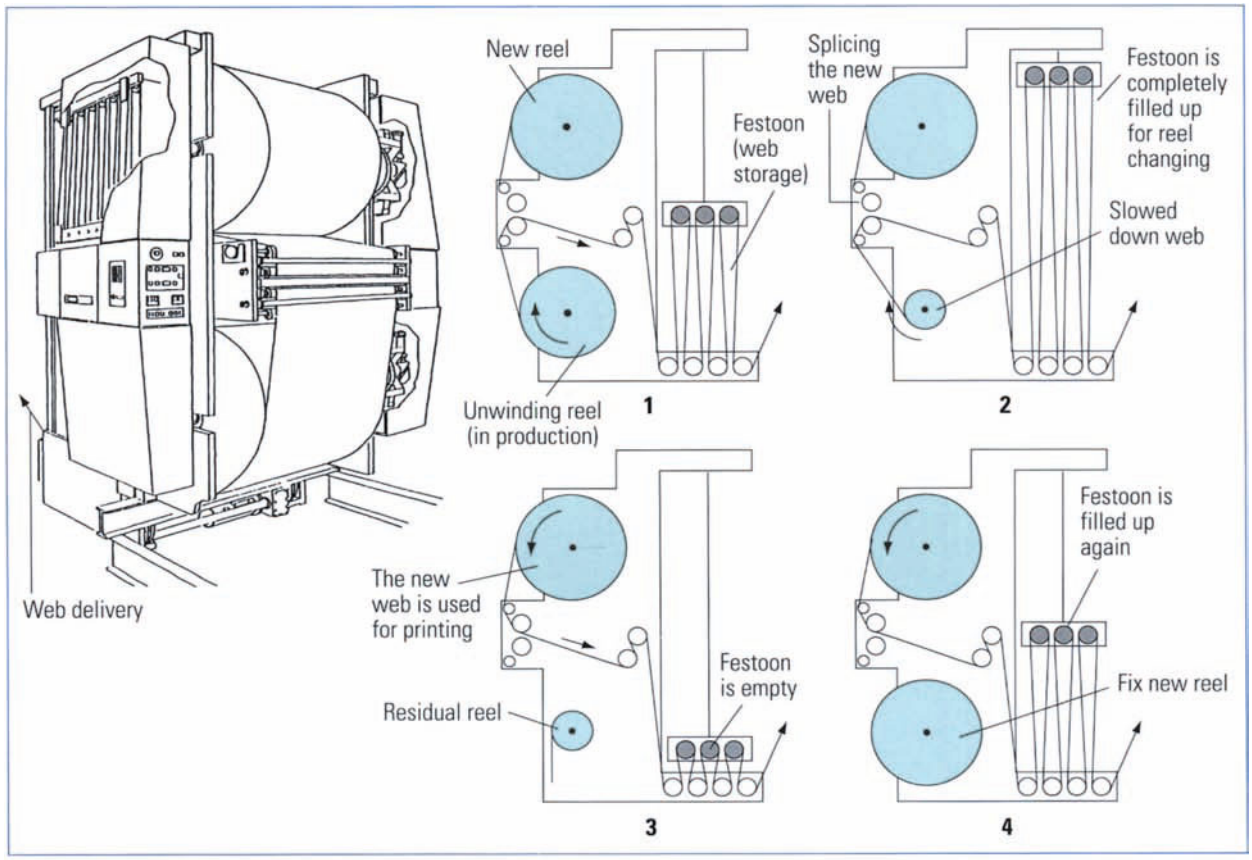


Fig. 2.1-81 Zero-speed web splicer (Buttler)

Pre-Tensioning Unit (Infeed Unit)

Generally, the adjustment of web tension, which serves above all to provide even unwinding of the paper reel, is carried out in the reel stand. Today it is also usual to place a pre-tensioning unit (infeed unit) in front of the first printing unit to serve as further web tension control. The pre-tensioning unit for web offset presses is an independent unit standing in line with the processing units (see also fig. 2.1-98). The pre-tensioning unit used with newspaper web presses is either housed in the substructure of the printing units or attached to the reel stand. The pre-tensioning unit is essentially composed of a draw roller with either nip pulleys or a pressing roller (three-roll units that only operate with looping effect have also been constructed), together with a downstream measuring roller for determining the tensile force of the web.

In the past, a mechanical variator was controlled at the draw roller in accordance with the measuring signal, and was later replaced by a direct-current servomotor positioned at an HD drive (HD = Harmonic Drive). The HD drive is a compact gear with a very high step-down ratio and has the capability of overlaying another movement coming from the servo motor. Today, this is only carried out by motor-controlling means for frequency-controlled alternating-current direct drive (shaftless), and so it becomes a very compact control unit.

In web offset, a web cleaner is frequently operated either by rotating brushes and vacuum suction removal, or by electrostatic forces and idle brushes, or else by a dampened cleaning cloth. Very careful handling of the web surface is important to avoid creating any fresh dust produced by detached paper fibers. In papermaking, dust is already produced when paper webs rub against each other and when the tambour is cut up into the required reels at the paper manufacturer's.

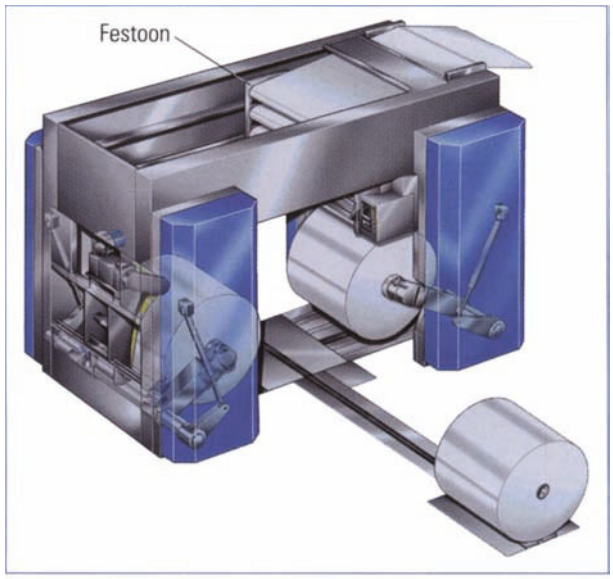


Fig. 2.1-82
Zero-speed web splicer in horizontal configuration (simplified reel change) with integrated festoon (SH 50-RO, Heidelberg)

Web-Threading Device

The paper-threading device for automated or semi-automated paper web-up is of great significance for newspaper web offset presses, as it is for heatset web offset presses. Here a distinction must be made between devices with endless or finite web transport systems on the one hand (and the necessary machine parts for this), and belts, chains, and flexible conveying elements on the other.

The simplest version is composed of continuous belts between the reel splicer and the folder running at the edge of the paper web, with loops into which the front end of the web can be inserted in such a way that the paper web can be directed through the press. The paper-threading infeed device is of an endless design (i.e., it always goes back to the starting point, and so it is always ready for operation). The device is driven by a servo-motor and disengaged on completion of the feeding process. The guiding belts on the left and right sides of the web can follow different paths, thereby providing two different lead versions.

As far as the further development of the paper-threading device is concerned (fig. 2.1-83), finite chain sections 2 to 3 m long are used, driven at the same distances by sprocket wheels with pneumatic motors. Switches are used to lead to different web paths. Through reverse motion they arrive back in their original position.

Printing Unit

The printing unit is just one component of the production chain of the whole production system. Details of the construction of the printing unit or the printing couple are given in section 2.1.3.3.

A *printing couple* is the single component used to print ink on one web or sheet side characterized by a plate cylinder and a blanket cylinder (couple) with associated dampening and inking units, whereas a *printing unit* in web offset printing is composed of several printing couples combined into one closed unit. The simplest version of a printing unit is the vertical *blanket-to-blanket* one which uses a horizontal web-lead to print one color on the front and reverse side of the web; this is standard in *web offset printing* (fig. 2.1-84). The printing section is composed of two printing couples arranged in tandem.

In *newspaper printing* units are arranged more often horizontally than in the vertical because multi-web production is most widely used and it is easier to gather the individual color-printed sections in a vertical line before the individual webs are merged horizontally (see also fig. 2.1-87).

Depending on the *installation arrangement* of the printing system, there are *one-level* and *multi-level presses* (see also fig. 2.1-190). The reel stands can be positioned in front of or below the printing units. A reel stand made to specification can also be placed behind (next to) the printing units, and the web is directed in the travel direction of the web to the printing units via a turner bar.

Several means are employed to bring the printing units above reel stand level. There is the concrete substructure – designed as a table with supports that rests on a concrete foundation. The concrete foundation is mostly of a box-type design and rests on adjustable spring assemblies. The foundation is accessible and provided with electronic position detectors serving as early warning devices (for stability, position, and vibration behavior). Leveling wedges with special vibration-absorbing lining are arranged between the printing units and the concrete substructure and serve as damper (absorber) sections acting against the transmission of machine vibrations.

The concrete substructure is of solid design. However, it is not very adaptable (i.e., system extensions or system modifications are very difficult to implement).



Fig. 2.1-83
Automated threading in a web offset press. (Photos 1-4 show how the web is fed into the printing unit.) (M-600/Autoweb Up, Heidelberg)

Due to this, steel substructures are mainly preferred to concrete substructures nowadays. Steel substructures are supplied in pieces that can be screwed down, taken apart again, modified or supplemented. The steel substructure for light machines can be made of two double T-beams lying on the reel stand frames carrying the printing units. Substructures made of cast iron are also in use.

Imprinters. They can be installed in web offset systems to serve as accessory printing units. A voluminous print run can thus be divided into individual print-run segments by imprinting various texts or additional information on the fly differing regionally in one color, for example, in different distributions.

Besides *offset imprinters*, there are also *flexo imprinters* used in newspaper printing that feature a simple inking unit structure. However, in general they require a dryer for the low-viscous ink (see also sec. 2.3.3.2). The changeover procedure in both cases, offset and flexo, is in principle the same. Flying plate change techniques – the interaction between the active printing unit and the uncoupled printing unit in preparation – are also used today for the "primary" print of newspapers and even for the relevant four-color set.

Dryers

In newspaper printing, the printing ink dries on the paper substrate by mere absorption or penetration into the paper fibre body ("*coldset*" method). In commercial printing, the printing ink on coated papers, that is, less absorbent papers, also needs to be dried by heat evaporating the solvent (*heatset* method). Long extended hot-air dryers are used (fig. 2.1-85) to blow hot air over both sides of the fresh print via nozzles. The upper and lower nozzle bars are staggered; the blast direction of the nozzles for the drying air is set in such a way that the nozzles also serve to carry the web, that is to say, supporting idler rollers are not required in the dryer (see also fig. 1.7-9).

Precautions have to be taken to make sure that the web does not remain in the dryer in the event of a web break; this would result in burning. To this end, a pair

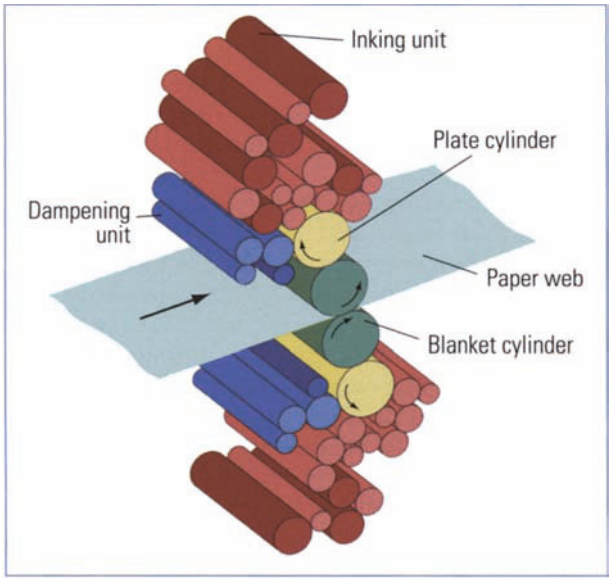


Fig. 2.1-84
Blanket-to-blanket printing unit of a web offset printing press (M600, Heidelberg)

of pinch rolls is mounted in front of the dryer at the web infeed to secure the web front end if there is a web break, while the web tail is transferred automatically out of the dryer by folder traction. In addition, flaps on both sides of the dryer open automatically to ensure a rapid temperature drop in the dryer area.

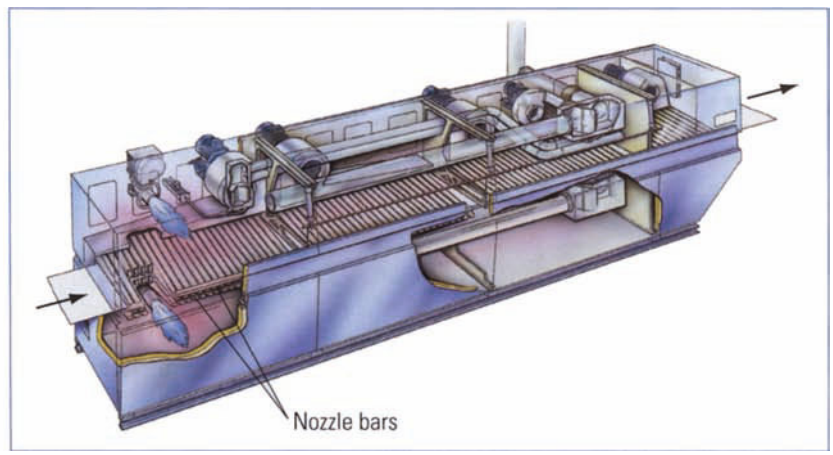
In the past years, much was done to optimize hot-air dryers, for instance, by way of nozzle geometry design and formation of optimum temperature profiles in the travel direction of the web. Combinations of hot-air dryers and infrared dryers are also in use. Infrared dryers are used in newspaper printing only to stimulate ink absorption, thereby facilitating printing with higher ink density, that is, with higher ink application. Nowadays UV radiation dryers are hardly ever used, due to their limited quality (there is no "ink melting effect" giving brilliance) and to the high printing ink costs they incur in web offset. For the same reason, electrobeam dryers or ink curing systems have not come to be generally accepted in practical operation, although they have good drying properties.

Hot-air dryers producing hot air by gas burners are equipped with catalytic afterburners to keep waste air clean. For heat recovery, these afterburners are switched in a circuit with the dryer. As far as highly productive web offset systems are concerned, heat recovery demands more attention today than it used to, and appropriate investment is required.

Chill Roll Assembly/Stand

Both the hot-air drying method and the infrared drying method require a cooling process, as the printing ink and the paper web heat up to approximately 130 °C, thereby affecting plasticity and tackiness of the printing ink. Cooling is carried out by a set of chill rolls mounted in the chill roll assembly (fig. 2.1-86), which is provided with air knives and an exhauster hood. The web winds round the chill rolls at the greatest possible angle of wrap to ensure effective cooling of the web by direct heat conduction. The air knife/blade "removes" drag air before the web makes contact with the following chill roll, and the air is then

Fig. 2.1-85
Hot-air dryer for web offset printing presses (Ecoweb Convertible, Heidelberg)



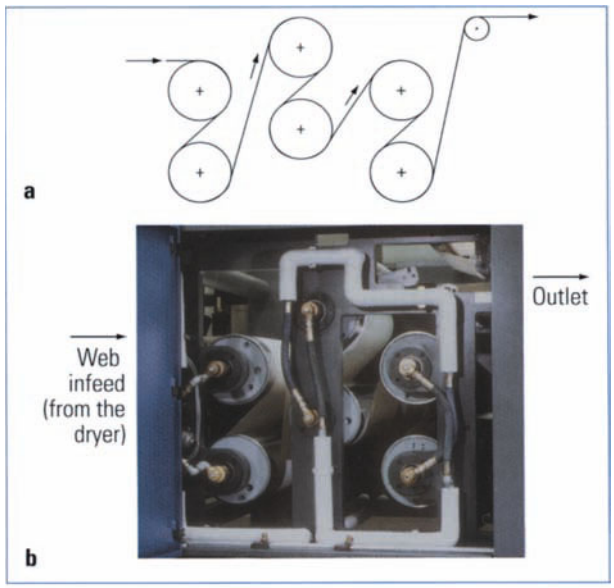


Fig. 2.1-86 Chill roll stand with six chill rolls.
a Chill roll configuration with web travel;
b Chill roll stand (Heidelberg)

sucked off above the exhauster hood. The temperature of the expiring web should equal room temperature.

Folder Superstructure

Due to their different functions, the folder superstructure and the folder will be dealt with separately. Cut-off, separated products are processed with the folder, whereas continuous web-shaped products are processed in the folder superstructure. The main functions of the folder superstructure include *longitudinal slitting* the web and *superimposing the ribbons* produced in this way into ribbon bundles *via turner bars* (fig. 2.1-87). In order to avoid web breaks, draw rollers are required, together with measuring and control devices to maintain precise web tension.

Commercial web offset presses are very often equipped with a *silicone application unit*, which is installed in front of longitudinal slitting devices and the turner bars to avoid ink set-off and possible smudging on the deviation elements (fig. 2.1-77). Silicone application units are either continuous-type H-type systems or jet units transferring water-soluble silicone onto the print carrier. *Remoistening* of the web is required if drying dehumidifies the print substrate so much that further processing might become difficult.

In-line finishing devices, such as plow blade folding systems, perforating, or glue application units, are often housed in the folder superstructure. Punching operations are generally carried out with separate racks.

The *former* (fig. 2.1-88) is the most important part of the folder superstructure, in both commercial and newspaper printing. The first *longitudinal fold* is executed by the former (as far as tabloid products are concerned, the former can just be seen as a turning device with the round former side-walls acting as turner bars, see section 2.1.3.4). In general, the former walls are cone-shaped, diminishing to the former nose and washed round by air escaping from small blast air nozzles to reduce friction. The roller top of former (RTF), a driven draw roller, is mounted at the infeed of the web or webs onto the former, where the superimposed ribbons are gathered into a ribbon bundle.

It must be ensured that each ribbon is governed by defined traction conditions. Therefore, two draw rollers, that is, RTFs, are arranged closely in tandem in order to seize the ribbon bundle. The ribbons are pressed on the draw roller by spring-loaded rubber-coated nip pulleys (similar to those in fig. 2.1-89 for the draw rollers). The former nose (fig. 2.1-88) is a crucial part of the former. The geometrical design of the former nose is calculated or optimized more through practical tests than in theory. The nose shape is responsible for both folding quality and folding productivity. The former nose is followed first by the infeed rollers, non-driven but provided with a cross-ribbing, then by the twin draw rollers (sandwich rollers) of the succeeding folder, which take over the product (fig. 2.1-89).

Folder

The folder (e.g., fig. 2.1-89), or "folder cylinder part", starts with the above-mentioned sandwich rollers, mostly in the form of multi-layer rollers (similar to fig. 7.2-24) with rubber and steel rings alternately fitted together in the axial direction through which the ribbon bundle travels. The draw rollers are provided with a separately adjustable motor drive.

The ribbon bundle is cross-cut with the serrated knife of the cutting cylinder. The cutting cylinder moves against a cutting bar on the tucker blade cylinder. Simultaneously, the front end of the ribbon bundle is held on the tucker blade cylinder by pins so that it follows the latter (fig. 2.1-89). As soon as the rear end is cut in the succeeding cycle, the ribbon bundle is turned into a sheet bundle which lies on the tucker

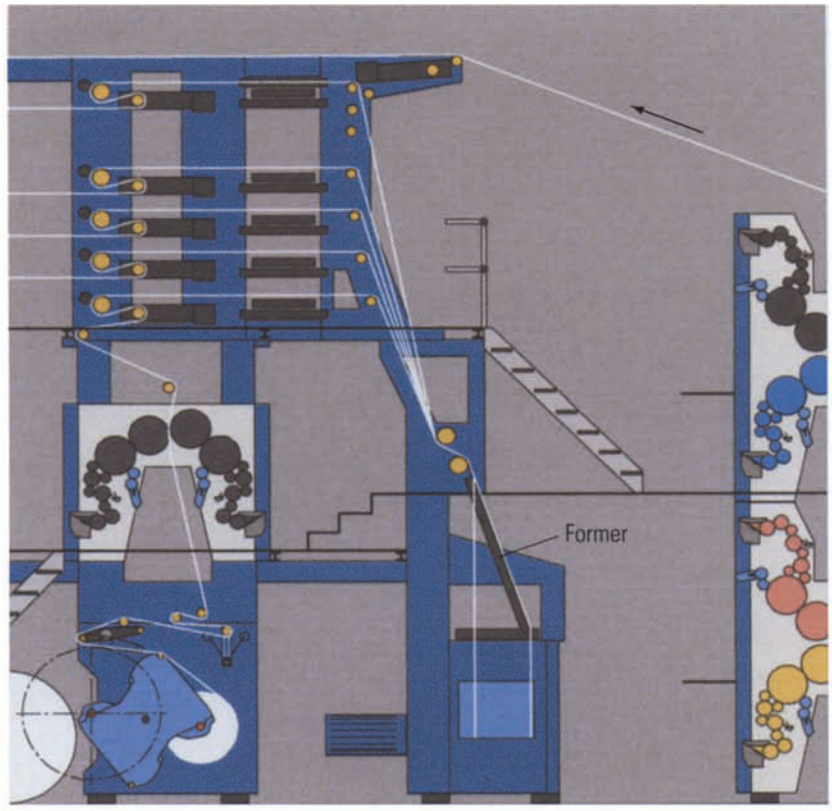


Fig. 2.1-87
Folder superstructure on a newspaper offset printing system for gathering several webs/ribbons before they are fed into the folder (KBA)

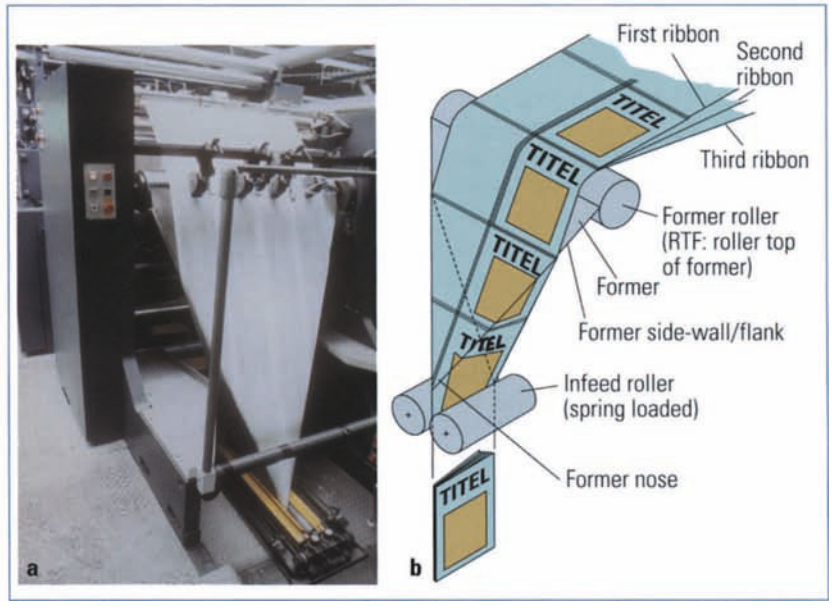


Fig. 2.1-88 Former.
a Former on a web offset press (M-600, Heidelberg);
b Former with 3 webs running in (IFRA)

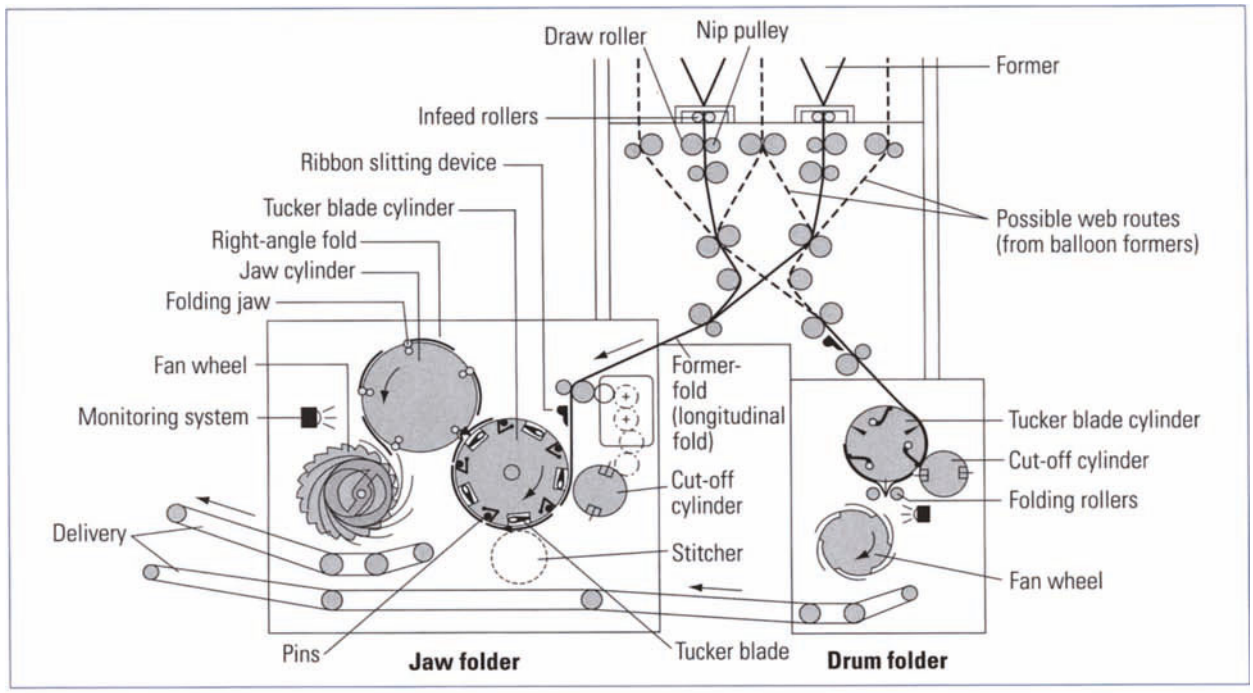


Fig. 2.1-89 Double folder (2:5:5 with 2:3), (MAN Roland)

blade cylinder. In the case of collect-run production, the tucker blade cylinder revolves twice, that is, two succeeding layers of sheet bundles are superposed before the fold is executed. Both layers are held by pins.

To execute the *right-angle/cross fold*, the cam-controlled tucker blade emerging from the tucker blade cylinder at the narrowest pass pushes the sheet bundle into the open folding jaw of the jaw cylinder. The folding jaw closes directly (spring-loaded), thereby folding the product and effecting further transportation. The folding jaw on the opposite side of the jaw cylinder opens, and sheet separators direct the product supported by the force of gravity into a fan wheel. The crooked shovels of the fan wheel reduce the traveling speed of the product and stagger the product in a shingle-like stream. Rotating stops and lateral adjustable discs ensure that the individual products are accurately aligned from a geometric point of view and that they leave the folder on a delivery belt as a relatively slowly moving shingle stream.

For special purposes, a third fold can be executed as a *quarter fold* (or second *longitudinal fold,* chopper/cross fold) before the product reaches the fan wheel (fig. 2.1-90). Different folder configurations are described in section 2.1.3.4.

Open Sheet Delivery/Sheeter

For commercial web offset presses and complicated folded products, it is useful to deliver unfolded sheets to an open sheet delivery (sheeter) rather than via a folder (fig. 2.1-91). The larger the sheet, the more difficult it is to deliver. Generally, production speed needs to be cut. As far as wider sheets are concerned, the trim itself is difficult when executed as a straight-cut. Trimming by a rotating knife against a stationary lower knife is only partly satisfactory; an upper and lower knife, both rotating, are preferable. Through advanced drive technology, the product is accelerated in the circumferential direction to produce the follow-on trim as a shear cut (figs. 7.2-9 and 7.2-10). It helps to put the sheets on the subsequent delivery in a shingled stream, in order to provide better grip and to gain more time for aligning. All other functions as regards stack lowering and pile change are similar to those of the sheet-fed printing presses.

Ink Supply

Nowadays web offset presses are supplied with ink via *returnable container systems* or stationary tanks (see sec. 8.11.3 and fig. 8.1-6). Returnable containers are steel

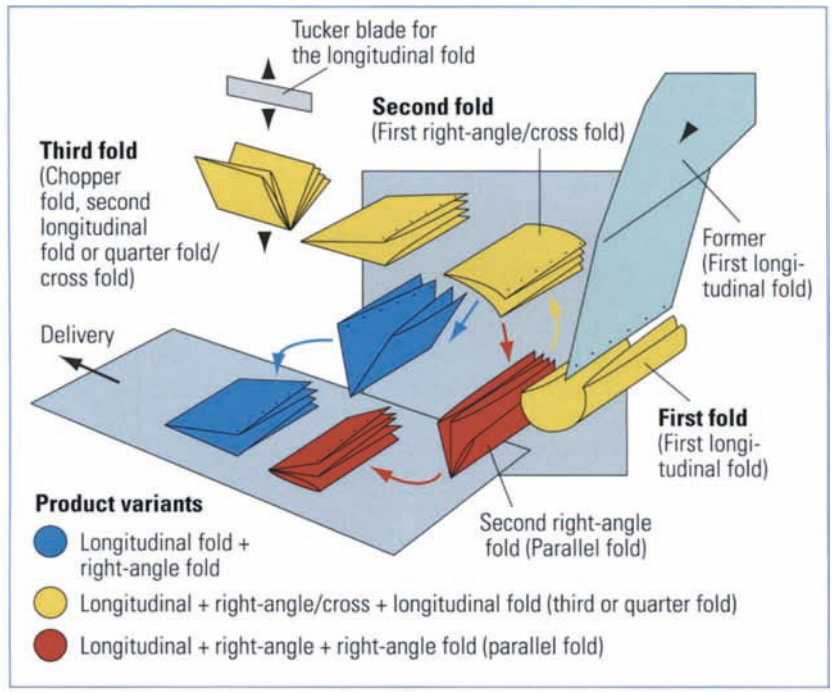


Fig. 2.1-90 Folding variants

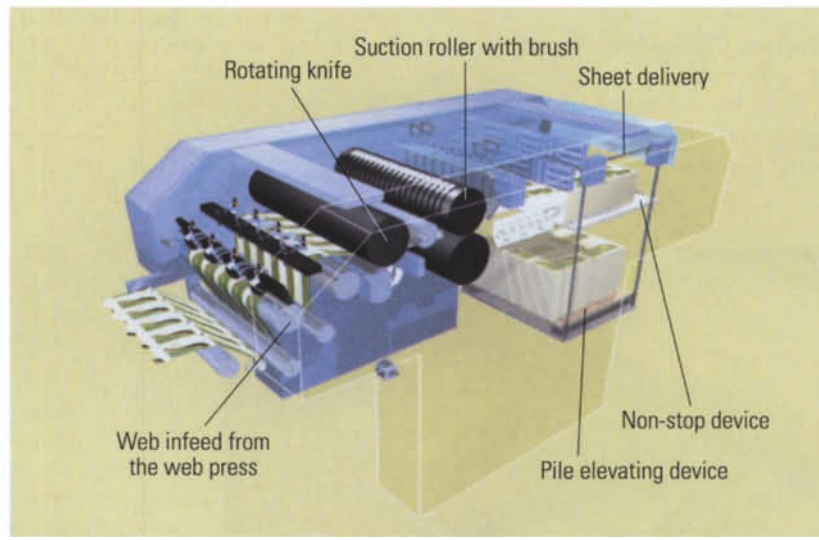


Fig. 2.1-91
Open sheet delivery (sheeter) for web offset printing (VITS)

containers tapering to the bottom with a capacity of approximately 700 kg of ink; they are mounted on pallets. These containers are emptied by electrically operated plunger pistons mounted on a second pallet above the steel container and sealed against the container wall by relatively soft rubber lips. The printing ink flows through the tapered part into a pipeline and then into the press. The stationary tanks are filled and emptied by regenerative pneumatic or electrical pumps.

For automated ink supply to the ink fountains of the individual inking units, it is vital that they are equipped with a *level control* in the form of a non-contact sensor

(fig. 2.1-165). Evenly metered ink in the ink fountain makes for reliable production and contributes to a constant ink feed into the inking unit.

It is useful to attach an *ink agitator* to the ink fountain for high-viscosity inks used in commercial printing, that is, a motor-driven cone-shaped stirrer (fig. 2.1-92), which rotates steadily and moves to and fro alongside the ink fountain via a toothed rack. In this way, constantly conditioned ink is supplied to the inking unit.

For *spot colors*, which are rarely used, it is often not worthwhile piping the presses, since only tiny quantities are used and cleaning becomes necessary when changing the ink. Therefore, small, wheeled containers equipped with manual plunger pistons are rolled to the ink fountains and from here the ink is filled into the ink fountains. To avoid storing many spot color inks, special ink mixing systems have recently been developed. These systems can automatically mix the desired spot color, in accordance with the HKS or the Pantone matching system from twelve basic colors. The four process colors are not sufficient to achieve the brilliance of certain spot colors, since they do not contain the special pigments required for this.

Dampening Solution Supply

The dampening solution used in offset printing is 95%–98% water. Untreated water available from the city water network generally contains too many mineral salts, that is, it is too hard, and needs to be softened before use. Softening is carried out mainly with systems operating by reverse osmosis. The process water produced needs a hardness of approximately 8°dH (degree German hardness, see definition in 2.1.1.2/Dampening Solution) for an optimum printing result to be achieved.

To turn the process water into a usable dampening solution for offset printing, a dampening solution additive needs to be added – preferably isopropyl alcohol, as it is offered on the market in many variations and can in general be matched to printing inks. In newspaper printing, special alcohol-free dampening solution additives are used. In addition, the pH value should be set and kept constant (approximately pH = 5), and steady cooling of the dampening solution at around 10 °C should be carried out.

Dampening solution for printing is supplied by dampening solution storage tanks and dampening solution circulating containers located at the press. Cooling the dampening solution, measuring and adapting the pH value, as well as adding the metered dampening solution additive – all these processes take place in the press-specific circulating containers, which, in most cases, comprise the dampening systems of several printing units. The cycle between the circulating container and the dampening systems in the press is provided by a pump fitted with valves located in the dampening water fountain which is itself controlled by automatic level indicators or by direct-connected nozzles for jet-spray dampening units. Today, this whole process is fully automated with appropriate measuring and controlling systems supplied by independent subcontractors.

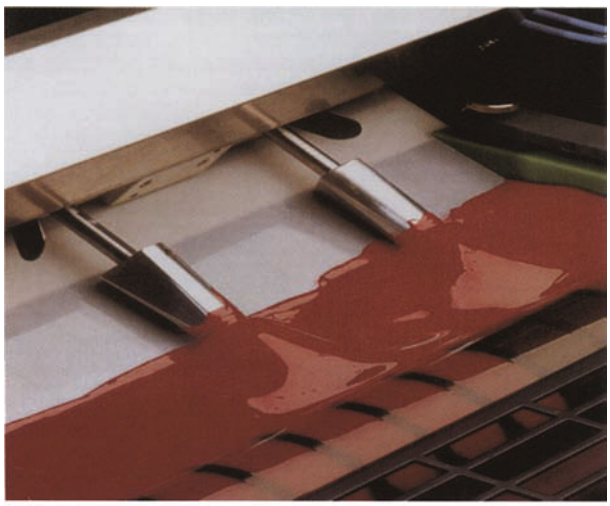


Fig. 2.1-92 Ink fountain with ink agitator (ESS)

Control Console

Originally, the control functions of a web offset press only consisted of press drive commands that could be accommodated in a small switch panel at the folder. With increasing motorization/automation of most setting functions of the production plant, such as the side lay and circumferential register and the ink control, it became necessary to unite them in one central control console together with the accompanying operator control elements and displays (fig. 2.1-93). It was also useful to place the sample for inspection on a panel area so that the remote-controlled ink zones in the inking units could be allocated more quickly during ink feed adjustment. A web-offset press is usually equipped with one separate control console for the upper (front) side and one for the lower (reverse) side of the web. This resulted in very long control consoles equipped with operator controls and displays.



Fig. 2.1-93
Remote control station for web offset press with separate operation consoles for upper and lower side of the web (Heidelberg)



Fig. 2.1-94
Control console with monitor (touch screen), ink zone and color register control functions (Ewert Ahrensburg Electronic)

The transition to programmable control systems in the mid 1970s, as well as the trend towards relocating control units from the switch cabinets into the press, made it possible to centralize the control console functions. Visual display units with synoptic graphic displays were introduced to reduce the number of individual display elements, and a large number of switches and push buttons were replaced by "soft keys" or touch areas on the screens (fig. 2.1-94).

In addition, the ergonomic design of the monitor control consoles was optimized; for example motor-driven console tops could be raised or lowered, thus allowing the operator to work either standing up or sitting down. The only hardware switches left on the control console are the main drive commands of the press and the keyboard for controlling the different ink zones. The former is there as a result of the requirements of the factory inspectors or the employer insurance liability organizations (see sections 13.2.2 and 14.6), while the latter provides for a better geometric allocation of zones to the sample sheet lying on the console.

Occasionally, separate control consoles are used for press operation and ink setting. Ink setting control consoles are equipped with standardized lights (D65 or D50) so that visual inspection of the color tone in the print compared to the "ok- sheet" by the operator is not interfered with by the interior lighting (fig.2.1-93).

Measuring instruments (see sec. 2.1.4) are used for quantitative evaluation of the color quality. This is usually carried out with hand-held densitometers. The best measuring standard, however, is achieved with colorimetric scanning using a spectrophotometer. Automation variants range from off-line measuring systems where the sample sheet is evaluated outside the press to in-line measuring systems integrated in the press. Camera systems can record an image section in real-time for visual inspection. Very often, in-line color register measuring and control systems are used.

At the push of a button, the *sample sheets* are automatically ejected from the sheet stream in the delivery.

Noise-Protection Encapsulation

Constant efforts are being made to reduce noise emission of presses by primary measures (structural measures); they are often equipped with noise-protection encapsulations as secondary measures (fig. 2.1-95). Figure 2.1-96 shows how accessibility to the press is ensured. With large installations it is preferable to encase the control station in noise-protection walls, rather than encapsulate the entire printing system optimally (fig. 2.1-97).

Noise-protection encapsulation of web offset presses is generally achieved by covering the whole press with a housing (fig. 2.1-95) made of special multi-layer noise-absorbing walls with windows and doors. Figure 2.1-97 shows a noise protection cabin accommodating the control consoles for a newspaper rotary press.

Depending on the legislation applicable, a maximum noise level of 80–85 dB (A) is permitted at a workplace (see sec. 13.2.1). Current noise-protection encapsulations conform to these requirements. As not all press control functions can be managed by remote control, operators sometimes have to work directly at the press and thus may be exposed to higher noise levels. Should this be the case, the operator must wear earmuffs. To separate several press sections for acoustic reasons, partitions or movable noise-protection aprons hanging from above can be used.



Fig. 2.1-96
Access to the printing units on a web offset press with noise-protection encapsulation (Heidelberg)

2.1.3.2 Web Travel (Infeed and Further Processing)

Since a web offset press features numerous components, links are required to ensure reliable web travel

Fig. 2.1-95
Noise-protection encapsulation (cabin) of a web offset printing system (Heidelberg)



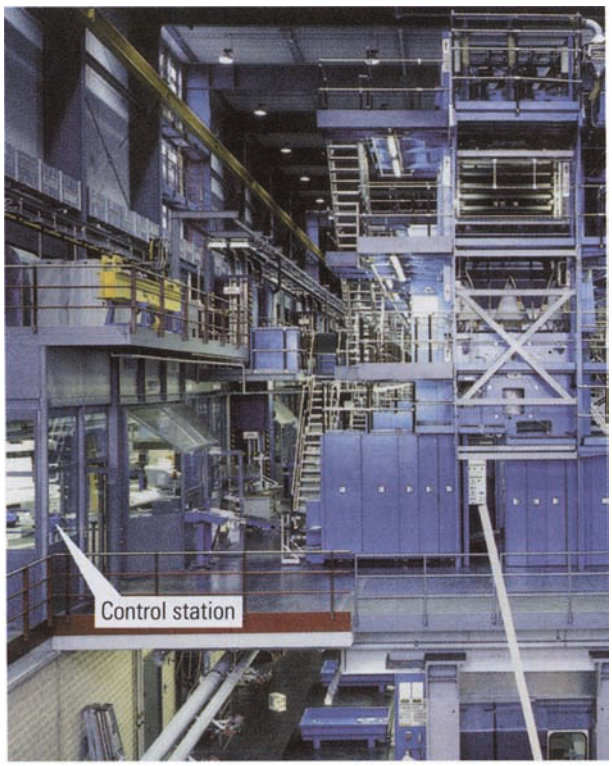


Fig. 2.1-97
Control station in noise-protection cabin on a newspaper printing press (KBA)

and an efficient interaction of the individual processing stations. As already mentioned in section 1.6.2, web offset presses and sheet-fed printing presses differ mainly in those press components effecting the transport of the substrate and less in the structure of the printing unit and inking unit.

Web Tension Control

In contrast to sheet-fed offset printing, the paper web must be kept at a certain tension to retain a certain dimensional stability in web offset (register accuracy). Optimal tension depends on two factors: dimensional stability and risk of tearing. Control of the web tension is imperative, as on the one hand the elasticity of the paper web can change from reel to reel and, on the other, interference factors such as loss by friction affect the paper web tension.

The simplest way of achieving a certain web tension is to use an intermediate weighted pendulum or dancer roller. The dancer roller serves both as a sensor element and at the same time the active element (actuator) of the control circuit, where the motion represents the measured quantity value and the compensated web load the manipulated variable (see also fig. 2.1-80b). So that the neutral point can be retrieved, the controlling elements are provided with a PIV gear, which can change the transmission ratio.

Since these mechanical controls are encumbered by the inertia of mass, they are no longer sufficient for today's high-speed web offset printing presses and have been superceded by electronic control systems. Here, a measuring roller, that is, a web guide roller, running on electronic load cells, is the receiving element; an electronic controller optimally converts the measuring signal into an actuating signal. The control of web tension by means of the draw roller drive took place in several stages. Nowadays frequency-controlled alternating current servo-motors providing fast data communication via optical fibers are used.

High-transmission HD gears (harmonic drive) and PIV gears, which are also adjustable during press run, represent essential innovation steps in web tension control systems. The fact that this development process has only taken ten to fifteen years bears witness to the significance and rationalizing effect (for mechanical engineering) of electrical engineering and electronics in conjunction with mechanics (mechatronics). This, however, meant that the simplicity of function elements was lost, which in turn meant that special skills were required of servicing and operating staff.

The key position for web travel, where the web tension is applied by a controlled draw roller as described above, is in front of the first printing unit, that is, after the reel stand. This point is referred to historically as the infeed unit (fig. 2.1-98). Nowadays, such controlled draw rollers are also installed after the printing units. The draw rollers act as clamping points, that is, they make use of spring-loaded rollers between which the paper web is guided. Since the paper web is flexible and the pulling forces are generated by the frictional forces, this process is an interaction of stationary motion and slipping, which takes place between the draw roller surface and the paper web.

Web Edge Control

Various factors can cause the paper web to change its lateral position when leaving the reel stand. The whole paper roll can be moved up by the lateral adjustment of the reel stand shaft; however, this adjustment is too sluggish for dynamic control. Therefore, after leaving the reel

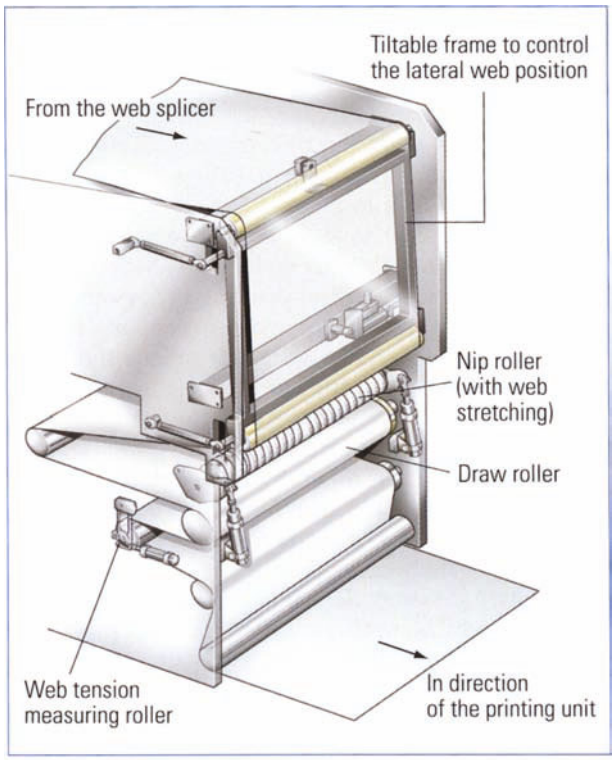


Fig. 2.1-98 Infeed unit (Heidelberg)

stand, the paper web is directed over a tiltable frame of parallel rollers located in the infeed unit (fig. 2.1-98), which provides for the lateral adjustment of the web during travel. The motorized positioning movement is effected by a controller that is linked to a web edge sensor. A wide range of different physical working principles can be applied for designing these sensors, extending from simple light barriers, pneumatic, ultrasonic and infrared sensors, through to cameras with CCD arrays. A distinction must also be made between control using two sensors to control the middle position of the web or to check to right edge of the web with the right-hand sensor and conversely the left edge with the left-hand sensor.

Register Control

Differentiation has to be made between the *circumferential* and *lateral register* in multicolor printing, the straight printing/perfecting register when printing on both sides, and the cut-to-print register in the folder. In addition, there is *diagonal register* or "cocking," which serves to correct an image copied obliquely by cylinder tilting (or plate shifting) and to compensate the "*fan-out*" *effect* of the web (enlargement of the web width) caused by the dampening during the printing process. With gravure presses, *print-to-print/color register control systems*, which are installed in-line and that adjust the register position during production automatically, are part of the standard equipment; however, they are now also used in web offset presses and newspaper web offset presses. Register control systems use optical sensors to detect register deviations on register marks printed on the web and initiate impression cylinder or web travel adjustments by means of servo-motors.

Register control is based on the following, proven principle: register marks are printed by each printing unit on the blank margin or on non-image areas on the prints. The deviation from the target position is measured by opto-electronic sensors and a correction impulse is calculated by the controller for the particular register servo-motor. Appropriate sensor or measuring systems can read very tiny register marks. Due to their size – sometimes only a fraction of a square millimeter – these register marks are hardly recognizable on the printed image, that is, they do not disturb the image and are easy to arrange. Newspaper printing presses using shaftless drive designs create optimal ways of register adjustment by means of electronic direct drives.

The latest development is aimed at recording print-to-print/color register together with other parameters in the print, such as image inspection and color measurement with special measuring devices, video cameras, and magnifying optics, which display the data on the screen for evaluation by the operator or make automatic adjustments.

Cut-to-print register control is necessary when running up the press, especially when using drum folders, in order to avoid a shifting of the fold in relation to the print. However, the shaftless drive has improved this situation to the extent that cut-to-print register adjustment can be occasionally left out.

"Fan-out" Control

Control and adjustment of the lateral register is particularly difficult in *newspaper printing*, for instance, two times four individual printing plates are mounted on one plate cylinder across the printing direction and each plate has already been produced with a lateral register error (see fig. 8.1-4). With the normal lateral register adjusting mechanism it is only possible to move the whole plate cylinder, and so only one of the eight plates would be properly adjusted. The "fan-out" effect causes anoth-

er problem, which could only be compensated for by the printing plates if they could be stretched laterally.

To compensate for the "fan-out" effect, the individual printing plates are arranged on the plate cylinder slightly off-center, that is, slightly less than the web is stretched by the fan-out effect. The fine adjustment is ensured by means of so-called buzzle wheels (fig. 2.1-99), which only allow the web width to be reduced. An optimal lateral register is thus achieved.

The "buzzle wheels" (fig. 2.1-99) in their simplest form are arranged on both sides of the web and are pressed into the paper web, thereby causing a waved deformation of the web. In more recent variants the buzzle wheels are driven at a lower speed, so that harmful effects reducing the product quality (e.g., ink set-off) and smearing are eliminated.

Slitters

With double-width newspaper web offset presses, the web must be cut into two halves in front of the former or formers to create a common newspaper product. For *tabloid products* printed on web offset presses, the web has to be cut to the former center (see fig. 2.1-113). In other words, the complete web is divided into a number of individual ribbons. However, any intervention on the web disturbs the web travel, as does slitting.

Slitting also involves the risk that the slitter might notch weak points into the paper, thus causing the web or the individual ribbons to tear. As is the case in metallurgy, a peak stress is exerted on the notches, which will cause the paper to tear even with the tiniest oblique line. Therefore, the web tension in the slitting knife area is sometimes reduced by installing controlled draw rollers that are set to low tension values in front of and after the slitters.

As far as slitter technology is concerned, there is a distinction to be made between shear cut-knives and blunt-cut knives (see fig. 7.2-9). To produce a shear cut, an upper and a lower knife operate like a pair of scissors, whereas the blunt cut is produced by a blunt knife pressing on a hardened smooth roller while the paper is running through between them. To produce a smoother cut with less serration, investigations are in progress to slit the web with high-pressure water jet or laser beam techniques. These methods are not yet in use.

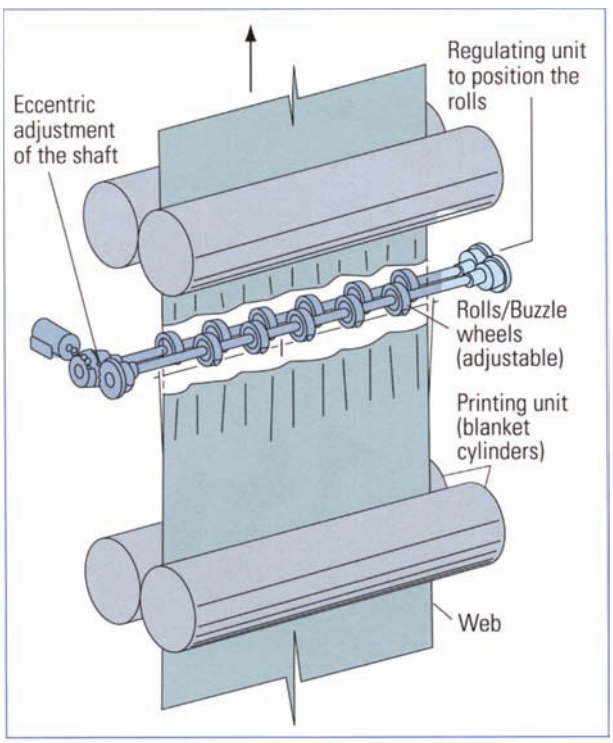


Fig. 2.1-99
"Buzzle wheels" for lateral "web buckling" to compensate for the "fan-out" effect (TKS)

Turner Bar

Another element that might influence the web tension and the position of the web is the turner bar (fig. 2.1-100). Turner bars are used to route one slit half of the web (a ribbon) from one side to the other, or to turn a ribbon to achieve a varying page arrangement within the product (fig. 2.1-116a). To compensate for the loss of tension, controlled draw rollers are incorporated into in the turner bar assemblies.

Blast air is circulated around the turner bars so that there is no friction and the ink does not offset on the turner bars and thus smudge the printed image. For the same reason, turner bars are chromium-plated. To circulate the blast air around the turner bars, the air is routed inside the hollow turner bar and then penetrates to the turner bar surface through very fine nozzles, that is, around those places where the paper wraps around the turner bar (fig. 2.1-100, see also fig. 2.2-20).

It has proved very useful to employ cantilever turner bars for fast paper infeed; this is on account of the greater accessibility.

Former

The effect of a former (fig. 2.1-88) is the same as using two turner bars arranged at an angle to each other, so



Fig. 2.1-100
Turner bars for turning the web, changing web travel direction and position (Heidelberg)

that they taper towards the tip. In addition, this triangle is aligned at an angle to the web so as to gather the web halves running over the triangle sides at the tip, thereby producing a ribbon bundle that is folded lengthways. To reduce friction and ink set-off, the former flanks are cushioned by blast air. This is done by admitting blast air to the slim and hollow cylinder cores, and it penetrates onto the surface through very fine nozzles.

The former flanks are chromium-plated, as is the former plate enclosed by the former flanks, which is of minor importance for web guiding. The plate only serves to ease manual paper threading.

Another controlled draw roller is installed in front of the former, which has the additional task of merging the individual ribbons (see fig. 2.1-88); this is why this roller is also referred to as the roller top of former (RTF). Different wrap angles at the RTF can result in heavy deviations of tension, an so present RTF configurations are mostly arranged in tandem, that is, behind one another, so that the bottom ribbon of the first roller will be the top ribbon of the second roller and so on. The former nose is flanked by two relatively thin, non-driven rollers, which support the gathering of the two ribbon halves.

The Web Traction between Former and Folder

Two variable-speed draw rollers (figs. 2.1-101, 2.1-89) are arranged directly underneath the non-driven former outlet rollers. Earlier draw roller configurations consisted of just one roller and spring-loaded soft nip rollers resting on top. Today, real draw roller couples are employed, that is, there are roller bodies on either side, equipped with alternately meshing steel and rubber rings. These are also called "sandwich rollers" (see fig. 7.2-24). To stop the web from slipping on account of the high traction required by the ribbon bundle, two pairs are arranged at a time, one below the other.

The moment the ribbon bundle is cross-cut, the tucker blade cylinder of the folder (see fig. 2.1-89) needs to exert tensile strain on the ribbon bundle, which

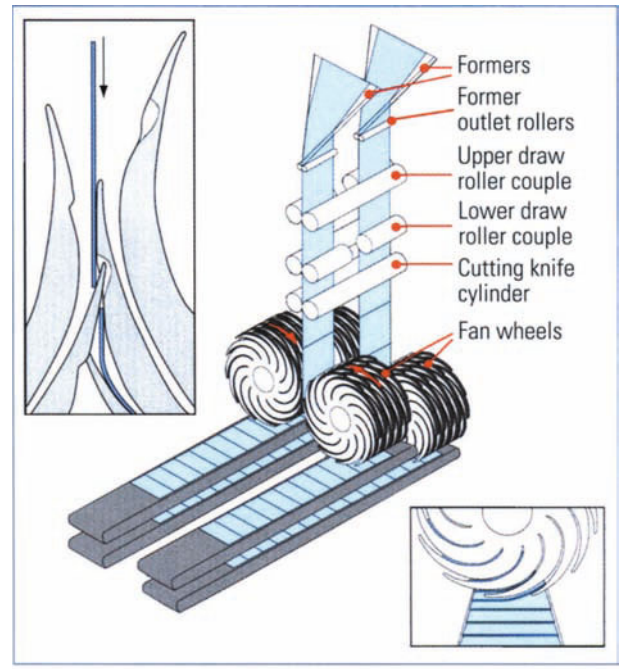


Fig. 2.1-101 Fan wheels dividing the product stream (Heidelberg)

means that the tucker blade cylinder is equipped with pull rings that are adjustable in their radial height in accordance with the pagination to be processed. The simplest configuration can only be adjusted at press standstill by lifting or lowering the pull rings via thread screws. With high-performance folders, the pull rings can usually be adjusted during press run. This requires complex planetary adjusting mechanisms on the cylinder shaft. The basic functions of the folder have already been described in section 2.1.3.1, which also contains brief explanations on the cutting units, the pins and the gripper transport (fig. 2.1-89). The following paragraphs contain additional information of significance for the web or product transport.

Cutting Unit

In newspaper and magazine printing, the ribbon bundle is usually cross-cut with a finely serrated knife working against a hard rubber strip. We are used to this serrated cut on newspapers, but on magazines and other commercial printed products it is trimmed off (three-sided trimming) in a subsequent finishing process.

Even with commercial web offset presses, shear-cut knives for the straight cut are rarely used nowadays, as the setting procedure is very complicated and they need to be constantly readjusted.

Transportation with Pins or Grippers

Pins/needles are screwed onto the tucker blade cylinder and/or the collector cylinder (fig. 2.1-89) where the front edge of the section is located. The pins are barbed and are arranged in the form of a Christmas tree. The product or section of a product is pressed onto the needles so that the product is held on the cylinder surface. Naturally, this leaves needle punctures on the bottom margin of the product. These are tolerated in newspapers; in magazines and commercial print work they are cut off in a finishing process by trimming. For the transfer of the section to the jaw folder, the pins are retracted under cam control, thereby releasing the section from the tucker blade and collector cylinder.

The folder for gripper transfer requires a totally different design, comparable to the design of variable format folders on gravure printing presses. Unlike pin transfer, gripper transfer of the folded product/section requires a gap between the individual sections, so that the gripper can move down on to the section. This means that the cross-cut of the ribbon bundles cannot be performed between the cutting knife cylinder and the tucker blade cylinder, but that the cutting knife couple must be located above this area.

Fan Delivery

The fan wheel (see fig. 2.1-89) forms the shingle stream for the delivery and slows down the copies gently. This results in a wedge-shaped cross section of the fan wheel segments in the curved blades. For the finishing processes, products must have some degree of positional accuracy, and so the fan wheel needs to be equipped with adjustable discs serving as side limits and movable stops, which are attached to the fan wheel. Another option is to have the product collected by revolving grippers for a short period. Figure 2.1-101 shows a special fan wheel configuration for distributing the product stream to two adjacent delivery systems.

2.1.3.3 Printing Unit

The term "printing unit" in this section encompasses the entire printing system with all associated functions – not only the part where the actual print is produced, that is, the transfer of ink onto the substrate. The printing system – especially in newspaper printing – consists of several individual subassemblies described in the following.

Impression Cylinder (Satellite Printing)

The satellite printing principle (fig. 2.1-102) has a common impression cylinder (also referred to as CIC) around which the printing units are arranged in a satellite configuration. One might describe the CIC as the "sun" of the satellite system. It is composed of a thick-walled steel cylinder with a hard chromium-plated surface that prevents the ink from offsetting. Its surface is very smooth and has no recesses, since it only serves to produce the counter pressure. The impression cylinder generally has double-row roller bearings to provide an easy-running and stable base and is driven by a helical toothed wheel. It has the simplest structural design in the entire printing unit. The printing unit shown in figure 2.1-102 – a "combination satellite" – allows for printing of either four colors on one web side (satellite printing) or two colors on either side of the web respectively (blanket-to-blanket printing).

Blanket Cylinder (Blanket-to-Blanket Printing)

Figure 2.1-103 shows the double printing unit of a web offset press. The upper and lower web sides are printed simultaneously, that is, "blanket-to-blanket" printing. The blanket cylinder transfers the image from the plate cylinder onto the substrate, thereby ensuring a

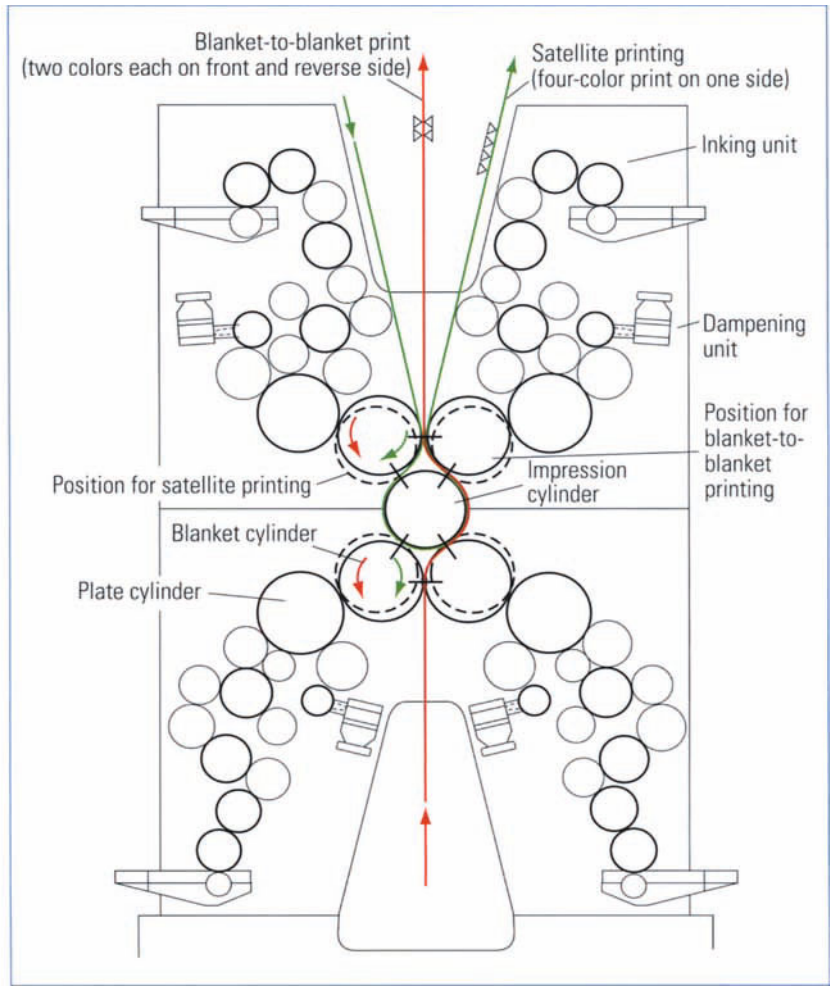


Fig. 2.1-102
Combi-satellite configuration for newspaper printing (MAN Roland)

high-quality print on account of its elastic (soft) surface.

The cylinder usually has a thick nickel layer to prevent corrosion. The blanket is mounted on the cylinder and fixed into the cylinder gap with clamping bars. To attain the correct cylinder height, the blanket is packed with an underlay sheet. The bearer height serves as a reference line for height adjustment (the plate cylinder is also equipped with bearer rings). There are also presses without bearer rings; they are fitted with gauge rings on the blanket cylinder instead of bearer rings and where the gauge ring does not make contact with the opposite cylinder.

With blanket-to-blanket printing presses, the blanket cylinder – as the ultimate link in the inking unit chain – is driven by the longitudinal shaft or has its own direct drive. For impression throw-on/off operation, the blanket cylinder runs on eccentric bearing-housings or on levers and is moved pneumatically or hydraulically. To provide for this mobility, the drive needs to be adapted. When shaftless drives are used, mobility is provided by toothed belts or hollow shaft motors located on the cylinder shaft. In the case of conventional shaft drives, the helical toothed wheels must always be engaged during throw-on/off operations.

With special configurations on high-speed web offset presses, gapless blanket sleeves (fig. 2.1-104) are employed instead of conventional blankets. Thanks to this technology, there has been both a considerable reduction in gap-induced vibrations and a high quality of

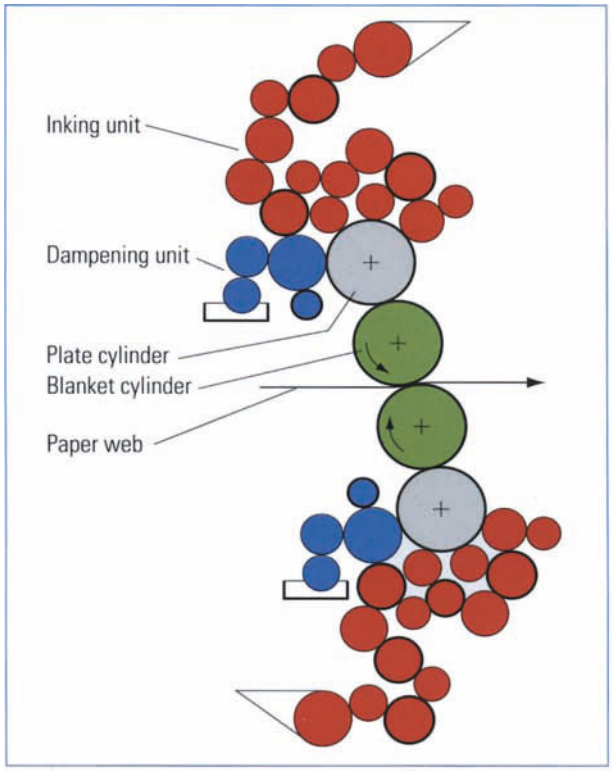


Fig. 2.1-103
Blanket-to-blanket printing unit of a web offset press (M-600, Heidelberg)



Fig. 2.1-104 Blanket cylinder sleeve (M-3000, Heidelberg)

print even at web speeds of up to 15 m/s (3000 fpm, which corresponds to 100 000 cylinder revolutions/h).

Plate Cylinder

The plate cylinder carries the printing plate, which is also clamped inside a cylinder gap. The clamping mechanisms consist mainly of hook-like clamping flaps into which beveled edges of the printing plate are hooked. There are also simpler designs consisting of a thin beveled slit into which the plates are inserted and held in place by their own residual stress. The clamping mechanisms are mainly opened and closed by rocking levers that can be operated with a screwdriver-like tool located inside the clamping flap. The flap is spring-loaded to enable automatic retensioning. Figure 2.1-105 shows an example of the plate clamping mechanism on a commercial web offset press.

So that the printing plates can be mounted in accurate register, the clamping bars are provided with register pins that engage into the grooves on the printing plates. In newspaper printing, the single printing plates on one cylinder can be laterally adjusted to compensate for the fan-out effect caused by moisture on the paper.

Like blanket cylinders, plate cylinders have a thick nickel coating even though they are less exposed to corrosion on account of frequent plate change. The clamping flaps and the clamping mechanisms are usually made of stainless steel.

Circumferential and lateral register adjustments are integral components of the bearing and drive mechanism for the plate cylinder. The simplest method of carrying out a register adjustment would be to move the cylinder in the lateral direction and at the same time shift the helical gears against each other, thus causing the cylinder to turn in circumferential direction in accordance with the helix angle. However, in order to avoid the coupling of the circumferential and lateral register, adjusting mechanisms need to be kept apart. This is achieved through somewhat complex mechanisms.

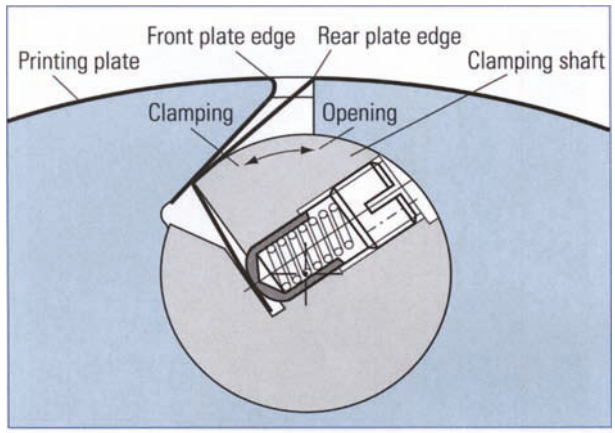


Fig. 2.1-105 Plate clamping mechanism (M-600, Heidelberg)

Inking Unit

Basically, the main differences between the designs of inking units for web offset and sheet-fed offset presses result from speed requirements and the paper qualities being processed. Substrates in sheet-fed offset presses run at a speed of up to 5 m/s while the web in web presses can travel at a speed of up to about 15 m/s. Generally, higher-quality paper is used for sheet-fed offset presses in order to ensure high-quality printing.

Inking units in web offset presses, and in newspaper presses in particular, differ from inking units in sheet-fed offset presses in their continuous ink supply, that is, the inking units have no cycled vibrator rollers. Instead, "continuous-feed inking systems" are used. The fast-running film roller is installed near the slow-running fountain roller. It takes the top ink film layer off the fountain roller. The relatively thicker ink film is produced by an ink fountain blade, which can be adjusted in zones (see sec. 2.1.1.3).

Another distinguishing feature is the way the ink fountain blades are arranged. There are designs where the fountain blades are either located at the top (overshot) or bottom (undershot). In addition, the inking units for web-offset presses and sheet-fed presses differ in the number of ink form rollers; that is in the storage volume of the inking unit. Whereas sheet-fed offset presses need four ink form rollers (in some cases even five) to achieve even plate inking, web offset presses usually do not need as many rollers to achieve even inking of the plate; this is due to the simple inking-unit dynamism resulting from the smaller gap. Three ink form rollers suffice for commercial web printing (fig. 2.1-103), and for newsprint even plate inking is achieved with just two form rollers. Occasionally, distributor (rider) rollers are placed on top of the ink form rollers to achieve an even and smooth ink application profile.

The roller train between ink fountain and the ink form rollers consists of driven and oscillating distributor rollers, which usually have a Rilsan (polyamide) coating and non-driven rubber rollers. In the last few years, many optimization calculations have been made for roller arrangement, varying diameters, and separate ink flows. The ink flow on the inking unit shown in figure 2.1-103 can be set (fig. 2.1-106), that is, the three ink form rollers transfer different portions of the ink onto the printing plate. At a 100-0-0 setting (fig. 2.1-106), the first ink form roller transfers all the ink onto the plate, while the other two rollers merely smooth and even out the ink layer. With an 80-10-10 setting, 80% of the whole ink is supplied by the first form roller, whereas only 10%

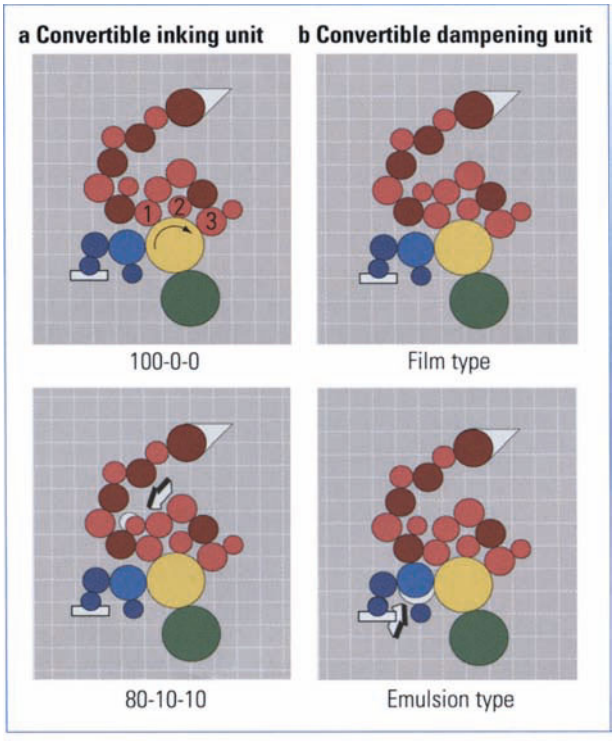


Fig. 2.1-106
Inking unit with changeable ink and dampening solution flow.
a Inking unit change-over;
b Dampening system change-over (M-600, Heidelberg)

is added by the second and also the third roller respectively. This is regarded as the basic setting.

Due to the high speed and roller set-up on web offset presses, the roller locks for the removable rubber rollers and the throw-on/off mechanisms for ink form rollers are designed differently to those for sheet-fed offset presses. Furthermore, the inking unit on web offset presses might need to be equipped with special devices and rail systems for changing rollers, on account of their great weight.

Dampening System

There is a large variety in dampening system designs, not to mention the fundamental categorization into contact and non-contact dampening systems, that is, the dampening solution is sprayed onto the plate surface or applied via the roller train. Spraying is the preferred method in newspaper printing today, as the dampening solution is not soiled by the transfer of dirt particles from the plate and the ink form roller into the dampening solution fountain. Higher quality requirements (more finely metered dampening solution) mean that contact continuous-feed inking systems are being used in commercial web offset printing.

The dampening solution distribution in non-contact dampening systems (figs. 2.1-107 and 2.1-108) is based on the following operating principles:

- brush-type dampening systems with water fountain roller (fig. 2.1-107a),
- brush-type dampening systems with immersing brush (fig. 2.1-107b),
- catapult dampening systems with rotor (fig. 2.1-108a),
- jet-spray dampening systems (fig. 2.1-108b), and
- turbo dampening systems (spiral roller, see fig. 2.1-15e).

Brush-type dampening systems with a water fountain roller collect the dampening solution film from the fountain roller revolving in a water bath and then catapult it onto the dampening form roller by holding back the bristles and releasing them suddenly (fig. 2.1-107a). With the second variant of brush-type dampening systems, the brush is immersed directly in the water, and it absorbs the water with its bristles; the water is then catapulted onto the dampening form roller by a flicker blade divided into zones (fig. 2.1-107b). Since there is no direct contact between dampening form rollers and brushes, dirt particles cannot get into the dampening solution fountain.

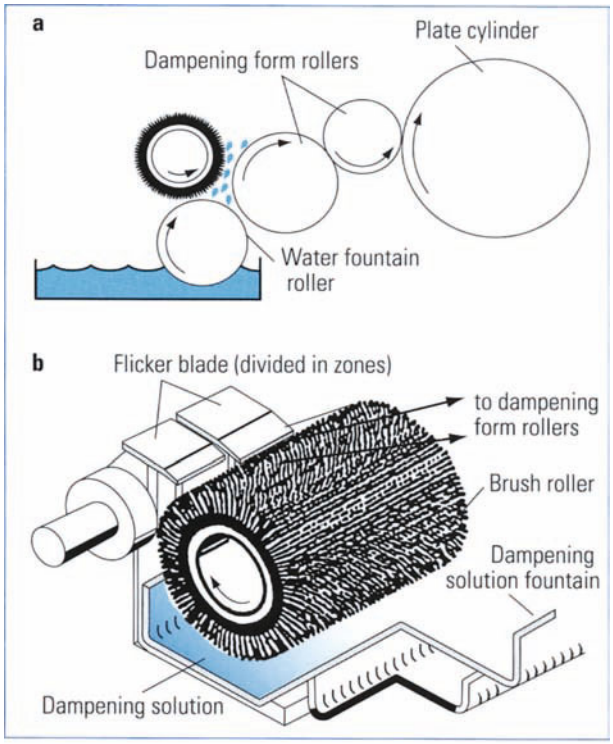


Fig. 2.1-107 Brush-type dampening system.
a Brush for catapulting the solution from the fountain roller onto the form roller;
b Brush for conveying and catapulting the solution via flicker blades (IFRA)

This catapulting process can be done in many different ways. In addition to brush-type dampening systems, dampening systems with catapult rotor disks, spiral rollers or fountain rollers with special surface structure/profile and jet-spray systems have been developed (figs. 2.1-108 and 2.1-15).

Jet-spray dampening systems are used very often, as they are easy to exchange. They consist of a pipe with jets. The spraying interval and duration is controlled by a solenoid valve. This requires the dampening solution to be pressurized in a suitable pump. The spray nozzles produce a wide jet cone and the nozzles are located at some distance from the dampening form rollers, so that the neighboring jet cones overlap only slightly. In this way, homogeneous application of dampening solution over the entire width is ensured. Figures 2.1-103 and 2.1-106 show examples of printing units equipped with a contact dampening unit. Figure 2.1-106 shows a convertible dampening unit where the

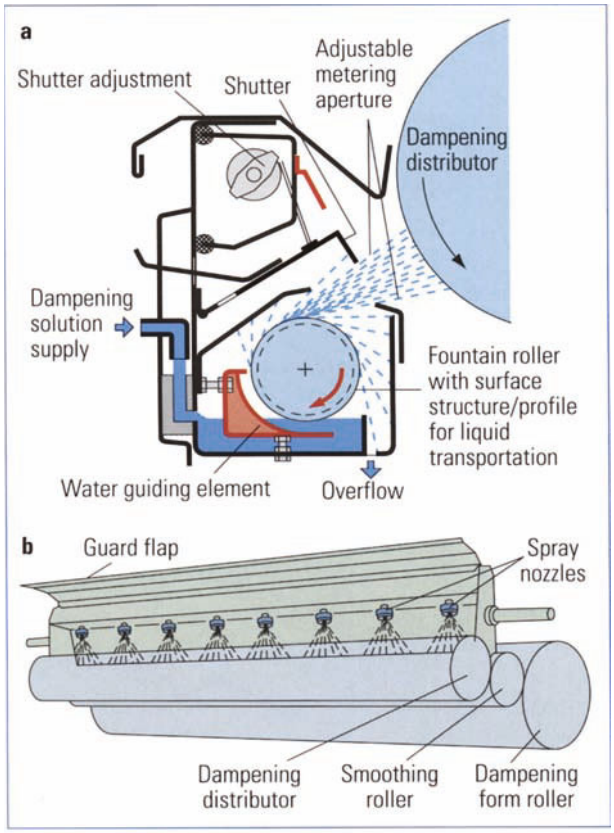


Fig. 2.1-108 Non-contact dampening systems.
a Catapult/centrifugal dampening system (MAN Roland);
b Jet-spray dampening system (Jimek-Graphotec)

application of dampening solution is independent of the ink flow (film type) or coupled to the inking unit (emulsion type).

Individual Drive (shaftless/gearless)

In the last few alternating years, advances in current servo-motors with fast data communication for frequency control of the motors have made it possible to eliminate mechanical shaft couplings or gear wheel meshing between the cylinder groups in the printing unit and, consequently, to drive such cylinders as blanket cylinders directly (fig. 2.1-109). For reasons of cost, other cylinders are coupled via gears in order to be driven by the same motor.

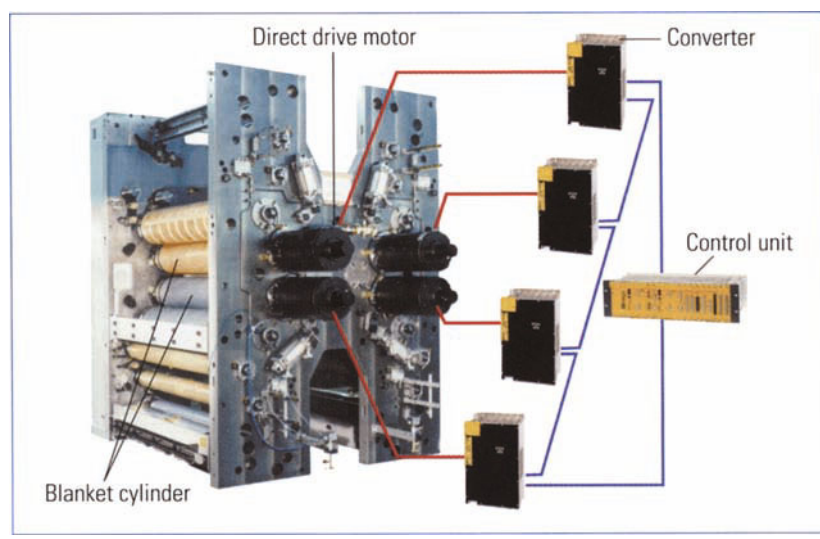
It seems rational that the motors themselves can act as actuators for the circumferential register adjustment.

Control engineering for these sorts of direct drives originates from machine-tool manufacturing and, for the most part, is supplied to the printing press manufacturer by its subcontracting industry. There are no substantial differences between individual makes because the machine-tool manufacturing industry agreed to generally binding standards (e.g., SERCOS-Serial Realtime Communicational System) at an early stage.

2.1.3.4 Folders and Print Product Variations

Folders are the bottle neck of a flow line production in web offset printing. The definition of a folder should include the folder superstructure (fig. 2.1-110, see also fig. 2.1-87) insofar as it is involved in forming the prod-

Fig. 2.1-109
Direct drive of a blanket cylinder in a newspaper printing unit (Baumüller)



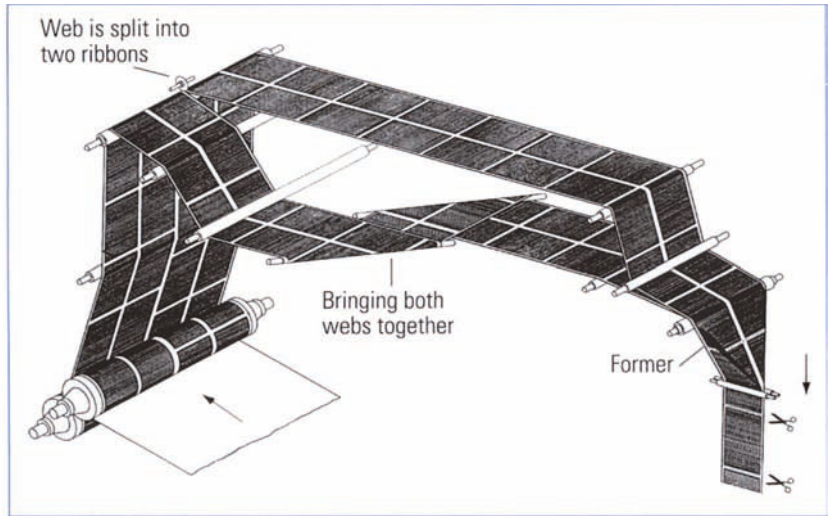


Fig. 2.1-110
Folder superstructure on a newspaper rotary printing press (IFRA)

uct. If the folder itself is meant, it is referred to as the "cylinder section of the folder".

Jaw Folder

The jaw folder is the cylinder section of a folder most commonly used in commercial web offset presses and newspaper web offset presses. The web running out of the former consists of several layers and is normally closed on one side; it is first routed into the cross-cutting section (fig. 2.1-111). This cross-cutting section has a two-piece cutting knife cylinder operating against a three-piece tucker blade cylinder equipped with three cutting bars of elastic and resistant material. The cutting knife is serrated like a saw and performs a cut that leaves the sheet edges serrated, too. With commercial print jobs, these edges are later cut off with a straight trim cut. However, as far as newspaper products are concerned, the serrated cut is regarded as a product-specific characteristic.

The real distinguishing feature of a jaw folder, however, is the type of fold performed by the tucker blade and folding jaw. To this end, the three-piece folding cylinder and a two-piece jaw cylinder act together after the cut has been performed (fig. 2.1-111). The folding cylinder must be divided into three segments, or any other odd number of segments. The reason for this is that with collect-run productions, the two product sections arranged in tandem on the folding cylinder are placed on top of each other to ensure that a first section is always joined to a second section and not the same product sections. For products with higher pagi-

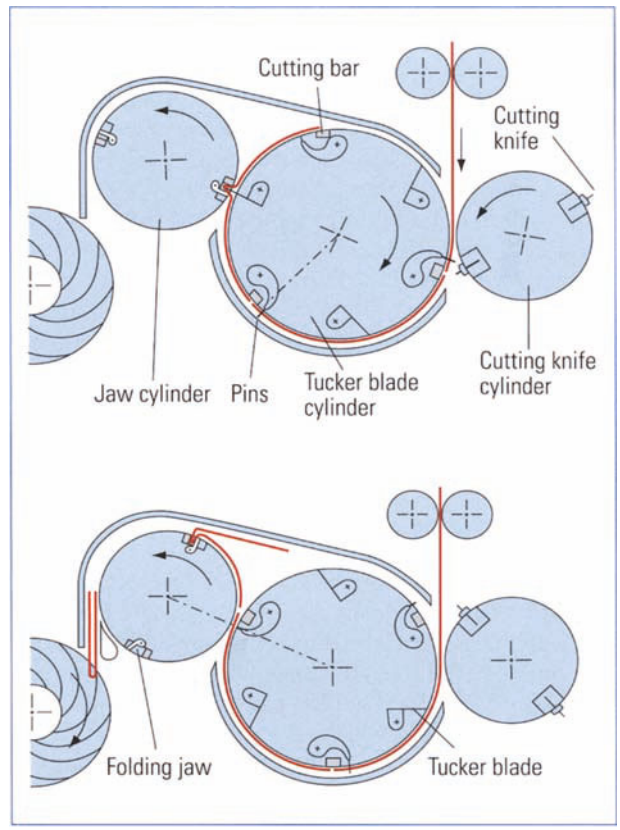


Fig. 2.1-111
Jaw folder. Interaction between cutting knife, tucker blade, and jaw cylinder (IFRA)

nation and for higher production speeds, five-segment and seven-segment folding cylinders are also used.

The jaw fold is produced by the cam-controlled tucker blade moving out of the cylinder when the tucker blade and jaw cylinder come into contact, thereby pushing the cut ribbon bundle into the cam-controlled open folding jaw. At this point the folding jaw, which consists of a spring-loaded steel rail with counter-rail, closes immediately and retains the product, while the cylinder continues to run. While the following product half is steadily transferred over from the folding cylinder to the jaw cylinder, the advancing product half must be pulled tangentially over the wedge formed by the two cylinders. This whip-like movement is the crucial point in jaw folder design. Specially shaped guiding elements or cushioning brushes are used to stop the product from being damaged.

The jaw cylinder can be segmented into two parts. Due to the fold being produced, only two quarters of the cylinder at a time are covered with products. To facilitate setting operations for precise interaction between the tucker blade and the folding jaw, the jaw cylinder and the folding cylinder are segmented equally, that is, the same tucker blade always engages in the same folding jaw. This is referred to as a 2:3:3, 2:5:5, or 2:7:7 folder where the segmentations of the cutting knife cylinder, the folding cylinder, and the jaw cylinder are shown with their respective segment ratios.

On completion of the folding process and half a turn of the cylinder, the folding jaw opens again, and this is also a cam-controlled operation. Separator elements engaging in the cylinder grooves remove the product from the cylinder surface and allow it to drop into a fan wheel by means of gravity and centrifugal force, with the folding spine ahead. The product is then slowed down and delivered in a shingled stream.

Gripper Folder

On the jaw folder described above, the product is transported over the cylinder by pins (see fig. 2.1-111). For many applications, pin holes on the product are not acceptable. The pin holes are tolerated on newspapers if they are at the bottom of a newspaper page. (On Japanese and Chinese newspapers, which are read from the back to the front, the former incline needs to be the other way round; otherwise the pins would be at the top of the newspaper.) To avoid pin holes altogether, gripper folders are used.

Since there must be a gap between successive sections so that the grippers can pick up the sections, the cutting knife cylinder cannot intermesh directly with the folding cylinder, but has to be provided with its own cutting counter-cylinder which is located in front of the folding cylinder. Upon cutting, the product section is accelerated for a short time by conveyor belts, thus creating the gap to the next section. The front end of the product is transported into the open grippers of a gripper bar. Subsequently, the grippers are closed by a cam disk. The grippers are designed and controlled in such a way that they leave no mark on the product. The grippers are spring-loaded, and their contact surfaces are roughened to ensure reliable transport over the cylinders despite the relatively low clamping force. The successive folding procedures correspond to those on a jaw folder.

Drum Folder

The drum folder, also called a "rotating folder" (fig. 2.1-112), works on a completely different folding principle compared to other types of folder. Apart from a cutting knife cylinder, the drum folder is equipped with a folding cylinder that pushes the ribbon bundle between two folding rollers using the folding/tucker blade. As the tucker blade has to travel a long way, the operation cannot be cam-controlled but works with a special planetary gear. The successive product sections are simultaneously gathered on the folding cylinder (gathering), which requires the cylinder to make two revolutions together with the product. To stop the tucker blade from coming out three times and possibly damaging the products, the folding cylinder needs to be specially designed.

The tucker blades are mounted in a second, smaller cylinder that is eccentrically supported in the actual folding cylinder. This means that the rotating tucker blades cut twice into empty space, that is, in the gap between the eccentric inner cylinder and the outer cylinder, which carries the product sections. Only at the very bottom, where the two folding rollers are directly opposite the cylinder, do the tucker blades come out of the outer cylinder periphery. At the same time as it is pushed between the folding rollers, the product is seized by knurled nip rings on either edge of the folding rollers, and the fold is performed. Every so often knurling can leave marks on the product margin.

The particular problem with this fold type is the vast acceleration in the direction of the folding rollers. Reliable folding without damage is achieved by specially shaped guiding elements and cushioning.

Former Fold

The former fold is the folding unit located in front of the cylinder section of the folder. Unlike the sudden

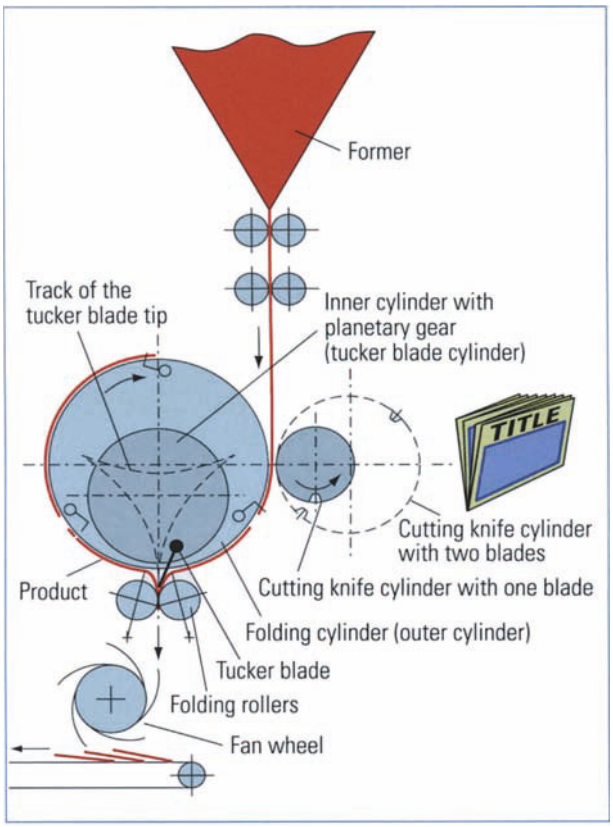


Fig. 2.1-112 Drum folder (IFRA)

cylinder fold, the former fold is a continuous-flow fold. The web or the ribbon bundle is directed in the shape of a bag around two former flanks that are at an angle to one another (approximately 60° to 70°) and inclined in the travel direction of the web. In this way the longitudinal fold is performed at the former nose (for details, see secs. 2.1.3.1, fig. 2.1-88 and 2.1.3.2).

Single-width presses are usually provided with one former, whereas double-width presses have two formers (fig. 2.1-113). As the number of formers determines the number of possible sections/parts of a product (for example a newspaper), more than two formers are sometimes used. Three formers are used adjacently by guiding one half of the web via parallel turner bars to the third former outside the web track. Four formers used one pair on top of the other pair are called "balloon formers" (fig. 2.1-114). There are also configurations where there are three levels with two formers each arranged on top of one another, for the production of up to six sections per product or even twelve sections in collect-run production. A *section* is the part of the product that has the same spine, that is, former fold. These sections are also called "books." To achieve various combinations, the ribbon bundles of these books can be transported along different routes from the balloon formers to the cylinder section.

Cross-Fold, Parallel Fold, Delta Fold

The cross-fold has already been described in the beginning of section 2.1.3.4. There are different variants of this type of fold to increase the product variety of commercial web offset presses in particular.

By fitting a second smaller folding jaw cylinder on the periphery of the folding cylinder that folds the product in the middle prior to the cross-fold a paral-

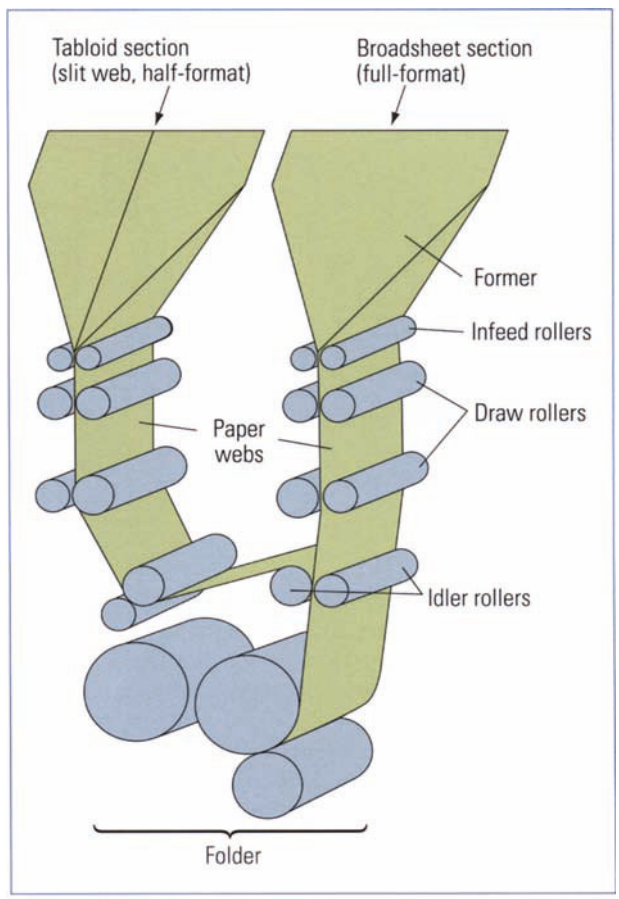


Fig. 2.1-113 Formers arranged in parallel for web gathering (IFRA)

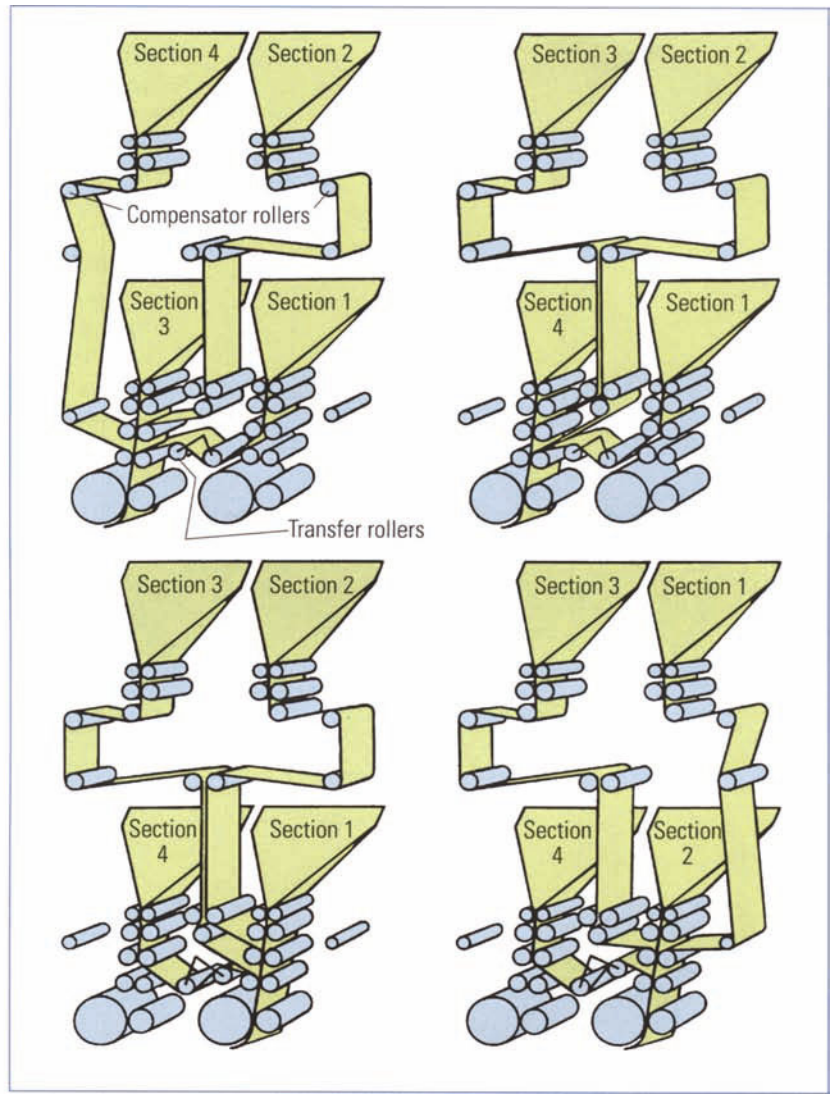


Fig. 2.1-114
Balloon former; former combination for the production of ribbon bundles (IFRA)

lel fold product used, mostly for products of paperback size, is produced. In this way, two products are formed in one production flow. They are still connected at their head and are separated later in a finishing process.

A square product or "delta fold" is produced if the small auxiliary jaw cylinder is positioned within the first third of the product lying on the folding cylinder. Folded products of this kind are very popular in advertising. This shows how versatile the fold types can be, even with a folder that is otherwise a fixed-size folder or fixed-size web offset press.

Quarter Fold

The "quarter fold" (also called chopper fold, third fold or second longitudinal fold) describes the fold performed after the former fold (first longitudinal fold) and the cross-fold (the second fold). The folding principle used for the quarter fold is similar to the folding principle used in the drum folder (fig. 2.1-112). A rotating tucker blade pushes the product sections between two folding rollers performing the fold. Figure 2.1-90 shows the quarter fold as a variant. Figure 2.1-115 shows a configuration to produce the third fold. It becomes clear that production is possible with or without the

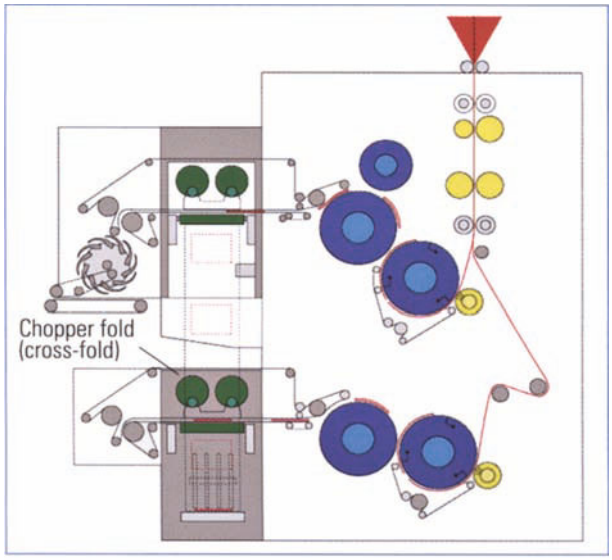


Fig. 2.1-115
Folder with two quarter fold (chopper fold) units with several delivery and folding variants (IF-50ST, Heidelberg)

chopper fold and with two web ribbons on two different fan wheels or delivery belts. To increase throughput and also to split the product stream, the product sections are routed onto two different "chopper fold tables" by means of controlled diverters. In this way the folding speed can be halved.

Apart from problems caused by acceleration during folding and the risk of "dog ears" at open product edges, there is also the problem of product creasing, which results from air getting trapped in the closed product spine. To overcome this difficulty, the ribbon bundle is perforated longitudinally in the folder superstructure or moved against a sharp stop knife on the chopper fold table, which slightly slots the folding edge so as to remove trapped air.

When two quarter fold units are connected in series this is referred to as the "Swiss postal fold". This fold is used to produce a "pocked-sized" newspaper.

Turner Bars

Turner bars (see also sec. 2.1.3.2, fig. 2.1-100) are used to position one half of a web on top of the other half, thereby producing a ribbon bundle that can be fed into a former. Two turner bars are required for this operation: one turner bar to deflect the web half at right angles, and another one to redirect the web half at right angles to the travel direction of the web, however shifted in the track (fig. 2.1-116a). Figures 2.1-116a and b show how the web is reversed by means of two turner bars and a cross-roller located in between. (These are also called "pony turner bars".)

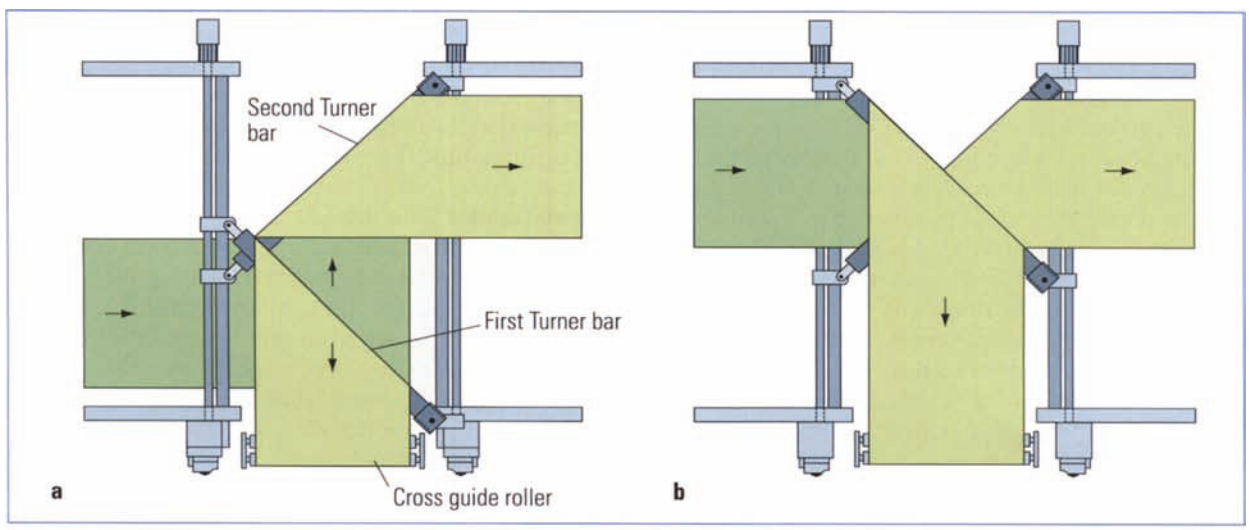


Fig. 2.1-116 Turner bar configuration.
a Arrangement for moving and turning the web;
b Arrangement for turning the web (MAN Roland)

In addition, one half of the web can be returned in the reverse direction to be printed on the reverse side in another printing unit, that is, to produce perfecting jobs with a double-width printing unit on a single-width web.

In-line Finishing

"In-line finishing systems" with their own supplier industry have extended product variety even further. Devices supplied include plow fold tools for longitudinal folds where two ribbon halves are placed on top of each other and a longitudinal fold is produced. These plow fold tools work like formers, with the difference that the fold is produced on a web travelling in a straight line. This tool is mainly used with narrow ribbons, which makes possible a non-supported web guide. Other in-line finishing equipment incorporated in the superstructure includes cutting and perforating devices, window-cutting, and pattern-gluing machines, in addition to gluing machines for self-adhesive glue coating.

Stitchers

Single sheets can be bound/held together either by an in-line application of glue or by stitching the product together with wire staples. High-performance stitchers (see also fig. 7.2-75 and table 7.2-22 in sec. 7.2.5.5) are incorporated at different positions in the production line, depending on the type of production.

High-performance stitchers operating at full production speeds are incorporated in the folders (e.g., as shown in fig. 2.1-89). The cylinder stitcher works together with closing heads that are fitted on the tucker blade cylinder.

The stitcher itself consists of two or three revolving closing heads with shaping wheels that shape the automatically fed staple wire into U-shaped staples after it has been cut. When the product comes into contact with the folding cylinder, that is, with the closing heads mounted on the folding cylinder, the cam-controlled stitching heads drive the staples through the ribbon bundle onto the closing heads, which automatically bend the staple legs over to secure the product.

This type of stitching is especially used for tabloid products. As shown in figure 2.1-113 (left part), in tabloid production, the web is halved on the folding former, the halves being placed on top of each other, which means that two streams are fed to the folder even if there is only one former.

In addition to cylinder stitching machines, there are also ribbon stitchers that are used to staple quarter fold products (first longitudinal fold, cross-fold, second longitudinal fold; see also fig. 2.1-90) for double production (two copies per revolution of the plate cylinder). They are integrated in the folder superstructure after the first longitudinal fold. The product is stapled in the longitudinal direction employing the ribbon stitcher, which operates together with the closing head cylinder.

2.1.3.5 Newspaper Printing

Compared to commercial web offset printing, newspaper printing features several distinguishing characteristics, mainly concerning the design of the printing unit.

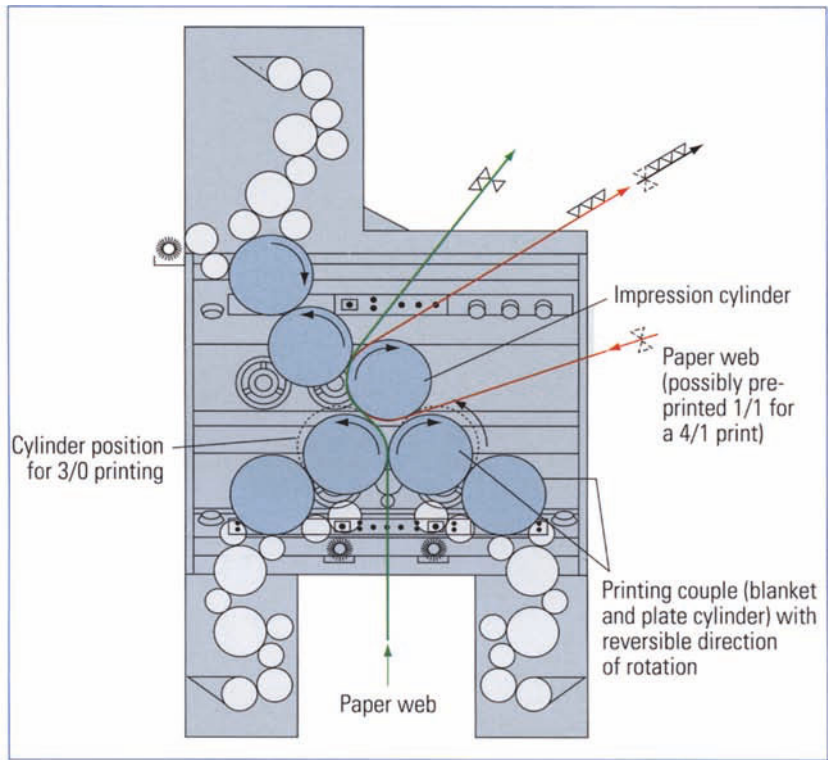
Vertical and Horizontal Printing Unit

Today, commercial web offset presses usually feature the vertical blanket-to-blanket printing unit with *horizontal web lead* (cylinder groups, plate and blanket cylinders of the printing units for top and reverse side of the web are arranged almost vertically, fig. 2.1-84), since the satellite design of earlier magazine presses did not, on account of their rigidity and size, prove successful. Occasionally, the satellite design is used in newspaper printing, however, the horizontal web lead and its inaccessibility are problematical for multi-web production used in newspaper printing because of the large number of pages involved. For this reason, *vertical web lead* is favored in newspaper printing, and this has led to the development of the horizontal printing unit, also called "*U-type or arch-type printing unit*", with the cylinder groups for either side of the web arranged in the horizontal position (fig. 2.1-120), that is, turned at an angle of 90° as compared to the vertical printing unit (fig. 2.1-103).

Three-Quarter Satellite

The "three-quarter satellite" (fig. 2.1-117) was developed in the United States to produce color print jobs on preprinted webs. The three-quarter satellite has three printing couples arranged around a common impression cylinder, where one of the printing couples makes possible a change of rotational direction (in fig. 2.1-117 this printing couple is located at the bottom right). Together with an adjacent printing couple, a 3/0 job can be printed; however, the printing unit alone can also be operated on its own to print a 2/1 job. This flexibility and the rare need for four-color prints are both reasons for not opting in the first place for a complete satellite configuration (e.g. the combi-satellite illustrated in fig. 2.1-102).

Fig. 2.1-117
Three-quarter satellite (GOSS)



Y-Type Printing Unit

The Y-type printing unit is a simplified version of the three-quarter satellite (fig. 2.1-118). In this configuration there is no common impression cylinder and no way of reversing rotation. The three blanket cylinders are arranged in such a way that one blanket cylinder is also the impression cylinder for the two other blanket cylinders. Figure 2.1-118 shows the three possible variants of web travel. For 3/0 jobs, the third color is printed in a "di-litho process", that is, directly from the plate onto the paper web.

Combi-Satellite

With a view to flexibility regarding the choice of 2/2 jobs and the capacity thus to process two webs in one printing unit without having to "tear apart" the four printing nips in one color set, the combi-satellite (fig. 2.1-102) has been developed. The four blanket cylinders arranged around the common impression cylinder can be repositioned so that printing takes place either in satellite mode (i.e., rubber to steel) or the blanket-to-blanket mode. This, of course, requires at least two printing couples to be reversible. To be able to produce 4/0 jobs in addition to 0/4, all four printing units are very often reversible in the direction of rotation.

Strangely enough, two different designs have developed over the years: vertical web travel and horizontal web travel, both regarding the blanket-to-blanket mode. It is difficult to say why this has happened. It actually only makes sense for twin satellites (see fig. 2.1-121), in that this creates an open gap for installing a cleaning device for the second impression cylinder. This alternative structural design was, however, developed long before the twin-satellite design – and, moreover, in the selfsame printing press manufacturing company.

Semi-Satellite

The semi-satellite or "ten-cylinder satellite" (fig. 2.1-119) is a special type of combi-satellite. The common impression cylinder is divided into two impression cylinders. (There are three different designs: the vertical design with a vertically travelling web printing blanket-to-blanket, the horizontal web travel design printing blanket-to-blanket, and the sitting design with the blanket cylinder extended at the bottom for greater accessibility.)

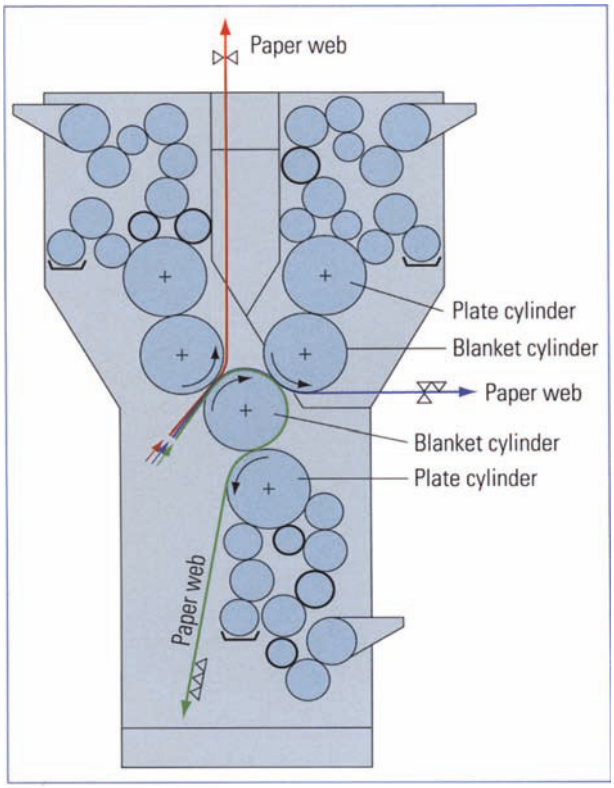


Fig. 2.1-118 Y-type printing unit (KBA)

"Color Deck"

The term color deck goes back to the time when newspaper printing units could only print monochrome, and "color decks" were installed above the actual printing units to imprint spot colors (see also figs. 2.1-200 and 2.1-201). Since a satellite printing unit (see fig. 2.1-102) is only suitable for four-color prints on one side, color decks were also used at a later date to print a web on both sides in one printing unit. The color decks were mostly constructed as a U-shape printing unit consisting of two printing couples, either with or without their own impression cylinders or else with a common impression cylinder. In this way it was possible to add 1/1 or 0/2 prints to the four-color prints or to webs with a spot color.

Four-High Unit

Four-high units were developed in the second half of the 1980s in response to an ever-rising number of different printing unit configurations available on the market, as a kind of "renaissance and back-to-nature movement." Four-high units are the simplest and the most compact method of producing a 4/4 job with one single printing unit. Here, too, two variations are available:

- four-high units consisting of two H-type printing units (fig. 2.1-120) arranged on top of each other (the H-type printing unit consists of an arch-type printing unit and a U-type printing unit) or
- four-high units consisting of four arch-type printing units arranged on top of each other. The latter has mainly been developed for printing units with keyless inking units to ensure equal geometrical ratios in all printing units.

To control lateral register deviations, the printing plates in four-high units must be laterally staggered to compensate for the expected "fan-out" effect (the web is laterally extended under the influence of dampening solution from the offset dampening unit). Minor corrections during printing can be carried out by anti-fan-out controllers, known as "buzzle wheels" (see sec. 2.1.3.2 and fig. 2.1-99).

Twin Satellite

Twin satellites (fig. 2.1-121) have been developed to produce 4/4 prints with a single printing unit, but without any fan-out effect. Since there are so many different types of satellites, combi- and semi-satellites, twin-satellite designs have proliferated accordingly. However, modern systems are mainly offered without conversion, that is to say, we should no longer really talk of combi-satellites.

Twin-satellite designs are mainly used in Europe. In the United States, Asia, and Australia, four-high unit construction is still preferred.

Dampening Systems

With dampening systems in newspaper web offset presses, linting (i.e., fast soiling of the dampening solution) is an issue. As a result, there should be no reverse transfer of dampening solution to the water fountain with these systems. Hence, all dampening systems used in newspaper printing feature non-contact design. At the beginning, brush-type dampening systems were predominant. They were equipped either with an immersing brush or with a brush that was in contact with the water fountain roller (fig. 2.1-107). There is also a kind of "spiral roller" in the form of a turbo-dampening unit. However, jet-spray dampening systems are

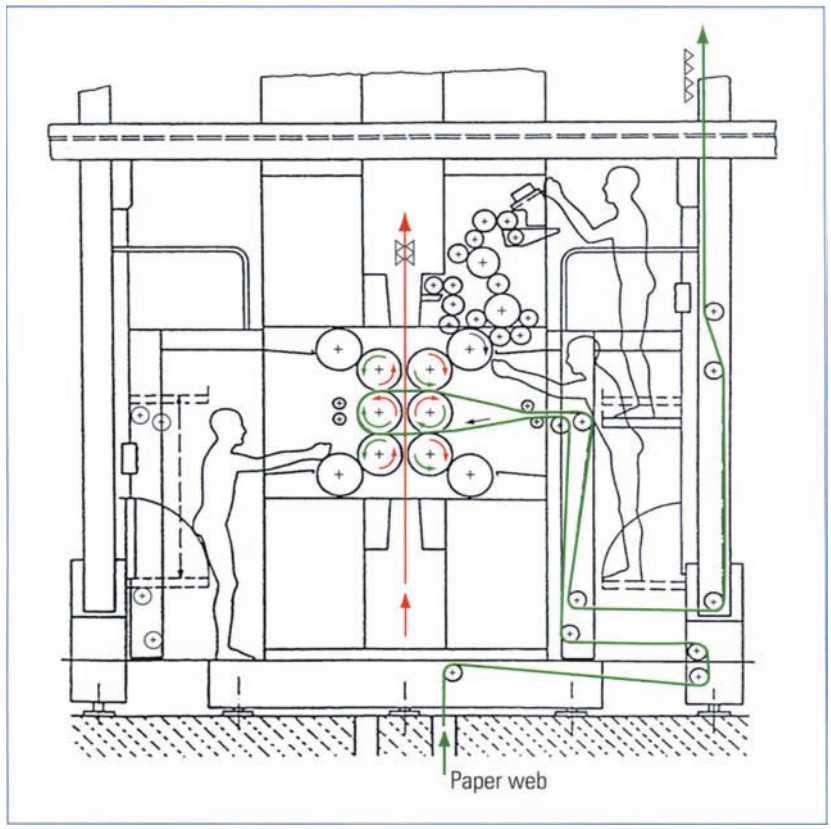


Fig. 2.1-119
Semi-satellite (10-cylinder satellite) with vertical web travel and blanket-to-blanket printing (WIFAG)

used nowadays for the most part, due to their easy maintenance (see also fig. 2.1-108).

Keyless Inking Units

For thirty years, newspaper printing has been doing pioneering work in the field of keyless inking units. Solutions have been worked out that basically remove the residual ink film or the inhomogeneous ink relief from the ink form roller completely and apply a new homogeneous ink film. Until today three different designs have been used in practice (fig. 2.1-122):

- keyless inking units with Anilox (screen) rollers, that is, engraved, or structured metering rollers with doctor blade (figs. 2.1-122a and b);
- with pick-up roller and scraper blade (figs. 2.1-122d, e and f);
- with oscillating doctor blade (fig. 2.1-122c).

The second and the third designs enable a positive ink-feed, but in the case of the first design this needs to be achieved via the concentration or dilution of ink. It is said, however, that for normal newspaper printing this is hardly ever necessary.

Inking units with oscillating doctor blades represent the shortest design as far as the roller train is concerned; designs with pick-up roller and scraper blade are the longest, and inking units with an Anilox roller are in the middle. Advantages gained from keyless inking units suggest that keyless inking units will also be used in commercial web offset and sheet-fed offset presses in future. There are also developments aiming at waterless offset printing and the use of emulsion inks that already contain the emulsified dampening solution and thus do not require any additional dampening system.

Flying Plate Change and Changing the Web Width

In newspaper printing, several plates are usually mounted on one plate cylinder. This means that these plates can also be exchanged individually (see figs. 2.1-110 and 8.1-4).

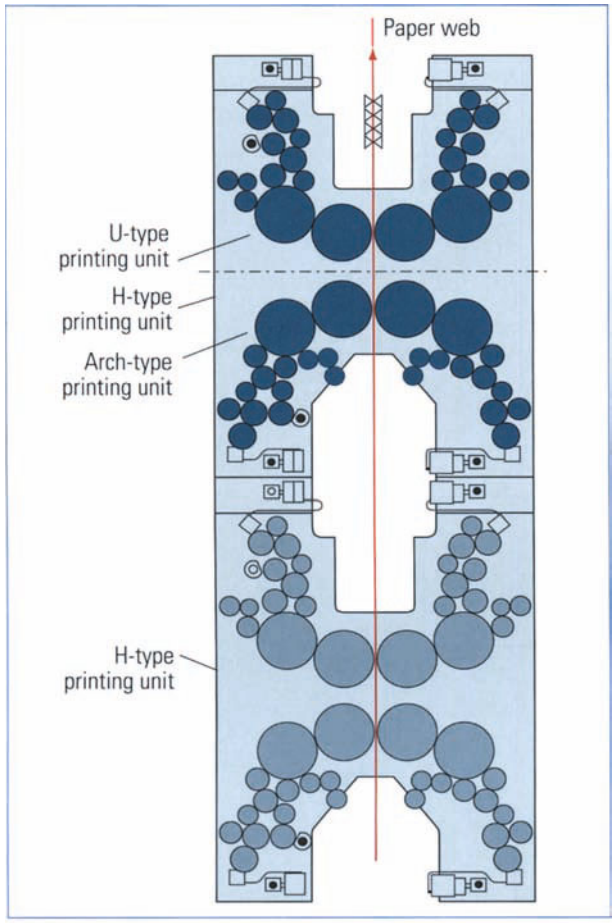


Fig. 2.1-120
Four-high unit composed of two stacked H-type printing units (GOSS)

With the transition to shaftless drives on newspaper printing presses, the flying plate change (i.e. while the press is running), as it has been used for years with imprinting units on rotogravure and web offset presses, has also become of interest and feasible for newspaper web offset presses, since many different local editions can be printed in one pass uninterrupted by makeready times. This, however, requires double the number of printing units, with half the number being prepared at standstill while the other half is printing. Once the circulation of the local editions is complete, the "flying plate change" takes place and printing continues without interruption. The flying plate change is even used for four-color prints in addition to single-color imprints.

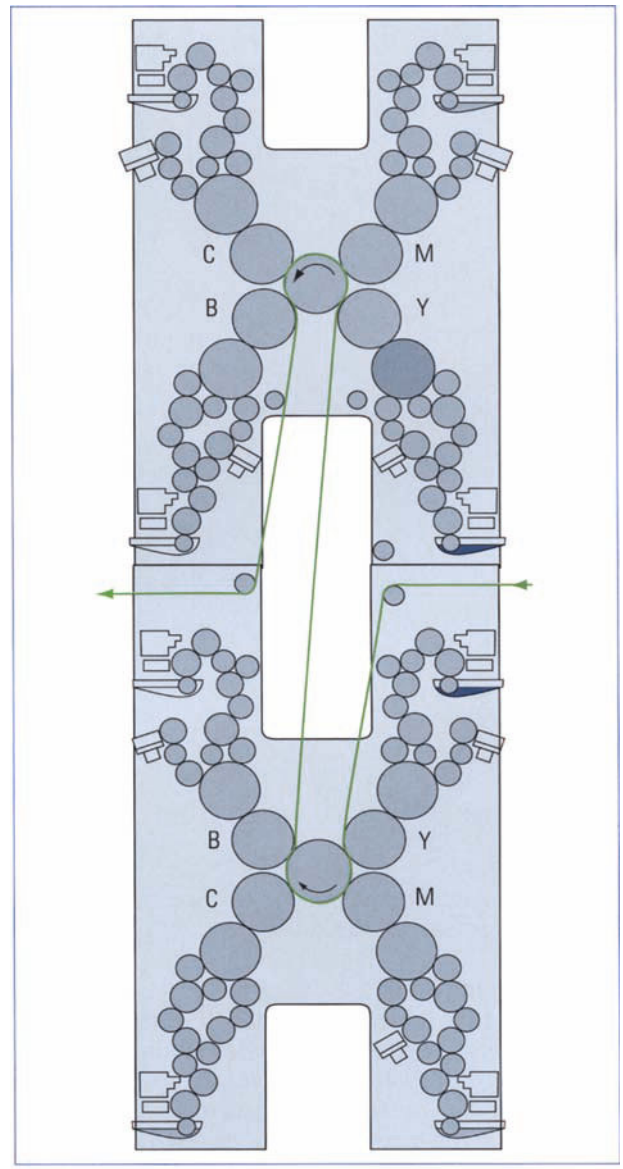


Fig. 2.1-121
Twin-satellite configuration for 4/4 prints (MAN Roland)

It is logical to combine a change of the number of pages in the run with this process. To do this, a flying change of web width is required. This is only possible to a limited extent and requires a reduction in production speed while the change operation is in progress. A reel stand with separate reel-arm adjustment is a prerequisite here. In this version, a full-width paper reel

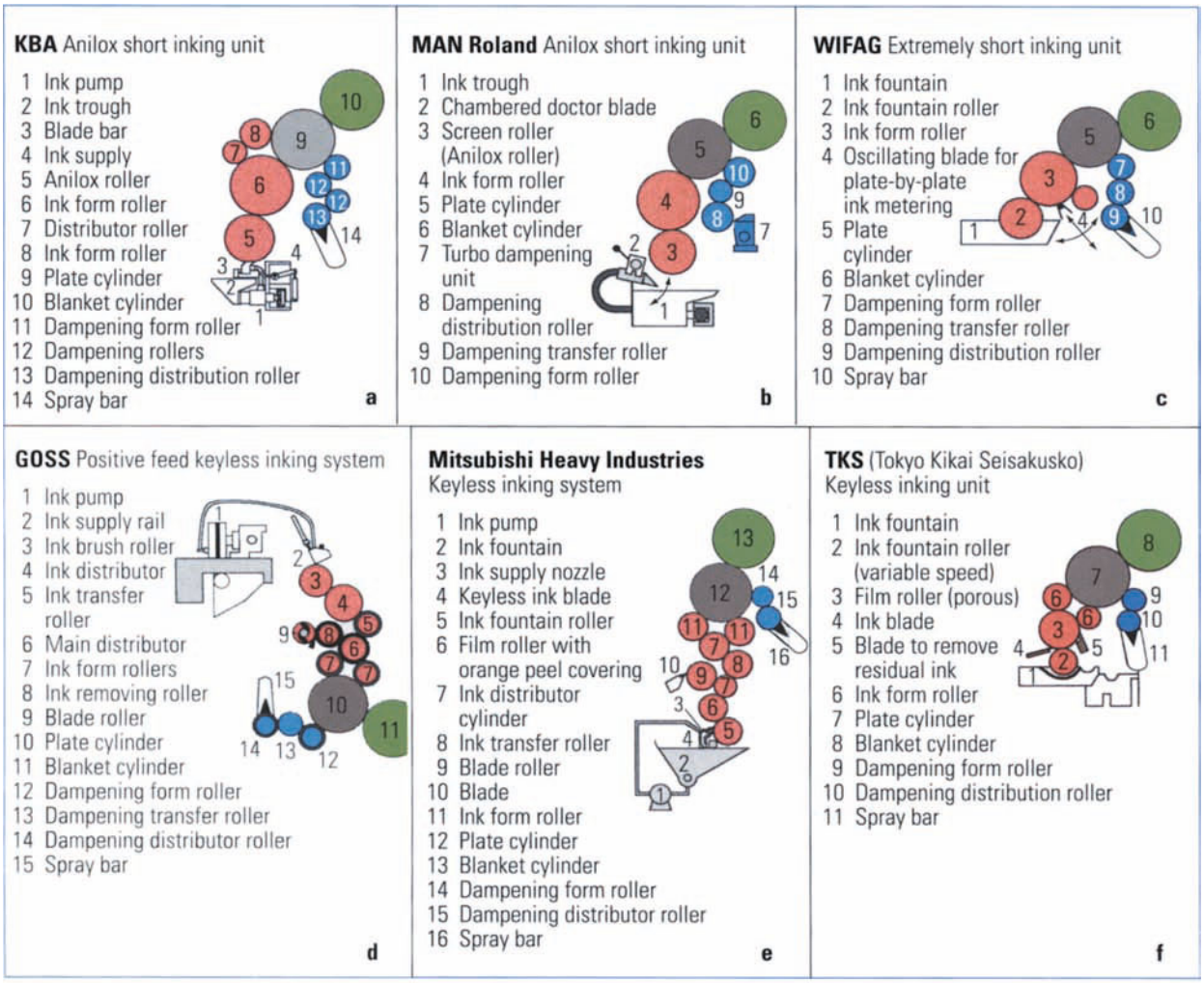


Fig. 2.1-122 Examples of keyless inking units (KBA)

runs in one half of the reel arm, while a half-width paper reel is mounted in the other half. On the flying splicer, the half-width web is pasted to the full-width web, and the pagination of the product is reduced correspondingly.

2.1.4 Remote Control, Measurement and Control Technology/Systems

The running of an offset printing system, whether it be sheet-fed or web-fed printing, involves many adjustments of the various components of the press, especially when *setting the press up* for the job to be printed and monitoring it during the *print run*. As far as print quality is concerned, this mainly involves setting the different printing units for *ink feed* and *color register*. Then, the dampening units, paper feed, blast and suction air, powder spray device and dryers have to be set to meet the requirements of the job. Machinery also has to be cleaned and washed down from case to case.

If all this work had to be carried out directly on the relevant units of the printing press – that is, on the feeder, printing units, and delivery – it would take a number of operators, or mean moving long distances from control to control, especially with multicolor presses with six to ten printing units, or even web-fed offset

presses with their numerous attachments, such as dryers, folders, and other finishing equipment, which are located relatively far apart. This leads to particularly long setup/makeready times and systems would be slow to respond when any settings had to be changed, leading to high paper waste rates and costs.

Central control consoles, with controls for *setting the main press functions remotely*, have long been standard. With the development of remote control, measurement and control systems, drives, and actuators, settings can be made remotely, not only with the big presses such as those in web offset or newspaper printing, but also in sheet-fed offset presses. Powerful systems have been available since the mid-1970s and these are evolving all the time.

Section 2.1.5 (automation in the print media production) looks at press control consoles and measurement and control systems in detail in connection with special jobs. This is followed by an outline of the individual components of remote control, measurement and control systems, with notes on how they work and the technology used.

2.1.4.1 Press Remote Control Systems

Press Remote Control Console

Figure 2.1-123 shows the control console of a sheet-fed offset press. One of the sheets that have come off the press in the current run is laid out on the console, with the master proof for that job on a lighting unit. With an illumination system equipped with a special light source meeting standard requirements, the operator can compare the sample taken from the run visually with the master proof. For remote setting of the ink feed on the press, the control console has function keys/push-buttons corresponding to the *ink zones* of the printing unit, which the operator can use to adjust the ink zone openings in the individual printing units and bring the colors into line with the master proof. The control console also has function keys that are used to set the *ink register*, that is, the positions of the individual plate cylinders can be adjusted in circumferential and lateral direction in a series of small steps. There are also displays, showing the current settings of the individual press units. Most control consoles also have facilities for downloading job data (such as color settings) held on storage media.

While control consoles were initially there to set ink feed and register, an increasing number of *other functions* have been added. Figure 2.1-123 also shows a second display area on the control console which is used to set up other controls, such as dampening unit settings, blowers, and suction controls. It can also be seen that the control console includes a measuring device for *checking color register and match*. Register and color measuring systems are described in more detail later. The *light pen* fitted at the front, which is wired to the control console computer, is another way of setting a color profile via a specially designed *ink zone display*.

Figure 2.1-124 shows a more recent model of a remote control console for sheet-fed presses. Most of the setting controls are no longer present. Individual controls are now set via a graphic user interface and a *touch screen*. What has been retained are the inputs directly related to the printed sheet to adjust the ink supply in the printing units: in the example shown, this is done using a membrane keyboard. The push-buttons in figure 2.1-123 have been replaced by new controls, which are much less susceptible to dirt and knocks.

The control console shown in figure 2.1-124 has had another automation module added in the form of a *measuring device for color measurement* directly on the printed sheet, which it does by scanning with a special optical unit. The measured print image is displayed on the color monitor. (The performance of this color measuring and control technology is described in more detail later on in the next section, see also fig. 2.1-137.)

Figure 2.1-125 shows a remote control console, as shown in figure 2.1-123, installed on a five-color sheet-fed offset press with coating unit and extended delivery. This clearly shows how essential a *central control console* is when it comes to operating a long-line, multi-stage press efficiently, comfortably, and safely for cost-effective production in consistently high quality.

The control console in figure 2.1-125 also has a monitor fitted, as part of a *production management and control system*, providing the press operator with information on forthcoming production schedules, the jobs allocated, and progress on the current job.

Ink Feed Preset Systems

Figure 2.1-125 also shows what is known as a *plate image reader*, which is used for color presetting operations. Such devices scan a plate to see how much ink it will require and the data is then input into the press control console for a remote adjustment of ink zone openings, via a cassette tape or other data carrier.

Using this kind of color preset systems greatly reduces makeready (setup) times and wastage rates. By taking the area coverage of the plate and using it to set the *ink zone openings* and *ink strip widths* (as shown



Fig. 2.1-123
Remote control console for multicolor sheet-fed offset press with lighting unit for printed sheet inspection and handheld measuring instrument for color register adjustment (CPC1/CPC41 Register mark reader, Heidelberg)



Fig. 2.1-124
Remote control console for multicolor sheet-fed offset press with touch screen monitor for remote setting press functions, connected on the left to a color measuring system for color and image control (CP2000/CPC24 ImageControl, Heidelberg)

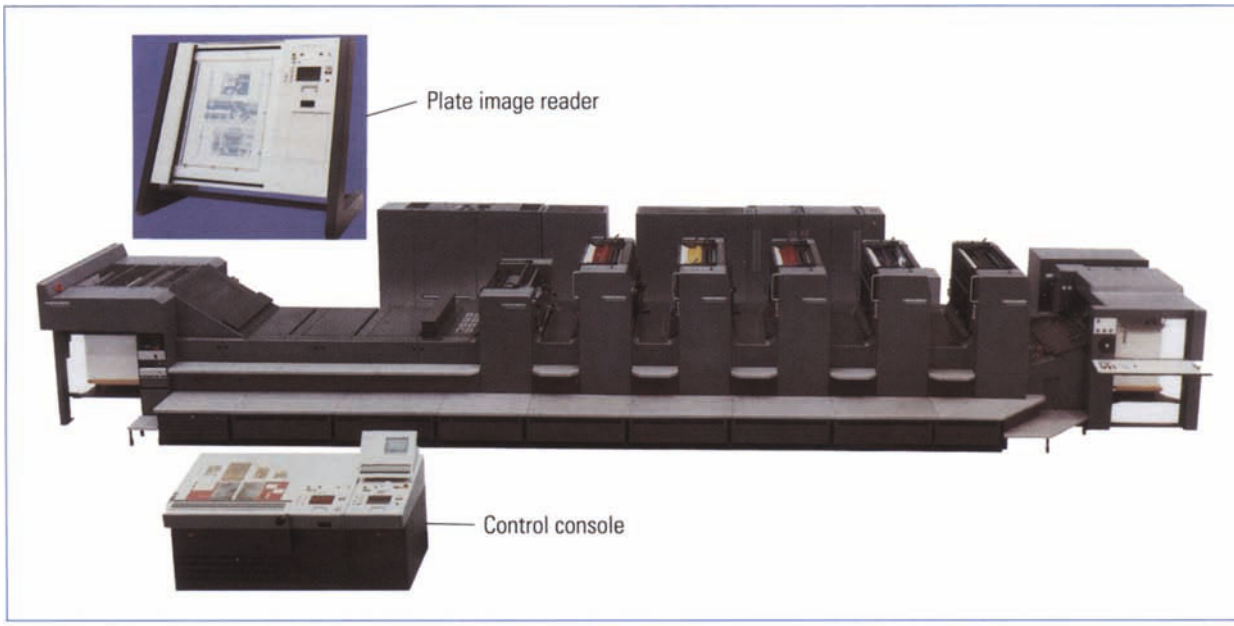


Fig. 2.1-125
Multicolor sheet-fed offset press (with coating unit and extended delivery) and control console for remote press settings and production monitoring, and plate image reader for ink zone presetting (SM 102/CPC 31/DataControl, Heidelberg)

in fig. 2.1-126b), the inking unit can be brought up to an almost ideal setting for production before a single sheet is fed. With the support offered by measurement and control systems, the ideal setting of the color for each color separation and the final print can be reached with just a few minor adjustments.

Figure 2.1-126 shows how color presetting systems work (see sec. 2.1.1.3, fig. 2.1-13).

Figure 2.1-127 shows a selection of color presetting systems, which first appeared in printshops around 1982. All these designs rely on optical sensing using a moving scanning bar fitted with a lighting unit, sensors, and filters. There are other designs using CCD cameras, which do not use mechanical moving parts to scan a plate, but these have proved less popular (in particular due to the lighting problems).

Color Quality

The main factors that govern the quality of the printed image are the *ink supply* to the paper and *the register*, that is, how the individual color separations are printed one on top of the other to give a multicolor image.

In addition to the printer's eye, color measurement and control systems are used that can be utilized not only to set up a job quickly and keep it adjusted on the run, but also to monitor production itself. Printing *measuring targets/patches in color control strips* for zonal color measurements and individual register marks for color register measurements are now standard. Figure 2.1-128 shows a *color (print) control strip* of this type on a printed sheet taken from the delivery of a sheet-fed press.

The following sections will deal with systems for measuring color and color register. Measuring methods and procedures have already been examined in section 1.4.4; the emphasis now will be on describing complete measuring systems for off-line measurement, that is, off the press, and for in-line measuring, that is, quality measurement and control during the run, using the measuring systems fitted to the machine.

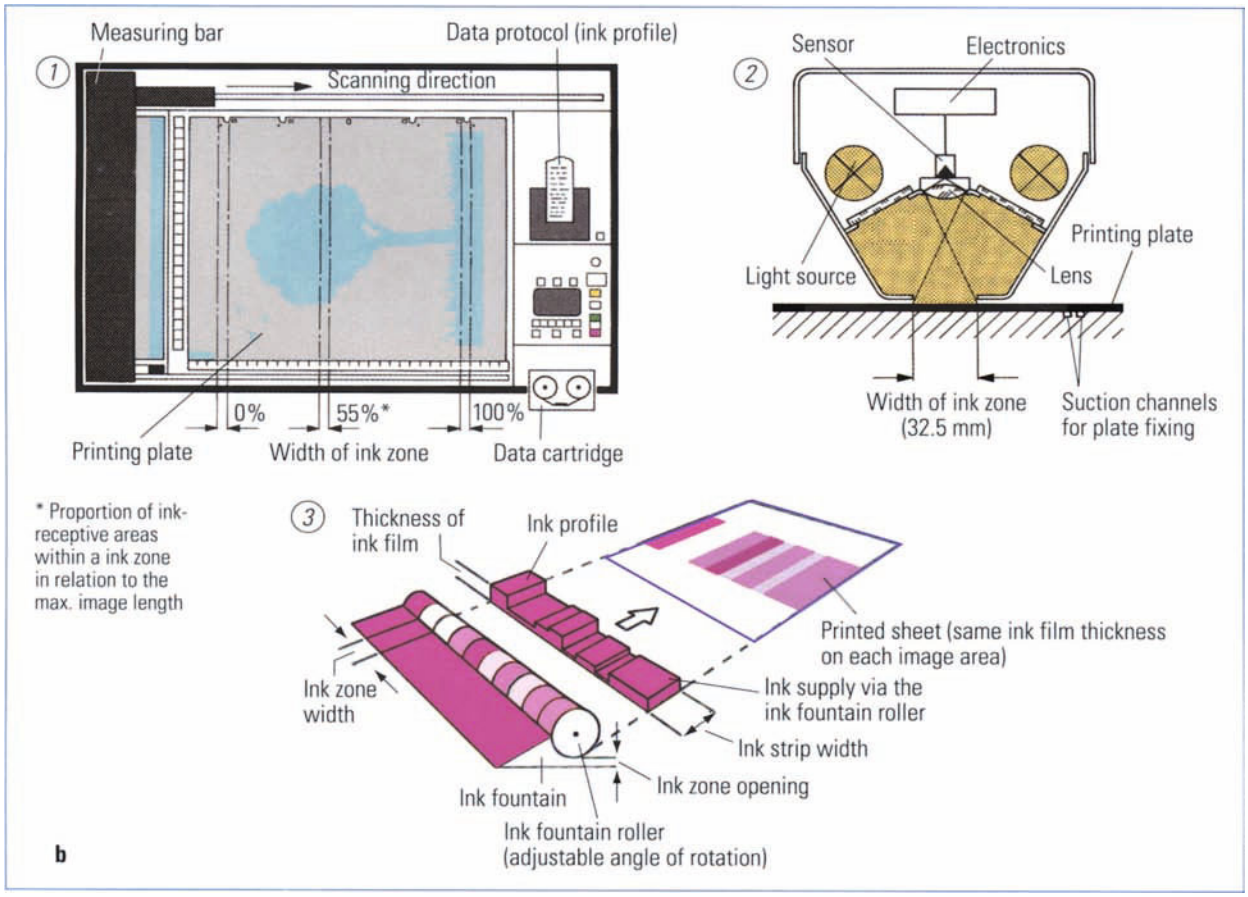
2.1.4.2 Color Measurement and Control Systems

There are two basic methods of color measurement: *densitometry* or *colorimetry*. Both systems can be employed in practical use: in handheld equipment for individual readings, or scanning systems for testing a complete sheet automatically. For details of how they work, and how they can be used – the physical princi-

Fig. 2.1-126 Plate image reader.
a Plate image reader for measuring the ink distribution on an offset plate (status: 1982);
b Method for calculating zonal area coverage
1 Zone by zone plate scanning with data output facilities
2 Cross-section of an optical system for measuring zonal area coverage
3 Setting the ink feed on an offset printing unit (ink zone openings and ink strip width) (CPC3, Heidelberg)
Note: CPC31, an advanced model, is shown in Fig. 2.1-125



a



b



Fig. 2.1-127 Plate image reader designs for ink presetting operations.
a DEMIA plate image reader (Device for Measuring an Image Area, Dai Nippon Printing);
b CPC3 plate image reader (Computer Print Control, Heidelberg);
c EPS plate image reader (Electronic Plate Scanner, MAN Roland);
d CPC31 plate image reader (Heidelberg)

ples of densitometry, colorimetric and spectrophotometric measurement systems – see sections 1.4.1, 1.4.2, and 1.4.4. Densitometry measures the optical density of an ink film, which essentially depends on how thick that film is and does not, in principle, measure values. Spectrophotometry and colorimetry make it possible to take readings that correspond to how the human eye sees colors, both qualitatively and quantitatively. It therefore enables much more efficient measurement and control of print quality than densitometry.

Densitometric Color Measurement

A wide range of *handheld equipment* is available for measuring optical density; one example is shown in figure 2.1-129 (and other examples in sec. 1.4.4). To use handheld densitometers efficiently, special measuring targets/patches must be used in the *color control strips*. In addition to the control strips shown earlier (sec. 1.4.4), figure 2.1-129 shows another variant of powerful control elements, arranged in a control strip (System Brunner). Handheld densitometers are also available which meas-



Fig. 2.1-128
Printed sheet taken from the delivery of a sheet-fed offset press for quality control purposes (Heidelberg)



Fig. 2.1-129
Handheld densitometer for scanning measurement targets in print control strips (R410SB, Techkon/System Brunner)

ure a series of measuring elements (e.g. eight) by scanning a small area with the recording system.

A printed sheet that is 100 cm wide will typically have approximately two hundred test elements arranged across it. At the least, the solid-tone patches per ink zone and printing unit must be measured, which for four-color printing and thirty-two ink zones gives a total of 128 readings, not to mention the readings for halftone values, ink acceptance, and so on. A typical *measuring patch* is approximately 5×5 mm^2, although some systems can use smaller areas (e.g., 3×4 mm^2).

To increase the level of *automation* and for rapid measurements, there have been measuring systems under development since around 1977 that can measure a number of color control strips *simultaneously* and in later versions by scanning.

Figure 2.1-130 shows one of the earliest systems; simultaneous measurements per ink zone were carried out by a measuring bar (*integrated in the control console*) color by color in specially designed color control strips by moving the bar sideways in several positions.

In the early 1980s, this was followed by systems in which a scanning densitometry sensor head scanned the control strips on a printed sheet automatically in a single pass (figs. 2.1-131, 2.1-132, and 2.1-133; TOBIAS Inc./USA was also a pioneer in the development and use of scanning densitometers).

For a more efficient use of such valuable sensor systems, they have been designed for *multi-machine operation*, such as that shown in figure 2.1-131. Here, a single color measuring system covers printed sheets from a number of presses (practically three or four at most) and sends the data to the relevant control consoles where it appears on the display and the operator can release it to set up the press. The system in figure 2.1-131 can be combined with the control console shown in



Fig. 2.1-130
Densitometer measuring bar for simultaneous color control patches measurements according to ink zones on the printed sheet on the press control console, with color variation displayed zone-wise (CPC I & CPC II, Heidelberg/Gretag)

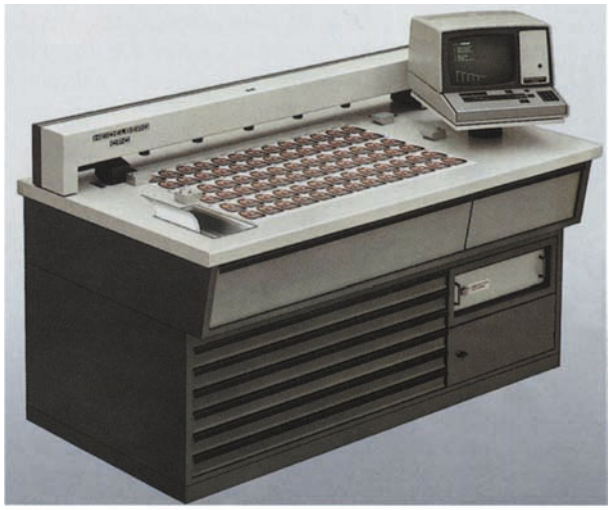


Fig. 2.1-131
Scanning densitometer for color measurement and data transfer to the press control console for ink control in multi-machine operating mode (CPC 2, Heidelberg)

figure 2.1-123. The development of powerful, practical measuring equipment was accompanied by the development of control algorithms for using the color readings and any variations from measured reference values or setpoints from the proof sheet to calculate adjustments to the ink feed in the printing units and use them to make rapid adjustments during the run.

In contrast to "*stand-alone*" *systems* for densitometric color measurements on printed sheets and the ability to cover more than one press at once, there are also systems where densitometric sensors are incorporated in the *press control console* itself. One such measurement and control system is shown in figure 2.1-132a.

As shown in figure 2.1-132b, this system also has optics for simultaneous spectral density measurements. As explained in section 1.4.4, the color filters are not equipped with the usual standard broad-band transmission ranges, but rather with color filters in the path of the beam, which only transmit a narrow wavelength band from the light reflected from the sensor field.

Using specially-designed two-dimensional scanning densitometers, measuring areas in the print image can be selected. This comes in useful for making maximum use of the printed sheet when printing multiple-ups and when continuous control strips (all patches in one row) cannot be used, for instance, in the field of packaging. In this case, staggered control strips are used in the printed

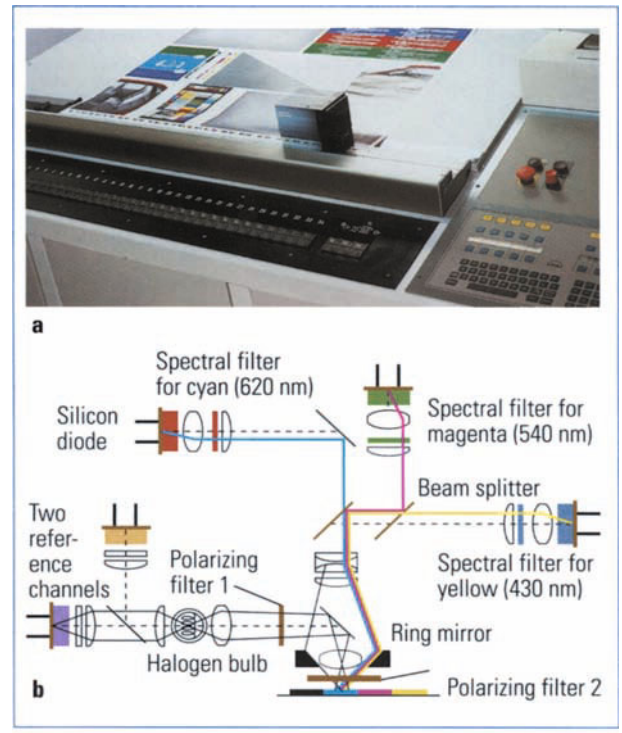


Fig. 2.1-132
Scanning densitometer for measuring spectral density.
a Scanning densitometer assembled on the press control console;
b Narrow-band densitometric measurements with spectral filters (CCI, MAN Roland/ Grapho Metronic)



Fig. 2.1-133
Scanning densitometer for two-dimensional measurement positions on the printed sheet (Densitronic, KBA)

image. In a system like the one shown in figure 2.1-133, the densitometer head is moved in the x and y axes to bring it into position at the preprogrammed coordinates.

Spectral Color Measurement

By the late 1980s, the performance and quality of color measuring equipment and its use in the pressroom experienced a breakthrough by providing innovative opto-electronic equipment, and powerful computing systems, and by making components cheaper. Color measurement could be taken out of the lab and put to practical use.

Figure 2.1-134 shows a system with a *scanning spectrometer sensor head*. Such measuring systems can record the three coordinates for precisely specifying color in a color space (e.g., L*a*b*color space).

The components of the system in figure 2.1-134 and how they work are shown schematically in figure 2.1-135. The measuring patch is illuminated by an annular optic and the reflected light is passed to a fixed spectrometer in the unit via light guides/fiber optics as the measuring lens is moved. This spectrometer uses the light diffraction from a holographic diffraction grating, which passes the light received from the measuring patch to a row of diodes where the light is analyzed in the visible wavelength range in a narrow band process. The reflected spectrum from the ink is thus recorded as a kind of "fingerprint" of 36 measured values at wavelength intervals of 10 nm. The color values are then computed from the reflectance spectrum. Any color deviations in the print can be assessed as the human eye would see them.

To *control the inking* on the press itself, the colorimetric values have to be converted to settings for the



Fig. 2.1-134
Spectrophotometer (scanning spectrophotometer) for color measurement and control (CPC2-S, Heidelberg)

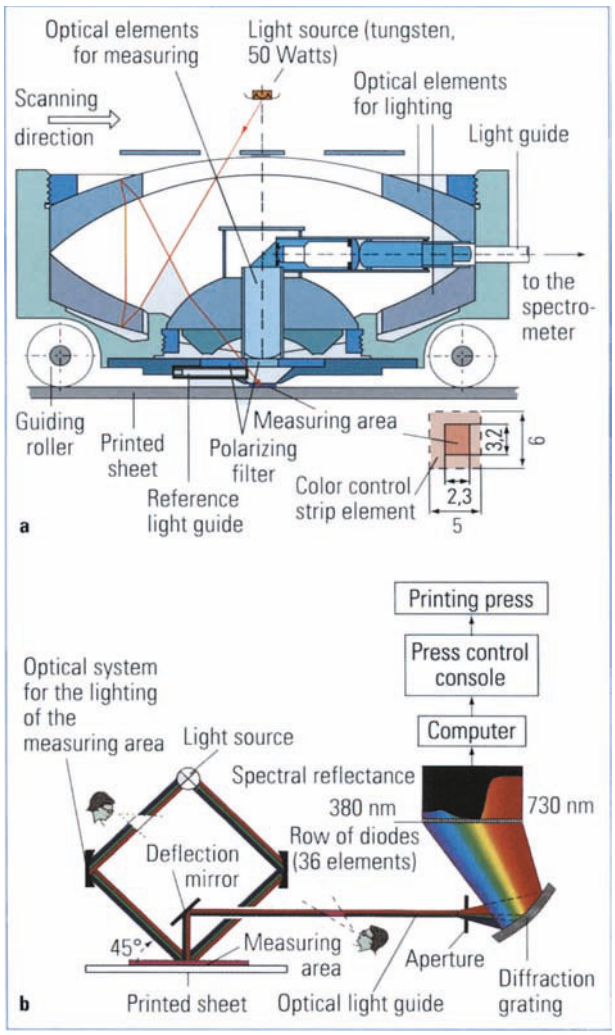


Fig. 2.1-135
How the scanning spectrometer in figure 2.1-134 works.
a The optical measuring system;
b Beam path for measuring the reflected spectrum and components for processing signals

inking units for the four process colors (cyan, magenta, yellow, and black). This meant creating *specific algorithms*, using empirical parameters to some extent due to the complexity of the numerous processes involved in measurement and printing and since results vary from one print stock to another. Adaptive, self-learning systems can improve the continuous conversion of readings to settings on the press as the readings themselves vary. Figure 2.1-136 shows how the inking on the press is controlled in simplified diagrammatic form.

Typically, spectral color measurement and control enables the color to be brought up to specification within three or four adjustment steps, whereas densitometric measuring techniques can take up to eight or ten adjustments, depending on how complex the job is and what the print stock is being used.

In the diagram showing how color values are converted to press settings in figure 2.1-136 an intermediate value is used, namely the *optical color density*: this enables the control algorithm in the press control console, which was originally designed for color density readings, to continue to be used. In this way both density and colorimetric readings can be used for control purposes.

A wide range of *handheld spectral color measuring devices* is also available and has, in fact, become virtually standard since around 1995. Nearly all such models include a facility for separately calculating and displaying optical density values from spectrum readings (spectrophotometer). This can also be done with colorimetric, tristimulus filter-based measurement instruments.

Image Measurement

Both optical density measurement and spectrophotometry are based on measuring patches (color control strips) that are printed together with the image. Knowing the area coverage of the individual color separations and using colorimetric measuring techniques it is, in principle, possible to use the printed image itself to control the press settings during *setup/makeready* and during *production*. However, the data from the prepress is needed for this, especially on the coverage of the individual colors. During the production itself, specially selected sections of the print image can be used (such as solid-tone patches of individual colors). As mentioned before for densitometric measuring systems, there are X/Y coordinate systems where the sensor head moves in two dimensions to specified coordinates in the test area. This is essential where the color control strips are staggered, that is, distributed over the image area, but they are also capable of recording and analyzing positions in the print image itself.

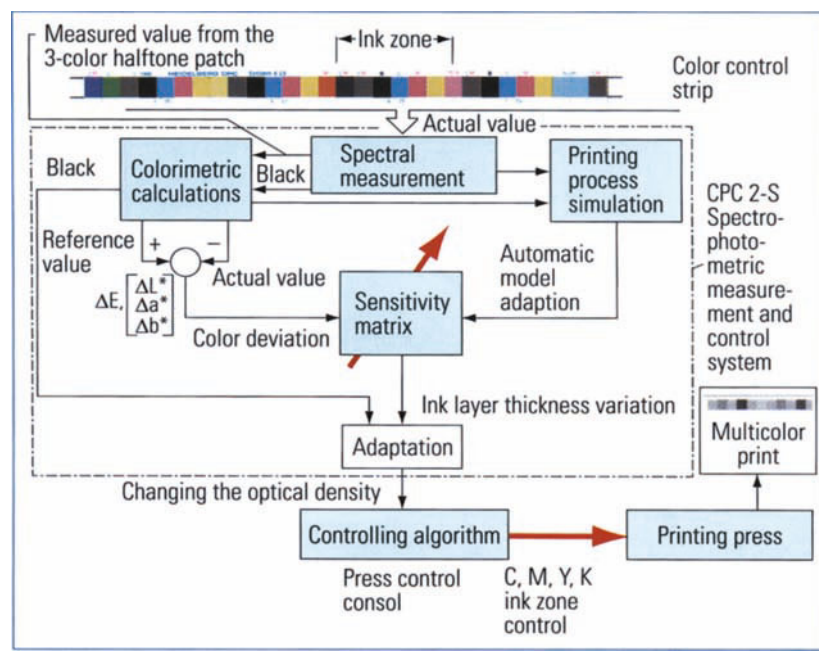


Fig. 2.1-136
Block diagram for converting the color variation ΔE to control variables for adjusting the ink supply on the press (Heidelberg)

The spectrophotometric measuring unit shown in figure 2.1-137 can cover the entire image area, scanning it at a resolution of approximately 2 × 2.5 mm². This system can be used for analyzing a series of consecutive control strips or test points distributed over the image area. Alternatively, predefined points in the image area can be selected and used for *measurement and control* purposes. One of the major advantages of such a system, which can scan the whole image area, is that as well as checking the print color it can also be used to *inspect the printed image* overall, i. e. for scratches or blemishes, using suitable image processing algorithms. This system can therefore be used both for conventional densitometry, spectrophotometry on print control elements and for checking the image itself.

Man-Machine Control Systems

With these densitometry and colorimetric systems, it is possible to control what happens on the press. Since, however, checking the printed sheets on the run involves the operator taking a sheet from the delivery as in figure 2.1-128, so that the checking takes place off the press, a closed *loop control circuit* in the strict sense of the term is not realized. The press operator determines the intervals at which checks are made and it is he who starts the checking process. The computer in the measurement and control system determines the deviations between the measured values and the setpoint values and calculates the adjustments that need to be made to the ink supply for the individual inks accordingly. Generally speaking, the density and/or color value readings and any adjustments required are first shown on the measurement and control system screen. The operator is then free to make adjustments/corrections based on his experience and to decide at the push of a button about releasing the values to the press for adjusting the printing units. In other words, it is the operator who completes/closes the feedback loop. In system terms, this is a "*sample-and-hold control*" with operator-controlled measurement and control cycles. Comparing the readings with the reference settings, and allowing for permitted tolerances, the press operator monitors the colors converging towards the setpoint and decides himself when to remove another sample sheet and whether those readings justify adjusting the press. The man-machine interaction governs the quality, and hence the cost effectiveness, of the printing process.



Fig. 2.1-137
Spectrophotometric measuring system for color measurement and control and for print image inspection and analysis (CPC 24/ImageControl, Heidelberg)

2.1.4.3 Register Measurement and Control

At the same time as measuring and controlling the ink supply/the color, the color register is measured and controlled: that is, the color separations are put into register in the individual printing units.

Once again, systems with different levels of automation are available. As detailed in section 2.1.5, this may be anything from simple visual aids (*optical magnifying glasses*) to handheld instruments that check the register reliably, quickly, and accurately from register marks aided by opto-electric components.

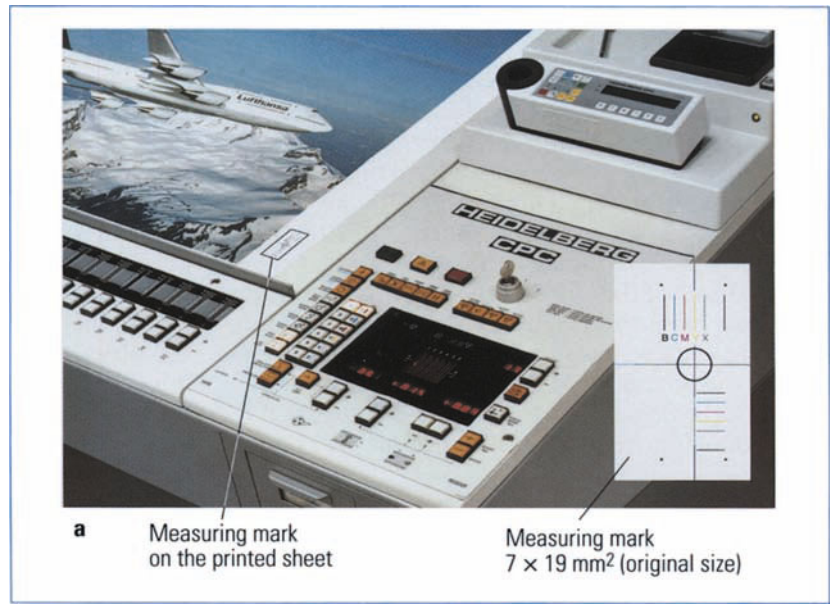
Figure 2.1-138 shows a *register measurement and control device*, which is also shown installed in the control console in figure 2.1-123, in more detail in terms of its constituent components and how it works.

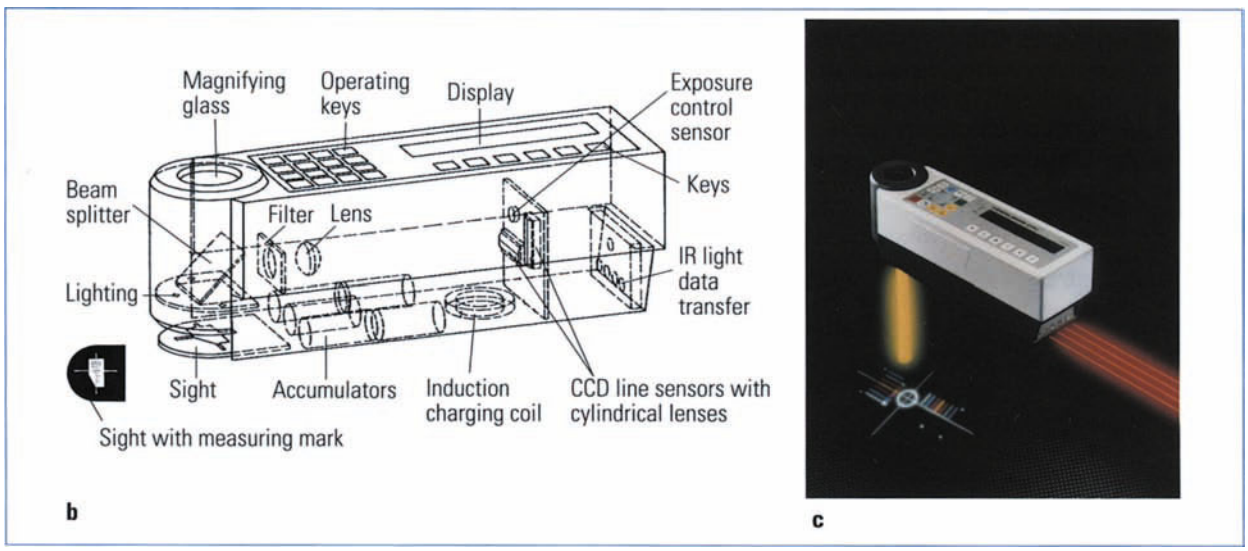
The cutaway view (fig. 2.1-138b) shows how the unit uses two high-resolution CCD line sensors (accurate to approximately 5 µm) to measure the distance between lines and register marks: one CCD line senors for the register lines for measuring the circumferential register, and one CCD sensor for the register lines in print direction to check the lateral register.

This measuring system is designed so that any variations in the register marks regarding reference values are passed to the computer in the control console via infrared light, from where the plate cylinders are adjusted.

Another register measurement system is shown in figure 2.1-139. The *video magnifying glass* can be used to

Fig. 2.1-138
Handheld instrument (register mark reader) for color register measurements of printed measuring marks.
a Register mark reader on the control console of a sheet-fed press and measuring marks;
b Electronic/optical components of the measuring instrument and a measuring mark "in the sight";
c Transmitting data to the press control console computer by infrared signals (CPC41 Register mark reader, Heidelberg)





display register marks in the image area on the monitor. By checking the register marks by computer and using appropriate image processing algorithms, any register adjustments required can be detected and quantified. The operator then adjusts the press accordingly.

Thanks to today's register systems used in the platemaking process, plates can be mounted with such a high degree of register accuracy that only minor corrections in accordance with the image are still necessary. These can then be carried out quickly and easily by the operator. Setting the ink supply correctly is the greatest challenge and also where the greatest potential for reducing makeready times lies. The register is generally set up at the same time as the ink supply; in fact, the correct color register is reached more quickly than the correct ink supply.

2.1.4.4 Inspection of the Printed Image

The ink supply and color register are not the only factors affecting print quality. The images themselves may

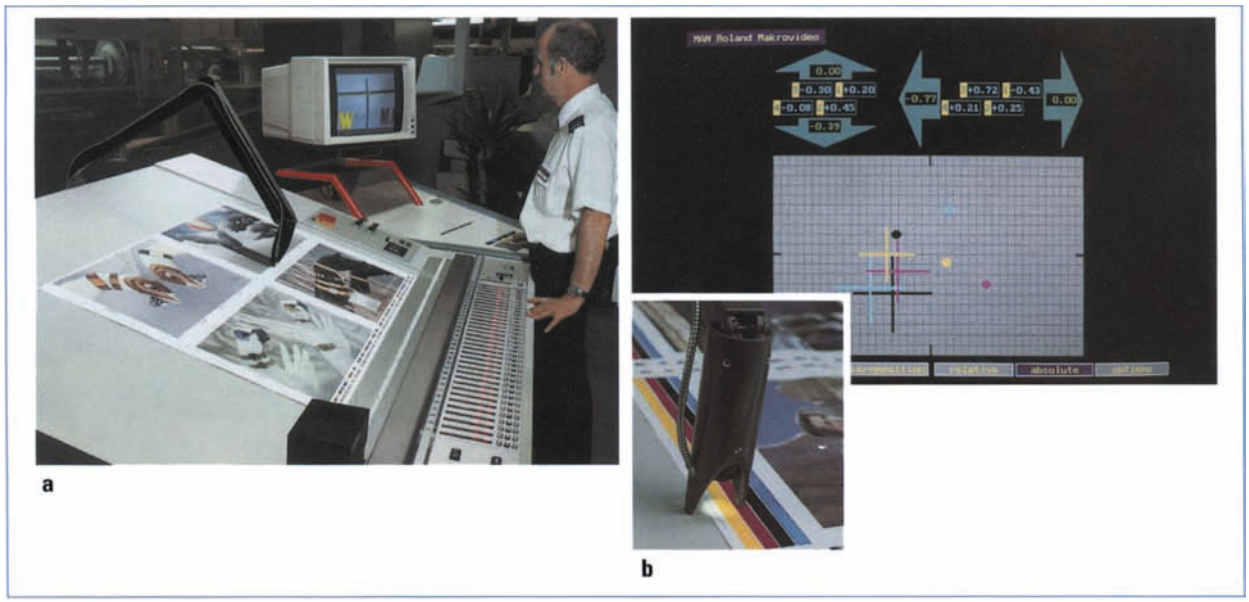


Fig. 2.1-139 "Video magnifying glass" for color register measurement and control.
a Video magnifying glass with color monitor on the control console of a sheet-fed offset press;
b Video magnifying glass with lighting unit and display of the register mark positions on the monitor (CCI, MAN Roland)

be particularly delicate, or the client may want particular details brought out. There could also be printing problems arising from problems with the paper feed or the print run itself which may not show up on any measuring elements. These may include such things as scratches because the paper is not feeding correctly or "hickeys" due to spots on the blanket.

To check the print quality, especially on fast moving webs in web presses, *visual inspection tools* are used that enable the operator to detect such faults quickly, or that warn him to take corrective action. Such monitoring systems rely mainly on sophisticated high-grade camera equipment.

By way of example, figure 2.1-140 shows an image captured and displayed on a color monitor. Any deviations in image quality, and in measuring marks in particular, show up quickly. With properly calibrated color monitors, *color deviation* between ok image (reference image) and printed image can be detected. But this depends largely on the skill of the operator since measuring color variations via video camera systems is a relatively inexact science.

Figure 2.1-141 shows a number of other examples of image inspection. *Splitting the display into two parts* to visually compare the reference image and current print image has proved useful. The system's high-resolution camera also spots small *measuring marks*, whose position indicates *color register problems* that can be passed on directly to adjust the plate cylinder settings.

Such high-resolution camera-based print monitoring systems generally look at just small sections of the print image, yet can monitor the *entire print image* if powerful and sophisticated enough. Depending on the computing power and memory available, these systems can be used to monitor the print run at high speeds in *real time*, process data immediately and pass warnings on to the operator as necessary. This enables the operator to monitor the status of the print run or analyze the quality from a single copy in detail. The printed image can be displayed on screen at specified intervals while, within the press itself, data can be read and analyzed in real time.

Such camera-based web monitoring systems are mainly used with *web-fed offset presses*; but there are also systems that can record and analyze part or all of the print image in sheet-fed offset machines.

Figure 2.1-142a shows a camera system fitted to the delivery of a sheet-fed offset press. The cameras are in-

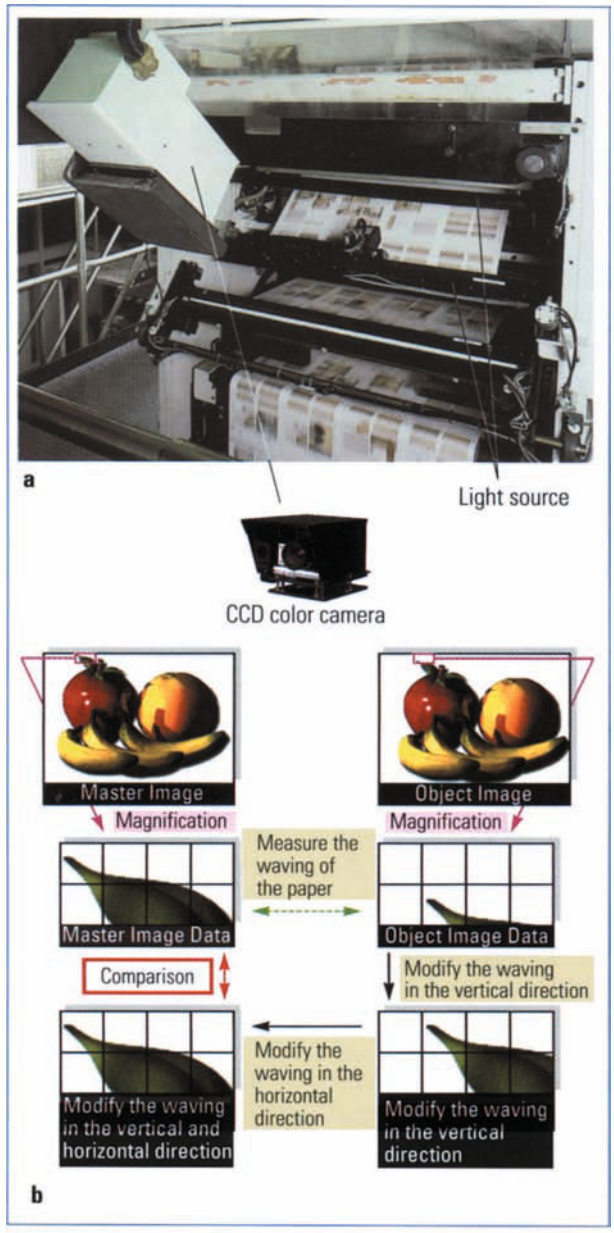


Fig. 2.1-140 Image inspection system on a web offset press.
a CCD line color camera and illumination in the superstructure of a web offset press;
b Example of image inspection and web positioning/web guiding system without special measuring marks (DOPRIME, Dai Nippon Printing)

tegrated into the delivery and record the evenly conveyed sheet.

Using two CCD cameras, the system shown in figure 2.1-142b scans multicolored printed sheets on a line by line basis where readings are taken on the impression cylinder of the coating unit or last printing unit.

Such systems are technologically complex and do not yet meet the measuring quality required for automated color and register control purposes. Systems still have to be developed specifically for this purpose.

Figure 2.1-143 shows the basic outline of an in-line print control system for a sheet-fed offset press. There are a number of technological challenges here. The control system has to be capable of resolving the geometry and colors of the print image, work fast enough to record and process data on the run, and position the printed sheet for measurement purposes on the cylinder. The measuring optics cannot generally handle major positional variations so that, as figure 2.1-143b shows, blowers have to be used to blow the sheet onto the impression cylinder to ensure that the rear edge of the printed sheet is always at the same position on the cylinder when it leaves the nip between the blanket and impression cylinder.

The actual print image is compared with the reference image using *image processing tools*. If it is out of true, there are a number of options available. The image can be displayed on screen, *marking the area* where it has been seen to be out of register, and the operator can then intervene (fig. 2.1-143c). Any print defects can be easily tagged by initiating an *alarm* and/or inserting a *marker strip* (tape inserter) in the delivery pile, as in figure 2.1-143b (the pile must then be sorted manually). The system in figure 2.1-142b has a double delivery with a *waste diverter*, which can be used to sort out any misprinted sheets automatically. Figure 2.1-143c shows a number of examples of detected quality flaws, such as splashes of oil on the blanket resulting in smudges on the print, colors out of register that show up in close register areas, and color defects, which show up as gray scale variations on the camera color channels. The operator can spot these but the monitor display, with alarms if fitted, will guide him to make the necessary visual inspection. This design dates back to around 1987.

The possibilities offered by opto-electronics, powerful color camera systems, and image processing algorithms have resulted in a wide range of specialized systems. Special applications have been developed for different printing methods and production systems,

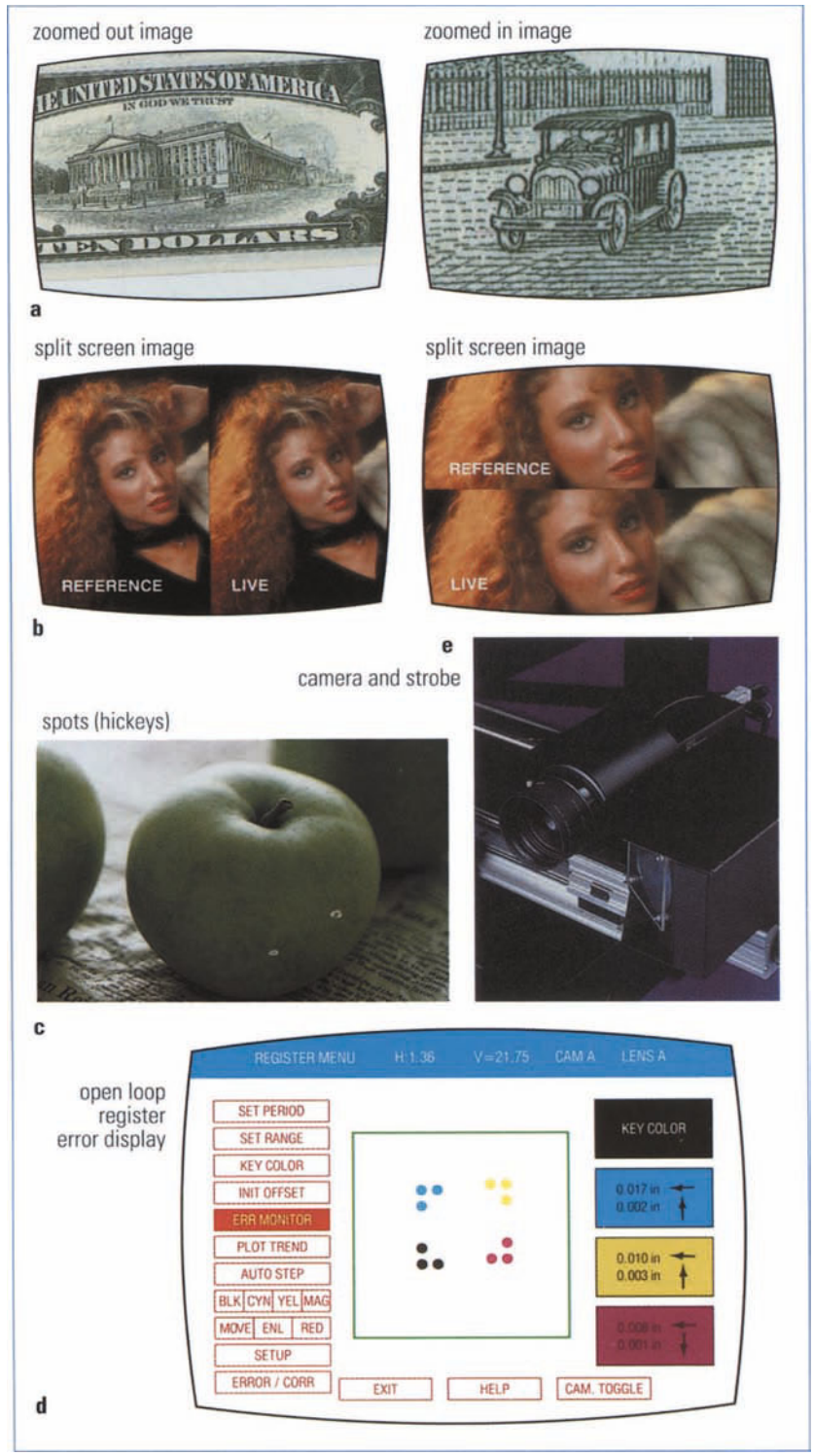


Fig. 2.1-141
Print image inspection examples (recorded with CCD array color camera).
a Details of monochrome print image;
b Visual comparison of the coloring on the color monitor with a multicolor print (split screen image);
c Spots (hickeys) in the print image;
d Color register marks in the print image (monitor display);
e Camera and illumination system (Image Inspector, Baldwin)

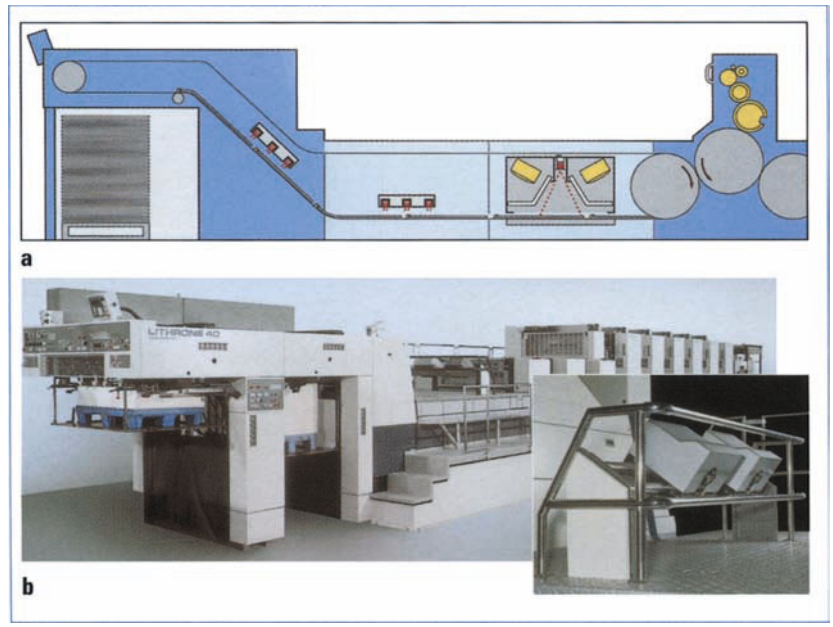


Fig. 2.1-142
In-line print quality inspection in sheet-fed offset presses.
a Inspection of a printed sheet using color camera system in the extended delivery (Qualitronic/Rapida 104, Eltromat/KBA);
b Print quality assessment system for inspecting printed sheets on the impression cylinder of the coating unit, using two color camera systems (PQA/Lithrone 40, Komori)

especially for web offset and the production of special printing products, such as labels (see sec. 2.5.3, e.g., fig. 2.5-23) and security printing. The most commonly used applications are those for web monitoring in web offset and rotogravure; yet there are also models for special "stand-alone" print quality measuring and checking equipment.

Figure 2.1-144 shows an example of such a *print quality/image inspection system* that can be used to check multicolor sheets across the entire sheet once they have been printed. Any sheets that fail to pass inspection can be diverted via a waste diverter.

There are not as yet any image inspection systems that can measure and control color in-line with the necessary precision while at the same time being financially viable. All the leading press manufacturers and suppliers are, however, working on them.

The next section looks at special systems for in-line print quality measurement and control.

2.1.4.5 In-line Print Quality Measurement and Control Systems

In-line Color Measurement Systems

Figure 2.1.-145a shows one of the first installations (around 1985) of an *in-line color measuring system* for sheet-fed offset presses.

This system uses a densitometer measuring head/bar to read the color control strips on the impression cylinder of the last printing unit. The readings are displayed on a monitor fitted to the press control console. The operator calculates the ink settings required from the density readings, and sets the individual inking units by remote control from the press control.

If such control systems are not very widespread as yet, this is probably because they are very expensive and not very cost-effective. More importantly because they are not very powerful when it comes to *setting up* print jobs. It is easier to use systems for monitoring on the *run*, which do not require high-precision absolute readings, but merely indicate if the print settings/reference values are off. With current offset presses, on the other hand, there is no need to monitor the ink feed continuously on the run. Once set up, presses print in a very stable condition, so the off-line print quality measurement for the setup/makeready phase and checks on the run usually suffice.

From an economic standpoint, *in-line color measurement systems* are generally more suitable for web printing than sheet-fed printing presses. This is, on the one hand, based on the comparison of the additional costs that arise from an in-line measurement system with the high base costs of the production system for web printing systems and on the other hand also due

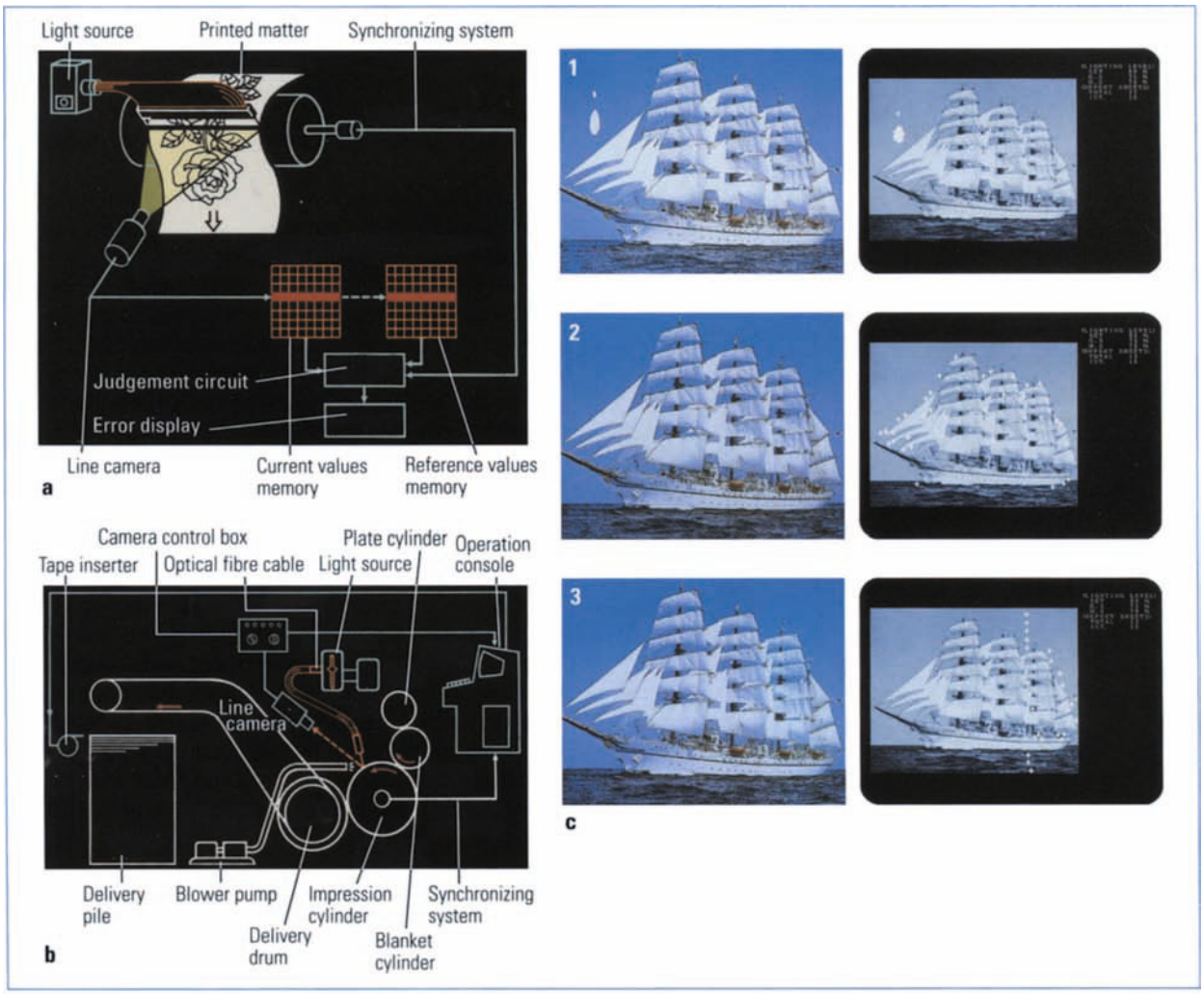
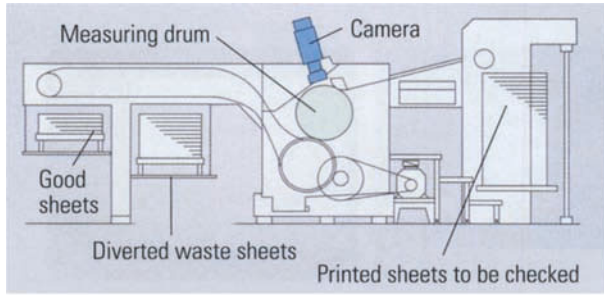


Fig. 2.1-143 Print quality control system for sheet-fed offset presses.
a Measured-value recording and image processing;
b Arrangement of system components in the printing unit of a sheet-fed offset press, with device (tape inserter) for marking faulty sheets in the delivery stack;
c Typical print image defects and corresponding displays on the color monitor
1 Spots, due to inking problems, for instance oil drops on blanket
2 Colors out of register, visible in fine structures of the image
3 Serious color variations detected by changes in gray scale readings of the camera system (Mitsubishi)

to the advantages of *constant quality monitoring* at extremely high production speeds. Technical concepts for in-line color density measurement are based on *color control strips* that are printed together with the image, whereby the measurement takes place either via a measuring head mounted at right angles to the direction of web travel or a measurement system that simultaneously records all measured values across the width of the web. There are examples of both of these concepts installed, although *scanning systems* are more common, primarily due to the significantly lower technical expenditure. A *web-wide measurement sys-*



a



b

Fig. 2.1-144
Measuring equipment for the inspection of printed sheets.
a Diagram of the "measuring machine" for printed sheet inspections;
b Color camera system for inspection of the entire sheet (Symphony Color SLC/SKS, DAC Engineering/Hirose)

tem has the advantage in web offset printing of recording the zonal measurement values for color control quickly at the makeready stage and above all from the same web section. For *production*, on the other hand, the successive recording of measured values with a scanning system that only releases all the zonal measurement values after measuring several web sections/signatures is sufficient due to the stability of the ink feed in production.

Figure 2.1-145b shows an example of a measuring unit that determines color values on color control strips by a *measuring head,* which moves at right angles to the direction of web travel. It should be emphasized that the measurement systems can be designed in such a way that only narrow measurement sections in the direction of print are needed (e.g., 2 mm at a width of approximately 5 mm) and therefore hardly any detrimental paper cutting is needed or that these narrow color control strips can be incorporated in the gutter or trim edges of the end product.

Once in-line color measurement and control systems become available that can successfully handle a number of tasks at once, such as *color control, register, and image inspection*, they could really make a breakthrough into the market. When it comes to *certifying* businesses to ISO 9000, which imposes high quality requirements for printed products such as are required in the packaging industry, using such measurement systems becomes interesting. The challenges to designers and manufacturers are mainly in terms of optimum system configuration, designs and cost structures to give a viable return on investment.

Figure 2.1-146 shows a design for a *multi-functional in-line print quality measuring system*, using advanced technology to capture the entire print image in fine resolution (approximately 1 × 1 mm²), plus a colorimetric system for color-measurement and controlling the inking units. Sophisticated fiber optic systems, especially designed CCD area arrays for measuring color across the whole format simultaneously with four channels to carry out colorimetric and black measurements, and high-precision optical modules were required.

Figure 2.1-147b shows a color monitor on the control console of a sheet-fed offset press, showing a printed sheet display supplied by the measuring system as shown in figure 2.1-146. Figure 2.1-147a shows how the signals are passed from the measuring bar via fiber optics to the CCD array in the receiver unit. This system not only monitors printing on the run in real-time, that is, on a sheet by sheet basis, but can also be used for makeready purposes, and in particular obviates the need for color control strips. With this system, the digital data for the individual color separations is provided from prepress, or else a copy is measured to serve as a reference sheet.

This system is not widespread at present, despite successful test installations and field trials and this can mainly be attributed to the costs involved. These kinds of systems are, however, set to become more popular as high-tech components in printing become more cost-effective. Systems like this will be another major step towards ensuring output, increasing productivity and making life easier for the operator.





Fig. 2.1-145
In-line color density measuring systems.
a In-line color densitometer for use with print control strips on the impression cylinder of the last printing unit in a sheet-fed offset press (Reprotest);
b Scanning system for in-line color measurement (optical densities, colorimetric values) on web offset printing presses (ColorQuick, Graphic Microsystems)

In-line Color Register Measurement System

As illustrated in the previous sections, in-line color register monitoring is feasible with *web-fed presses*, given the existing measurement systems available.

Particularly in terms of investment, the use of advanced measurement and control systems as required for register control at high speeds (up to 15 m/s) can be extended to the entire production system as a whole. Such systems are particularly necessary in web-fed presses, with their high output and correspondingly high scrap rate if problems occur, not to mention the fact that with production systems that work on a reel to reel basis it is impossible to divert individual sheets for checking off-line.

Figure 2.1-148 shows a measuring system especially designed for register control. A measuring head at right angles to the print stream monitors small register marks in the gutter or trim edges, or those that can

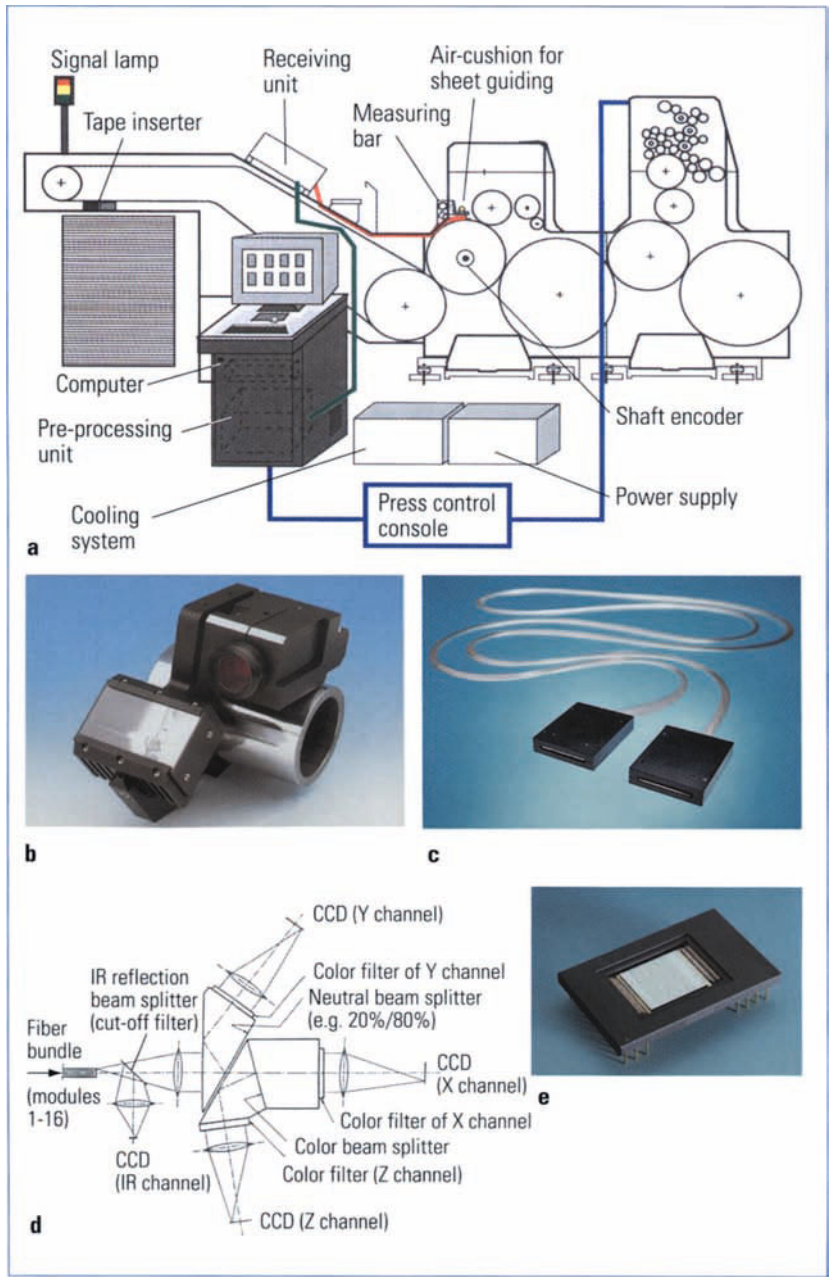


Fig. 2.1-146
In-line color measurement and control, and image inspection system.
a System components and their locations in a sheet-fed offset press;
b Sensor module used as part of the measuring bar (16 modules across the full width of the sheet, module width 65 mm) with illumination and optical sensors;
c Fiber optic module for transmitting measuring signals (module width 65 mm) to the receiver unit;
d Beam splitter for splitting the recorded light into the three color channels for colorimetric measurement (with tristimulus filters) and in IR channel for measuring black;
e CCD receiver array for measuring color signals from the measuring bar (16 modules for 32 ink zones) for one color channel (CPC 23, Heidelberg).

be "hidden" in the print image itself. Similar systems are so sensitive that they can reliably sense measuring targets of less than 1 mm in diameter and use them for control purposes (the smallest targets at present are approximately in the range of 0.2 to 0.3 mm in diameter).

In-line color register systems have also established themselves in practice and proven themselves cost-effective in *sheet-fed offset*.

One such control system is shown in figure 2.1-149, where two register sensors on either side margin of the printed sheet monitor register marks with the press run-

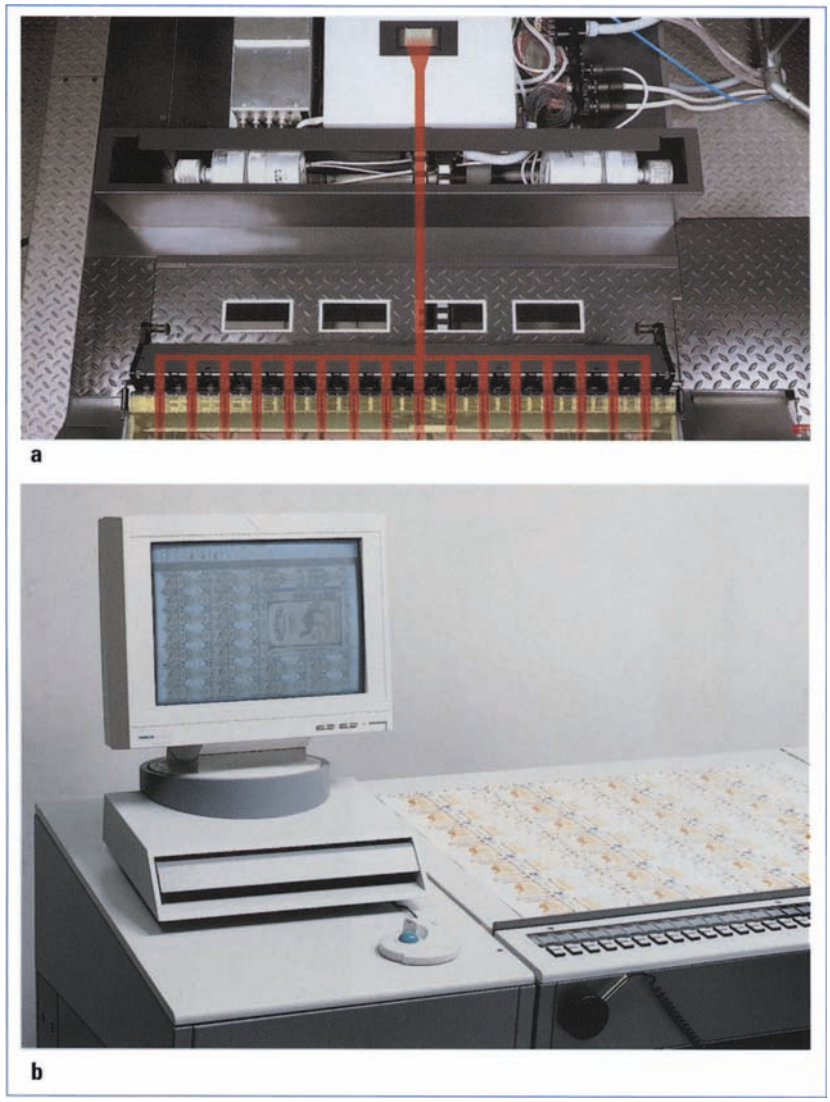


Fig. 2.1-147
In-line image inspection (with measuring system, shown in fig. 2.1-146).
a Transmitting optical signals from the measuring bar (16 sensor modules) on the impression cylinder via fiber optics (and beam spitter) to the CCD array in the receiver unit;
b Printed image (with zoomed-in detail) displayed on the color monitor of a press control console (CPC 23, Heidelberg).

ning at full speed. The sensors are fitted near the impression cylinder on the last printing unit as shown in figure 2.1-149b. The readings can be used directly to make the necessary circumferential, lateral, and diagonal (cocking) registers adjustments. The register marks are shown in figure 2.1-149a. Each mark is approximately 1 mm × 1.5 mm.

2.1.4.6 The State of the Art in Remote Control, Measurement and Control Systems

To summarize, it can be said that the present position in terms of remote control, measurement and control systems is as follows. Powerful measurement and control systems are available for a large variety of printing systems, from web-fed offset presses/production systems, high-quality, large size multicolor to small size, simple sheet-fed offset presses. In the last ten to fifteen years, using them in printshops has made working much easier and improved quality enormously, not to mention profitability. Print quality has become a measurable variable and the print process itself can now be measured and controlled based on objective data.

Depending on the demands print buyers make on their printers, print-quality control systems can be installed

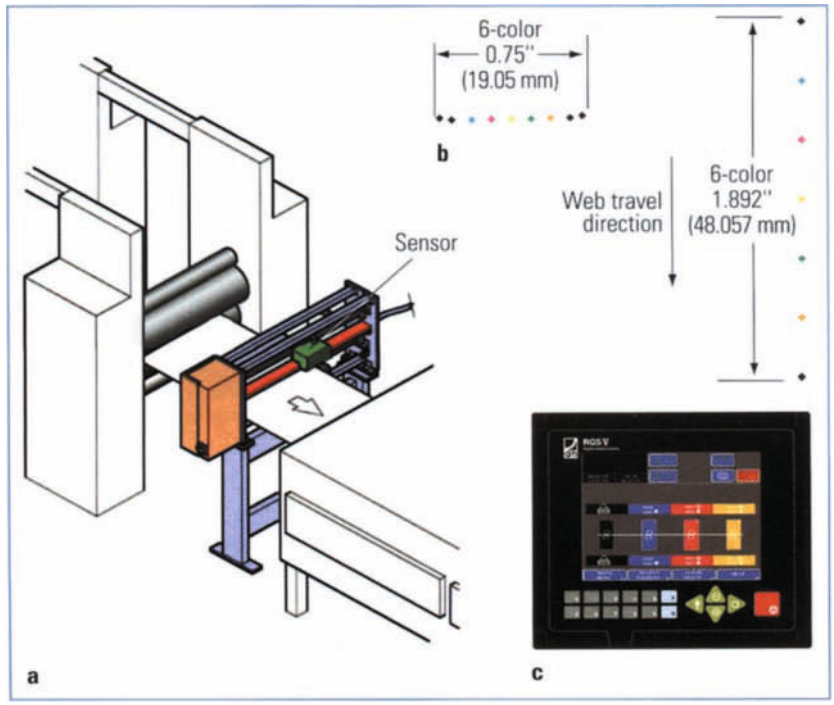


Fig. 2.1-148
Color register measurement system for web-fed offset presses.
a Optical sensor fitted between the last printing unit and the dryer (contact-free web guidance in the sensor area through flow mechanical effect);
b Color register mark systems for multicolor printing, arranged at optionally different positions in the print area (size 1 mm × 1 mm);
c Monitor display with register setting controls (RGS V Air, Quad/Tech Intern.)

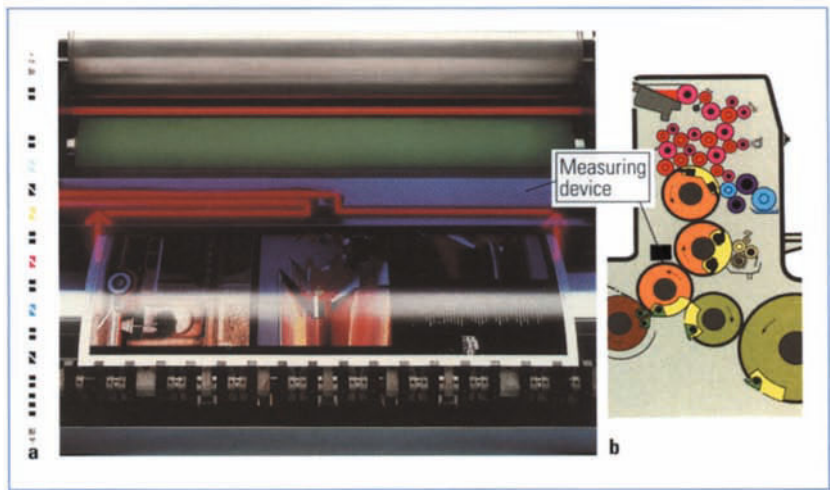


Fig. 2.1-149
In-line color register measurement and control system for sheet-fed offset press with two moveable sensors for measuring register marks in two tracks on the printed sheet.
a Circumferential and lateral register marks (approximately 1 × 1.5 mm²);
b Arrangement of sensors in the printing unit for measurements on the impression cylinder (CPC42, Heidelberg)

and tailored to meet those requirements. Whether they use densitometric or spectral measurement or off-line and/or in-line color and color register measurement and control systems depends on the quality requirements and working methods at the individual company. Either way, quality assurance calls for both control consoles with simple, reliable press settings and color and register control systems that can make both quality assessments independent of the operator's subjective observations and also perform adjustments quickly and easily on the run, setting up in just a single step if possible.

Figure 2.1-150 shows a state of the art measurement and control system for a sheet-fed offset press, together with a structure for describing the different possibilities and components for automated print quality measurement and control.

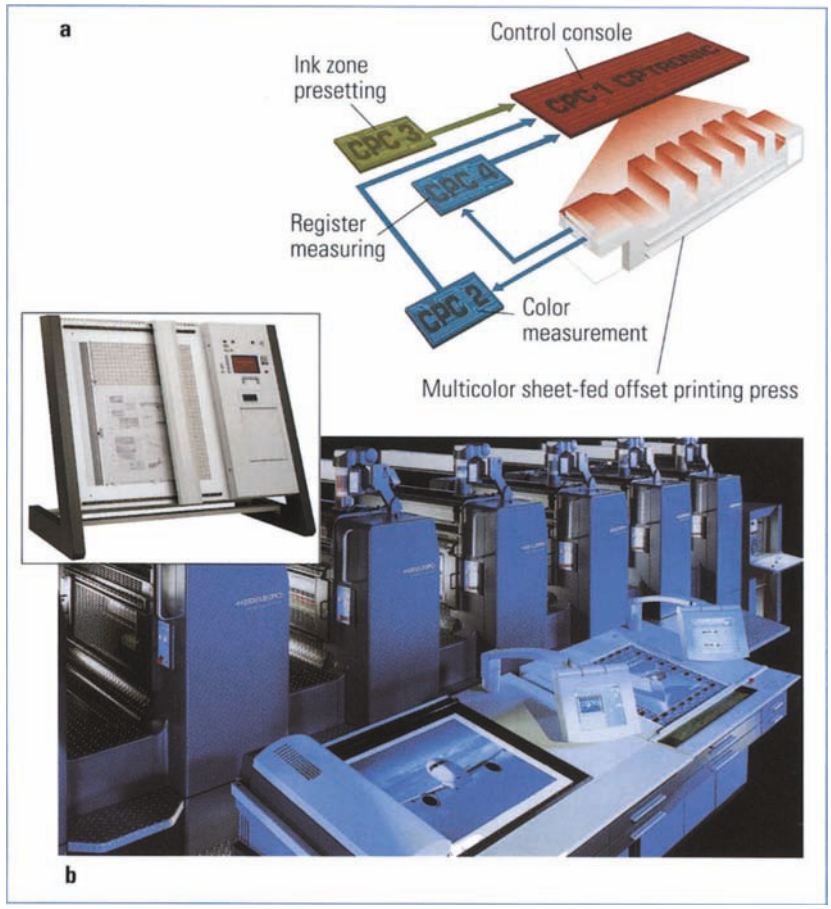


Fig. 2.1-150
Modular structure of a remote control, measuring and control, and presetting system for printing presses.
a Modular structure of a computer print control system for remote control and automation during setup, on the run and between jobs, with the components: control console (CPC1), color measurement and control (CPC2), register measurement and control (CPC4), and ink zone presetting (CPC3);
b Example of a sheet-fed offset press with control console, off-line color measurement and control, and image inspection system, in-line register control and ink zone presetting via prepress interface or data carrier with readings from the plate image reader (Heidelberg)

The previous sections have dealt with trends and the potential for further improvements in individual areas.

The next section will detail automation methods and what can be done with the remote control, measurement and control systems surveyed.

2.1.5 Automation in Print Media Production

Based on the example of offset printing, the options, methods, and systems available to automate the process of printing for longer multicolor print runs within the entire printing process is described in this section. The information given applies to sheet-fed offset as well as web-fed offset presses.

The production speed of the multicolor presses available, which is typically approximately 15 000 impressions an hour for sheet-fed presses and approximately 60 000 impressions an hour for web-fed presses, is at a very high technical level, and consequently, increasing these speeds is less of a priority than efforts and measures to reduce time spent on preparing the press prior to printing production (makeready time).

The efforts to shorten the job makeready time go hand-in-hand with endeavors to minimize waste, that is, the production of unsaleable printed sheets. As already mentioned, before the production of a print job can start, the press must be set up as regards paper format, ink and, in particular, the set of printing plates. The "traces" of the preceding print run have to be eliminated first; for example, the inking units must be cleaned and the plates for the completed job removed.

Once the new plates are mounted, the feeder is supplied with the necessary paper and the ink fountains filled with the desired inks in the specified sequence for

multicolor printing, including special inks, if required. The ink feed and color register must be adjusted to the production of the print job.

The basic operations for setting up a press are illustrated in figure 2.1-151. The typical time savings are shown comparing manual *preparation and makeready of the press* for the next print run with automated makeready operations. Judicious use of automated processes is bound to lead to significant reduction in makeready time. With sophisticated systems a typical four-color job can nowadays be set up in about 15 to 20 minutes as compared to a makeready time of 60 to 90 minutes for a purely manual mode of operation. The number of adjustments required to arrive at the desired ink setting, in particular, has been considerably reduced, leading to drastic reductions in waste sheets.

Another requirement on the automation of makeready is to simplify press operation for the operator, that is, to relieve him of physically demanding work, to prevent possible dangers within the production process, and to enable work to be performed in clean and environmentally friendly surroundings. The end result of all this is that the operating personnel are able to devote themselves fully to the actual specialist task, the economical and on-schedule production of consistently high-quality printed products. Technical equipment currently available largely meets such requirements.

In the following sections the individual makeready and preparatory operations are described with examples that are representative of the technologies being developed and supplied by all leading manufacturers.

2.1.5.1 Wash-up Procedures

In the offset printing process the inking unit, the printing plate, the blanket on the blanket cylinder, and the impression cylinder must be cleaned for each job change or interruption in accordance with operating conditions and requirements. It may even be necessary to clean the blanket cylinder during the print run, if, for example, paper dust or particles from the paper surface build up on the blanket and cause faults or defects (e.g., hickeys) during the production run. Similarly, the printing plate may also need cleaning during production, if the printing plate's surface has changed as a result of malfunctions in the dampening and inking supply or of faults induced by paper-related factors impairing printing quality. The impression cylinder may need to be cleaned, if, on the one hand, ink has been printed on it by mistake or, in the case of perfecting, if ink set-off on the surface becomes a problem.

When changing a job, the ink left over from the old job must be removed from the ink fountain, if a different ink is to be used for this printing unit, such as ink for UV drying or ink of a different color.

There are automated devices available to clean inking units and the cylinder surfaces referred to above. They provide technical solutions based on various design concepts with differences in effectiveness, the chemical agents required for cleaning, and the degree of automation.

The press diagram shown in figure 2.1-152 illustrates how the *blanket and impression cylinders* of a sheet-fed offset printing unit can be cleaned by a single wash-up unit installed in a given position. Figure 2.1-153 shows in greater detail how this system operates with regard

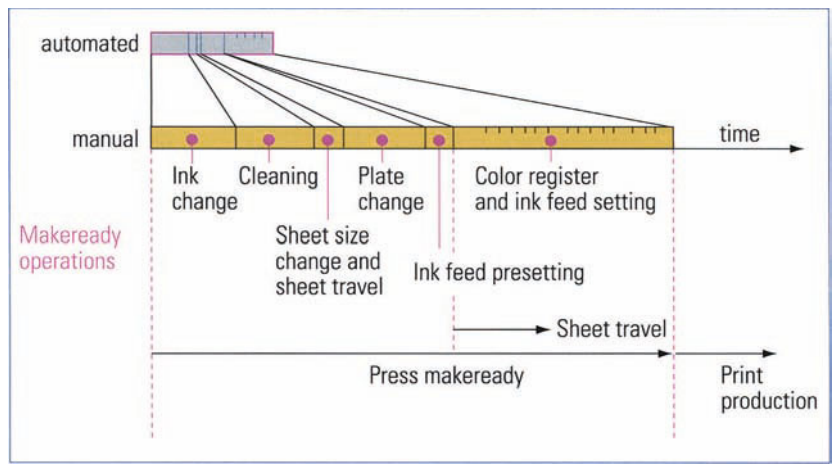


Fig. 2.1-151
The operations required for the makeready a printing press for the production of a multicolor print job (Comparison of the times taken for manual makeready procedures and makeready procedures assisted by automation)



Fig. 2.1-152
Wash-up/cleaning system for blanket and impression cylinders (1), wash-up device for inking unit (2) on the printing unit of a sheet-fed offset press (SM 74, Heidelberg)

to its wash-up position for cleaning the blanket cylinder and the impression cylinder, as well regarding advancing the cleaning cloth and pressing it against the soiled surface by means of a diaphragm that can be controlled by compressed air. The cleaning cloth width is equal to the width of the printing unit. The cleaning liquid is finely metered in accordance with the degree of soiling and sprayed onto the surfaces by nozzle rows. Used cleaning materials can be disposed of easily and to some extent recycled.

Figure 2.1-154 shows a cleaning device that cleans by means of a brush roller. The cleaning liquid is transferred to the surface via this brush roller in order to remove the dirt particles; the chemical cleaning process is assisted considerably by the mechanical motion.

Figure 2.1-154 also shows how an *inking unit can be cleaned* by a special spraying device incorporated in it. Located opposite the spraying system there is an ink trough, which is used to squeeze off the ink on a roller that is in contact with the final inking form roller (see also fig. 2.1-152). If necessary the entire inking unit can be cleaned in this way. This inking unit cleaning process can be automated, that is, supply, carrying-off, and removal of residual ink takes place via a control system. However cost/benefit calculations very often fail to justify a high level of automation.

If disruptive elements have built up on the blanket of the blanket cylinder (or on the printing plate) during

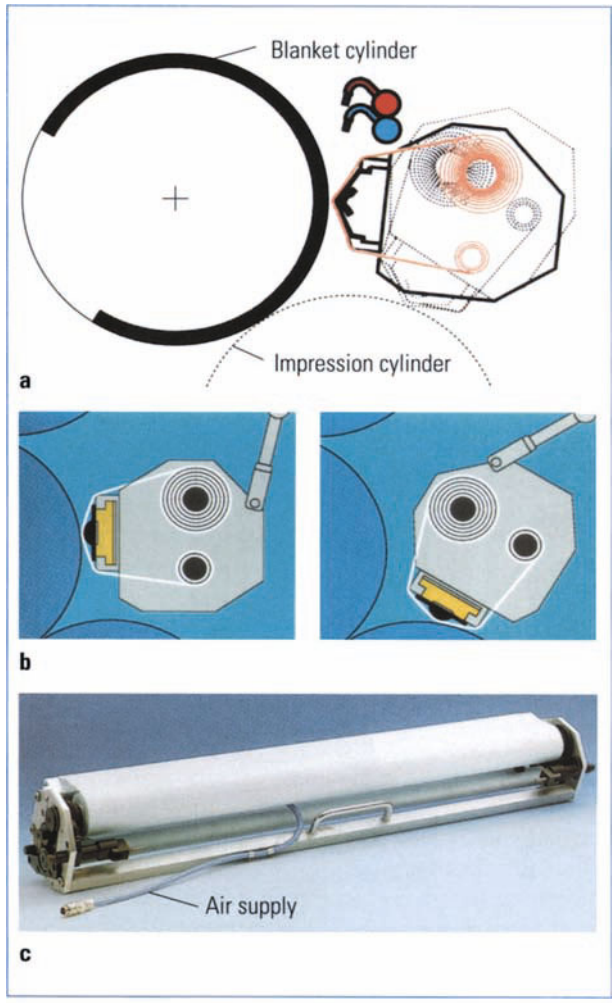


Fig. 2.1-153 Convertible cleaning system with washing cloth.
a Washing cloth reel system with diaphragm (pneumatically controlled) and liquid feed for cleaning operations (two systems);
b Cleaning device that can be positioned on the blanket cylinder or impression cylinder;
c Cleaning device with compressed air supply (Heidelberg)

printing (e.g., particles of paper or dirt that show up on the printed image), there are special devices, called "*hickey removers*," which will remove the disruptive elements in a selected narrow zone of the blanket cylinder by means of a rubber blade.

2.1.5.2 Plate Changing

Removing the printing plates from the preceding job and mounting the printing plates for the next job can

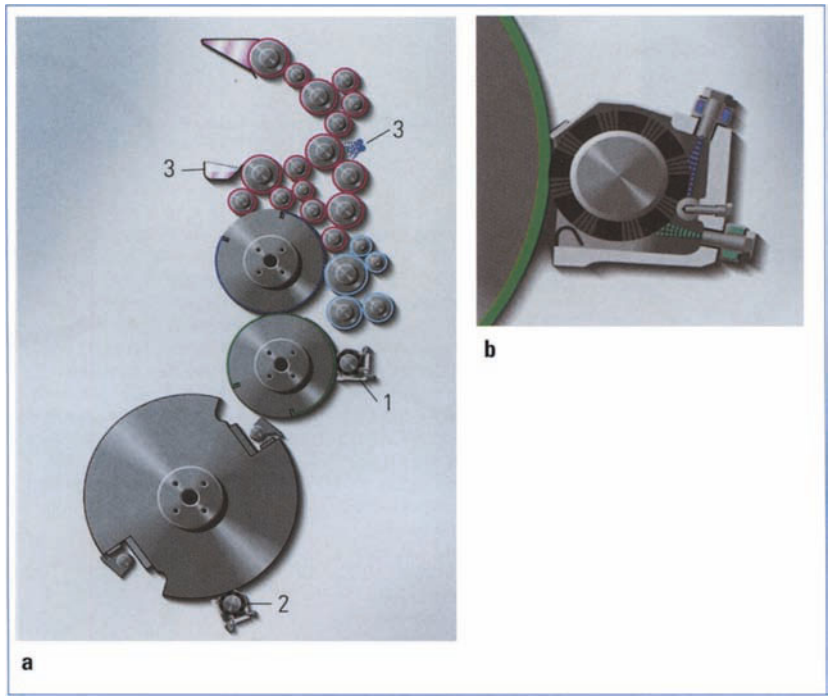


Fig. 2.1-154
Automated washing equipment with cleaning brush roll.
a Printing unit with washing equipment for blanket cylinder (1), impression cylinder (2) and inking unit (3);
b Blanket wash-up device (1), (Roland 700, MAN Roland)

take place at various stages of an automated process. Plate removal and feeding operations may be performed successively for individual plates with the assistance of the operator or fully automatically by means of cassette systems with no operator intervention once the change-over process has been initiated. The first designs for automatic plate changing systems for sheet-fed presses came from Japan around 1990.

When mounting a set of printing plates for a multicolor job, it is essential that the printing plates are clamped in accurate register on the plate cylinder. This is achieved by means of the register holes on the printing plate and suitable guide systems. It implies, of course, that in prepress the color separations will have been exposed in accurate register on the printing plates.

The requirements for the reliability and efficiency of automated plate feed systems are very exacting, since accurate positioning of the plate in the printing unit can be achieved even with manual plate feed because of the high-quality register systems available in prepress and the press. The particular advantage of automatic plate feed is that no manual clamping of the plate is required, no operator-related factors are in effect, and plate change-over can take place on all printing units of the press at the same time (not always synchronously – this depends on the cylinder arrangement and cylinder position in the several printing units regarding the cylinder gap).

Various stages of the *automated plate feeding* operation are shown in figure 2.1-155. First, the plate is prepared/placed ready in the printing unit for the new job, and then the plate is placed ready for mounting on the plate cylinder, which is followed by the automatic feeding and clamping process. Figure 2.1-155b shows how the plate is fed into the plate cylinder's clamping system and how loading systems are designed.

Another system in cassette design is shown in figure 2.1-156. Figure 2.1-157 shows how plate removal and plate feed can be done automatically via a *cassette system*.

There are designs for an automatic plate change, where the printing plates for several jobs can be stored in one cassette in the correct sequence. This means that the plates for several successive jobs can be ejected and loaded automatically. Such a system is shown in figure 2.1-158. However, these multi-plate cassette systems might prove to be troublesome in the case of malfunctions or if rescheduling measures have to be taken on short notice, for example changes in the press assignment or the processing sequence of orders.

Automated plate changing systems are also used on web offset printing systems. Figure 2.1-159 gives an ex-

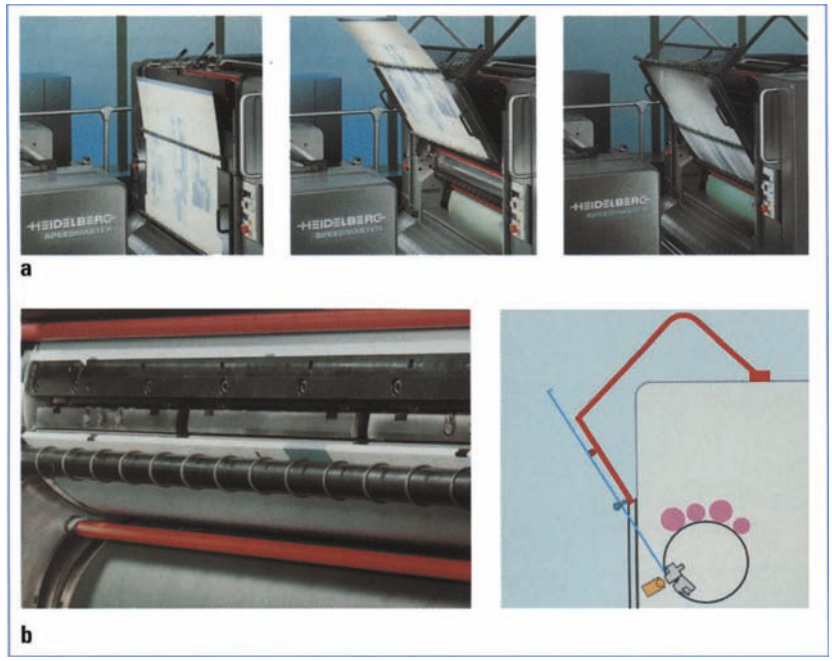


Fig. 2.1-155
Automated plate feed on the printing unit of a sheet-fed offset press.
a Feeding the plate;
b The structural design of a plate clamping mechanism (SM 102/Autoplate, Heidelberg)

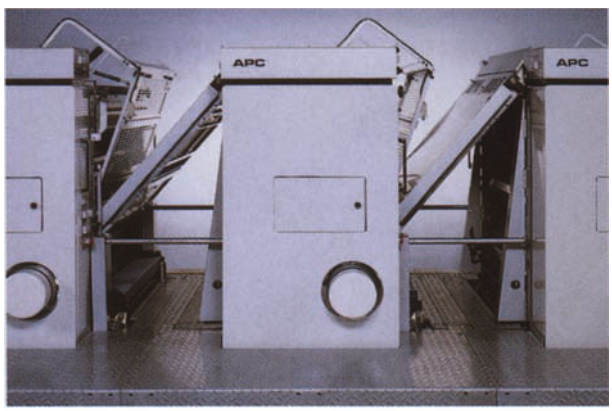


Fig. 2.1-156
System for automated printing plate change on a sheet-fed offset press (Lithrone/APC, Komori)

ample of how the plates for the upper and lower printing unit/couple on a blanket-to-blanket unit are changed by means of a cassette system.

2.1.5.3 Sheet Size and Paper Travel Adjustment

The feeder and delivery of a sheet-fed offset press have to be adjusted if there is a *change of paper format* from one job to the next. The positioning of the paper pile in the feeder and the setting of the suckers to pick up the sheet and transport it into the first printing unit, as well as the sheet guidance and alignment elements on the feeding table (guide rollers, front and side lays), all need to be adjusted. The blast and suction air systems that support paper travel must likewise be set to the new format. With present-day technologies for remote adjustment and position measurement this procedure can be automated. For example, the format specifications can be entered on the press control console and the paper guiding elements repositioned as a result of this. This is possible for both sheet feeders and sheet deliveries.

Figure 2.1-160b shows a sheet feeder with a suction head together with a display on the operator's control panel (fig. 2.1-160c), from where the paper format, as well as the adjustments required as a result of a different paper thickness, can be set by remote control or automatically in the feeder area. Figure 2.1-160a shows the infeed process over the feed table to the first printing unit. The sheet guidance elements and the stops for aligning the sheet before it is taken over by the feed system to the first printing unit are adjusted by remote control.

On *perfecting presses*, which can print both sides of a sheet in one sheet pass, both the gripper system of the

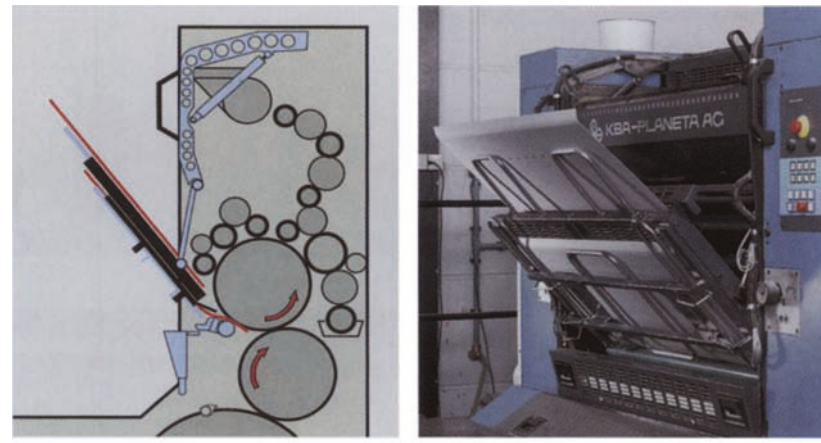


Fig. 2.1-157
Automated change of printing plate using a cassette for plate removal and plate feed for the next job on the printing unit of a sheet-fed offset press (Rapida 105, KBA)



Fig. 2.1-158
Fully-automatic printing plate change on a 4-color sheet-fed offset press with multi-plate cassette system (SM 102/Multiplate, Heidelberg)

sheet reversing unit and the suction systems must be adjusted to the sheet size when the press is converted from straight printing to perfecting. Depending on the structural design of the press, this can be a very time-intensive and demanding manual process. More recent press engineering solutions provide the means for an automated, easy, and safeguarded adjustment by the operator.

Long print runs on highly productive sheet-fed offset presses necessitate multiple *pile changes*, which means that press stoppages and restarts to change the piles are inevitable; yet feeders making possible a fully automatic pile change have been developed for sheet-fed offset presses. A feeder of this type is shown in figure 2.1-161. The almost empty pallet can be taken over by a special rake system (fig. 2.1-161b) and a new pile can be loaded underneath. The sequences for changing the corresponding pallet-carrying systems run automatically. Systems of this kind are explained in greater detail in sections 2.1.2.8 (figs. 2.1-69, 2.1-70) and 8.1.1.5. With devices such as these, a sheet-fed offset press can operate non-stop for the entire print run, in a similar



Fig. 2.1-159
Automated printing plate change on a web offset printing system (M-600, Heidelberg)

way to web offset presses. Naturally, the rather high investment for such systems must be justified by the printing company's customer and order profiles.

The paper guidance in the delivery, that is, the format-related mechanical components and the supporting blast and suction air systems, can also be adjusted by remote control. Drying units and powdering devices installed in the delivery section can also be adapted to the paper format with the support of automatic features.

2.1.5.4 Ink Feed Presetting in the Printing Unit

If the register systems for mounting the printing plate are accurate and the preceding platemaking operations for the individual color separations have been performed in accurate register, no special presetting is required for the color register – fine adjustment can be done in a few steps after the first sheet has been printed.

This is not the case for the ink feed for inking up the printing areas on the printing plate. The ink feed to the individual printing units through the zonally divided ink fountains (see also fig. 2.1-158) depends on how much of the printing plate surface is occupied by image areas. Each ink zone has to be set to the corresponding area coverage of an ink-zone-wide strip on the

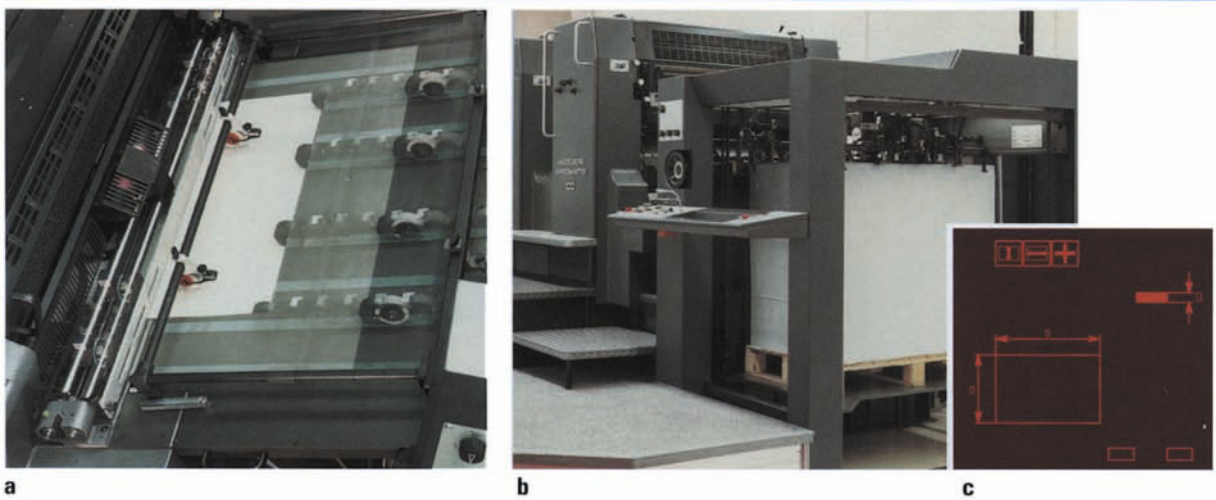


Fig. 2.1-160 Automated sheet size adjustment at the feeder of a sheet-fed offset press.
a Feed table and sheet feeding to the first printing unit;
b Feeder with paper pile and suction head and equipment for sheet separation and transport to the feed table with cor...
c Display for operator guidance fitted on the control panel (SM 102, Heidelberg)

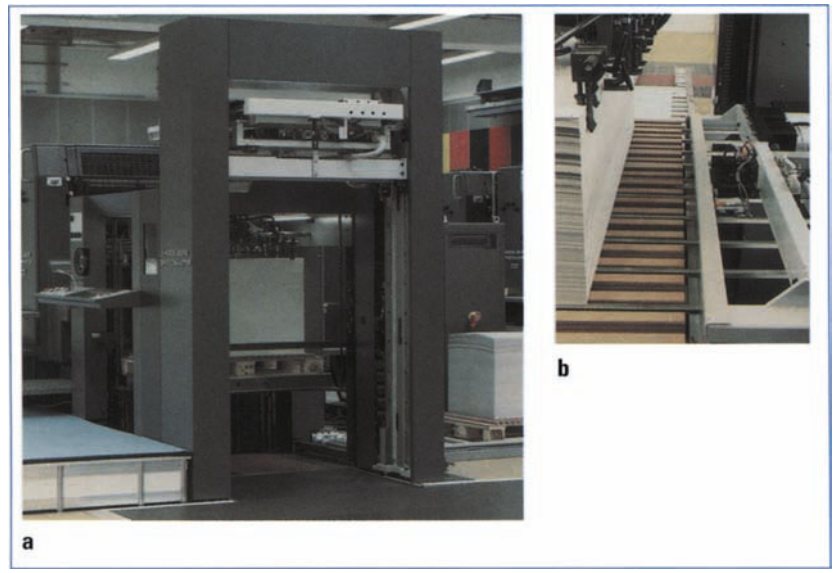


Fig. 2.1-161
Non-stop feeder for automatic pile change for sheet-fed offset presses.
a Non-stop feeder with pile rake in neutral position;
b Pile rake in action, taking over the residual pile for a pallet change (Autopile, Heidelberg)

plate in the direction of printing. The ink strip width, which affects all ink zones, is adjusted to the printing plate through the angle of rotation of the ink fountain roller (e.g., based on the mean value of the area coverage). Therefore adjustment of the ink strip width and the ink-zone opening must be done printing unit by printing unit (see also figs. 2.1-13 and 2.1-126).

This is a time-consuming process, if the operator has to set the ink zones directly on the ink fountain manually and printing unit by printing unit. Furthermore it is a very imprecise method, which very much depends on the experience of the press operator, the quality of his visual assessment of the zonal ink requirement, and the resultant setting of the zone opening. Even though ink-zone adjustment by remote control via the press control console has been possible for a long time, quantitatively accurate presetting had still not been achieved. A fundamental step towards a reduction in makeready times was the development of so-called *plate image readers*, with which the zonal ink requirement of the printing plate could be measured automatically before the plate was mounted in the printing unit; the first systems came on the market around 1982 (e.g., DEMIA from Dainippon Printing and CPC3 from Heidelberg; see also sec. 2.1.4.1 and fig. 2.1-127).

A *plate image reader* of this kind is shown in figure 2.1-162. An optical scanning system measures the mean percentage area coverage within the ink zone on the basis of the different reflection behavior of ink-accepting and ink-free surfaces (solid area corresponds to 100%). The settings for the ink zone opening and the ink stripe width of the ink fountain are determined on the basis of an algorithm that takes into account the inking unit design, print characteristic curve, and the effects of ink and paper. The data can either be trans-

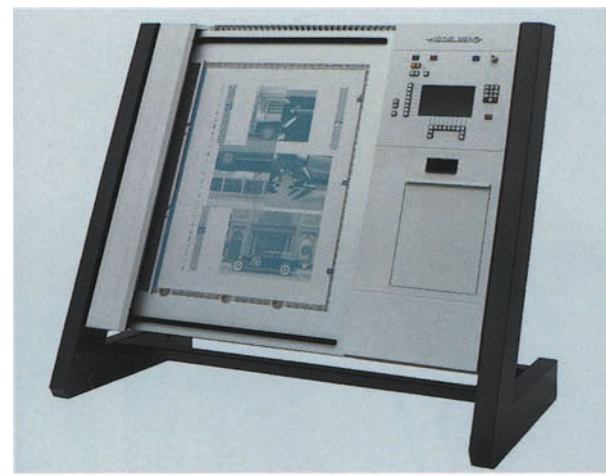


Fig. 2.1-162
Plate image reader for determining the zonal ink requirement of an offset printing plate for ink feed presetting (CPC 31, Heidelberg)

ferred directly to the press via a data line, or preferably, handed over to the printer on a data carrier (e.g., a flash card that can typically store approximately fifty four-color jobs) together with the other information for the print job. The ink feed on all printing units can be preset on the basis of these data, before the plates are mounted and paper travel is started in the press. Other settings can be deduced from the ink requirement and the ink distribution on the printing plate, for example the starting position of the distributor rollers in the inking unit in relation to the plate cylinder gap and the amount of dampening solution required for the print job.

Digitization has provided prepress with the option of specifying the print job in an entirely digital form, which means that the area coverage of the individual color separations can be calculated zone by zone from the data file specifying the entire contents of the printed sheet of the job to be printed, in which case a plate image reader is not required. Calculating ink presetting using the print image data from prepress is an example of the application of a *prepress interface* (as discussed in greater detail in sec. 8.2.3, see also figs. 8.2-12, 8.2-13). Information for presetting the press, and in particular the ink feed, is transferred via this interface using a special data format (PPF: print production format). Figure 2.1-163 shows on screen how the area coverage values in the different ink zones have been calculated from the individual color separations for the entire print image for the process colors black, cyan, magenta, and yellow. The calculation and setting of the ink zone openings and ink stripe widths can preferably be done on the computer in the control console, taking the particular press characteristics into account.

With conventional offset printing, the printing unit must be *supplied with a dampening solution* in addition to the ink; the dampening solution feed has to be set, too. The necessary dampening solution feed requirement can be roughly calculated from the print-job-related ink requirement, and presetting for the dampening solution feed can be derived from this in accordance with the type of dampening unit used. Zonal feeding of the dampening solution is not usually necessary; setting a mean value from the dampening ductor speed will suffice for the application of the thin film of dampening solution onto the printing plate. With current continuous-type dampening systems a film of 1 to 2 µm is sufficient. (For special applications inking units can be equipped with blast air units by means of which a special dampening solution profile can be achieved.) Therefore the dampening ductor speed can be set together with the presetting data for the ink zones.

How much ink is in fact transferred to the printing plate is dependent on numerous factors influencing the ink flow in the printing unit. Among the decisive ones are the fluid dynamic processes involved in the transfer of the ink from the ink fountain to the roller system, the ink splitting processes and the ink flow in the vicinity of the individual zones, and the phase relation of the lateral distribution (starting position of the *lateral distribution* in relation to the plate cylinder gap). The dampening solution also has an effect on the ink-water emulsion. Trans-



Fig. 2.1-163
Determining the zonal area coverage for offset printing plates from the data file specifying the entire multicolor print sheet (Prepress Interface CPC 32/CIP3-PPF, Heidelberg)

fer from the ink form rollers to the printing plate, from the printing plate to the blanket, and then from the blanket to the paper, are similarly affected by the characteristics of the materials and the mechanical tolerances and printing pressure settings in the printing unit. The *optimum* provided by theoretical assessment of the ink zone presetting merely on the basis of the ink requirement will only be an approximation to the actual ink feed during production. Systems using special *learning algorithms* can, as a result of the differences between the presetting and the final setting values during production, produce better presettings for the subsequent print jobs. *Self-learning, adaptive systems* of this kind contribute a lot to the success of ink presetting. Furthermore, ink presetting is based on certain default values. Should the print job, however, not correspond to standard parameters, it must be possible to adapt the ink presetting accordingly by entering the relevant characteristic curves or parameters.

2.1.5.5 Ink and Dampening Solution Supply

To fill the ink fountains on sheet-fed offset presses with ink, the operator will normally use just a spatula to transfer the ink from the ink can directly into the ink fountain.

There are systems available offering an even simpler and more convenient method of filling up the ink fountains on sheet-fed presses; *ink cartridges* are used to perform the automatic fill-up procedure. Figure 2.1-164 shows an ink cartridge holder that moves automatically from side to side to ensure that the ink fountain is evenly filled up with ink. The filling level is recorded by a sensor (e.g., ultrasonic sensor) and topping up is initiated via a control system. This type of cartridge system is operator-friendly and the automation and monitoring technology associated with it ensure that the operator is informed of the ink reserve status throughout the print run.

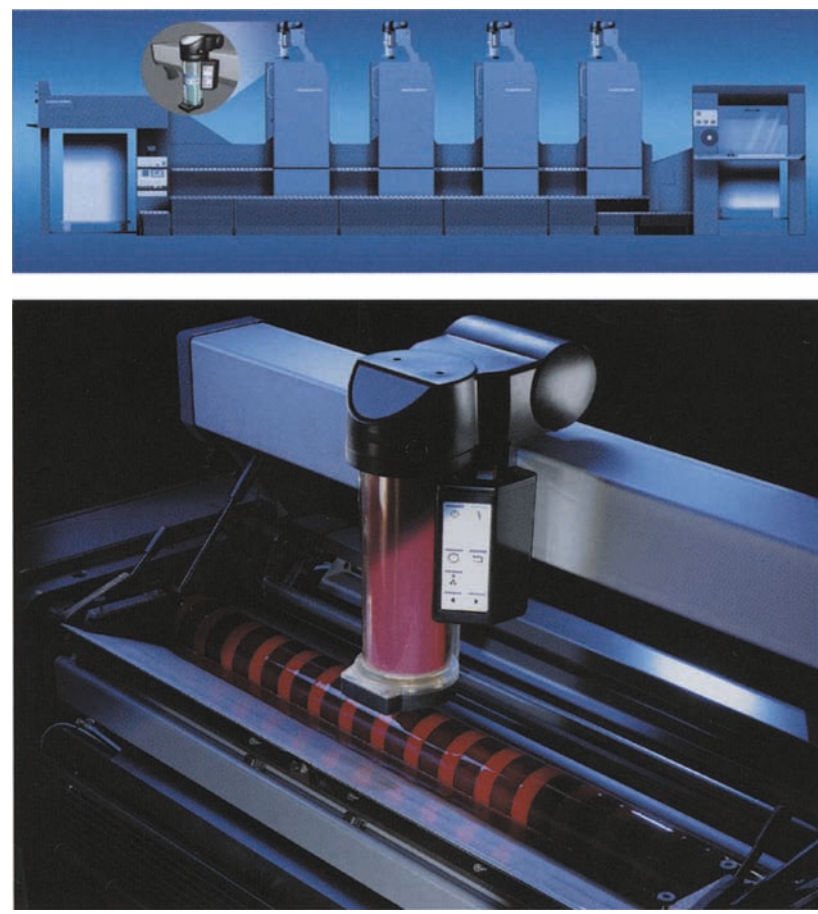


Fig. 2.1-164
Automatic ink fill-up system for the ink fountain on a multicolor sheet-fed offset press (InkLine, Heidelberg/ Technotrans)

The automatic ink supply in conjunction with filling-level monitoring and control systems in the ink fountain have long been state of the art on web offset presses, because of their far higher productivity and print run length. Figure 2.1-165 shows how the ink is supplied to the ink fountains of a web offset press by means of *ink pumps* and piping systems. An ultrasonic sensor, which is used to measure and control the filling level, can also be seen. Similar ink supply systems are also occasionally used in sheet-fed presses.

There are also measuring and control systems for the *dampening solution supply*; they ensure that there is always an adequate amount of dampening solution in the dampening fountain on the printing unit, but above all they monitor the composition of the dampening solution and guarantee by means of metering systems that the correct concentration is maintained. Automated dampening solution systems of this kind are also equipped with temperature control units to keep the dampening solution at a constant temperature.

2.1.5.6 Makeready for Print Production

After completion of the various cleaning processes, presetting the units for paper and ink feed as well as changing plates, the final step in the preparation of the press for the next print job can take place, that is, fine adjustment during paper travel.

Like the preparatory operations prior to paper travel, this can be done straightforwardly, simply, and quickly from a *central control console*, as illustrated in figure 2.1-166 for a sheet-fed offset press with ten printing units. All press functions are displayed on a monitor and adjustments can be initiated directly from there. The control console has a special ink-zone keyboard for remote control of the ink feed. As shown in figure 2.1-166, the operator can assign the printed image and the ink zones to one another, which means that he is able to make specific fine adjustments to the ink feed by visual inspection or with the help of hand-held measuring instruments. The fine adjustment for the *color register* and the printed *color* is supported and/or automated with the help of measuring and control systems as already explained in section 2.1.4.

The multicolor offset press shown in figure 2.1-167 serves as an example of the use of electronic and optical measurement systems, such as the scanning of the printing plate by a plate image reader for ink presetting, the electronic register mark reader for measuring and controlling of color registers, and the spectral measurement and control system for setting the ink feed to the specified color values and maintaining the print quality throughout the entire print run, in addition to the central control console.

The preparatory operations prior to paper travel in the press described above lead to considerable savings on paper waste, compared to older methods without automation technology. At the *start of printing* and of the paper travel, the inking unit must be brought into a

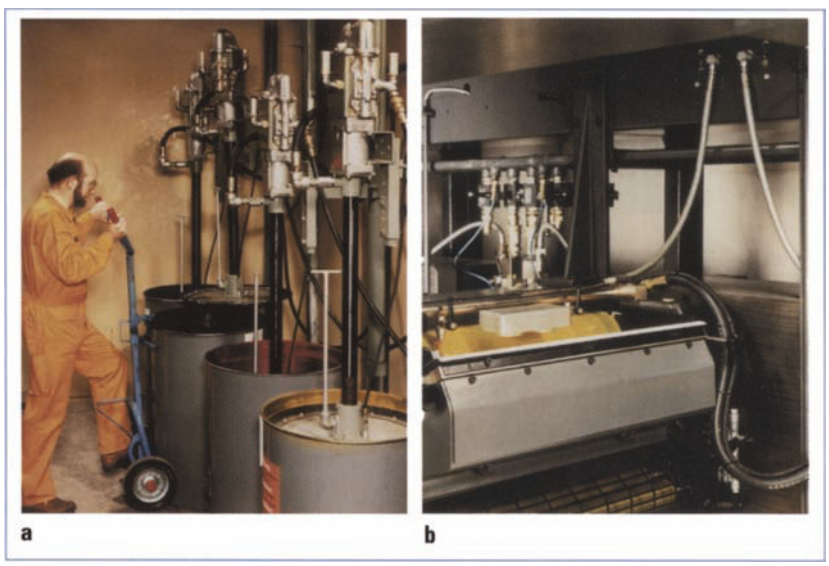


Fig. 2.1-165
Automatic ink supply for a web offset press (around 1982).
a Ink container with ink pumps and supply system;
b Ink fountain with ink supply pipe and filling level monitoring (Web 8, Heidelberg)



Fig. 2.1-166
Central control console for the remote control of a 10-color sheet-fed offset press (SM 102/CP 2000-System, Heidelberg)



Fig. 2.1-167
Multicolor sheet-fed offset printing system with central control console and measurement and control systems for ink presetting, color register and ink feed/color (CPC-System, Heidelberg)

steady condition in accordance with the ink feed presetting parameters. Because of the generally large number of ink rollers in an inking unit this is a relatively tedious process; a virtually steady condition is only reached after approximately 150 revolutions of the plate cylinder and the transfer of ink onto the paper. This would mean that a large number of waste sheets would be printed before measurements can be taken for adjustment of the ink supply. There are now methods (algorithms in particular) by means of which the response time of the printing unit/the ink flow until a stable state can be accelerated. There are algorithms controlling the ink flow by means of which more ink is fed into the inking unit for a short, specified period, and only then are the ink zone openings set to the values required for steady production (e.g., dead-beat processes).

Fine adjustment during paper travel generally takes place at a printing speed lower than *production speed*. The acceleration of the press to production speed might change the ink feed ratios, in particular. This can be compensated for by means of powerful computer-aided control systems. The dampening solution supply system, the blast-air and suction-air devices and perhaps even the control of the drying units are also adjusted in accordance with the speed.

Figure 2.1-168 shows the display options of the *control console* depicted in more detail in figure 2.1-167. The settings in the printing units, in the feeder and delivery are displayed on screen at the control console. The press operator is provided with concise information by means of pictograms. The display can be switched over to focus on particular press setting operations to be performed.

The monitor on the control console (as shown in fig. 2.1-168) is one component of a *production and information system*. Data can be transferred via a network, not only from the pressroom, but also from the prepress department. Production planning, press utilization and job scheduling data can be displayed, and up-to-date job status messages can also be called up to assist the operator.

The equipping of production systems with the aforementioned components for automation, production-control and monitoring is virtually state of the art.

Figure 2.1-169 gives an overview of system configurations from various manufacturers including components for remote control and measurement and control technology for the efficient, economical operation of presses, as well as elements for networking the entire production flow.

Chapter 8 describes in detail the material logistics and data flow within the press area, within the entire printing company, and in relation to central networking. In particular, an explanation is given of the logistics components for materials conveyance and the automation of the latter.

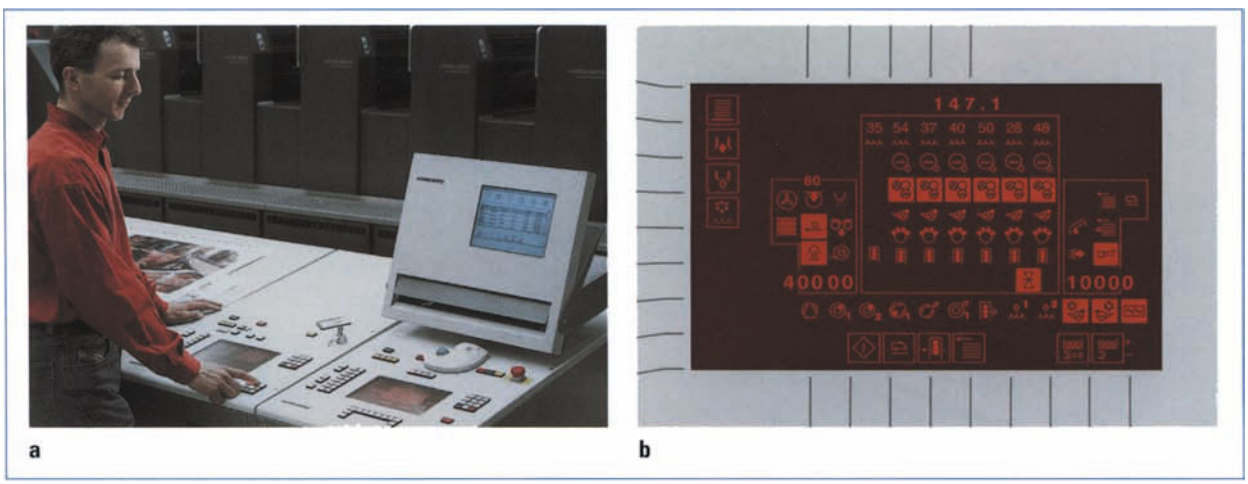
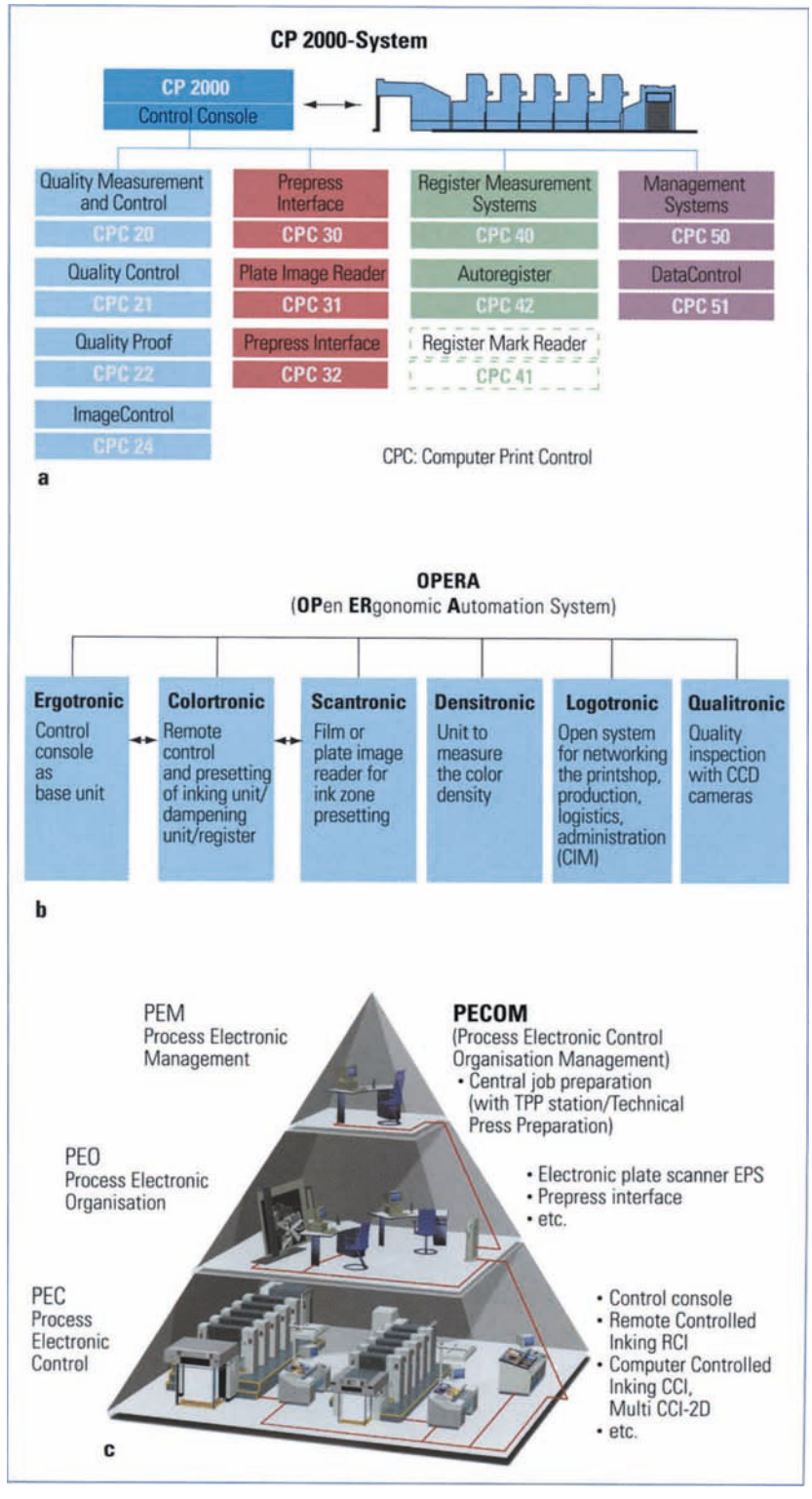


Fig. 2.1-168 Control console for the remote control of a sheet-fed offset press.
a Control console (CPC 1) with press status display (the display is integrated in the control console) and monitor for the production and information system (DataControl);
b Display, integrated in the control console displaying information/settings on the feeder, printing units and delivery (CPC-System, Heidelberg)

Fig. 2.1-169
System components for automation, measurement and control technology, networking and logistics around the printing press.
a CP 2000 System (Heidelberg);
b OPERA System (KBA);
c PECOM System (MAN Roland)



2.1.6 Examples of Offset Printing Presses and Production Systems

2.1.6.1 Sheet-fed Offset Printing Presses

The previous chapters and section 2.1.2 in particular dealt principally with press concepts and individual press components. The following examples represent a selection of sheet-fed offset press configurations from various manufacturers that are currently used in the printing industry. This is in addition to the examples given in sections 2.1.4 and 2.1.5.

Sheet-fed offset presses are grouped according to *sheet size classes and sheet size ranges*, that is, by the maximum printable sheet size (tables 2.1-3 and 2.1-4). Other significant *attributes* are:

- range of application (substrate, print quality, market sector, etc.),
- productivity,
- level of automation,
- arrangement of cylinders/sheet travel,
- operation,
- flexibility (sheet size, perfecting),
- physical size.

Sheet size class	Print format (approximate value in inches)	
00	up to 35 cm × 50 cm	(13 3/4 × 19 5/8)
01	46 cm × 64 cm	(11 1/8 × 25 1/8)
0b	50 cm × 70 cm	(19 5/8 × 27 1/2)
1	56 cm × 83 cm	(22 × 32 5/8)
2	61 cm × 86 cm	(24 × 33 7/8)
3	65 cm × 96 cm	(25 5/8 × 37 3/4)
3b	72 cm × 102 cm	(28 3/8 × 40 1/8)
4	78 cm × 112 cm	(30 3/4 × 44 1/8)
5	89 cm × 126 cm	(35 × 49 5/8)
6	100 cm × 140 cm	(39 3/8 × 55 1/8)
7	110 cm × 160 cm	(43 3/8 × 63)

Table 2.1-3 Sheet size classes for sheet-fed offset presses

Presses in the *70 cm × 100 cm sheet size range* with four to six printing units and at least one sheet reversing device are classed as all-round printing presses and are very flexible in their application. Figures 2.1-170 through 2.1-175 show different printing presses of this kind from various manufacturers.

Sheet size ranges		Maximum sheet size of the press* (max. print format)	Corresponding standard formats (DIN/ISO)			
			A formats		B formats	
cm	inch (approx.)	mm	mm	inch (approx.)	mm	inch (approx.)
35 × 50	14 × 20	370 × 520 (360 × 520)	A3 (2 × A4) 297 × 420	11 3/4 × 16 1/2	B3 353 × 500	12 7/8 × 19 5/8
50 × 70	20 × 28	520 × 740 (510 × 740)	A2 (4 × A4) 420 × 594	16 1/2 × 23 3/8	B2 500 × 707	19 5/8 × 27 7/8
70 × 100	28 × 40	720 × 1020 (700 × 1020)	A1 (8 × A4) 594 × 841	23 3/8 × 33 1/8	B1 707 × 1000	27 7/8 × 39 3/8
> 70 × 100 e.g. 100 × 140	> 28 × 40 40 × 55 1/8	1020 × 1420 (1010 × 1420)	A0 (16 × A4) 841 × 1189	33 1/8 × 46 3/4	B0 1000 × 1414	39 3/8 × 55 5/8

* Substrate format that can be printed/fed in the press; printable format reduced in direction of print due to gripper margin (examples, depend on model manufacturer).

Table 2.1-4 Format ranges for sheet-fed offset presses and the corresponding substrate and printing formats (selection)

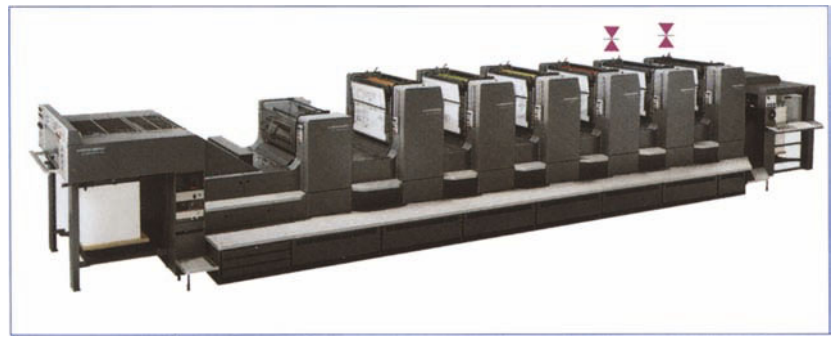


Fig. 2.1-170
Speedmaster SM 102 with six printing units, coating unit and high-pile delivery. The fact that sheet reversal can take place after the first or second printing unit increases flexibility; sheet size 720 mm × 1020 mm, printing speed 13000 impressions/hour, printing unit diagram see fig. 2.1-37 (Heidelberg)



Fig. 2.1-171
CD model of the Speedmaster SM 102 (for cardboard printing), 6-color press with coating unit and extended delivery, with double-size impression cylinders and triple-size transfer drums; sheet size 720 mm × 1020 mm, printing speed 15000 impressions/hour, see press diagram figure 1.6-5c (Speedmaster CD 102-6+L(X), Heidelberg)



Fig. 2.1-172
Rapida 105, 4-color press, with 2/2 sheet reversal; sheet size 720 mm × 1050 mm, printing speed 15000/12000 impressions/hour, reduced speed for perfecting, see press diagram figure 1.6-5b (KBA)

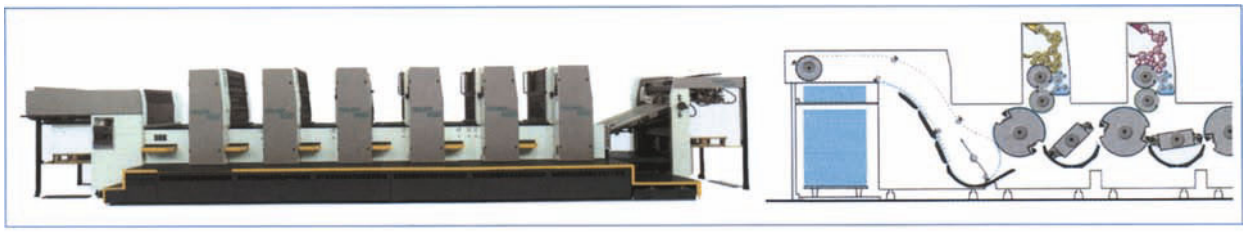


Fig. 2.1-173 Roland 700, 6-color press; sheet size 740 mm × 1040 mm, printing speed 15000 impressions/hour (MAN Roland)

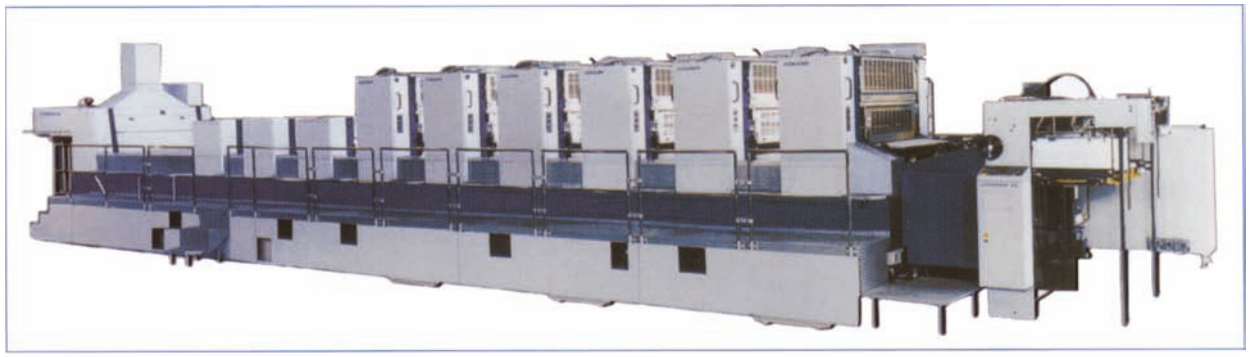
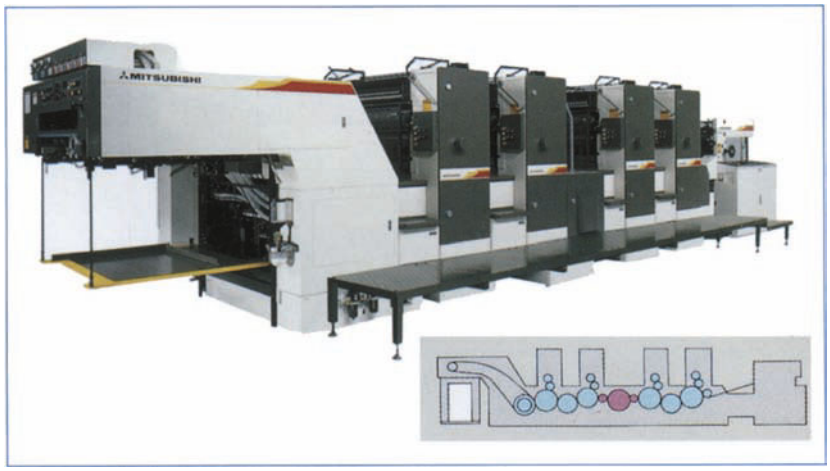


Fig. 2.1-174
Lithrone 40, 6-color press, two coating units, unit for intermediate drying, hot-air extraction in the delivery; sheet size 720 mm × 1030 mm, printing speed 15000 impressions/hour (Komori)

Fig. 2.1-175
Model 3FR-4, 4-color press with sheet reversal for 2/2 printing; sheet size 720 mm × 1020 mm, printing speed 13000/11000 impressions/hour, reduced speed for perfecting (Mitsubishi)



"Large format presses" (sheet size up to approximately 120 cm × 162 cm) are typically used for the printing of packaging (folding boxes), large posters, and maps. Figure 2.1-176 shows an example of this kind of press, (other manufacturers are KBA or Komori, for example).

There are also sheet-fed offset press configurations in unit construction in the *70 cm × 100 cm format range* with more than six printing units. *Eight-color presses* for 4/4 double-sided printing are particularly popular, but there are also configurations with ten and twelve printing units (status 2000), so that with 4/4 double-sided prints, one or two additional spot colors can be printed (fig. 2.1-177).

The following figures 2.1-178 through 2.1-182 show a selection of presses from various manufacturers in the *50 cm × 70 cm sheet size range.*

The small format sheet-fed offset printing presses in the *35 cm × 50 cm sheet size range* have the greatest diversity. These range from highly automated presses for single and multicolor printing to simple single color



Fig. 2.1-176
Roland 900 in a press room; sheet size 1020 mm × 1420 mm, printing speed 12000 impressions/hour (MAN Roland)



Fig. 2.1-177
Speedmaster SM 102 with ten printing units, perfector after the fifth printing unit; sheet size 720 mm × 1020 mm, printing speed 12000 impressions/hour, CP 2000 control console for remote control (Heidelberg)



Fig. 2.1-178
Speedmaster SM 74 with eight printing units, perfector after the fourth printing unit; sheet size 530 mm × 740 mm, printing speed 15000 impressions/hour, press diagram see fig. 1.6-5a (Heidelberg)



Fig. 2.1-179
Roland 300, 4-color press, sheet reversal; sheet size 530 mm × 740 mm, printing speed 15000 impressions/hour (MAN Roland)

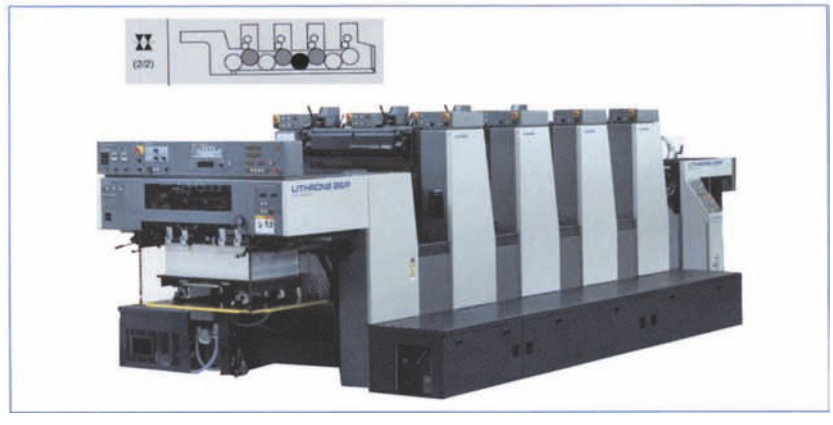


Fig. 2.1-180
Lithrone 26 P, 4-color press with 2/2 sheet reversal; sheet size 480 mm × 660 mm, printing speed 15000/13000 impressions/hour, reduced speed for perfecting (Komori)

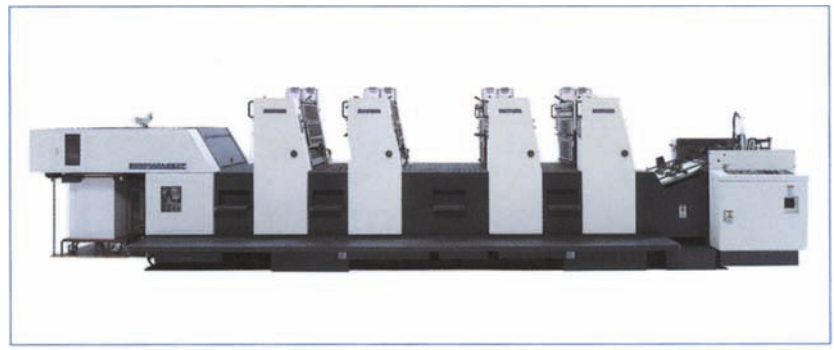


Fig. 2.1-181
Shinohara 66 IVP, 4-color press with sheet reversal. Printing units 1 and 2 are connected by a double-size transfer cylinder, as are printing units 3 and 4. Sheet reversal with a 3-drum system after the second printing unit; sheet size 483 mm × 660 mm, printing speed 13000 impressions/hour (Shinohara)

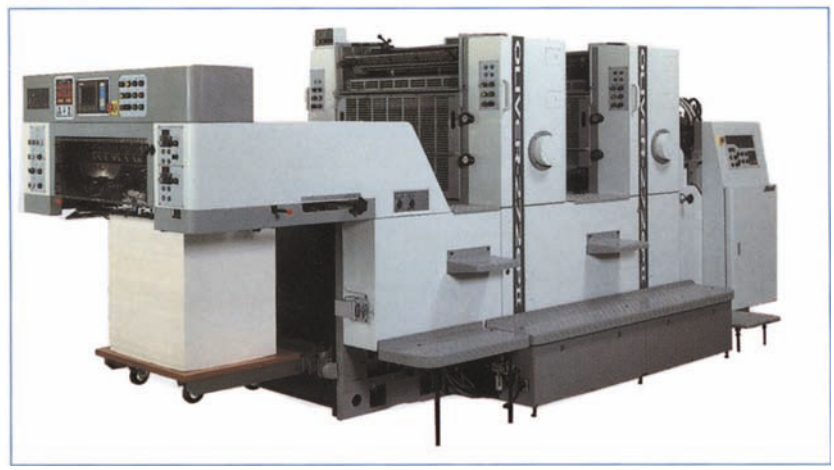


Fig. 2.1-182
Oliver-272EPII, 2-color press with sheet reversal; sheet size 520 mm × 720 mm, printing speed 12000/10000 impressions/hour, reduced speed for perfecting (Sakurai)

presses. Sheets can be printed in both the landscape and portrait format. This type of press is predominantly used for short print runs and special printing materials.

Numbering and perforating devices are often used on these presses. Figures 2.1-183 through 2.1-187 show just a small selection of presses.

2.1.6.2 Web-fed Offset Printing Presses/Systems

In section 2.1.3 are described web-fed presses primarily according to their individual units and components. This chapter will illustrate and outline the complete production systems combined from the individual sub-assemblies. The examples given are shown in diagrammatic form or complete systems as they are installed in printing companies.

A collection of examples of *commercial web-fed offset printing systems* is shown in figure 2.1-188, mainly for single web operation. Figure 2.1-188b shows a two-web offset printing system, in which the printing units are arranged in line and the two hot-air dryers are placed above each other.

Figure 2.1-189 shows a commercial web offset printing system equipped with eight blanket-to-blanket printing units (2 × 24 pages), in which the printing units for the two webs, together with dryers, chill rolls and slitting unit, are *stacked*. After the webs have passed through the turner bar section, they are fed into the "pinless former folder" (PFF) and the finished printed product is delivered. The folder and control station are encased in noise protection walls. This two-tiered design produces a compact, short, space-saving web-fed printing press/system. Forty-eight page presses are predominantly used to print signatures for periodicals and books.

"*Hybrid presses*", which combine heatset offset printing with coldset offset printing in one and the same machine, were often installed at the end of the

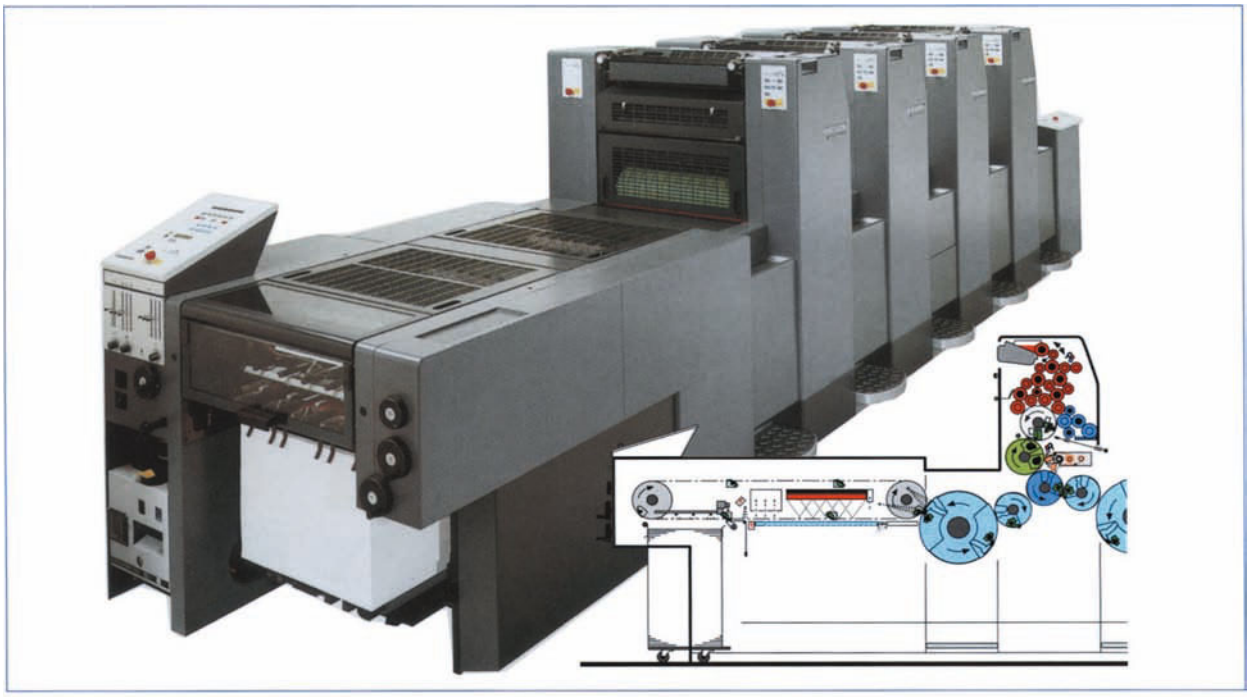


Fig. 2.1-183
Speedmaster SM 52, 4-color press, 2/2 sheet reversal, high-pile delivery; sheet size 370 mm × 520 mm, printing speed 15000 impressions/hour (Heidelberg)

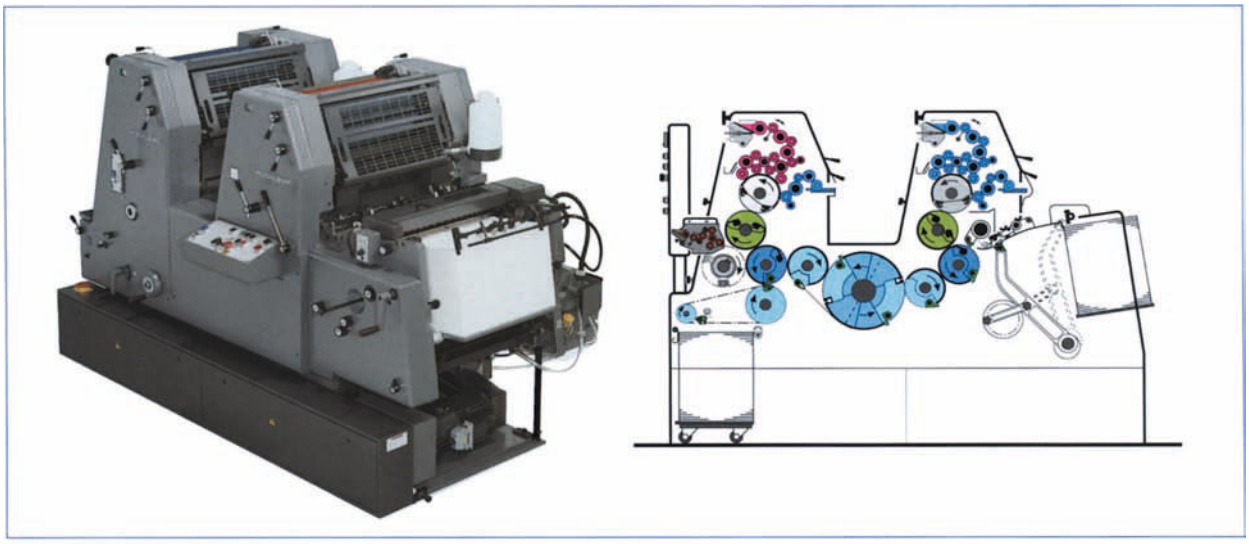


Fig. 2.1-184
Printmaster GTO 52-2 as a typical small-format offset press with perfecting unit, high-volume inking unit for high-quality printing and ink fountain zones which has to be set manually. 4-color prints in two passes are also possible. Fitted with numbering device; sheet size 340 mm × 505 mm, printing speed 8000 impressions/hour (Heidelberg)



Fig. 2.1-185
Sprint GS 226P, compact 2-color press with sheet reversal. Control console integrated into delivery; sheet size 480 mm × 660 mm, printing speed 12000/10000 impressions/hour, reduced speed for perfecting (Komori)

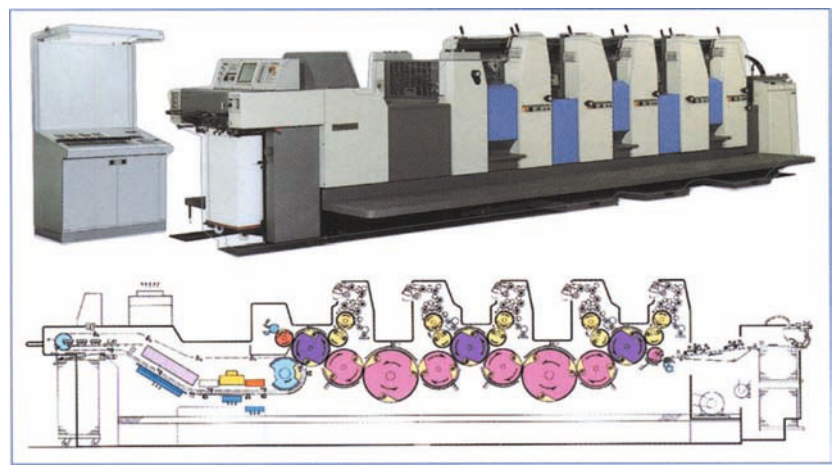


Fig. 2.1-186
Ryobi 525, 5-color press with coating unit and high-pile delivery, 5-cylinder system; sheet size 520 mm × 375 mm, printing speed 13000 impressions/hour (Ryobi)

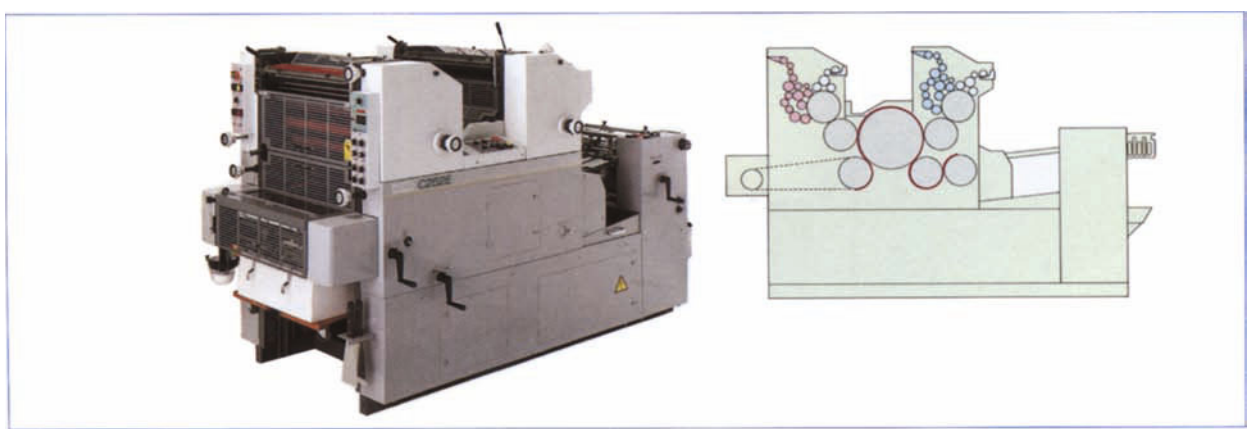
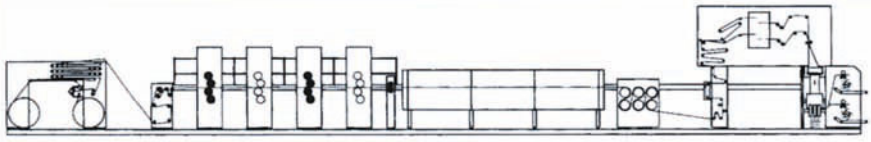
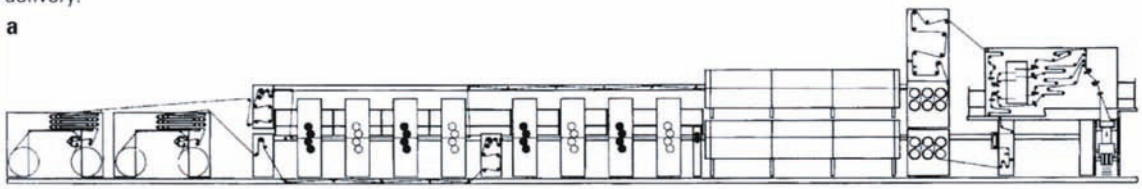


Fig. 2.1-187
Hamada C 252, 2-color press based on the 5-cylinder system; sheet size 520 mm × 365 mm, printing speed 10000 impressions/hour (Hamada)



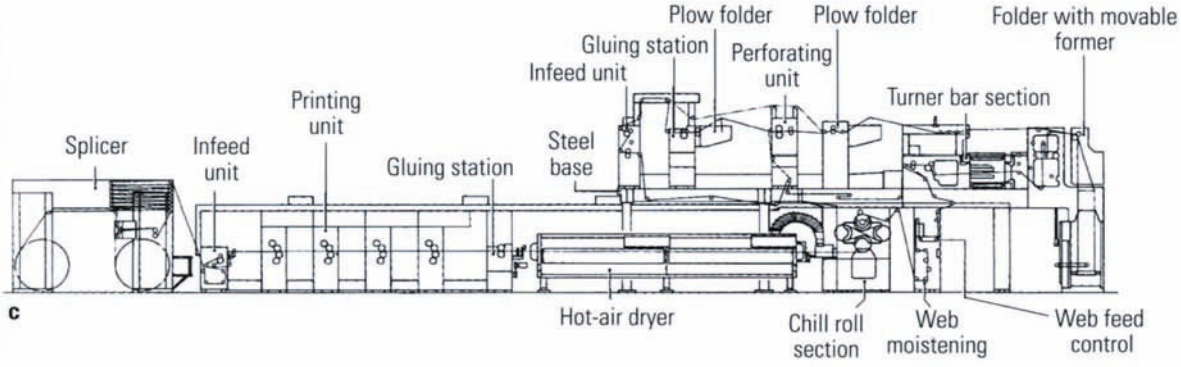
Single web offset printing system with four blanket-to-blanket units.
The press is equipped with a zero speed web splicer with horizontal festoon, hot-air dryer, cooling system and folder with dual delivery.

a

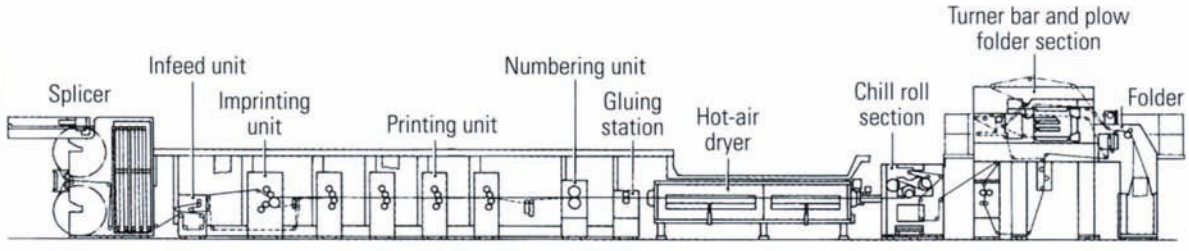


Two-web offset printing system with 2 × 4 blanket-to-blanket printing units.
The installation is equipped with two zero speed web splicers and horizontal festoons, two heatset dryers, cooling system and folder.

b



c



d

Remark: Examples (c and d) of web offset printing presses for publication printing fitted with very different peripheral equipment for finishing the printed web.

Fig. 2.1-188 Commercial web-fed offset printing systems ([2.1-7])

1970s and the beginning of the 1980s. They facilitate economically produced printed products in that only part of the total product is produced on relatively expensive coated paper with heatset inks (cured by heat), which are also expensive, while the other part, more often than not the inside part of the product, can be printed on more favorably priced standard newsprint without the use of dryers. An example of this can be seen in figure 2.1-190, where the coldset part is on the left and the heatset part with the hot-air dryer on the right. In the middle is the folder with its superstructure, into which all six webs are fed for the combined product to be produced. The six reel stands are in the basement.

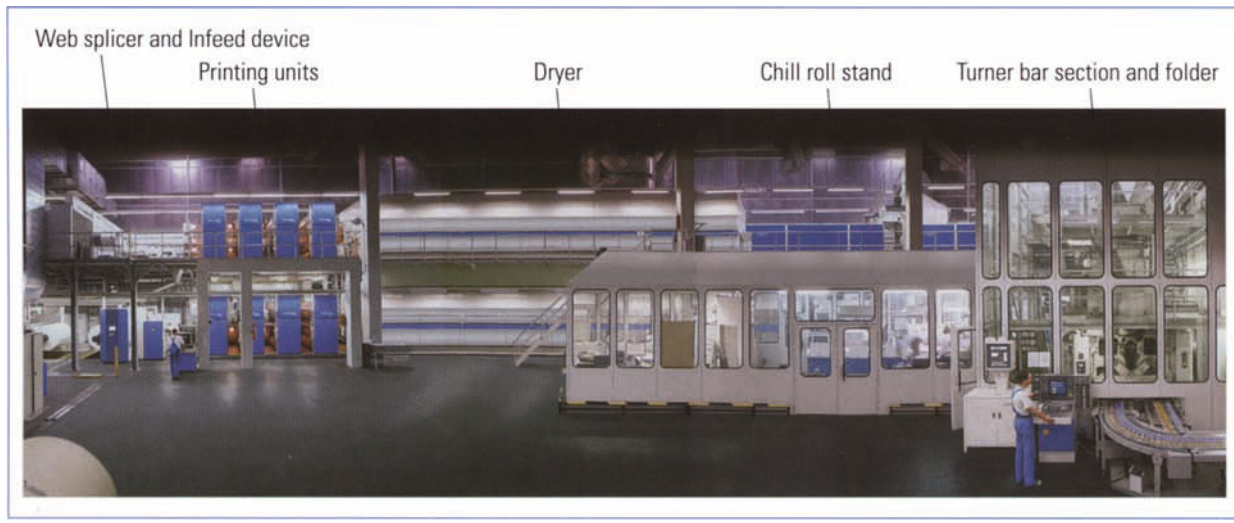


Fig. 2.1-189
Two-storey commercial web offset press for two-web operation; M-3000 Sunday Press with max. web speed of 15 m/s, 48 pages and PFF-3 folder (Heidelberg)

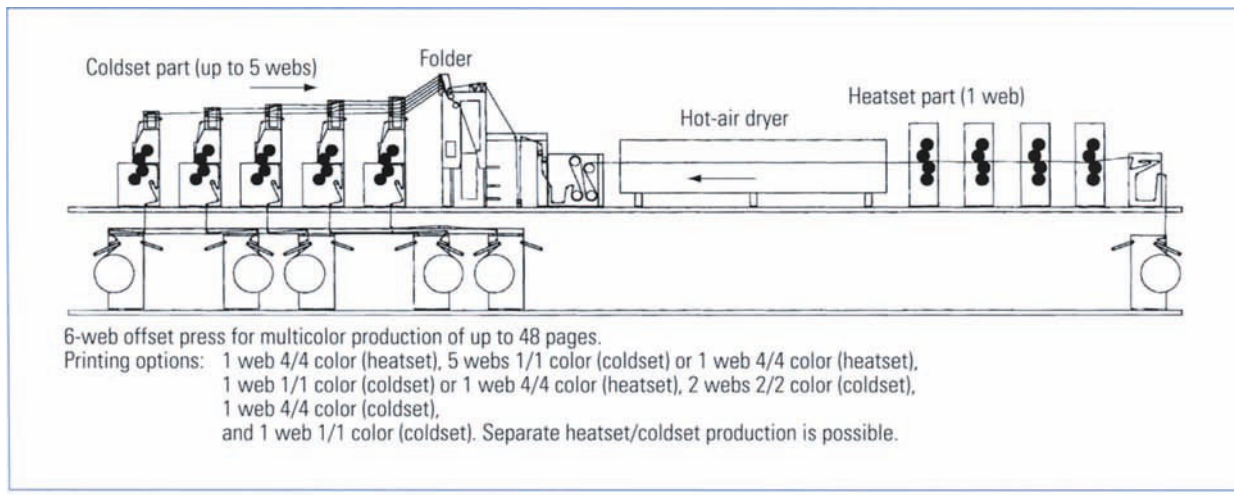


Fig. 2.1-190 Example of a hybrid printing system for heatset and coldset web offset ([2.1-7])

Figure 2.1-191 shows that lengthy heatset dryers (hot-air nozzle dryers) can also be stacked on top of typical double-width *newspaper web offset presses*. The dryer has been placed above the printing units and folder superstructure so that the length of the web-fed press installation is not prolonged unnecessarily (as the printing system shown in fig. 2.1-190). The *four-high unit* between the left folder and the heatset dryer in this case proves to be a series of four blanket-to-blanket printing units rotated in a vertical direction to produce 4/4 prints, before the web enters the heatset dryer. Since there is also a folder on the right-hand side, the system can be divided, so that in addition to the hybrid operation already described, heatset and coldset products can be produced separately with this equipment.

Considerably shorter structured *infrared (IR) dryers* are used in newspaper web presses for semi-commercial printing instead of the relatively long-structured *hot-air dryers*. They do not offer the same quality as heatset dryers. They do not vaporize solvent or give the ink the desired gloss, but they tend to support the absorption of inks and to achieve higher density values. As can be seen in figure 2.1-192, they are located above and need considerably less space, which is why several dryers can be used for several webs.

That there are also single-width and considerably more simply constructed newspaper presses in addition to the double-width newspaper rotaries is clearly shown by figure 2.1-193. In this example even the reel stands are integrated in the printing units, in order to save space. The three printing units are designed as *Y-type printing units* and thus allow 2/1 printing on each of the three webs. Combined printing by two printing units is shown on the left of the illustration, and this allows 4/2 printing on one web, while 2/1 printing occurs on the second web. A sixteen-page full format (broadsheet) or a thirty-two-page tabloid newspaper is produced in the folder in this way. A quarter of its pages can be in four colors and half in two colors, only a quarter is in a single color. This produces a thoroughly respectable newspaper, in spite of the relatively small size of the installation.

One way to increase the number of pages is to link together two *parallel installations* by means of turner bars, which is shown in figure 2.1-194. (In the illustration the two installations are actually shown standing one underneath the other, but they must be imagined as standing next to each other.) Once again the system produces with single-width printing units, the webs of which are led into one of the two folders on the far outside right via the turner bars on the right. One installation (lower) is equipped with a compact hot-air/infrared dryer, so that hybrid-mode production can also take place.

Figure 2.1-195 shows that the units can be *stacked*. Steel frames support the upper printing units and connect them with the lower ones. The folder is arranged in the middle, and the reel stands/splicers are partly built into the printing units. An example of an installation in which two commercial web offset presses are configured one above the other has already been shown in figure 2.1-189.

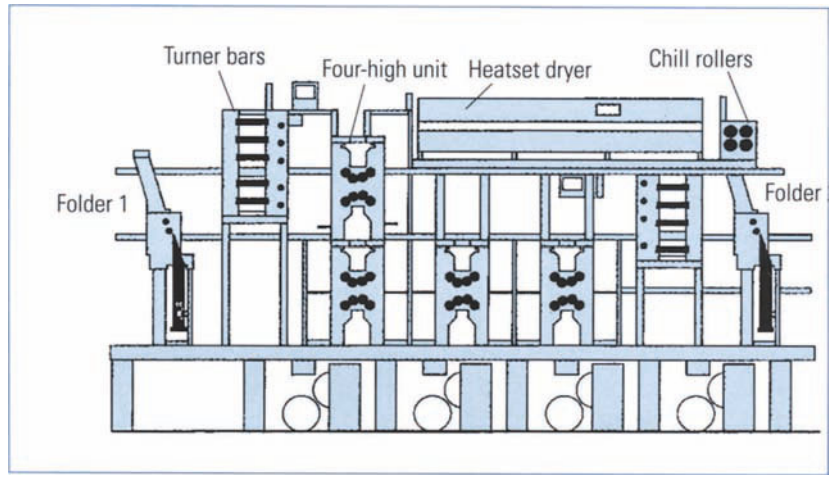
Figure 2.1-196 shows a web-fed newspaper printing system suitable for a confined space. The two four-high printing units (on the left) are *very compact* in structure thanks to the design with lateral extraction of the inking units and have been installed in the basement, while the three reel stands take their place next to them on the right. The folder, too, has been installed in the basement, so that the folder's superstructure would not stand higher than the printing units.

A typical *single-level installation* with three Y-type printing units is shown in figure 2.1-197. In this installation all units of the press are at the same level. Since the webs must, to a certain extent, be drawn through under the printing units, the units stand slightly raised on pits. Thus a gallery for running the installation is only required on the folder superstructure. The flight of stairs included in the drawing makes this clear.

Figure 2.1-198 shows a typical *four-high, web-fed press installation*. It is standing on a concrete substructure with reel stands underneath. Densely packed turner bars or folder superstructures are fitted above the four folders and the planned expansion with an infrared dryer is indicated by the broken lines. The "skip slitter" (intermittent web slitter) on the roller top of former (RTF) for printing tabloid-in-broadsheet products (see also fig. 2.1-113) can also be seen. The four-high units are formed from *H-type printing units* stacked on top of each other, which in turn consist of an *arch-type printing unit* and a U-type printing unit standing above it.

It becomes clear in figure 2.1-199 that besides the four-high units consisting of *stacked H-type printing* units there are also configurations that comprise only stacked arch-type printing units; in this case an installation with anilox inking system (see fig. 2.1-122).

Fig. 2.1-191
Newspaper press with a heatset dryer above it (IFRA/KBA)



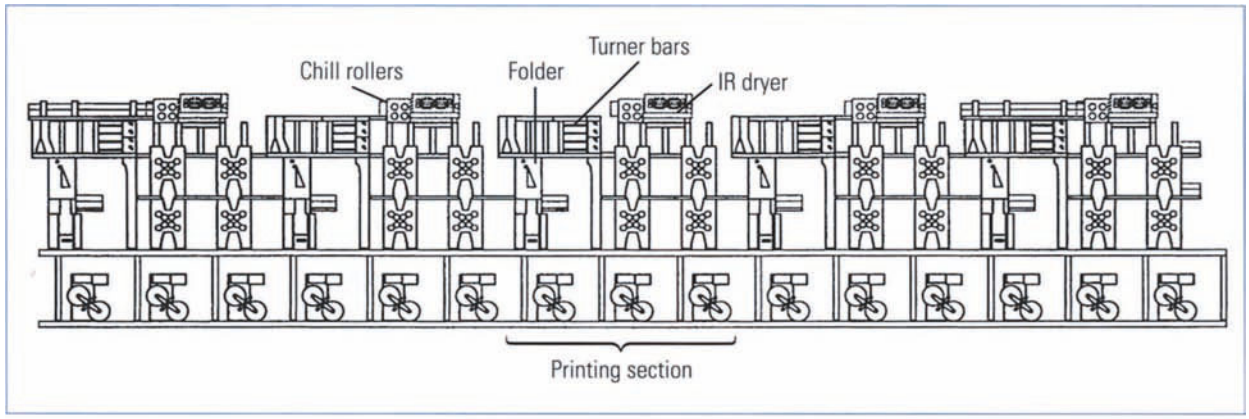
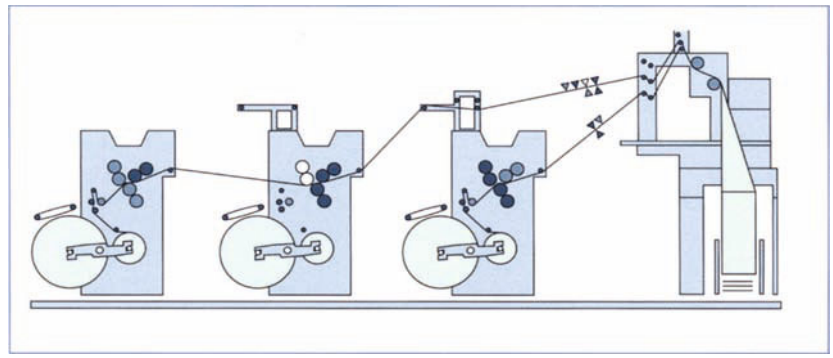


Fig. 2.1-192 Long web-fed printing system for newspaper printing with infrared (IR) dryer above it (IFRA/MAN Roland)

Fig. 2.1-193
Simple newspaper press with Y-type printing units (IFRA/MAN Roland)



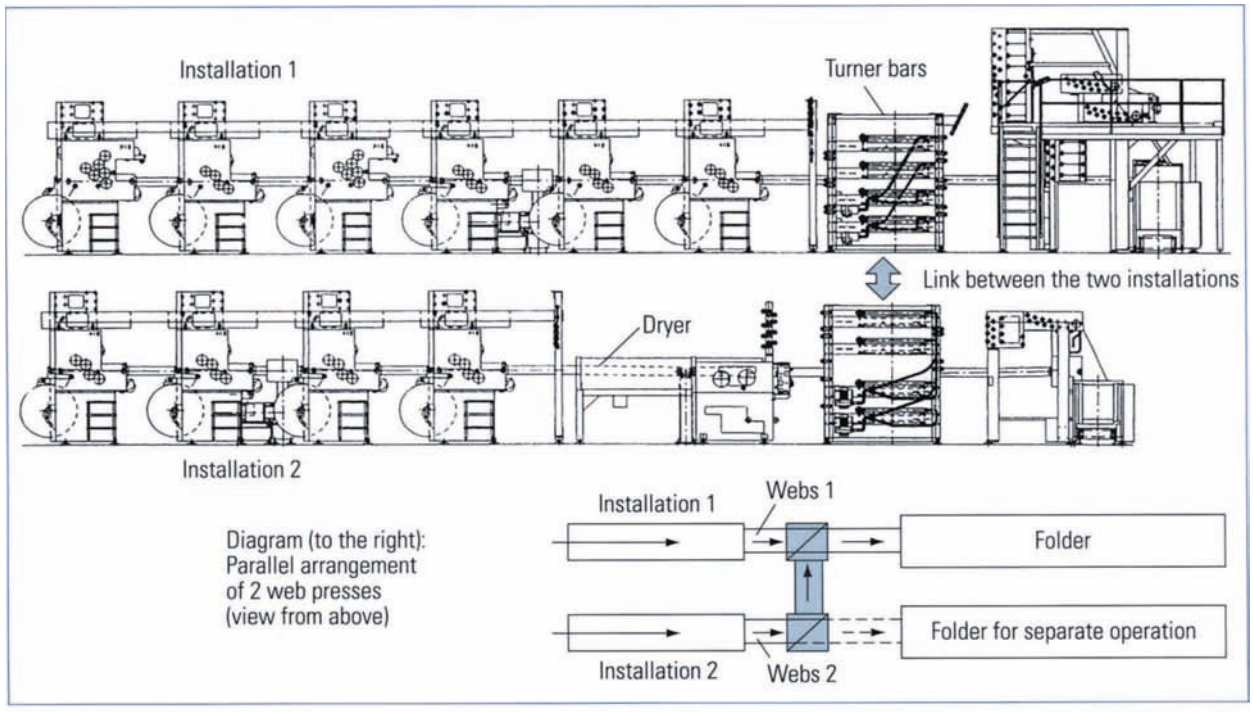


Fig. 2.1-194
Parallel configuration (next to one another) of two production systems for newspaper printing and transfer of the webs by means of turner bars (IFRA/Solna)

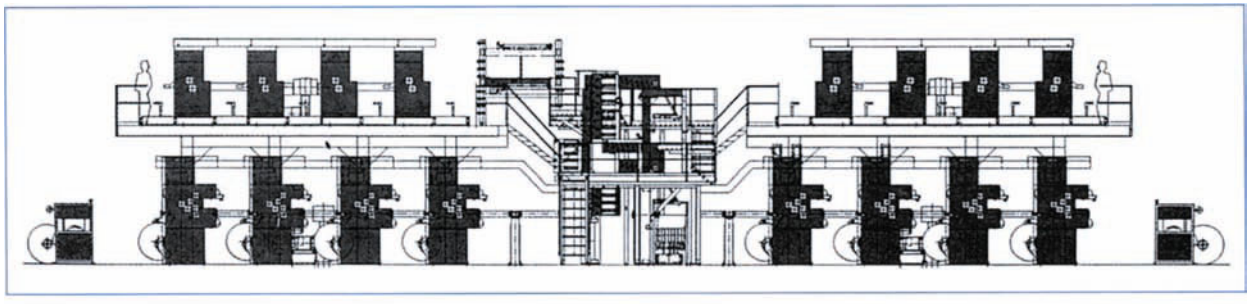


Fig. 2.1-195 Vertical configuration of printing systems above one another for multi-web newspaper printing (IFRA/Solna)

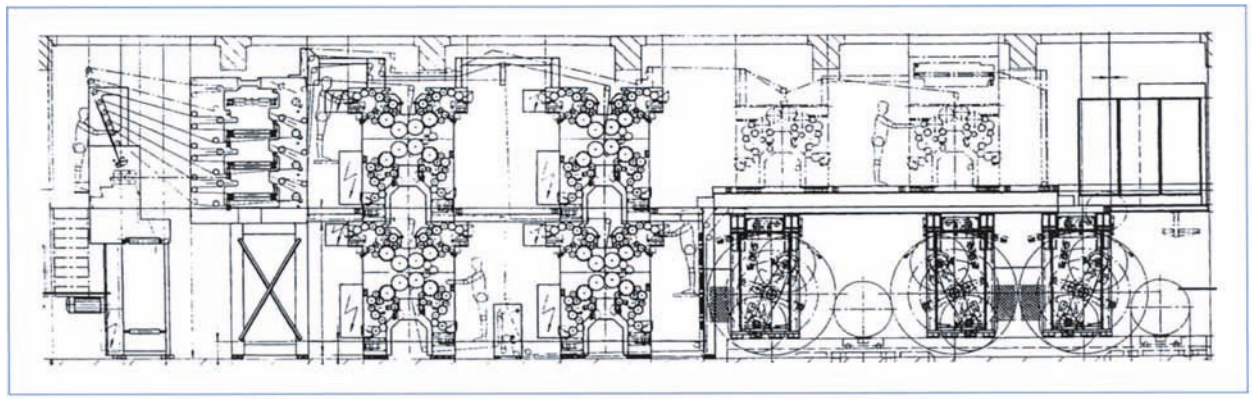


Fig. 2.1-196 Four-high units (compact design) and arch-type printing units in newspaper printing (IFRA/KBA)

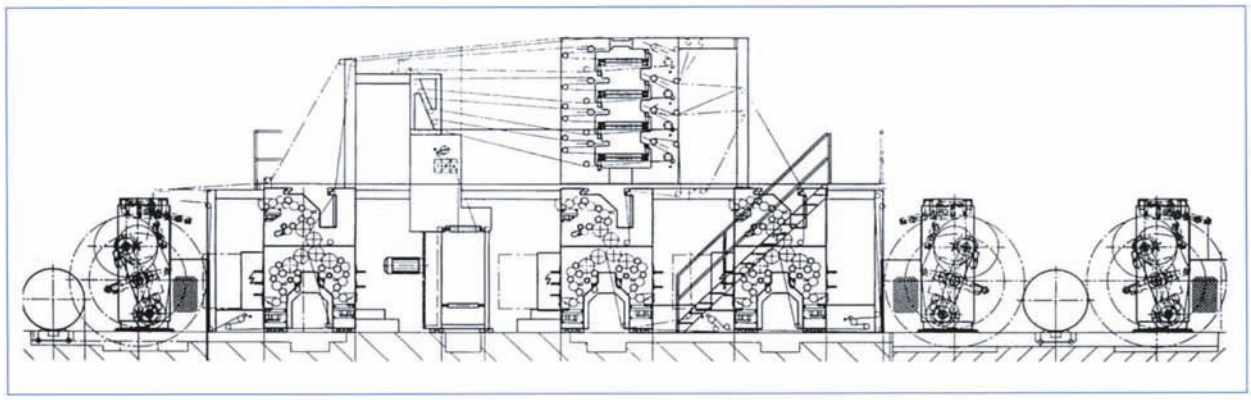


Fig. 2.1-197 Single-level design of a web printing system with Y-type printing units for newspaper printing (IFRA/MAN Roland)

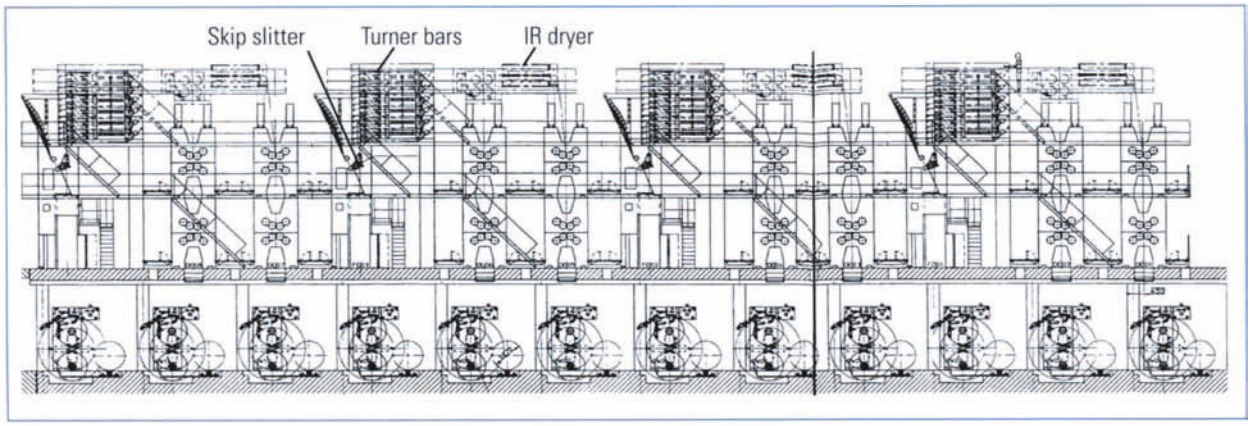


Fig. 2.1-198 Long web-fed printing installation with four-high units made up of H-type printing unit (IFRA/MAN Roland)

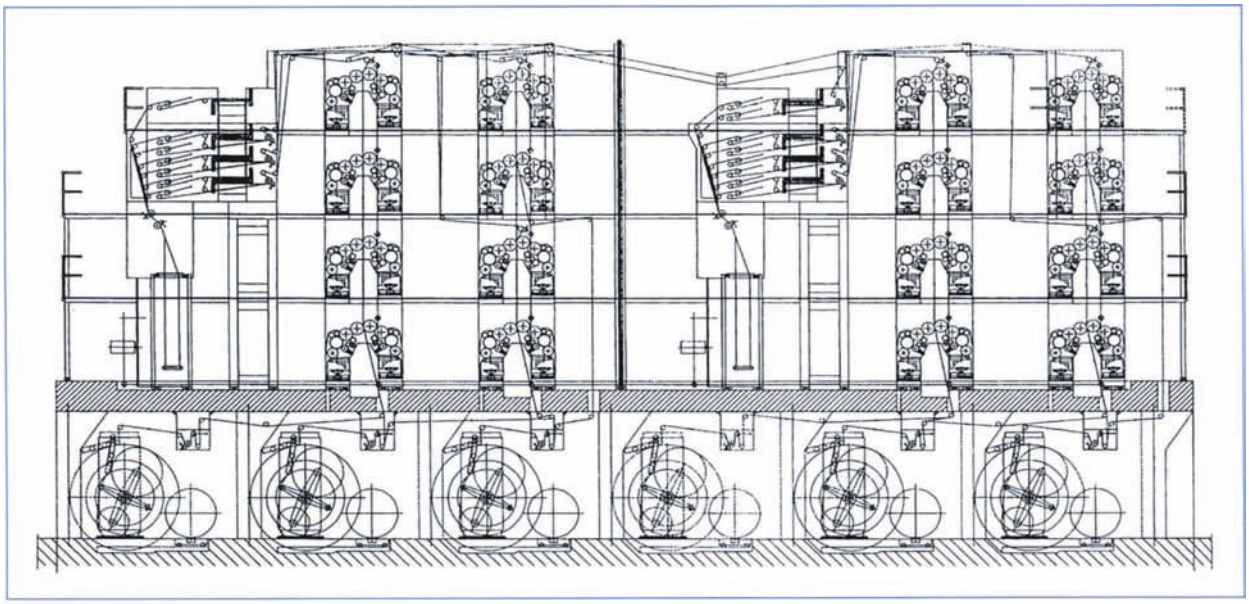


Fig. 2.1-199 Web-fed printing system with four-high units in the form of stacked arch-type printing units (IFRA/KBA)

The drawing clearly illustrates that the same geometrical ratios exist on all stories, which can be an advantage from the operational point of view. Each story can be reached via its own operating gallery. The folders are on the left and in the middle, the reel stands in the basement.

The peculiarity of the installation shown in figure 2.1-200 lies in the fact that it is assembled using both four-high units and *ten-cylinder satellite printing units*. The four-high units on the left have even been extended to form *six-high units*, by further H-type printing units being placed on top of the four-high units. An infrared dryer is located above the ten-cylinder satellite printing units. The upper parts of the ten-cylinder satellites involve typical "*color decks*", originating from the time when only spot colors were printed on newspapers (instead of the present-day four-color printing).

The same principle can also be applied with *nine-cylinder satellites*, as shown in figure 2.1-201. The press stands on a steel substructure, and the reel stands are housed between its props. The upper parts of the printing units function again as color decks (see also sec. 2.1.3.5), each printing couple (plate and blanket cylinder) having its own impression cylinder and consequently offering great versatility of use. There are also color decks in which two printing couples are engaged in a V-shape with one common impression cylinder.

In figure 2.1-202 it is demonstrated that the long *hot-air dryers can also be installed vertically* between the printing units.

The many very different examples of printing systems make it clear that in the construction of *web-fed printing systems* (and in particular for newspaper printing) one installation scarcely resembles another. Even if the same units of machinery are used, their assembly differs from customer to customer according to the different product ranges, the different space ratios and not least the individual preferences of the publisher and the printing company's manager.

A succession of illustrations shows a selection of *installations in printing companies* for production plants with web offset printing systems. The first examples are concerned with the production of *commercial print jobs* (figs. 2.1-203 to 2.1-207); the examples shown in figures 2.1-208 to 2.1-212 are installations for the production of *newspapers*.

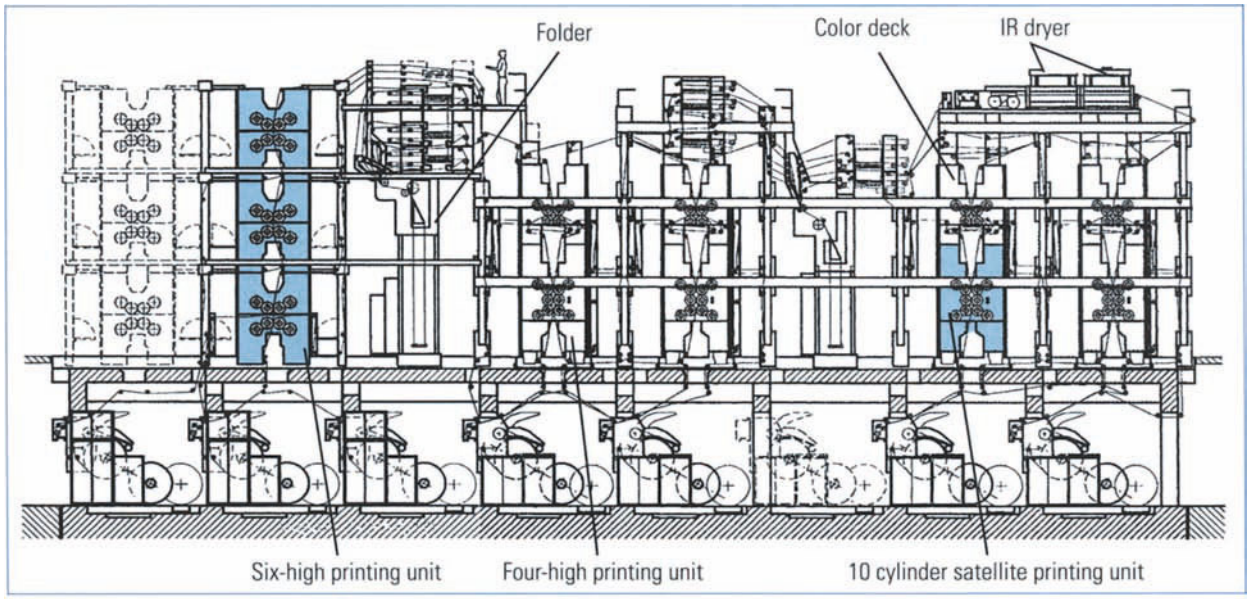


Fig. 2.1-200
Web printing system combining 10-cylinder satellites, color decks and four-high units, extended to form six-high units (IFRA/WIFAG)

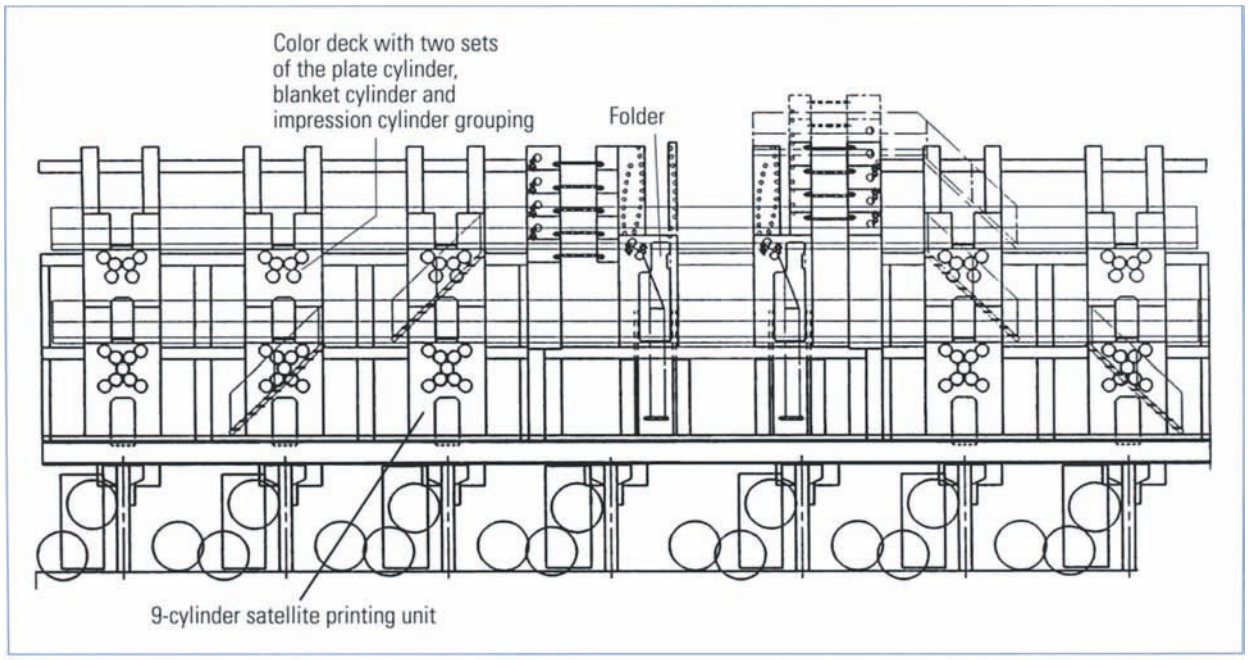


Fig. 2.1-201 Web printing press consisting of 9-cylinder satellites with attached color decks (IFRA/MAN Roland)

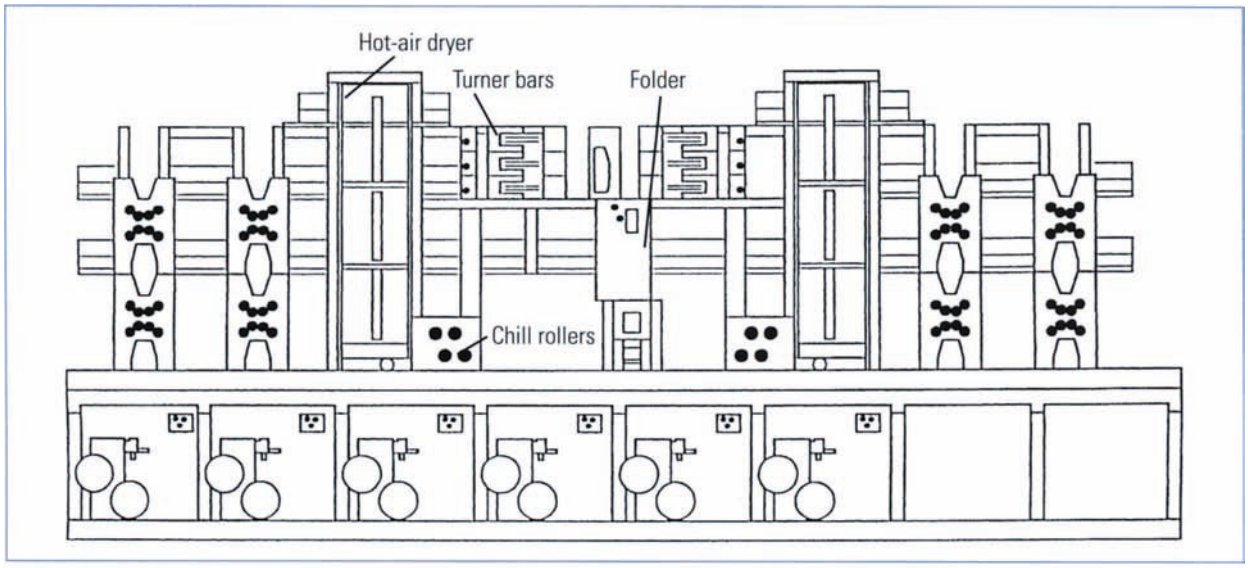
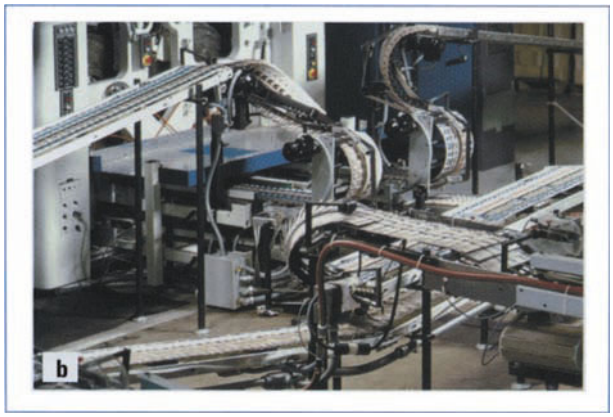


Fig. 2.1-202 Example of a web printing system with vertically configured hot-air dryers (IFRA/MAN Roland)



Fig. 2.1-203
a Commercial web offset printing system (48 pages, double-sized cylinders, 50000 revs./hour, max. 100000 copies/hour, web speed 15 m/s) with zero-speed web splicer in horizontal design (M-4000, Heidelberg);
b Folder with double stream delivery, copy stream diverters and gathering (PFF-3, Heidelberg)



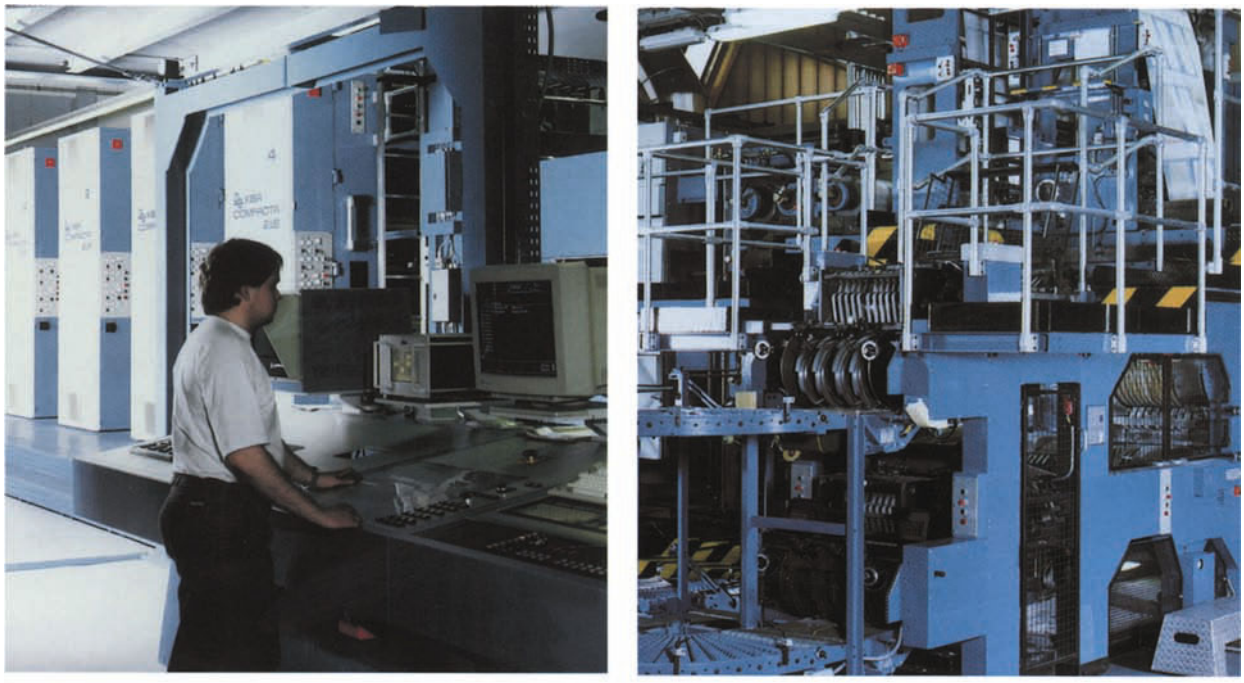


Fig. 2.1-204
Web offset printing press (16 pages, max. 80000 copies/hour) with central control console and modular folder with two deliveries (Compacta 218/folder P3, KBA)

Fig. 2.1-205
Web offset press (16 pages, up to 60000 copies/hour) with control consoles for remote control, color register control and web inspection (Lithoman III, MAN Roland)

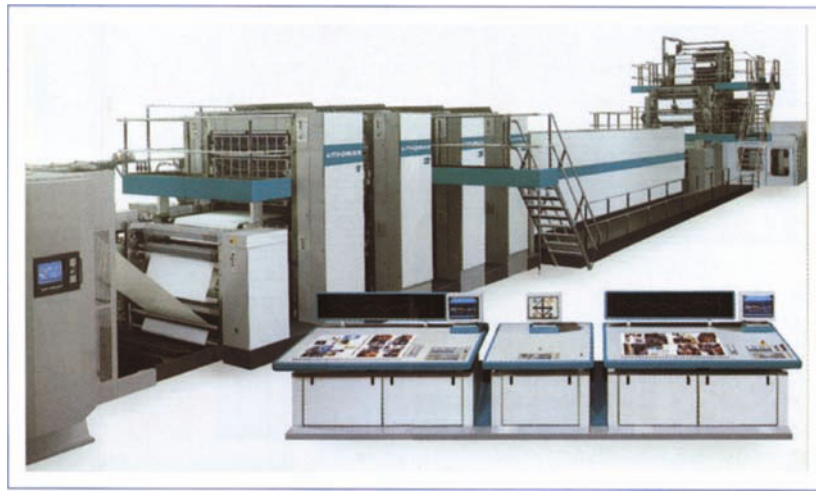


Fig. 2.1-206
Web offset printing system (16 pages, max. web width 880 mm, cut-off 546 mm, max. 48000 copies/hour) with double delivery and packaging unit (System 35, Komori)

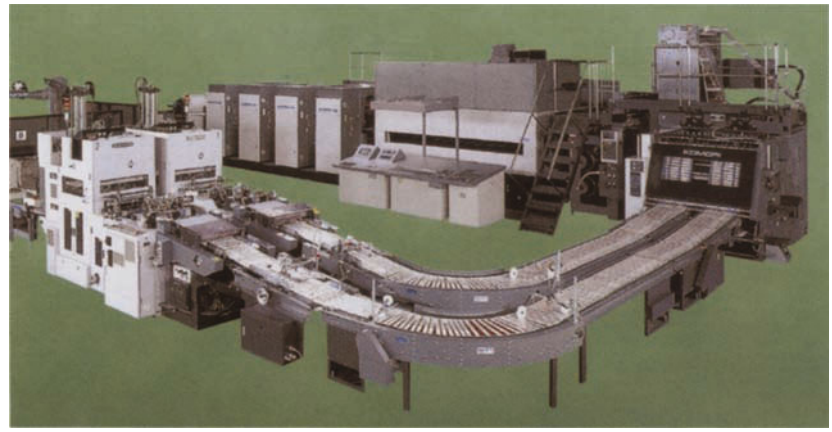


Fig. 2.1-207
Web offset printing press (max. web width 880 mm, cut-off 546 mm, max. 48000 copies/hour) with reel splicer in swing-arm design (Lithopia BT2-800, Mitsubishi)



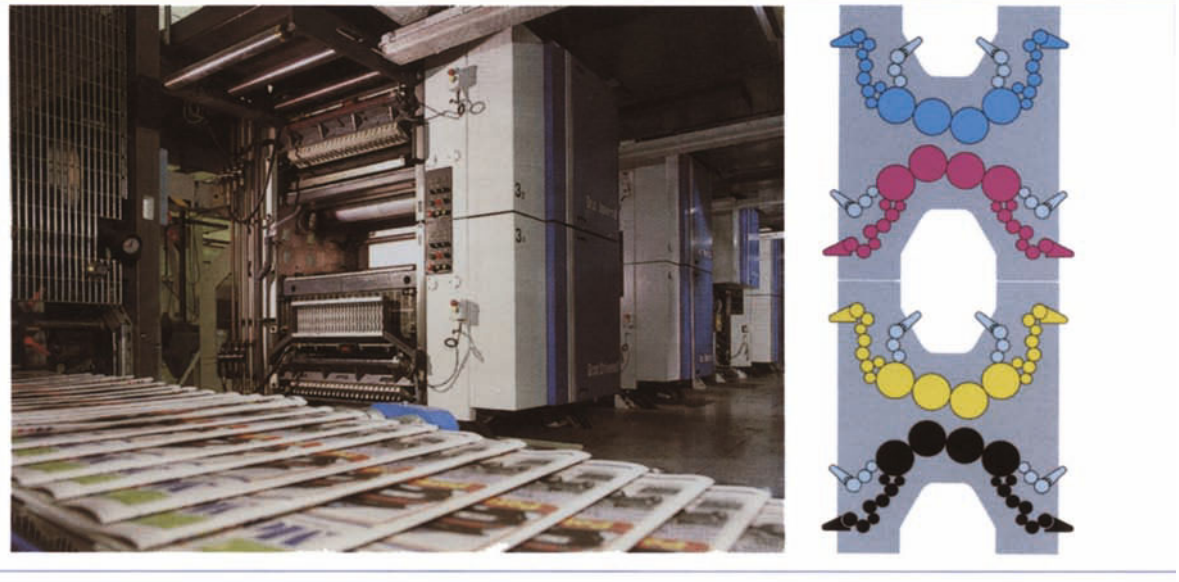
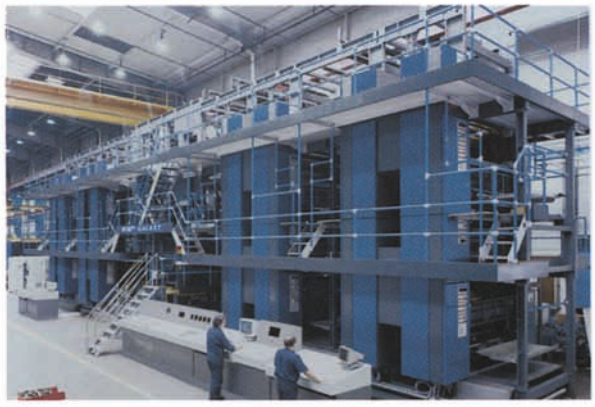


Fig. 2.1-208
Web offset printing press for newspaper printing (max. web width 914 mm, cut-off 600 mm, max. 70000 copies/hour) with printing units consisting of H-type units; four-high unit constructed with two H-type units (Universal 70, GOSS)





Fig. 2.1-209
Examples of installations of a web offset newspaper printing system (Model line for max. web width of 1020 mm, cut-off max. 630 mm; for coldset max. 45000 copies/hour, for heatset max. 35000 copies/hour) (Mercury, Heidelberg)



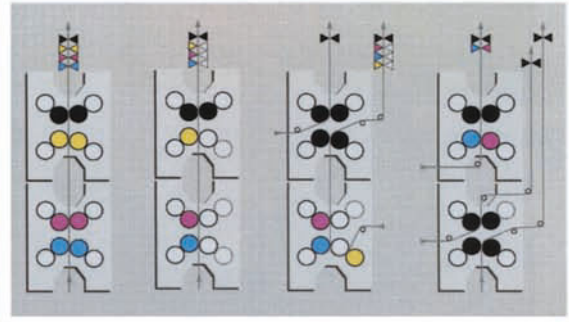
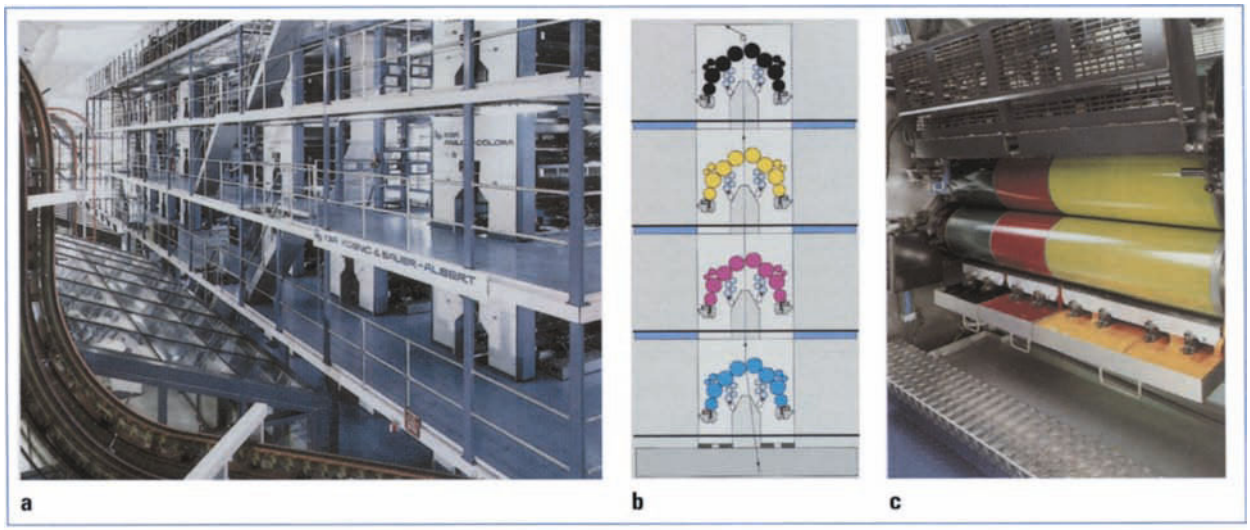


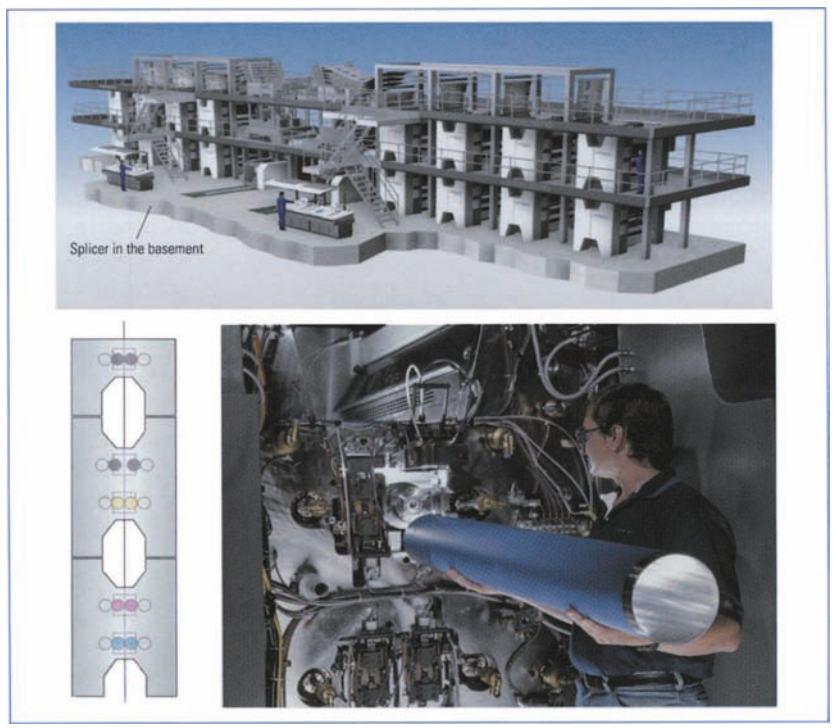
Fig. 2.1-210
Web offset newspaper printing system (16 pages, double-sized cylinders, max. 35000 revs./hour, max. 70000 copies/hour) with variants for web feeding and color arrangement in the four-high units (Galaxy, Heidelberg)



a b c

Fig. 2.1-211
Web offset newspaper printing system with Anilox short inking units (web width max. 1680 mm, cut-off max. 578 mm, double-sized cylinder, max. 70000 copies/hour in double production).
a Newspaper printing system;
b Four-high unit constructed of four arch-type printing units with Anilox short inking unit;
c Anilox offset short inking unit with quarter and half width ink fountains for printing different colors page-by-page across the total web width with the same printing unit (Anilox-Colora, KBA)

Fig. 2.1-212
High-speed web offset newspaper printing system (8 pages per blanket-to-blanket printing unit, 80000 copies/hour) with four-high units consisting of two H-type printing units and the option of integrating an arch-type unit for on-the-run change of the printing plate for black (e.g., for different versions within a print run), gapless blanket cylinder and multi-motor drive. Configuration (figure at top) with eight 4-high units for a 64-page production. Web splicers are installed in the basement (Mainstream 80, Heidelberg)



2.1.7 Potential for Further Development

The offset process has long been the leading print technology for economical production for high-quality medium and long print runs. The success of offset printing since around 1960 has been such that the image carriers used for this lithographic printing can be produced very cost-effectively offering high-quality reproduction and long service lives, at relatively low costs, under standardized conditions, and in an environmentally sound manner. Furthermore, production processes and system components for offset printing have been developed to provide for fast makeready and stable production conditions. The printing systems are operated via user-friendly interfaces. Digitization supports and simplifies procedures and makes them more reliable throughout the entire printing process. In particular, with regard to operating the printing press, the printer is no longer an expert on performing manual tasks, but is increasingly taking on the role of a data manager. Sophisticated equipment, materials, and production technologies are available, and the supplier industry uses an efficient component and material coordination network based on generalized standards.

Despite the achievement of an already very high technological level there is obvious further potential to optimize print media production based on offset printing technology.

This applies especially to the following topics:

- improvement and stabilization of print quality;
- improvement of offset processes through new methods and provision of innovative materials;
- shortening of makeready times and reduction of waste.

2.1.7.1 Print Quality

Frequency-Modulated (FM) Screening

Through digitization in prepress it is possible to use frequency-modulated screening more widely (see sec. 1.4.3). This screening process makes it possible to reproduce finer structures in the printed image (fig. 2.1-213) and, additionally, to eliminate disturbing effects such as moiré and rosette patterns (see figs. 1.4-28 and 1.4-31), connected with the periodic structure of an amplitude-modulated screen. Moreover, frequency-modulated screening of color separations makes multicolored images less susceptible to color variations caused by register deviations.

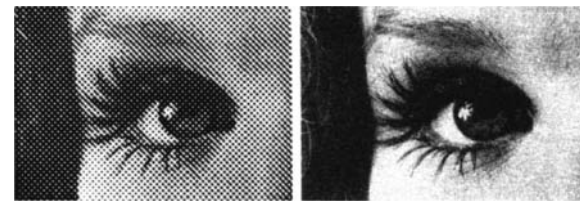


Fig. 2.1-213
Frequency-modulated screening (on the right) compared to conventional, amplitude-modulated screening (on the left)

This implies that there is potential for increasing the reproducible quality in the print through the use of available technologies. The insensitivity of the stochastic screen to color register deviations enables the printer to attain the desired production conditions faster; also during production the multicolored image reacts less sensitively towards color register deviations, which can occur as a result of variations in paper quality in the pile, climatic influences on the press or ink, or dampening solution effects.

These facts alone indicate that frequency modulation will be widely used and holds potential for improving production. Prepress and press technology and equipment are prepared for this.

High-Fidelity Colors (HiFi Colors)

For special printing applications that demand the highest reproduction quality, fine screens with the highest resolution are used, and in order to reproduce a large color space (fig. 2.1-214) more than four colors are printed. In addition to the process colors cyan, magenta, yellow, and black, the complementary colors blue, green, and red are used in seven-color printing. This leads to a much greater reproducible color gamut and, with it, more intensive coloring, as well as to greater variation of color shades. Therefore, the qualitative gap in quality color reproduction on an efficient color monitor or on high-quality photographic paper for color photographs is somewhat closed.

Employing high-fidelity color systems, the provision of the corresponding inks by the ink industry, as well as optimized color separation technologies, broaden the area of application of offset printing processes. This is reinforced through the increasing use of sheet-fed offset presses with eight and ten printing units, not only for four-color printing on both sides, but also for halftone printing with colors for high-fidelity (HiFi)



Fig. 2.1-214
Color space for specification of visually perceptible color gamut

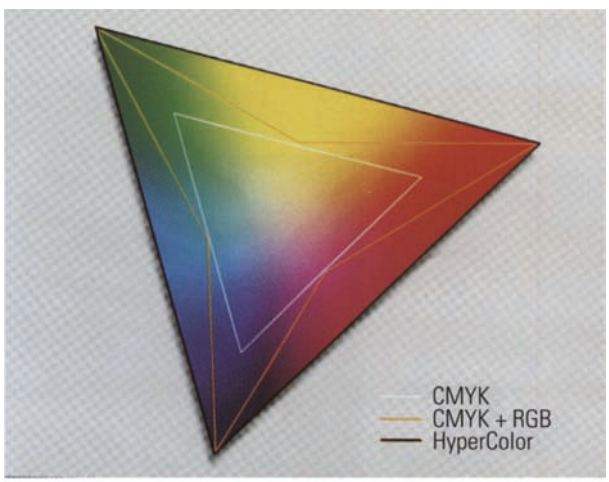


Fig. 2.1-215
High-fidelity multicolor printing (HiFi color) to expand color gamut in offset printing; diagrammatic (HiFi color system: HyperColor, DuPont)

printing (fig. 2.1-215 also includes a special color set, a HiFi color system).

2.1.7.2 Offset Printing Process

Waterless Offset Printing

Waterless offset printing (also known as "dry offset") has existed since about 1980. The combination of certain printing plate coating materials with adapted printing inks and inking units made offset printing possible without it being necessary to dampen the printing plate. In principle this technology is to be embraced; after all, customers assess visible print quality purely by the quality of color application. Ink is the only thing visible on the product, and additional materials such as dampening solution used in conventional offset printing are merely an aid to maintaining the printing process. When the operator can concentrate solely on ink application/color quality, without having to think about applying dampening solution, press operations become easier and safer, and as a result the entire process is more straightforward. Waterless offset printing is, therefore, from the user's point of view, a desirable print technology, which can make the workplace more interesting and the processes simpler.

The fact that waterless offset is not yet more widespread (optimistic estimates calculate the proportion of print media produced in offset using the dry offset method to be in the region of 5%) is largely due to the following factors:

- The printing plates are markedly more expensive than the established, conventional plates; however, change is underway here, since the years of monopoly by one company are over, and a number of large printing plate manufacturers have voted in favor of waterless offset, which will eventually bring costs in line with those for conventional printing plates.
- A further drawback to waterless offset printing is the fact that inks with a different viscosity (greater tack) are used, which places greater demands on the paper surface during printing, so that paper with less stable coating or portions of fiber and paper dust can lead to more rapid dirtying or deposits collecting on the blanket (the automatic cleaning effect of dampening solution found in conventional offset is not present); this results in deficient print quality and means that the press has to be stopped for cleaning.

The fact that the waterless offset process requires a printing unit temperature control within relatively narrow tolerances as compared to traditional offset printing is no obstacle to it becoming more widely used. Today's presses are either fitted with an inking unit temperature control as standard, or else they are available as optional extras (fig. 2.1-216).

- The surfaces of waterless offset printing plates are generally more susceptible to mechanical damage and wear and tear; this calls for more careful handling within the entire process. Potential for improvement is available in the form of materials/coatings. One can assume that these new materials will soon be available for practical use.

It is predicted that, in the coming years, waterless offset will become more widely accepted and that printing companies will concentrate more intensively on the use of this technology.

Direct Imaging and Re-imageable Printing Plates

In conjunction with digital penetration of prepress, platemaking directly in the offset press has become possible (computer to press/direct imaging, fig. 2.1-217). Thermal ablation plates, which are imaged for a specific job with thermal laser light directly on the plate cylinder, are available for waterless and conventional offset alike (see also sec. 4.4).

One technological challenge is the development of printing plate materials or preparation processes that make it possible to re-use for the next print job the printing plate that was imaged and used for the previous job; that is, to achieve the innovation of being able to erase and re-image the image carrier/plate surface (see sec. 4.4.2). This could on the one hand reduce preparation times (no changing around of plates) and on the other lead to better quality results and lower costs.

2.1.7.3 Drying

One problem with offset printing is that the ink is usually not sufficiently dry after printing, and therefore direct further processing/finishing of printed sheets is not possible.

In offset printing a sufficiently dry sheet that can be further processed is only achieved through special additional drying units integral to the machine (see also secs. 1.7 and 2.1.2.6). Hot-air and infrared drying are state-of-the-art; in particular, UV drying, in conjunction with special inks, makes it possible for the sheet to be dry when it arrives in the delivery or to be directly further-processed in line. For process reasons web offset presses are equipped with hot-air dryers for in-line drying, since finishing operations such as cutting, folding and so on, come directly after printing. The dryer is accepted as state of the art here and is justifiable with regard to production costs. But, of course, here, too, it would be desirable if one could do without these space-consuming units.

In sheet-fed offset insufficient drying is often compensated for by the application of powder in the delivery section so that undesirable quality-reducing ink setoff in the pile is prevented, and furthermore rather quicker finishing is possible (see sec. 1.7.3.1). Powdering is an additional operation bound up with costs,

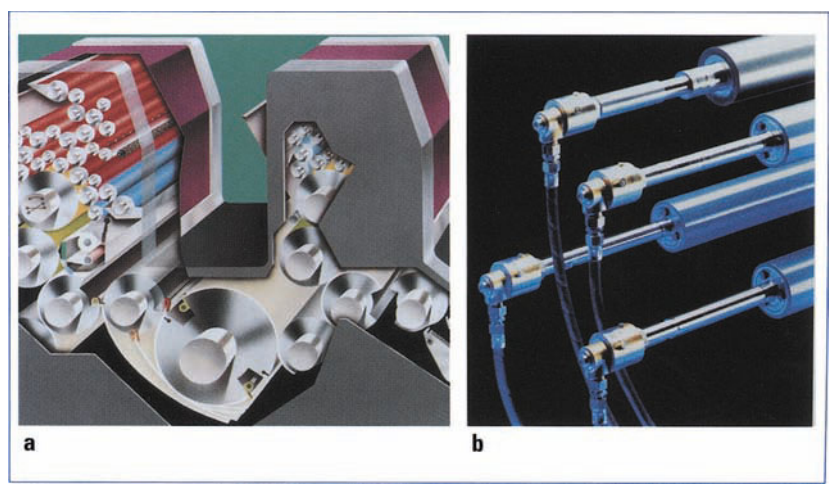


Fig. 2.1-216
Inking unit temperature control in printing units for waterless offset (dampening unit can be switched off/left off).
a Printing unit;
b Rollers in the inking unit (distributor rollers and ink fountain roller), connected to the temperature control cycle (Heidelberg)

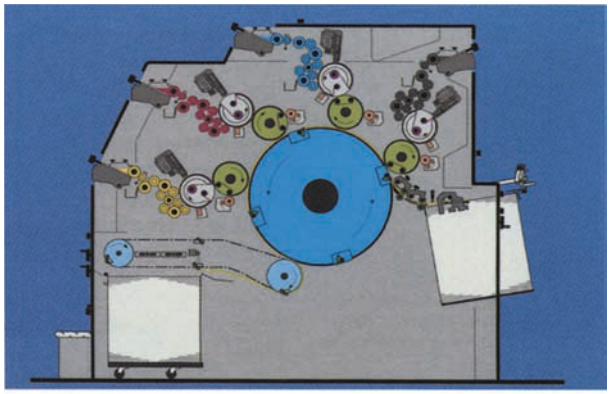


Fig. 2.1-217
Computer to press/direct imaging printing system (QM DI 46-4, Heidelberg)

and it leads to certain areas of the press getting dirty, and therefore to extra cleaning work and possibly also quality-reducing effects (e.g., in print jobs with coating, or through the generally gloss-reducing effect of fine powder particles).

A particular challenge facing ink manufacturers is the development of new ink systems to bring about speedier drying. A number of proposals are under discussion, for example the development of water-based, quick-drying offset inks. The development of new drying equipment and drying processes is likewise just as great a challenge for the supply industry as it is for printing press manufacturers.

2.1.7.4 Automation

Automation using remote control and measurement and control technology in carrying out the makeready in printing systems and in monitoring the print run is of a very high level (fig. 2.1-218 and secs. 2.1.4 and 2.1.5). Nevertheless, there is potential for further development aimed at further reducing makeready times and waste.

Inking Units

Among the factors we should mention here is the development of quick-reacting inking units with a shorter ink train and quicker uptake of stable production conditions after changes in the ink supply. "Short" inking units, with fewer inking rollers and optimized roller diameters that prevent quality-reducing effects such as ghosting, are at the trial stage; they are in use in newspaper printing (see figs. 2.1-11, 2.1-122) and could also be interesting for sheet-fed offset printing.

Remote Control

"One-person operation" is already a reality even with large presses. The operator can initiate all functions and monitor the entire process from the central control station (fig. 2.1-218, see also sec. 2.1.4.1).

Measurement and Control Technology

The further development of in-line measuring technologies is only constrained by cost factors, and there are system designs for in-line color measurement and image inspection (see sec. 2.1.4.5). A challenge for the development of efficient color measurement and control systems is the measurement in the image, that is, measuring print quality without having to print extra measuring elements/patches for color and color register along with the image. Color control strips, which on the one hand involve unnecessary paper trimming/waste, and on the other mean more work in prepress depending on the technology used, would no longer be necessary if measurement technologies and analysis algorithms were developed to acquire the information on print quality and press control directly from the printed image. This is in the interests of the press operator (for quality evaluation purposes), the entrepreneur (because of cost), and the customer (for reasons of cost and quality assurance) alike. The customer is interested in the printed image and not the control elements, which are still today a necessary aid to printing.

Job Preparation

Automatic wash-up devices, automatic plate changing, and automatic adjustment of paper guiding elements are in general use. However, there is still potential for improvement in these technologies.

The perfect inking unit and automation system should be of such a design that the first sheet printed is produced in a saleable quality. Today it might still take 100–200 sheets before ink feeding and print quality have stabilized. New inking unit designs and intelligent, adaptive measurement and control software and systems (including color management) are cutting down further on start-up waste.

In-line Production

Carrying out more and more print media production tasks in a printing system directly is a goal to work towards for numerous job-specific applications. This is



Fig. 2.1-218
Measuring and control system with automation components for a sheet-fed offset press (see also fig. 2.1-150), (Heidelberg)

not only for economic and quality reasons, but also to create innovative printing products. In-line finishing such as cutting and perforating, as well as personalization, binding, folding, and so forth, has a role to play in the development of printing systems.

However, practicability and customer benefit need to be considered most critically – flexible use of printing systems has a high status.

Environment

There is continual reduction of cleaning processes, above all cutting down on the use of chemicals. Environmental concerns and safety questions are being resolved satisfactorily and beyond mere mandatory restrictions (see also sec. 13.2.1.2).

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2.2 Gravure Printing

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Gravure printing is a very old printing process, whose beginnings (copperplate engraving) date back to the early fifteenth century (cf. sec. 13.1.1). Today, gravure printing accounts for a market share of 10–15% in industrialized nations. This percentage share has remained almost constant for two decades, with a slight downward tendency. The simplicity of its printing principle has, in comparison to the offset process, always fired experts in this field with enthusiasm and the keyless inking systems of newspaper offset presses and anilox inking units used in flexography ultimately took their inspiration from the inking principle of gravure printing.

The simplicity of the printing principle (fig. 2.2-1, see also sec. 1.3.2.2) is, however, offset against the problem of a labor-intensive and costly manufacture of the gravure cylinder. Hence, gravure printing is principally used for very long print runs. The minimum print run is approximately one million copies. Weekly magazines of general interest and mail order catalogs are therefore the main products produced by means of gravure printing. Another major area is in the printing of packaging, from extremely thin foils to thick cardboard.

Figure 2.2-2 shows a gravure printing press used for the production of magazines. With gravure printing, straight printing and perfecting is done in systems where the first side of the web is printed in multicolor and then (in-line) on the opposite side (see also figs. 2.2-17, 2.2-28).

2.2.1 Process

The principles of gravure printing and some typical specifications are described in section 1.3.2.2.

2.2.1.1 Gravure Cylinder Manufacture

With the exception of sheet-fed gravure printing (see fig. 1.6-8), which is now found only rarely, web-fed gravure printing requires a gapless *gravure cylinder*, onto which the image is applied directly, by means of etching or engraving. For this, the cylinder must be prepared in a costly mechanical and galvanic process.

In its basic design, the gravure cylinder consists of a thick-walled steel tube with flanged steel journals. To increase the stiffness of this hollow cylinder, some of the cylinder journals are drawn inwards and are supported inside the tube on additional steel discs. All of these joints are welded during the manufacture of the gravure cylinder so that a solid roller body is created, which still has to be balanced so that there are no vibrations when running at high speed (typically up to 15 m/s) in the printing press.

The cylinder receives a base copper layer on its surface, which, among other things, serves to achieve the specified diameter of the finished gravure cylinder.

For the application of another copper layer (figs. 2.2-3 and 2.2-4), which varies from print job to print job, there are several methods that are described in the following sections (note: the top copper layer is twice as hard

H. Kipphan (ed.), *Handbook of Print Media*
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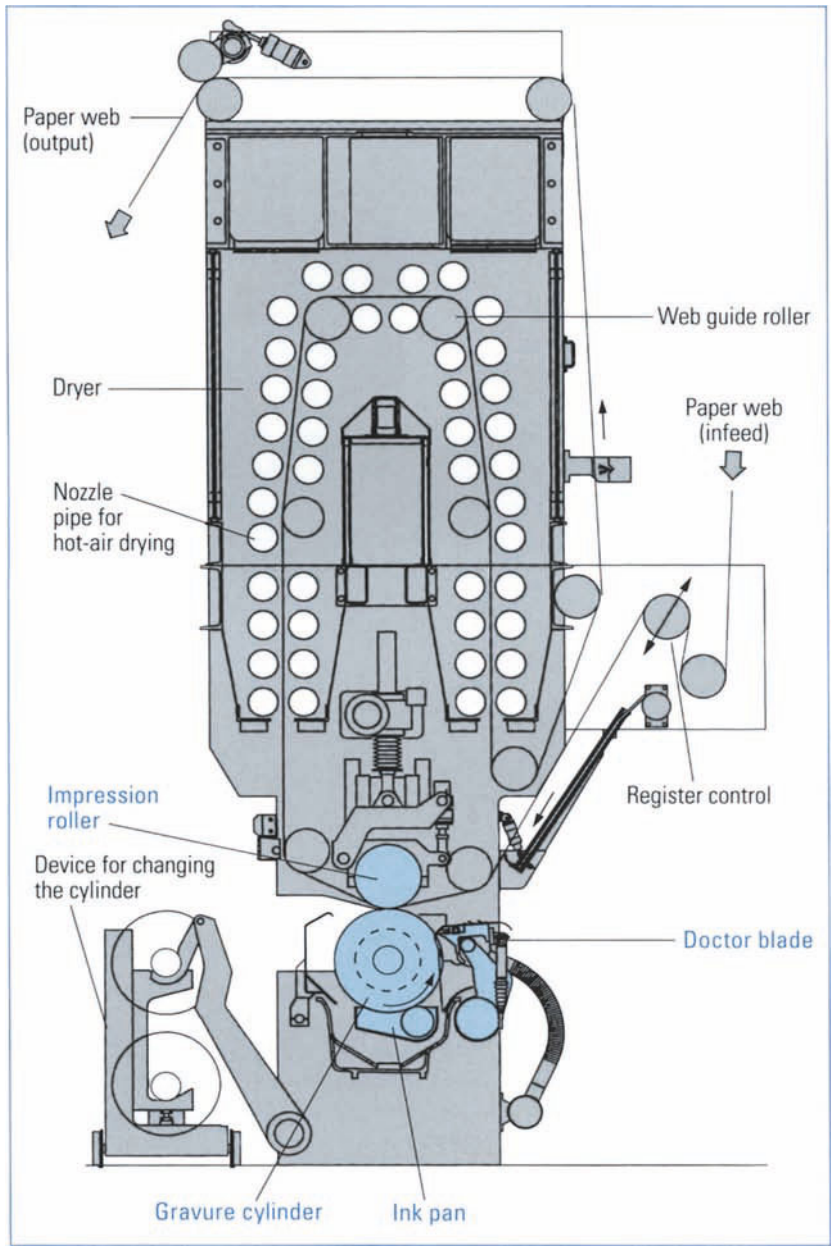


Fig. 2.2-1
Schematic illustration of a gravure printing unit (KBA)

(Vickers hardness approximately HV 200) as the base copper, so that this copper layer has good cutting properties as regards the electromechanical engraving process):

- *The thin layer method* (fig. 2.2-4a):
  The base copper layer is coated with an engravable copper layer (approximately 80 µm) in an electroplating process (fig. 2.2-3). This thin layer only allows a one-time engraving. The advantage of the thin layer technique is that all the gravure cylinders of one type have the same diameter dimensions and less mechanical surface treatment is required after the electroplating process than with thick layer processes (see below). The removal of the en-



Fig. 2.2-2
Part of a rotogravure printing press; the row of individual printing units is shown with the ink supply tanks in the foreground (KBA)

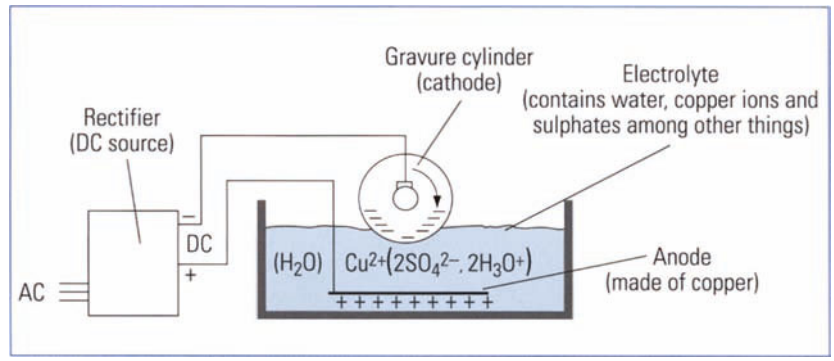


Fig. 2.2-3
Electroplating of a gravure cylinder; the copper ions Cu^{2+} settle down on the cathode (gravure cylinder) and form a copper layer

graving (after dechroming) is achieved by dressing or milling the copper. After this, a new copper layer is applied. (In the special process known as copper recycling, the copper layer is removed in an electroplating reversal process. In this process, an additional nickel barrier layer of approximately 25 µm between the base copper and engraving copper is necessary.) The thin layer technique is used in some 35% of cases, whereby the copper recycling method only accounts for some 5%.

- *The Ballard skin method* (fig. 2.2-4b):
  This method is also a thin layer process (one-time use of the engraving copper layer). The base cover is electrically covered with a removable copper skin (80–100 µm), whereby a special layer between base copper and Ballard skin ensures that the Ballard skin can be peeled off the gravure cylinder after printing. The Ballard skin method is employed in approximately 45% of cases.
- *Heavy copper plating (thick layer technique*; fig. 2.2-4c):
  An approximately 320 µm thick layer of engraving copper is applied onto the base copper in an electroplating process. This thickness of the layer permits engraving for approximately four print jobs. After each print job, a layer of approximately 80 µm is removed in a multi-stage mechanical process (milling, grinding). The former image is thus removed. When the engraving copper is used up, a new copper layer (hard) is applied by means of electroplating. This method is employed in about 20% of cases.

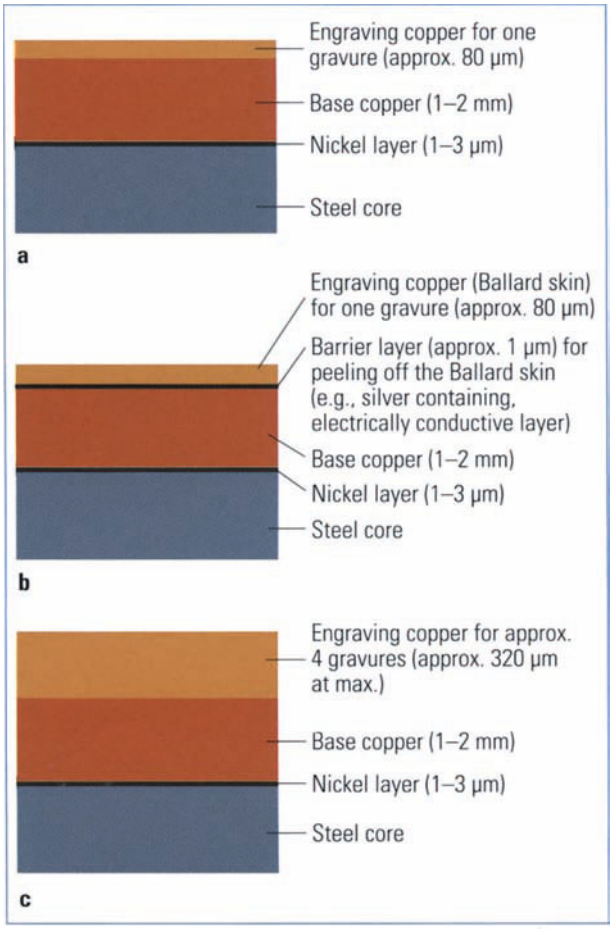


Fig. 2.2-4
The various methods of copper plating the gravure cylinder.
a Thin layer method;
b Ballard skin method;
c Thick layer method

With all methods the cylinders are always *hard chrome-plated* after etching or engraving to reduce wear and tear. Therefore chemical chrome deplating with hydrochloric acid must be undertaken prior to removal of the image carrying layer.

The *process sequence for preparing an engraving cylinder* is generally as follows:

- removing the used gravure cylinder from the gravure printing press;
- washing the gravure cylinder to remove residual ink;
- removing the chrome layer;
- removing the copper image-carrying layer, either chemically, by means of electroplating, or mechanically;
- preparing the copper plating process (degreasing and deoxidizing, applying the barrier layer if the Ballard skin method was employed);
- electroplating;
- surface finishing with a high-speed rotary diamond milling head and/or with a burnishing stone or a polishing band;
- etching or engraving (producing the image on the gravure cylinder);
- test printing (proof print);
- correcting the cylinder, minus or plus (i.e., reducing or increasing the volume of cells);
- preparing the chrome-plating process (degreasing and deoxidizing, preheating, and – if necessary – sometimes polishing);
- chrome-plating;
- surface-finishing with a fine burnishing stone or abrasive paper;
- storing the finished cylinder or installing it directly in the gravure printing press.

Today, all these operations are performed, more or less fully automated, in production lines, whereby overhead traveling cranes and in some cases the transportation of the gravure cylinder from station to station is carried out by automated guided vehicle (AGV) systems.

2.2.1.2 Gravure Cylinder Imaging

In addition to an image-carrying function, the *screen structure* of the gravure cylinder surface has the significant task of guiding and supporting the doctor blade. The blade supports itself on the cell walls, which demarcate the cells. The continuous-tone-like graduation in the image of conventional gravure (etching) is achieved through the various depths of the cells. However, there is a mixed form, the variable area and depth gravure process, in which the cell diameter and depth of the cells are altered for the continuous tone graduation. Variable area gravure printing without cell depth variation (corresponding to the dot size variation in offset and letterpress printing) has gained little significance (see fig. 1.3-11). Electromechanical engraving with diamond stylus (variable area and depth gravure) is the dominant process. Only seldom is etching still used as an imaging process in

gravure printshops. Despite this, and in the interests of thoroughness, a short description of this process is given below.

Etching

For transferring the image onto the gravure cylinder, conventional etching processes use a pigment paper, which is coated with a gelatin layer and sensitized (i.e., made light sensitive) with a chrome saline solution just before use. First the crossline screen and then the imaging film are exposed onto the pigment paper in a copying frame. The pigment paper is then "laminated" onto the gravure cylinder surface in a special pigment-paper transfer machine. A stabilizing base paper, which is later removed, ensures that this transfer takes place in accurate register. The use of an "autofilm" where the photo emulsion is poured onto foil makes this base paper redundant. The process that follows, involving softening, base paper peeling, and washing out of the unexposed and therefore soluble gelatin in approximately 40 °C warm water (in this process the cylinder turns in a water bath) followed by a drying process, can be described as "developing." All these operations are carried out in program-controlled automatic developing machines. A relief (corresponding to that of the etched cylinder) with gelatin layers of varying thickness forms between the raised cell walls.

Prior to etching, all non-printing sections are covered with an acid proof asphalt varnish – certain imperfections from the transfer can also still be corrected in this way. The actual etching procedure takes place in a program-driven single-bath etching machine. Here, the cylinder is bathed in or sprayed with a ferrous chloride solution until the required etching depth is achieved. The ferrous chloride solution "eats" its way through both the gelatin layer and into the copper of the image-carrying layer. The deeper the gelatin cell is, the sooner the acid comes into contact with the copper and the deeper the cell created on the image-carrying layer.

Electromechanical Engraving

The operations involved in electromechanical engraving are significantly shorter compared to the etching process. Nowadays, they are normally controlled directly with the data recorded in prepress. In this way the mounting of a scanning original on a separate scanning drum (see fig. 1.3-14) that runs synchronously with the engraving machine is also no longer needed. Hence, the engraving machine only consists of a lathe-like device, into which the prepared gravure cylinder is mounted. The engraving procedure is similar to a rotating cutting process, but the cut is intermittent (stylus frequency).

The gravure cylinder rotates during engraving at a constant surface speed (depending on the screen at approximately 1 m/s). At the same time the diamond stylus of the engraving head moves at a high frequency (4–8 kHz). The diamond penetrates the copper at different depths and produces the cell. Possible results of this process are illustrated in figures 2.2-5 and 2.2-6.

The cells are equidistant from each other in the circumferential direction (direction of engraving) due to the continuous circumferential velocity and the engraving frequency. Engraving of neighboring tracks is semi-staggered (figs. 2.2-5 and 2.2-6). The lateral repeat length corresponds to the forward motion of the engraving head per cylinder revolution in the shaft direction of the gravure cylinder.

Depending on the width of the web to be printed, up to sixteen engraving heads (typically eight) with styli are used for publication gravure printing (fig. 2.2-7, see al-

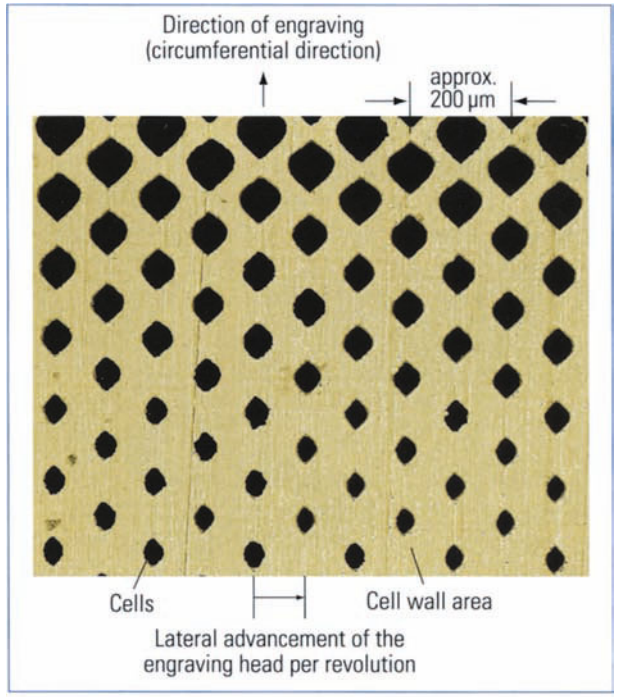


Fig. 2.2-5
Electromechanically engraved cells on the cylinder surface. The halftone values result from the varying cell volumes; variable area/variable depth.

so sec. 4.3.4). The burrs on the copper surface are usually removed by a *scraper* which is fixed to the engraving head during the engraving process. The cylinder must therefore only be lightly polished before it is used for a test print in a proofing press, corrected manually in accordance with this, and then finally *chrome-plated.*

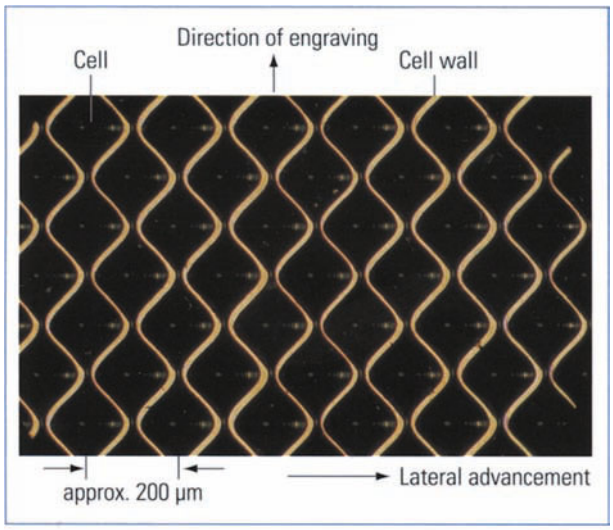


Fig. 2.2-6
Electromechanically engraved cells (maximum engraving depth)

Laser Engraving

In the past, there have been numerous attempts to make engraving faster and cheaper. One possibility lies in the implementation of *non-contact methods*, such as electron or laser beam. In individual cases, laser engraving is already in practical usage today. In the year 1995, a direct engraving process using a laser was brought onto the market ("Laserstar" by Max Dätwyler AG), where a solid-state laser engraves a *zinc layer*. The cell shapes produced are similar to those of etched cells (the process operates at 70 kHz engraving frequency). The engraved cylinder is chrome-plated after a grinding and cleaning process. Dressing of the gravure cylinder after printing is carried out using similar chemical, mechanical, and electroplating methods as with a copper cylinder. Basically the step of copper plating (to permit engraving copper) is replaced by a process of electroplating zinc.

Laser engraving opens several new doors for gravure printing. The unwanted saw tooth effect with fine fonts can be reduced. Alongside this, there is the possibility of working with frequency-modulated screens (see sec. 1.4.3).

Indirect laser engraving processes use a light-sensitive black layer that is applied onto the copper of the gravure cylinder. The laser removes this layer in accordance with the image (on the basis of already available digital data files). The gravure cylinder is then etched (e.g., "DIGILAS" by Schepers-Ohio).

Fig. 2.2-7
Engraving machine for electromechanical stylus engraving with up to 16 engraving heads (HelioKlischograph K 406-Sprint, HELL Gravure Systems)



Proof Prints

In order to reduce the burden on the print production system, proof prints are produced on special *proof presses* (figs. 2.2-8 and 2.2-9), which consist of a simple unwinding unit (normally designed for various web widths), four printing units, and an open sheet delivery (sheeter). The drying distances between the printing units are significantly shorter due to the low printing speed (approximately 15% of the production speed), and drying usually takes place on one side only. The throw-on mechanism of the impression roller is equipped with a three or four-part revolver for impression rollers of various widths (fig. 2.2-8). In order to achieve a result comparable with production, the inks must be adapted accordingly to their rheology.

There are also simpler gravure proof presses where a sheet of paper is mounted on a large drum and onto which the four gravure cylinders of a four-color print are printed one after the other. A special accelerating device provides conditions similar to those of production.

2.2.1.3 Storage and Changing of Gravure Cylinders

It is understandable that well-organized *stock-keeping* becomes necessary when storing many heavy gravure cylinders of various sizes. Paternoster elevators (a row

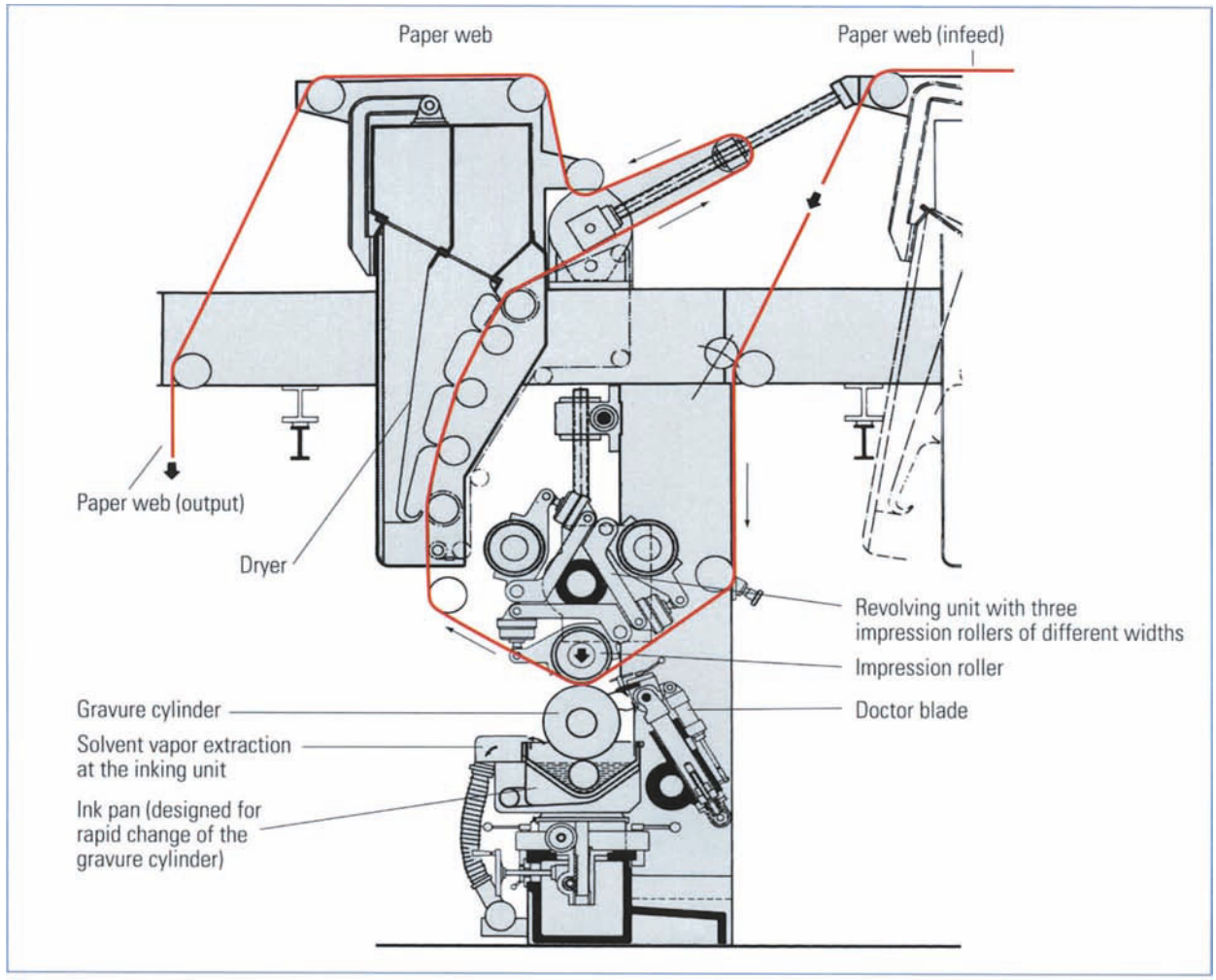


Fig. 2.2-8 Structure of a gravure proof press unit (KBA)

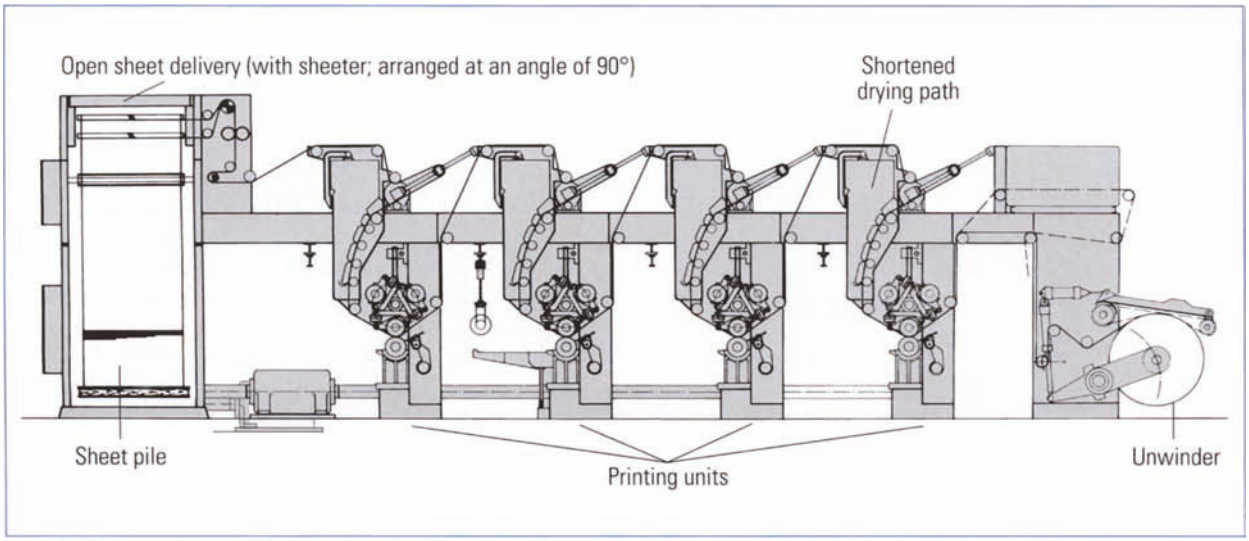


Fig. 2.2-9 Diagram of a gravure proof press with four printing units (fig. 2.2-8), unwinding unit and open sheet delivery (KBA)

of risers) are generally employed here as they permit access to every individual cylinder. For transportation automatic overhead cranes or automated guided vehicle (AGV) systems can be used. To identify the gravure cylinders they are marked; sometimes electronic, non-contact recognition means (electronic labels) are employed. To protect the surface, the gravure cylinders are often packed in thick felt mats and zipped shut.

The simplest way to *change the gravure cylinder* in the printing press takes place with manually attachable support rails (fig. 2.2-10) via which the cylinder is rolled onto a transport carriage. A further, more automated variant, is the use of hydraulic lifting units (fig. 2.2-11). The highest level of automation at present allows the cylinder to be changed together with its inking unit in a slide-in unit. In this way cleaning takes place outside the press, enabling the shortest possible change-over times.

For *mounting* the gravure cylinders in the gravure printing press, roller bearings fixed in stable bushings must be attached to the ends of the shafts (fig. 2.2-10) before they can be rolled into the horizontal slots on the printing unit side frames and fixed into place with clamping sockets. The drive-side journal is then connected to the drive gear box via a flexible clutch for a motor-driven revolving of the gravure cylinder. The drive gear box, normally designed as a free-standing unit, also contains the gearbox and servomotors for the circumferential and lateral registers as well as the drive for the axial reciprocating motion of the doctor blade. It is reasonable to expect that electronically controlled individual drives (shaftless drive) will be developed and offered for gravure printing presses as well, especially since corresponding preliminary tests date back to the start of the 1970s.

As with the gravure cylinder, the *impression roller* (rubber-coated roller) needs to be changed from time

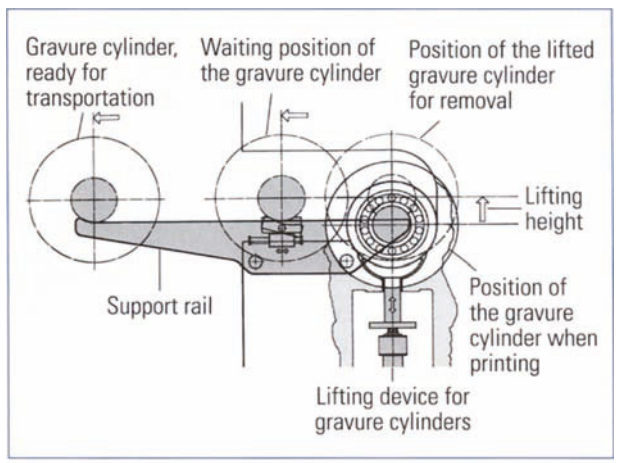


Fig. 2.2-10 Support rails for changing the gravure cylinder (KBA)

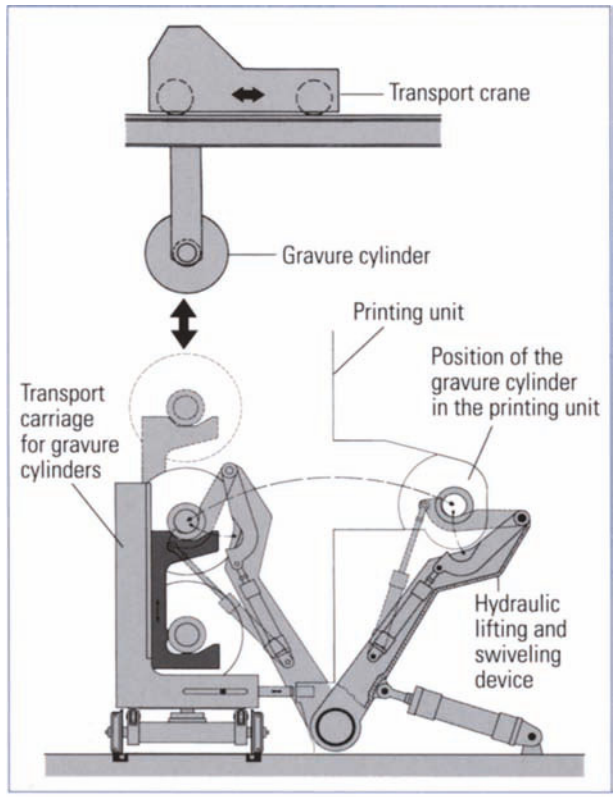


Fig. 2.2-11
Hydraulic lifting unit for gravure cylinders on a gravure printing unit (KBA)

to time when a new rubber coating or regrinding becomes necessary due to scoring effects on its surface, or if a different paper width is to be processed. The transport devices for the gravure cylinder are therefore equipped with fixtures that can also carry the impression roller.

2.2.1.4 Impression Roller

As in every conventional printing process, in gravure printing there is also an *impression roller*. This cylinder must be sufficiently stable and as small as possible in its diameter to assure a narrow printing nip for a better (i.e., sharper) print of the gravure cylinder. Therefore, previously (prior to 1960), it was common to arrange the gravure cylinder, a smaller intermediate roller (impression roller), and a larger cylinder above one another in a three-roller system. (If the small intermediate roller were brought into contact with the gravure cylinder without the pressure from the large cylinder, there would be too large a deflection of the impression cylinder. Hence, the contact pressure in the center of the two cylinders would no longer be sufficient in the printing nip.)

The trend towards higher production speeds and the consequent need to reduce heat generation favored two roller systems, which led to the development of *deflection-compensated impression rollers* in the 1960s and 70s. Their design was based on rollers used in calenders (stack of rollers). Above it all, it was the "swimming roll" from the company E. Küsters and the "NIPCO roller" (fig. 2.2-12) that became established in superwide designed gravure printing presses. In the case of the latter, small hydraulic cylinders, supported on a fixed, stationary body inside the impression cylinder, act as "saddles" (hydraulic supports) and press the rotating sleeve of the impression roller against the gravure cylinder. The hydraulic fluid penetrating on the surface of the "saddles" serves both as lubrication and as cooling.

In the further course of developments, the gravure printing press manufacturers have worked on further solutions, such as deflection-compensated impression rollers that were based on the principle of "indented bearing points." On the "K2 impression" roller (fig. 2.2-13), additional hydraulic pressure is applied to the extended shaft ends (fig. 2.2-13b) of the inner body, so that inside the roller the drawn-in bearings exert a counter-bending moment on the impression roller sleeve, which is counteracted by the normal hydraulic throw-on mechanism of the impression roller. The impression roller, therefore, deflects downward and is only brought back into even contact with the gravure cylinder by the normal throw-on mechanism.

These deflection-compensated impression rollers are also cooled from inside in order to prevent the impression roller covering from becoming too hot. This is not only done to preserve the covering, but also to prevent heat transmission into the inking unit.

The *impression roller covering* consists of a special rubber layer of high shore hardness (approx. 95 Shore A) and is applied seamlessly. The impression roller is driven non-positively via the gravure cylinder when in contact with the printing material. In order to promote the *transfer of ink* from the etched gravure cylinder onto the paper wrapped around the impression roller, the impression roller or the web is *electrostatically charged* just beforehand. The ink meniscus (the top surface of a column of liquid) in the ink cells is thus raised and wets the

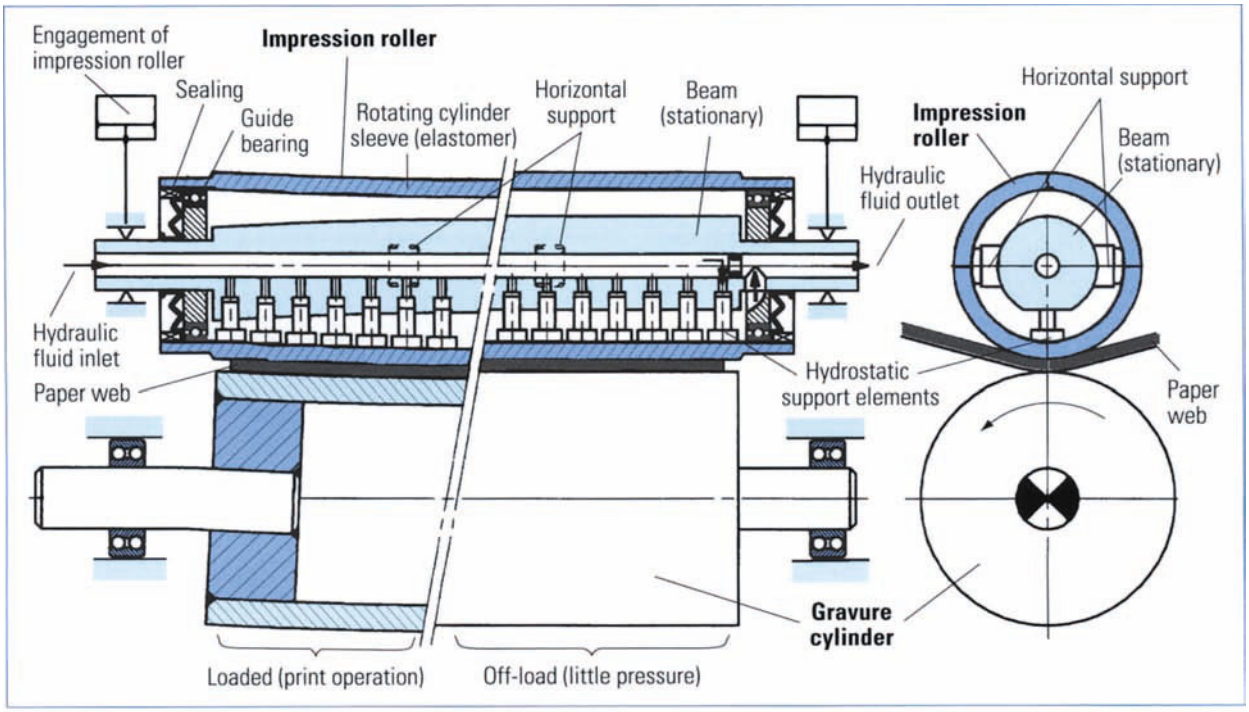


Fig. 2.2-12
The principle of the deflection-compensated impression roller. A number of support elements inside the roller compensate the deflection of the gravure cylinder and ensure that the contact pressure remains practically constant along the entire web width (of the paper). A hydrostatic bearing is located between the immovable support elements and the rotating sleeve (NIPCO, Voith-Sulzer)

paper more effectively. This device, which works with special voltage generators, is called ESA (Electro Static Assist). For this the impression roller must be supported by its bearings in an electrically insulated manner.

In contrast to letterpress printing, where the ink is applied on a raised image carrier, and lithographic printing, where the ink is applied onto a planographic image carrier, in gravure printing the ink must be applied into engraved cells of the gravure cylinder surface. For this the ink (see sec. 1.5.2.3) must have a very low viscosity (approximately 1 Pa · s) – it mainly consists of a solvent with a low boiling point (Toluene) and pigment-containing resins or resin-embedded pigments (again, see sec. 1.5.2.3).

To fill the indented elements, that is, the etched or engraved cells, only requires an ink pan that is filled with gravure printing ink, into which the rotating gravure cylinder is immersed (fig. 2.2-14a). In order to prevent strong foam formation and splashing of the ink, a pan roller with a soft covering runs simultaneously in the ink pan. Due to friction, this roller runs more slowly than the gravure cylinder circumference. This allows the application of a homogenous ink film onto the gravure cylinder without splashing. Special splash guard plates on the gravure cylinder ends also prevent ink splashes at the cylinder edges and the superfluous ink falls into the ink trough beneath the height adjustable ink pan. From the ink trough, the ink flows into an ink tank positioned in front of the printing unit; there it is mixed with fresh ink, cleaned by filters, its viscosity is checked and it is pumped back into the ink pan.

Since the gravure cylinder also takes up ink on the non-printing areas when dipped into the ink pan, the superfluous ink must be removed from the gravure cylinder surface by means of a *doctor blade*. This blade

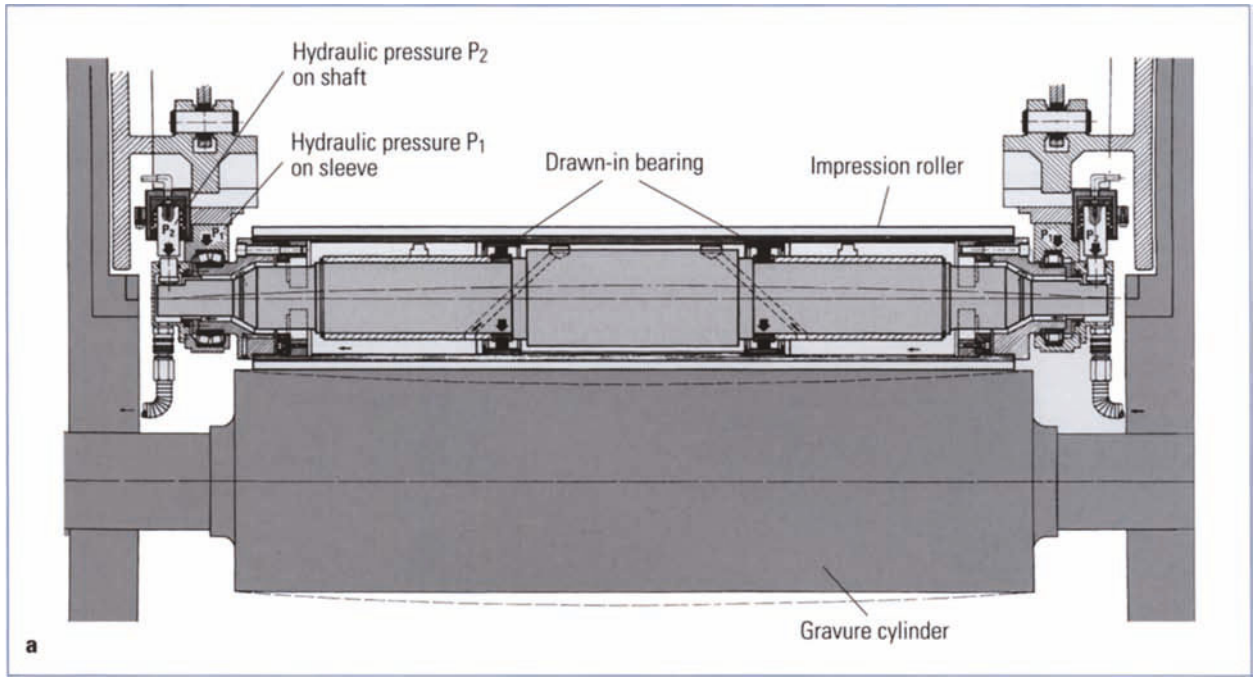


Fig. 2.2-13
Deflection-compensated impression roller (K2, KBA).
a Gravure printing unit with K2 impression roller;
b Effect of the (hydraulic) pressures P_1 and P_2 on the contact pressure

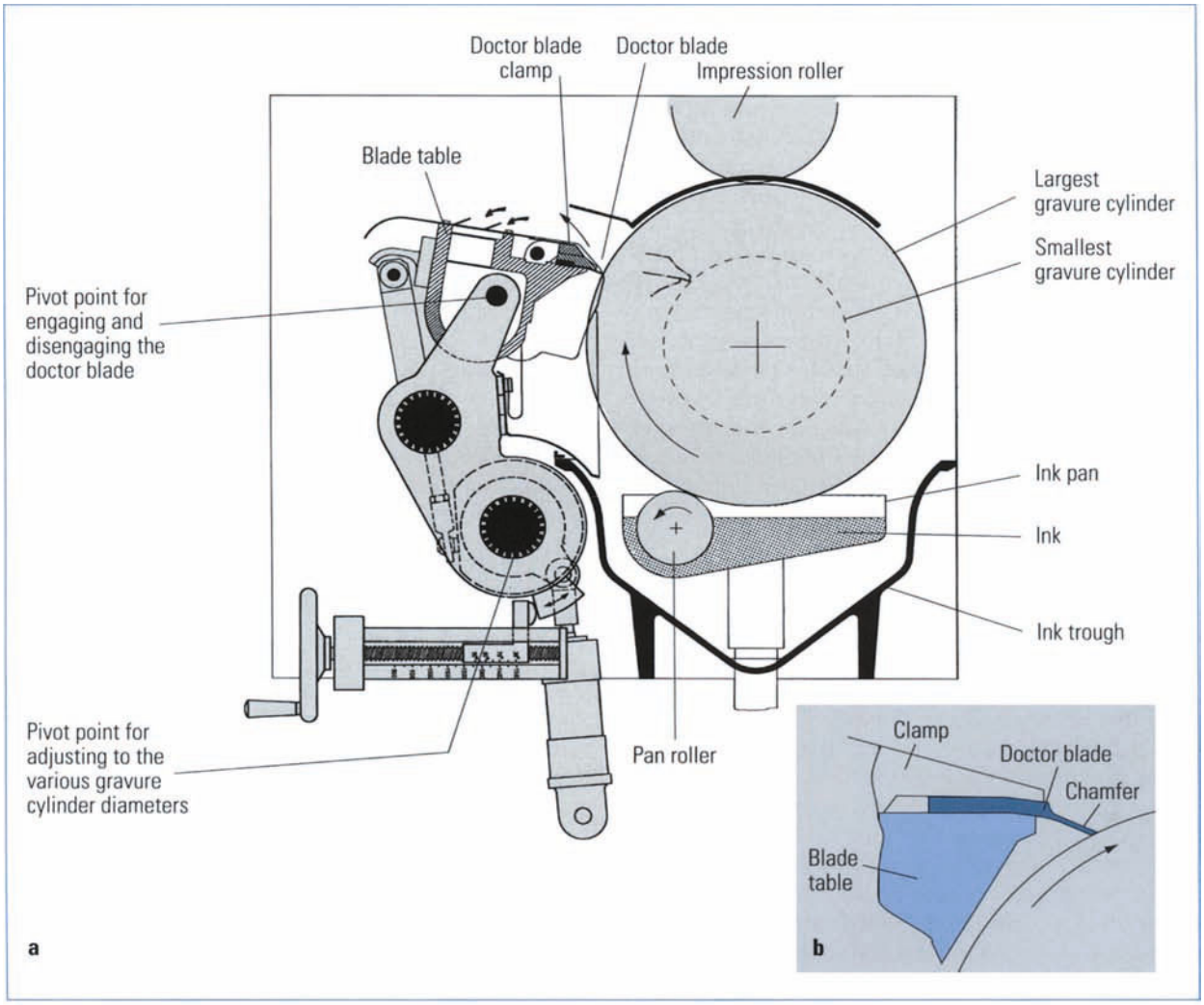


Fig. 2.2-14 Gravure inking unit.
a Principal structure;
b Doctor blade (detail), (KBA)

is often referred to as the "soul" of gravure printing; its design is of immense importance. The blade itself simply consists of a thin, wear-resistant steel strip that is bent slightly and mounted in a blade holder (fig. 2.2-14b). Previously, a distinction was made between a thicker support blade, located above and set slightly further back, and the blade itself. Today, it is usual to use blades with thicker but shorter profiles. These are chamfered on their cutting edge (i.e., ground thinner, fig. 2.2-14b) and are fitted in a clip instead of a holder.

For *engaging and disengaging the blade* (pneumatic or hydraulic), two articulating, suspended machine elements (fig. 2.2-14a) are needed. The first is the blade table for throwing the blade on and off and for applying the blade pressure. The second is the blade frame, needed for adapting the blade to gravure cylinders of various sizes and also for swinging away the entire device when changing the gravure cylinder if two blade devices are needed for the *change-over operation* (i.e. the plate cylinder rotates in the opposite direction).

The blade must reciprocate to avoid *blade marks* (and thus the wear and tear of the blade) in the print. This can be achieved via a crank mechanism in the gear box from the longitudinal shaft or via a returning worm gear from a separate gear motor. Here, it is important that there is no rational transmission ratio to the gravure cylinder drive, in order to assure a constant shifting of the blade at any possible damaged areas on the gravure cylinder and thus prevent a cumulative abrasion of the same point of the blade.

The blade is subject to a high level of wear and must be changed regularly (normally with a new print job). The blade must be aligned exactly parallel to the gravure cylinder surface, assured today by the hydraulic blade clamping with pressure selection and self-alignment. The *angle of contact* is also important for a good result and is used as a control parameter with difficult images ([2.2-1]and [2.2-2]).

2.2.1.6 Drying

The ink used for gravure printing has a low viscosity, so that the ink in the cells can run out properly and be transferred onto the paper. This low viscosity is principally achieved by using a high proportion of *solvent* with low boiling point in the ink. To dry the printed ink, the solvent must evaporate in a high velocity air dryer after leaving the printing nip.

Previous solutions, such as counter flow/parallel flow drying systems and heating drums are no longer used. Today, *high-velocity nozzle dryers* are used (fig. 2.2-15, see also sec. 1.7.1.2). Radial fans route the air in pipes fitted closely above the web and equipped with circular or slot nozzles. The air hits the web vertically, and thus the fresh print. The effect of the impact turns the air around by 180° and returns between the pipes back to the radial fans to be fed back to the nozzle pipes. In front of the radial fans, a part of this circulated air is branched off and routed into a solvent recovery unit in order to prevent the concentration of solvents in the ambient air from rising strongly. This proportion of air is automatically replaced by fresh air or ventilation air.

In many cases, the modern high-velocity nozzle dryers can operate without the need for heating the air – air at room temperature is sufficient for the slightly volatile Toluene (solvent) to evaporate from the ink; the air is slightly heated due solely to its friction by circulation. If an additional heating unit is required, this is installed behind the exhaust of the radial fan (fig. 2.2-15).

Since not only the speed at which the air emerges from the nozzles, but also the length of the dryer plays a decisive role in determining the effectiveness of drying and therefore the maximum production speed (typically 15 m/s) of the gravure printing press, the dryers are placed on both sides and surround the entire printing unit. Therefore, the term "drying hoods" is often used. Depending on the type of solvent used, shorter drying units, which do not surround the entire printing unit, are sufficient (fig. 2.2-16).

The solvent (normally *Toluene*) must be recovered for environmental and financial reasons (fig. 2.2-17). The solvent recovery unit consists of large vessels that are filled with activated carbon and through which the air charged with solvent is routed. In this process the solvent settles down on the activated carbon, whereby the air is freed from the solvent and simultaneously cleaned in an environmentally sound way. In order to release the solvent from the activated carbon for re-use, steam is sent through the activated carbon vessels in the "reversal process," which washes out the solvent. Since the solvent has a lower specific gravity compared to water, it can be easily separated from condensed steam, as it separates itself from the mixture onto the surface (cf. sec. 1.7.1.2).

2.2.1.7 Circumferential and Lateral Register

By the end of the 1930s, the first register control systems were already being used in gravure printing presses. For register measurement and adjustment, *register marks* are printed onto the white margin of the web (or on blank areas in the fold), optical sensors (today mostly cameras) determine their location to one another in each printing unit from the second printing unit onwards, and a positional command is calculated in a control unit. This positional command is transmitted to a register servomotor which then adjusts a register roller. The register roller is a web guide roller that runs on two linear moving ball screw bearings. By adjusting the register roller, the distance between two printing units is shortened or lengthened so that the four image carriers of a four-color print are located register-true on top of one another in the direction of web travel (circumferential register).

The term "*web-to-web comparison*" is used when register marks on the web are compared to one another. If the register mark is compared with an impulse at the gravure cylinder drive, the term "*web-to-cylinder comparison*" is used. The latter is used in the *cut-off register control* if the cross-cutting of the ribbon package in the folder is to be set to the print image. When setting up the *lateral register* for multicolor printing, the gravure cylinders can be aligned to one another in respect of their lateral location.

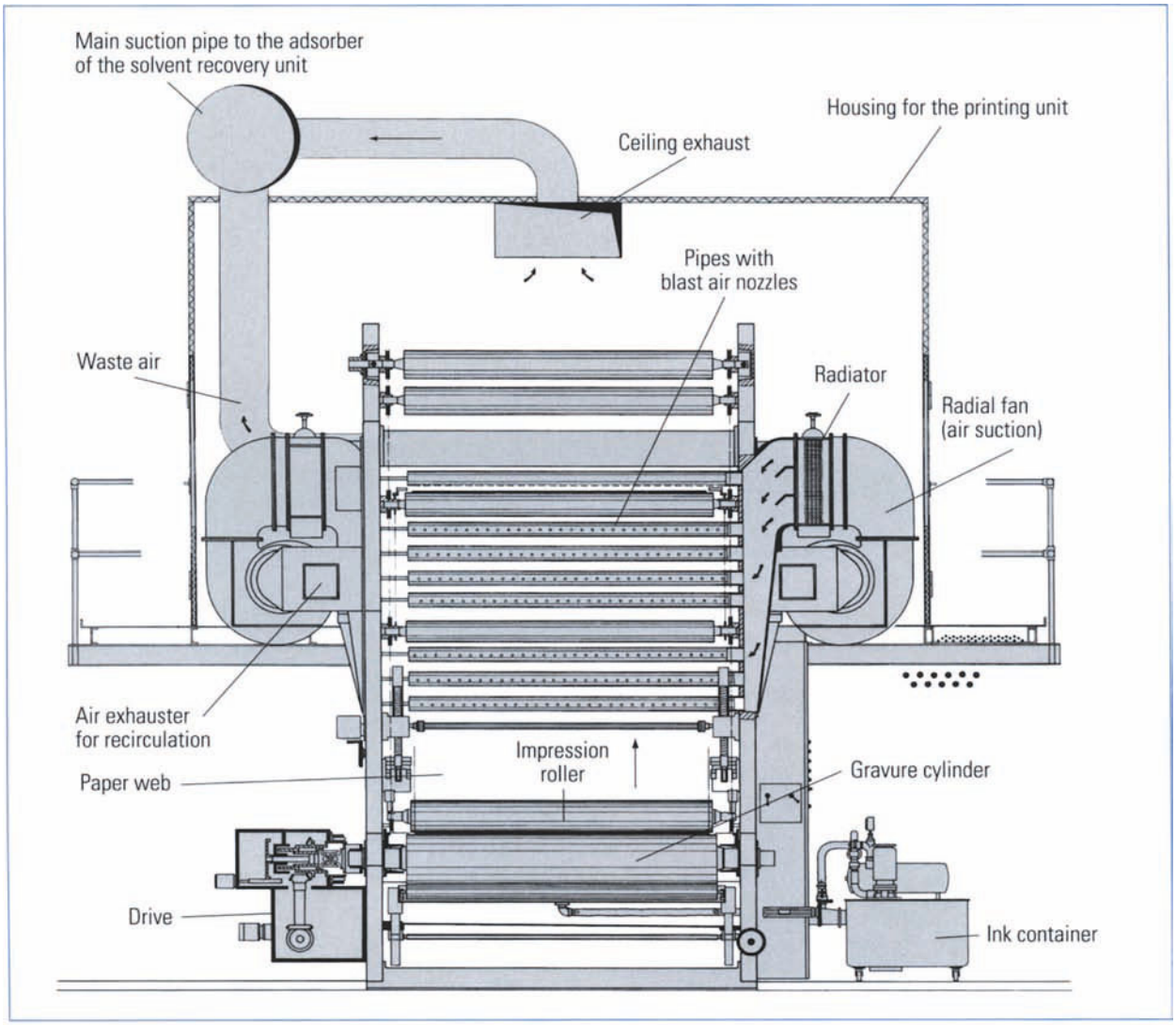


Fig. 2.2-15
Cross-section of a gravure printing unit with the significant elements for drying (high velocity nozzle dryers). The stream of air through the nozzle pipes in the center is fed by two radial fans, located at the side (KBA)
(Note: Figure 1.7-7 shows a corresponding side view of a high velocity nozzle dryer.)

While with web offset printing the web becomes wider due to the dampening influence of the dampening fluid – known as a fan-out effect (see sec. 2.1.3.2) – it shrinks in gravure printing. This is due to the drying employed between each printing nip, which not only expels the solvent from the paper, but the water as well. To keep the *lateral register* under control, the individual engraved pages on the gravure cylinder are positioned further inwards in accordance with the *shrinkage* factor (approximately 1–2 mm). Only in this way is it possible to print web widths of up to 3.6 m and more in an accurate lateral register.

To carry out small corrections during production, steam rods are used to *dampen the web* when it leaves the drying unit and thus partially to reverse the shrinking of the web before it enters the next printing unit. A

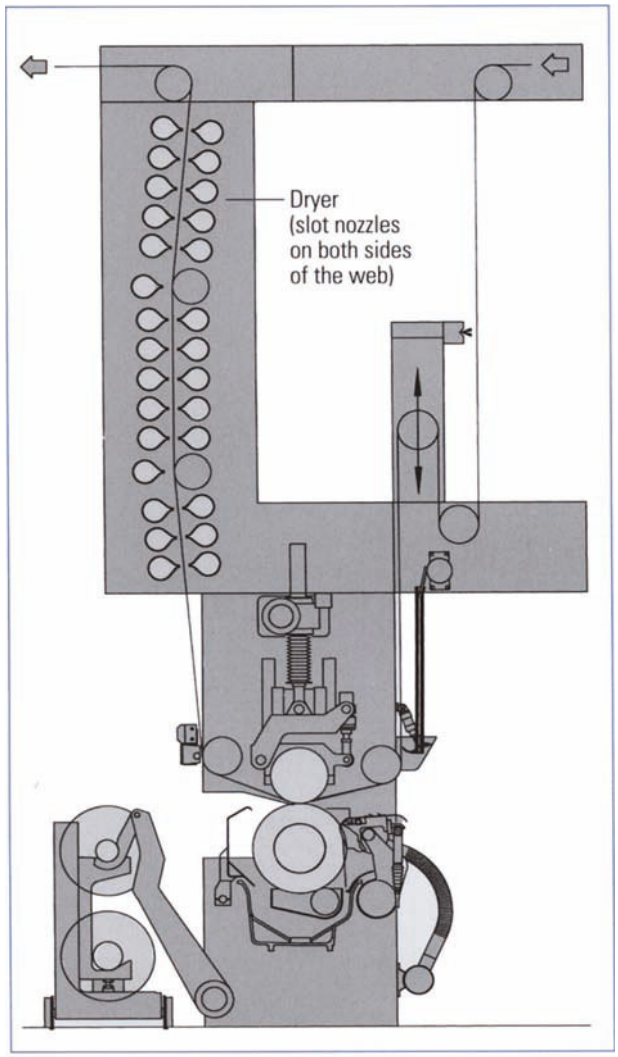


Fig. 2.2-16
Dryer with slot nozzles. The paper web is blasted with air on the front and reverse side from the slot nozzles because some of the solvent penetrates through the paper to the reverse side. The arrangement of the dryer is single-sided with regard to the printing unit (KBA)

similar effect can also be achieved if the temperature in the drying unit is reduced slightly, provided that the drying result permits this.

2.2.1.8 Magazine Turner Bars Superstructure

In the *superstructure of turner bars* on gravure printing presses, a wide web (currently up to 3.6 m in width) is first cut into individual ribbons – sometimes into more than twenty (fig. 2.2-18). *Longitudinal slitter knives* are used for this. They are suspended freely, with as little vibration as possible, in sturdy slideways (channels) for an easy lateral positioning. The lower knives are driven by electric motors while the upper knives are carried along by friction (fig. 2.2-19). They are engaged at a slight angle to produce a smooth shear cut. Each knife group can be moved laterally by motor and preset via a program that is adapted to the production requirements. The upper and lower knives are connected to an extraction system with filtering for the removal of dust arising from the longitudinal cut. Additional suction heads on the subsequent draw roller remove further remains of dust.

The turner bars represent a second element in the superstructure, they guide the longitudinally cut webs over one another by right-angle turning. The *cantilever design of turner bars* (i. e., the single-sided bearing) has become generally established to achieve good accessibility when feeding in the paper web. The individual ribbons are guided out (fig. 2.2-18b) on one side (previously two sides), in order to feed the ribbons together to the cylinder section of the folder via the individual ribbon register rollers (which ensure the alignment of the individual ribbons on top of one another in accurate register). Draw rollers support the accurate feed of the ribbons.

The magazine turner bars are fixed in box frames, which can be moved transversely (fig. 2.2-20). To provide the *air cushion* necessary for preventing friction between web and bar, they are connected to a blast-air line. The magazine turner bars can be used for various formats. Therefore, there are pistons inside the turner bars that can be set from outside and limit the air blast in accordance with the ribbon width. The magazine turner bars are also chrome-plated to prevent ink deposits. To reverse the ribbon, the turner bars are reversible via a swivel point in the center.

2.2.1.9 Gravure Printing Folders

In comparison with the fixed-format folders of web offset presses, the typical folders of gravure printing presses is of *variable format*, since a large range of *cut-off lengths* can be processed in gravure printing (varying diameters of the gravure cylinders). Gravure printing folders (fig. 2.2-21) work with grippers to transport the cross-cut folded sections (offset folders usually work with pins). As already described briefly in section 2.1.3.4, a separate cross-cutting unit is used in a *gripper*

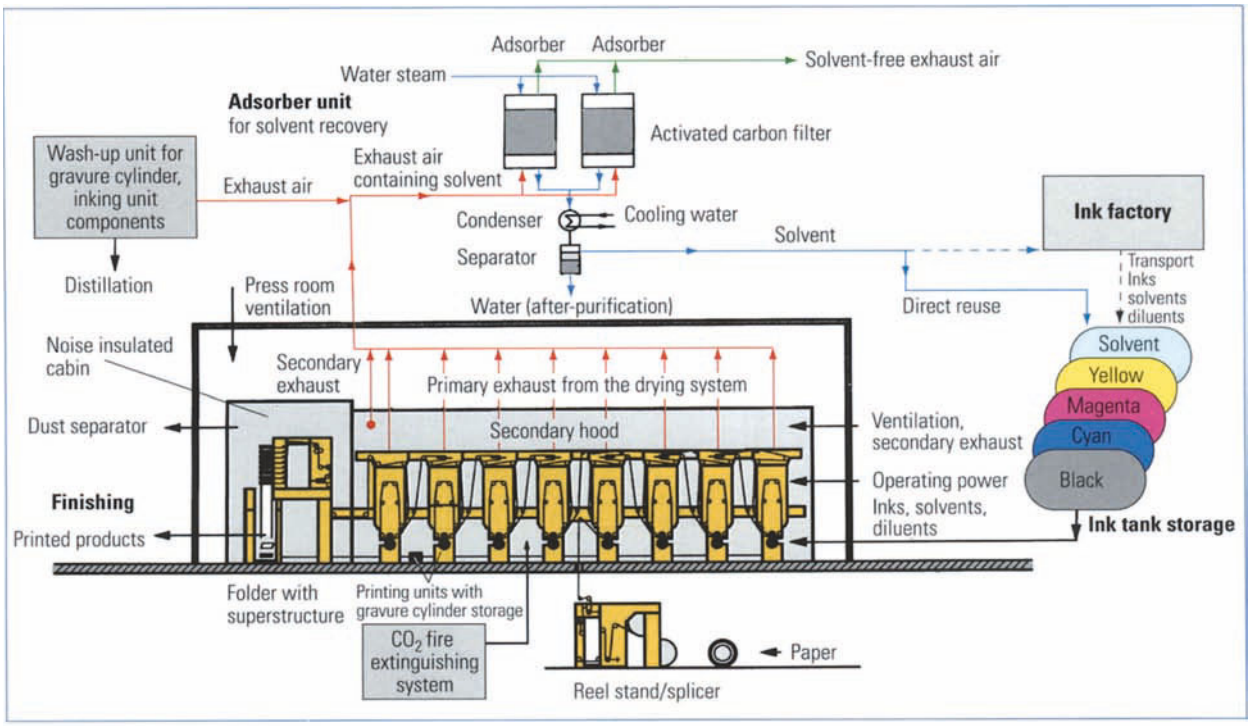


Fig. 2.2-17 Gravure printing system (for 4-color perfecting) as a production system with integrated solvent recovery unit (KBA)

folder. Whereas the two-piece cutting knife cylinder has a combined action with the three- or five-piece tucker blade cylinder in a fixed-size jaw folding unit (web offset), the cutting unit of the variable format gripper folder is positioned outside and separately (fig. 2.1-111). Therefore a cutting knife cylinder and a cutting bar cylinder comb together, and their diameters can be kept relatively small; i.e. the circumference corresponds to only one section. The cutting cycle must be precisely maintained and specified by the gravure cylinder drive (also with differing gravure cylinder diameters or circumferences).

After cross cutting the ribbon package, the *copy signature* is accelerated so that the front cut edge reaches into the opened grippers of the tucker blade cylinder. These then close immediately (cam-operated) and transport the signature on the circumference of the tucker blade cylinder. The need for acceleration between cross-cutter and tucker blade cylinder is a consequence of the variable format nature of gravure cylinders.

If two signatures (four tabloid pages on the circumference of the plate cylinder; so-called 4-around cylinders) are to be assembled on the tucker blade cylinder to create a complete copy, the signature must rotate twice with the correspondingly configured tucker blade cylinder, so that it is brought into register with the second signature. A short gripper holds the first signature while a long gripper fixes the second signature. Modern gravure printing presses, however, are also able to gather *three signatures* on top of one another by using gravure cylinders with a total of six tabloid pages around instead of four (see also fig. 2.2-22). The main purpose of increasing the diameter is to improve the stiffness of the gravure cylinders when processing wider webs (e.g., 3.6 m) and yet also to increase the production capacity per web. On the other hand non-collect-run production can deliver three different products. This requires three delivery fans with controlled diverters in the belt transport.

In the USA, it is common to use *folders that are twice as wide*, whereby two different products can run side by side. The three-product deliveries with three folders are thus doubled to make six. Double folders, which are arranged back to back (i.e. delivery to the front and to the rear), could even achieve twelve deliveries due to

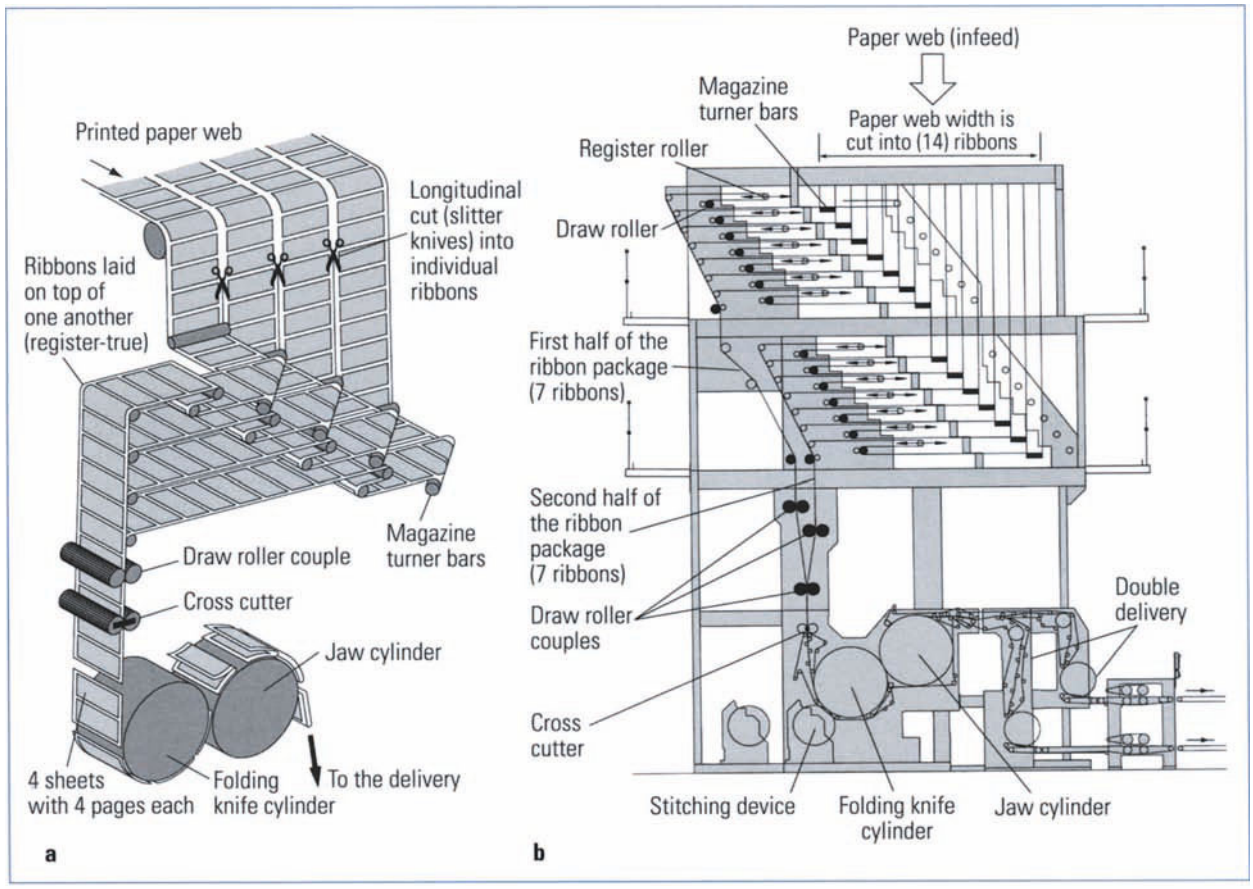


Fig. 2.2-18 Cutting and folding in rotogravure/gravure printing.
a Longitudinal cut of the web and placing the cut webs (ribbons) on top of one another by means of turner bars and delivery via folding unit; **b** Interaction of the turner bar superstructure and folding unit (example of 14 ribbons with double delivery), (KBA)

the double-width designs. The multitude of variations in the cylinder section of the folder and its superstructure is characteristic of the gravure press engineering.

The *folding procedure* itself runs on the same principle as already described in section 2.1.3.4 for the fixed-size jaw folder. Since gravure printing presses are often also used for manufacture of mass printed brochures in smaller formats, one or two quarter fold units are used more often than is the case with newspaper presses. A parallel folding unit is sometimes also required. In contrast to normal folding units, this is not achieved with a small additional cylinder on the circumference of the tucker blade cylinder (fig. 1.6-19), but rather with a further jaw cylinder in the production flow. This allows higher speeds and also more pages per signature.

The *cover folders*, also called "cutters," are in a class by themselves. This folder only cross cuts the four-page sheet, does not produce any folds and is used to produce magazine covers of thicker paper. The covers are either delivered separately to the bookbindery or are processed directly with a gripper folder (fig. 2.2-22), whereby the thicker cover sheet is laid directly on top of the signature package on the tucker blade cylinder and finished (i.e., folded) together with the signature package.

Since gravure printing presses are almost exclusively used for the processing of tabloid formats, the magazine turner bars were a key point when considering the folder superstructure. In some cases gravure printing presses make use of *formers* (fig. 2.2-23), to enable the production of formats similar to those of newspapers.

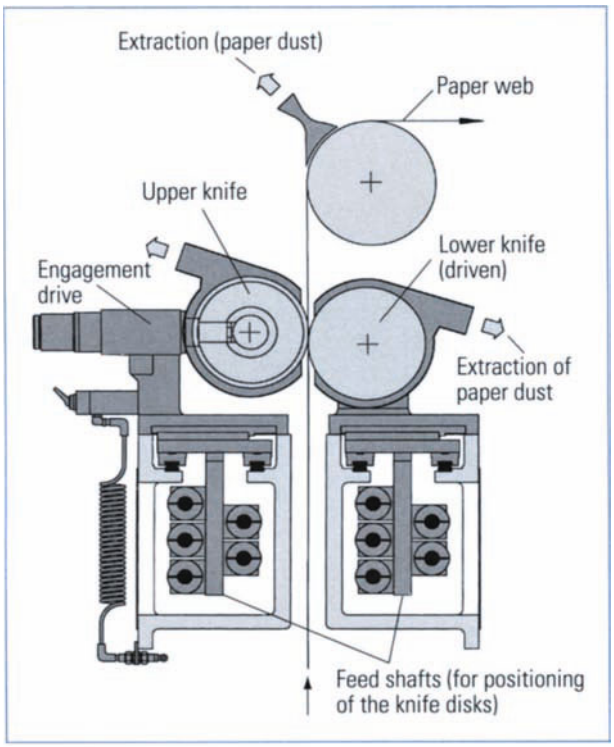


Fig. 2.2-19
Slitting unit integrated in the superstructure of the gravure printing press (KBA)

2.2.1.10 Reel Stand

Reel stands on gravure printing presses are principally only offered in a two-arm design for the *"flying" web splice* and are driven by belts (fig. 2.2-24) due to the large inertial mass of the wide paper reels. In order to avoid crease formation or split sections in the paper reel due to the sagging of wider paper reels, especially with thin LWC paper, the configuration with a driving belt positioned at the bottom has been generally accepted (fig. 2.2-25), whereby the belt props up the reel in the center and thus counteracts the sagging effect caused by the reel's own weight.

Gravure printing reel stands are designed to carry the heavy loads of the paper reels (5000–6000 kg), which can no longer be transported manually. The *reel loading process* has therefore been fully automated (see also sec. 8.1.1.2), as has the alignment of the reel before it is mounted in the reel chucks, which takes place via a hydraulically driven lifting table. The chucks have an external diameter of 150 mm (as opposed to the most commonly applied standard used in web offset printing of 75 mm) in order to be able to take up the load better and also to avoid the vibrations of the reel stub just prior to the reel change when reaching the critical speed.

2.2.2 Examples of Gravure Printing Systems

This section describes and illustrates typical configurations of *publication gravure printing systems*. Packaging gravure printing presses are dealt with in the following section (2.2.3).

Figure 2.2-26 shows a press configuration in schematic form, where *two gravure printing presses are set up next to one another*. This illustration makes it clear how much space such installations require. The two folders, each with three deliveries, are arranged in the basement, where the reel stands are also located. Each of the 2 x 2 webs are divided into ten ribbons in the magazine turner bar superstructure and fed to the 7:7 gripper folders which are variable in format. The operator area with the control consoles and, above them, the control cabinets are located in the center between the two production lines. Two overhead cranes carry heavy press components and are used for any repair work that might become necessary.

Figure 2.2-27 again shows a press arrangement where two printing presses are set up parallel to one another. Devices for the *automatic change of the gravure cylinders* are arranged between the presses. The control consoles of each press are located outside. The two folders are at the same level as the printing units. A noise protection wall that extends up to the ceiling separates the operator room from the press.

Figure 2.2-28 shows the longitudinal cross-section of a gravure printing press that extends over *two levels*. The reel stand and folding unit are located in the basement. The (ten) printing units and the magazine turner bar superstructure are arranged one level higher.

The reel stand, printing units, and folder with superstructure can also be arranged on one level as shown in figure 2.2-29 *(first-floor arrangement)*. However, when changing over to perfecting, the web needs to be underpassed in some section, which can be disadvantageous when feeding the paper (if the paper is fed manually rather than automatically).

Further configuration variations result from the arrangement of the magazine turner bar superstructure and the folder. Figure 2.2-30 shows the *coupling*

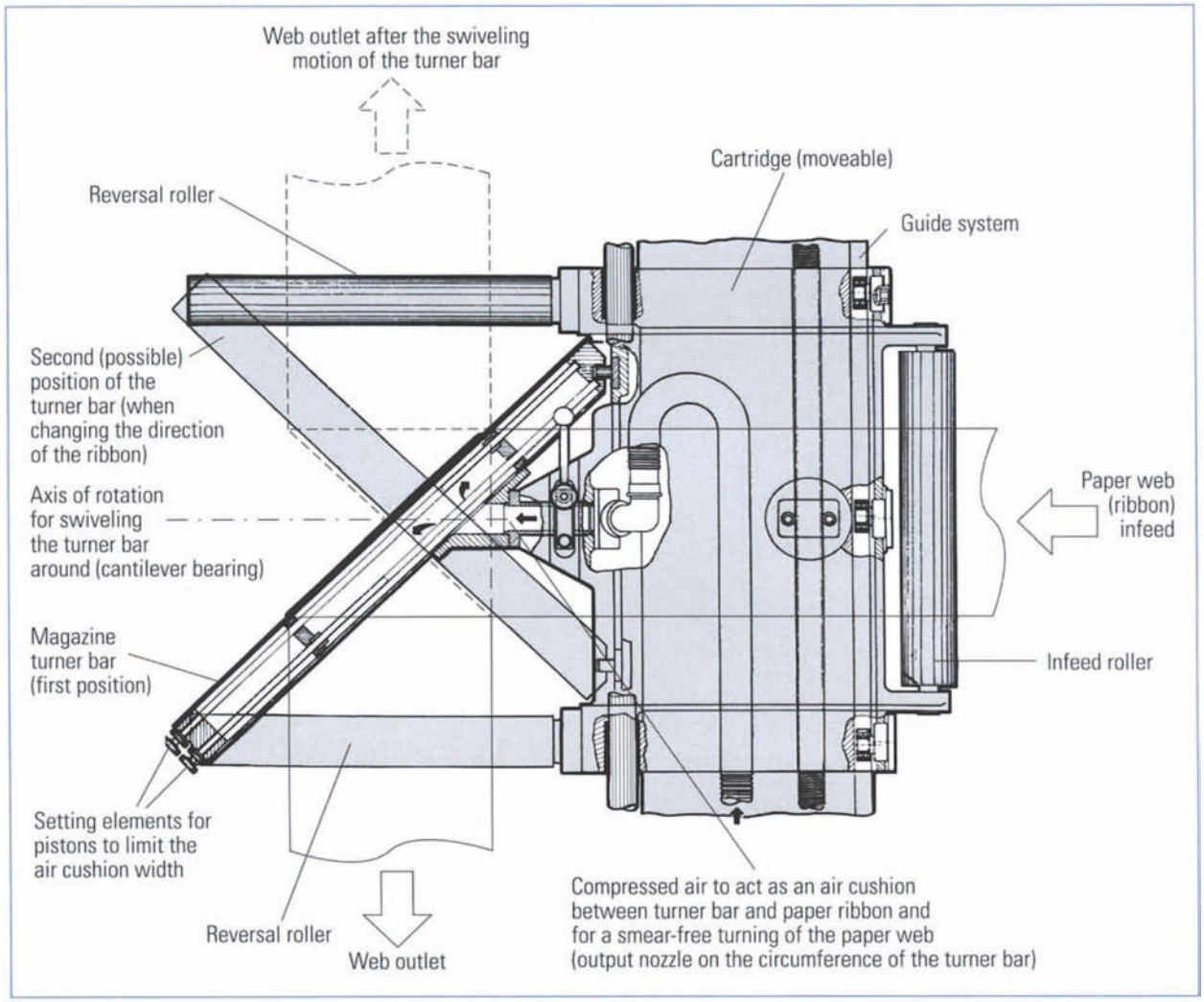


Fig. 2.2-20
Magazine turner bar in the superstructure with cantilever bearing arrangement; the turner bar can be used in two positions (KBA)

of two printing presses to one folder, standing in the center.

Figure 2.2-31 shows a printing press equipped with two turner bar superstructures and folders located next to one another. This does not only improve the availability of the installation, should one folder fail to work, but it is also possible to *divide the product streams*. This is particularly important for the production of printed matters with few pages in large numbers in a fixed amount of time. Figure 2.2-31 highlights the possibility of integrating *flexographic imprinting units*. In the example shown, the flexographic imprinting unit does not have a dryer.

A *flexographic imprinting unit* with high velocity air dryer can be seen in figure 2.2-32. Flexographic imprinting units increase the diversity of gravure printing production with respect to partial runs which can, for example, be printed with varying prices and addresses (hybrid printing technology). To produce alternate imprints during production (flying plate change), the

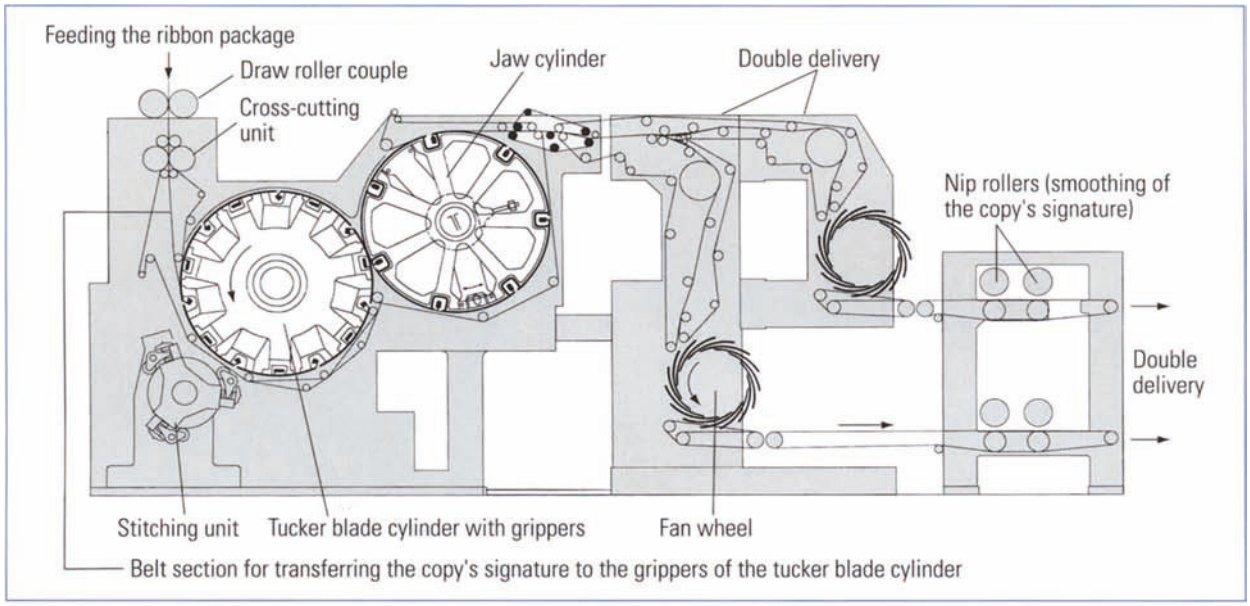


Fig. 2.2-21 Gravure printing folder for variable formats (KBA)

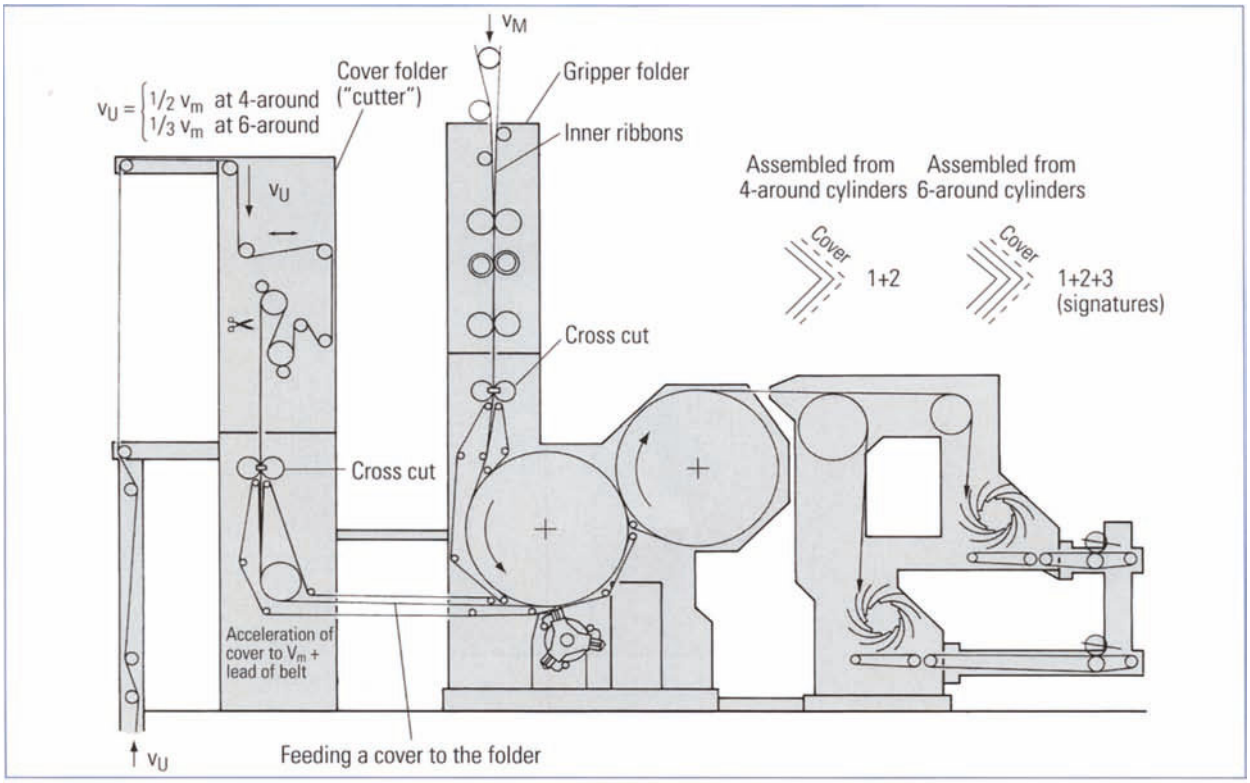


Fig. 2.2-22 Devices for feeding covers to a gripper folder (KBA)

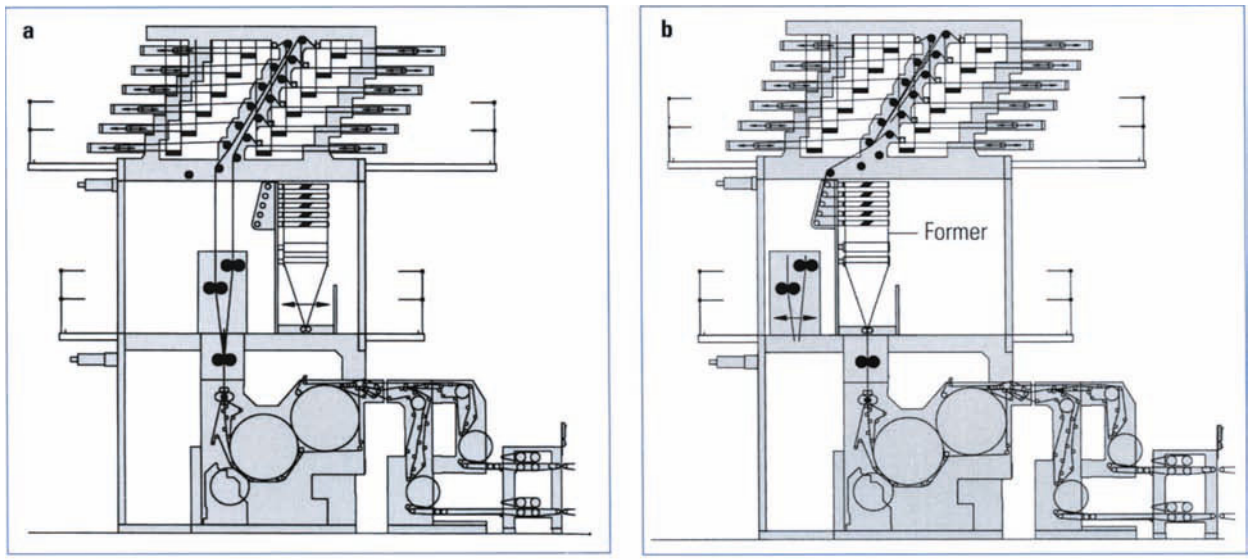


Fig. 2.2-23 Use of formers in gravure printing.
a Ribbon infeed into the gripper folder for production with turner bars (tabloid/magazine formats);
b Ribbon infeed into the gripper folder for production with former (newspaper formats) (KBA).

Fig. 2.2-24
Structure of a gravure printing reel stand for flying reel change (KBA)

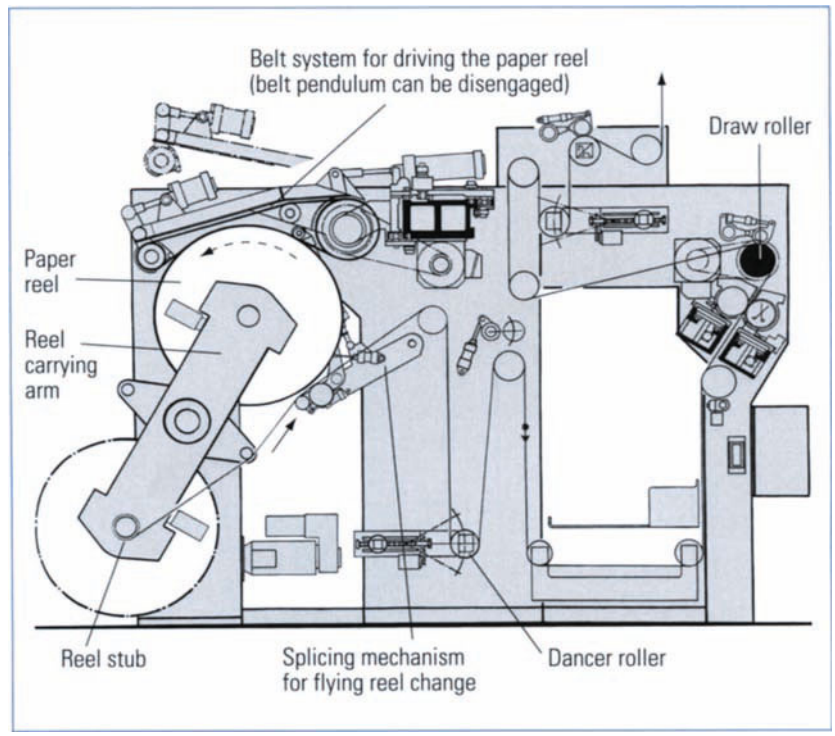
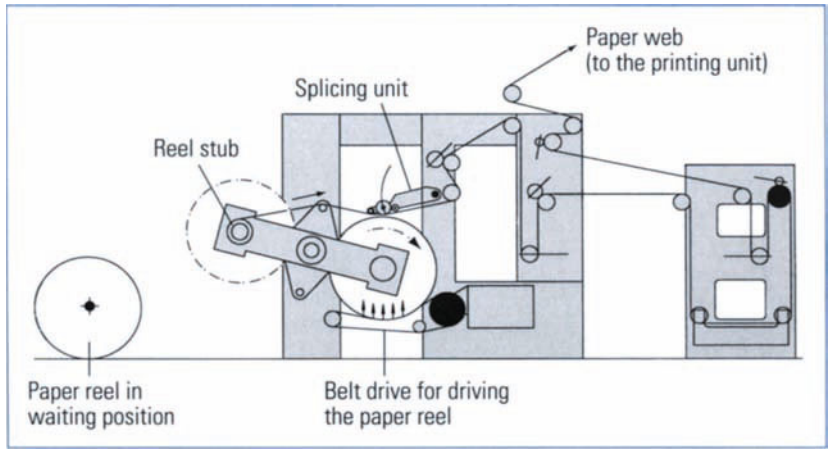


Fig. 2.2-25
Gravure printing reel stand for flying reel change with one drive belt located at the bottom as support for the paper reel (KBA)



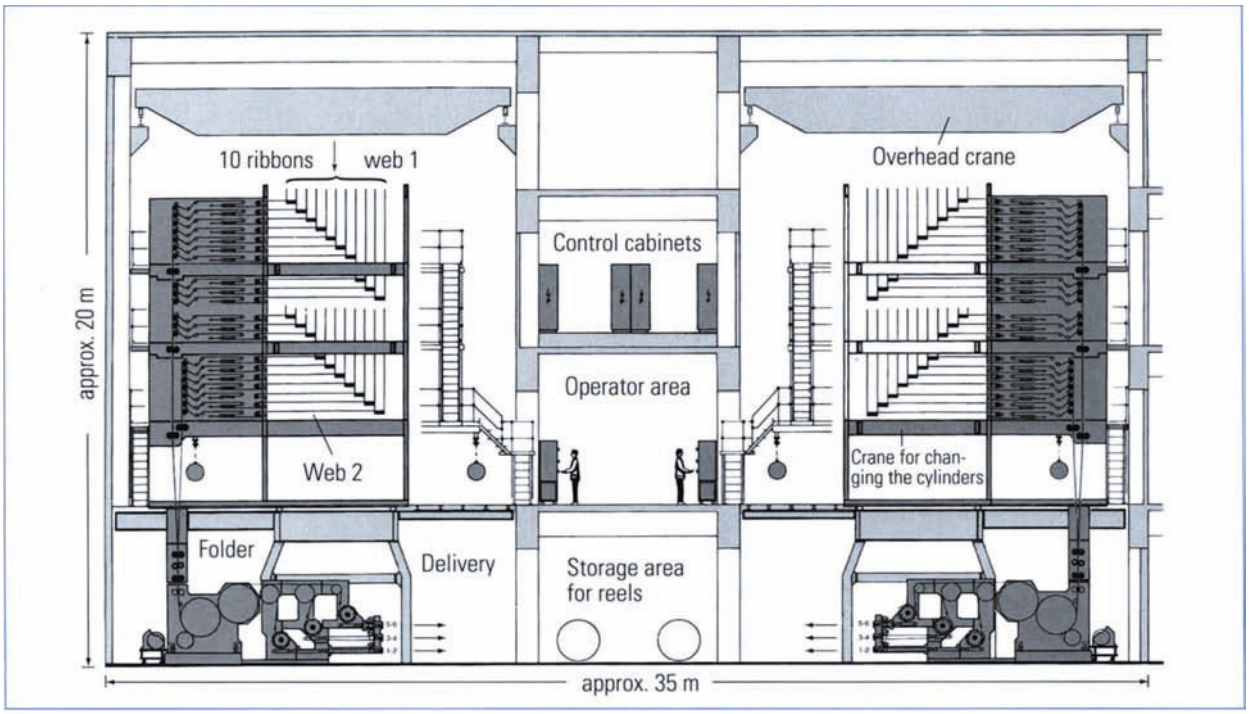


Fig. 2.2-26 Parallel arrangement of two gravure printing presses with central control area (KBA)

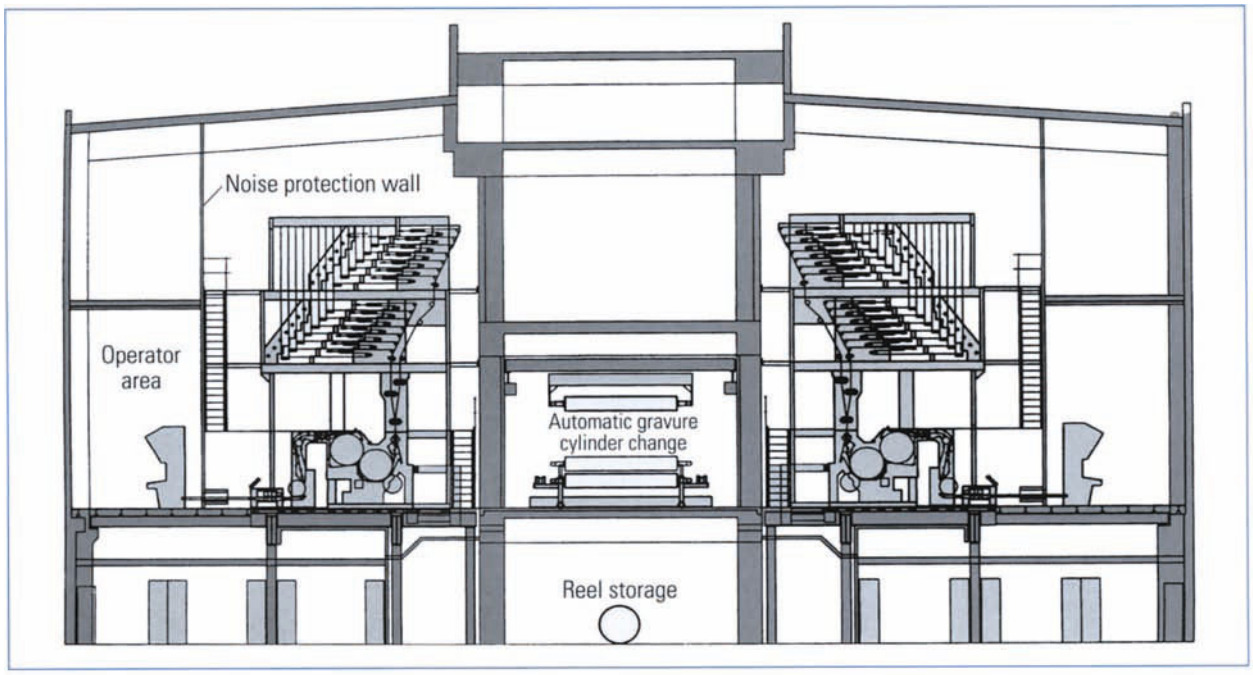


Fig. 2.2-27 Parallel arrangement of two gravure printing presses with a central device for automatic gravure cylinder change (KBA)

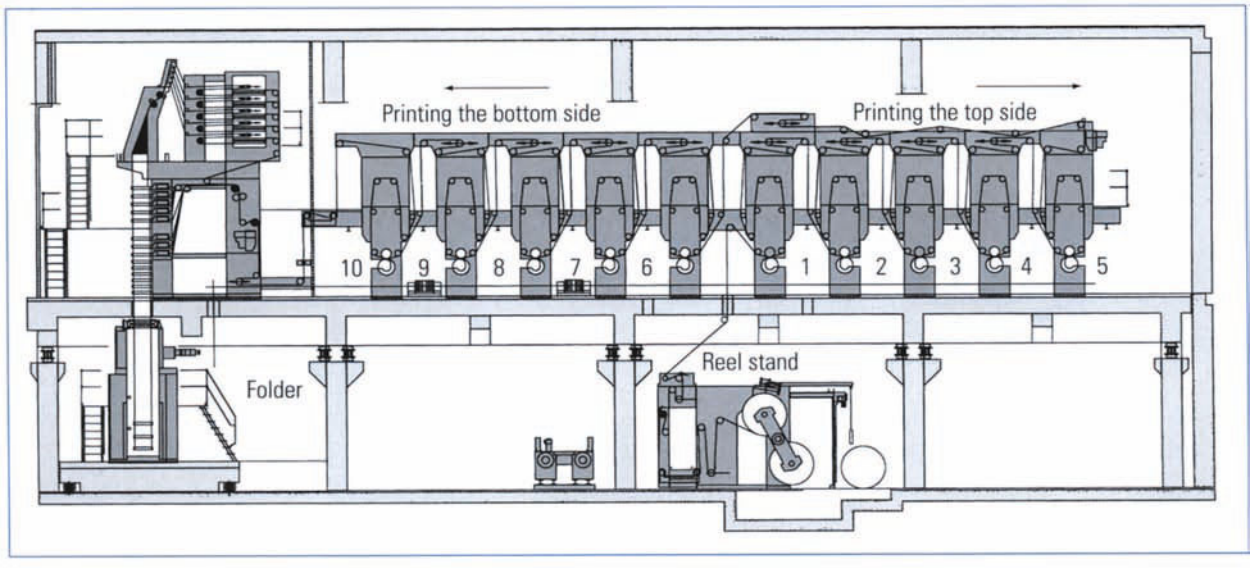


Fig. 2.2-28 Installation of a gravure printing press for perfecting with reel stand and folder in the basement (KBA)

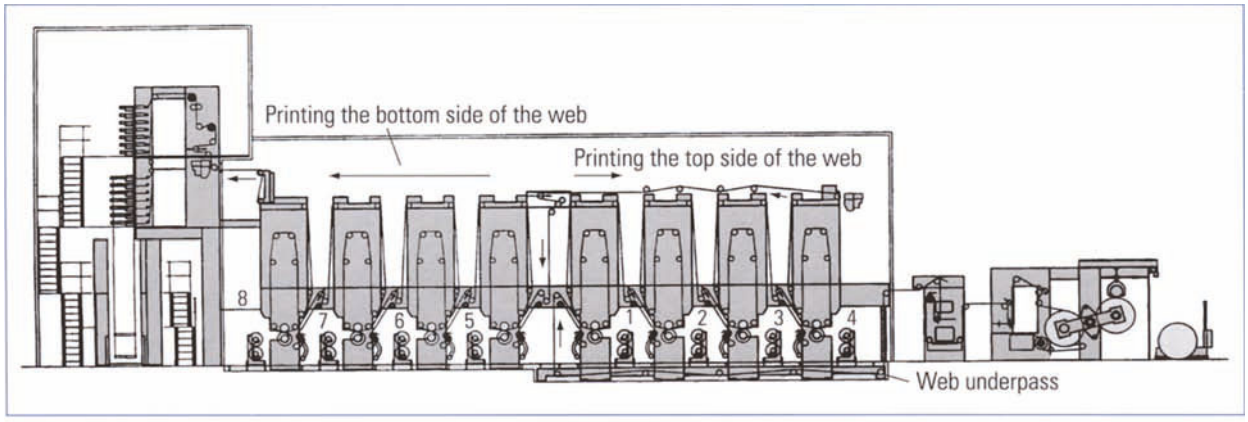
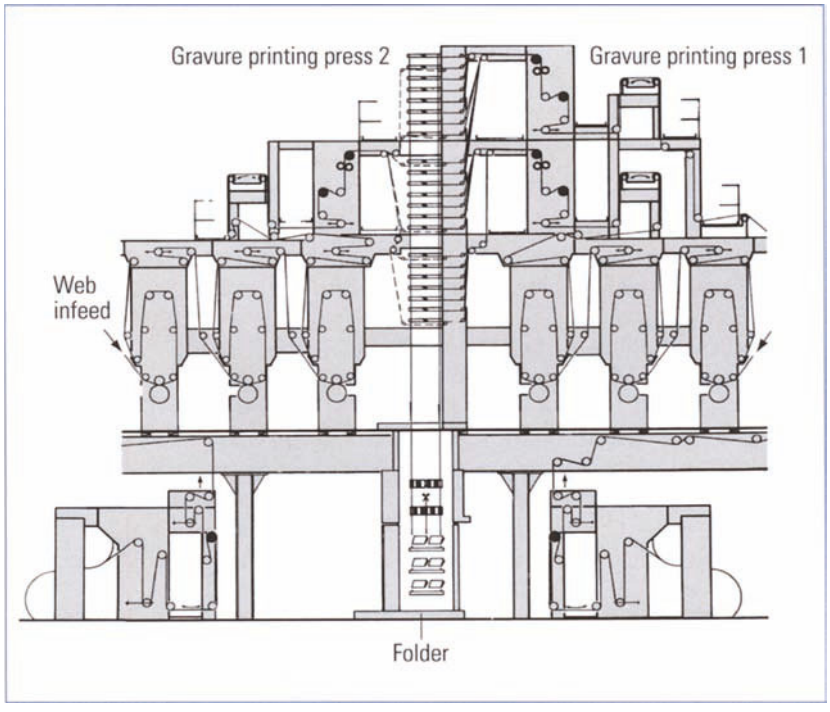


Fig. 2.2-29 Gravure printing press with reel stand and folder on the same floor (KBA)

Fig. 2.2-30
Arrangement of two gravure printing presses (section) with shared folding unit in the center (KBA)



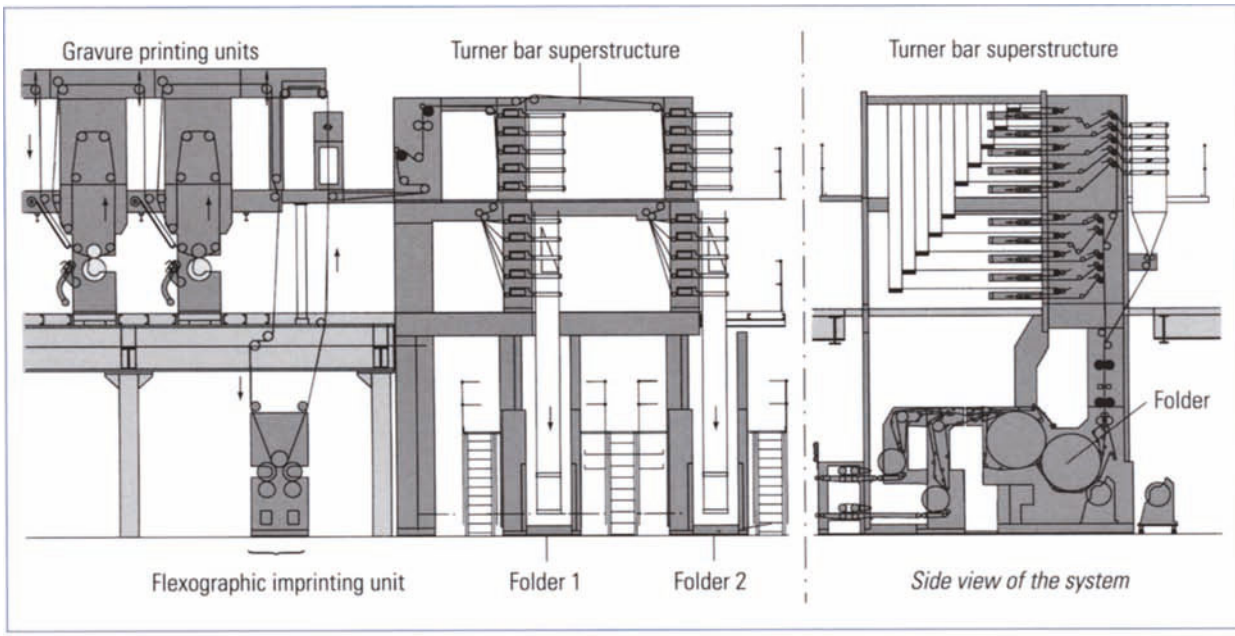


Fig. 2.2-31 Press installation with two folders alongside one another and an additional flexographic imprinting unit (KBA)

imprinting unit shown in figure 2.2-32 (also fig. 2.2-31) is equipped with two independent printing stations (two plate cylinders and two inking units, but one impression cylinder).

Tipped-in reply cards are an additional element in the conception and production of magazines. With the help of so-called *"add-a-card" devices* (fig. 2.2-33a), these postcards are automatically tipped-in at full web speed, as shown in figure 2.2-33b. The "add-a-card" machines process reply cards that are joined together in a perforated web. The accurate cycle-feed is achieved through line-hole punching. The cards are glued to the paper web with hot-melt glues.

2.2.3 Gravure Printing in the Packaging Industry

Gravure printing presses for package printing are equipped differently from those used in illustration printing. The main difference lies in the substrates and inks used, as well as in the finishing of the printed web. In *gravure package printing*, both sheet-fed and web-fed presses are utilized. Sheet-fed gravure printing presses have the advantage that shorter runs can also be produced economically, due to the more flexible and inexpensive manufacture of gravure cylinders or gravure plates. Gravure printing, and especially web-fed gravure printing, is of particular interest for the printing of packaging material as it can process:

- various formats (repeat in a circumferential direction),
- a wide range of inks with the most diverse properties, such as non-toxic, odorless, sealing effect, or metallic glaze,
  and is
- cost-effective with long print runs.

Gravure printing enables high-quality and consistent reproduction of the finest photographic details in even the smallest of images on thin and flexible printing material and a large number of multiple-ups on one gravure cylinder. Furthermore, this process achieves the highest, most constant and continuously reproducible print quality. Moreover, printing on both sides of the web can be carried out easily in one pass, even with an alternating number of colors. Webs printed in gravure printing can be finished immediately and long runs can almost always be printed with one set of gravure cylinders.

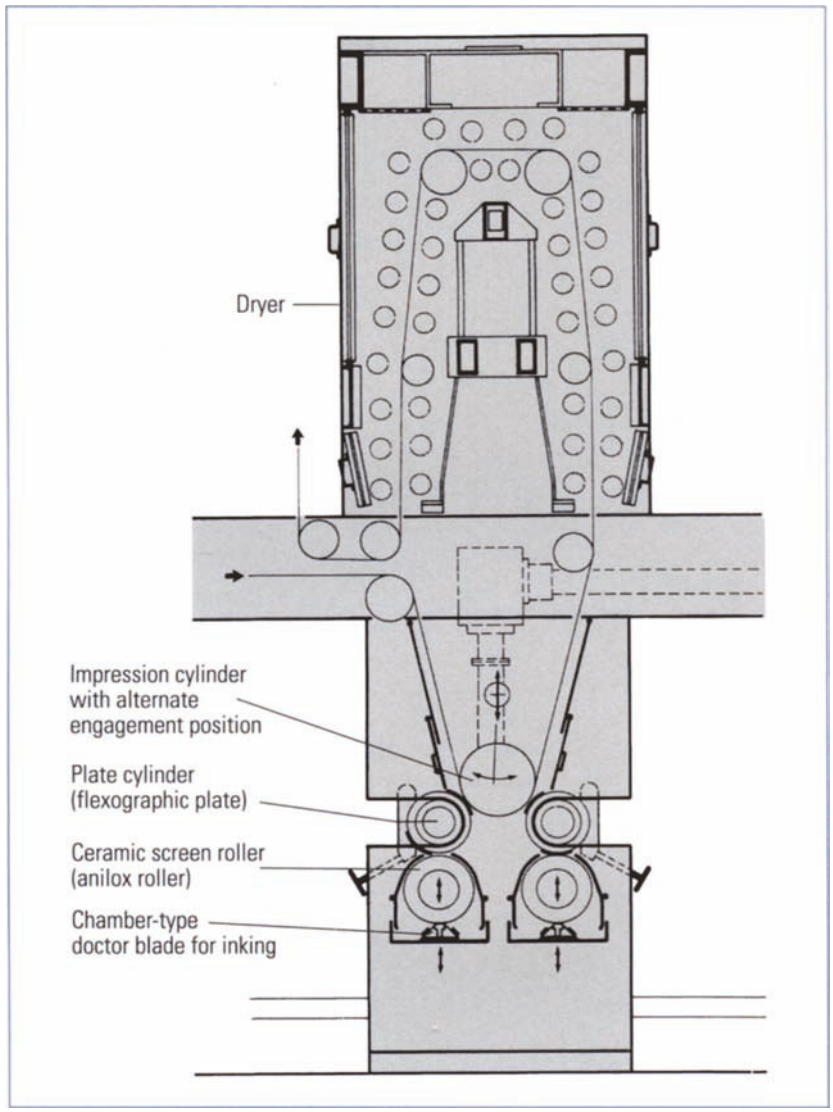


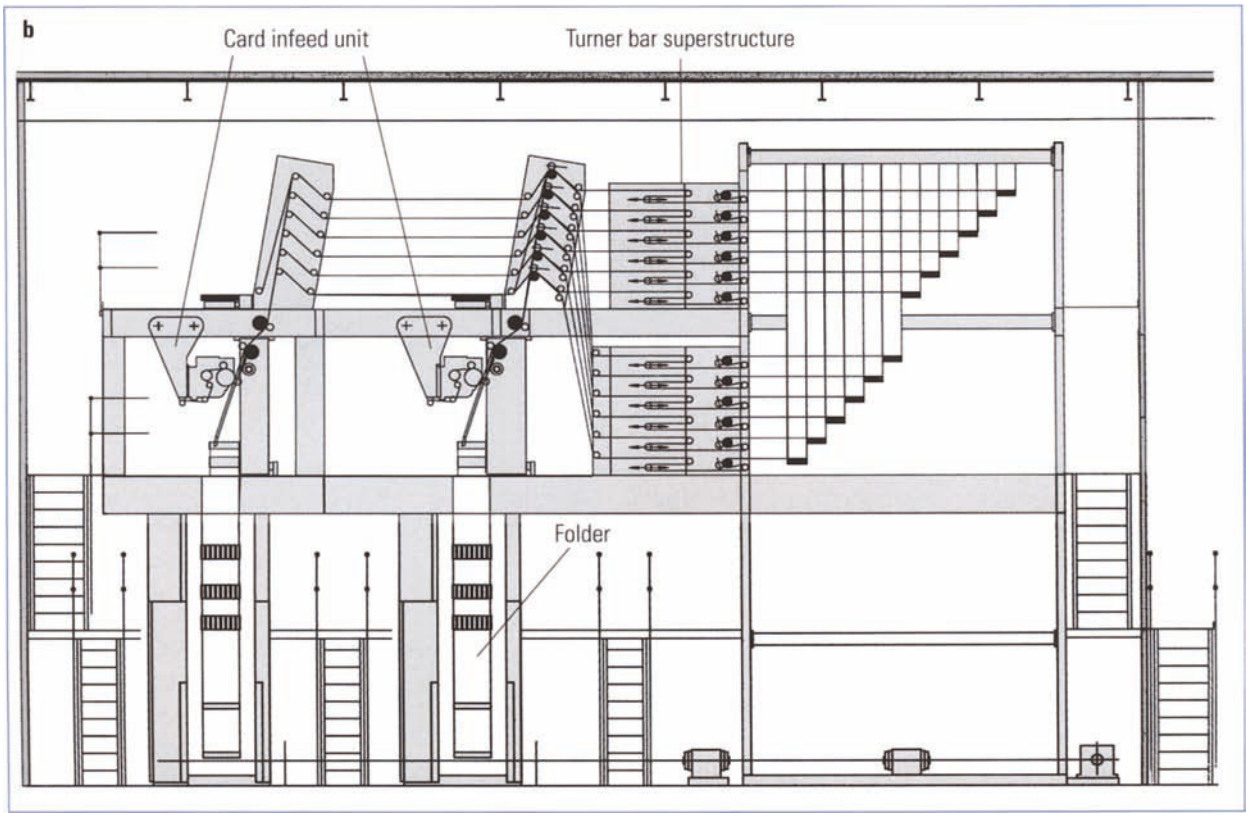
Fig. 2.2-32
Design of a flexographic imprinting unit for gravure printing with device for "flying" plate change (KBA)

Today, *sheet-fed gravure printing* only plays a minor role. Examples of sheet-fed gravure printing presses are "Color-Palatia" (historically, a significant high-speed press from the Schnellpressenfabrik Frankenthal, see figs. 13.1-10 to 13.1.-12), and "Rembrandt" (KBA). Sheet-fed gravure presses shown in figure 2.2-34 (and fig. 1.6-8) for multicolor printing have a drying section after each printing unit. To achieve long enough drying times, long dryers are required. For presses with short distances between the printing units this has, for example, led to "tile-like" arrangements of the dryers.

Rotogravure (web-fed gravure) presses are usually economically more efficient than sheet-fed gravure presses due to the generally long print runs. Therefore, we shall concentrate on the topic of web-fed gravure printing.

A web-fed gravure printing press for package printing (figs. 2.2-35 and 1.6-18) consists of an unwind unit, gravure printing units arranged successively, and a *rewind unit*. The simplistic equipment, in connection with a simpler construction of the printing units, made it possible for relatively small machine manufacturing companies to produce this type of machinery. As such,

Fig. 2.2-33
Tipping in of reply cards during the production of magazines.
a Structure of a reply-card feeder ("add-a-card");
b Arrangement of the reply-card feeder ("Add-a-card") in a gravure printing press with two folders (KBA)



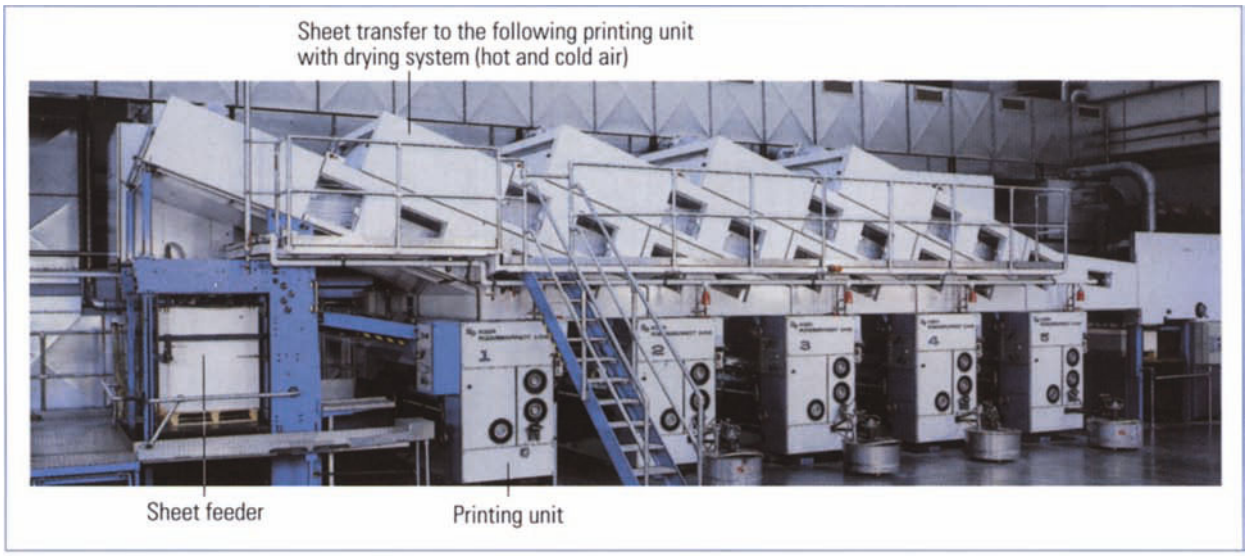


Fig. 2.2-34 Multicolor sheet-fed gravure printing press for printing of packaging material; diagram in figure 1.6-8 (Rembrandt 142, KBA)

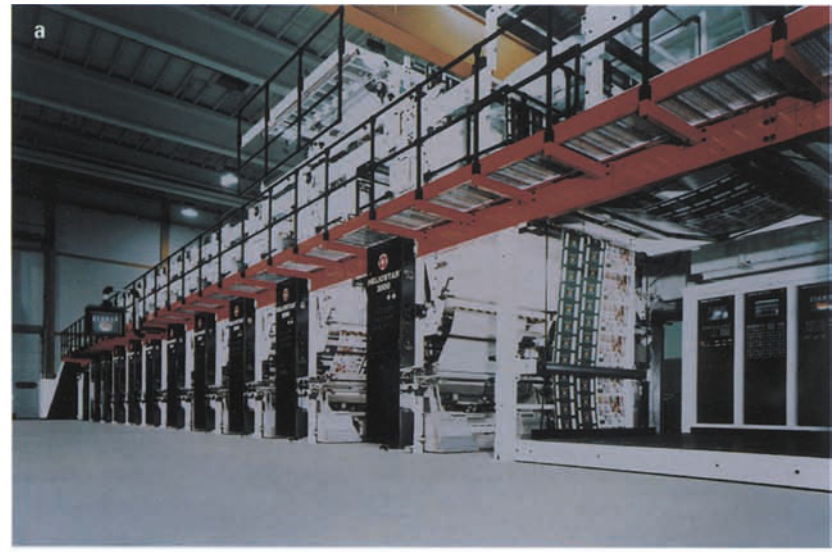
a range of companies came about (especially in Italy) that offered the established manufacturers of gravure printing presses competition and even forced some of them to give up this branch of manufacture. Not until specialization into the high-quality printing of technically and particularly top-quality packaging material, such as cardboard and thin foil, could the long-standing companies assert themselves with special and sometimes patented press designs. Automatic in-line packaging production meant that in the construction of systems, gravure printing systems were almost forced into the background alongside special processing units, so that one could almost talk about a packaging machine with connected printing units.

Around the end of the 1950s, the "golden age" of gravure printing began in the packaging industry. This development was further assisted by the simultaneous *introduction of new packaging materials*, such as cellophane. This meant that many brand-name goods manufacturers were able to offer their products visually to the customer with better packaging conditions. For good quality printing of this material, the gravure printing presses of the time had to be modified. To achieve good adhesion of the newly developed inks on this non-absorbent material, it became necessary to modify the dryers of gravure printing units, and the foil surfaces had to be pretreated with base varnish. Moreover, the web substrate tension in the entire press had to be reduced, above all at the rewind unit to prevent blocking of the rewind reels.

The need for ever thinner *polyethylene foil* for printed packaging led to gravure printing losing ground to flexography (central impression cylinder flexographic presses; see sec. 2.3.3). This was aggravated by the fact that it became apparent that on most of the existing gravure printing presses no perfect printing results could be achieved without carrying out expensive modifications. This was due to the long web travel distances, the insufficiently sensitive web tension controls, the sturdy winding units, which responded too slowly for this sensitive material, and the non-adjustable drying systems of the gravure printing units. Therefore, the existing presses of that time had to be modified to conform to the new, higher demands. Higher requirements placed on the machine technology by packaging printers and at the same time a declining need for new presses resulted in a drop in the number of press manufacturers. With new investments, many of the packaging printers opted for flexography instead of gravure printing.

Nevertheless, gravure printing was able to assert itself in market sectors, such as with long print runs on paper, *light cardboard*, *transparent foil*, and *aluminum foil*, and in some cases the printing on *plastic foil* as well. Many brand-name goods manufacturers employ gravure printing for the printing of their packaging for

Fig. 2.2-35
Gravure packaging printing press.
a Overall view (10 printing units);
b Printing units with different dryer sections (Heliostar 2000, W&H)



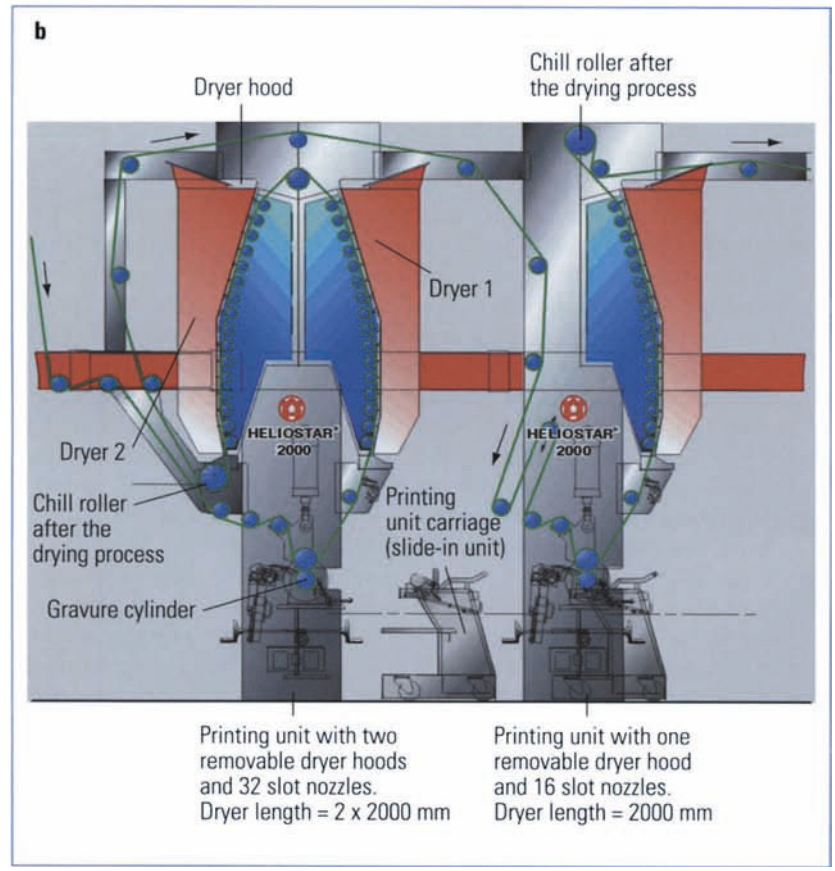




Fig. 2.2-36 Examples of packaging products produced in gravure printing (W&H)

cigarettes, candy, soup packets, coffee, cakes, pastries, butter, and cheese (fig. 2.2-36). Even washing detergent boxes, plastic bags, and wrapping paper are often printed on gravure presses.

Several gravure press manufacturers have developed machines on which thin, flexible polyethylene foil could be printed in good quality. For this, the existing press designs had to be overhauled and equipped with sensitive and precise web tension and measuring devices, DC-powered drawing devices, particularly smooth-running web guiding elements, completely new chill roller systems and modified non-stop unwinding and rewinding devices with DC drive engineering. Moreover, the entire drying system (fig. 2.2-35b) and the register control systems, had to be adapted and enhanced to meet the high demands. Some printing companies, for the most part in Europe, have used such presses to specialize in the printing of flexible plastics and have successfully maintained or even expanded gravure printing's share in the healthcare product, frozen food, and high-grade plastic bag sectors. A modern printing press of this kind is shown in figure 2.2-35.

Despite an increased need for extremely diverse and high-grade packaging materials, the pressure of costs is on the rise for printing companies. For this reason, the printing press manufacturers are concentrating on developing methods to further reduce the change-over times of the new presses, increase production speeds, simplify press operations, and increase automation. Several manufacturers of gravure packaging presses offer press configurations based on *slide-in systems* (figs. 2.2-37 and 2.2-35b). Figure 2.2-38 shows the *change-over of the impression roller sleeve*. This simplifies the change-over procedures when preparing the press for a new print job and is more user-friendly.

Some presses are able to reach production speeds of up to 6.7 m/s. The print width of modern high-performance presses, as shown in figure 2.2-35a, normally comes to 120, 140, or 160 cm. Due to the increasing quality demands, seven or eight colors, and therefore the corresponding number of printing units, are required



Fig. 2.2-37
View of a printing unit carriage with gravure cylinder and inking system for fast job change (slide-in system), (W&H)

for more and more types of packaging. A varnishing and/or cold sealing application and possibly lamination must be carried out in-line; the installations, therefore, often consist of more than ten printing and finishing units. Today, such universal presses of modular design are almost always designed for printing packaging materials covering a broad market segment. They are equipped with *non-stop winders* (fig. 2.2-39).

The cost of gravure cylinders, the long and labor-intensive job change-over times and the high waste rate of 3% and more (for long runs), which can arise when setting up and starting a new print job, represent a high cost factor, especially with relatively short runs. It is therefore understandable that the perspectives for gravure packaging printing are not too positive and that its projected worldwide market share for the year 2001 varies considerably. Alongside flexographic and offset printing, gravure printing's share of the packaging printing market in Europe is predicted at approximately 19% with a slight downward trend, whereby the shares in France and Italy, for example, are much higher. In the United States, a country with a fairly inactive gravure packaging printing market, a figure of around 8% with a similar downward trend is expected, while the market share for Asia is predicted to be about 50%, and for Japan even a fairly constant 85%.

If success is achieved in significantly reducing manufacturing costs for gravure cylinders – for instance by using new plastic materials or laser systems for imag-

Fig. 2.2-38
Impression roller sleeve for simple and fast change of the impression rollers for gravure printing (the illustration shows how it is mounted onto the roller core, after removal from bearing), (W&H)



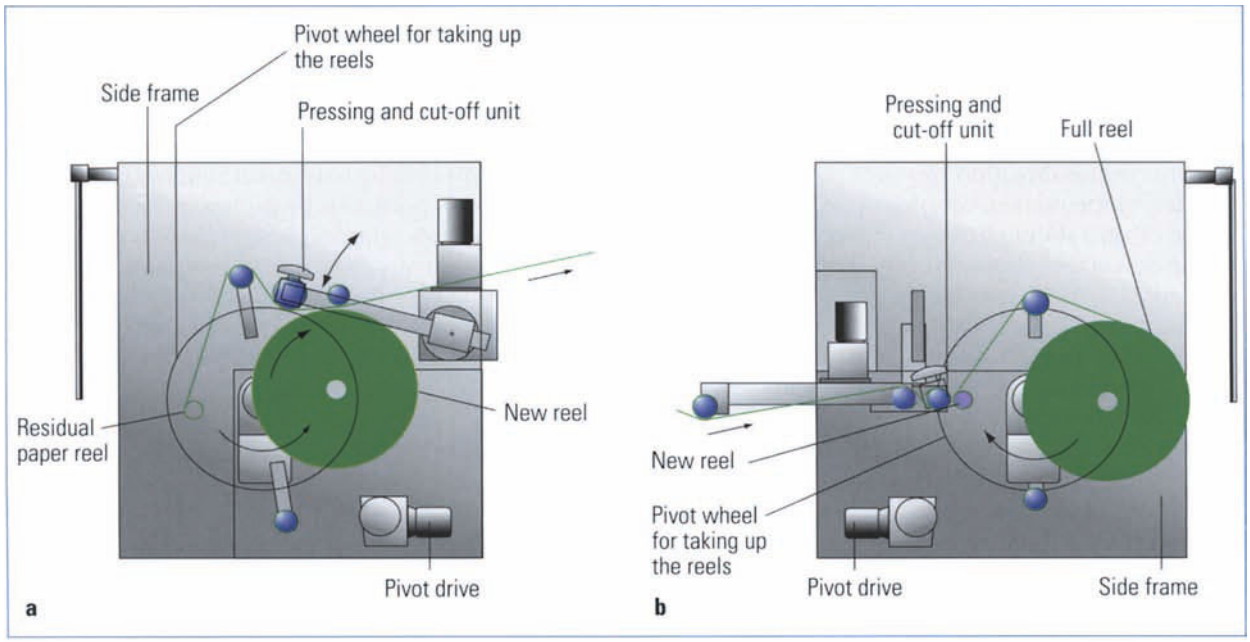


Fig. 2.2-39 Non-stop winders for unwinding and rewinding with fully automated reel change on gravure packaging printing presses.
a Unwinding unit;
b Rewinding unit (W&H)

ing/engraving and drastically reducing the press downtime and the waste rate – gravure printing, which is the simplest and best known printing process, could well become more widespread.

2.2.4 Potential for Further Development

Gravure Wrap-around Plates

The advantages of gravure printing lie in the (comparatively) simple principle of the process and in the high quality of the printed products. The significant disadvantage is the expensive and time-consuming gravure cylinder preparation. Therefore, there have been continued attempts to replace the rigid gravure cylinder with quickly changeable wrap-around plates for rotogravure/web-fed gravure printing. Flexible copper plates are already known from sheet-fed gravure printing (fig. 13.1-11), yet these are only sufficient for use at low production speeds. Added to this, there are sealing problems at the joining point when using wrap-around plates and the ink can get under the plate and onto the cylinder, which leads to blurred prints.

The German immigrant Wilhelm Huck experimented as early as in the 1960s at the US state printshop in Washington D.C. with bent gravure printing plates. These plates were held on the cylinder by means of a T-shape hold-down clamp and vacuum (fig. 2.2-40). Yet all attempts failed since printing ink kept penetrating under the plate. Dot squeezes (butterfly patterns) at the plate's contact lines were the consequence. The gravure printing press manufacturer Albert-Frankenthal, today KBA, carried out further extensive development projects in this field in the 1970s. For example, there were attempts to seal the contact lines with UV curing plastics and to tear open this seal by pulling up a wire strip when changing plate. Later it was BASF who continued the developments, in particular to market "Nyloprint" printing plates as "Nylograv" plates in the gravure printing industry. Yet these tests, boosted by large capital investments, were not blessed with any success (fig. 2.2-41).

Speed and Web Width

The gravure printing process for printing magazines and catalogs made a significant breakthrough to be-

come economically more effective in the second half of the 1970s, since both the production speed (fig. 2.2-42) and the printable web widths were increased considerably. Today, *web travel speeds* of up to 15 m/s and *web widths* of up to 3.6 m are achieved. Whether the developments in this direction can continue, or will be demanded by the market, remains open.

First of all, it should be noted that with the speed and web widths stated above, the highest productivity values have already been achieved compared to all other printing processes, which means that there is no similar experience to fall back on. It must also be taken into consideration that most of the problems associated with a further increase in speed become considerably more severe and that a further increase in the web width would place higher demands on other elements of the printing process, such as the transport of paper reels or logistics in general.

On the other hand, a contrary trend has become apparent for some years now. The increasing individualization of printed products means also that mass products must be replaced by individual products suited to special interests, hence shorter print runs. However, gravure printing is poorly prepared for this, due to the expensive gravure cylinder preparation. For this reason the majority of these new products are produced on heatset web offset presses. A move towards smaller, more functionally flexible gravure printing presses, on which the change-over of product can take place more quickly, can therefore more likely be expected. In the coming years the industry will concentrate on the development of easy-to-change printing units and perhaps also simpler gravure cylinder preparation.

Moreover, modern web offset presses with a maximum print speed of up to 15 m/s are already in use. This was achieved in particular by gapless blanket cylinders (sleeves) and plate cylinder clamping mechanisms with an extremely narrow gap width (approximately 1 mm), which lead to a considerable reduction of vibrations influencing the quality of print (e. g., the web offset press M-3000/"Sunday Press" by Heidelberger Druckmaschinen AG).

Cylinder Engraving

There have been many attempts in the past to engrave the gravure cylinders more quickly. Non-contact techniques, such as *laser engraving* or *electron beam engraving* (Hell) should first be mentioned. Systems working with a laser are already on the market (cf. sec. 2.2.1). Manufacturers can be expected to follow this trend and offer further laser engraving processes. In addition, faster mechanical systems are also being developed which are based on stylus engraving. The majority of modern electromechanical systems work with a 4 kHz engraving frequency. Electromechanical systems working at 8 kHz have been on the market since around 1998 (e. g., the HelioSprint system by Hell Gravure Systems) and systems that work at even higher frequencies (10 kHz) already exist as prototypes and could be available shortly.

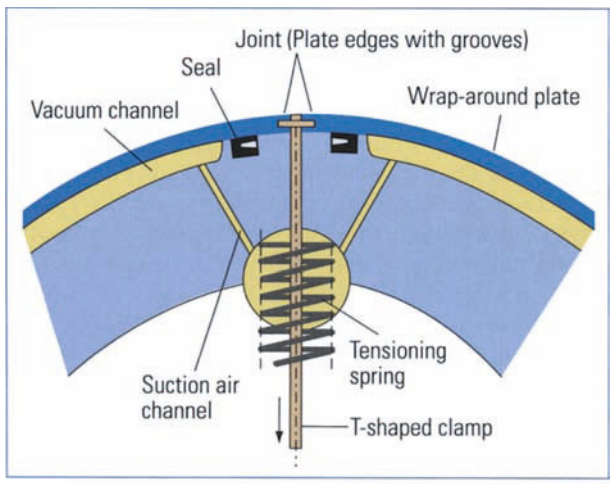


Fig. 2.2-40
Wrap-around plate with clamping mechanism for rotogravure (Huck)

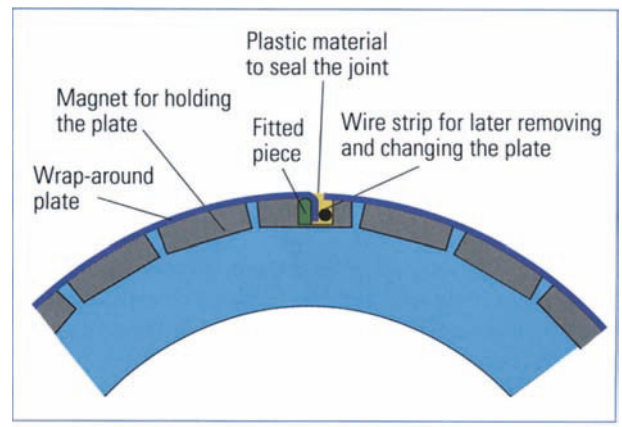


Fig. 2.2-41
Concept for covering the joint on a gravure wrap-around plate (KBA)

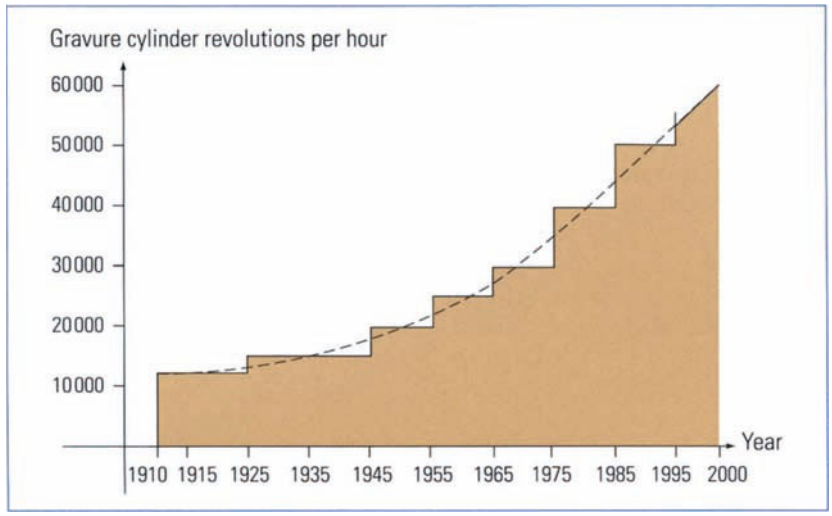


Fig. 2.2-42
Trend towards greater productivity (cylinder revolutions per hour) with rotogravure/web-fed gravure printing presses; with increased productivity through a broader web width of 3.6 m instead of 1.6 m (IFRA)

Gravure Cylinder Conditioning

Gravure cylinder manufacture is a multi-stage and expensive process. Cylinder manufacture includes procedures such as electroplating (copper and chrome plating), mechanical machining processes (milling, lathing, grinding) and last but not least the engraving (stylus, etching, or laser). To shorten the entire gravure cylinder manufacturing process, all process stages must be taken into account. Engraving is only one step in the whole chain, even if a particularly important and time-constrained one (due to the fact that the printed products have to be absolutely topical). However, one should not disregard that in other areas, too, such as mechanical machining operations (e.g., milling), progress has been made in the last few years – milling speeds have been increased (e.g., "Super Polishmaster" by MDC Max Dätwyler AG) or several processing steps have been combined. With certain processes, dechroming and the removal of the engraving (copper) can be achieved in one operation through dressing (e.g., "Cylinder-finishing Machine" by Kaspar Walter).

Other Developments

Gravure printing with a re-usable gravure cylinder and *inline imaging* ("DICOweb Gravure") is one of the most noteworthy developments. In 1995, MAN Roland Druckmaschinen AG exhibited a process as a technology study/lab prototype in which the cells of an evenly pre-engraved cylinder made of ceramic or steel were filled with plastic (polymer). This plastic can be removed inside the press by a laser beam in accordance with the image to be printed in a screen definition that is finer than the pre-engraved base cylinder, so that a cell structure is produced and the cell walls of the pre-engraved base cylinder take over the supportive function for the doctor blade. The gravure cylinder can be dressed and reused again and again by removing the plastic from the cells of the base cylinder, which carry the image, through a high-pressure water blast and then fully refilling them with the polymer. On DICOweb Gravure, printing occurs via a blanket cylinder used as the intermediate carrier (indirect gravure printing) from which the image is printed onto the substrate. The process has, however, not yet reached a level for practical use (see sec. 4.4.2.1 for details).

Just as interesting are the developments in the area of *water-based inks* for gravure printing. This kind of ink could replace Toluene inks and the associated recycling process. The existing Toluene recycling systems are sufficient to meet the current exhaust air regulations. A tightening of the regulations could raise the costs in designing such processing plants.

With regard to new inks for gravure printing, a development by "Siegwerk Druckfarben" is worthy of mention. A new ink is being developed there ("Hottech"), which has the following significant special properties: the ink

- is solid at room temperature,
- melts at approximately 80 °C (strictly defined melting temperature),
- is solvent-free.

The use of such an ink system requires several changes to conventional gravure printing presses (e.g., heating the gravure cylinder). A particular appeal of this technology lies in the fact that no dryers are needed as the "Hottech" ink contains no solvents (such as Toluene) and the stabilization of the ink takes place by solidification (cooling down) on the substrate.

Prognosis

The number of gravure printing companies has declined in the last few years. Only large printing groups are still able to afford the high initial investments and achieve an economic utilization of the installations. Even optimistic projections do not foresee a large increase in the share of gravure printing.

References in 2.2

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[2.2-2] Ollech, B.: Tiefdruck (Grundlagen und Verfahrensschritte der modernen Tiefdrucktechnik). Polygraph-Verlag, Frankfurt/Main 1993.

2.3 Letterpress Printing

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2.3.1 Basic Principles

Letterpress (relief) printing, of which traditional letterpress and flexography form a part, is the oldest printing technology. Printing is done by means of raised printing elements.

Letterpress printing is a mechanical technology in which a relatively high pressure is required to transfer the highly viscous, pasty ink to the paper via the hard printing elements (fig. 2.3-1). In the chronology of their development, presses and machinery are subdivided into hand presses and platens, high-speed presses and web presses (see also sec. 1.6.2), on the basis of the different pressing methods involved (see sec. 1.6.1).

For centuries *letterpress printing* with rigid printing plates, predominantly made from alloys of lead, tin and antimony, was the dominant printing technology. For many years letterpress printing has been increasingly losing favor, having been replaced primarily by offset printing, and it is now only used in niche areas. Letterpress printing is sometimes used for printed products such as paperbacks and telephone books that do not impose particularly high demands on printing quality, and for some daily newspapers. *Indirect letterpress printing (letterset)*, in which the print image is transferred to the substrate from the inked-up printing plate via a blanket cylinder, is still used in certain special fields, packaging printing in particular.

In the last several decades, a modified letterpress printing method, *flexography* (fig. 2.3-2), has become increasingly more prevalent, especially in the packaging industry, for printing on the most varied materials.

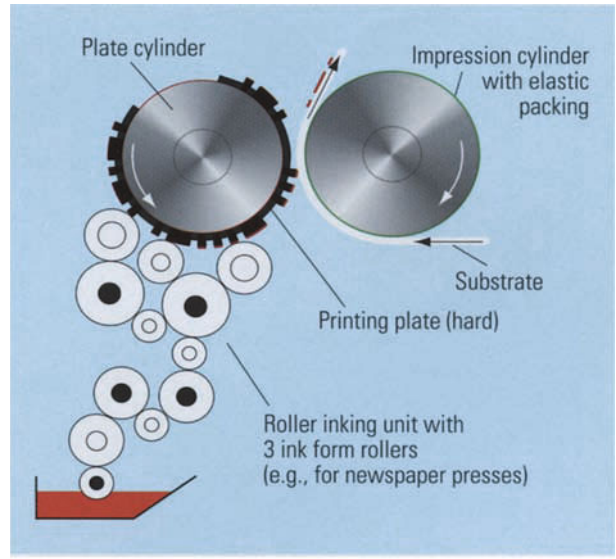


Fig. 2.3-1 Letterpress (the principle of the process)

The term "flexography" was introduced at the beginning of the 1950s (it was previously known as "aniline printing"). Unlike letterpress printing, flexography uses low viscosity inks and resilient or soft, flexible printing plates, and the pressure applied between plate cylinder and substrate is low ("kiss printing"). Because of the flexible printing plates, which were formerly made solely from rubber and are now made mostly from photopolymeric plastic, printing can also be done

H. Kipphan (ed.), *Handbook of Print Media*
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on materials with very rough surfaces and even on fabrics (see sec. 2.3.3). Figure 2.3-3 shows the scanning electron microscope (SEM) exposure of a photopolymer letterpress printing plate for high-quality printing.

2.3.2 Letterpress Printing (Process and Applications)

Letterpress printing was the predominant book-printing process. For four centuries it was also the predominant printing technology for posters, announcements, printed matter for churches, government and businesses, single- or two-page local news-sheets, and daily and weekly newspapers, as well as sundry simple print jobs. Initially printing was done by the *platen* method (fig. 1.6-1). The invention of the *high-speed press*, a cylinder-type printing press, by Friedrich Koenig in 1812, was a decisive factor in the progress of letterpress printing, because it offered higher productivity.

The invention of the semi-circular stereotype plate (1854) was a prerequisite for the construction of *web presses*. Large-circulation newspapers, in particular, could be printed and colorful, luxurious printed products could be produced on various special presses. Special satellite-configured letterpress rotaries (each with a large impression cylinder with up to twenty printing units) were developed for wallpaper printing. Many different letterpress printing presses were supplied for the graphic arts industry. As for instance the Heidelberg platen (fig. 13.1-19) became the most widely-used letterpress platen press in the world.

The fundamental disadvantages of letterpress printing compared to offset printing are the expensive printing plate, the costly makeready of the printing plate, the limited print quality and the limit of production speed.

Letterpress is still used to print forms, labels, lottery tickets, security papers, telephone books, and paperbacks, though there is a downward trend. Letterpress was also used for newspaper web printing with inking units in accordance with figure 2.3-1 (e. g., the "Courier" model from KBA). A few newspaper rotaries are still in use both for direct and indirect printing (letterset, with blanket cylinder). The last newspaper letterpress printing presses were delivered in the 1980s.

The most prevalent printing plate is the wash-off printing plate. There are very different wash-off sys-

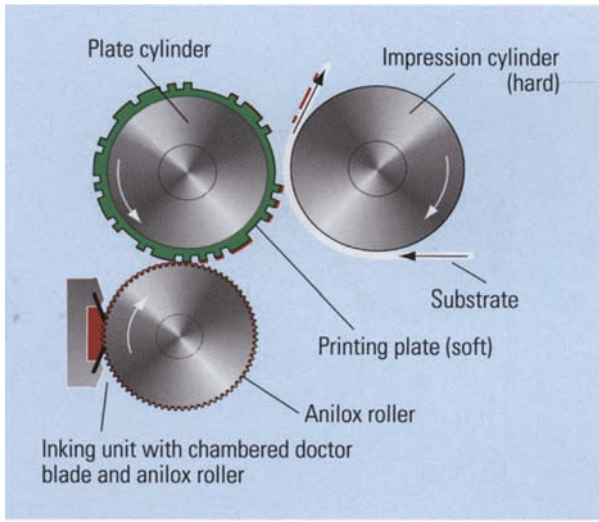


Fig. 2.3-2 Flexography (the principle of the process)

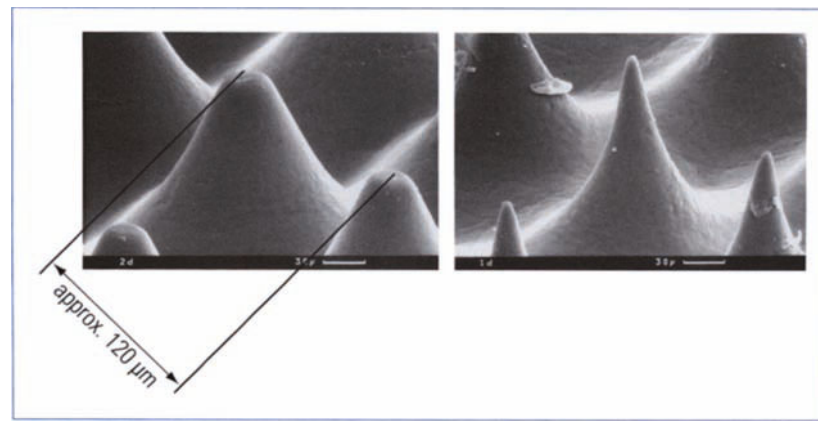


Fig. 2.3-3
Microphoto of a relief printing plate for flexography; print elements on the printing plate for various tonal values (Nyloflex, BASF)

tems and wash-off depths available in conjunction with different bases. The production process is described using the example of "Nyloprint" printing plates (from BASF).

The structure of the layers of a Nyloprint plate is shown in figure 2.3-4. Steel, aluminum, and polyester are used as base materials. The plate thickness is approximately 0.8 to 1.75 mm, depending on the type, and the relief height between 0.2 and 0.67 mm, depending on the application and the type of plate. The relief layer consists of a photopolymer (UV light-sensitive, 360–370 nm), which is firmly attached to the base material.

The following operational steps are necessary to make the Nyloprint plate:

- Removal of the protective film.
- Exposure of the polymer coating through a negative film – the exposed areas cure (crosslink). The smaller the covered areas, the smaller the later depth of the relief. There are flat-bed and external drum imagesetters and also step-and-repeat systems available.
- The photopolymer that is not crosslinked is washed off with water or an alcohol and water mixture. The print relief is produced.
- Drying the print relief.
- The complete polymerization of the print relief, and therefore its curing, is ensured by the flat UV post-exposure.

Fine lines up to 50 µm wide and small isolated dots 200 µm in diameter can be achieved.

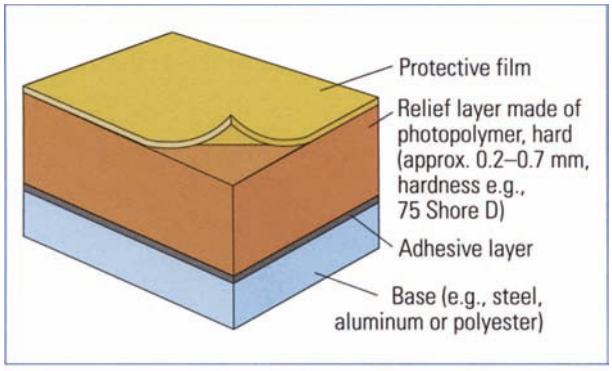


Fig. 2.3-4
Layer structure of a photopolymer letterpress printing plate (Nyloprint, BASF)



Fig. 2.3-5 Magnetic cylinder with letterpress plate (NELA)

Letterpress plates with a steel base can be attached easily to magnetizable plate cylinders (fig. 2.3-5).

2.3.3 Flexography

The basic principle has already been described in section 2.3.1 and figure 2.3-2. Flexography is the only printing technology by means of which printing can be done on very thin, flexible, and solid films, virtually all papers, thick cardboard, rough-surfaced *packaging materials*, and fabrics.

The print quality that can be achieved in flexography is lower compared to offset printing. The resolution is usually lower with flexography (48 lines/cm, 120 lpi using conventional production methods) than with offset printing which has a standard of 60 up to 120 lines/cm (150 up to 300 lpi). However, modern printing plates, especially those produced using computer to plate imaging systems, have improved printing quality markedly. Print work with a screen frequency of 60 lines/cm (even of up to 120 lines/cm) can be produced. The use of new types of printing plates with adapted inks and technical printing press developments, especially with respect to inking (inking units), have tremendously improved the printing quality offered by flexography.

2.3.3.1 Process

The resilience of the flexographic printing plate in conjunction with *low viscosity ink* (see also sec. 1.5.2 and fig. 2.3-2) makes it possible, in particular, to print on the non-absorbent and rough substrate surfaces that are

often typical of packing. Moreover, flexography is particularly suitable for printing on flexible materials such as plastic film.

The printing technology requires only a *slight contact pressure* to enable reliable ink transfer from printing plate to substrate. This contact pressure must, however, be exerted as evenly as possible on all printing locations along the contact area and during the pass of the entire print length. Eccentricities in the cylindrical form and radial deviations can be compensated by setting a somewhat higher pressure. The satisfactory preliminary requirements for even print-out of the entire print image are met if a contact pressure can be maintained with only slight fluctuations. Soft, flexible printing plates facilitate a good print result even with such low contact pressure that printing can be done even on corrugated board without damaging it.

It must be taken into account that too pronounced a deformation of the flexible printing plate leads to considerable *dot gain*, especially in the light image areas, due to the small, slender, and therefore easily deformable printing elements there. Since in this case it is mostly a matter of random errors, compensation by, for instance, altering the tone value in prepress is not possible. The wear of the printing plate, which increases with the number of impressions, results in increasing dot size, and so also in dot gain.

Printing Plates

The printing plates are made from rubber or photopolymers. Their hardness and thickness are adapted to the particular substrate and motif. Since, on the one hand, the types of substrate to be printed range from corrugated board via paper, plastic film, and metal foil to composite materials and on the other, extremely varied requirements (different requirements apply for the packaging of industrial products than those for the packaging of foodstuffs) have to be met, numerous types of ink are used for flexography – water-based inks, inks containing alcohol or benzene, ester inks, UV curing inks, and so forth. The printing plate material must be selected so that it will not be swollen, etched, or embrittled by the inks.

Printing plates are either flat and fastened onto the plate cylinder with adhesive or double-sided adhesive film, or they are produced in cylindrical form (e. g., *sleeve technology*).

Rubber Plates. Rubber plates are produced by molding a matrix (embossed casting mold) using natural rubber with subsequent vulcanization. The plate is sometimes worked to an even thickness by grinding of the reverse side.

The best quality rubber and elastomer plates are produced when the print image relief is applied by laser engraving to plate cylinders that have been fully coated with elastomer and then precision-ground. With this process, the side walls of the printing elements can be shaped – in contrast to photo-chemical production – so that only the foot is at a slant, to increase stability, and the upper area has a vertical side wall, so that any resulting dot gain is to a large extent avoided during abrasion of the plate during printing (fig. 2.3-6). Laser-engraved plates are not yet widely used; at approximately 40 lines/cm, the screen frequency is clearly lower than with photopolymer plates (around 60 lines/cm).

Photopolymer Printing Plates. Photopolymers for flexographic printing plate production are available in liquid or solid form, with the solid systems becoming increasingly more prevalent. Untreated photopolymers consist of elastomer vehicles, unsaturated monomers, and UV photo-initiators. They are soluble in water or in organic solvents. A crosslinking reaction takes place as a result of exposure with UV light. The crosslinked photopolymers are then no longer soluble. Photopolymers can be crosslinked locally by partial exposure, the unexposed areas retaining their solubility and therefore their wash-off ability. This property is exploited to produce relief printing plates.

Solid photopolymer base plates are nowadays supplied ready-for-use (e. g., Nyloflex printing plates from BASF or Cyrel from DuPont). They are available as single or multi-layer plates.

Single-layer plates consist of a relief layer (untreated photopolymer) that is covered with a protective film.

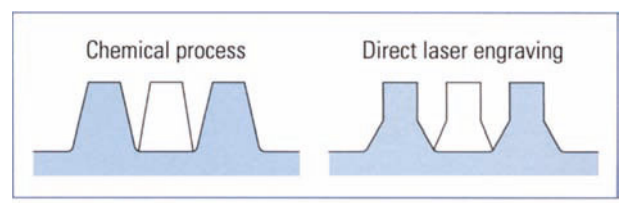


Fig. 2.3-6
Comparison of the relief of a photopolymer printing plate produced in a photographic/chemical process with a laser engraved printing plate (rubber)

A separation layer allows easy removal of the protective film. A polyester film on the reverse side of the plate serves to stabilize the untreated plate. The layer structure of a single-layer plate is shown in figure 2.3-7a.

To process the single-layer plate, the reverse side of the plate is first exposed completely and evenly without film copy through the stabilization film (usually polyester film). The reverse side exposure brings about the full-surface crosslinking of the lower area of the untreated plate and thus restricts the wash-off depth. It also increases the light-sensitivity of the coating, ensures a stable side wall structure, and facilitates the anchoring of a relief with a greater number of recessed layers.

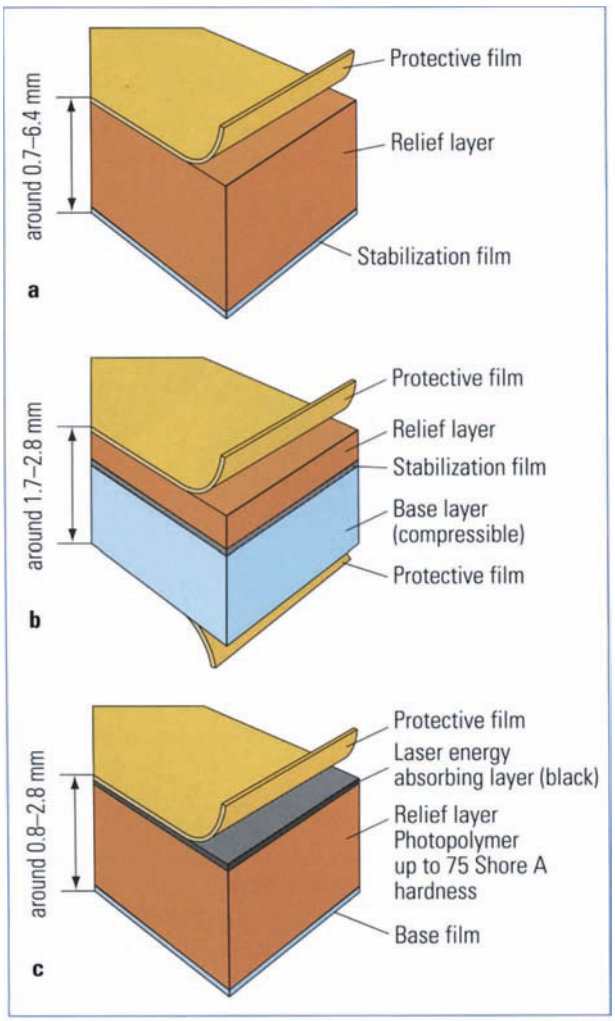


Fig. 2.3-7 Structure of the various flexographic plates.
a Single-layer plate (BASF);
b Multi-layer plate (BASF);
c Plate for computer to plate imaging systems (digiflex, BASF)
Note: 75 Shore A considerably softer than 75 Shore D for letterpress plate in fig. 2.3-4

After the protective film has been peeled off from the top surface, the main exposure is done under vacuum through the negative film (film copy) that has been placed on top. The relief is formed by photopolymerization. The duration and intensity of the main exposure affect the dot anchoring, the side wall angle, and the intermediate depths in fine structures, such as halftone areas (fig. 2.3-8).

The main exposure is followed by the washing-off process. The unpolymerized areas of the plate are dissolved with a solvent, with brushes supporting this dissolving process mechanically. After washing-off, the plate has to be dried thoroughly, in order to evaporate any wash-off agent that has penetrated the relief layer. This is followed by all-over post-exposure without film, in order to crosslink all parts of the relief completely. In this state, the flexographic printing plate has a sticky surface, on which dust and dirt would collect. This stickiness disappears as a result of exposure to UV-C light (which leads to a complete reaction, see fig. 1.7-11a) or after immersion in a bromine solution. Now the flexographic printing plate is complete.

Single-layer plates are made in thicknesses of 0.76 mm (e. g., for printing on plastic bags, film, and fine cardboard products) to 6.35 mm (e. g., for corrugated board and heavy-duty bags made from paper and film). Screen frequencies of up to 60 lines/cm (150 lpi) can be achieved with plates less than 3.2 mm thick. The possible tonal range here is about 2–95%. Thicker plates (around 4–5 mm) are suitable for screen frequencies of up to 24 lines/cm (60 lpi)with a tonal range of approximately 3–90%.

Multi-layer plates for high-quality halftone printing are structured as shown in figure 2.3-7b. In their structure they combine the principle of relatively hard thin-layered plates with a compressible substructure. The base layer itself forms a compressible substructure for the relief layer and consequently absorbs deformation during printing; the image relief remains static, however (fig. 2.3-9). The stabilization film ensures that virtually no longitudinal extension occurs as a result of bending during mounting of the flat plate on the impression cylinder. A comparable improvement in print

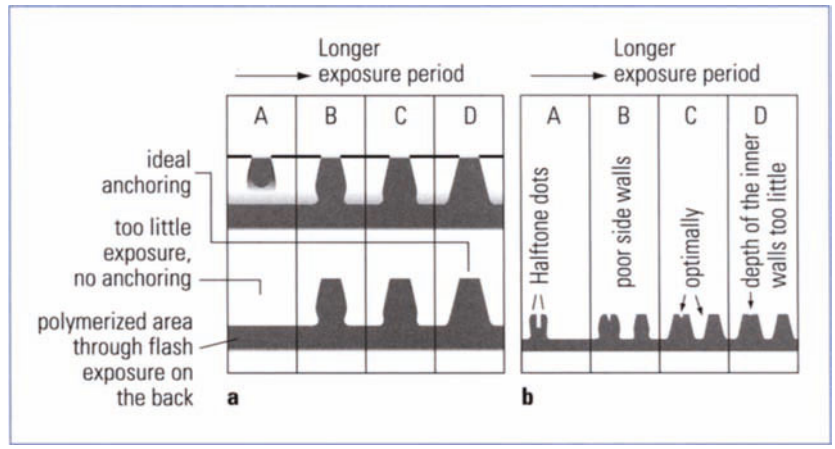


Fig. 2.3-8
Main exposure, effect of exposure time.
a Dot anchoring (e.g., with line structures) by UV exposure;
b Side wall angle and intermediate depth (with screened image elements); relief in the case of a 1.14 mm digiflex plate about 0.6–0.7 mm, intermediate depth min. 70 µm

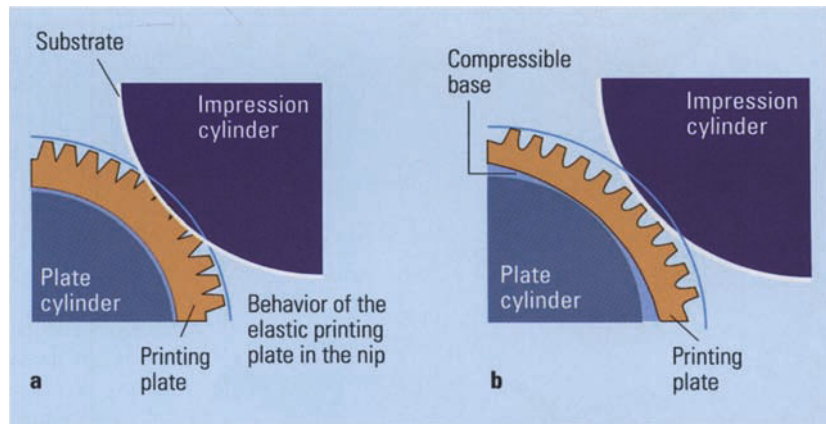


Fig. 2.3-9
Print image transfer in flexography.
a Printing plate deformation, single-layer plate (fig. 2.3-7a);
b Adequate transfer of the print image using a printing plate with compressible base (multi-layer plate in accordance with fig. 2.3-7b), (BASF)

quality is also achieved when thin single-layer plates with compressible cellular film are stuck onto the plate cylinder.

Untreated plates for digital print image transfer by *computer to plate systems* have the structure illustrated in figure 2.3-7c (e. g., BASF digiflex plates). The "black" layer is revealed on removal of the protective film, and it can be ablated to produce the image with the beam of a YAG laser (1064 nm wavelength). In this process the laser beam destroys the black, energy-absorbent layer, so that dot-by-dot imaging of the plate takes place. The black layer takes on the role of the *film copy (negative film)*. After imaging, the full surface of the plate is exposed (first exposure and main exposure) and it is further processed in the same way as a single-layer plate in order to create the relief (no laser-engraving takes place here, as was explained for the production of rubber plates).

Mounting the Printing Plate. The flat plates are fastened in accurate register onto the plate cylinder with double-sided adhesive film. When doing this, the plate must be brought into the shape of a cylinder shell. The image dimensions have to be reduced in prepress in the direction of printing to compensate for the longitudinal increase in size.

Sleeve Technology. The principle of sleeve technology consists of a thin-walled metal sleeve, the inside diameter of which is dimensioned so that the sleeve can be expanded under compressed air and pushed axially onto the plate cylinder. Once the compressed air has been

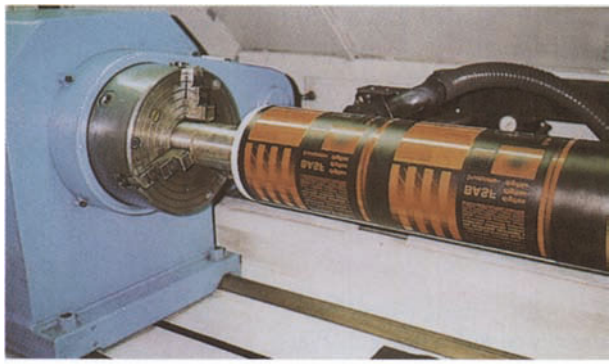


Fig. 2.3-10
Laser exposure of a sleeve printing master (digiflex, BASF)

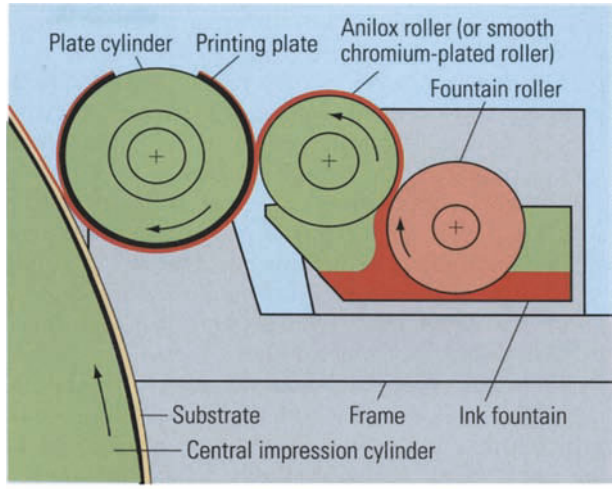


Fig. 2.3-11
Flexographic inking unit with ink feed via roller system (fountain roller system)

turned off, the sleeve sits firmly on the plate cylinder by force fit. Before being pushed onto the plate cylinder, the entire outer surface of this sleeve is covered with plate base material. The cylindrical plate is directly imaged using lasers in a round imagesetter (fig. 2.3-10). With this process the longitudinal extension that takes place during conventional mounting and the inaccuracies connected with the attachment of the block do not occur.

There are two modes of procedure for sleeve technology:

- Covering the sleeve with a laser exposable plate cut exactly to the size of its cylinder casing, in which case the sleeve has a seam.
- The use of seamless sleeves which have been already fully prepared by the manufacturer with the relief layer (e. g., BASF digisleeve).

2.3.3.2 Printing Unit

Printing units usually consist of an inking unit, a plate cylinder and an impression cylinder, as illustrated in figure 2.3-2. There are two different types of inking unit in current use:

- Fountain roller system where ink metering is effected by squeezing off the ink supply in the roller nip (fig. 2.3-11) between anilox roller and fountain roller.
- Doctor blade inking unit with anilox roller and blade, notably the chambered doctor blade (fig. 2.3-12).

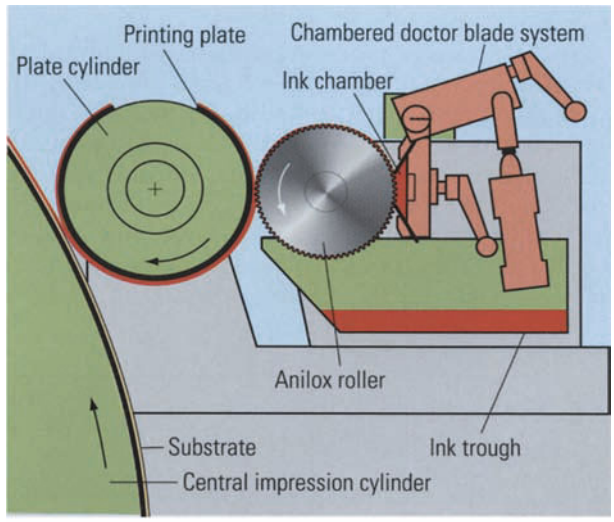


Fig. 2.3-12
Flexographic inking unit with ink feed via chambered doctor blade

The *fountain roller inking unit* (three-roller inking unit) is the original, simpler, lower cost system, though it is only rarely used now in new press systems. Good ink metering is only possible to a limited extent with this system. If too much ink is transferred during fairly long production runs, the spaces between the screen dots of the printing plate clog, and the print image

smudges. If too little ink is transferred, it can no longer be ensured that the printing plate will be inked up completely, and flaws occur in the print image. In offset printing, this metering system is frequently used in conjunction with coating units for full-surface and spot coating using flexographic plates.

With the increasing importance of halftone printing and the higher requirements on print quality, enhanced inking systems became necessary. Inking units with *anilox rollers* and enclosed *chambered doctor blade systems* are now standard components of all high-quality flexographic printing presses.

The *anilox roller* is the core element of the inking unit. The cell geometry and the cell distribution in principle determine the scoop/cell volume (cm^3/m^2) of the anilox roller (fig. 2.3-13). Rollers with different cell volumes have to be used, according to the requirements for ink film thickness. The blade unit ensures that the cells are filled so as to be reproducible with ink and that consequently a specified volume of ink is always transferred to the plate.

The ink transfer process (evenness, ink film thickness, the absence of moiré effect, etc.) is affected by *cell volume*, the cells' *emptying behavior*, the rheological properties of the ink, and the mechanical throw-on and rolling, as well as the behavior and adjustment of the surface properties of printing plate and substrate.

Chrome and ceramic (currently the most widely used) roller surfaces are standard (for production details see table 2.3-1). *Screen frequencies* of 150–300 lines/cm for a cell volume of 10 cm^3/m^2 are typical values. The following rules of thumb apply for the selection of anilox rollers:

- For a 2 µm ink film (wet) on the substrate (equivalent to 2 cm^3/m^2) the anilox roller's cell volume should be equivalent to 4 cm^3/m^2, (also, in flexography, as in offset printing, it is assumed as an initial approximation that the ink splitting is about half; see fig. 1.3-5.). The screen frequency of the roller should be greater than the plate screen by a factor of at least 5.5 (which means at least 260 lines/cm for the usual 48 lines/cm screening of the image). Lower plate screen frequencies are also covered by the higher screen frequencies of the anilox roller. If the screen frequency of the roller is too low in comparison with the screen of the plate, defects in the inking-up and/or moiré phenomena may occur.
- An engraving angle (angular position in relation to the roller's axis) of 60° in conjunction with a hexagonal cell shape is preferable in many cases but cannot be asserted as a general rule.

General descriptions and data on chrome and ceramic rollers can be taken from table 2.3-1.

The Design of Presses for Multicolor Printing

Flexographic presses are predominantly designed as web presses in the three configurations:

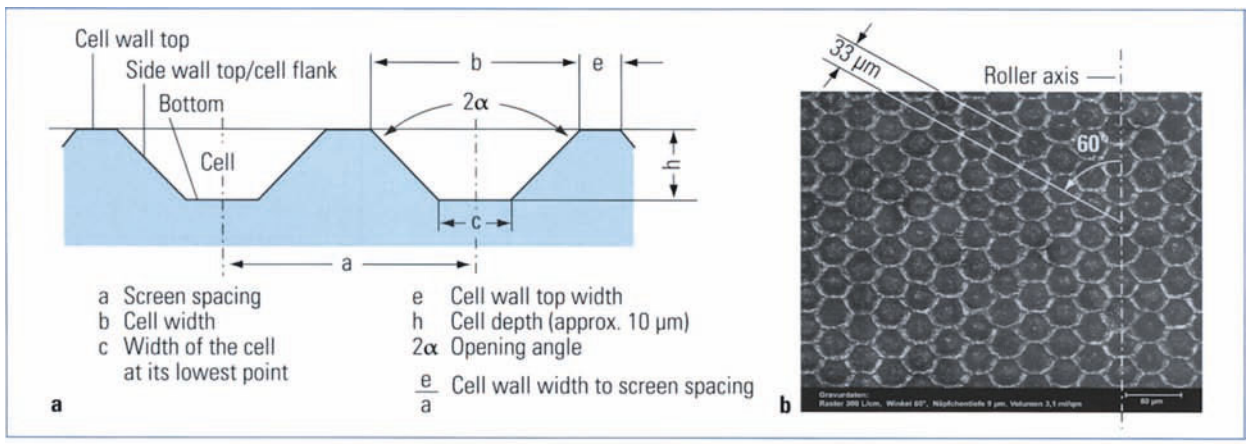


Fig. 2.3-13 Anilox roller.
a Cell geometry;
b Microphoto of the surface of a ceramic roller, 300 cells/cm (Haldenwanger)

Table 2.3-1
Properties and manufacturing process of chrome and ceramic anilox rollers

	Chrome roller	Ceramic roller
Properties	• Low cost; low execution time • Screen frequency up to approx. 200 cells/cm (500 cells/inch) • Cell volume restricted by production process	• Expensive, highly wear-resistant • Screen frequency up to 600 cells per cm (1500 cells per inch) • Greater level of fine engraving detail, different cell volumes possible with the same screen ruling
Production	• Copper-plating of the roller blank (e.g., steel) • Shaping of the surface by: – roll embossing (embossing with knurling tool) – striking the cells with diamond tool (electronically controlled) – stylus engraving – etching after mask application • Chrome-plating of the surface (wear protection coating)	• Plasma coating of the roller blank (e.g., steel) with ceramic • Fine-machining (grinding and lapping of the surface) • Laser engraving (evaporation of the material)

- central impression cylinder system (fig. 2.3-14a), and
- in-line (unit) design (fig. 2.3-14b), and
- stack-type design (fig. 2.3-14c).

Central impression cylinder presses (satellite printing units) have advantages over stack type presses in the precision of the longitudinal register, above all for printing flexible materials (plastic film), due to their large wrap angle. In-line presses are flexible and expandable with respect to the number of printing units and the usable printing processes (combination of different processes). The stack type and central cylinder system, on the other hand, are restricted to a specified choice of printing and inking units.

It is usual practice for the *sheet-fed flexographic process* to be applied in the coating units of sheet-fed offset presses (see sec. 2.1.2.7).

Multicolor sheet-fed flexographic presses (fig. 2.3-23) are also used for special applications (e. g., high-quality printing of metallic inks on packaging material, or printing on plastic material).

Central Impression Cylinder Presses. These presses were originally developed to make possible in-register printing on flexible film (fig. 2.3-14a). The substrate lies on the large impression cylinder throughout the entire printing process, thus achieving the greatest possible positional stability. Four to ten inking units with intermediate dryers can be configured round a central impression cylinder (diameter greater than 2 m and web widths of 300–3000 mm). To maintain the necessary even pressure in the printing nip, the central impression cylinder must be manufactured with a low runout of less than 5 µm and be temperature controlled with a tolerance of +/–1 °C (in the case of a 1.80 m diameter steel cylinder, for example, 1 °C difference in temperature brings about a difference in the radius of approximately 10 µm).

The printing units are engaged manually and/or by motor via adjusting spindles. Modern presses operate under NC control, which engages and positions the printing units in register with an accuracy of up to 1 µm in relation to the impression cylinder, taking into account job data such as plate thickness, rolling length, and substrate characteristics. Standard presses have a printing width of 1300 mm and a printing length of up to 1000 mm, with a production speed up to 6.7 m/s.

Multi-Cylinder Presses in Unit Design. With these types of presses, the same printing units are arranged in a row (fig. 2.3-14b). The web of material is usually diverted between the printing units in order to accommodate dryers with the corresponding drying length as well as web-tensioning and guidance elements. Unit design initially found favor in narrow web presses (with web width of up to around 500 mm) for label printing and more recently has tended to appear increasingly on

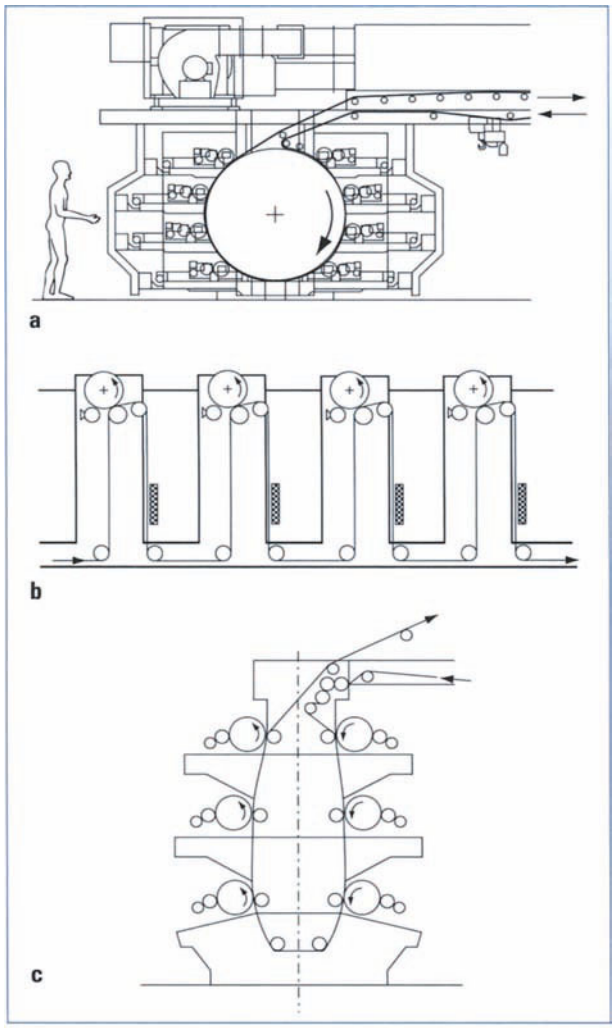


Fig. 2.3-14
Web-fed press designs for multicolor flexographic printing.
a Central impression cylinder system;
b Unit or in-line design;
c Stack-type design

the market with web widths of up to around 1500 mm. Production speeds of up to 4 m/s are possible. Direct drives on the individual printing units facilitate extended interconnection of machinery and high register accuracy in conjunction with high-quality web travel controls even for flexible materials.

Flexographic printing units are interchangeable and can also be combined with offset or gravure printing units for the construction of *hybrid printing systems*.

Stack-type Presses. These press types are only used for simple print jobs because of their poor register accuracy (around +/- 0.2 mm in longitudinal register), for instance, as auxiliary printing units for bag production (fig. 2.3-14c). An advantage that this design has over central impression cylinder presses is that with appropriate web guidance printing can be done on both sides.

2.3.3.3 Examples of Flexographic Printing Presses

An eight-color *central impression cylinder flexographic printing press* (the corresponding layout is shown in fig. 2.3-14a) with the state-of-the-art control technology and automatic reel change is illustrated in figure 2.3-15. The dryer is configured in the superstructure between the reelstand and the printing unit.

Equipping of the press with *plate cylinders* by means of a robot system from a loading trolley is shown in figure 2.3-16. It takes around twelve minutes to change eight cylinders.

A change of *plate cylinder sleeve* through the side frame is shown in figure 2.3-17. Figure 2.3-18 shows a change of plate cylinder sleeves and *anilox roller sleeves*.

The fundamental developments in recent years in the design of flexographic central impression cylinder presses are summarized in the model shown in figure 2.3-19: individual drives for the inking and printing units and automation modules are interfaced via an "industrial field bus", so that faults can be analyzed via a modem by means of a remote diagnostics system; computer controlled engagement and cut-off of the inking units, non-stop winding systems with automatic reel change at maximum production speed, and so on.

A flexographic printing press in *unit design* (fig. 2.3-14b) and comprising an integrated die-cutting unit is shown in figure 2.3-20. It is used for producing folding boxes. Board from 200 to 600 g/m² can be processed, with a maximum reel diameter of almost 2 m and a maximum width of 82 cm.

Figure 2.3-21 shows a *narrow web label printing press* with integrated rotary die-cutter. In many cases labels are printed using UV inks, and a UV dryer is therefore installed after each printing unit.

The great variety in the application of flexography becomes apparent in figure 2.3-22, which shows a *multicolor newspaper printing press* with 144 printing units. Printing is done with water-based inks.

Figure 2.3-23 shows a *two-color sheet-fed flexograhic printing press*.

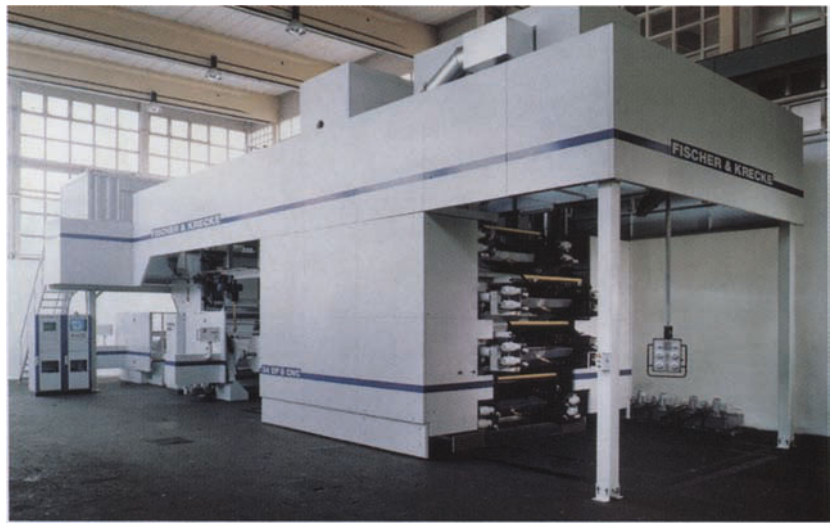


Fig. 2.3-15
Eight-color flexographic printing press with a central impression cylinder, cylinder diameter 2275 mm, web width up to 1700 mm, printing length up to 1400 mm, printing speed 6 m/s (34 DF/8-CNC, Fischer & Krecke)

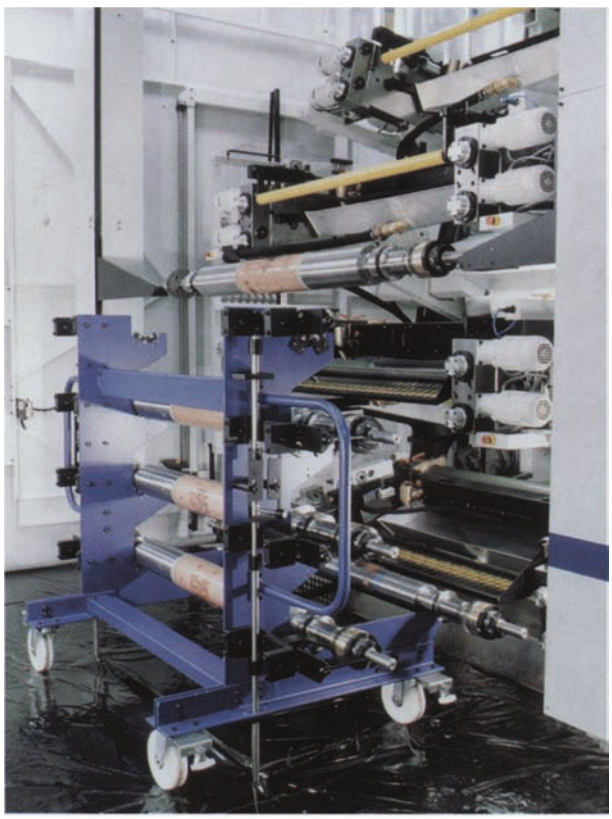


Fig. 2.3-16
Plate cylinder change with automatic cylinder loading system for a flexographic printing press with a central impression cylinder (Fischer & Krecke)

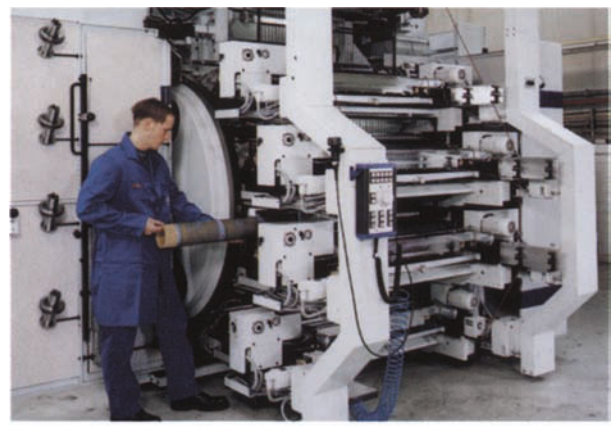


Fig. 2.3-17
Change of a flexographic plate cylinder sleeve (Fischer & Krecke)

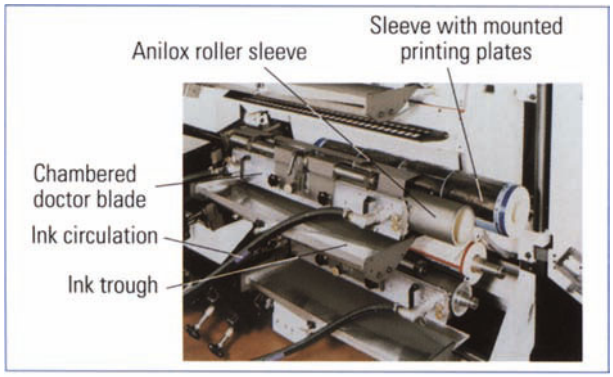
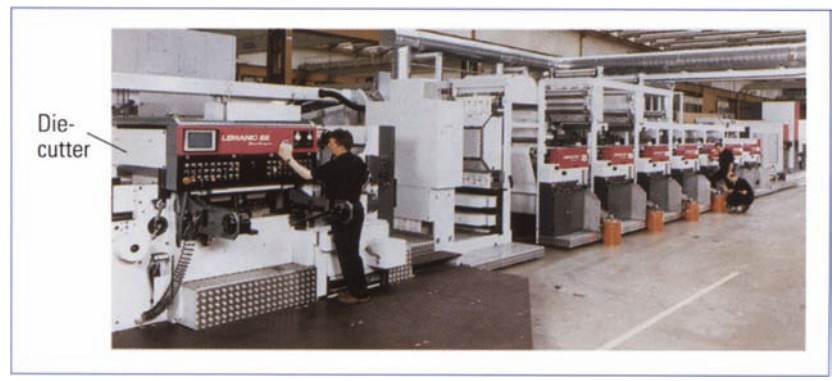


Fig. 2.3-18
Change of a plate cylinder and anilox roller sleeve in a flexographic printing unit (Soloflex, W&H)

Fig. 2.3.-19
Flexographic printing press with a central impression cylinder with eight printing units and a high degree of automation (Astraflex, W&H)



Fig. 2.3-20
Flexographic printing press with in-line units (unit design) and with integrated die-cutting unit for folding box production (printing on reel material, delivery of die-cut sheets), production speed 3.5 m/s (Lemanic 82 F, Bobst)



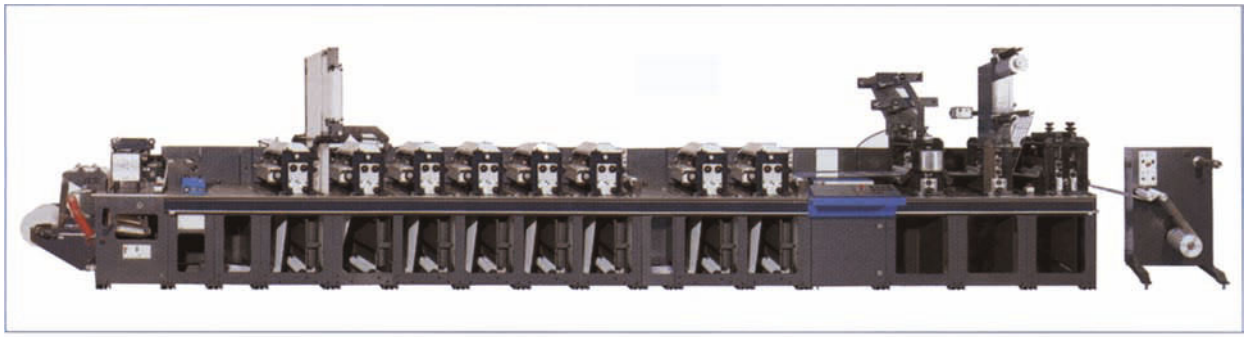


Fig. 2.3-21 Flexographic label printing press with UV drying and rotary die-cutter, speed 2.5 m/s (Arsoma EM 510, Heidelberg/Gallus)



Fig. 2.3-22
Newspaper press for multicolor printing with 144 printing units (Flexocourier, KBA)

2.3.4 Potential for Further Development

Traditional letterpress has become virtually insignificant and is therefore not included in this description.

The importance of *flexographic printing* has increased noticeably world-wide thanks to the many new developments and enhancements in this field and the good results achieved in the packaging industry. Depending on the substrate and the motif, the *quality* of products printed in flexography is improved and the gap to the high quality of offset and gravure printing is reduced. Flexography has turned out to be a qualitatively good printing technology suitable for industrial printing. At a rate of around 3% p.a., its market share has risen above average in recent years, especially in the packaging industry, and noteworthy growth rates are predicted in many markets for the coming years.

On the other hand, flexography will play a subordinate role in the *newspaper sector* in the future.

Vast progress has been made in the entire *prepress area* of flexography as a result of the introduction of computer to plate technology. These developments, together with efforts towards standardization, are being purposefully continued. Current practical results are very promising and are comparable with offset and gravure printing. The greatest advantages of the digital computer to plate technology lie in the high print quality with lower dot gain and a greater range of print contrast, in the cost savings due to films and film chemicals no longer being required (which means that it is also environment-friendly), in possible data transfer, as well as in the electronic image composition.

The use of *sleeves as printing master* is making a strong contribution to the good print results. Sleeves covered with laser-sensitive printing plates for subsequent laser imaging are already in use. Seamless sleeves comparable to gravure cylinders and providing for printing of the entire circumference are being introduced onto the market. The digitally produced, full-size, no make-up printing plate is a reality.



a



b

Fig. 2.3-23 Sheet-fed flexographic printing press.

a Two-color press for 70 cm × 100 cm (28" × 40") format, up to 12000 impressions/h;
b Cylinder with printing plates and ink form roller (FlexoGold, Aurelia)

Robot systems, ink supply systems, and cleaning devices for all ink-conducting parts integrated in the press have helped to improve the economic efficiency of flexography. These systems will be developed further in the future, thus enhancing operation, print quality, and reliability of flexographic printing presses.

Further Reading for 2.3

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2.4 Screen Printing

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2.4.1 Basic Principles/Process

Screen printing is one of the most versatile processes for transferring ink and technical coatings. Its application ranges from artistic applications to the large-scale industrial sector, from extremely small components in sensor production to 3 m × 6 m formats in flat glass finishing, from single-item production to long print runs. Printing can be done on paper, textiles, ceramics, and plastics, in the form of endless webs and single sheets, and also on objects of the most varying nature and shape, such as glasses, mugs, and control panels .

The range of inks is correspondingly varied. Very often special inks are involved that are adapted to the relevant applications. The four-color process typical of publication printing is also used. The appliances, machinery, and systems utilized for screen printing range from the simplest of devices and machines for crafts work to large-scale plants on an industrial production scale.

Screen printing is a push-through process, a special type of stencil printing, which means that during the printing process the ink passes through the screen and onto the substrate (see also sec. 1.3.2.4, where screen printing, its processes, and its printing methods are described within the context of master-based printing processes).

The *stencil printing process* is one of the oldest printing processes. Lettered stencils, stencils for applying embroidered artwork for monograms on laundered items, or for applying text and markers to all types of mailroom packaging have been in common use for a long time and are still in use today. The use of stencils enables a fast application of information in the form of texts, symbols, and pictograms on the most diverse of substrates. Here, the stencil is fastened onto the surface on which printing is to be done, and the ink reaches the desired position through the stencil apertures. The ink can be painted on with a brush or a squeegee (see fig. 2.4-11), or sprayed on with a spraygun or an airbrush (fig. 2.4-1).

Stencil printing has one general disadvantage that restricts its use, namely that all parts of the stencil must be connected to each other. This means that with most letters, for example, stabilization gutters are needed to link the inner parts or those parts that might easily snap off to the surrounding material. This produces the typical structure of stencil lettering, in which the line strokes are broken off at intervals (fig. 2.4-2).

This disadvantage does not occur with *screen printing*, where the screen/silk fabric (fig. 2.4-3) takes on the function of the gutters and thereby places no restrictions on the motif's design. The ink surrounds the screen mesh and forms closed surfaces between the masking parts of the stencil. The stencil is placed on or within the screen, glued to it, and held in position in that way.

Thus the screen is merely a carrier for the stencil. The stencil is the carrier of the printed information. The printing plate is the combination of screen and stencil. This allows virtually complete freedom for designing the motif, right up to halftone printing. It must only be

H. Kipphan (ed.), *Handbook of Print Media*
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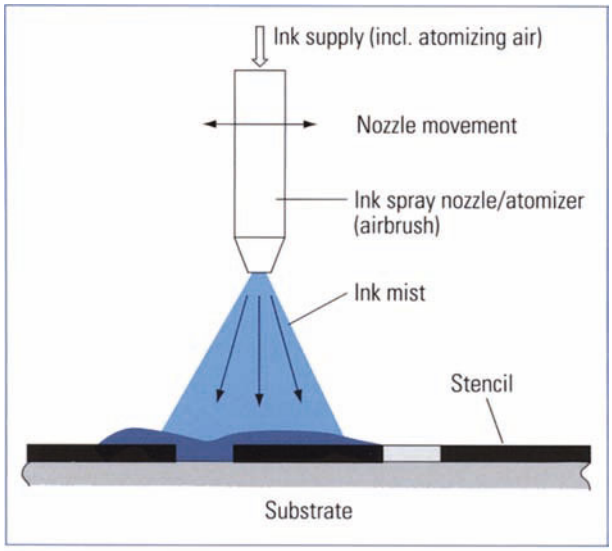


Fig. 2.4-1
The principle of stencil printing (application of ink through ink spray nozzles)

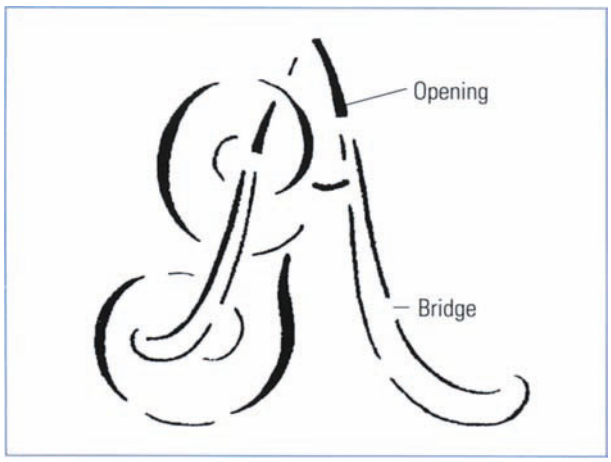


Fig. 2.4-2 Stencil for embroidered artwork

ensured both that the smallest masking reference surfaces of the stencil are still held in the screen fabric and that the smallest openings of the stencil are not closed by screen threads or threads crossing, which would result in the ink transfer being partially prevented or at least impaired. This limits the potential screen definition and range of tone values.

The direction of the fabric threads must be taken into account when screen angles are selected in order to avoid unwanted moiré phenomena during printing. If a print result of the desired quality is to be achieved, screen, stencil, and ink must meet a number of particular requirements, a typical one being halftone screens of up to approximately 40 dots/cm (100 dpi) with thread counts currently up to 200 threads/cm. The screen angles correspond to those of offset printing with an additional rotation of 7.5 degrees in relation to the direction of the screen fabric's threads.

2.4.1.1 Platemaking

The screen printing plate consists of the screen, the frame covered with the screen fabric, and the stencil containing the printed information.

Frame

There are diverse types of frames for screen printing. Wood, steel, and, more often, aluminum is used. Frames with clamping devices for the fabric are used, as are designs where a specific clamping arrangement using several clamping devices on each side of the frame is employed to avoid distortions to the image structure. The stability of the frame is also vital with respect to the quality of the printing. Low frame weight is expedient for ease of handling, especially in the craft work sector.

Screen Fabric

The type of fabric to be used depends only on the requirements arising from the process. The fabric's material must allow good connection to the stencil material and must not be affected by the ink solvent or cleaning agents. It must be sufficiently abrasion-resistant to withstand the stress created when the squeegee is brought into contact with the substrate. The mesh width must be sufficiently large, if coarse-pigmented inks or coating materials are to be used, and on the other hand sufficiently fine to provide safe anchoring for the smallest parts of the stencil during halftone printing. The fact that it must also be possible to expose and develop high-quality direct photographic stencils on the screen calls for high resistance to UV radiation. The fact that light scatters through the fibers during UV exposure, which can lead to a reduction in quality, is largely prevented by a yellow tinting of the material that is consistent with the light source.

A large number of fabric types are presented and described in [2.4-1]. One of the most important param-

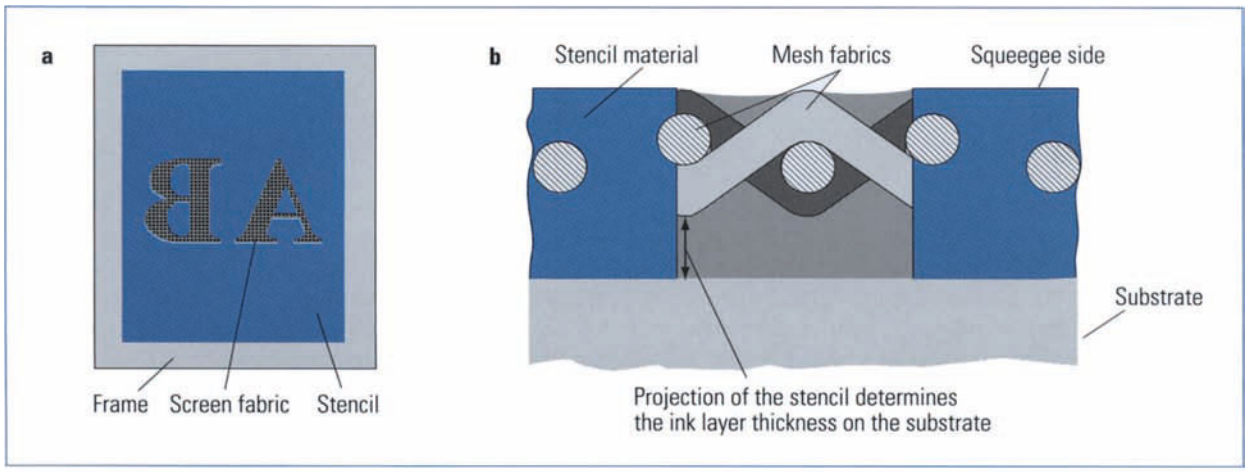


Fig. 2.4-3 Printing plate: screen with stencil.
a Seen from the print side;
b Cross-sectional view of a printing plate (Note: thanks to the technology applied for coating the screen with the stencil material, the stencil material is also applied to the squeegee side to protect and stabilize the fabric. The screen material is fully sheathed.)

eters is the fabric count, which corresponds to the number of threads/cm. Fabrics are available with *thread counts* from 10 to 200/cm. The fabric quality is determined by the *thread thickness* used. It is indicated in a maximum of four thicknesses that range from "light" to "heavy." The *mesh width*, and consequently the open screen area (as a percentage of total surface, see fig. 2.4-4), is determined by the fabric count in threads/cm and the thread thickness in µm, for example 180/27. This measurement and the stencil's thickness influence the thickness of the ink film actually transferred. Greater smoothness of the printing plate (with lower screen and squeegee wear) is achieved with after-treatment of the screen fabric through a calendar prior to covering with the stencil material.

The print quality of halftone images is restricted by the stencil and screen parameters. The small parts of the stencil must be of a certain minimum size so that they can anchor themselves securely in the fabric of the screen. On the other hand, the apertures should be at least so large that they cannot be closed by threads and crossed threads. It must also be ensured that the apertures are not smaller than the thickness of the stencil, otherwise the ink channels will not allow smooth transportation of the ink onto the substrate. The thread/fabric count must be at least four times the screen to be printed, if a tone value range of 5–95% is to be achieved with certainty. Failure to optimally

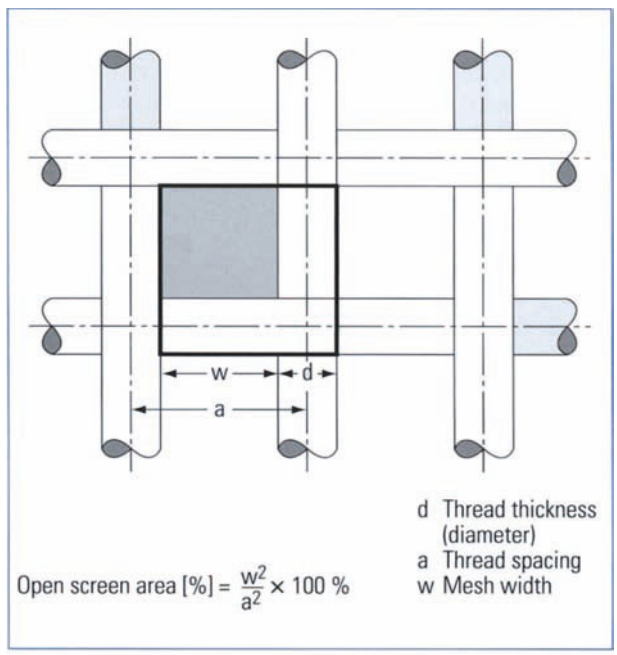


Fig. 2.4-4 The screen geometry

coordinate fabric fineness, screen resolution, and the desired ink film thickness (projecting stencil) may also result in moiré-type defects.

The correct *screen tension* is an important factor in achieving good print quality. There must neither be disruptive distortion of the image as a result of the shear force applied by the squeegee during the printing process, nor must the screen tension reach the yield point of the material, otherwise the screen would be damaged. Particular attention must be paid to this with multicolor printing or when printing in the technical field, such as in printed circuit board production, where high demands have to be made on the register precision of the impressions.

Screen tension depends on the material, the fabric count, the fabric quality, and the yield point they determine. The screen loading may be 0–25 N/cm. The tension that has been applied diminishes depending on the nature of the screen fabric, the stress during printing, and the passage of time. It is therefore possible, in the case of synthetic fabrics for example, for the tension to fall by 50% after just two days, depending on the type of adhesion technology employed. Also, the flexible frame leads to uneven tension, which may lead to distortions in the image. Figure 2.4-5 shows a manually operated screen tensioning device with tensioning clips and measuring equipment. Pneumatic, self-adjusting screen tensioning systems support even tension, since they also compensate for the frame deformation factor.

Stencil

The carrier of the printed information, the stencil, is produced in a different way. Production methods vary from extremely simple manual work to the high-tech methods of "computer to screen" (see also sec. 4.3.5).

Manual Stencil Production. The following methods are primarily used in the hobby area or even by artists during *serigraphy*, the name given to artistic screen printing:

- *Cutting.* Films on base material are available for hand-cut stencil making, which are transferred from the base and "stuck" to the screen after the printing image areas have been cut away. There are films for "ironing on" or etching/gluing with a suitable solvent.
- *Masking.* In this process the stencil material is transferred to the screen in a similar manner to varnish, with a brush for example.
- *Washing off.* Whereas with masking the information to be printed is applied as a negative image, in the washing off process the image information (which becomes permeable for the ink) is applied to the screen using a water-soluble varnish, after which the screen is completely coated with the ac-



Fig. 2.4-5
Screen tension device with manually operated tensioning clips and measuring instrument (Steinmann), (Note: The combined load and measuring device attached to the cantilever arm supports the selective adjustment of the screen tension.)

tual stencil material, a varnish based on a different solvent (e.g. acetone). The material applied initially is then washed off (with water in this example) and the printing image areas become permeable for the ink. Coating and washing off can be alternately combined in such a way that two-color printed graphics can be created from one screen.

Photomechanical Stencil Production. The most commonly used method of plate making for screen printing is currently the application of photomechanical stencil material based on diazo (photopolymer).

- *Direct stencil.* The stencil material, a UV-cured varnish, is applied to a screen that is more often than not set to a vertical/slightly inclined position with the help of a coating channel, in a comparable way to manual application by squeegee or better still with coating equipment. To achieve high stencil quality and high ink film thickness during printing the screen can be coated repeatedly both from the stencil side and from the squeegee side, with several intermediate drying operations, if necessary. The varnish comes through on the stencil/printing side. The less the screen structure appears on the stencil surface, the better the print result, as the stencil has to lie evenly on the substrate during the printing process with no splits or capillaries being produced into which ink might penetrate. The flat, uniform positioning of the film that is used for copying is also a factor determining quality as unsharpness and defective transfer of print information can then be avoided. The direct stencil meets most requirements and is therefore the most frequently used. A section of the printing plate surface is illustrated in figure 2.4-6a.
- *Indirect stencil.* The indirect stencil is used when there are particularly high requirements on the precision of the stencil's coating thickness (e.g. applying conducting pastes to solar cells, or printing a specified ink film thickness on fittings). The material of a precisely defined coating thickness provided on the base film is exposed and developed on this film and only then transferred to the screen (stuck on, dissolved, ironed on).
- *"Direct/indirect stencils"* [2.4-2]. The stencil material provided on the base film is first transferred to the screen and then exposed and developed like the direct stencil. This type of stencil is used for extremely high precision applications. A scanning electron microscope (SEM) exposure of stencil and screen is shown in Fig. 2.4-6b.

Other stencil and screen production options are:

- *Cutting on a cutting plotter.* Stencils can be cut directly out of the appropriate films by means of graphics and CAD programs. They are then transferred and stuck onto the screen. The process used here is comparable to hand-cut stencil production.
- *UV projection for oversize formats.* Projectors that expose the photosensitive stencil material with UV light (fig. 2.4-7) are used to save on film costs, or so that comparatively very large screens can still be exposed with manageable film formats.
- *Ink jet process.* Some manufacturers supply ink jet systems (Piezo Drop on Demand Systems) that spray a UV impermeable ink (or wax) onto a conventionally coated screen in accordance with the

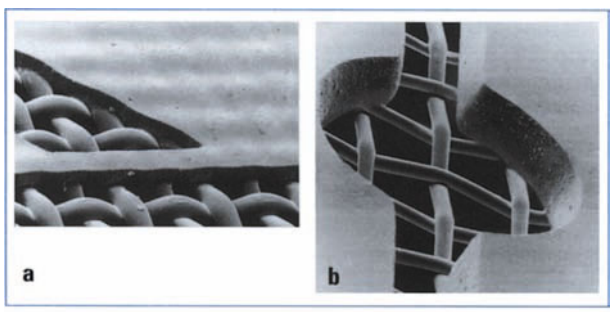


Fig. 2.4-6
SEM exposure of a photomechanically produced screen (view from the printing/substrate side).
a Direct stencil;
b Direct/indirect stencil (Kissel + Wolf)

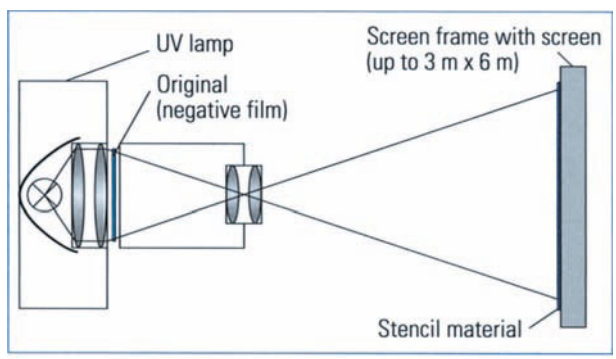


Fig. 2.4-7 Direct UV projection for screen printing stencil exposure



Fig. 2.4-8
Imaging a screen printing plate (creating a mask) using the ink jet process, wax-type ink, 1016 dpi resolution (JetScreen, Lüscher) (Note: light yellow areas (wax emulsion) correspond to the print image, the wax emulsion is washed off with water after exposure)

print image (fig. 2.4-8). The sprayed-on ink replaces the film (having the effect of a positive film). The UV exposure cures the unmasked parts of the stencil. The ink/wax, with ink jet produced film is removed in the subsequent development process and the uncured areas are washed off.

- *Rotary screen production.* The nickel-based flat plates are stuck or welded or clamped to the appropriate end pieces to produce rotary screen plates (fig. 2.4-9). In decorative printing, for example, *seamless rotary screens* are made using electroplating techniques (fig. 2.4-10).
- *Screen printing plates produced from electroformed screens (Stork).* Electroformed screens (flat and rotary) made from nickel are primarily used for rotary screen printing (figs. 2.4-9 and 2.4-10). There are several *stencil making* options for this type of screen:
  - The screen is first coated with a photopolymer, which then undergoes conventional (film) exposure and washing off.
  - The screen is coated with a photopolymer as in the previous example and imaged by the ink jet process, then exposed and washed off.
  - The photopolymer-coated screen is completely exposed/cured and the appropriate image perforations are then burned into the polymer with a CO_2 laser.
  - The screen is enclosed in a special polymer and this is then developed directly with a laser (488 nm). Unexposed parts are washed off by chemical means.

2.4.1.2 Printing Process

General Information

As shown in figure 2.4-11, the ink is first spread over the plate by a squeegee as evenly as possible and with virtually no pressure. This takes place without contact between screen and substrate. This "flooding" produces a cleaning of the ink residues remaining in and on the plate from the preceding printing processes. The ink is then pressed through the plate and onto the substrate with a higher squeegee pressure. The wetting connection between ink and the surface to be printed is produced by this process, which is followed by the separation of plate and substrate.

During this separation the ink is really drawn out of the screen mesh (in a comparable way to the emptying of the gravure printing cells). This process is particularly well-supported by the fact that the screen is not placed directly on the substrate, but rather at a certain distance above it and only comes into contact with the surface to be printed as a result of the squeegee. The screen tension built up in this way leads to the screen withdrawing from the ink adhering to the surface immediately downstream of the squeegee area.

Flat-bed Screen Printing (Screen Printing with a Flat Printing Plate)

The printing plate, which is typically the screen tensioned on a frame with the stencil fitted on it, and the substrate are on planes parallel to each other (see fig. 2.4-11, also fig. 1.3-24a). The printing table base holds the paper, card, or film substrate. If printing is to be done on textiles or fabrics, they must be laid out flat and clamped or fastened to the printing base with special adhesive. This is particularly important for in-register multicolor printing. Other substrates are usually held in place by vacuum.

A flat printing plate and a frame holding screen and stencil are also used to print on cylindrical and conical objects (so-called body or geometric printing, see also fig. 1.3-24b). The frame is guided at a tangent over the object to be printed, which rotates beneath it. The rotational motion of the object to be printed and the motion of the screen is synchronized by a gearwheel and rack. The straight-edged squeegee sits firmly in place

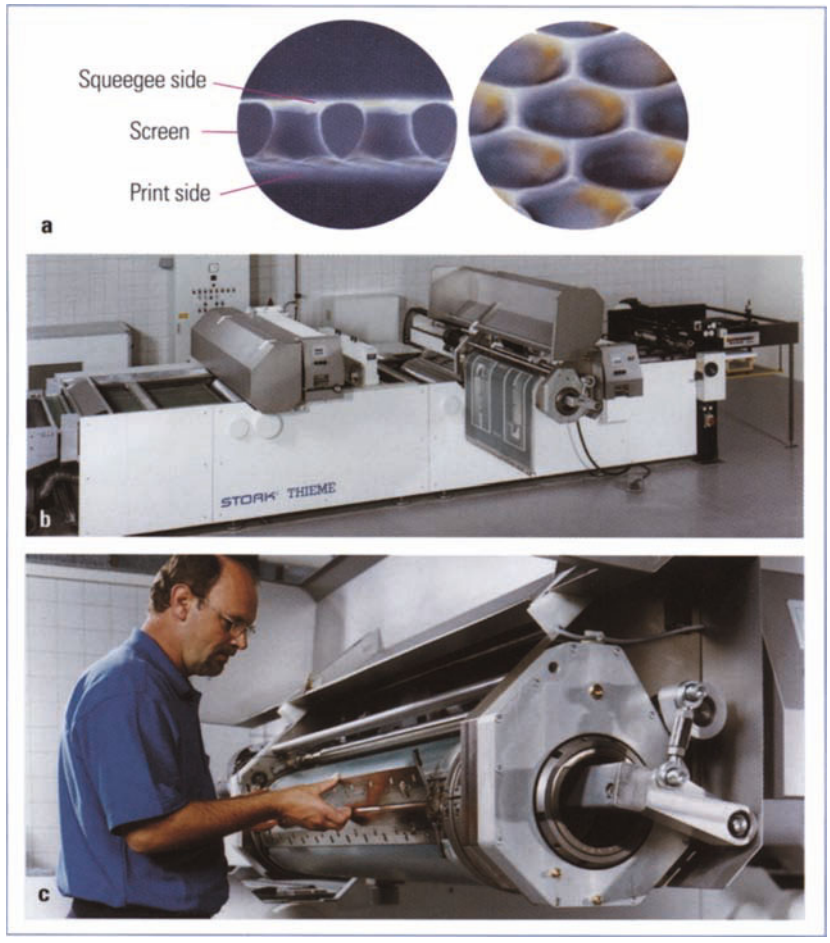


Fig. 2.4-9 Electroformed nickel screen.
a Structure of the openings (min. diameter up to 24 µm, up to 305 holes/inch, plate thickness 80 µm);
b General view of the rotary screen press;
c Fitting the flat printing plate on the cylinder (RotaPlate, Stork/Thieme)



Fig. 2.4-10
Rotary screen printing masters/cylinders (seamless) of varying diameters (RotaMesh, Stork)

on the line in which the contact between screen and substrate/object occurs. Conical objects, such as mugs, can also be printed. In this case the printed image might need to be distorted on the plate. Soft conical and cylindrical objects require an appropriately shaped mandrel to hold them. Plastic bottles filled with compressed air can be used as supports during the printing process.

In principle it is also possible to print on curved, bellied, and spherical objects as well as cylindrical or conical ones. In this case, the edge of the squeegee has to be adapted to the convexity of the body's surface to ensure even printing (fig. 1.3-24b). Coordination of the rotational motion of the object to be printed with the tangential motion of the screen is required, as described above. In the case of a very curved object, such as a spherical vase, the tensioning of the screen at an angle

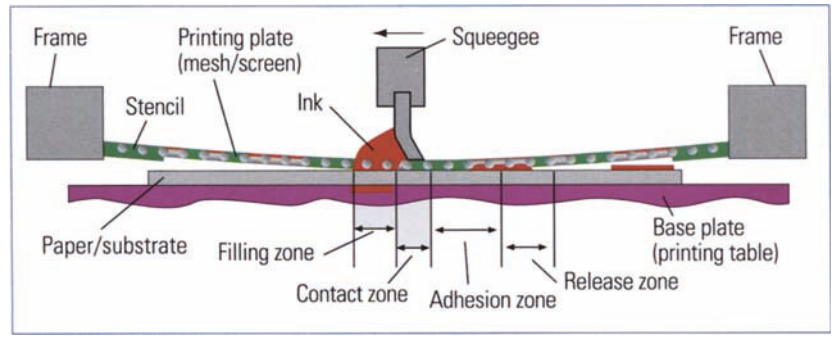


Fig. 2.4-11
Inking and printing process in screen printing

to the direction of printing has to be reduced considerably. In practice this can be done by making "relief cuts" in the screen in the direction of printing at the edges of the frame, so that during the printing process the screen is drawn over the body's surface like a ribbon.

Rotary Screen Printing

Development of the rotary screen enabled repeat "flatbed printing" of endless webs for textile, wallpaper, and decorative printing to be replaced by a continuous rotary printing process that is able to print without seams using a corresponding plate. As already described, the rotary screen printing plate is open at the ends (fig. 2.4-10). The openings in the cylinder enable the insertion of the squeegee and guide it over the printing nip. The ink is pumped into the screen by a tube system on the squeegee holder (see also figs. 1.3-24c and 2.4-18b).

Drying

Since very thick films of ink are applied in screen printing, the drying process of the most commonly used solvent-based inks requires a relatively long time. Products lying flat, such as posters or clothing, are dried in drying racks and by blowers. Continuous ovens with different hot air blowers and/or radiation sources (with UV light for UV inks) are also used.

2.4.2 Applications

2.4.2.1 Screen Printing on Flat Surfaces

Posters and Graphics Printing in Short Print Runs. Large-format posters in particular can be produced relatively conveniently in fairly small print runs. The quite thick ink film produces coloring that is very brilliant and resistant even with halftone color impressions.

Traffic Routing Systems and Signs. Large printing surfaces for high resistance inks are found with traffic signs and routing systems. The requirements they impose are best met using screen printing.

Vehicle Fittings and Instrument Dials. With vehicle fittings a narrow tolerance range of the translucency of the impression is required in addition to its precision. For example, it must be possible for control lights to light up in precisely defined colors.

Printed Circuit Boards for Electronics. Due to its simplicity and flexibility, screen printing is an important process during the development of printed circuit boards for electronic circuits. Accurate printing onto copper-laminated hard paper or glass-fiber reinforced epoxy board with etching allowance, solder resist, or assembly designations in the necessary coating thickness is only possible in large quantities with screen printing. Restrictions are, however, imposed on the latter as a result of the extreme miniaturization of components and printed circuit boards.

Photovoltaic. Special conductive pastes are used to print on photoresistors and solar cells, which serve as the contact points for current transfer. In doing so, particular importance is placed on high coating thickness in areas that are, at the same time, extremely small and covered with printed conductors, in order to optimize the efficiency of the energy production with the solar cells as fully as possible.

Compact Discs (CD). Screen printing is one of the major processes for printing on CDs. Pad printing and more recently even offset printing are also used.

Textiles. The depth of the ink absorption in textiles calls for a large volume of ink to be supplied and screen printing is the preferable process for applying it. Clothing, canvas shopping bags, webs of material, and so on, can be printed in both flatbed and rotary screen printing.

Transfer Images. Screen printing is frequently used to produce transfer images for ceramic decoration. These images are put together from ceramic pigments for firing. The pigment's grain size necessitates the use of a screen mesh that is not too fine. After detachment the images are removed from the base material and placed on the preburned bodies by hand. A recognizable feature of these ceramic products is the thick layer of ink. The images can be placed above or below the glazing.

Decorative Products, Labels, Wallpapers. Seamless decorations such as textile webs, wallpaper, and other decorative products, as well as labels often require rotary printing combined with reel material. Special machines are designed for this. Rotary screen printing with sheet material is used primarily for higher print runs (examples are given in sec. 2.4.3).

Surface Finishing. *Transparent varnish* can also be applied using screen printing technology (for spot varnishing, in particular) *to finish* the printed product.

2.4.2.2 Screen Printing on Curved Surfaces

Almost any body that has an even, convex and concave (to a limited extent) not too structured surface can be printed using screen printing. There are virtually no restrictions with regard to the material of the body to be printed on.

Ceramics can be printed directly with screen printing. Ceramic pigment inks can be used for subsequent baking or just a low durability varnish applied to the glazed product.

It is not always possible to print directly onto plastic components. Surface treatment, for example involving flame treatment, corona charging, or the application of primer is often necessary to ensure that the ink adheres.

Bottles. Glass bottles with a baked finish or pretreated plastic bottles for the food and domestic products sector are printed using the screen printing process.

Toys. Toys, such as balls, and so forth, can be printed in full in several operational steps.

Glasses. The screen printing process is often used for drinking glass decoration, with thick coatings of all inks and also gold being applied.

Advertising Media. The type of advertising medium that can be decorated or provided with some other overprinting by the screen printing process ranges from cigarette lighters or ballpoint pens to pocket knives and pocket calculators.

2.4.3 Examples of Machinery

As already mentioned in the introduction, the potential uses of screen printing are very complex. Screen printing equipment, which covers the wide range from manual operation to a high level of automation, is consequently equally complex. An overview of the great variety of machinery is given below.

2.4.3.1 Equipment and Machinery for Flat-bed Screen Printing

A screen printing table with squeegee guidance is illustrated in figure 2.4-12. These devices, designed purely for manual operation, are fitted with high-precision guides on the screen frame holder to ensure accurate positioning of the screen in the printing situation. A vacuum suction plate is used to hold and fasten down the substrate during the printing process. On account



Fig. 2.4-12 Flat-bed screen printing equipment (Siri/Steinmann)



Fig. 2.4-13
Screen printing equipment for multicolor printing of T-shirts (Siri/Steinmann)

of the squeegee guidance, the printing process can be executed with a specified squeegee angle and pressure force. Sheet feeding and delivery are done manually.

Figure 2.4-13 shows a simple device for multicolor textile printing. Printing in up to four colors can be done on T-shirts or other textile items such as canvas shopping bags in small print runs with this very simple equipment. The figure shows a rotating table with four arms, each of which can be fitted with a screen printing frame. Printing is done in the sequence of the selected inks onto the textile item, which is attached to the holder or a base with special adhesive.

Semi-automatic machines, as shown in figure 2.4-14, enable production capacity to be increased in comparison to manually-operated screen printing equipment. The screen is raised and lowered automatically. On account of a combination of two squeegees, the screen flooding and the actual printing process where ink is pressed through the screen take place automatically. In this case it is possible to program multiple squeegee operations, if a particularly large amount of ink is required, which is the case with textiles. With semi-automatic machines the feeding of the sheet and delivery of the printed sheet are still done manually on a vacuum printing table.

Fully automatic machines are used in industrial screen printing. They are equipped with sheet feeder and delivery units. Such machines will often have several printing units for multicolor printing and an appropriately designed drying line (hot air, IR drying, UV drying).

2.4.3.2 Screen Printing Machinery for Printing on Curved Surfaces

Universal machines with special holders for the printed product are used for small print runs of all kinds of articles in daily use such as bottles, packaging, and so on.

Figure 2.4-15 illustrates printing on sensitive glasses or mugs (coffee cups in this illustration). The positioning in the holder and the printing are done manually. There is mechanical synchronization of the screen guidance and the rotational motion of the body to be printed on by use of gearwheel and rack.

Single or multicolor printing on plastic or glass bottles, mugs, and similar objects is done in semi- or fully-automatic machines, depending on the numbers involved. Figure 2.4-16 shows a multicolor automatic screen printing machine and a selection of the articles that can be printed in these automatic machines. The articles are printed automatically at each printing station and transferred to the next station after each printing process. Plastic bottles are inflated in the course of this for stabilization purposes. Intermediate drying must sometimes take place, depending on the substrate and the ink.

2.4.3.3 Rotary Screen Printing Presses

High printing output (several 1000 prints per hour) is achieved on rotary screen printing machines. There are various designs on the market, for printing web or sheet material.

The combination of a *flat screen with a sheet-guiding cylinder*, that is, the flat-to-round, comes closest to classical screen printing (fig. 2.4-17). The sheet is taken from the feeder pile by single-sheet or stream feeders, aligned, and fed to the stationary printing cylinder. The sheet is held on the cylinder by grippers or vacuum pressure, depending on the manufacturer. As illustrated in figure 2.4-17b, the screen and the cylinder move synchronously while the squeegee remains static. The sheet is taken over by vacuum belts, approximately 90° downstream of the nip, and either fed through the dryer to the next printing unit or delivered.

Screen printing presses with the most varied drying and delivery systems are available on the market as single- or two-color machines and with sheet formats of



Fig. 2.4-14
Semi-automatic screen printing machine for printing on flat substrates (Siri/Bochonow)

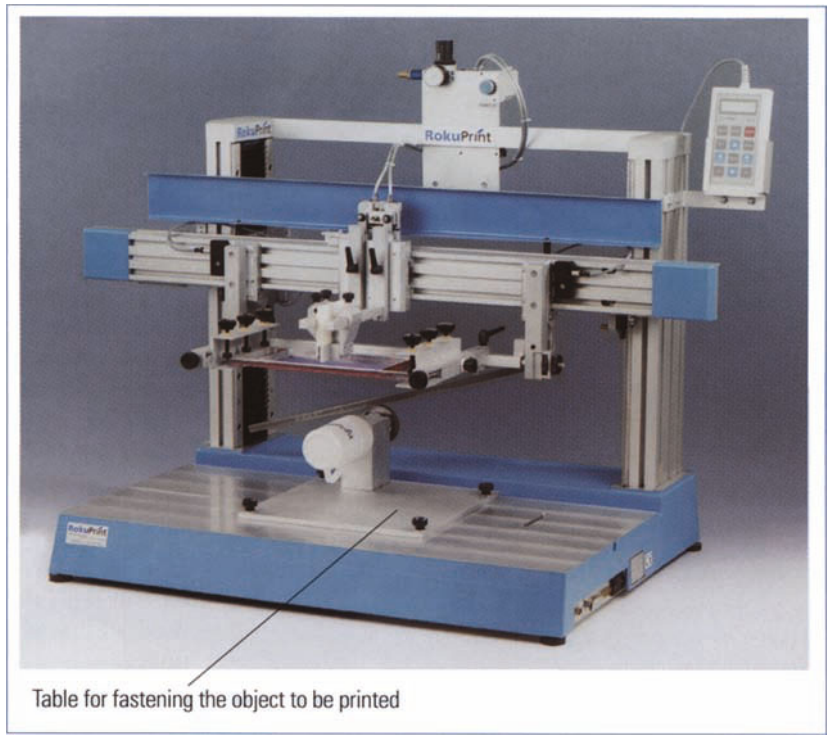
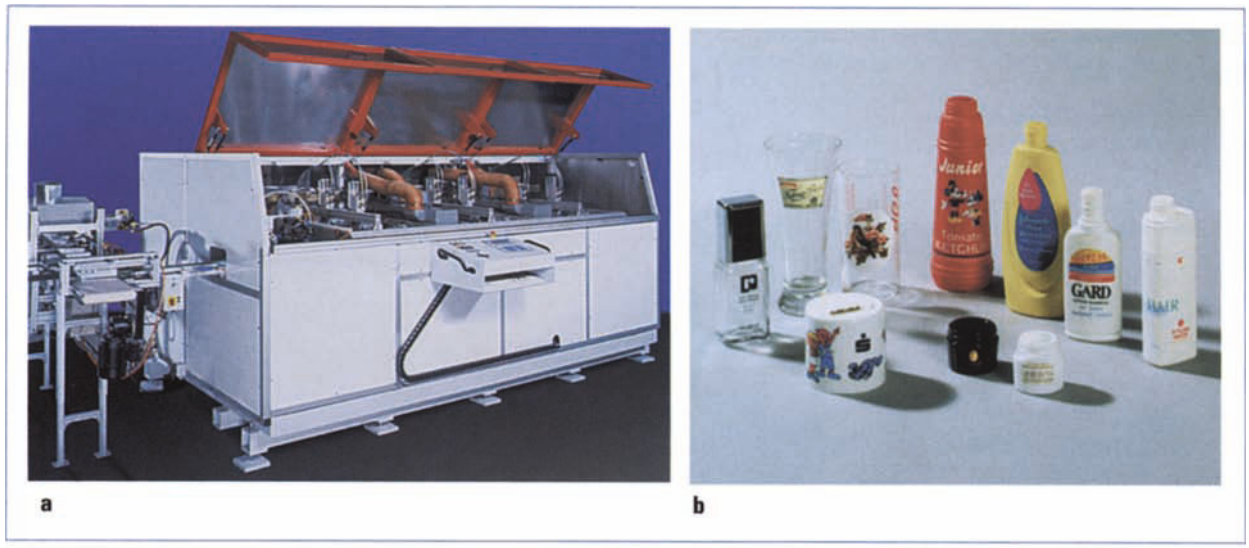
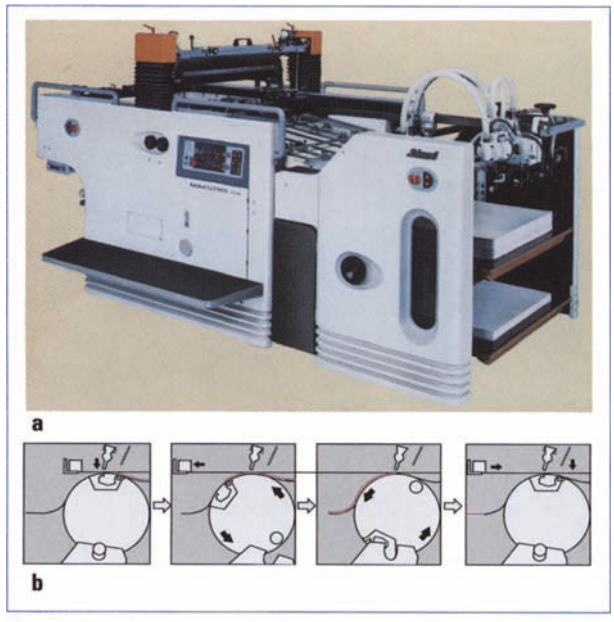


Fig. 2.4-15
Screen printing device for printing on curved objects/bodies (RokuPrint/Steinmann)



a b

Fig. 2.4-16 Multicolor automatic screen printing machine for printing on bottles, glasses, etc.
a Automatic machine (EC/4F);
b Samples of printed products (ISIMAT)



a b

Fig. 2.4-17 Cylinder screen printing press (flat-round).
a Printing system (model: Maestro, Sakurai);
b The printing sequence

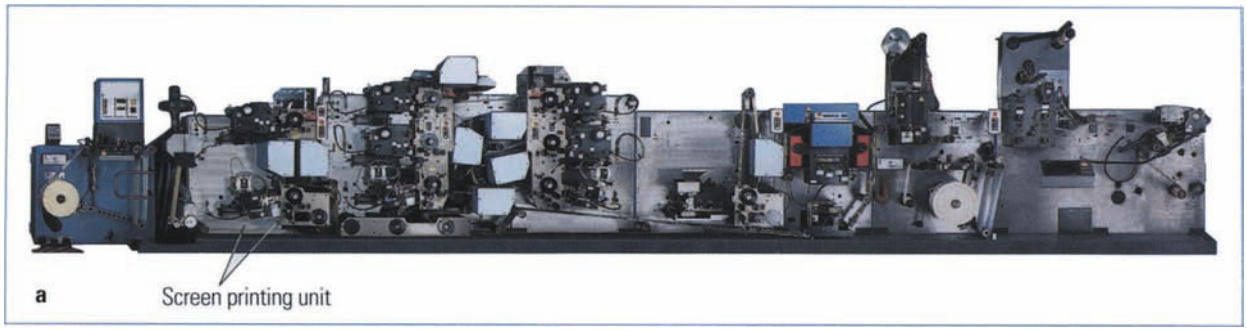
up to 1.45 m × 1.88 m (57" × 74"). Printing speeds of up to 3000 sheets/hour can be reached.

Up to 4000 sheets/hour can be printed with the *round-to-round system* (fig. 2.4-9). The metal screen (RotaPlate from Stork) is exposed and developed flat. The screen is fastened round the open cylinder by means of suspension rails and is also clamped axially (fig. 2.4-9c). The squeegee is lifted off during printing in the area where the screen is suspended (cylinder gap). Only single- and two-color machines have so far been made available.

Web-fed screen printing presses use closed screens that are either glued or welded together at the seam or produced as seamless rotary screens (RotaMesh). Printing speeds of up to approximately 2 m/sec. can be achieved. Figure 2.4-18b shows the detail of a printing unit as used in label printing machines in conjunction with letterpress units (fig. 2.4-18a).

Figure 2.4-19 shows a twelve-color textile printing machine with unwinder, printing section, hot-air dryer, and fan-fold delivery. Seamless rotary screens are used, so that printing can be done without gaps in the image.

Figure 2.4-20 shows a type of equipment with which the screen printing plate/stencil is produced using thermal writing heads. Special stencil material is used, on



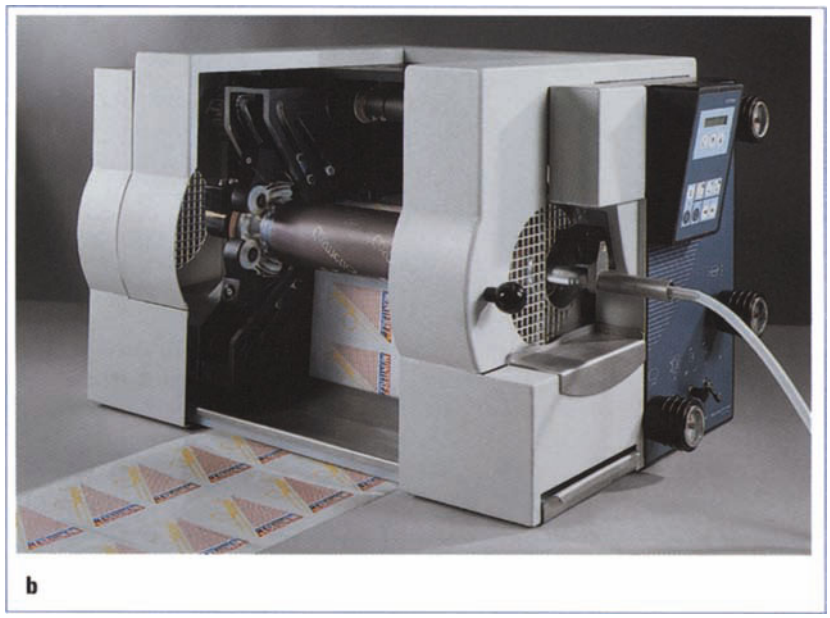


Fig. 2.4-18
Screen printing unit in-line with a label printing system.
a Hybrid machine (combination of letterpress and screen printing) (Gallus R 200, Heidelberg/Gallus);
b Screen printing unit with seamless rotary screen (Stork)

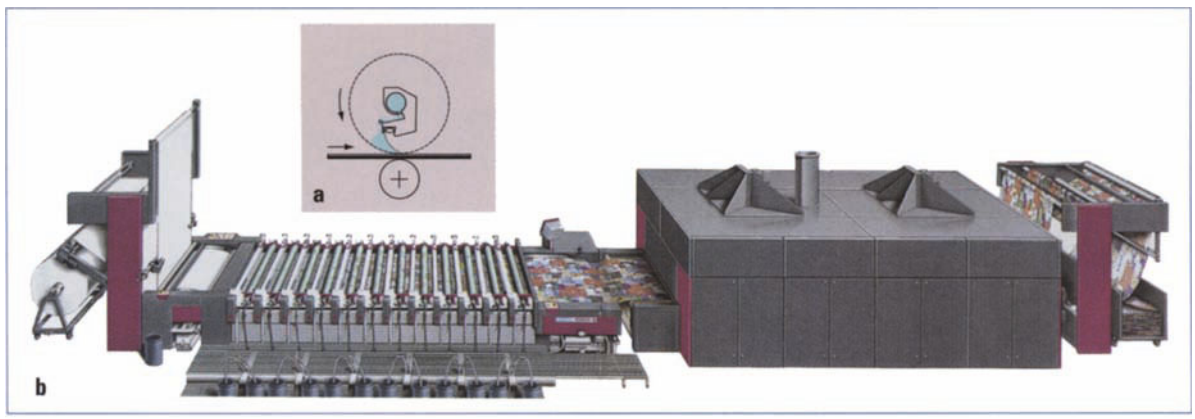


Fig. 2.4-19 Screen printing system for multicolor textile printing.
a Diagram of a rotary screen printing unit;
b "Pegasus" 12-color textile printing press with "RotaMesh" seamless rotary screens (Stork)

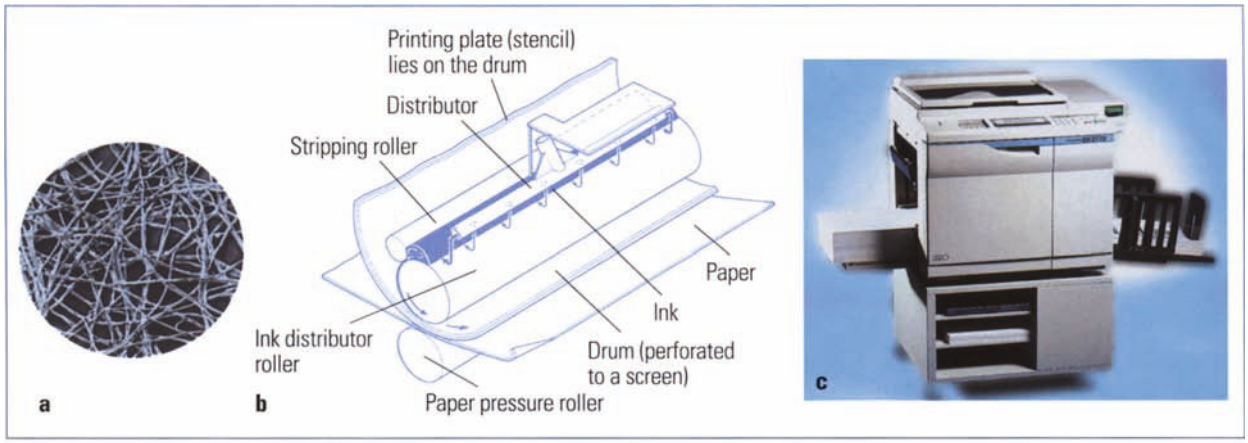


Fig. 2.4-20 Stencil/Screen printer for office applications.
a Base material for producing the stencil;
b Printing unit designed for change-over to a different color;
c Fully automatic stencil/screen printer (Riso, see also fig. 4.4-19)

which the structure is stabilized by the fibers of the base material. This screen printing system, which digitally images stencils with high resolution (up to 600 dpi) using thermal heads directly in the machine, is used for office applications (see also sec. 4.4.1.2, fig. 4.4-19).

2.4.4 Potential for Further Development

The main focus of further development lies principally in the platemaking sector:

- The direct imaging of screens (computer to screen) will become more and more prevalent, especially in conjunction with rotary screen printing units for large print runs.
- The already available but still little used filmless stencil production with ink jet printing technology is of particular interest for large-format applications. At approximately 600 dpi, the resolution guarantees sufficiently good print quality even with color gradations.

Machines for multicolor printing (four or more colors) on sheet material can be expected. New types of high-performance materials for screens that can be processed into particularly fine wire and consequently into meshes with a high mesh count are being developed. This new mesh must be considered in conjunction with coordinated stencil material, which is also under development.

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2.5 Special Printing Technologies and Product Specific Applications

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2.5.1 Security Printing

Security printing does not refer to a separate printing technology but rather to an application or combination of conventional printing technologies such as offset, gravure, and letterpress. Security printing encompasses the printing of bank notes, postage stamps, stamps, and documents such as stock certificates, identity cards, passports, checks, and deeds. A product of security printing is expected to withstand all external influences on it for a long time (years or decades) and still be distinctly recognizable as a security document.

Security papers should be practically forgery-proof. This is achieved not only by the way in which the printing technologies and their combinations are used, but also through the substrate, the ink, and special additional elements such as security threads, holograms, and so on.

2.5.1.1 Bank Notes

For *security reasons* currency or bank notes are only printed in state or government printhouses and by companies that hold a license issued by the government. Depending on the bank notes concerned, nearly all well-known printing technologies are applied. The generally multicolored background is printed in offset or *indirect letterpress* (letterset) and also *indirect steel engraving* (gravure printing via blanket cylinders). The background usually consists of elaborately interwoven *guilloches* (regular wave or arch shaped lines, example in fig.2.5-1), which are produced according to mathematical laws on guilloche machines with complex control systems. In addition to the purely mechanically controlled guilloche machines, later models are computer-controlled. This background is usually printed in multicolor, where the line segments of the guilloche are assigned with different colors.



Fig. 2.5-1 Example of a guilloche

The quality of the background print depends on extremely precise registers; this applies both to multicolor printing on one side and also between top and reverse side (to achieve *shine-through effects* such as creating a complete picture from sections on the front and on the reverse side of the bank note). To maintain this precise register, special printing units were developed known as *collect-run or simultaneous printing units*. The impressions of up to four plate cylinders are collected on a single blanket cylinder (transfer cylinder) and are then printed on paper against another blanket cylinder,

H. Kipphan (ed.), *Handbook of Print Media*
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which can also collect the prints from up to four plate cylinders. The printing sheet (fig. 2.5-2) or the paper web (fig.2.5-3) is passed between the two blanket cylinders.

This ensures that once the register between all eight printing plates has been set it can be maintained over long running periods. The possible influences caused by a variation in humidity or stretching of the substrate play no role. The in-register image has been reproduced as an intermediate image on the stable surface and position of the blanket cylinder and is only then printed onto the substrate. In order to maintain a highly accurate register (within a tolerance of less than 0.04 mm) these presses are equipped with special devices in the cylinder sections (e.g., to minimize backlash), and with mechanisms for adjusting the lateral and circumferential registers as well as for aligning the prints on front and back.

To make forgery of the bank notes even more difficult, the individual plate cylinders can be inked simultaneously with several colors. The ink fountain is divided into segments vertically to the printing direction by ink fountain dividers, so that different colors can be printed within one inking unit (this is known as "*rainbow printing*", see also sec. 2.1.2.8, fig. 2.1-76). To be able to print these inks next to one another without a visible gap, two ink fountains are used, which ink up the ink zones alternately (figs. 2.5-2 and 2.5-3).

In the printing unit shown in figure 2.5-2 all the multicolored image sections are collected on each of the three blanket cylinder segments and then transferred directly onto the paper. With the *Orlof method* (fig. 2.5-4), the multicolored image on the blanket cylinder segment is first transferred onto a printing plate (letterpress plate with the entire "single-color" background image). This image is then transferred onto a second blanket cylinder. By this method *guilloches* can be printed with sharp definition in *multicolor* and two-dimensionally. The press diagram in figure 2.5-4 shows an additional printing unit, which can print the security paper with a colored homogeneous background.

In the configuration shown in figure 2.5-4 the front side is printed with the Orlof technology (offset and

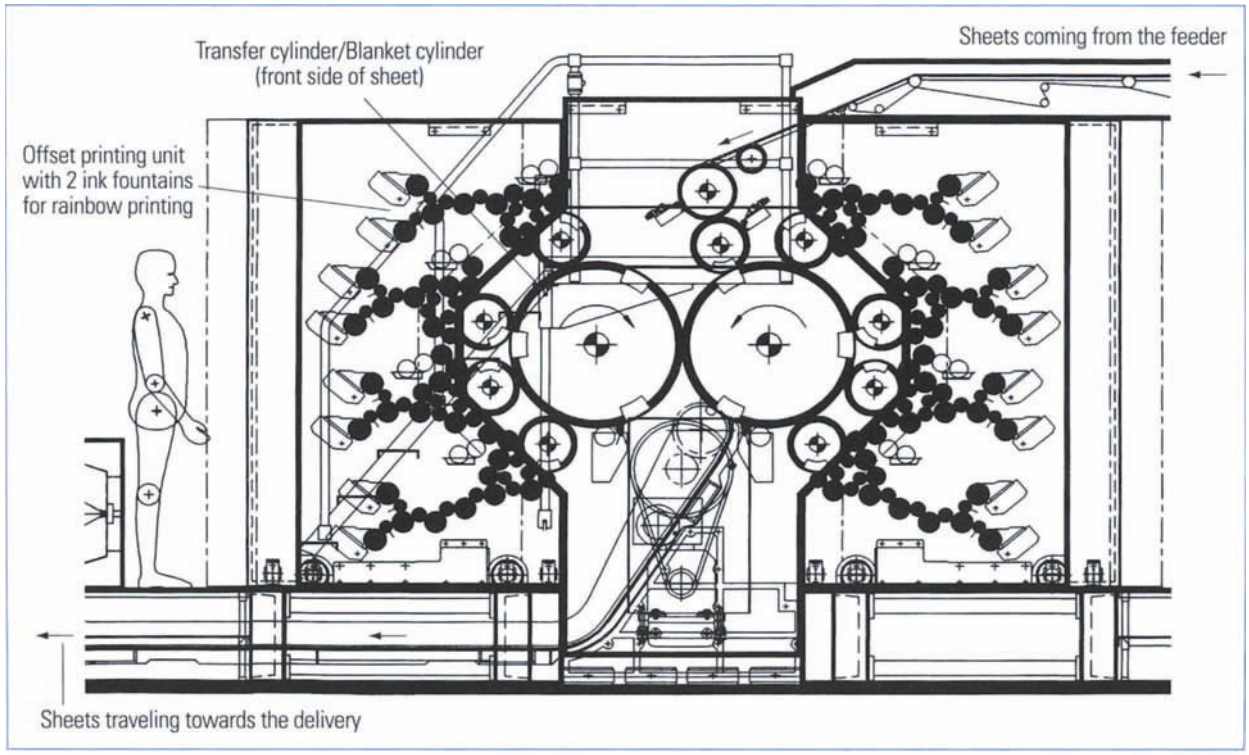


Fig. 2.5-2 Sheet-fed offset printing press for printing bank notes simultaneously on both sides (KBA)

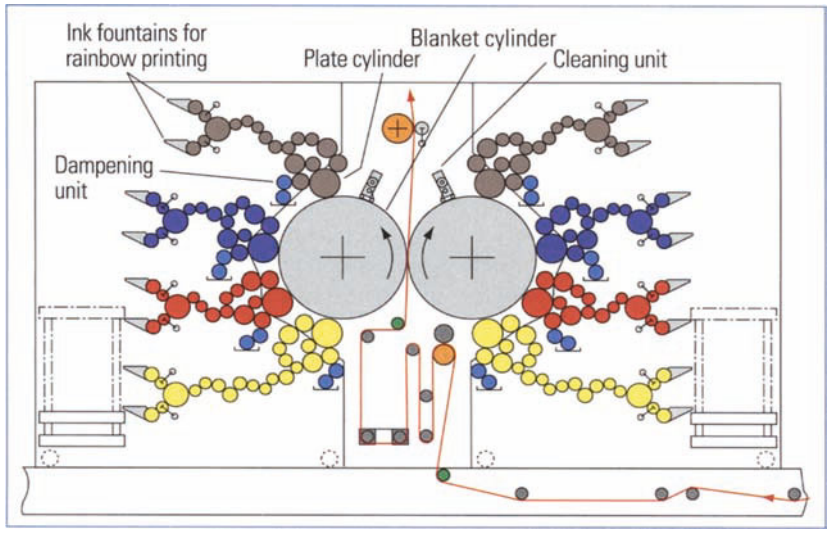


Fig. 2.5-3
Collect-run printing unit for web-fed offset printing of securities (Goebel)

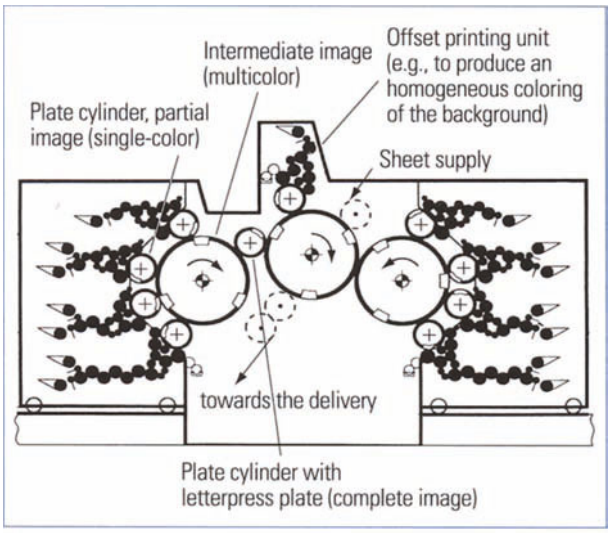


Fig. 2.5-4
Orlof printing unit for very precise multicolor printing of the background pattern of bank notes in offset on one side with the fifth offset printing unit; conventional offset collect-run printing unit for printing the reverse side of a sheet (Super-Simultan 312 (detail), KBA)

letterpress), with an additional color in offset and the reverse side is done conventionally in collect-run production with four offset printing units (di-litho).

The background printed, for example, in offset, is usually supplemented by *steel engraving* (gravure printing), which can be done in multicolor on both sides. Gravure printing is also called "*intaglio printing*"; this terminology is used particularly often for steel engraving in security printing.

The originals for producing the steel plates or cylinders are engraved by hand. This *hand engraving* is an important part of the security system. It is duplicated by electroplating and then combined on multiple-up plates (e.g., $5 \times 7 = 35$ bank notes per printing sheet). As a result all bank note plates are exactly the same and correspond to the hand-engraved original (see also fig. 2.5-7).

Steel engraving is particularly important in the printing of bank notes. The engravings are up to 180 µm deep. The bottom of the cells with a width of more than approximately 600 µm is roughened, in order to hold and print large quantities of ink. All of the ink in the cells should be transferred onto the substrate as much as possible. Very strong forces (line pressures up to 10 000 N/cm) have to be used between the gravure cylinder and the impression roller to print the image, that is, to achieve a good ink transfer. In addition the inks are warmed up to a temperature of 50–70 °C in the inking units to improve their workability.

The impression roller is covered with special thin (approximately 0.5 mm) blankets. The *impression rollers* of the web-fed presses are often rollers of pressed paper-base laminate onto which thin blankets are stuck. Due to the large force applied in steel engraving, the bank note paper *is additionally embossed in the non-inked image areas* and the high ink volume of the

gravure printing master virtually creates an "*ink relief*". Experienced cashiers in banks and businesses feel the relief when they are counting and they can, therefore, very quickly recognize forgeries.

Figure 2.5-5 shows a printing press for three-color web-fed gravure printing. The gravure cylinder is inked up with different colors. In addition the *ink form roller* is adapted to the contours of the image section for this color; in this way the ink roller becomes a *letterpress printing form*, which supplies the ink to the engraving.

The form or plate cylinders are flooded with ink by short inking units. A "*vibration roller*" ensures that the engraving is well filled. This roller can also serve as an "ink saving roller" for one-color printing; it removes any excess ink from the printing master and feeds it back to the process. Finally, the printing plate/gravure cylinder is cleaned with a *paper wiping unit* (fig.2.5-5) or a *fluid wiping unit* (fig. 2.5-6), so that only the ink needed for the next impression is in the printing master.

When inking up the steel engraved master in multicolor the inks should not mix. This can only be achieved with partially cut-out ink form roller surfaces. The partial surfaces of the individual ink form rollers make up a complete multicolor inked surface on the gravure cylinder. The engraving master is inked with different colors in different areas and wiped as described above. There are only a few *color mixtures* that are generally accepted, and to some extent requested as a further security feature. It is important that the gravure lines are completely inked up with different colors leaving no gaps in the print.

In another configuration of printing presses for *intaglio* (gravure) printing, the partially cut-out inking rollers are first inked up, then they partially ink up an elastic letterpress plate (fig.2.5-6). This letterpress plate then inks the steel engraving plate in multicolor using the *Orlof technique* (similar to fig.2.5-4). Surplus ink is next cleaned off this plate with a *fluid wiping system* (fig.2.5-6) so that ink for the next impression only remains in the engravings.

Figure 2.5-7 shows the steel engraving master on the gravure cylinder of a bank note production system; the individual image sections are inked with different colors.

The highly viscous *printing inks* are dried conventionally, with hot air or through electron beams. The

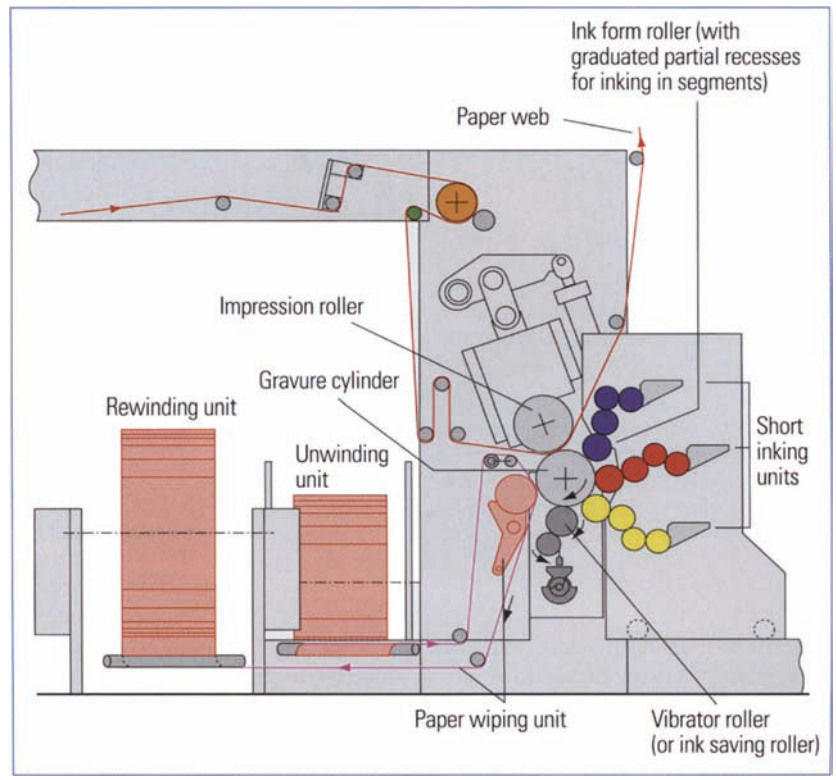


Fig. 2.5-5
Multicolor steel engraving printing unit (with paper wiping unit) for web printing (Goebel)

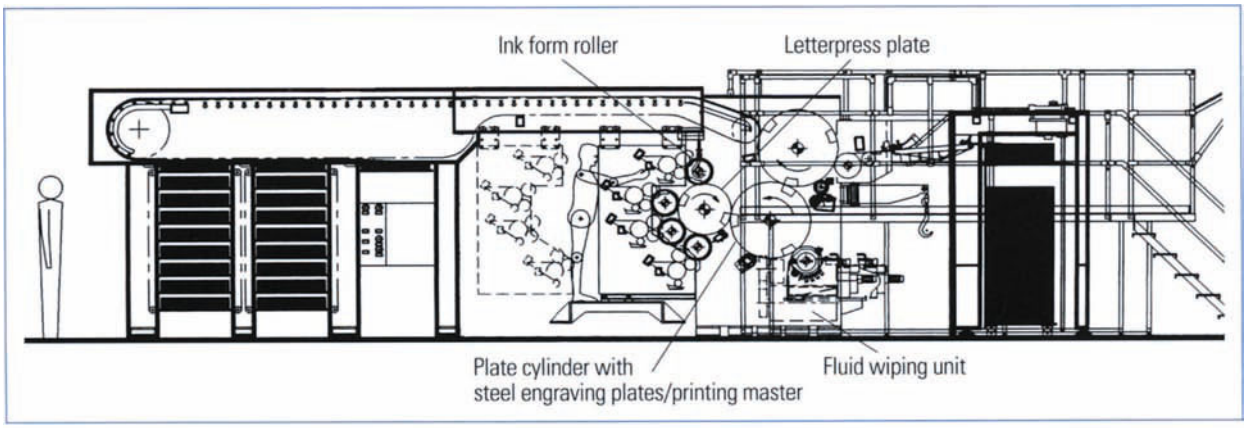


Fig. 2.5-6 Orlof steel engraving unit for one-sided printing, including a fluid wiping unit (Super-Intagliocolor 212, KBA)

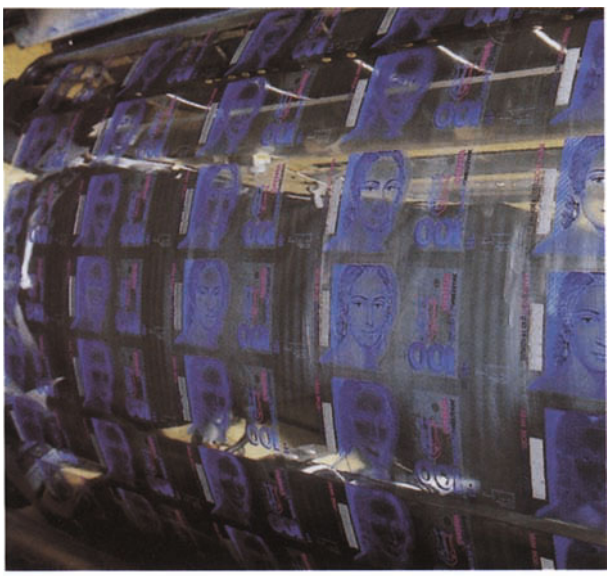


Fig. 2.5-7
Steel engraved printing master (inked with four colors) shown on the plate cylinder of a bank note printing press (G&D)

printing inks for security printing are produced according to special, strictly secret recipes. They not only fulfill the specific requirements for the printing process, but also contain components of a comprehensive security system against forgery.

Steel engraving with its relief-like ink application is also used by many state printhouses to imprint special signs (e.g., *Braille script*) that help blind people to find out the value of bank notes by feel.

Number Printing, Date, and Signatures

Bank notes are printed with a continuous serial number. This number usually appears twice on a bank note. The printing of the numbers is done by sheet-fed printing on a separate letterpress machine (fig. 2.5-8).

The indexing of the *numbering units* and the quality of the print is monitored fully automatically by electronic equipment. Usually the date and the signatures are printed at the same time as the numbers. The date and signatures can also be printed in offset together with the background pattern.

For security reasons many national banks require that the bank note series consist of completely consecutive number sequences. In this case any misprinted bank notes will be sorted out before numbering and waste sheets produced during numbering are replaced by so-called "*star sheets*". On the star sheet the number that does not fit in the consecutive sequence is marked with a star.

When the *bank notes are printed on webs*, the background pattern and the steel engraving on both front and reverse side, the numbering, the date, and the signature are printed in one pass. The fully printed web is rewound or cut into sheets by a sheeter and delivered as sheets similar to a sheet-fed press (fig. 2.5-9).

The bank note rolls are then inspected in special machines that check the printing and image quality for completeness and consistency. If there are any misprints that have not already been detected by the

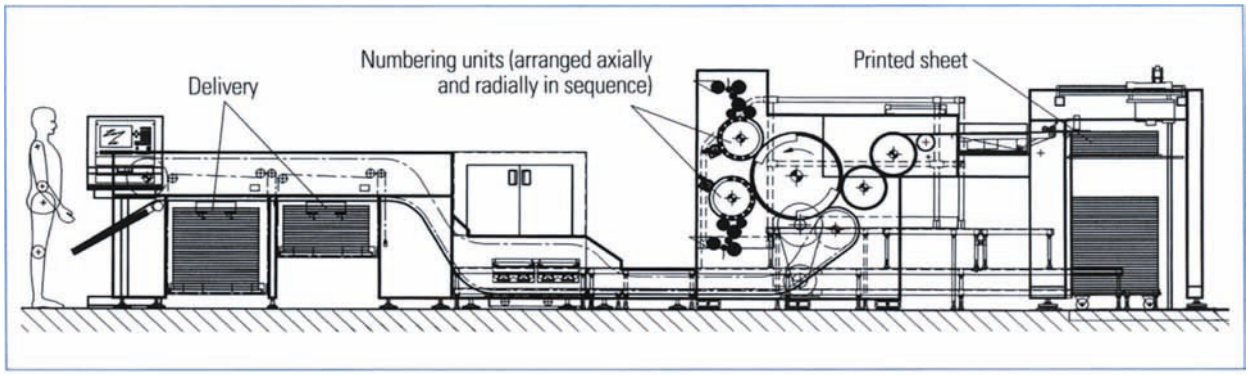
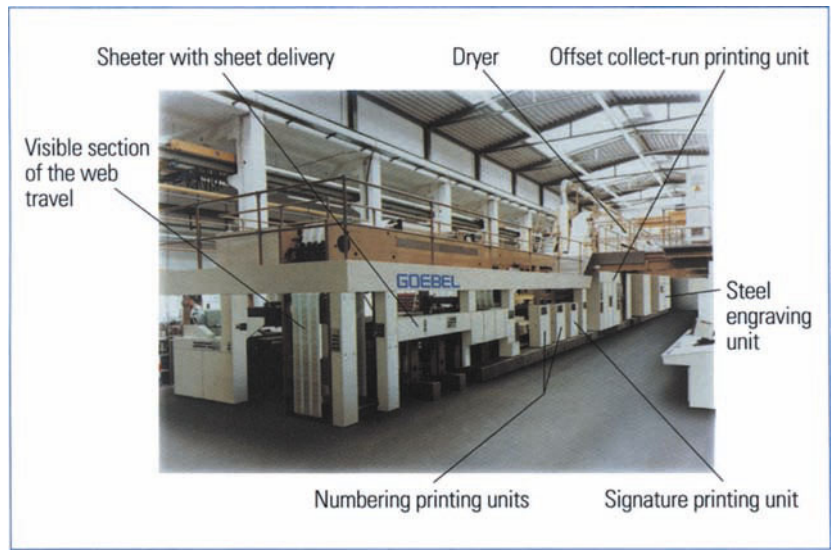


Fig. 2.5-8 Numbering machine for security printing (Super-Numerota, KBA)

Fig. 2.5-9
Bank note web-fed press for two-sided offset collect-run printing, one-sided steel engraving printing unit for signatures and numbering units (BNR, Goebel)



automatic *inspection and marking units* in the printing press, these will now be marked. These marked misprints will be automatically sorted out in another machine. The correct bank notes are counted, wrapped, sealed in security packaging, and packed in boxes. A very reliable electronic system keeps a perfect record of good bank notes and misprinted bank notes.

If the *bank notes are delivered as sheets*, they can be sorted, numbered, cut, counted, wrapped, sealed in security packaging, and packed in boxes on fully automated production lines. The entire process on the production line is also checked and documented by an electronic security system.

Bank Note Paper

Authorized specialist paper manufacturers deliver an exact number of sheets of paper to the bank note printhouses. The whereabouts of each individual sheet at any particular time must be accounted for. The same applies to the delivery on reels; the paper manufacturers will maintain a precise record of how many bank note sheets or bank notes the roll will yield.

The paper normally used for bank notes is rag (paper mainly consisting of textiles, linen, hemp fibers, etc.) with positive (appearing dark when seen against the light) and negative (light) *watermarks* – that is, some parts of the watermark are more transparent and others less transparent than normal paper. Depending on

the requirements of the national bank the watermarks can stretch over the entire bank note or placed in a particular position. They are produced on *cylinder paper machines* (see fig. 1.5-5). Figure 2.5-10a shows a section of cylindrical sieve for making watermarks, and the respective banknote.

In the majority of cases the watermarks are to appear on a specified position on the bank note, usually in an image-free area. To achieve this, the sheets are cut out of the web of the paper machine in accurate register with the watermark. Mistakes in the distance between sheets in the paper web are identified by the cutting register control and rectified. In sheet-fed presses, the sheets are always aligned by the same trimmed edges for feeding into the press; in this way the register between watermark and print is ensured.

If the bank notes are to be printed in accurate register with a watermark on a web-fed press, the watermarks on the web must have been produced within very strict tolerances. The exact distance and the permitted tolerances must be very conscientiously coordinated between paper manufacturer and printer. The bank notes are printed under high pressure in steel engraving units of web presses and an adjustment of the watermark register is possible only to a very limited extent through stretching the paper web when it is fed into the press and in the printing units. Special register control systems support the necessary register adjustments.

In order to increase the security of bank notes, they are fitted with additional checking features; a few of those will be described here as examples. Many countries have *security threads* inserted into the paper when it is made in the paper factories. These threads can have an imprint. The threads are woven into the paper web before the wire end section within the paper machine. Since the arrival of sophisticated color electrophotographic printers, broader *metal strips with an intensive reflection* are used. They are partly visible on the surface and partly buried in the paper. An electrophotographic copier is not able to reproduce these strips and through an additionally metallized *hologram*, the copies can be detected "at first glance" as being fakes. The genuineness of bank notes can easily be checked using the appropriate illumination to show the *fluorescent particles* in the paper and the ink. Printing *micro letters* into the background patterns is an additional security measure. Most of the security features are only known to experts and are normally not detectable.

2.5.1.2 Postage Stamps, Stamps

Postage stamps, revenue stamps, and every kind of state stamp are, like bank notes, only produced by state or licensed printhouses. Since they have an immediate value (very often the exact value is printed on the stamp) a number of security measures are taken at the stages of papermaking and printing in order to prevent forgery, or at least to make it very difficult. States see their stamps, just as they do their bank notes, as a kind of quality certification and pay particular attention to the appearance and quality of the reproduction of the motifs.

For postage stamps, coated rag paper or rag-containing paper is often used. It can have watermarks, and be fluorescent. The paper webs are already gummed on the reverse side in the paper factory.

Some years ago stamp-vending machines were introduced where stamps with a standard print could be

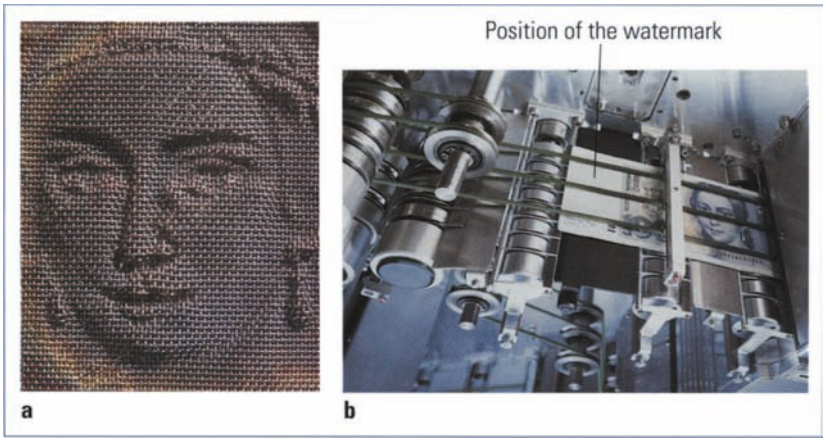


Fig. 2.5-10
Watermark in paper for bank note printing.
a Section of cylindrical screen/wire for producing watermarks in bank notes;
b Bank note during checking in a bank note processing/checking machine (G&D)

bought. The value of the stamp is preselected and only then is it printed on to the stamp. The stamps are also gummed on the reverse side. The standard print, which is the same for all stamps, is preprinted in an offset or indirect letterpress technology.

Printing Technologies

Various printing technologies are used to produce these special printed items such as bank notes and stamps. The printing technology used in any particular country has a great deal to do with the press configuration available and the artistic designs. Offset, indirect letterpress, gravure, especially steel engraving, letterpress (almost no longer used), and combinations of these are the common printing technologies. Printing takes place on sheet-fed presses or special narrow-web (up to around 560 mm wide) web-fed presses. For multicolor printing the stamp sheets/signature pass through several printing units. Both sheet-fed presses and web-fed presses can produce combination prints using offset, indirect letterpress, steel engraving, and other gravure technologies.

The manufacturing of *steel engraving cylinders* for postage stamp web presses is based on a special technology which ensures that all the stamp engravings on the cylinder (which can be more than 1000) are absolutely identical. A "*counter die ring*" is created from the hand engraving master in a series of steps. This counter die is hardened. On a die-transferring machine (fig. 2.5-11), the counter die ring is pressed against a form cylinder which is under great pressure and runs in perfect synchronization. The counter die is rolled stamp by stamp against the cylinder and embossed into it. This process is repeated many times until the counter die has been reproduced exactly in each stamp area.

To treat the counter die with care and to facilitate the process, the form cylinder has a copper jacket which is chrome-plated after the die transfer process to increase resistance to wear and tear. In order to extend the life span of the form cylinder it can be deplated if there is any wear and tear and provided with a new chromium plating.

Figure 2.5-12 shows a *postage stamp printing press* using offset and steel engraving processes. This press is equipped with a *web cleaning device* that helps to ensure good quality and reduces misprints.

After printing, the stamp sheets are perforated in a perforating machine or punched in a punch.

After printing in a web press (figs. 2.5-12 and 2.5-13), the web passes through a dryer, perforator or rotary

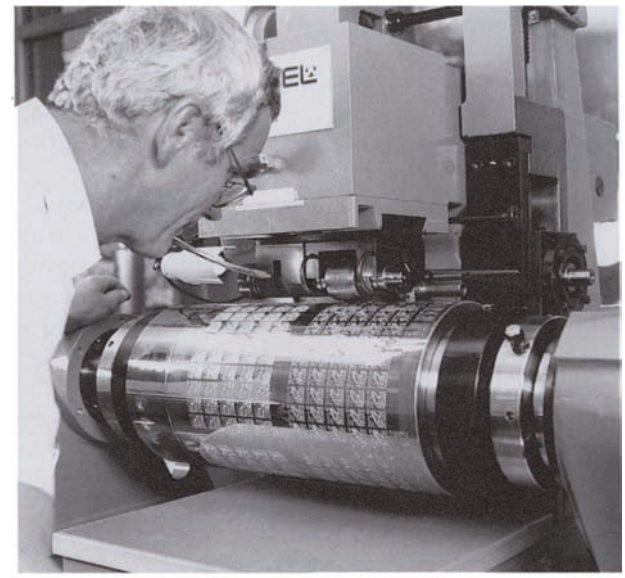


Fig. 2.5-11
Die-transferring machine for producing steel engraving cylinders for postage stamp printing (Goebel)

punch, and a numbering device. Numbers are printed on the reverse side of the stamp web. When the web runs into the press, a *security numbering shaft* prints a number and date on the edge of the web. This security numbering shaft is firmly interlocked with the press drive; it cannot be turned backwards. It indicates exactly how many revolutions the machine has made and serves as a proof for the bill-making and as a verification of the number of stamps printed. Finally the web is cut into sheets by a sheeter or rewound on a winding unit for the later production of *booklets or small rolls*. The production installation shown in figure 2.5-13 can be used to produce stamps on sheets or on rolls.

The speed of production is basically determined by the performance capacity of the perforator. The types of perforators used are comb perforators, oscillating plate perforators, and rotary grinding perforators.

Perforating Machines

Comb perforators oscillate along the web travel direction and perforate two rows of stamps running synchronously with the movement of the web. They work at a speed of up to 1200 strokes per minute depending on the size of the stamps. With a stamp height of 26 mm

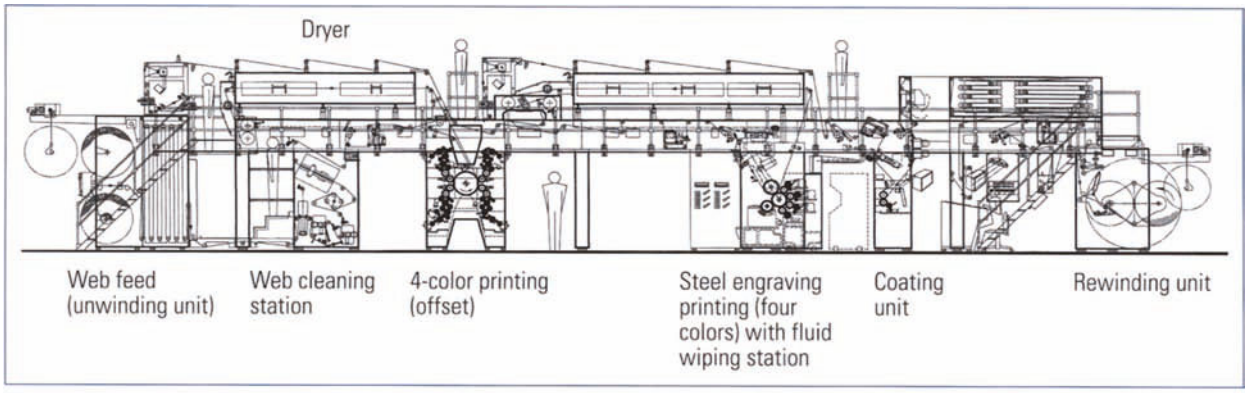


Fig. 2.5-12 Combined offset printing and steel engraving printing web-fed press for the reel-to-reel production of stamps (KBA)

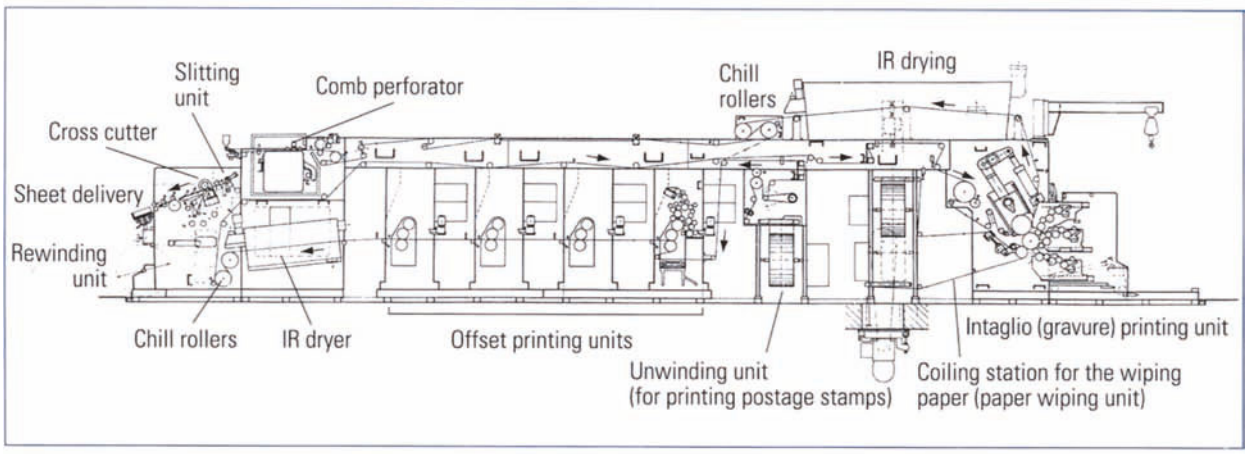


Fig. 2.5-13
Combined stamp printing press (optionally and in combination offset and intaglio printing) with comb perforator and sheet delivery or rewinding unit (BRMSTO, Goebel)

a web speed of about 1 m/s is reached (figs. 2.5-13 and 2.5-14).

Oscillating plate perforators work on the same principle but are more complicated in design, because the oscillation path is essentially longer and the mass to be moved much greater in comparison with the comb perforator. Plate perforators cut through a complete sheet of stamps with one stroke. These sheets may have unprinted areas at the beginning and at the end that are not perforated. You find these kinds of sheets in the stamp folders at retail outlets. A conventional plate perforator can achieve a maximum speed of 100 strokes per minute, which produces a web speed of about 0.5 m/s.

When a *stroke perforator* is used the perforating tool is stationary in web direction, the printed web is intermittently moved to-and-fro. Stroke perforators can achieve speeds of up to 400 strokes per minute.

Another type of perforating machine is the *rotary grinding perforator,* which can reach even higher running speeds. The stamp web is taken round a counter die roller (a relief roller that lifts the section of the web to be perforated). A rotating milling or grinding roller is located opposite to this at a distance of only a few

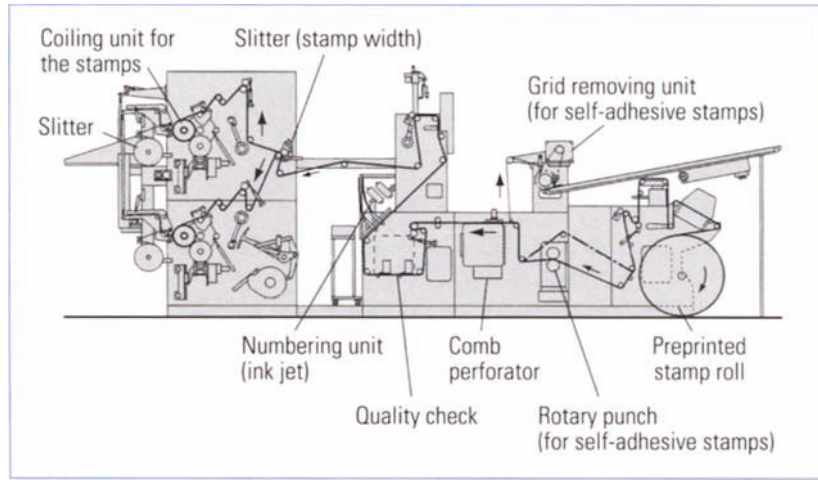


Fig. 2.5-14
Automatic stamp coiling machine (installation height about 3 m; RM, Goebel)

thousandths of a millimeter. All sections of the paper web on the raised parts of the die counter roller are ground away. In this way almost any shape can be cut out of the paper web. A disadvantage of this "perforating method" is that the hole margin is not as precise as in the case of punched holes.

Comb perforators and grinding perforators are used especially for continuous perforation of stamp webs, which are then processed into small *stamp rolls* and booklets.

Finishing

Special machines have been developed for the production of small *stamp rolls* for automatic vending machines and for selling stamps over the counter. Examples are simple counting and wrapping machines or fully automatic machines that can produce small stamp rolls of 50–10 000 stamps from a continuous printed web.

In an *automatic stamp coiling machine* (fig. 2.5-14) the preprinted rolls, which have already been checked and marked for misprints, will be guided in accurate register, perforated with a comb perforator or punched in the case of self-adhesive stamps and then cut lengthways. The individual strips of stamps are then coiled up into rolls containing a preselected number of stamps per roll and wrapped with a band label. The cut is made exactly on the perforation. The stamp rolls are coiled up without glue either on a core or without a core so that no stamps are damaged or lost. When the stamp rolls are delivered, the spoilage marked beforehand is removed.

In an automatic *stamp booklet machine* (fig. 2.5-15), pre-printed and checked stamp webs are also fed, perforated or punched, and cut lengthways into web sections in accordance with the size of the booklets (any residual webs are coiled up again for further production stages). The web sections are routed through reversing units and, if necessary, longitudinal fold tables, so that they lie on top of each other; finally they are glued together with the cover web. All webs are crosscut into sections of one or two stamp heights and then folded lengthways and glued into finished stamp booklets. The cover web is provided with imprints on the front and back (sometimes multicolored) in the *stamp booklet machine* in an offset, letterpress, or indirect letterpress technology. The finished booklets are counted, given a band label, and then packaged.

The advantage of using these types of coiling or booklet machines for *off-line finishing* of pre-printed rolls of stamps rather than in-line in the stamp printing press is that the web printing press can be operated at maximum production speeds and need not be restricted to the much lower performance of the perforator.

2.5.1.3 Documents

Stock certificates, identity cards, passports, savings books, and checks are also printed according to the rules for security printing. As with bank notes all types of printing presses and technologies are used. The annual print volume is a decisive factor for which press and technology will be employed. These securities are obviously only produced by special licensed printshops.

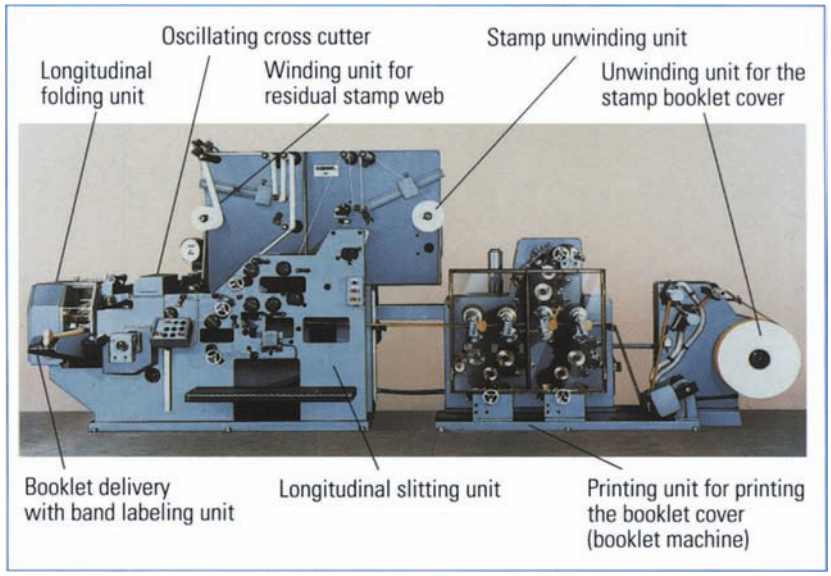


Fig. 2.5-15
Stamp booklet machine (installation height about 2 m; HM, Goebel)

Stock certificates are almost always printed on sheet-fed machines as they are needed in relatively small numbers by each company.

Identity cards, passports, and *savings books* are printed in most countries on sheet-fed offset presses. They are numbered, personalized and, if necessary, thread-stitched and sealed on special machines. The passport number is imprinted extra on passports. The use of rag paper with positioned watermarks enhances protection against forgery.

Checks (bank checks) are also printed in a very complex production process because the danger of forgery is very great. The background pattern on checks is printed, as in the case of bank notes, on collect-run printing presses. The printing methods used are either offset or indirect letterpress. Travel checks are provided with a steel engraving in addition. As bank checks are needed in large numbers and varying formats, special variable web presses have been developed exactly for this.

The blanket cylinders of *presses with variable cut-off* (fig. 2.5-16) are only half-covered in their circumference with blankets. After the impression, a variable adjustable paper web transport mechanism exactly guides the paper web in the print-free section of the blanket cylinder to the position for the next impression. In this way the web can be printed continuously without gaps. Since the printing register on a collect-run press is not affected by the paper web, the intermittent web travel has no negative consequences. The watermarks can be accurately positioned without any difficulties.

The names of the issuing bank can be printed in subsequent offset printing units. The sort code of the bank and a consecutive number, which are machine readable using MCR processes (Magnetic Character Recognition), are printed on the check with a special numbering unit. These variable web presses produce continuous fan-folded check webs that are passed on to imprinters for further processing (see also fig. 5.3-6, application of NIP technologies). Many simple bank checks are printed on business form printing presses. The risk of forgery is relatively small. As a special service checks are often personalized on special machines and bound into check books or put into bags.

2.5.2 Business Forms Printing

Business forms printing comprises a very wide and complex area. It ranges from simple listing paper, sales receipts, insurance certificates, lottery tickets, entrance tickets, or travel tickets to sophisticated personalized, multicolored advertising circulars. A business document often has an advertising function in addition to its particular purpose. Billing forms are provided with the company's logo and information on its product line. Certain quality standards particular to the com-

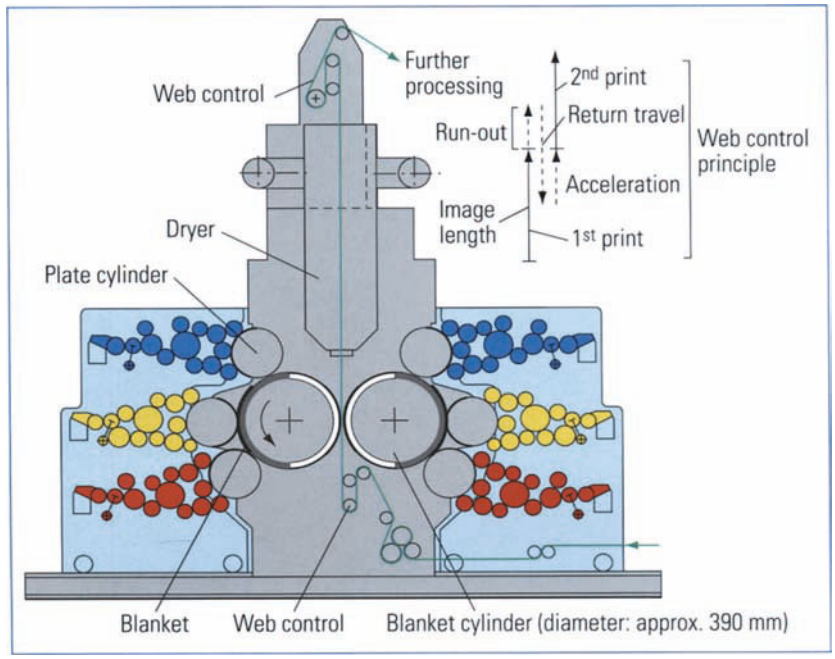


Fig. 2.5-16
Variable cut-off web offset press (waterless offset) for the printing of checks (BNRV, Goebel)

pany are therefore also specified for the printing of business forms.

The users of these business forms might require forms in one or more colors, printed on the front or also on the reverse side, fan folded, provided with sprocket holes in webs or on rolls. The nature of the business forms will also be closely connected with the finishing equipment (personalizing). The diversity of the product calls for a variety of printing presses and production systems. Many business forms are also produced on conventional sheet-fed presses.

The business forms printing presses are mainly designed as web-fed presses with working widths of 280 mm to 960 mm. The forms are printed and produced as separate sheets on a pile, fan-folded, or rewound to a roll. Some forms are produced in volumes of millions, and are then further processed in computer-controlled printers (NIP technology) where they are provided with different imprints sheet by sheet and finished.

A *continuous form printing press* has one or several unwinding stations, an infeed unit with web edge control for each web, several printing units, perforation stations for the sprocket holes, longitudinal and cross-perforation, and file hole punching, an outfeed unit, a fan folder, winding unit, and possibly also a sheet cutter with delivery (fig. 2.5-17).

Forms are sometimes put together with *carbonless copy paper* after printing, in order to keep special business stationery/forms sealed when they are intended for confidential distribution such as salary statements. These can then be passed on after they have been personalized with their confidentiality protected.

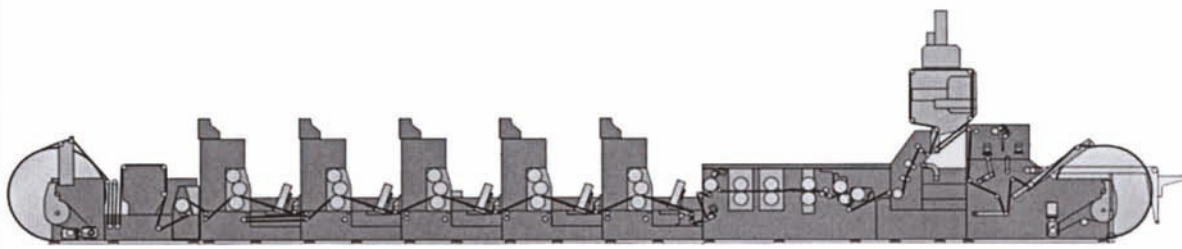
A distinction, especially regarding the cut-off, is made between *fixed-format* and *variable-format* presses. The formats are for historical reasons stated in inches; the reason for this is that the single line spacing of all typewriters and computer printers is 1/6" and therefore all formats are also stated in inches. Even DIN formats are printed in approximate inch dimensions. Metric graph paper is printed on continuous form presses with special drives for metric formats.

The units on *fixed-format* presses are designed for printing one certain format. These units are of a less complicated design compared with variable-format presses. They can be optimized for the one format. These types of presses are opted for whenever there are enough printing jobs for a particular format in the foreseeable future. Bulk orders for listing paper are produced on fixed-format presses of this type from reel to fold (fan fold). Figure 2.5-18 shows an example of such a press.

The working width of these presses is between 800 and 1600 mm. The production speed is between 450 and



a



b

Fig. 2.5-17 Web-fed offset business forms printing press.
a Printing system with six offset printing units, UV intermediate drying, punches, perforating unit, and rewinding unit;
b Press diagram with five offset printing units and finishing unit (Concept, Müller-Martini)

600 m/min. Listing paper is generally only printed in one color in indirect letterpress (letterset) or offset.

After printing the tabular page (reading lines, explanatory notes, etc.) the web is punched with sprocket holes. These "*sprocket holes*" serve as feed holes for computer printers. The web is perforated lengthways parallel to the sprocket holes at a distance of a ½ inch, in order to be able to separate the punched margins from the form easily. Before the web is fan-folded it is perforated perpendicular to the web direction. Hardened perforating knives are fixed on a rotating knife cylinder, which perforates the paper web against an equally hardened rotating anvil cylinder.

Dimensional accuracy and zero backlash of the *perforating cylinder* are of particular importance since this ultimately determines at what speed the press can be driven without vibrations arising, that reduce the quality as well as the life of the perforation knife. The hardness of the anvil cylinder and the perforating knife is balanced in such a way that the inevitable wear and tear is borne

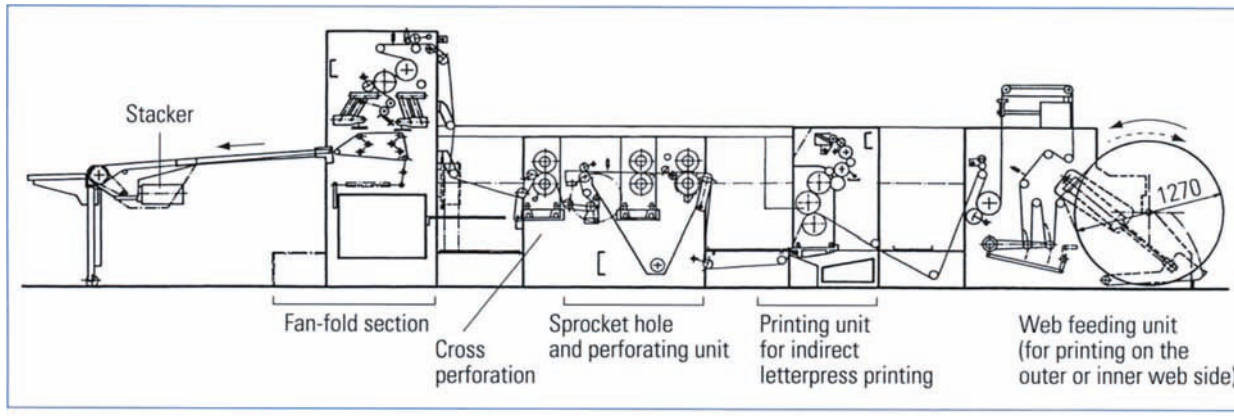


Fig. 2.5-18
Printing press for the production of single-color listing paper on one side applying indirect letterpress processes (Dataform FRR 865, Goebel)

by the perforating knives. "*Fan folders*" are used to fold the printed products. Rotating spirals support the accordion fan-folding process by letting out the trapped air and so stacking the folded forms. These powerful machines can be linked with counting and packing stations, which pack the forms into boxes and then stack them on pallets and wrap them in shrink-foil. The automation of these sequences is so well advanced that several printing presses can be supervised by a single operator.

There are also a large number of fixed-format multicolor continuous form presses for the production of normal, common business forms (in working widths of about 280–960 mm). They are particularly widespread in the USA.

However, to be able to adjust to the changing demands of customers and the market quickly, *variable-format presses* are frequently used for business forms printing. The units of these machines are designed in such a way that they can quickly change from one format (cut-off) to another by replacing the format-dependent components (e.g., the plates and blanket cylinder of an offset printing unit). Sophisticated slide-in unit design (e.g., *cassette-type printing units*) not only permits the format to be altered, but the printing method can also be changed from offset to letterset (indirect letterpress) or letterpress (e.g., for numbering jobs). Figure 2.5-19 shows such an offset printing unit of slide-in unit design.

In order to print on a web without wasting paper between the individual printed images/cylinder revolutions, it is essential to have an *alternating web transport* (similar to that shown in fig. 2.5-16). Special structural solutions in the control concept are required for machines with variable image cut-off (cylinder diameter).



Fig. 2.5-19
Exchanging the slide-in printing unit for the variable-format (e.g., cut-off range: 432 mm to 711 mm) offset print (A68, Müller-Martini)

To cover the vast number of special requirements for printing forms, there are also slide-in printing units for flexographic and screen printing.

Apart from the printing units, the other format-dependent units have to be reset in the case of format changes, for example, the perforating tools, the tools for making the file holes (fig. 2.5-20). The folder also has to be adjusted each time to the new format length.

Continuous form presses are equipped with feed mechanisms that can be set so that the paper is advanced by a certain distance independent of paper thickness and weight. This becomes necessary if various pre-printed form webs are to be gathered and glued or bound together into sets of forms on *collators*. There are two types of collators, reel collators and pile collators. With reel collators, the form sets are compiled from preprinted reels, or in the case of pile collators, from fan-folded piles (fig. 2.5-21). If form sets have to be consecutively numbered, the collators are equipped with a "*crash numbering box*". This numbering ensures that all the parts of a form set – the original paper and all the copies – have the same number (fig. 2.5-22).

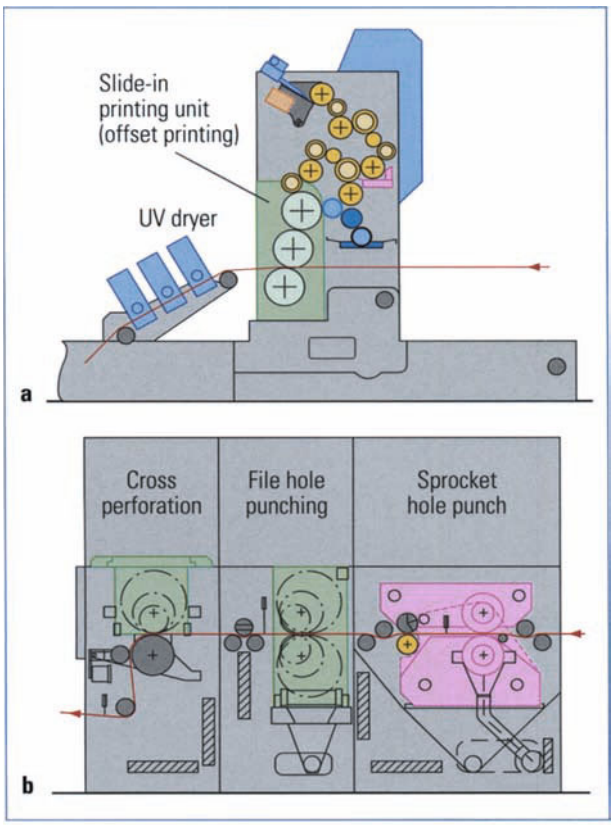


Fig. 2.5-20 Slide-ins for variable-format business forms printing.
a Offset printing unit;
b Punch and perforating equipment (Novaprint, Goebel)

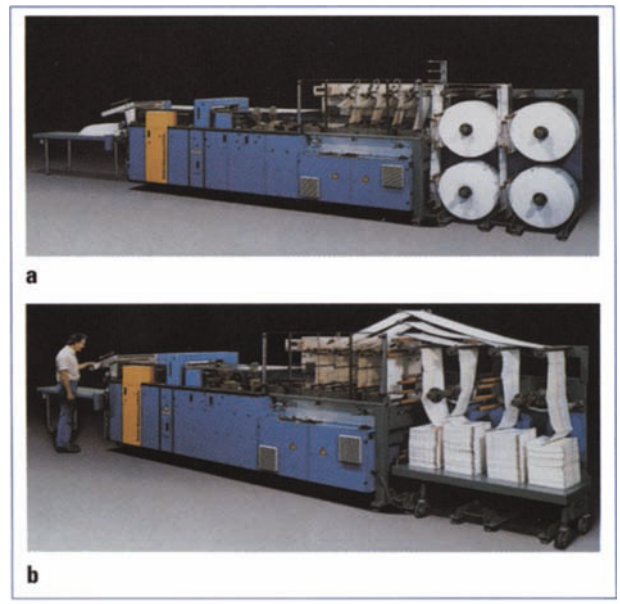


Fig. 2.5-21 Collator for continuous business forms printing.
a Reel collator;
b Pile collator (P300, Bielomatik)

Multiple web systems are used to advantage for the *in-line production* of two- and three-section form sets. The different webs of the form set are brought together in the right order and are glued or stitched together in an in-line finishing process to produce complete form sets.

Business forms presses are very suitable for producing *mailings*. They can be printed in multicolor on both sides. Presses with eight or ten printing units are not uncommon. With increased ink application, UV dryers or hot air dryers must be used. The mailings are personalized and provided with additional information either directly in the press or off-line by a subsequent machine. Digital printing processes based on non-impact technology such as electrophotography or ink jet are applied, but digitally controlled matrix printers (impact printer) are still employed.

The diversity of use of business forms printing machines can be shown on the example of the production of *rub-off lottery tickets*, where the actual information (e.g., ticket number, etc.) only becomes visible after rubbing off a surface layer. The covering rub-off material is applied with special application units (e.g., letterpress) within the printing press.



Fig. 2.5-22
Pile collator with adhesive tape binding equipment and crash numbering box with letterpress inking unit (Rotalock S-D, Jakob Maschinenbau)

In order to produce complicated *form sets* in large volumes, continuous form presses are fitted with additional units such as fixed-size gluing stations, longitudinal fold units, and stitching units etc. Extra webs can be brought into the production of form sets by additional unwinding units. The use of *carbon paper webs* to produce carbon copy form sets has become less common. Increasingly, carbon printing units or coating units are used to apply an invisible autocopying layer, in which for example *microcapsules* are deposited that release colorant under pressure.

2.5.3 Label Printing

The *labels* of today are very diverse and the machines for producing them are equally varied. A label may describe the product, advertise the contents, and also carry out security functions. In the simplest cases it may contain only price information and/or barcodes.

Labels often replace printing of the packaging. Many products in the cosmetic industry are bottled in plastic bottles or containers of different shapes. These containers are equipped with attractive, advertising labels. Care is increasingly being taken to ensure that the labels are made of materials that do not for recycling require the container and the label to be separated.

The printing of labels is usually done on relatively small format flexo printing presses on *web material* with a working width of 180 to 560 mm (narrow web). The labels are often printed on "table top machines", where the printing and processing units are arranged on a machine table.

Labels are also produced on *sheet-fed presses*, narrow web gravure presses, and web-fed offset presses equipped with the necessary extra units.

In order to produce labels on reel material without large print-free areas, and to do this with machines that are variable in format (cut-off), an alternating web transport mechanism is used (similar to fig. 2.5-16).

The intended use of the labels determines the method of production. Beer and wine-bottle labels, for example, are printed on single-ply papers and die-cut. The labels must be suitable for further processing under the humid conditions of a bottling plant.

To give the buyer of a product the impression that it is of a particularly high quality, labels often receive a gold printing or are laminated with gold foil in a hot foil station. To increase the visual effect the foil can then be shaped in an embossing station.

Label printing machines are usually of modular design, making the choice of production method more flexible. They have a single unwind unit with an infeed device and paper guide, and several *printing units*, which can take up different *slide-in units* for offset, flexographic, screen printing, letterpress printing, or a hot foil stamping/embossing unit, and sometimes an intaglio unit, coating unit and UV dryer. Other possible additions are rotary die-cutters, perforating units, embossing station, rewinding unit, fan folder, and sheet cutter. Numerous flexographic print units have an anilox roller with a chambered doctor blade (see also sec. 2.3.3) for inking. Modern systems are also equipped with double unwinding and rewinding units for a nonstop reel change providing the means for an uninterrupted operation with an increase in productivity and reduction of waste. Figure 2.5-23 shows a *flexographic press* for label printing.

Figure 2.5-24 shows the structure of a label printing system where the various *printing stations cover a range of possible printing technologies* (basis: offset printing).

Further examples of label printing presses are shown and described in figures 2.5-25 to 2.5-27.

Depending on the substrate of the label (film, foil, paper, or card) and its application, the substrate may already have an adhesive layer, which must be dampened before the label is attached to the packaging. There is an increasing use of self-adhesive labels. They can be separated relatively easily from the carrying web (which also serves to protect the adhesive layer),

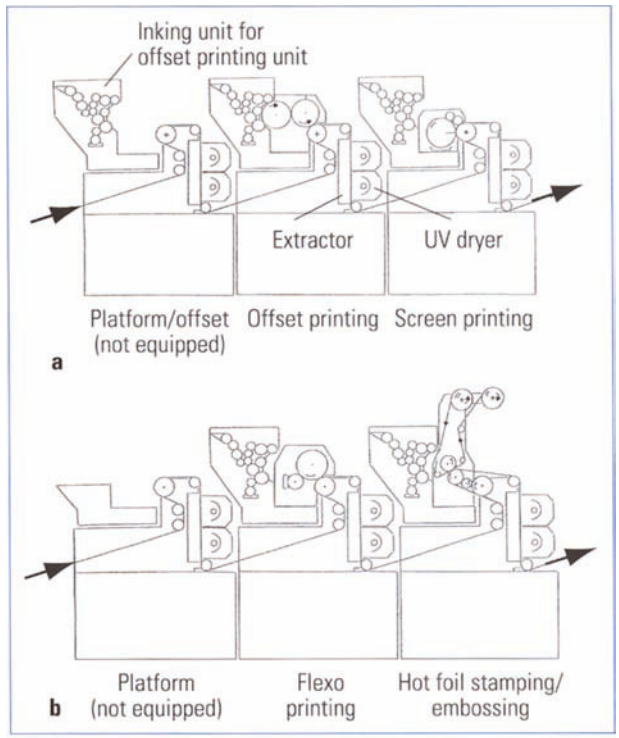


Fig. 2.5-24
Printing stations/platforms which can be equipped with a variety of slide-in units.
a Offset printing, screen printing;
b Flexographic printing, film laminating; offset inking unit and dampening system not used (Nilpeter)

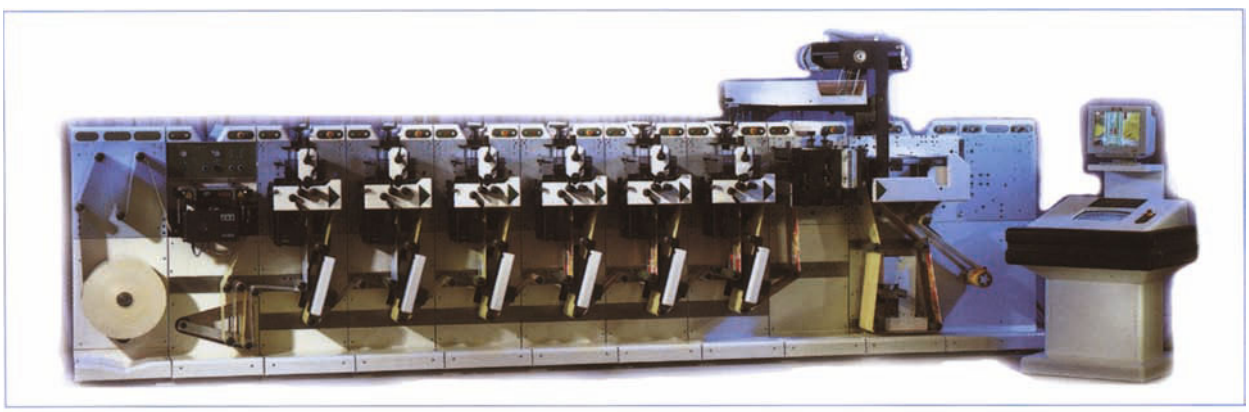


Fig. 2.5-23
Label printing system with flexographic printing units, rotary die-cutter, winding unit for removing the waste grid, and image inspection for the production of self-adhesive labels (GLS-2000, Nilpeter)



Fig. 2.5-25
Label printing system with flexo printing units, UV drying, web turning, rotary die-cutter, winding unit for the waste grid, printing widths of up to 510 mm, printing speed 150 m/min (Arsoma EM 510, Gallus/Heidelberg)

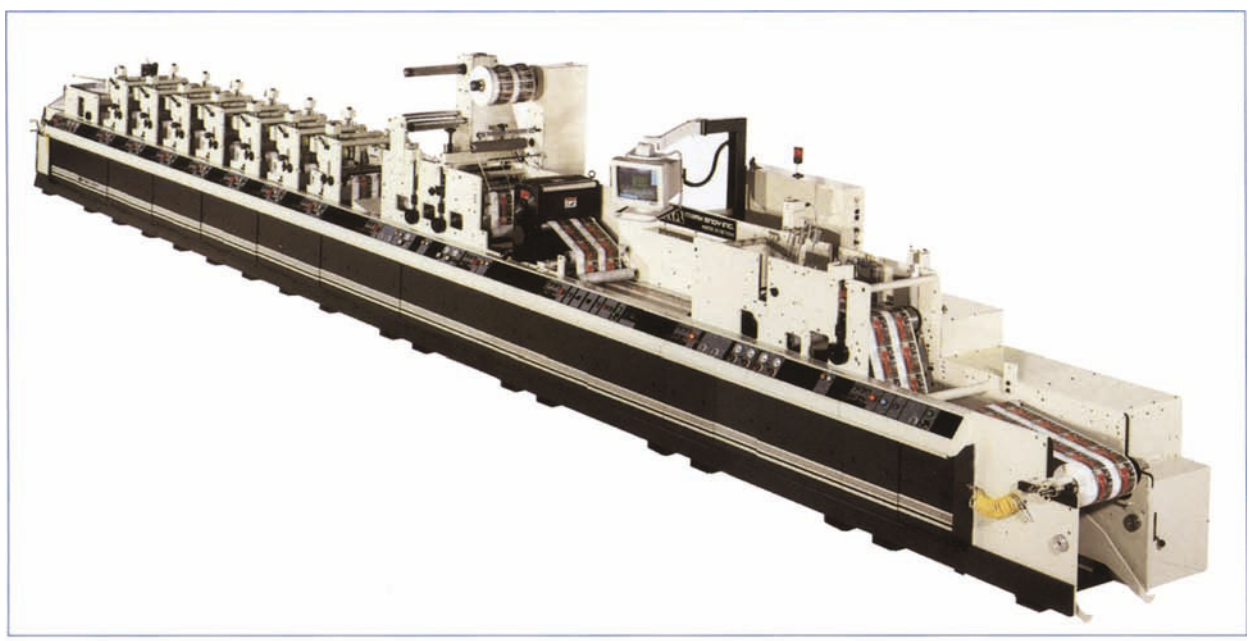


Fig. 2.5-26 Label printing press with flexo printing units, rotary die-cutters, rewinding station (4200-System, Mark Andy)

and can be stuck on the product directly. The material webs needed for self-adhesive labels consist of a siliconized carrying web and the label web, which is gummed on the reverse side. To keep the waste low, particularly with high-quality label materials, printing systems have been developed that permit changes of format and of printing plate without the need to take the web out of the press and without damaging the web. The impression cylinders remain in the press and only the plate cylinders and possibly the blanket cylinders are replaced using the slide-in technology. There is normally a dryer (most commonly a UV dryer) positioned after each printing unit to prevent undried ink from setting off on the following transport rollers.

In addition to printing halftone images with offset or flexographic printing processes, additional information and image elements can be printed with a very

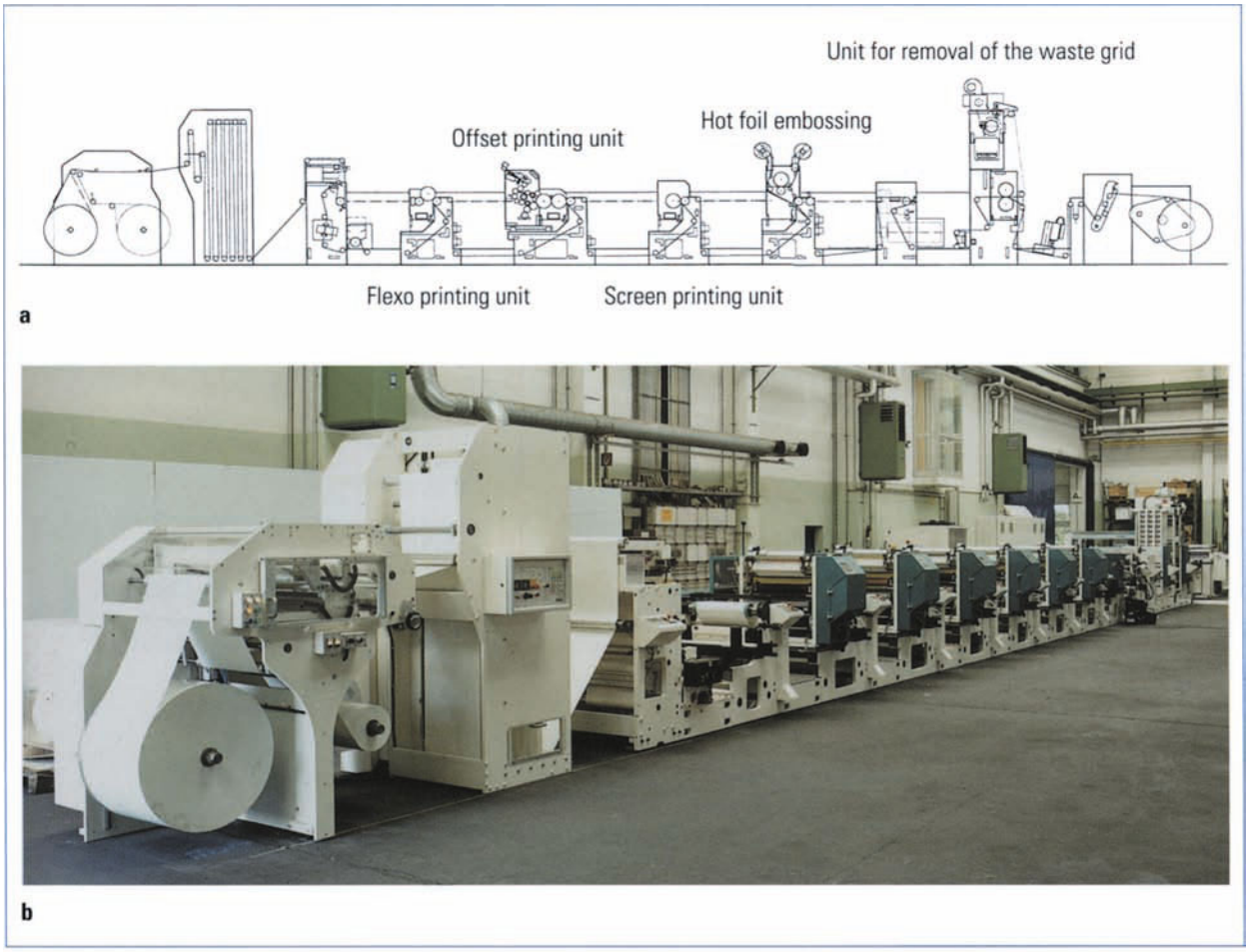


Fig. 2.5-27
Label printing system (web width of 560 mm) with flexo, offset and screen printing units, hot foil embossing, and non-stop grid removing station for printing self-adhesive labels.
a Press diagram;
b Installation example (Combiprint, Goebel)

thick ink film to produce strong color effects using *rotary screen printing units* (fig. 2.5-27a). Figure 2.5-28 shows a rotary screen printing module as it is being prepared for installation in a label printing system (e.g., corresponding to fig. 2.5-25).

The printed labels are punched out in-line at another processing station. The die-cutter has to work so precisely that only the web with the gummed labels is cut through; the carrying web material must not be damaged. The waste grid of the punched-out labels is removed and rolled up at a special station (fig. 2.5-26),

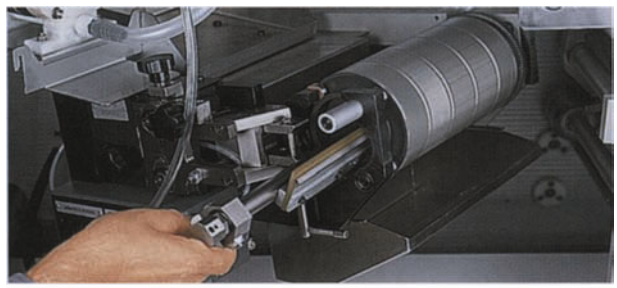


Fig. 2.5-28
Rotary screen printing module for label printing (Gallus/ Heidelberg)

or is directly fed to the waste disposal unit after rolling up.

In accordance with customers' requirements, the carrying web with the punched self-adhesive labels is either rolled up again, cut into sheets, or fan-folded.

Digital printing technologies based on non-impact technology are also used in label printing for different applications. This is significant in the case of short print runs and for personalizing. These digital printing systems are either stand-alone units for personalization of the printed label web or they are linked directly with finishing stations of conventional label printing presses. Figures 2.5-29 and 2.5-30 show examples of installations for in-line personalization or the production of short runs.

2.5.4 Pad Transfer Printing

Pad transfer printing is an *indirect gravure printing* process that uses an intermediate element known as a "pad" or "roller" to transfer the print image (fig. 2.5-31). The origins of the process can be traced back to Switzerland and the printing of clock faces, where a gelatin pad

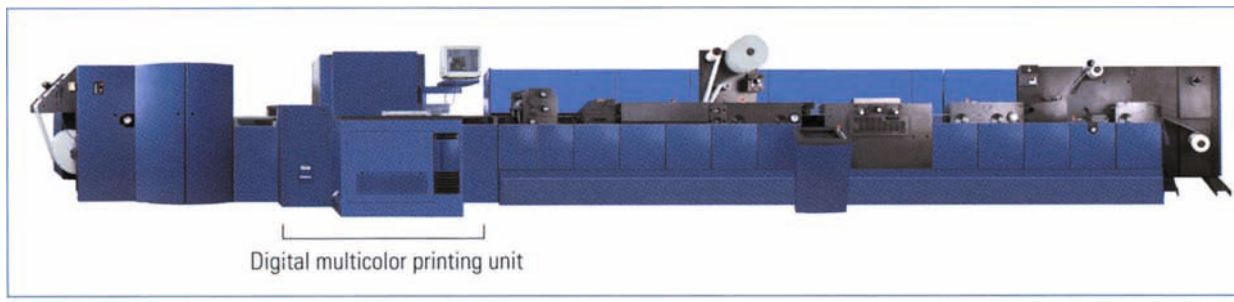


Fig. 2.5-29
Digital label printing system with NIP multicolor printing system (electrophotography with liquid toner; Omnis, Indigo, see fig. 4.5-5) and finishing equipment for coating, laminating and die cutting (DO 330, Gallus/Indigo)



Fig. 2.5-30
Digital label printing system with NIP multicolor print system (electrophotography with powder toner; DCP/32S, Xeikon, see figs. 4.5-3 and 5.2-14), festooning unit and finishing units (DL-3300, Nilpeter/Xeikon)

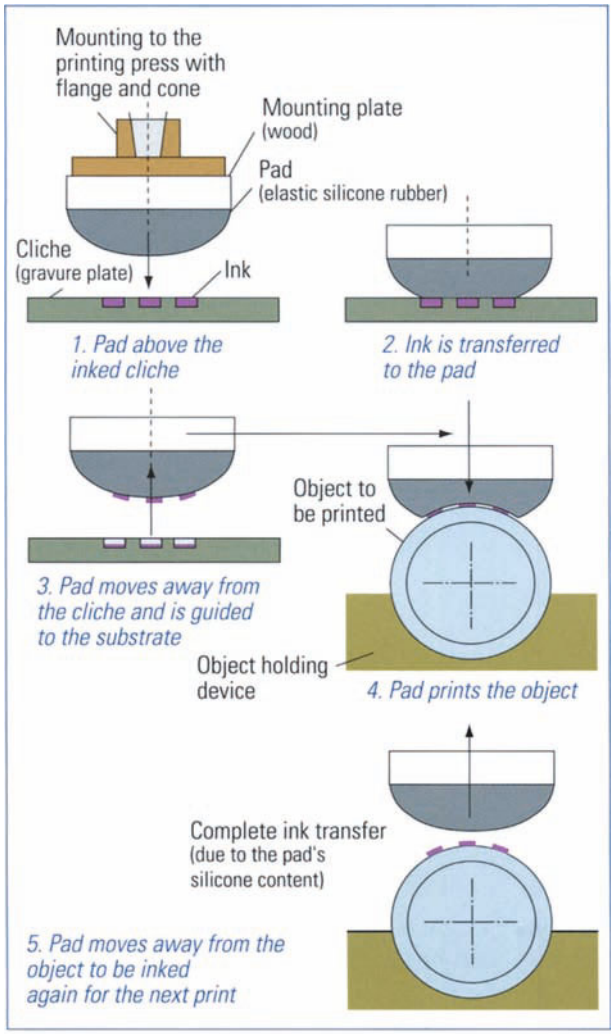


Fig. 2.5-31 Schematic diagram of pad transfer printing

was used as the transfer element. In the middle of the 1960s the first prototype of a pad transfer printer with electrical drive was presented. The breakthrough for the process came with the development of cold-vulcanizing silicone pads and it has now been used successfully for some thirty years to print the most diverse of objects and surface structures. Wet-on-wet printing with solvent-based inks, which were originally used in screen printing, permits multicolor prints and today even halftone prints in quite good quality. The process is based on ink transfer from a usually flat gravure printing master onto objects or surfaces of virtually any shape (e.g., badges, glasses, tennis balls, pens, etc.).

2.5.4.2 Cliche Making

Pad transfer printing uses an *intaglio/gravure cliche* as its image carrier. The cliche is filled with ink using a blade while the pad is located above or on the substrate/object. After printing the pad moves over the cliche where the excessive ink has been removed, leaving ink only in the recessed cells. The *pad* is now lowered and covers the print image on the cliche due to its elasticity (fig. 2.5-31). The *ink* must be formulated with specific characteristics so that it adheres to the pad despite the pad's silicone-content. Next the pad is lifted off the cliche and moved over and brought into contact with the substrate/object. The elastic pad surface molds to fit the surface of the object. The ink on the pad has continued to dry in the meantime and its surface now adheres to the object. The *silicone oil in the pad* ensures that all the ink is transferred onto the object surface (almost *100% ink transfer*). The whole procedure is now repeated with the object either being changed or remaining in its position for a second print, if particularly strong coloring is required (fig. 2.5-31).

Open Systems

The first pad transfer printers operated with an *open inking system*. A few of these machines are still in use today for specific applications. The ink is kept in a small ink trough behind the cliche. As the pad is moved forward to the object to be printed, a certain amount of ink from the trough is spread over the cliche with a *squeegee blade*. The *main blade* (steel) is raised during this process. As soon as the pad moves away from the object and towards the ink trough, the main blade is brought into contact with the cliche, removes the surplus ink from the surface of the cliche and routes it back into the ink trough (fig. 2.5-32). Figure 2.5-34a shows a single-color pad transfer printer with open inking system.

Closed Systems

With so-called closed systems an *ink pot* that has a precision edge made of hard metal (*blade ring*) is used. The cliche must be large enough so that the ink pot can be moved over the print image during inking and positioned in the non-engraved areas while the ink is transferred to the pad. The pot is pushed to the side to make the cells filled with ink accessible (fig. 2.5-33). The ink pot is now positioned in the non-image area of the cliche. The non-image area must be large enough so

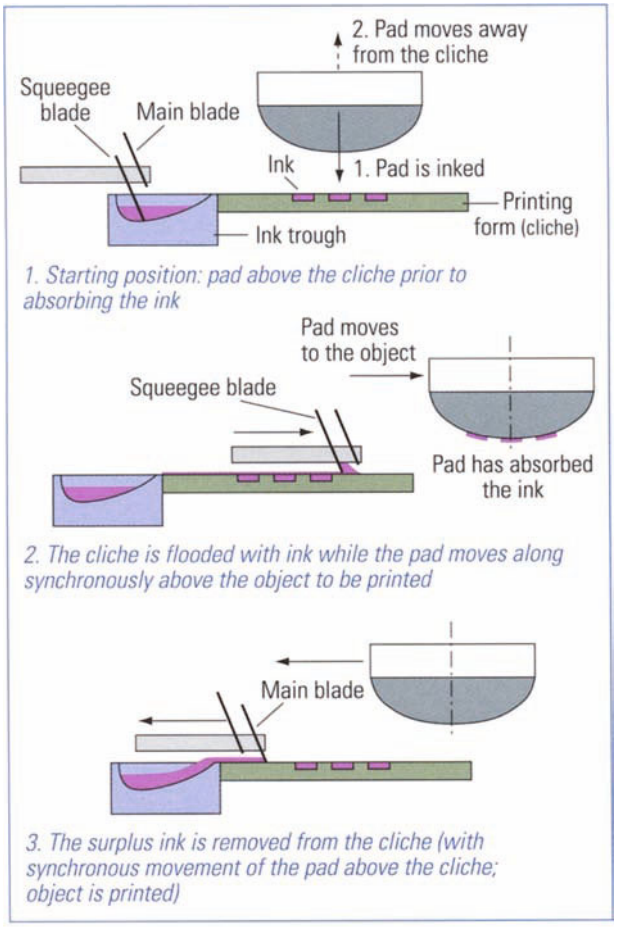


Fig. 2.5-32
Open system for inking the cliche in pad transfer printing

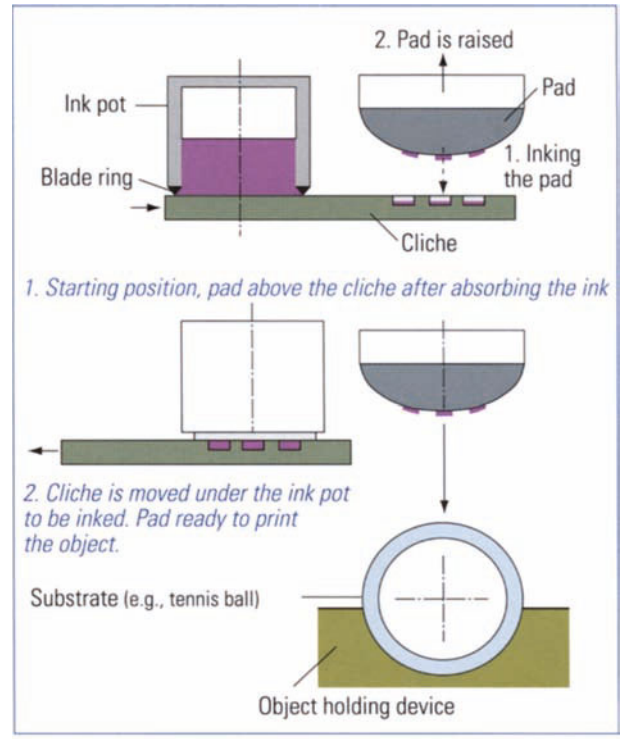


Fig. 2.5-33
Closed system for inking the cliche in pad transfer printing

that the tampon can be easily lowered onto the image on the cliche. The ink pot can remain in this position for almost any amount of time, for example, overnight or over a production-free weekend, without the ink losing any significant amount of solvent. For long production runs, ink pots are equipped with an integrated solvent and ink feed system. The system is used more and more frequently in pad transfer printing. Figure 2.5-34b shows a single-color pad transfer printer with closed inking system. Figure 2.5-35 shows an ink pot used for two-color print jobs.

Pad Transfer Printing for Flat Substrates/Objects

To print objects with an even surface, such as CDs, screen printing is replacing pad transfer printing to an increasing extent. (More recently offset and NIP technologies are sometimes used to print CDs.)

Body Printing

The key advantage of pad transfer printing is that it can be used to print surfaces of almost any shape. The printing procedure corresponds to the one already described. However, the distortion of the print image in relation to the shape of the surface to be printed and the pad used to transfer the print image onto the substrate are important factors that influence the print result. The distortion of the image has to be taken into account when making the cliche. Digital image processing programs can offer useful support here. Image distortion is currently the object of research and development projects.

Rotary Pad Transfer Printing

Rotary pad transfer printing is a useful method if large quantities of substrates, such as bottle tops, need to be



Fig. 2.5-34 Single-color pad transfer printers.
a Press with open inking system (TS 150/200/31, Tampoprint);
b Press with closed inking system (Pad Printer PP 200, Mino Group)

processed. It is very closely related to indirect gravure printing, yet the special feature of this process is the pad, which is in the shape of a roller. The image carrier is engraved or etched onto a cylinder (fig. 2.5-36). Production systems apply this technique to achieve a production capacity of fifty to eighty thousand bottle tops per hour (fig. 2.5-37).

2.5.4.2 Cliche Making

Various types of cliches are used:

Steel Cliche

The *steel cliche* consists of a steel plate with high-precision and extremely finely lapped surface into which the motif is etched. Here, the plate is first coated with a photoresist coating. The image is transferred to the plate via a film, the photoresist coating (etching capability) is developed, and finally the plate is etched. The print image is represented through deep-etched structures. The cliche-making process resembles that of an etched gravure cylinder for halftone printing.

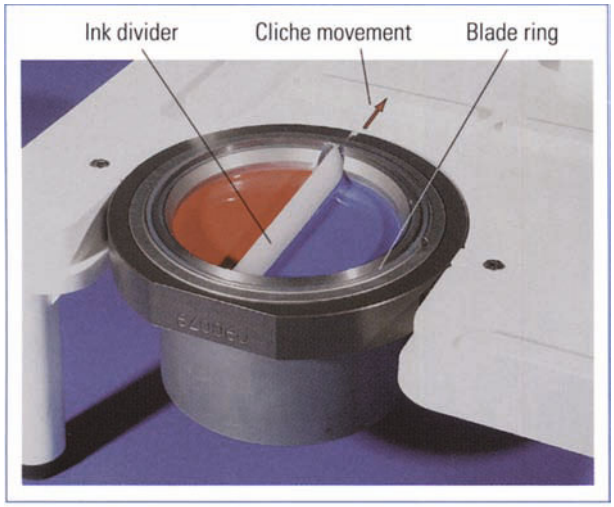


Fig. 2.5-35
Ink pot with two printing inks for simultaneous inking of a cliche for two-color printing; shown in its fill-up position (Tampoprint)

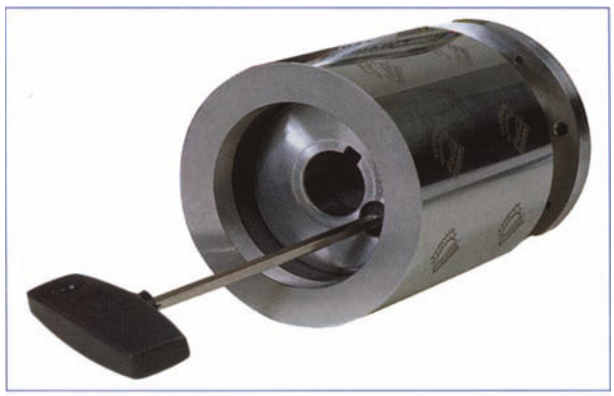


Fig. 2.5-36
Cliche cylinder (gravure master) for rotary pad transfer printing; see also fig. 2.5-37 (Tampoprint)

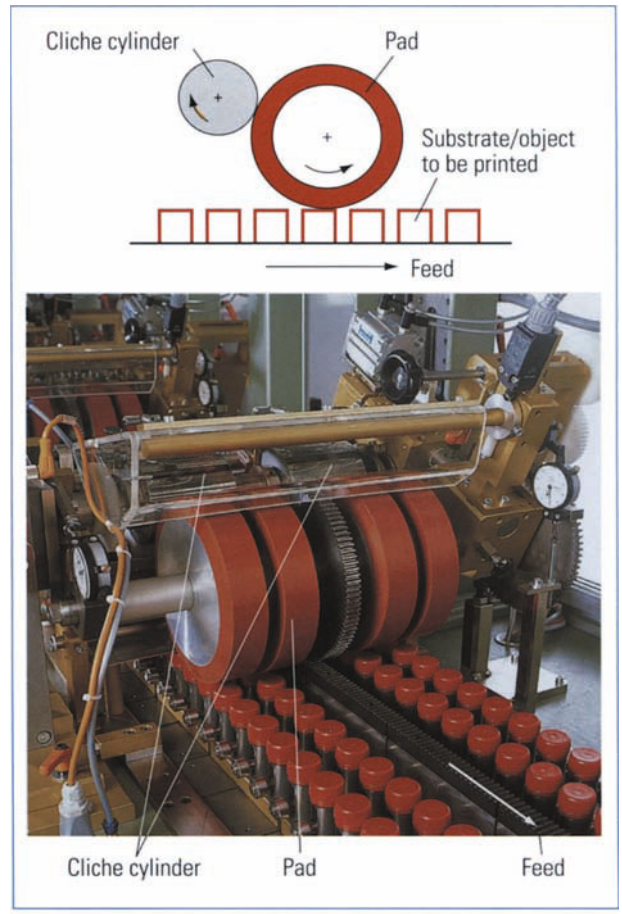


Fig. 2.5-37
Rotary pad transfer printing (with four product streams and two printing units) for printing caps (Tampoprint)

The *sheet steel cliche* is cheaper to produce than a solid steel cliche and made of sheet steel. The type of cliche preparation is comparable in both cases (fig. 2.5-38).

Photopolymer Cliche

The photopolymer plates currently on the market, which were actually developed for sheet-fed gravure printing, are also suitable for use as cliches in pad transfer printing. The type of photopolymer plates used for book printing are also occasionally used (as a gravure printing plate). The cliche-making process, with its stages of exposure and wash-out (see sec. 2.3.2), is relatively simple; it produces a cliche of considerable quality and is appropriate for many applications, making this type of cliche very popular.

The simplest way of *mounting the cliche* is by gluing it on to its support, but magnetic tables and special mounting devices are also employed.

As with gravure printing, cliche making is relatively costly. This is one of the reasons why intensive research and development is being carried out in this sector. One of the aims is to develop an image carrier made of

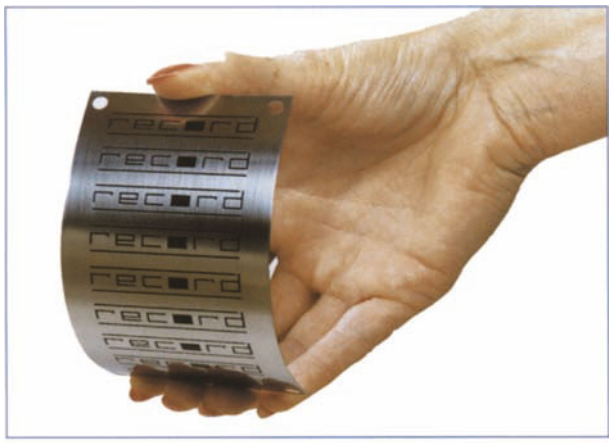


Fig. 2.5-38
Gravure cliche for pad transfer printing made of sheet steel (Tampoprint)

cheaper material that can be digitally imaged directly from a computer (computer to plate).

2.5.4.3 Pad, Ink, Object Holding Device

Pad

Cold-vulcanizing hard *silicone rubber* in various formulae and degrees of hardness is available for the production of pads. Numerous shapes, matched to the object to be printed and for the most diverse of applications, have been developed and used as required. The basic shape of a pad is an original made of aluminum with an extremely finely polished surface. This original is used to produce the casting mold made of plastic for the actual print tampon. The liquid silicone mass is poured into this shape and covered immediately with a wooden plate, which then adheres firmly to the pad. The mounting elements for fixing the pad in the press are then screwed to this wooden piece. It is sometimes still necessary to trim the cast pad or cut some pieces out, so that it is optimally adjusted for the particular item to be printed.

Ink

Pad printing ink (see sec. 1.5.2.7) was a further development from inks used in screen printing. The preferred type of inks are solvent-based inks, which dry relatively quickly. The content of the solvent and the drying retarder or accelerator are used to adjust the drying process to the printing speed, with the result that adhesion is clearly greater on the printing substrate's surface than on the pad. Pad printing ink should adhere especially well to plastic surfaces. This is achieved by using additives that lightly etch the surface to be printed.

Object Holding Device

During the printing process the holding device must fix the substrate in a specific position. Devices where the object is changed manually are of a relatively simple design. Extremely precise engineering is, however, required if apron conveyors and carousels are used for mass production. Each object must be printed in exactly the same position. Linear slide tables with two axes/coordinates are often used to ensure the precise positioning of the substrate/object.

2.5.4.4 Multicolor Pad Transfer Printing, Applications

Examples of Printing Systems

The range of pad transfer printers extents from the single-color printing system with a single printing unit, through two-color systems right up to four-color and systems with more than four colors. There are multicolor configurations where the cliches and pads are arranged directly alongside one another (fig. 2.5-39), *in a series of individual single-color units* with a common drive, or in *carousel form*. The carousel system shown in figure 2.5-40 represents a special design where the individual printing units are moved past the substrate to perform the print.



Fig. 2.5-39
Four-color pad transfer printer, with the pads arranged in a line (TPX 500, Teca Print)



Fig. 2.5-40
Multicolor carousel pad transfer printer (MKM 125, Morlock)



Fig. 2.5-41 Examples of pad printing applications

Applications

Only a few of the multitude of possible applications can be listed here. Some of these applications are in direct competition with screen printing when it comes to the printing of substrates with flat or convex yet less structured surfaces (see sec. 2.4.3.2). Some examples of applications that use pad transfer printing are: CDs, many kinds of toys, model railways, dials, computer keyboards, syringes, capsules, screw-on bottle tops, ceramics, crockery, promotional material, ball-point pens, lighters and household appliances (fig. 2.5-41).

Further Reading for 2.5

Bührer, R.: Fachbuch für den Tampondruck; Verlag Der Siebdruck, Lübeck 1988.

3 Prepress

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3.1 Conventional Prepress

The process of producing printed products can be divided into three parts: prepress, printing (press), and print finishing (postpress).

Printed products are graphic products in the widest sense: books and brochures, newspapers and magazines, leaflets and posters, labels and stickers, stamps and securities, credit and check cards, as well as folding cartons and blister packs, bags and pouches, beakers and tins, paper plates and lanterns, paper tissues, beer mats, mailings, and much more.

Prepress includes all the processing steps required to go from the preparation of the text, original images and graphics as well as the design concept right up to the production of the ready-for-print master; the master (printing plate) is then employed at the printing stage to produce the job (see sec. 1.2.2).

The informational content and professional typographic/graphic design of printed products are also a useful starting point for publications in the field of electronic media even outside print media, such as homepages on the Internet or CD-ROMs containing text and pictures. In a wider sense, therefore, "prepress" is also referred to as "pre-media", meaning the preparation of text and image for the several publication media. As can be seen in figure 3.1-1, the premedia production stage may already be incorporated in the actual prepress stage.

A fundamental technological change has taken place within prepress. The use of conventional typesetting machines, repro cameras, and film has been replaced by computer technology in virtually all branches of this industry. Text and image are digitized or actually created digitally, processed electronically and output directly onto the printing plate in print format, and increasingly without the use of film intermediates. Nevertheless, for many companies film remains an indispensable information carrier, albeit for a short-term transitional phase. It is for this reason that both prepress technologies,

- conventional and
- digital

are discussed. The distinguishing factor between them is the way the films are used: all technological variations where individual films are used for the page or print sheet composition and require conventional, mechanical/manual film assembly processes, and do not there-

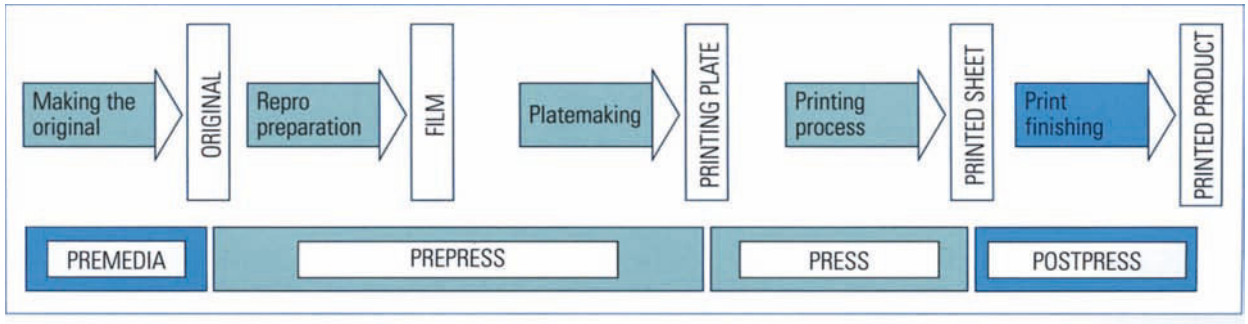


Fig. 3.1-1 The production of film and printing plate within the process chain for producing print media

H. Kipphan (ed.), *Handbook of Print Media*
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fore employ digital full-page film exposure systems, are dealt with under the category "conventional prepress." The section "digital prepress" (sec. 3.2) outlines the processes of digital image processing, computer to plate, computer to film, and so on (see fig. 1.2-30 for a comparison of these processes).

Gutenberg's invention of movable metallic type (1440), their production and the letterset printing press not only revolutionized the education system by enabling mass production of printed products, it provided at the same time the impetus for a series of diverse solutions to the general problem of converting text, images and layout as efficiently as possible into a printing master in order to be able to produce quality printed products more and more economically and up to the minute – which has continued up to the present day.

Machines that mechanized and automated the typesetting process with letterpress type – such as "monotype" and "linotype" (see sec. 13.1.1) – are just as much milestones in this chain of development as is the invention of lithography by Senefelder in around 1800, which released an impressive amount of development potential and led to modern high performance offset printing. The worldwide dominant position of offset printing compared to other printing processes was made possible to a considerable extent by the efficient production of offset plates and the outstanding print quality achievable on a wide variety of substrates.

The first step in producing a printing plate is the creation of the masters/film copies for the printing plates (fig. 3.1-1). Film copies contain all of the information to be printed on the printed sheet corresponding to each color, but also opaque black-and-white originals especially for single-color work. In contrast to the digital production of masters where text and image processing are carried out at the same time, in conventional prepress text creation and image processing are carried out separately.

Photomechanical processes are used in image processing, predominantly for line art images (graphics), but still also for continuous-tone images, an area which is increasingly being replaced by digital processes. Typesetting is carried out without exception on (desktop publishing) computers (e.g., Apple Macintosh, IBM compatible PCs) in combination with powerful software and automated imaging systems to produce the text film masters. Text and image are combined in assembly processes (cutting, positioning, pasting, etc.) to produce the film copy.

3.1.1 Word Processing, Typesetting

Typesetting processes in manual or machine type or phototypesetting are described in detail in the literature [3.1-1]. These now rarely used processes will not be discussed here.

Today's typesetting begins with the inputting of text into a computer. Word processing on computers with powerful, user friendly word processing programs has become state of the art.

3.1.1.1 Typesetting Procedure

The starting point for typesetting is the manuscript created by the author (see sec. 3.1.1.2). Clarity and correctness are more important in the manuscript than the question of style and aesthetics. Necessary corrections should ideally be made as soon as they are recognized. In the interest of clarity, corrections should be made according to the rules of correction for instance, as described in DIN 16 511 or ISO 5776.

Text input is the first stage of typesetting (see also sec. 3.1.1.3). This task is increasingly being undertaken by the author himself. Since there is a wide variety of hardware and software products for the PC there may be a compatibility problem when the printing house comes to process text files. Interface compatibility is therefore vital. Printing houses have to employ a large number of programs ("import filters") to convert documents supplied to them and to be able to input them into the word processing systems they have.

Text input is followed by *word processing*, which creates the design parameters planned in the layout such as the choice of font, font size, line length and spaces for images to be added later (see sec. 3.1.1.4). The layout data are set by the author and publisher or agreed upon between the author, publisher, and printing house.

Word processing is followed by *text output* (see sec. 3.1.2). The designed blocks of text are output onto film or paper. In this form they are ready for manual page make-up, that is, for completion with images and graphics required by the page of the book. If page layout including the integration of text and image is carried out electronically in the computer, the completed page is output on film or paper. The file forms a useful starting point either for electronic/digital processing, such as computer to plate or computer to film, for digital printing by direct imaging, and so on, or for further use in electronic media.

Corrections to the output text are time-consuming and expensive and should therefore be avoided as

much as possible. For this reason a number of correction stages are incorporated into the procedure. "House corrections" are made in the printing house with the help of paper printouts of the digitally stored text. Corrections by the author follow the completion of the designed columns of text. These are output as galley proofs on paper and sent to the author for proofreading. When corrections have been made the page is made up. The main function of the correction process which forms page make-up is the placing of the pictures in the correct position on the page, the correct and complete assigning of the picture captions, footnotes, cross references to other pages, and the arranging of headers and footers including page numbering.

Since corrections from this point on can be very expensive, it is important to ensure that the previous correction stages are carried out with utmost care and attention so that work can be guaranteed to be as free of errors as possible. After further proofreading and checking the author signs to confirm that the pages are correct and ready for printing, that is, he passes them for press.

3.1.1.2 Manuscript

A manuscript in the classical sense is the devised handwritten text that is to appear in print. The clearer and more error-free the written manuscript is, the faster and more error-free the subsequent input via the keyboard. The author should give the printing house the manuscript in its final form; it should not undergo any fundamental changes at a later stage.

Easy *text creation and editing* is made possible by the wide variety of programs available. Tables, graphs, and drawings can be created and inserted into the text. Using these aids, even non-specialists in typesetting, which is generally true of authors, can achieve a good result. As a rule the printing house is supplied with a printout of the text on paper as well as a data carrier with the relevant file of digital data.

3.1.1.3 Text Input

The manuscript first reaches the *preproofing* department of the printing house (mostly a publisher or prepress/premedia). Necessary corrections are made to the manuscript by the proof-reader (editor). The preproofing endows the manuscript with typesetting data concerning type sizes for continuous text, headings, markings, footnotes as well as instructions with regard to layout such as picture inserts, indents, and so on.

After the *text has been input*, it is converted by the computer, character by character, into machine-readable codes. Text input is essentially done via the keyboard, but sometimes also using OCR technology or less frequently as input speech.

Input via the Keyboard

The text is input manually via computer keyboard as continuous text up to the end of a paragraph or appropriate typesetting mark. Line breaks are ignored at first. This leads to the text being automatically "justified", which means dividing into lines of a predetermined width. Moreover, text can "flow on" automatically and error-free when corrected. This means that it is re-justified from the point of correction. This process continues up to the end of the paragraph. The normal typewriter keyboard has become established for inputting text.

In the past, typesetting machine manufacturers developed special keyboards for text input devices, which allowed the trained typesetter to type particularly fast and error-free. This meant omitting the shift key which is used on normal keyboards to switch from lower case to upper case letters, for instance. Of course the principle of "one key for one function" resulted in a proliferation of the number of keys, but by locating them in a more favorable ergonomic position for the typesetter to reach and by working constantly with this key layout he could achieve a lower error rate and faster typing. These keyboards are no longer in use.

Convenient and clear display of the input letter sequence and the user friendly, trouble-free correction facilities of modern text recording software have facilitated checking while typing so far that the cost of the special keyboard (as well as the training required by the operator to be able to use it "blindly") became unnecessary. Giving the author or a secretary the task of inputting the text also led to general use of the normal keyboard.

An example of software for inputting text in common use today is "Microsoft Word". Texts created with this software and stored on a data carrier can be further processed by the printing house with ease. Other common word processing programs are "Word Perfect", "MacWord", and many others. "Tex" is particularly suitable for scientific texts with formulae and special symbols.

Typesetting instructions concerning the layout of the text in continuous text manuscripts should be limited to the marking of headings and paragraphs and the positioning of images, if they are to be inserted in a particular place within the text, and the required start of a new page (or right-hand page if applicable).

Delivery of the text to the publisher or the printing house may be via data network (e.g., as an e-mail via ISDN lines) in order to save time and to keep up-to-date. For communication purposes, especially for compatibility and making corrections, it is essential to establish the output formats, devices, and interfaces for printing out the files.

Input by OCR

Text supplied in printed or typewritten format is converted using OCR technology (Optical Character Recognition) into coded (and therefore suitable for word processing) format. The paper document is first recorded as a bitmap image in an "imaging process" by means of optoelectronic scanning systems. In the subsequent OCR process the bitmap image of the printed text is converted to text code making it machine readable [3.1-2].

During the "imaging process" the document is scanned as a dot (pixel) matrix. The brightness or color value of each dot is stored as a digital value. A binary scan is produced from black and white documents and requires one bit for each dot. Up to 32 bits per pixel are required for a four-color scan. The scan resolution determines how accurately the scanned image matches the original. A resolution of 300 dpi give sufficient OCR accuracy for most texts (type size from about 4 mm character height, also depending on how sharp the reproduced characters are). Images and very small printed text in particular must be scanned at 600 dpi resolution. The image file format is typically TIFF (Tagged Image File Format). The OCR process (machine vision) includes the following five steps:

- identification of text and image blocks. Images incorporated into the text are passed over;
- character recognition by analyzing the shape and comparing it with characteristic features for each individual character;
- identification of words using dictionary files;
- correction of unrecognized words or symbols; they are shown on the screen and either confirmed or corrected by the operator;
- output formatting of the data in a chosen format such as ASCII, WORD, RTF, or PDF and saving them to a file (for data formats see sec. 3.2.9).

The result of the process is that the text exists in coded form. Thus it is just as suitable for word processing as text input via the keyboard.

OCR technology is particularly useful for recording typewritten manuscripts, library stocks to be stored in databases or for reprints of books that are only available in printed form. If the text is a bound book, there are machines available that automatically turn the pages and handle the book while scanning as well as optical equipment that ensures correct reading near the seam – even for high page count. Manual correction marks and additions to the text can also be recorded depending on the capability of the OCR software. A particularly widespread application of this technology is the automatic reading of bank documents filled-in manually, or for the distribution of mail.

The *error rate* of OCR equipment is less than 1%. This can increase dramatically if the text is smudged, the characters have not all been printed, or there are dirty marks on the paper; so that input by hand via the keyboard may be more effective. Criteria for use are the method of recognition, the original texts that may be used, recognition speed, range and quality of the dictionary, output formats supported, and the price. Examples of software products are OmniPagePro (Caere Corp.), Optopus (Makrolog GmbH), and Adobe Capture (Adobe Systems).

Speech Input

Direct machine recognition of the spoken language is a particularly comfortable form of recording text. However, the recognition rate for speech is too low for it to be a general alternative to input via the keyboard. Acceptable performance is achieved if a limited vocabulary is used, for example, when used within a specialist scientific discipline with limited specialist terminology. The system must be trained to recognize the voice of the person inputting the data. There is intensive research being carried out in the field of machine speech recognition [3.1-3 to 3.1-6]. Increasing capability of such systems as well as their ease of use mean that speech input may be expected to become more widely used in the future.

Importing Documents/File Transfer

Texts are supplied to the publisher or printing house on diskette/data carrier accompanied by a paper printout. (As mentioned before, the paper printout is an essential component for clear communication of content and page layout.) They may also be downloaded to the printing house via data networks and services. The printing house is then charged with the task of converting the data files, which have most often been

recorded into their own system format using a PC word processing program. This requires converting the data file using software tools called "filters"/"interpreters" to undertake the *conversion*. Although printing houses commonly possess import filters for documents that have been created using the common PC word processing systems, agreement between the author and publisher/printing house with regard to data formats and data carriers is desirable or necessary.

Common *systems* are Mac OS (Macintosh) and MS Windows with widely used *programs* being MS Word, Star Office and MS Works. There are few problems with transfer from one system to another for files in PostScript format, which has been in use for a long time. PDF files (Portable Document Format) allow largely trouble-free data transfer and are finding increasing use.

3.1.1.4 Word Processing and Typesetting

Desktop Publishing (DTP) *systems* are used for editing the input text. This is the technology of electronic publishing where full-page documents are designed on a stand-alone work station, which may be a Personal Computer (PC) or other work station. Texts, graphics, and images are designed according to a pre-determined layout and integrated into the page.

Cost effective DTP technology has now replaced the earlier photosetting technology. Typographically sophisticated DTP-typesetting/composition programs and a large choice of fonts enable photosetting quality to be achieved. Leading layout programs in the field of DTP are InDesign (Adobe Systems) and QuarkXPress.

Encoding of Characters

Text must be encoded to be edited in electronic text processing systems. A digital character code is assigned to each character of text. This clearly identifies the character without any further information such as character height, shape, position on the page, color, distance from other characters, and so on.

Encoded text consists of rows of character codes in sequence of the letters and symbols. The text content is thus clearly defined. The ASCII code (American Standard Code for Information Interchange) is used internationally for texts. Seven bits are the standard making a possible $2^7 = 128$ different character codes. They define 96 characters for creating the page content and 32 pieces of control information. Umlauts and special symbols are defined by combining with an eighth bit which is often specific to the manufacturer and may therefore lead to conversion problems when transferring data.

Font

There are many different shapes of typeface available for typesetting texts (see also sec. 1.2.1). Each typeface contains all of the lower case and upper case letters of the alphabet, all punctuation marks, the numerals from 0 to 9, the arithmetic signs and other symbols such as brackets, underscores, and special marks. "Font" describes the sum of all available characters and symbols (glyphs) in a computer and its accessible peripheral equipment.

The exact shape of all of the characters contained in the font is stored in the computer. There are two principles governing the method of storing font characters: bitmap font and outline font. In the *bitmap font* all of the characters are present as pixel files in a firmly defined type size. The pixel pattern is stored for each character at a corresponding type size and thickness. Each of the "image" dots shown in figure 3.1-2a is characterized by an address (x and y-coordinates). The degree of reproduction must match the required output quality and the maximum single dot resolution of the output systems. Bitmap fonts require a larger storage capacity than outline fonts.

An *outline font* is a character set in which the shape of each individual character is described by mathematically defined contours. There is a distinction between contour graphics and vector graphics. *Vector graphics* consist of rows of directional straight lines, the vectors (fig. 3.1-2b). Each of these vectors has a beginning and end point, which are all that is required to describe the vector. Although a character is made up of a number of adjacent vectors, there is still a large saving on storage capacity compared to a bitmap font.

Contour graphics is a modified version of vector graphics that allows for curved lines in addition to straight line combinations and these are described by means of mathematical approximations. These processes are, for instance, the smooth alignment of cubic curves, of Bézier curve functions, conic curves, or B-spline curves. In contrast to bitmap and vector data formats this method of describing contours is device-neutral and infinitely scaleable.

Figure 3.1-2c shows the arrangement of n anchor points on the letter contour. These are joined using n-1 *cubic polynomials* for each line drawn, which also agree mathematically in their first derivative at the tie points; this ensures a smooth, kink-free progression.

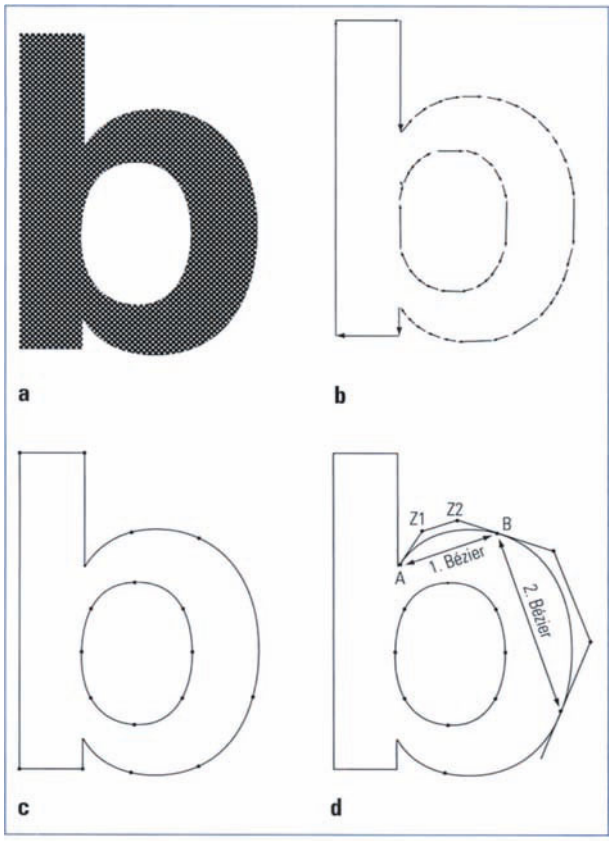


Fig. 3.1-2 Principles of character description.
a Pixel graphics;
b Vector graphics;
c Contour graphics (with cubic polynomials);
d Bézier curves (contour graphic with parabolas)

The more anchor points that are set, the closer the line of the curve matches the original contour – but this also means a greater amount of arithmetical calculation.

Bézier curves (fig. 3.1-2d) approximate the given letter contour by means of parabolas, which are defined by small linear elements. *Conic curves* improve the approximation through the use of parabolas, circles, ellipses and hyperbolas. The *B-spline technique* extends the process with segmented approximation using polynomials of an even higher order offering in this way a freer range of design possibilities.

The free scalability of outline fonts brings further savings with respect to the number of type sizes that need to be stored. Mathematically describing outline fonts enables representation of a typeface that is independent of the output device via a conversion instruction, which converts it to the specifications (especially the addressability) of the output device (monitor, printer, imagesetter). Therefore the characters are also depicted in their true form on the monitor. This is known as WYSIWYG (what you see is what you get) representation.

The page description language PostScript (see sec. 3.2.9) from Adobe Systems contains its own font technology. The PostScript font consists of freely scalable contour types.

Parameters/Specifications

Parameters to describe characters and special units of measurement such as the "point" (in the Didot system: 1p = 0.375 mm etc.) are dealt with in section 1.2.1.2.

Parameters describing paragraphs define the formatting of paragraphs. The technical solution to the problem is to attach formal attributes to the line length and alignment in the text block, the indents, heading alignment, footnotes, numbering, and so on. These attributes execute switch functions in the software. Important functions are:

- the design of headings and sub-headings with respect to type size and alignment according to the heading hierarchy established during the layout;
- the formation of lines from the continuous text (according to the values for the given width of the text block, the type size, chosen typeface and its preset spacing, and taking account of possible word splits);
- the alignment of lines as left aligned, right aligned or centered text;
- the justification of lines to the same length when producing justified text;
- line fall, that is, a well-balanced alignment of lines to the right side of the column with a text set flush left (the lines should end within a certain tolerance; the narrower the distance of the area chosen in comparison to the column width, the better the overall appearance of the text);
- Automatic and powerful programs are an essential aid to splitting words for the justification of the text that looks good typographically. Although the use of word splitting is in many cases a suitable way of creating well-justified lines, hyphens should be used sparingly in principle since too many in consecutive lines jar the appearance of the text and reduce its legibility.

3.1.2 Text Output for the Production of Film/Plate

During word processing the text is continuously output/displayed on the screen in front of the operator. Paper prints are also produced for proofreading purposes.

Should the further processing of the text into a master (film for platemaking) be done conventionally, that is manual assembly, exposed films are required. These may be produced either as columns or a page of text with blank spaces for the manual importing of pictures or as a complete full-page including pictures. The columns contain only text justified to the column or page width. This involves the largest amount of effort in the manual assembly of the page, the *page make-up*. It is better to pre-edit the page of text with a layout program that creates the blank spaces into which the images already present as film may be imported. The production of whole pages electronically, the displaying of text and image together, and outputting them at the same time on film requires that all of the images are stored in digital form in the computer and may be processed together with the text in the layout program.

Output to film is normally carried out in small-format imagesetters (also called "recorders") in approximately a 25 cm × 35 cm format, that is, approximately an A4 format. This section only deals with these small-format imagesetters, which are used for the production of films to be assembled with conventional assembly systems – that is not "totally digital" prepress. Large-format imagesetters, computer to film and computer to plate units are described in sections 4.2 and 4.3.

3.1.2.1 Designs of Output Devices

Output devices used for the exposure of films are called "film imagesetters". There are imagesetters of the flatbed design, capstan imagesetters, and internal and external drum imagesetters. In all of them exposure takes place spot by spot in lines across the whole area being exposed. In continuous exposure the pixels form straight lines in the direction of the lines of text and solid areas in conjunction with the pixels of the following lines. Letters and symbols are constructed using this process. The process assumes that each line of text is represented as a number of "micro lines."

If text and images are output together, the images, which are also divided into micro lines, are exposed in one pass along with the text. The separation of text and image into micro lines takes place in the RIP (Raster Image Processor).

To be able to produce letters with the smoothest possible contours and high resolution pictures, the exposure dot within a line, also called a spot, must have a very small diameter. The spot size limits the *resolution of the output device* (7 µm corresponds to approximately 5000 dpi and 30 µm approximately 1200 dpi; dpi: dots per inch). The individual dots must be located on the film so closely together that they can form a solid tone area. This determines the distance between the spots and from one line of spots to another.

Imagesetters on the market have a *spot size* from 7 to 45 µm; this corresponds to a resolution of between approximately 5080 dpi and 800 dpi or approximately 2000 cm^{-1} and 315 cm^{-1} (315 points per cm). High performance devices offer a resolution of 8000 dpi, that is 3150 cm^{-1}. This assumes that the spot size equals $\sqrt{2}$ × the pixel distance (the minimum required to achieve solid tone coverage by building up with individual pixels).

Figure 3.1-3 shows how a certain shape can be reproduced by circular pixels. In figure 3.1-3a the shape is only approximated. In figure 3.1-3b the pixel spacing and pixel diameter have been reduced by the half. This leads to a considerably sharper rendering of the shape, but at the same time the number of pixels is increased by a factor of 4 and thus requires much more storage capacity. Doubling the resolution is associated with a four fold increase in the number of pixels, which therefore means a correspondingly greater memory requirement.

The large number and small diameter of pixels that must be exposed one after the other demand beams of

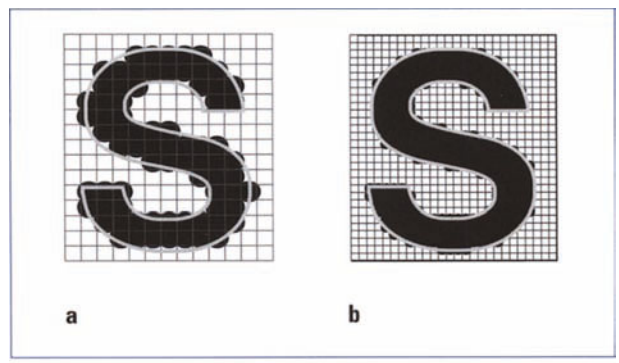


Fig. 3.1-3 Contour quality with digital output devices /imagesetter.
a Low resolution;
b Better quality due to higher resolution (double addressability and halved spot diameter)

light that may be very rapidly modulated; it also includes high energy light sources. Laser diodes or gas lasers in the visible range of wavelengths (e.g., laser diodes of 670 nm, helium neon lasers of 633 nm, argon lasers of 488 nm) adapted to the sensitivity of the film are used.

Flat-bed Imagesetter

In flat-bed imagesetters the material lies flat in the machine during exposure (see fig. 4.3-7). This allows a simply constructed exposure table and substrate holder. As the format of the total area to be exposed increases, the optical system required becomes more complex in order to guarantee the exact placing of the pixels at constant spot diameter on each part of the exposure area. Flat-bed imagesetters are renowned for their robust construction, high reliability and throughput for small to medium formats, which makes them particularly suitable for the newspaper sector.

Capstan Imagesetter

Figure 3.1-4 shows a capstan imagesetter. It processes media in a roll that is transported by rollers and wraps itself around a capstan roller that moves the media during exposure. Optical elements guide the laser beam along a surface line on the capstan roller across the total width of the film. The laser beam and movement of the film are synchronized such that exposure takes place line by line to build up a complete page/image. The capstan imagesetter is therefore similar to the flatbed imagesetter as exposure takes place line by line and the lines are straight. The use of material in a roll and the special transport mechanism mean that in principle there is no limit to the length of the film format to be exposed, giving this type of imagesetter a wide range of formats, which distinguishes it from other imagesetters.

The quality achieved depends on the precise synchronization between the film advance and the deflection of the laser beam and has a direct effect on the distance between the lines and pixels. Lack of synchronization leads to banding, shapes not forming part of the image, and register difficulties with process colors. Such faults in synchronization are particularly prone to occur when the operator interrupts the exposure in the middle of the text or image. Figure 3.1-5 gives a graphic representation of typical exposure errors in the direc-

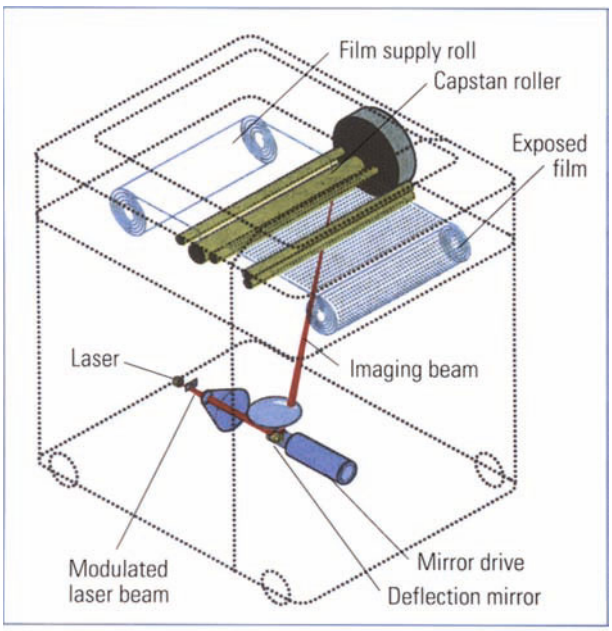


Fig. 3.1-4 Capstan film imagesetter (AGFA)

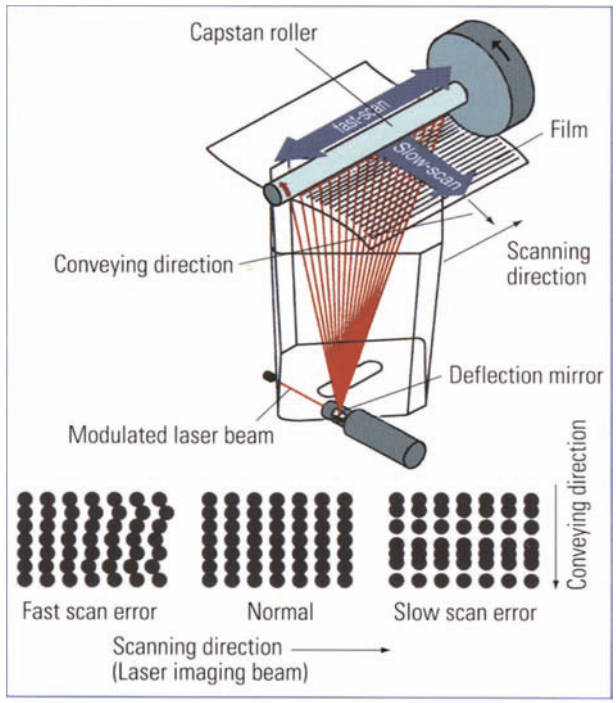


Fig. 3.1-5
Effect of synchronization errors using the Capstan film imagesetter as an example (AGFA)

tion of the laser imaging lines ("fast scan errors") and the direction of the film advance ("slow scan errors").

In general, imaging occurs only in the scan direction (not in reverse) and with the film transported via step motors. Sophisticated devices are able to reproduce colors absolutely accurately even in a stop-and-go mode (i.e., the film exposure for multicolor, screened images of the individual color separations meet the required register quality). A further criterion for quality is the precise reproduction of the exposure spot at the film edges; this is achieved by optical means (beam correction using special lenses).

External Drum Imagesetter

The carrier for the material to be exposed is a drum. During the exposure process this rotates at high speeed. The laser beam is guided slowly along the axis of the drum so that the exposure trace covers the drum surface in a uniform way similar to the thread of a screw. For this principle, too, the quality depends on the precise synchronization of the two motions together with the exposure frequency (fig. 3.1-6).

Particularly good scanning quality is achieved if the laser beam is directed across the drum step-wise so that it is advanced along the axis by one pixel distance after each rotation of the drum and then stops during one complete rotation (this is, therefore, a ring-like and not screw-like exposure).

Simple function and the short, constant optical path of the laser beam render the best exposure quality compared to the other types of imagesetters.

Internal Drum Imagesetter

Internal drum imagesetters (fig. 3.1-7) also work mostly with material in a roll that is inserted and held in a trough

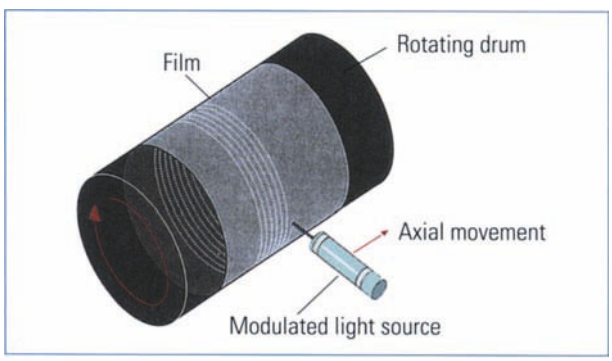


Fig. 3.1-6 External drum film imagesetter (AGFA)

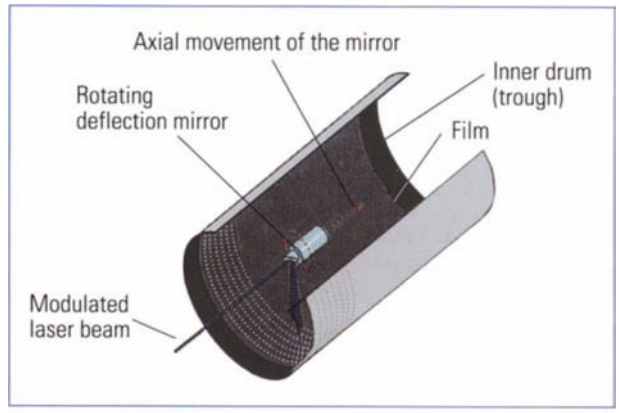


Fig. 3.1-7 Internal drum film imagesetter (AGFA)

in the shape of a segment of a hollow cylinder for exposure. The material does not move during the exposure process. Depending on the design of the imagesetter the trough consists of an internal drum segment of approximately 180° to 270°. The laser beam is directed precisely along the axis of the hollow cylinder and is deflected at right angles by a mirror or prism rotating at high speed around the axis projecting from within onto the surface of the cylinder casing. The deflector rotates at up to 30 000 rpm so that the whole surface of the film can be exposed in a short time if there is synchronization of movement along the axis (see also fig. 4.2-2).

In general laser light sources are moved along the trough axis together with the optical system.

The types of film used particularly for film imagesetters are subject to the following requirements:

- they must be dimensionally stable,
- the exposed/dark areas must have good opacity (optical density D = 4),
- the unexposed/light areas must be crystal clear (optical density D = 0.05),
- they must have very short exposure times, since the dots are imaged consecutively and the total imaging time must remain acceptable,
- they must have sharp edge definition,
- they must have high resolution,
- they must allow automatic development.

The function and possible designs of film developing equipment are described in section 3.1.3.4.

The large quantity of chemicals that must be disposed of when processing photographic silver halide films results in considerable environmental pollution. New technologies in the photographic industry employ the more environmentally friendly iso-salicylic acid in place of hydroquinol developers. Environmental pollution may be further reduced by the use of ablation films, which develop without wet chemical processing. The composition and performance of such "dry films" are described in section 4.2.2. These films must be exposed with IR light, thermal light (wavelength range approximately 830 nm to 1100 nm) initiating the ablation process. High opacity, good edge definition, high resolution, and good dimensional stability also characterize these films.

3.1.3 Photomechanical Image Processing/ Reproduction

Image processing or reproduction is the process that information in the form of images undergoes when it is converted from an original to a ready-for-print master/plate. In photomechanical image processing the master (usually film) is produced by using optical devices to record the images (camera, optics, filters, etc.) and process them (color filters, optical screens, special properties of the film material, etc.); no digital processes are used for photomechanical recording and processing the images, which is the case in "electronic reproduction technology" (see sec. 3.1.4).

Images may be present both as line art (graphics), black-and-white or colored (see figs. 3.1-2 and 3.1-33), and as black-and-white or colored continuous-tone images (figs. 3.1-8 and 3.1-9). The base material containing the image data is called the original. In the case of a continuous-tone original it is most often a photograph. A black-and-white photo contains a large number of gray values (fig. 3.1-8) ranging from the black areas of the image, the "shadows," to the white areas, the "highlights." Depending on the material and its processing, a color photograph (fig. 3.1-9) can reproduce virtually all naturally occurring visible colors – and each color in a continuous scale from dark to light and from an unsaturated (uncolored, gray) to saturated (clear) color.

In order to be able to reproduce continuous tones that are as true to the original as possible, the continuous-tone images must be converted according to the particular printing process into halftone areas and those with varying ink film thicknesses, as is the case for gravure printing. Prior to the screening process, colored images (corresponding to the way the human eye perceives them) need to be split into the three primary colors (cyan, magenta, yellow), which are then printed together – and usually complemented with black – to reproduce the colored image.



Fig. 3.1-8
Continuous-tone image, black & white (halftone reproduction)



Fig. 3.1-9 Continuous-tone image, in color (halftone reproduction)

Besides the accurate reproduction of colors, the structure of the details or drawing of an image is an essential component of the data. Clear contours of the original must remain as clear contours in the printed image and must be visible in light, medium, and dark areas of the image. Smooth, regular gray or colored areas should not be reproduced cloudy or appear distorted by shapes that do not appear in the image. The same is true of smooth, even tonal changes.

A print will satisfy high-quality demands if the latitude between the white available from the substrate and the full-coverage image areas printed with the maximum amount of ink is used in such a way that the content of the original picture is reproduced as fully as possible. As a rule, since the range of optical density of a positive slide, which is often the original for image reproduction, is greater than that of a print, it is necessary for adjustments to be made depending on the subject matter. In addition there is scaling (enlargement/reduction), image correction (spotting out unwanted details, smoothing of contours, addition or removal of elements of the image, etc.), color correction, and, as already mentioned, screening for the halftone reproduction of continuous-tone images for printing. This whole range of tasks must be accomplished during the image processing/reproduction process – efficiently and within tightly controlled limits.

There are two processing routes to achieve this goal, which involve different principles:

- analog image processing and
- digital image processing.

Analog image processing uses predominantly photomechanical, chemical, and physical means to complete the tasks whereas *digital* image processing is carried out electronically/digitized.

3.1.3.1 Use and Importance of Analog Reproduction

Analog reproduction is characterized by the use of film, camera, copy technology, and photomechanical (hardened or softened by light) emulsions, as well as mechanical and chemical processes for producing the printing plate. The materials and equipment used for analog reproduction have reached a stage of development that allows them to satisfy very high quality demands in printing plate production and process safety. The complete process of going from an original to a ready-for-print plate (or cylinder) is achievable with analog technology for offset, gravure, flexo and screen, and other printing technologies.

An important imperative for process reliability is the use of standardized processing conditions and the instrumental control of all processing steps. The employment of highly specialized trained personnel is vital to achieve high-quality results.

Despite extensive automation this technology requires a high proportion of manual input. The photographic and chemical parts of the process can cause environmental pollution. There is an increasing number of costs and resources involved in environmentally friendly disposal and recycling of waste. The handling of sometimes aggressive chemicals and working in a dark room mean unfavorable working conditions. When using analog reproduction technology for page make-up or assembly of text and image, the typesetting and preparation require separate technologies than image processing meaning a high level of technological and organizational input is required.

Digital image processing (see sec. 3.2) exists as a comfortable alternative that can in principle match and even excel the quality achievable by analog technology and has definite advantages and great potential for development in process safety, user and automation friendliness, environmental compatibility, use and integration of other media, local independence, and much more. Digital image processing also brings new possibilities in screening and image manipulation. Electronic text and image integration simplifies the technological process in prepress by making possible joint editing of text and image.

The trend in development from analog to digital image processing has already become widely established and the use of analog image processing is diminishing.

Despite digital prepress, *analog image processing* is a technology that still exists in many companies as it is well-known and mastered and its use is concentrated in special areas, for example:

- large format work (if the format is not covered by existing digital output technology),
- the use of existing films (especially when the customer wants to use the existing films),
- contingency process for disruptions to digital image editing,
- special jobs (e.g., artistic alterations required to be made to the film by hand),
- long term archiving in film form,
- analog proofing.

In certain cases partial use of analog technology is beneficial. For example, digitally created full-pages are exposed and assembled as the printing sheet in analog technology and copied onto the printing plate in the platemaking process. Analog full-page assembly is necessary if components for incorporation exist in analog form. Figure 3.1-10 shows the prepress steps involved in both the analog and digital methods.

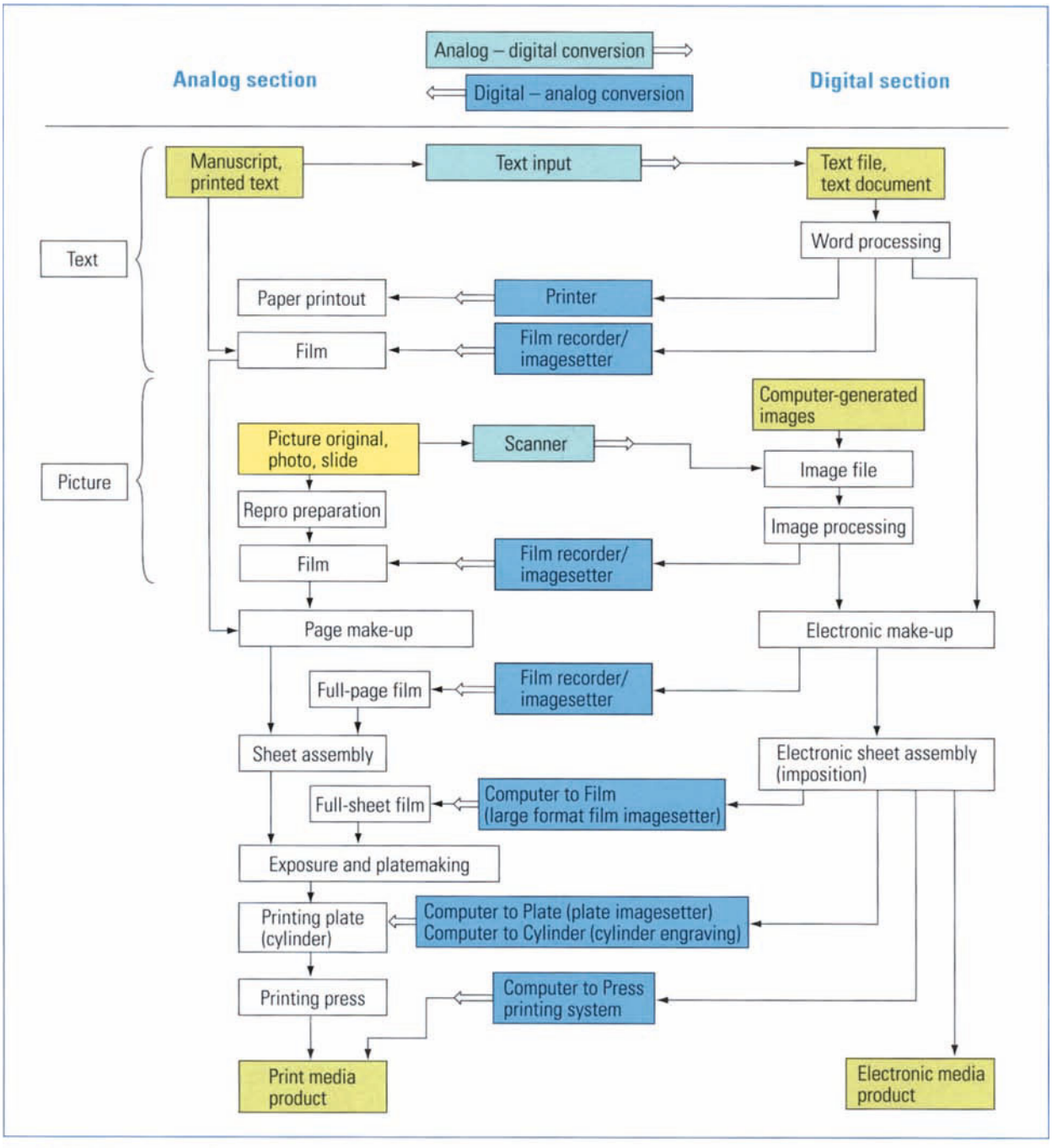


Fig. 3.1-10 Prepress workflow (analog and digital technologies)

3.1.3.2 Principles, Tasks of Photomechanical Reproduction

Photomechanical reproduction technology has the task of producing masters/copies (films) for the platemaking process from original images via a photomechanical route. A knowledge of fundamental definitions and laws of light technology and the properties of films used in repro technology is required in order to fully master the optical and photographic processes involved.

Primary Quantities of Light Technology

Light is a form of electromagnetic radiation. In the electromagnetic spectrum, which is arranged according to wavelength, visible light is positioned below the high frequency range (radio waves, television, radar) and above ultraviolet radiation and x-rays. Visible light covers the range of wavelengths from 380 nm to 780 nm (see fig. 1.4-15).

Individual wavelengths in the visible range are perceived as colors. Red has the longest wavelength, which decreases in the order orange, yellow, green, blue, indigo, and violet. White light contains radiation in all wavelengths of the visible range. There are two theories to explain the physical properties of light: wave theory (of Cristiaan Huygens) and quantum theory (of Max Planck). Both are equally valid. Depending on the question asked, one or the other theory may provide the answer. Wave theory gives a plausible explanation of polarization, refraction, and colors. Quantum theory helps to explain photographic processes and energy transfer processes such as the evaporation of matter.

In reproduction technology modulated light is the data carrier when exposing films or printing plates. Both the precise local dosage and measurement of light and a detailed knowledge of the reactivity of light sensitive coatings on film and printing plate material are essential for reliable control of the information process in reproduction technology. The following explains the most important relationships. Quantities and units used in light technology are defined as follows:

Luminous intensity I is the *quantity of light* Q given off by a light source per unit time t into the solid angle ω. Luminous intensity is measured in candelas (cd), the quantity of light in lumen seconds (lm · s) and the solid angle in steradians (sr). A steradian is the solid angle whose vertex lies at the center of a sphere and that cuts out a spherical cap from the surface of the sphere of an area equal to the square of the sphere's radius.

$$I = Q/(t \cdot \omega)$$

(I in cd, Q in lm · s, t in s, ω in sr).

Luminous flux Φ is the quantity of light Q emanating from a light source per unit time t and is measured in lumens (lm).

$$\Phi = Q/t$$

(Φ in lm, Q in lm · s, t in s).

Luminance L is the luminous intensity I emitted vertically and evenly from an area A and is measured in candelas per square meter (cd/m²).

$$L = I/A$$

(L in cd · m^{-2}, I in cd, A in m²).

Luminance in a direction inclined at angle φ to the normal has the value

$$L_\varphi = L \cdot \cos \varphi.$$

Illuminance E is the luminous flux Φ falling vertically on the illuminated area A. The unit of illumination is lux (lx).

$$E = \Phi/A$$

(E in lx, Φ in lm, A in m²).

For irradiation at an angle $E_\varphi = E \cdot \cos \varphi$ applies. In this case φ is the angle by which the irradiation is inclined to the normal.

Exposure/Luminous exposure H is the product of illuminance and exposure time.

$$H = E \cdot t.$$

For illuminance E(t) that is not constant over time exposure is equivalent to

$$H = \int_{t_1}^{t_2} E(t) \cdot dt.$$

The *photometric inverse square law* says that the illuminance E of a vertically irradiated surface reduces by the square of the distance r to the light source, which emits at constant luminous intensity I:

$$E = I/r^2.$$

For irradiation at an angle, where the direction of radiation is inclined to the normal by angle φ, then

$$E_\varphi = E \cdot \cos \varphi.$$

Reflectance ϱ, transmittance τ and absorptance α are quantities of matter in light technology:

Reflectance ϱ is the ratio of reflected luminous flux Φ_R to the incident luminous flux Φ (fig. 3.1-11).

$$\varrho = \Phi_R/\Phi.$$

Transmittance τ is the ratio of luminous flux that has penetrated the material Φ_T to the incident flux Φ.

$$\tau = \Phi_T/\Phi.$$

The *absorptance* α according to figure 3.1-11 is the ratio of the amount of luminous flux absorbed by the material Φ_A to the incident flux Φ.

$$\alpha = \Phi_A/\Phi.$$

The *reflectance factor* β of a test sample is the ratio of the luminous flux reflected vertically to the surface Φ_P to the luminous flux Φ_W, which is reflected vertically by a white reference sample if both samples are, for example, irradiated below 45° by a luminous flux of equal intensity (fig. 3.1-12) [3.1-9].

$$\beta = \Phi_P/\Phi_W.$$

For *transparent images* the *optical density* D equals the negative common logarithm of the transmittance τ of an image area.

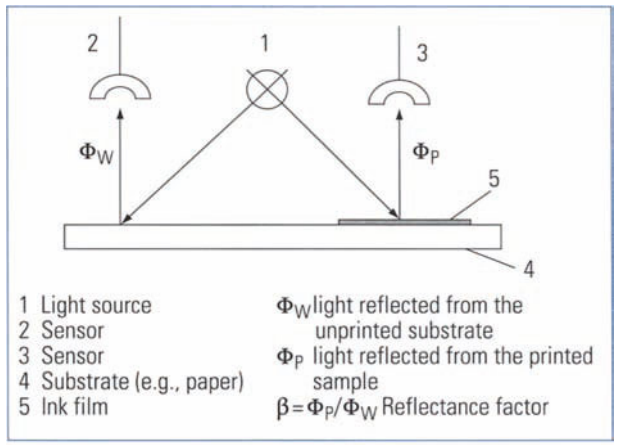


Fig. 3.1-12 Reflectance factor β

$$D = -\log \tau.$$

For *opaque images* the *optical density D* is the negative common logarithm of the reflectance factor β of an image area.

$$D = -\log \beta.$$

Sensitometry

Sensitometry deals with the relationship between exposure and the blackening of photographic materials it produces. The film material used in reproduction technology has the basic composition as shown in figure 3.1-13.

The film's clear *carrier base* consists of polyester or, for instance, triacetate. It is coated with an approx-

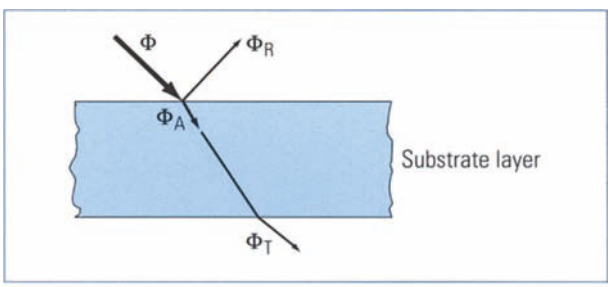


Fig. 3.1-11
Luminous flux Φ is split into partial fluxes Φ_R, Φ_A, and Φ_T by a substrate layer

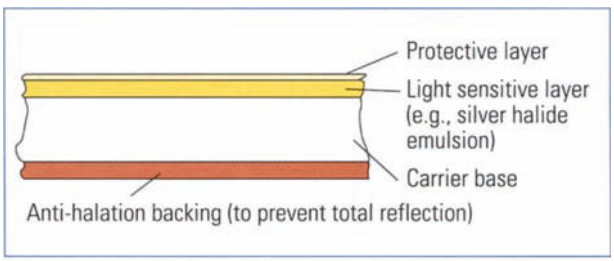


Fig. 3.1-13
Film composition; typical layer thicknesses: protective layer approximately 2 µm, silver halide emulsion approximately 20 µm, carrier base approximately 150 µm, anti-halation backing approximately 20 µm

imately 20 micron thick *light-sensitive coating* that contains a silver halide as the photographically active ingredient, for instance, AgBr (silver bromide). This is finely dispersed in gelatin. A *protective coating* over the top of this prevents damage to the light sensitive layer, for example, as a result of mechanical abrasion during transportation inside the camera, or in the developing machine. The reverse side of the carrier film is coated with an *anti-halation layer* which prevents total reflection of light on the reverse of the carrier film.

The photographic process (negative process, i.e., preparation for the later blackening of the light-sensitive layer) begins with the exposure of the film's light-sensitive coating in the camera or copying machine. This creates a latent image; it is not visible but, in the exposed areas of the coating, developable nuclei have formed that very rapidly reduce the silver halide to metallic silver and bromide ions under the influence of the developer chemicals; the blackening is caused by the silver.

If the exposure time is very long all of the silver bromide is progressively reduced, even in all the unexposed areas. The difference in development speed is the reason why there is a difference in blackening (contrast) between exposed and unexposed areas during the initial minutes of the exposure process. The latter must be stopped when the greatest degree of contrast is reached.

This happens when the film is first rinsed (stop bath) and then fixed. Figure 3.1-14 shows a plot of blackening in optical density units over the development time for exposed and unexposed areas (according to [3.1-9]). The greatest contrast is present after about $10^{2.5}$ seconds = 5.3 minutes: the exposed film has reached a blackening of S = 2.5 optical density units, while the unexposed film is just starting to show a veil of 0.1 optical density units.

The process parameters (developer concentration, temperature of the developing bath, movement of the bath chemicals on the surface of the film, and the developing time) must be maintained so as to prevent the unexposed areas from blackening. After development the coating still contains undeveloped light-sensitive material, which is removed from the coating in the fixing bath. This makes the negative light-resistant and it may be exposed to daylight again without affecting its degree of blackening. The products of the fixing process still in the coating as well as the remaining fixing chemicals are washed out in the next rinsing bath. After subsequent drying the negative is ready for further processing.

Image Transfer Properties of Photographic Films

Sensitometric Properties. The relationship between the exposure and blackening of the photographic coating is depicted by the *blackening curve* (gradation curve) (fig. 3.1-15). Optical density as a measure of the blackening is plotted against the log of the reference value for the exposure. Exposure H is calculated from the illuminance E and the exposure time t to give

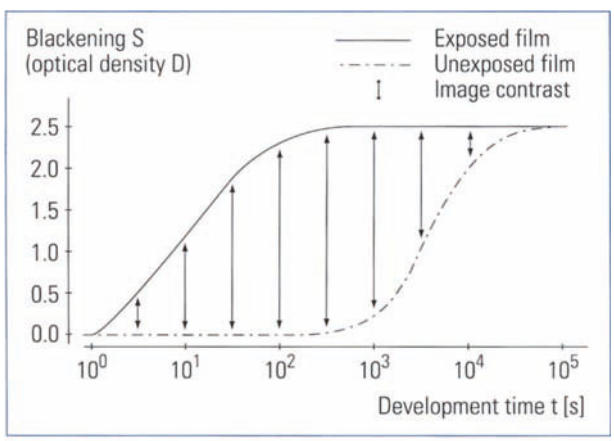


Fig. 3.1-14
Blackening of film depending on the development time [3.1-9]

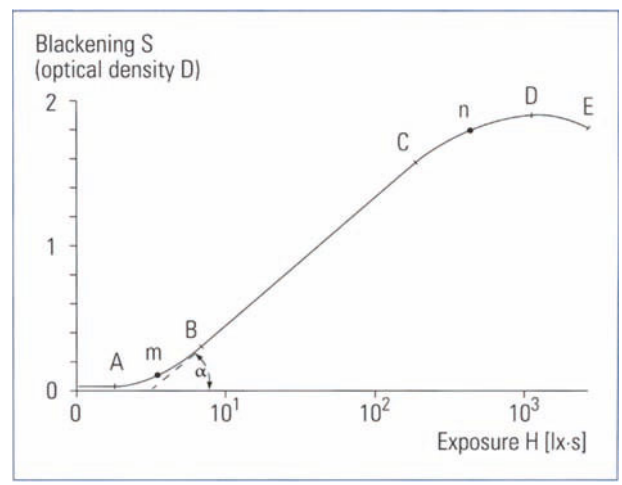


Fig. 3.1-15 Blackening curve (gradation curve)

$$H = E \cdot t,$$

when E remains constant over time.

Figure 3.1-15 shows the characteristic plot of the blackening curve. There is no blackening of the coating in the range from 0 to A. Point A represents the threshold blackening of the film material. For films for continuous-tone reproduction the threshold blackening should be as low as possible. Underexposure lies in the range A to B. Normal exposure begins at point B (the linear part of the curve), changing to overexposure at point C. The overexposure area ends at D. The way the coating reacted up to this point in giving greater blackening at higher exposure values is reversed between points D and E; this is the area of solarization. The total useful range lies between points m and n in the blackening curve.

The slope of the blackening curve characterizes the *film sensitivity*. This is called *gradation* and is given the value gamma (γ). It is

$$\gamma = \tan \alpha = \Delta S / \Delta \log H,$$

whereas emulsions that have a pronounced linear range are given a *gamma value* for this linear portion of the blackening.

For a light-sensitive material that does not have a pronounced linear region of the blackening curve, the mean gradient is taken as the characteristic value for sensitivity. The gradient is the slope of the blackening curve at a particular point. The arithmetic mean of the gradients in the useful area of the curve represents the mean gradient.

The light-sensitivity of films is not the same in all wavelength regions of light. Unsensitized material is sensitive to blue light. *Orthochromatic films*, which were used in the past, are blue-green sensitive. *Panchromatic films* are blue-green-red sensitive, thus covering the complete range of visible light.

Detail Transfer Properties of Photographic Films. The incident-directed light is scattered within the light sensitive layer (fig. 3.1-16). This *scattering* has the effect of forming a *diffusion halo* in the areas of sharp contours. This effect leads to ragged edges in the image details, a reduction in contrast in halftone screens depending on the screen frequency, and a change in the size of fine details depending on the exposure, leading to narrow lines being exposed as broader lines for instance.

If light beams penetrate the carrier film they will be reflected on its reverse side as soon as the angle of total reflection is reached or exceeded. This phenomenon is known as *reflection scattering*. The reflected light gives additional exposure to the underside of the coating forming a *reflection halo* (fig. 3.1-17).

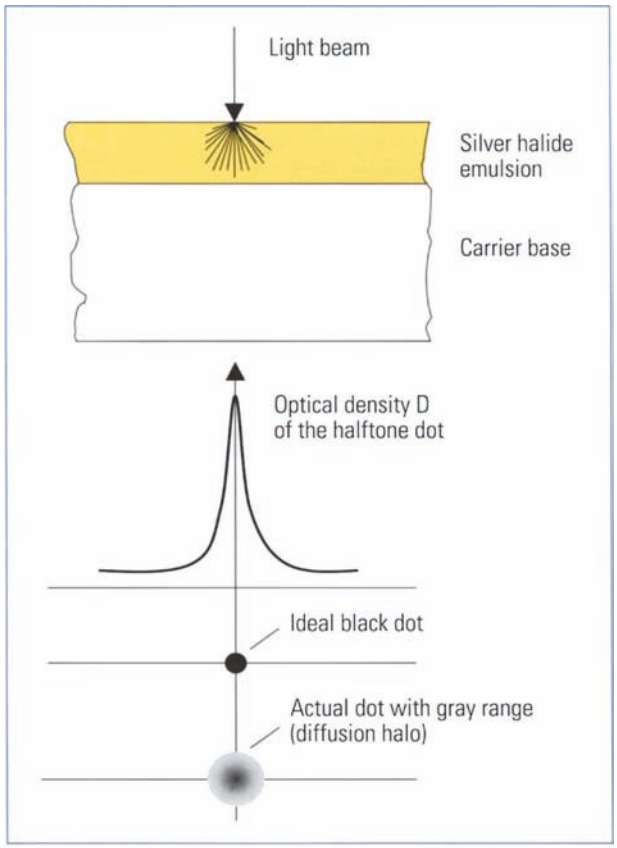


Fig. 3.1-16
Light scattering in the silver halide emulsion, diffusion halo

Reflection scattering is avoided if the reverse side of the film is coated with a layer having the same refractive index as the film carrier. This layer prevents refraction of light on the underside of the film carrier. The light enters the coating – the *halo protection layer*/anti-halo layer (see fig. 3.1-13). The halo protection layer absorbs those wavelengths the silver halide coating is sensitive to. An orthochromatic film (not sensitive to red) has for example a red, orange-red, or brown halo protection layer; panchromatic films have predominantly blue-gray, violet, or dark gray halo protection layers. The dyes are bleached or washed away in the developing or fixing bath.

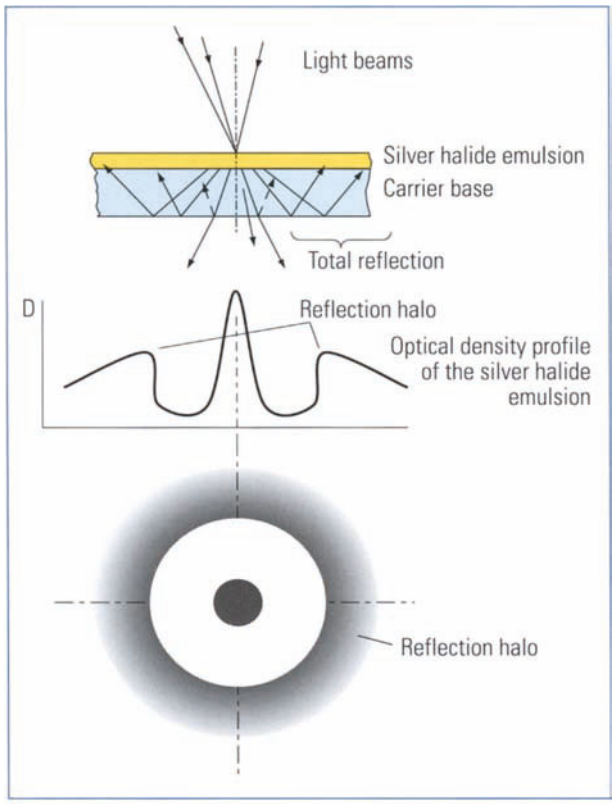


Fig. 3.1-17 Formation of the reflection halo by total reflection

Grade of film	Resolution (spatial frequency)
High sensitivity continuous-tone film	40...50 l/mm
Low sensitivity continuous-tone film	50...90 l/mm
Line film (dark room)	100...120 l/mm
Light room contact film	180...200 l/mm
Holographic film	500 l/mm

Table 3.1-1
Example resolutions of black-and-white films on contact exposure (application also for halftone images) [3.1-9]. Ideally the line width is equal to half the line spacing (i.e., line width 0.01 mm at 50 l/mm)

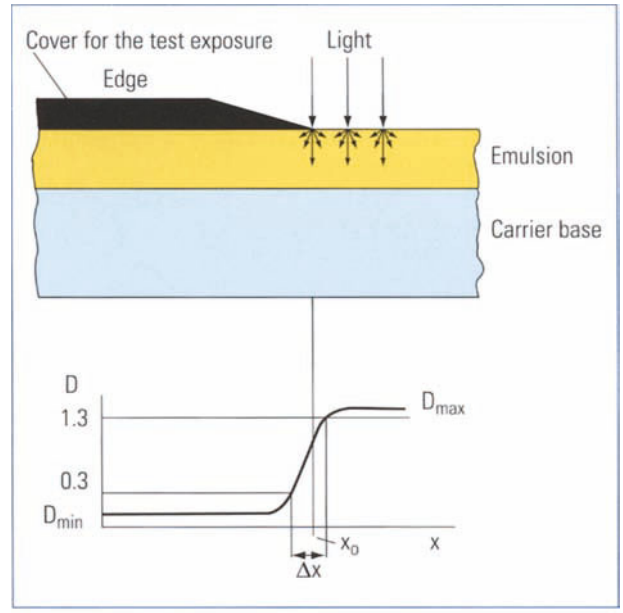


Fig. 3.1-18
Optical density gradation during contact copying of an edge (poor edge definition)

Resolution of Photographic Films. The *resolution* of a film is defined as the number of lines per millimeter that can still be reproduced separately. The graininess of the photographic coating has a fundamental influence on the resolution.

The *graininess* is the statistical distribution of grain clusters in an evenly exposed area of the developed film. It is dependent on the geometry of the silver halide crystals and their concentration in the coating. The diffusion halo reduces resolution. Likewise an increase in thickness of the photographic layer reduces resolution. Light of short wavelength is better at reproducing fine details than light of long wavelength.

Table 3.1-1 lists examples of the resolution of black-and-white films on contact exposure [3.1-9].

Another characteristic value besides resolution when reproducing details in reproduction technology is *edge definition*. It describes the increase in blackening at an edge (fig. 3.1-18). At the edge, blackening begins not in jumps, but with a gradual increase from the smallest optical density D_{min} – the optical density of the clear film – up to the maximum optical density D_{max} of the fully exposed film.

The distance Δx measured vertically to the edge of the film between the optical density values of $D_1 = 0.3$ and $D_2 = 1.3$ is described as *poor edge definition*.

The *contrast* K is defined as half the difference between the coefficient of transmission of an unexposed area τ_{max} and a black area τ_{min}, with respect to the median of the two coefficients of transmission τ_{max} and τ_{min}. It follows that:

$$K = (\tau_{max} - \tau_{min})/(\tau_{max} + \tau_{min}).$$

The contrast reproducible with a film reduces with increasing spatial frequency f_s as a result of diffusion scattering. *Spatial frequency* f_s is the reciprocal of the distance between the lines w in a halftone screen.

$$f_s = 1/w$$
(f_s in cm^{-1})

Special Effects during Exposure

Schwarzschild Effect/Reprocity Failure. According to the blackening curve (fig. 3.1-15) the optical density achievable on a film is a function of the exposure H, which represents the sum (or integral) of the illuminance E impinging during the period of time from t_1 to t_2. As already explained, this is equal to:

$$H = \int_{t_1}^{t_2} E(t) \cdot dt.$$

and at constant illuminance during the exposure time t

$$H = E \cdot t.$$

Ideally, a greater illuminance over a shorter exposure time should give the same optical density as a lower illuminance over a longer exposure time. This is stated by the *reciprocity law*:

$$E_1 \cdot t_1 = E_2 \cdot t_2.$$

This is not precisely true for exposure times over 16 seconds and below 1/1000 second. Behavior in these ranges is described by employing a correction factor, the *reprocity/Schwarzschild exponent* P:

$$E_1 \cdot t_1^P = E_2 \cdot t_2^P.$$

For photographic material this is $0.7 \leq P \leq 0.9$. The exact value of the reprocity exponent depends on the film material, the length of the exposure and the processing method.

Intermittence Effect. If exposure takes place intermittently, for instance, in two exposure steps of one half exposure each, blackening is lower than continuous exposure with the same total exposure time (this presupposes that the brightness is the same in both exposures).

Solarization Effect (fig. 3.1-15). In the region of very high exposure the blackening curve falls again.

Development Effects

Development effects are based on the fact that the development of areas with widely different exposure takes a different amount of time than areas of even exposure. This gives rise, for example, to pronounced dark or light edges to contours in the image.

3.1.3.3 Materials

The *types of film* used for reproduction technology should be selected according to their special application areas. For contact exposure the film is placed directly on the transmission copy. Table 3.1-1 lists the achievable resolutions with the grades of film listed.

Films for use in recorders must give trouble-free blackening despite the extremely short exposure time available for each pixel. The films, called "scanner films", are made to be highly sensitive to precisely the laser light employed and must therefore be produced specifically for each recorder.

Ablation films are processed without the need for a wet chemical developing stage and are therefore also described as "dry films". Their function is based on the partial fixing of a thin layer of carbon on the surface elements of the cover foil that have been exposed to laser light. The carbon layer of the exposed areas is removed when the cover foil is peeled away from the surface of the film and this process is known as "peeling". The technology behind this process is described in section 4.2.2.

3.1.3.4 Machines and Devices used in Reproduction Technology

Repro Cameras

The repro camera, also called process camera, consists of a holder for the original (the image that is to be reproduced), the lens and the camera's rear box with a device for supporting the photographic material (fig. 3.1-19). The planes of the original, the lens, and the film are arranged vertically to the optical axis. The basic elements of the camera are arranged (as in fig. 3.1-19) so that they are movable along the optical axis enabling the enlargement range to be varied.

The holder for the original is equipped with devices that can keep the original perfectly flat and in the desired vertical and horizontal position. This is often a large polished glass plate onto the reverse side of which is placed

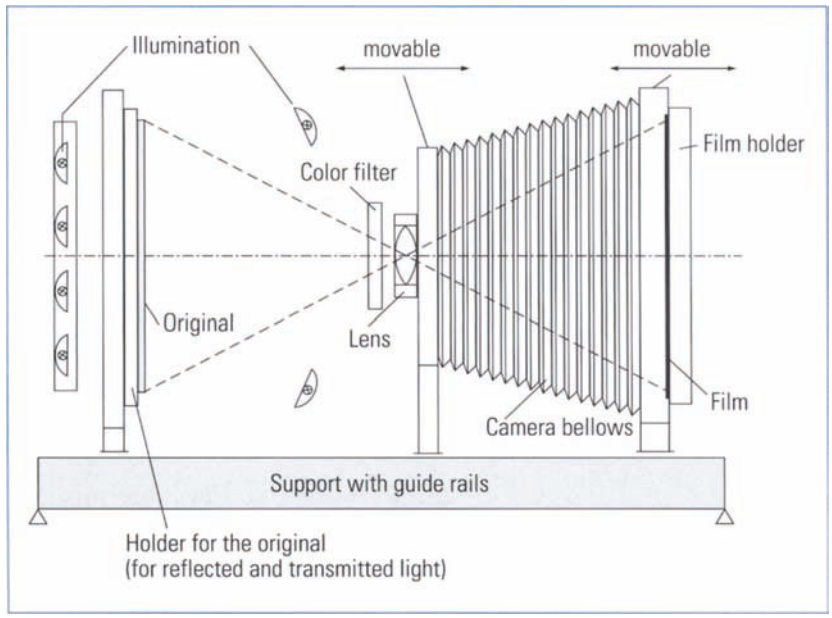


Fig. 3.1-19
Schematic structure of a repro camera

a rubber blanket. The space between the rubber blanket and glass plate is evacuated so that the plate and blanket are forced together under the pressure of the surrounding air without the glass plate being subjected to stresses from one side. Before creating the vacuum the original is positioned between the glass plate and the rubber blanket. The edge of the rubber blanket is sealed by rubber sealing lips. The surface of the rubber blanket is covered with a matrix of air channels to avoid the formation of air bubbles. The holder for the original is swung into the horizontal position for charging.

The lens is located in the lens standard. Light-proof bellows prevent the ingress of light from external sources.

The film is held perfectly flat in the image plane by the vacuum. The light-sensitive coating always faces the lens.

Light sources illuminate the plane of the original evenly. White artificial daylight, for instance, from high-pressure xenon lamps must be used, since colored originals are also processed, requiring color separations to be produced in the camera. Exposure of the film is controlled by the aperture and shutter speed so that the optimum exposure result is achieved for the film. Despite the use of exposure meters and a detailed knowledge of the film properties, it is still necessary to carry out test exposures with a test strip to determine practically the precise exposure parameters.

Color filters are placed in the optical path of the camera to produce the *color separations*: red, green, and blue filters produce the color separations for the cyan, magenta, and yellow printing plates and a so-called "visual filter" produces the black separation (fig. 3.1-33). In each case the color separations are all black-and-white films whose gray values correspond to the amount of each color in the observed image.

Flat mirrors or prisms are placed in the optical path of the camera to enable right-reading or wrong-reading images to be produced as required.

Plummeting lines in the original, which occur when a tall object is photographed with a camera held at a steep angle, may be corrected if the construction of the process camera includes the possibility of angling the planes of the original and film. A sharp reproduction will only be achieved if the planes of the original, the lens, and film intersect a common straight line (fig. 3.1-20).

Camera types

The most important types of process cameras are horizontal and vertical, according to the position of the optical axis, as well as compact cameras (fig. 3.1-21).

Horizontal cameras are of a standing (fig. 3.1-19) or hanging construction (regarding the guide elements for setting the reproduction scale) and are suitable for large-format work. Due to lower aberration, lenses with a long focal length are used resulting in a longer

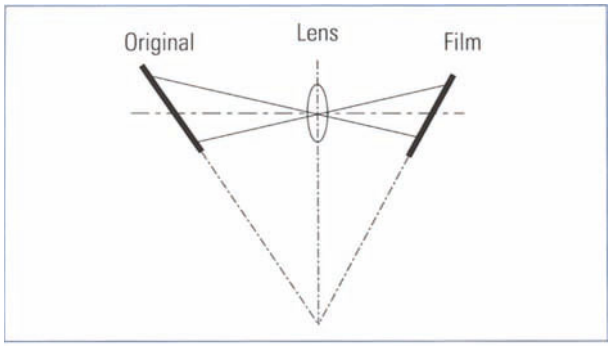


Fig. 3.1-20 Camera position to avoid plummeting lines

camera. This requires a particularly warp-resistant framework that must be constructed to withstand vibrations in the building. This largely prevents movements of the original, lens, and film relative to one another, which may be caused by vibrations during recording and which result in blurred copies.

Compact cameras have a vertical optical axis throughout. As the height of the camera is limited for ease of use, lenses with a short focal length and wide angle (up to 80°) are used in order to be able to cover the required reproduction scale (20% to 300%).

Vertical cameras have an angled optical axis achieved by incorporating a flat mirror. In these cameras the plane of the film is vertical while that of the original is horizontal, which provides advantages in handling.

A distinction is made between single- and dual-room cameras according to their location. For dual-room cameras the copy board is in the lightroom while the film is in the darkroom. The lens is located in a lightproof opening in the wall. Single-room cameras are constructed either as lightroom cameras with a lightproof portable film cassette (which is taken to a darkroom for film changing) or as a darkroom camera.

The copy board is equipped with transmission exposure units for processing originals in slide form (e.g., fig. 3.1-21a and b).

Contact Copiers

In contact copiers (fig. 3.1-22) the original film and the receiving film are in direct contact to produce copies of films. This allows the simple production of:

- copies of the originals,
- screened films from continuous-tone films by the use of a contact screen,
- color separations by introducing a color filter in front of the light source when colored originals are used,
- positive/negative conversions.



Fig. 3.1-21 Camera types.
a Compact camera (vertical beam path);
b Example of a compact camera (RTS Reprotechnische Systeme);
c Vertical camera (compact design with beam deflection)

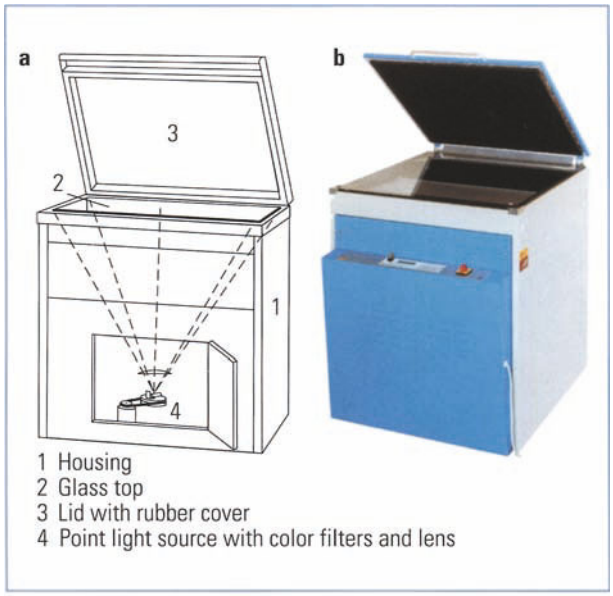


Fig. 3.1-22 Contact copier.
a Diagram;
b Example of a device (Sack)

It should be noted that in each case the contact copy is a mirror image as the principle involves working with emulsion coating against emulsion coating to rule out blurred images caused by refracted light.

Copying must be carried out in a 1:1 ratio only. Contact copiers do not have an optical focusing system. Directed light with minimal scattered light content is produced using a point light lamp. Scattered light required in special cases (e. g., to expose away cut edges or to produce blurred masks) is produced by incorporating additional diffusion lamps, diffusion panes, or dispersion foils that are placed below the copy material.

The original film to be copied is placed on the horizontal glass pane of the contact copier with the coating carrying the image facing upwards. The point light source is arranged below the glass plate. Between the two is a filter wheel that brings the chosen color filter into the optical path. The unexposed film is placed on top of the original with the emulsion coating facing downwards. A rubber blanket is placed on top as a seal. It has sealing lips at its edges. The air between the rubber blanket and the glass plate is expelled with a vacuum pump so that the atmospheric pressure of the surrounding air presses the glass plate, films, and rubber blanket firmly together. Good contact between original and film is essential during the exposure to ensure error-free copying. The exposure time is regulated by a shutter, which is programmed by a control computer to improve reproducibility between jobs.

Contact copiers for daylight processing are equipped with light sources that produce a high UV light content, such as halide mercury vapor lamps, and require the use of the corresponding film material.

Assembly Copiers

Assembly copiers or step-and-repeat machines enable one or several different originals to be copied to pre-defined positions on the light sensitive material (printing plates, film, pigment paper). The positioning program for the exposure head is input according to the make-up drawing, which details the position, format, and sequence of the films. The films selected for the job are arranged in sequence and placed in a pile in the machine. Only 1:1 copying can be done. The processing and exposure steps occur automatically in accordance with the program. The areas not to be exposed are covered automatically with masks (opaque films for example).

The machine has replaced assembly by hand. Color separations are printed exactly in register. Figure 3.1-23 shows an example of the type of assembly copiers used to produce printing plates (see also fig. 3.1-49).

Film Developing Machines

Repeatable and reproducible results for film development require precisely controlled process parameters. These parameters include first and foremost the chemical composition of the developer and fixer, their concentration, the reaction time, the movement of the bath over the surface of the film, the temperature of the bath, the degree of final rinsing, and careful drying.



Fig. 3.1-23 Step-and-repeat machine (StarLight, Krause-Biagosch)

The use of film developing machines is state of the art and offers advantages over manual developing: an increase in productivity and the possibility of using the machine in daylight since it is encapsulated in a light-proof housing; operators are no longer required to come into contact with the wet chemicals, which reduces the health risk and contamination.

Developing machines carry the film as a sheet or long web through the process with the aid of a series of rubber rollers and guide baffles. Although the rollers are pushed onto the film with gentle springs to ensure that it is transported safely, the coating is still subject to a mechanical stress from each pair of rollers. Repro films, therefore, have a resistant surface coating (protective layer). The surface of the rollers should be kept clean and free from damage to protect the surface of the coating.

The chemicals used in the baths are designed not to swell and soften the coating. An advantage of using rubber rollers inside the bath is that they produce intensive movement of the bath over the surface of the film. At the exit of each bath the rubber rollers positioned there squeeze the liquid thoroughly from the surface of the film, which means that intermediate rinsing between the developing and fixing bath is not required. On leaving the final rinsing bath no water droplets are left on the film; the subsequent drying process is therefore completed in a short time. The film leaves the machine in a dry state, ready for further processing.

Film developing machines are designed either as *deep tank developers* containing 30 to 60 liters of liquid in each bath (fig. 3.1-24) or equipped with *trays* containing 7 to 20 liters per bath (fig. 3.1-25). Since the necessary reaction time of the baths is predetermined by the technology, the flow rate for tank developing machines is clearly greater than for *tray developing machines* due to the longer distance that the developing material has to travel through the liquid.

The concentration and chemical stability in the baths is monitored and regenerated. Since the developer is used up depending on the quantity of film processed and its blackening content and since it is also oxidized over time by the oxygen in the air, the addition of regenerating liquid or fresh developer is dosed according to the measured quantity of film and time. The total processing time is reduced by maintaining the developer temperature at between 30 °C and 40 °C. The through-put time is around 90 seconds.

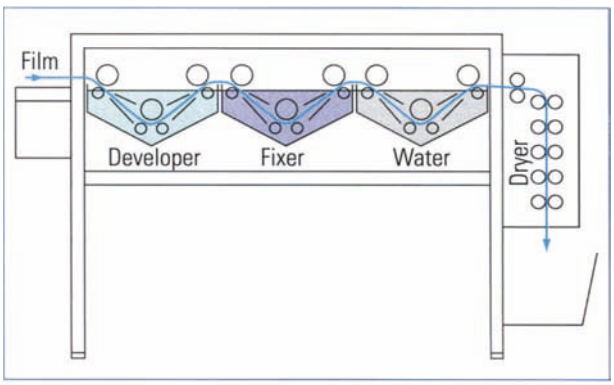
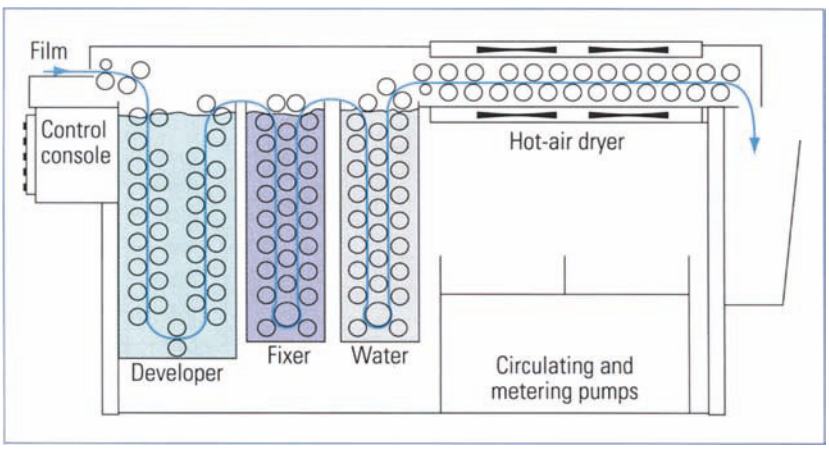


Fig. 3.1-25 Film developer in tray design [3.1-9]

Fig. 3.1-24
Film developer/processor with deep tank technology [3.1-9]



3.1.3.5 Production of Film Copies for Single-Color Printing

Analog production of printing plates requires *films* that usually consist of an image and a text component. In conventional platemaking both are processed separately and only then combined at the assembly stage to produce a complete page or sheet. The production of film copies for single-color images is described below (typesetting see sec. 3.1.1).

Image data are available as line or continuous-tone images and must undergo one of the processes depicted in the process diagram in figure 3.1-26 depending on the printing process to be used for the duplication of data, the type of original (line or continuous-tone), and the quality requirements (e.g., newspapers, high quality printing, glossy brochures).

Black and white *line art images* (graphics, etc.) require little effort. The image represents binary data since only black or white elements are present. Gray tones are not present so no screening of the film copy is required. Reproduction is limited to producing a film with sufficient coverage in the black areas (e.g., D = 2.5) and no more than a slight haze in the white areas (e.g., D = 0.05). The contours, that is, the transition from white to black, must be extremely sharp. According to practical guide values the transition from coverage in the black areas to the haze in the white areas should be complete within a distance of 4 microns measured vertically from the contour.

A very "hard" working film such as line film must be used to satisfy such requirements (table 3.1-1). The repro camera allows a variable wide range of reproduction scale. It also allows the conversion of positive into negative and right-reading into wrong-reading. The exposed and developed film is then ready for page make-up.

Continuous-tone originals (e.g., photographs) require more effort to convert them into a film copy for a specific printing process. The continuous tones must be adjusted to the particular printing conditions with respect to the tonal range and converted into printable halftone areas for letterpress, lithographic/offset, gravure, and screen printing. Figure 3.1-26 shows the processing steps required to produce film copies for the selected printing technologies.

Since the film coating (silver halide) must always be in contact with the plate surface when platemaking, the film must be produced either right-reading or wrong-reading depending on the printing technology. Since offset printing uses a blanket cylinder as an intermediate image carrier, a wrong-reading film must be used which produces a right-reading plate during the platemaking process. In letterpress and gravure printing the image carrier must be wrong-reading and therefore the film used as the film copy must be right-reading. Whether a negative or positive film is required depends on the platemaking process and the plate material.

Figure 3.1-26 shows that a right-reading halftone negative is produced as the film copy for letterpress technologies. The simplest method (*first* method, fig. 3.1-26) involves producing the film copy in a single processing step by direct screening (to be explained later). In the *second* method the production of a continuous-tone negative and a continuous-tone positive is carried out before the screened negative is produced. (Note: "continuous tone" means a continuous, non-screened density scale. The halftone negative, on the other hand, is screened, i.e., the individual halftone dots have ap-

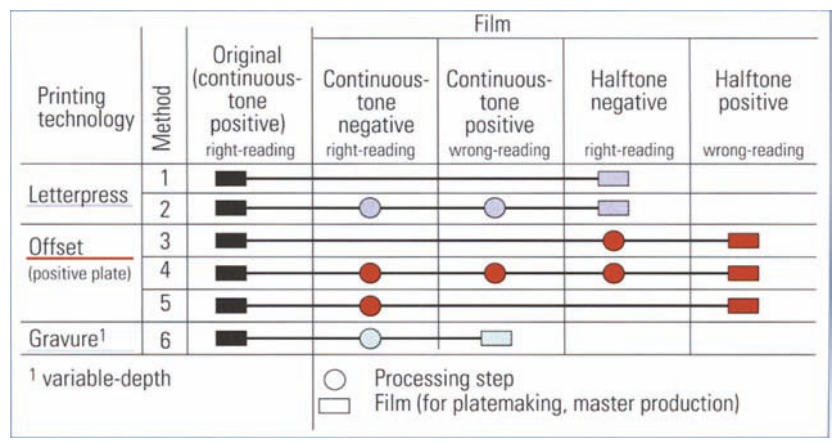


Fig. 3.1-26
Processing steps for the analog production of films for producing the printing plate/cylinder for selected printing technologies

proximately the same density, which means only two gray values are involved.) The intermediate steps are necessary to control tone value; this procedure allows higher quality demands to be met.

Offset printing requires wrong-reading halftone positives as film copies for producing positive plates. Here it is also possible to screen the original directly, as shown in the *third* method. The *fourth* method allows very precise control of tone values by carrying out the reproduction of the continuous-tone image as a negative and positive before screening. By choosing a film material with lower gradation and using a mask, the tonal range can be adjusted to suit the printing conditions. In the *fifth* method control of tone values is more difficult. The decision to use this method depends on the kind of original and the quality required. In variable depth gravure printing screening (*sixth* method) is not required when producing film copies. Necessary alterations to the scale, control of tone values, and corrections are carried out during the production of continuous-tone negatives or continuous-tone positives.

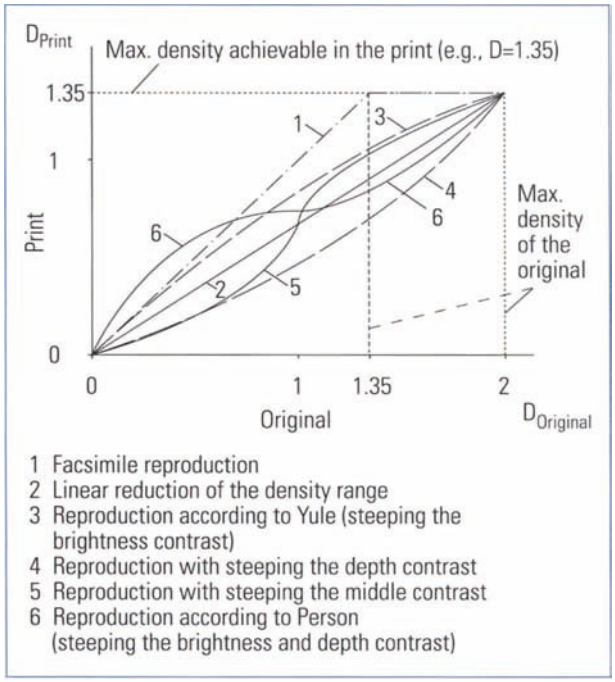


Fig. 3.1-27
Characteristic curves for the reproduction/transformation of the density range (optical density D) of the original in the print (reproduction characteristic curve)

Control of Tone Values

The difference ΔD in optical density between the lightest and darkest areas of a negative, diapositive, or opaque image is defined as density range. Only in exceptional cases does the density range of an original meet the conditions allowed by the printing process. For example, an original in the form of a transparency may have a density range of ΔD = 2.0. The standard density range for gravure continuous-tone positives as a single-color reproduction is ΔD = 1.35. In this case the object is to alter the density range of the original ΔD = 2.0 during reproduction so that all of the image data can be reproduced as far as possible within a range of ΔD=1.35. This cannot be achieved without a loss of image information, which should be as low as possible/as invisible as possible. This means that as much detail as possible must be visible on the continuous-tone positive to be used for the reproduction. Figure 3.1-27 shows various *reproduction characteristic curves* for transferring the densities of the original to the densities in the print.

A 1:1 transfer of the density values (*facsimile reproduction*) would only be able to reproduce part of the image data. This would correspond to the 45° characteristic curve 1 in figure 3.1-27; the image content up to a density value of 1.35 will be faithfully reproduced, but all of the details in the original (which in this example has a density range of 2.0) over and above the value of 1.35 look the same with a maximum density value of 1.35. They therefore become lost in the shadow tones/areas. The characteristic curve 2 offers the chance to linearly condense the total density range of the original down to the desired range of the reproduction. If we assume that details are visible if they differ in density by ΔD = 0.02, certain detail areas that are visible in the transparency copy will disappear in the reproduction. This may be associated with an enormous loss of information over the total image. For this reason it is necessary to decide, based on the content of the image, whether the details in the shadow area (high density) are more important than in the highlights (low density). If the highlights are more important a reproduction according to characteristic curve 3 would be used – or vice versa, characteristic curve 4. If the image is to have best mid-tone reproduction, for example for pictures of people, characteristic curve 5 is most suitable. Characteristic curve 6 reproduces details better in the highlights and shadows than in the mid-range.

Different types of characteristic curves are possible by controlling the gradation of the film material. Film

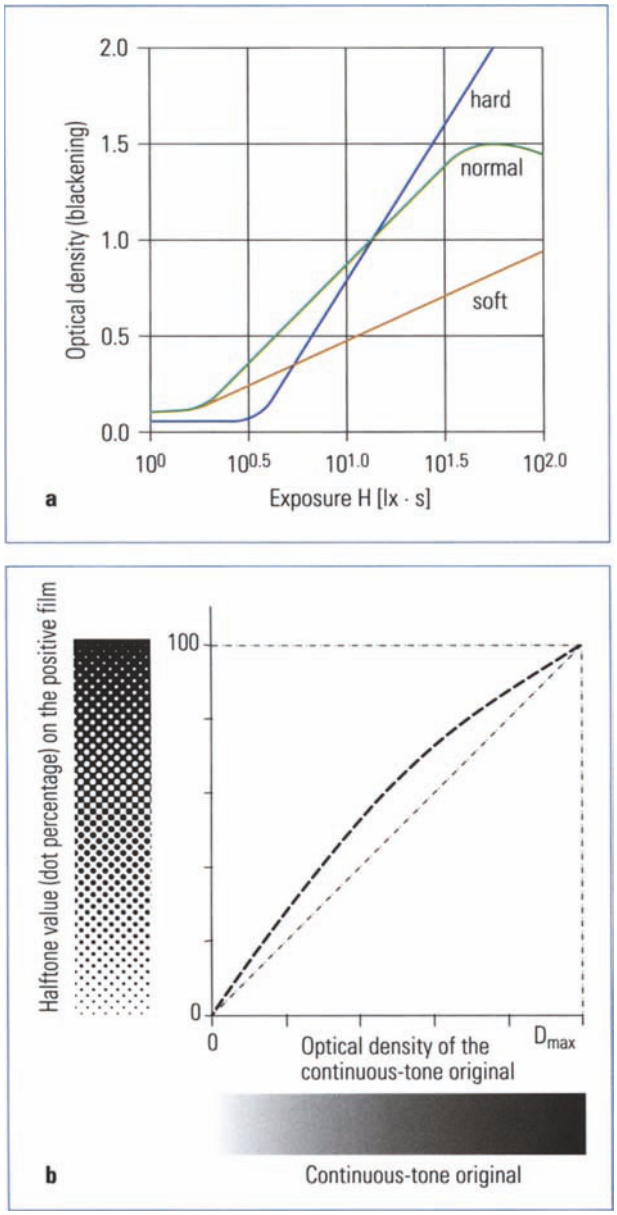


Fig. 3.1-28 Image processing for reproduction.
a Film material with different gradation curves enable the adaptation of density and tone values;
b Screening the continuous-tone original: correlation between optical density of the continuous-tone original and the halftone value of the positive film for positive platemaking at a specified reproduction characteristic curve (schematic)

materials with different gamma values are available for this purpose (fig. 3.1-28a).

The slope and line of the characteristic curve are also influenced by the development process and the use of masks (contrast reduction masks, highlight masks, etc.).

Photographic Screening Processes

Screening of a continuous-tone image, that is, an original or film with a continuous tonal gradation, may be either distance screening or contact screening. In both cases an autotype, that is, an amplitude modulated periodic screen, is created where the halftone dots are of different sizes but at an equal distance from one another. The special example shown in figure 3.1-28b is a graphic representation of how a halftone positive (where the image information is made up of differently sized halftone dots) is produced from a continuous-tone original.

Depending on the type of printing plate used in the platemaking process, there is a distinction made between producing a positive or negative printing plate. A positive printing plate requires a positive film, whereas a negative printing plate requires a negative film (fig. 2.1-4). In order to compensate in advance for process-inherent variations in dot size (dot gain) for the particular types of printing plate, the characteristic curves are adapted for the production of the screened film.

Figure 3.1-28b shows how a screened positive film is made on the basis of a special characteristic curve for a positive working plate.

The term "*autotype*" was coined by Meisenbach [3.1.10] in about 1880, who was granted a patent for his invention of an optical process for the automatic screening of continuous-tone photographic originals; the gray tone scale was automatically screened into individual halftone dots (types). The first screening processes were based on special glass screening plates positioned in the optical path and were called "distance screening".

Distance Screening

Figure 3.1-29 gives a schematic representation of distance screening. It involves placing a glass screen in the repro camera at a distance h in front of the film plane (the screen consists of two glass line screens fused at an angle of 90°). The lines are, for instance $w = 1/60$ cm apart corresponding to a screen ruling of 60 lines/cm. The lines have a width of $l = w/2$ and are colored black.

The glass screen may be rotated at an angle to the horizontal. The screen distance h is set so that the aperture opening of the camera behind each opening on

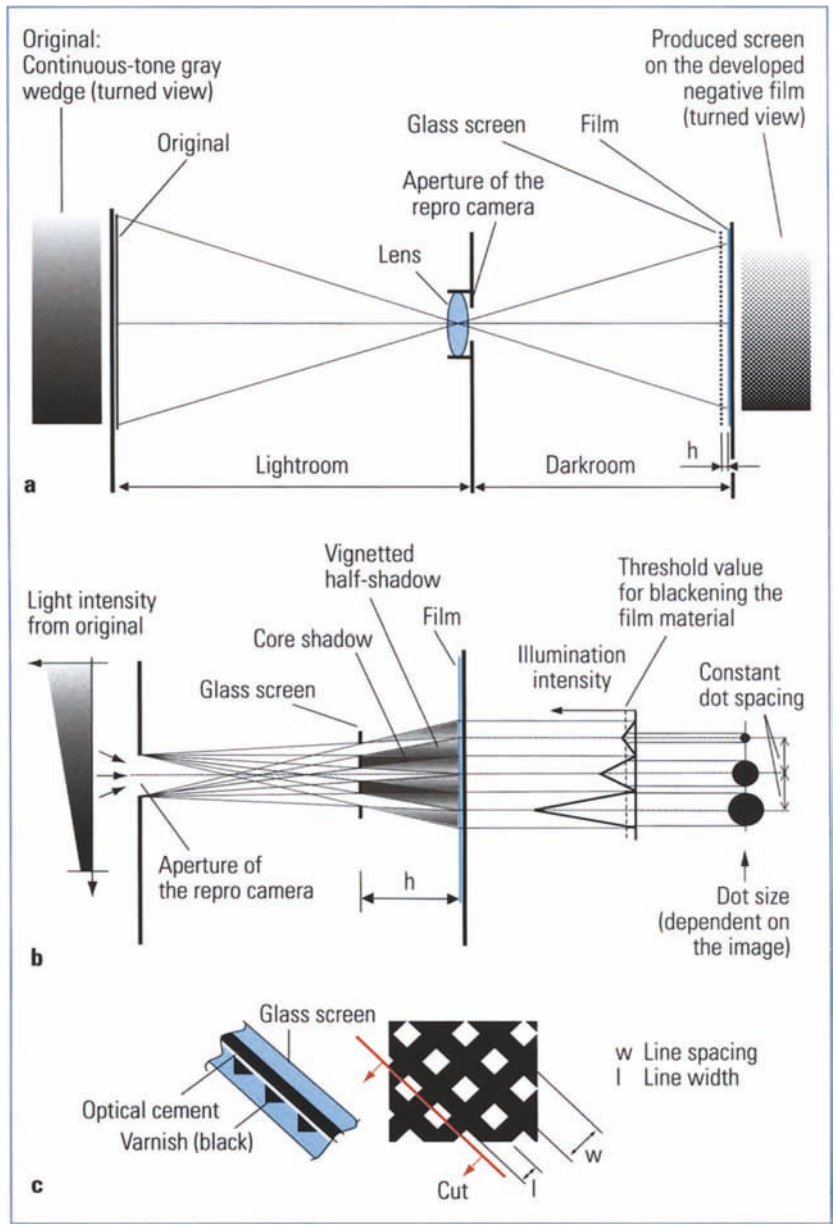


Fig. 3.1-29
Schematic representation of distance screening in the reproduction camera.
a Arrangement for screening the film;
b Schematic diagram of the dot generation;
c Glass screen (detail)

the screen is reproduced as a dot on the plane of the film. This dot is the brightest area on the film each time and the light intensity on the plane of the film decreases as we move away from this dot, reaches a minimum, and then increases again in the region of the next screen cell/opening.

If a continuous-tone image (original) is fitted in the camera's original holder, an image appears in the plane of the film that has a poor edge definition dot structure due to uneven brightness. These unsharp dots of uneven brightness are converted into highly opaque dots with sharp edge definition and of varying size using so-called lith films. They produce either transparent or highly opaque (black) image areas; there is no transition in between. The density of the blackened areas is greater than D = 3.

According to studies (see also [3.1-10]), a halftone positive produced with a distance screen shows a progressive increase the higher the density values are. If a halftone positive (image areas dark) with the correct tone values is reproduced as a halftone negative (image areas light), the transfer curve of this negative is no longer linear. Halftone copies with precisely the right tone values may be produced using special methods of exposure.

Contact Screens

Contact screens are exposed and developed films that already contain the dot structure of varying lightness described above (unsharp, gray value gradation). They are produced on an industrial scale and supplied in many variations: with different dot shapes and different density scale of the contact halftone dot. Figure 3.1-30 gives a schematic representation of the density profile in which the different gradation scales for halftone positives and halftone negatives are taken into account. With the aid of these positive or negative contact screens, film copies with correct tone values can be produced straight away without additional auxiliary exposures. Positive contact screens or negative contact screens are used to produce printing plates that are exposed with positive films or negative films respectively.

Contact screens are used in such a way that they are placed in the vacuum frame with their coating side in direct contact with the coating of the film to be exposed. The light modulated by the original passes through the contact screen and then impinges on the film creating dots of varying size depending on the density of the original.

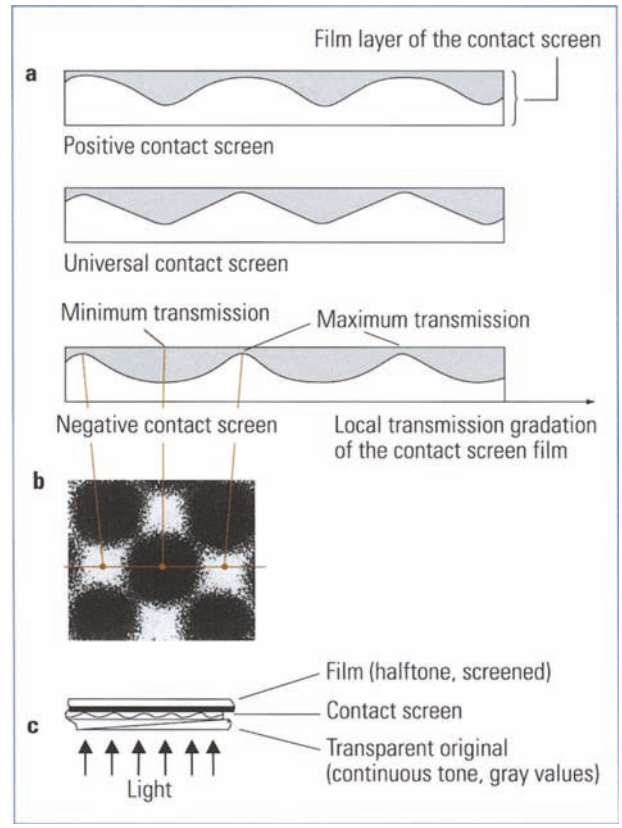


Fig. 3.1-30 Contact screen (schematic representation).
a Density profile of various contact screen films;
b Places of minimum and maximum transmission;
c Layer arrangement in the vacuum frame

Halftone Value

According to Neugebauer [3.1-11], the halftone value φ_i is defined as

$$\varphi_i = (1-\beta_{halftone})/(1-\beta_{solid})$$

where β is the reflectance factor and $1-\beta$ the quantity for the absorption of light. As described in section 1.4.4 (Quality Control/Measurement Techniques) the halftone value is also referred to as area coverage as it describes the optically effective portion of a control area that is covered with image elements. The symbol used to describe the halftone value is F_D instead of φ_D in accordance with section 1.4.4. Due to the correlation of reflectance factor β and optical density D ($\beta = 10^{-D}$), the following applies for the optically effective halftone value/dot percentage in the print (optically effective area coverage in the print):

$$F_D = (1-10^{-D_R})/(1-10^{-D_V}).$$

D_R is the halftone density and D_V the solid tone density. This correlation, known as the "Murray-Davies equation," describes the correlation between the optical density and the halftone value. If the halftone value is to be stated in percent, the following equation applies

$$F_D\,[\%] = [(1-10^{-D_R})/[(1-10^{-D_V})] \cdot 100\%.$$

To define the optically effective halftone value in the print it is necessary to measure the halftone density and

the solid tone density with the reflection densitometer. F_D can be calculated from both values using the given correlation.

To measure D_R and D_V in the film, a transmission densitometer is needed. The halftone value in the film (F_F) is calculated from it in accordance with the Murray-Davies equation (using the transmittance τ, see fig.3.1-11) .

System of Characteristic Curves. In going from the original to the finished print the image data goes through a range of processing steps that are associated with the transition from one carrier to another. Transfer of information occurs from the original to the film, the film to the printing plate, and from the printing plate to the paper. The aim is to control the whole process of tonal transfer from original to print so that an intentional overall characteristic curve is produced that allows the best possible repeatable quality.

It is well-known from the printing process that the reproduction of tone values, for example, in offset and flexo printing, is associated with an *increase in tone value* (dot gain) in the finished print – compared to the printing plate. The *print characteristic curve* (fig. 3.1-31) describes this relationship. The print characteristic curve in figure 3.1-31 shows as in 1.4.4 the relationship between area coverage of the film (as a parameter for the platemaking process) and the area coverage in the print, that is, it also contains the characteristic curve of the plate exposure. There are representations where the characteristic curve of printing refers to the area coverage of the plate. The extent of dot gain ($Z = F_D - F_F$; fig. 3.1-31) depends on the type and set-up of the printing press, the quality of the paper, the printing ink properties, and the screen ruling. If the dot gain in the mid-range has a value of, for example, 18% this means that a 50% dot percentage on the film is reproduced as a 68% dot percentage in the print.

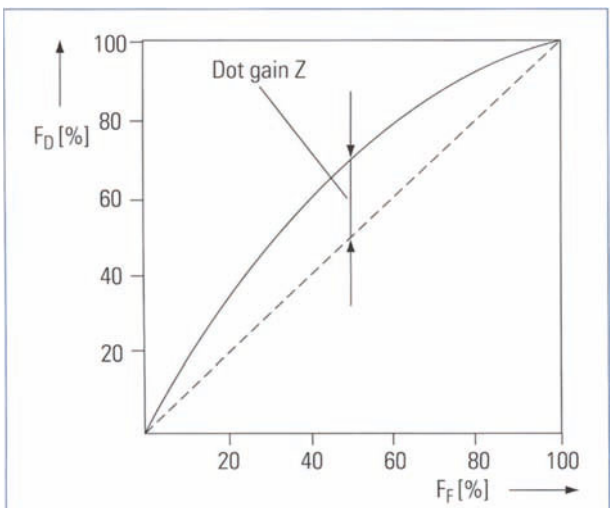


Fig. 3.1-31 Print characteristic curve and Dot gain

Even the transfer of the original (film) to the plate is associated with changes in tone values, albeit to a lesser extent. They are represented as a characteristic curve for the printing plate in the form of a function of the dot percentage F_{DF} of the printing plate over the dot percentage F_F of the film copy. Both of these systematic changes in tone value must be compensated for in the reproduction process.

The system of characteristic curves in figure 3.1-32 shows the relationship between the values mentioned and is represented as a so-called "*Goldberg diagram*" [3.1-8]. The first quadrant represents the overall characteristic reproduction curve as a function of the density in the print over the density of the original. The second quadrant contains the print characteristic curve represented here as a function of the density in the print over the dot percentage in the printing plate. The third quadrant plots the characteristic copy curve as a function of the dot percentage of the printing plate over the dot percentage of the film. The curve in the fourth quadrant can be constructed point by point from the other three curves. It represents the required range of dot percentage of the film copy as a function of the density of the original. This curve (fourth quadrant) must be reproduced during the reproduction process with the aid of special film materials, exposure processes, and so on.

3.1.3.6 Production of Film Copies for Multicolor Printing

The task when producing film copies (generally named: films) for multicolor printing is to create a film for each printing plate from a colored original for the colors that will be printed one on top of the other. The original image is split into three colors corresponding to the regions of sensitivity of the color receptors in the eye. This is done with the aid of red, green, and blue

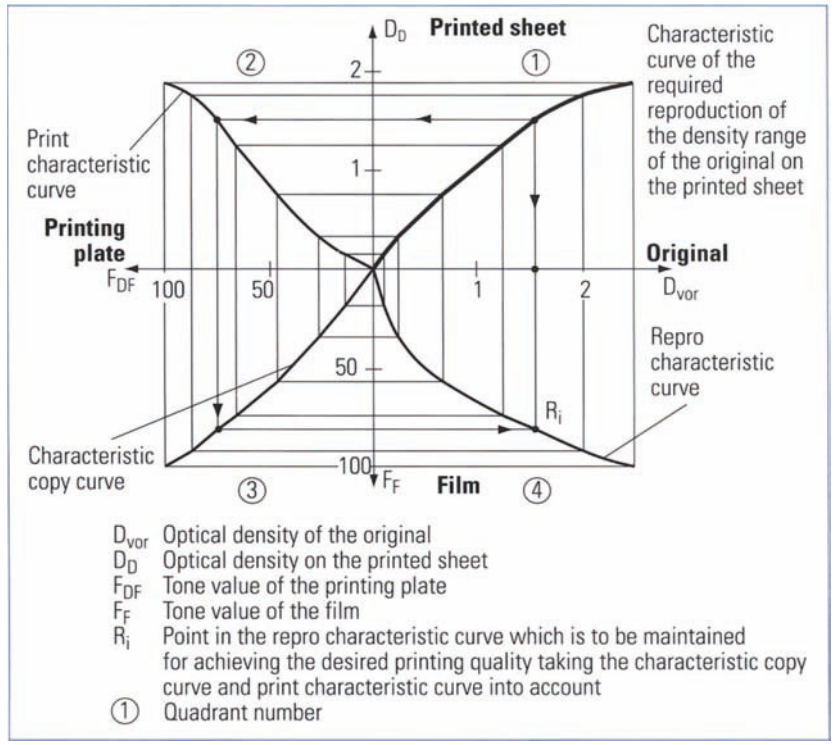


Fig. 3.1-32
Goldberg diagram; reproduction system of characteristic curves for transforming the optical density of the original to the printed sheet by adjusting tone value of film and printing plate [3.1-8]

color separation filters in the repro camera or contact copier. The *color separations* are made on a panchromatic film, which is sensitive to the whole of the visible region. In addition a black separation is also produced for offset and other autotype printing processes. The result is a set of black-and-white negatives, each of which represents the proportion of individual color in the image as a whole.

Printing can be based on the colors of the Europe scale according to DIN 16539: cyan, magenta, yellow, and black. In line with the laws of *autotype color mixing*, overprinting the four color separations creates the impression of printing the colored original as a whole. This assumes that white paper is used as the substrate and that the print is viewed under white (neutral) illumination, such as standard D65 light. It was Neugebauer who in 1934 developed the principles of an analytical approach to autotype color mixing, that is, overprinting screened color separations [3.1-11].

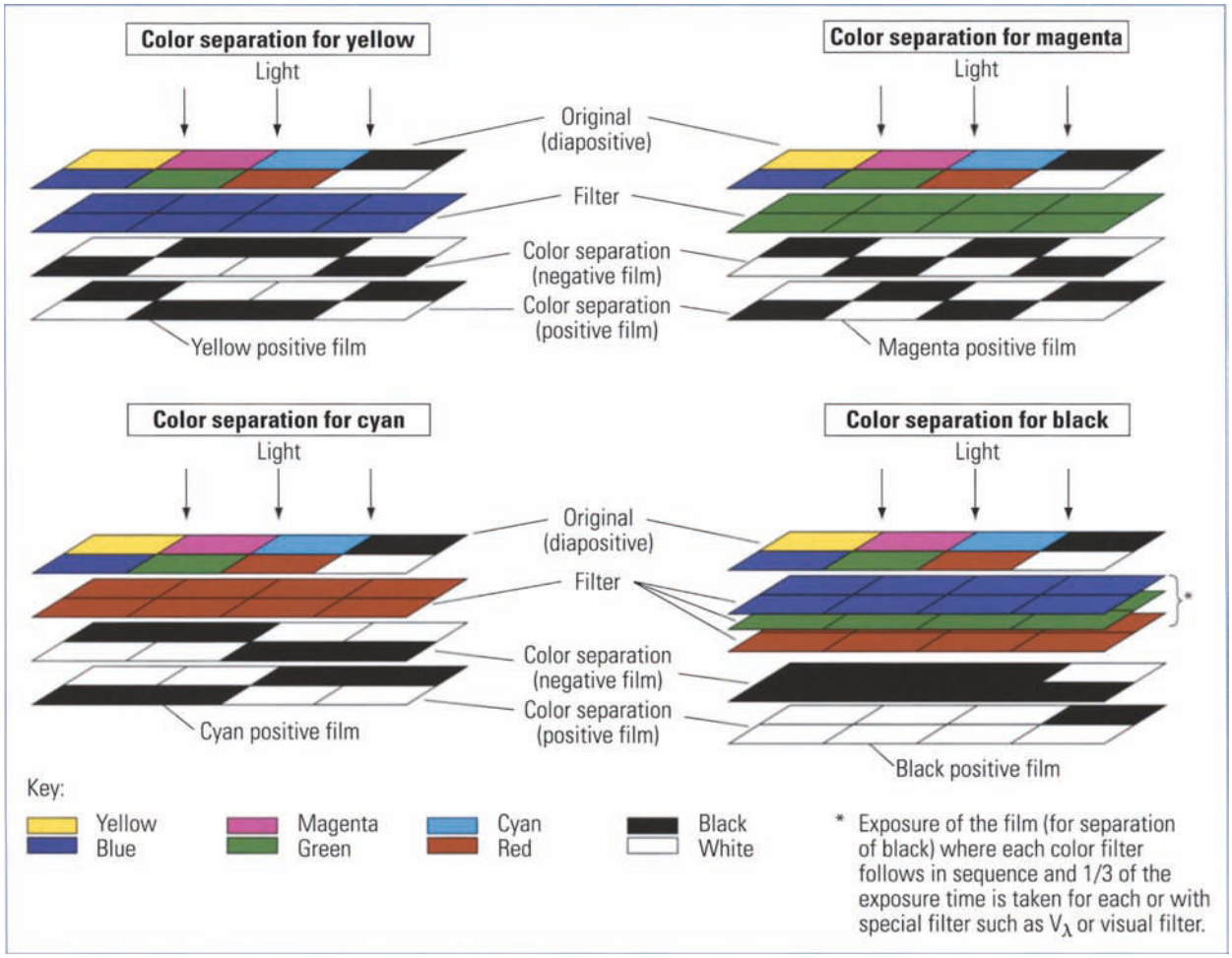
The cyan negative is exposed with the red filter, the magenta negative with the green filter, and the yellow negative with the blue filter. The black separation is usually produced by exposing through all three color filters one behind the other. Figure 3.1-33 is a schematic and idealized representation of the production of color separation films.

Multicolor printing is discussed in detail in sections 1.4.1 and 1.4.2.

Screen Angles

In autotype printing processes, *continuous-tone reproduction* is achieved by screening. The amplitude-modulated (AM) screening used in conventional prepress consists of halftone dots of different sizes according to tone value, but at constant distance from one another, for example, $w = 1/80$ cm in the vertical and horizontal direction for an 80 lines/cm screen (screen frequency $L = 80$ lines per centimeter or spatial frequency $f_s = 80$ cm^{-1}). The screen ruling is chosen so that the human eye is no longer able to define the individual halftone dots from a normal viewing distance, but instead registers an impression of continuous-tone-like color and structure through integration of the image elements (see sec. 1.4.3).

However, since increasing the *screen ruling* results in a reduction in the tonal range of the printed image and an increase in dot gain for offset printing, the lowest possible screen ruling should be selected. In addition,



Production of color separations (idealized representation, in particular there is no representation of gray tones on the films, and filters are assumed to be ideal with respect to their spectral gradation)

higher screen rulings require papers with a smoother surface for reproducing very small halftone dots. In offset printing, black-and-white continuous-tone images are reproduced with a screen ruling of predominantly L = 60 cm^{-1} and colored images of L = 80 cm^{-1} due to interference patterns (rosettes). In offset printing of newspapers L = 40 cm^{-1} (black-and-white) and L = 60 cm^{-1} (colored) are often used.

For single-color images the halftone structure has least visibility if it is rotated 45° to the horizontal; the eye is better trained to see horizontal and vertical lines and has a lower sensitivity to diagonals (fig. 3.1-34a).

Multicolored images are produced by overprinting the *screened color separation* images. Overprinting the dots of the individual images exactly is not technically possible, nor does it make sense and is not necessary; there are always variations in the position of the printed images, which can even vary from sheet to sheet. Although these variations are in the range of hundredths of a millimeter they are enough to produce clearly visible color variation in the printed image if the screens for the individual colors are set at the same angle. If, in addition to this linear variation, there is also a slight rotation of the screen of one par-

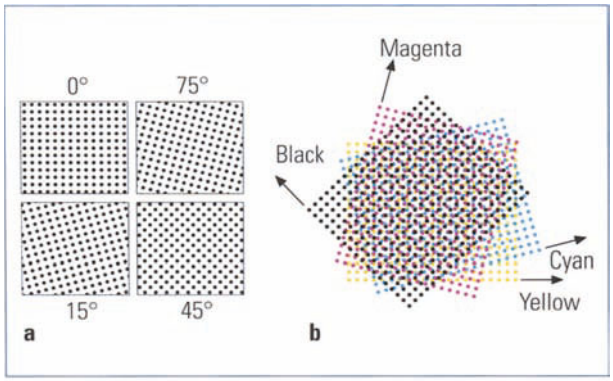


Fig. 3.1-34 Screen angles for halftoning.
a With monochrome images a screen angle of 45° will be least noticed;
b Typical screen angles for four-color images

tial image in relation to another, a regular geometrical pattern is clearly visible that has a noticeable effect on the reproduction of the image. This *unwanted interference pattern*, called "*moiré*", is dependent on the angle of rotation (see figs. 1.4-27, 1.4-28).

Rotating the screens 30° to one another produces a print that is virtually immune to the slight rotations and movements of the color separation images in relation to one another. But this angle of rotation allows only three distinct positions, since the relationships repeat themselves after each 90° due to the symmetry of the halftone structure. DIN standard 16547 for four-color printing defines, therefore, that the least noticeable color, yellow, is rotated at an angle of 15° between the other more distinct colors. This results in the *standard screen angling*: 0°, 15°, 75°, and 135°. Since the angles are repeated after 90°, the 135° angle corresponds to an angle of 45°. According to the standard it is recommended that the most noticeable color is set at an angle of 135°. This is often black but may also be cyan or magenta depending on the subject matter. Yellow is always set at 0°. The two remaining colors are set at 15° and 75° screen angles (fig. 3.1-34b).

If more than four colors are printed, the screen angles should be used twice. Experience has shown that complementary colors should be set at the same angle, for instance, in "*HiFi color printing*" where seven colors, that is red (15°) green (75°) and blue (0°), are printed as separate color images in addition to the standard process colors.

3.1.4 Electronic Reproduction Technology (Repro Scanner)

Electronic reproduction technology represents a high-performance, user-friendly technology. It is far in advance of photomechanical reproduction with respect to its processing possibilities and the precision involved in mastering the individual processing steps. In addition, it was not until the appearance of processes involving electronic reproduction technology that certain technologies such as non-periodic (FM) screening (see sec. 1.4.3), the chromatic composition with under color removal or achromatic composition of color images (see fig. 1.4-24) became possible. These are characterized by the universal use of digital technology and these current digital technologies are dealt with in section 3.2.

Electronic reproduction technology also came to be used at a very early stage in conventional prepress to record originals and process images. The output is generally a film that represents only a part of the page or sheet to be printed.

Repro Scanners

Electronic reproduction devices, also called compact scanners, color separation scanners or scanners for short, consist of three functional units: the input unit/scanning system, the computer or processing unit, and the exposure or output unit/recording system (fig. 3.1-35).

The *scanning system* is used to scan in the original in the form of lines or dots. This involves converting the

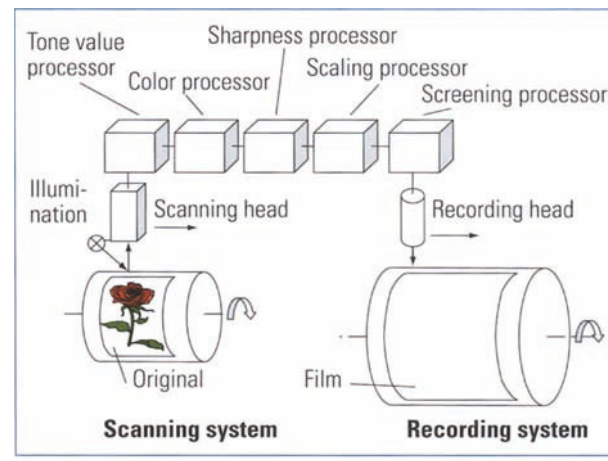


Fig. 3.1-35 Schematic diagram of a color separation scanner

light energy reflected (or transmitted in the case of transparent originals) by the original into an electrical analog signal, corresponding to the tone and color value of the original. This electrical signal is corrected, amplified, and sent to the output unit/*recording system*, where it is either converted into light energy and exposes light sensitive materials or used to control an engraving stylus for engraving gravure cylinders.

Scanning Unit. In the scanning unit the original is scanned by an optoelectronic sensor using the reflection or transmission process (fig. 3.1-36). The original is either scanned flat, line by line, based on the principle of the flat-bed scanner or is bent over a drum that turns at high speed during the scanning process while the scanning head is moved slowly along the axis of the cylinder so that it scans the original line by line similar to a very fine screw thread (see fig. 3.1-35).

Scanners for color separations (fig. 3.1-35) are typically of the *drum design*, the drum consisting of transparent plastic or glass. When scanning *transparent originals* the illuminant beam is directed internally along the axis of the drum and diverted vertically onto the drum wall via a mirror or prism. The scanning head, which is perfectly aligned with the illuminant beam, is located outside the drum. For color scanners, the illuminant must be white light (neutral). Halogen or high pressure xenon lamps are examples of suitable light sources. Monochromatic laser light is only suitable for scanning black-and-white originals. For scanning *opaque originals* the illuminant light is directed from the outside onto the scanning area of the original that is bent over the drum.

In the scanning head the scanning beam is split into four individual beams with the aid of optical beam splitters, for instance, semi-transparent glass plates. Three of them pass through the image aperture via one of the color filters (red, green, blue) onto a separate photomultiplier. The fourth beam passes through a larger aperture (sharpness enhancement), and impinges on a fourth photomultiplier, which is used to increase electronic acuity. The photomultipliers convert the illuminant light modulated by the original into an analog electrical signal. Figure 3.1-36 shows a diagram of a scanning head.

Flat-bed scanners are often equipped with *CCD lines* or arrays (CCD charge-coupled device). These are very small photocells arranged in a line or matrix. For example, a standard build length of 36 mm contains 1024, 2048, 3056, or 4096 pixels in one line. Using a lens & mirror system the width of the original, which lies flat on the bed of the scanner, is reduced enough to be

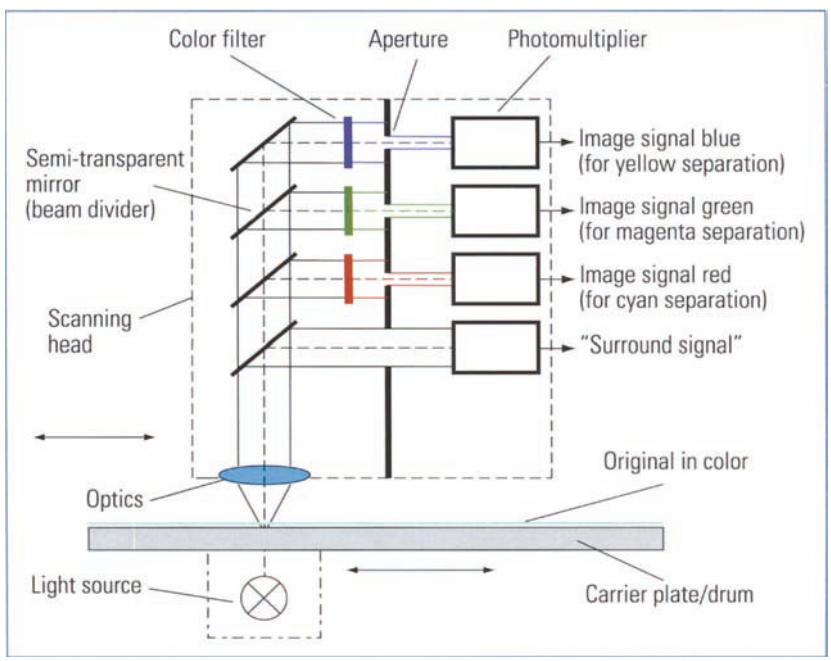


Fig. 3.1-36
Scanning head of a color separation scanner (schematic diagram)

completely picked up by the CCD line. Each pixel in the CCD line converts each tone value of the original line into an electrical signal. The mirror slowly passes across the whole length of the flat original and thus records it.

One CCD line is sufficient to record black-and-white originals. In color scanners the line being scanned is divided into three separate lines by beam splitters, each of which is recorded by a CCD line via a color separation filter (red, green, blue). Other designs employ CCD chip arrays that are equipped with lines of overlapping cyan and yellow masks (the mosaic filter technique) (see sec. 3.2.3). In the overlap area a green mask is produced and the color information for the red and blue portion of an image element is calculated from the individual color signals by logical operations.

Processor Unit. In the processor unit the signals produced by the scanning unit are processed with objectives that are relevant to the image. In early products the analog signals were varied, that is, corrected by potentiometer adjustments. This was done by changing the size of the signal voltage linearly. It is true that this method achieves the aim but voltage fluctuations lead to first-order errors in the total result. They cannot be recognized as errors and compensated for. Carefully designed and costly circuits are required to maintain constant voltage and achieve accurate, stable, and reliable correction. In addition, the small correction values, which are typically of the order of a percent of the signal value, can hardly be set with any degree of accuracy. Also, as a rule, the analog process is associated with real time processing. The scanned readings are immediately converted and output to the writing unit without being stored.

Digital processing allows greater control of these problems (voltage fluctuations, processing of very small correction values, real time processing without intermediate storage). The curve of the analog signal is described by a discrete sequence of numerical values by dividing the total range of signal values into steps of equal size (quantized). The smaller the steps chosen, the better the "stepped line" approaches the continuous analog curve.

When using the digital computation technique to process colored images in prepress the signal values for each color are usually processed with 8 bit (255 steps); the signal curve of each individual color is therefore divided into 8 bit = 256 values. As shown in figure 3.1-35 each scanner signal passes through the color processor, tone value processor, sharpness processor, scaling processor, and the raster processor.

The *color processor* carries out color correction. There are errors present in the system since color filters as well as printing inks do not have ideal spectral absorption or transmission behavior. On the one hand, therefore, there are small areas in the reflectance spectrum of an individual color that actually belong to other colors; on the other hand, the individual color does not attain its full color strength. These system errors are compensated for by the basic correction. Specific requests from the customer to alter the color or to address the lack of particular colors may be carried out using selective correction on the primary colors (cyan, magenta, yellow, and black) and on the first order secondary colors (red, green, and blue).

Originals often have a greater density range than can be reproduced in the print. The range must therefore be adapted to the print in such a way that the least amount of information (details) is lost. It is estimated that an observer is still able to distinguish differences in density of 0.02 optical density units (this value is highly dependent on the observer, his age, defective vision, training, tiredness, and attention, as well as on the subject matter, the distance between the surface elements being compared, their relative size, and the image background).

In an offset print that has a density range of 1.6 density units, 81 tone values are discernible according to the above assumption. If the original is a transparency with a density range of 2.6 density units, 131 tone values may be detected. A linear reduction of the density range of a transparency original to that of the print means a loss of information. The *tone value processor* offers the possibility of producing reproduction curves (gradation curves) with various paths. The operator must select the most favorable variant based on the subject matter. It is also necessary to adjust the gray balance, that is, the gray produced by overprinting cyan, magenta, and yellow, which is very sensitive to slight variations in the component colors, resulting in a color cast.

The *sharpness processor* is required to achieve an increase in sharpness from the image and surrounding signal (fig. 3.1-37). Since the scanning spot for the image signal is of a certain size (e.g., 30 microns in diameter), the result of scanning is associated in principle with the unclear reproduction of contours. A density jump in the original will be smoothed away as a gradual transition having the width of the scanning spot.

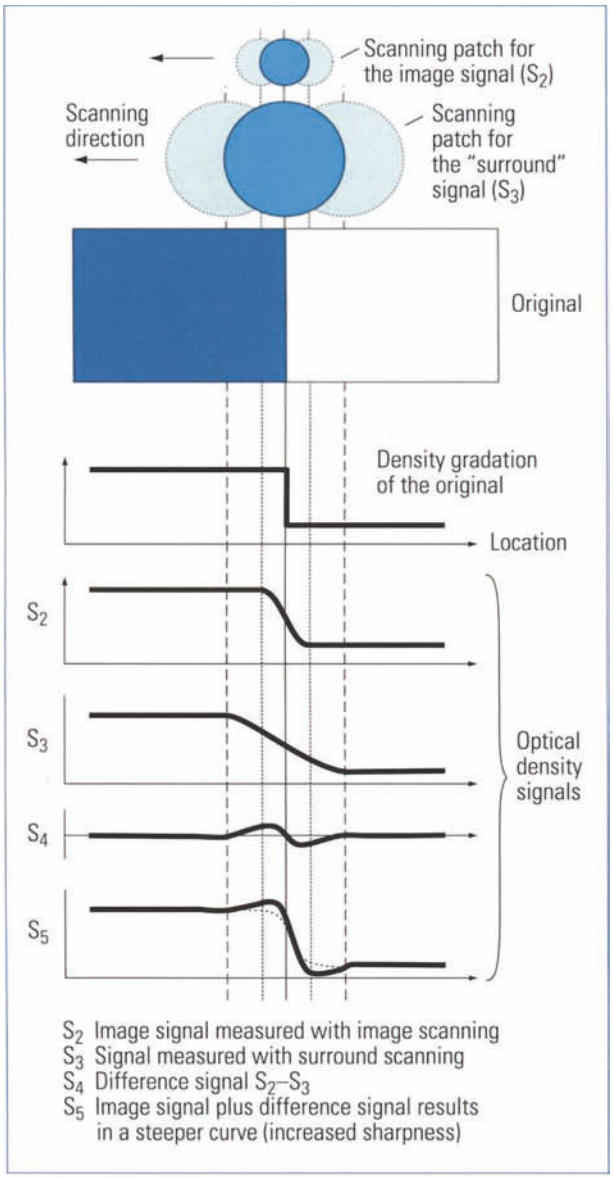


Fig. 3.1-37
Schematic diagram of increase in electronic sharpness improvement based on analog measuring signals

The combination of the scanning curve of the image dot with that of the greater surrounding dot gives a steeper reproduction of the transition curve, associated, however, with an increased height.

The scaling of the image to be reproduced takes place in the *scaling processor*. The scale may be altered in the horizontal and vertical direction independently – either fixed and/or movable. Two principles of scale alteration are used: the use of scanning cylinders with various diameters (corresponding to the whole, half, or quarter of the diameter of the writing drum, which can give 100%, 200%, and 400% lengthways) and/or electronic scaling (which requires intermediate storage and can be produced in any scale).

In the *screening processor* the tone values of the image elements for each component color are converted to the assigned size of halftone dots. This always occurs digitally after prior digitization of the measured analog signal. Electronic screening is described in sections 3.2.1 and 1.4.3.

Screening is carried out in the *analog recording process* by exposing the film after prior digitization of the measured analog signal with image modulated lightness through a contact screen placed on the film.

Output Unit. The construction of the recording system corresponds in principle to a drum imagesetter (see sec. 3.1.2). In compact scanners the recording drum and scanning cylinder are linked mechanically. In general digital scanners have separate scanning, processor, and output units.

3.1.5 Assembly

3.1.5.1 Page Make-up

The combination of text and images to form a page occurs during the page "make-up". In the production of conventional printing plates the complete page is put together manually by repro experts from text and images that exist mainly as cut films.

The *films* are placed on a carrier sheet, adjusted for position, and fastened in place. The quality of the print depends directly on the precision and care of the make-up. Register errors caused at this stage are unlikely to be able to be compensated for later in the print. Film stripping is carried out on a light table (see also fig. 1.2-24). Its work surface consists of a glass plate that is illuminated from below with diffuse white light. Two steel rulers at exact right angles, which may be moved in parallel, are used to ensure accurate stripping.

In preparation for the stripping a millimeter sheet is first placed on the light table with the carrier sheet on top and fastened with adhesive tape. The carrier sheet is a plastic film that is dimensionally stable, insensitive to moisture, crystal clear, clean, and free of scratches

and should be as resistant as possible to build-up of electrostatic charge. Polyester film with a thickness of 0.15 mm has proved useful for this purpose. Medium and large-format assembly work (e.g., sheet assembly) makes use of 0.3 mm film.

The several films are always mounted with the coating facing uppermost so that during subsequent copying exposure occurs coating to coating to avoid undercutting. This means that for an offset plate wrong-reading film copies must be produced. The films for text and image are placed in the correct position according to the layout and attached to the carrier sheet with liquid adhesive or adhesive tape. In addition the films must be cut to the required size without burring, using for example a scalpel and a glass base or a film cutter. The films on the carrier sheet must not overlap since intimate contact between the film and the printing plate will be affected by the thicker overlapping layers of film during subsequent copying leading to undercutting during exposure of the plate and an imperfect copy (undercutting) (fig. 3.1-38).

Offset printing employs mainly *positive printing plates* (see sec. 2.1.1.2). These require a wrong-reading positive film assembly, during which difficulties may occur due to the cut edges of the film, particles of dirt, or dust as well as scratches and the edges of the adhesive tape, which act as image areas during platemaking by increased light absorption.

Adhesive tapes for fastening the film securely to the carrier sheet are single-sided adhesive strips of 0.05 mm thickness. Crystal clear or light blue transparent adhesive tapes are used for positive assembly. Despite their thinness, they still disrupt the direct contact between the film and the printing plate during platemaking, which may lead to undercutting. Adhesive tapes must therefore only be placed on an image-free margin on the film that is sufficiently wide; there should be a minimum of 5 mm between the edge of the image and the tape. The adhesive strips must also be cut burr-free. If there is insufficient space available the film must be attached to the carrier sheet with a liquid adhesive or a spray.

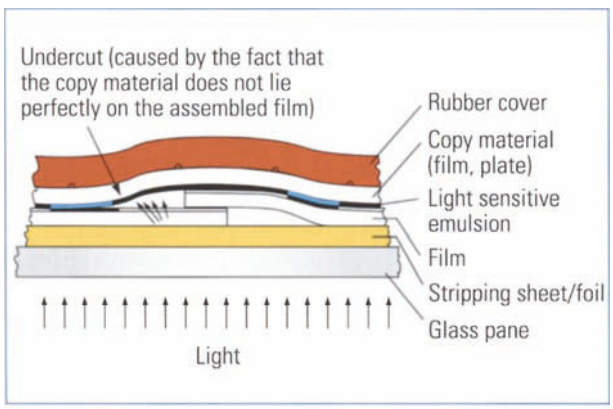


Fig. 3.1-38 Undercutting caused by overlapping films

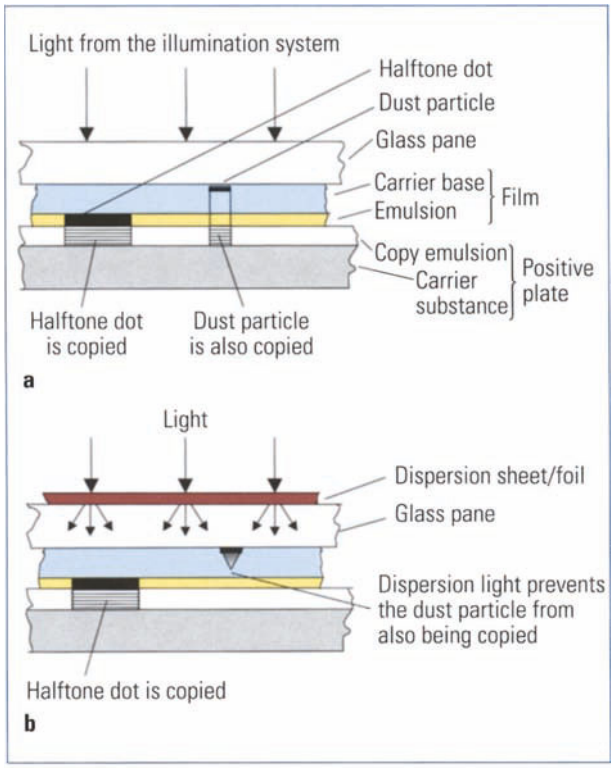
The assembly of multicolored images must be carried out with particular care as imprecision translates directly into register errors. In particular, errors of parallax caused by registering the color separations when viewing from an angle must be avoided. It is possible to improve precision during assembly by using a magnifying glass (pocket lens) or a microscope, which enlarges the image element under scrutiny and automatically provides a vertical viewing angle.

Two technologies have become established in the *assembly of color separations*:

- *Guide assembly.* A guide assembly is first produced with the separation films of the color having the clearest visible details. It acts as a base for all of the other separations that are each mounted on other carrier sheets. The contrast between the guide assembly and the separation being worked on is improved if a matte film is placed in between to make the guide assembly appear gray.
- *Blue key.* Better registration is achieved by this process. A positive or negative blue key is produced from the guide assembly on precoated light-sensitive plastic film. The light-sensitive coating is dyed blue or bluish red; the dye is transparent to the copy light. The separation is mounted on this film.

Cut edges and minor imperfections during positive platemaking are exposed away by placing a *dispersion sheet/foil* in between (fig. 3.1-39).

Negative assembly (i.e., ink-carrying/image areas appear light in the film) is frequently used in newspaper production. Dark brown or black adhesive tape is used to mount the negative films on the carrier sheet. The whole assembly area is covered with a backing sheet that is transparent on the light table but opaque to the UV-containing copy light. The backing sheet is cut away in all the image areas, which means there are no defects caused by cut edges or dust as may occur during positive platemaking. An imperative for negative assembly is that the image areas are perfectly transpar-



3.1-39 Exposing away of dust when imaging the plate.
a Copy without dispersion sheet;
b Copy with dispersion sheet which prevents dust particles from also being copied

ent (D<0.05) and non-image areas have good opacity (D>2.5).

Since manual registration of four-color images is difficult in negative assembly and is therefore fraught with greater errors, it is used predominantly for single-color work. It is advantageous to copy the images during a second stage in exposure onto a plate that has already been exposed with the text and graphics. The image areas are blackened out in the text film copy and the plate at first remains unexposed in these areas during copying. Alternatively, the non-image areas of the image film copy are black in order not to destroy the already exposed areas of text by a double exposure.

For *quality control* a blueprint proof is produced from each finished assembly, which is used to check the position, completeness in all color separations, and the text and image. These checks should be carried out very carefully as changes to the assemblies during the make-up stage may be made without a great deal of extra time, or financial or personal expenditure.

3.1.5.2 Sheet Assembly

If the ready made-up films (text and images are put together in the correct position) are available for all pages (full-page film), such as in the form of manually created assemblies or as electronically made-up full-page films output by the imagesetter, they must be mounted as a full-sheet size film, corresponding to the sheet to be printed. The positioning of the full-page films in sequence and orientation as well as the precise location of the individual pages on the sheet must be established by taking into account the following list of points (in addition other control and editing elements must be added to the assembly):

- printing process (halftone film copy for autotype printing processes, continuous-tone copy for variable depth gravure printing; right-reading film for direct printing processes, wrong-reading for indirect; positive film for positive-working plates, negative film for negative plates),
- type of printing press (gripper edge for sheet-fed machines; pin edge, roller gaps, register marks, transverse register balance of stretching due to humidity for web-fed machines),
- print format of the press used,
- method of turning the sheet for printing on both sides (work and tumble with sheet-fed presses equipped with a perfecting unit; work and turn or work and tumble with sheet-fed presses without perfecting unit; simultaneous printing on both sides with presses equipped with blanket-to-blanket units),
- imposition diagram of the folding machine or apparatus,
- method of binding the whole printed product (allowance in the inside margin for cutting off the folds in adhesive binding),
- method of finishing (overfold for gathering or inserting drum processing in the dispatch room),
- direction of paper travel (long grain, short grain paper for sheet-fed presses, see fig. 1.5-3, portrait or landscape formats for web presses),
- position of the folded sheet in the end product (arrangement of page numbers, e.g., one to thirty two on the first sheet as well as on the pages for the other sheets),
- number of colors per side of sheet,

- auxiliary marks (registration marks, trimming marks, folding marks, allocating marks, register marks, signature line, color identification, ID number),
- control patches (print control strips crosswise to the print direction over the total width of the sheet, copy control wedges on a non-printing area of the plate).

Other specifications must be observed according to the job.

This makes sheet assembly stand out as an information-gathering point of central importance for achieving trouble-free results. Although the handling of each individual stage is almost identical to page assembly, the content is much more comprehensive.

The first step in producing a sheet assembly [3.1-7, 3.1-12] is to draw a *layout sheet* containing the correct measurements (fig. 3.1-40). It is the same format as the sheet with an additional border and is made of dimensionally stable transparent material/paper. If we take a layout sheet for a sheet-fed offset press as an example, after positioning on the light table parallel to the axes and fastening with adhesive tape, the sheet format, gripper edge, the beginning of the print, and the center line are marked in. The data required for this are in the documentation referring to the press or may be obtained from the job itself.

According to the measurements given in the imposition diagram (which should be checked in each case with the aid of a hand-made folded sample) the exact outlines of all of the pages to be accommodated on the top surface of the sheet must be accurately drawn, in reverse (wrong-reading). These include the distances between the pages taking into account allowances for folding and trimming. The page number must be entered in the bottom outside corner of each page.

This clearly indicates the position and orientation (upright or upside-down) of each page. After marking in the position of the control elements and auxiliary marks, the layout sheet is complete. Cut and fold marks should be designed so that they cannot be confused during the finishing process and so that they cannot be seen on a final print that has been badly trimmed. Color control bars should be placed in the border so that they can be trimmed away from the print. The space for the sheet signature, the ink description and the ID number must be marked.

For the reverse side of the sheet the layout sheet should be marked according to the same considerations while taking account of the type of inversion to be used. Hence two layout sheets must be produced for each sheet.

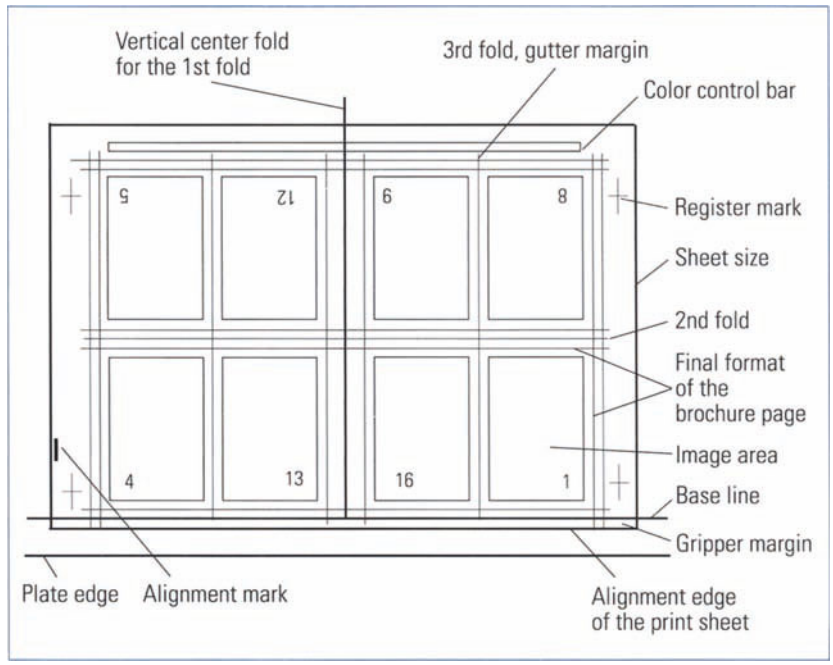


Fig. 3.1-40
Layout sheet for page assembly with regard to the print sheet and arrangement of control elements and print finishing information; example: front side of a 16-page brochure, produced through three folds

For the sheet assembly the layout sheet is accurately positioned and fastened on the light table – if necessary with a millimeter grid placed underneath. A carrier sheet/assembling film is placed and positioned above. The completely assembled films for the individual pages are registered on the layout sheet and stuck down. As with page assembly, sheet assembly of process color sets is carried out either using guide assembly technology or with a blue key.

Register Systems

Register alignment and setup operations require great care to keep assembly errors to a bare minimum. This makes such work very time-consuming and demanding. The time taken to achieve this or even greater accuracy may be reduced by the use of a mechanical registration system. This is particularly true if register systems are used throughout the entire processes of:

- page assembly,
- sheet assembly,
- platemaking, and
- mounting the plate in the press.

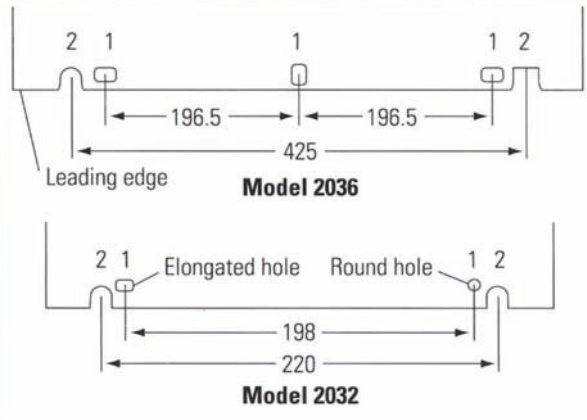
The principle of registration systems lies in the production of a one-to-one positive position fixing of the information carriers when relative movement to one another is still possible, which means before securing with adhesive tape in the case of page and sheet assembly, before pneumatic pressing in the case of vacuum frames, before clamping of the printing plates in the case of mounting the plates in the press, before beveling the plates for web-fed presses, and so on.

For example, *register pins* with a tight tolerance for their external diameter are used, on which the information carriers are placed having punched holes with equally tight tolerances in defined places. The register pins are applied to a flat *base rail*, which is fastened with adhesive tape to the light table in the exact position. The information carrier (e.g., the assembling sheet) is precisely fixed at certain points (x- and y-direction) by means of one register pin and the related hole. The remaining degree of freedom, the possibility of rotating the assembling sheet on the supporting surface around the register pin, is clearly fixed by a second register pin on which the assembling sheet with its punched elongated hole is placed. The axis of the elongated hole must lie in the direction of the center of the round register hole. This produces a definite one-to-one positioning. This principle is used for:

- positioning assembling sheets on the light table with attached millimeter grid, layout sheet, and ruler shifting device,
- positioning assembling sheets one below the other in multicolor assembly,
- positioning the assembling sheet to the printing plate in the vacuum frame before pneumatic tension,
- positioning the plate in the plate cylinder before attaching the clamping bars,
- positioning the plate in the beveling device for web offset machines.

Although one round and one elongated hole, each carrying a register pin, give an exact one-to-one positioning in the plane of the film/plate, for large-format work more elongated holes are punched out to ensure that position is maintained over a greater width without the edges of the elongated hole being exposed to excessive strain. Although this means that the system is overconstrained, this method of working has become accepted practice.

To mount the *printing plates* on the plate cylinders they are pushed into the open clamping bars. Threading them into punched holes would require too much effort; the plate is therefore provided with U-shaped, punched holes on the leading edge, that is to say half-round and half-elongated holes. When the plate is lying evenly on all the register pins of the clamping bar or plate cylinder,



1 Punched holes for the plate exposure to hold underlay rails with register pins (for aligning the film)
2 Punched holes for mounting the plate in the press on the plate cylinder

Fig. 3.1-41 Plate punch (CONTROL 2000 register system, Bacher)

it is in the correct position. Register scope pins allow an additional visual check of the correct position of the plate. Figure 3.1-41 shows a system for punching register holes. (Fig. 1.2-27 shows the positioning of the carrier sheet in the vacuum frame for the platemaking process.)

3.1.6 Proofs/Test Print

The result of prepress – in particular error-free typesetting and its correct location on the page, the quality of the images, the registration, the quality of color reproduction on the paper, the reproduction of details and their correct location on the sheet in all color separations/colors in accordance with the original – should be checked for accuracy at the earliest possible stages in the process. In doing so, the necessary corrections can be recognized in good time and printing errors avoided at the outset. Section 3.2.11 describes the proofing processes in detail, in particular for the digital proof. The following proofs are typical of what is used in conventional prepress:

- galley proof,
- position proof/blueprint,
- color proof,
- press proof.

Depending on its position in the total process the function of the proof is:

- quality control,
- quality monitoring,
- agreement document between customer and print producer,
- reference standard for printing the job,
- documentation for the job as the basis of possible repeat jobs.

The different proofs listed above are used in the following manner during prepress, up to the point of printing and during the job.

Galley Proof

Galley proofs are produced for corrections to typesetting products such as continuous text, headings and titles, headers and footers for individual pages, picture captions, footnotes, indexes, and tables of contents, as well as to control the completeness and correct location of marks and control strips. They are produced as a paper printout of typesetting files, or as a paper print or blueprint of typeset columns preset in film form or film assemblies. After checking and marking necessary corrections the originals are altered and released for the next processing steps.

Position Proof/Blueprint

Position proofs are required to check the completeness and correct location of text and image. Blueprints from the film assemblies or full-page films fulfil this purpose very well and are also cost-effective (see sec. 3.2.11.3, "*Blueprint*").

Color Proof

Color proofs are necessary for judging the quality of multicolor products. The color proof may be produced for individual images, but it is preferable to produce them for the whole page, although this is less often feasible for the whole sheet – mainly due to reasons of format. For the printing side the color proof may be used to control the correct position of the individual color separations on the page, accurately registered assembly, the approximate overall color effect of the page or the representative color reproduction of the printed product to be produced, but with certain limitations, since the proofing process and materials used are generally not the same as the technology and materials used to produce the job; color management assists in optimizing this (see sec. 3.2.10).

Analog proofing, that is processes that are based on film, use colored diazo layers on thin films, which are individually exposed with the color separation halftone film of each respective component color, developed using the wet process, and transferred to a carrier material. Examples of these are the products "Matchprint" and "Color-Key" from Imation (formerly 3M) or "Color Art System" from Fuji. The analog proofing systems "Cromalin Tonerproof" and "Cromalin StudioSprint" (or "EuroSprint") from DuPont use layers of colored powder toners that are applied dry or partially removed from evenly covered carrier films. The individual processes mentioned before work as follows:

The "*Matchprint*" proofing process offers a wide variety of color sets and the possibility of simulating various printing processes. A film is laminated onto a dimensionally stable white carrier, the film having a light-sensitive coating of the color to be proofed. The color separation for the job to be proofed is placed on this film in register and exposed in the vacuum frame. An analog image of the color separation is produced

during the subsequent wet development process. A film with the next color in sequence is now laminated onto this partially present image. This film has a light-sensitive layer for the respective color. The film of the color separation is laid on and positioned in register with the first color. In order to aid positioning, the color having the greatest contrast should be used as the first color, that is, black or cyan. After registering, the film is exposed and developed. This simulates the printing of the second color. The remaining color separations are processed in a similar fashion, until the complete multicolor print has been simulated.

The color films are available in process colors in accordance with the Europe scale and the American standard, as well as numerous special colors. They are available as positives or negatives to allow use for positive or negative films. In both cases the color densities and tone values are simulated according to the standard, for instance, a dot gain of 18–22% or 22–25% for a screen ruling of L = 60 cm^{-1}. Various carrier films and gloss adjustment foils are available to aid simulation of the whiteness, color, and gloss of the intended substrate.

The *Color Art System (overlay type)* from Fuji also uses colored transparent sheets that are produced for each separate color in an exposure, wet development, and drying process. The transparent sheets with the separated color images are transferred in the sequence black-cyan-magenta-yellow onto a receiver film in the Fuji Color-Art thermal-transfer printer/laminator. The four-color product can then be transferred onto a base paper with the thermal-transfer printer/laminator. To stabilize the transferred image a bump exposure is carried out. The product can finally be laminated with a matte film if required.

In the "*Color-Key*" color proofing process, films are produced by copying and wet development in each component color – positive films for color separations, which are then mounted in register onto a carrier board. This allows the final paper stock to be placed underneath so that the expected printed result can be easily judged. Color-Key films are also available in many hues.

The Color-Art system (*single sheet type*) from Fuji uses a similar method. Figure 3.1-42 shows the superimposed films with the color separation images for black, magenta, cyan, and yellow.

In the "*Cromalin Toner Proof*" a colorless transparent film with an adhesive acting layer on the surface (fig. 3.1-43) is laminated onto a white carrier and exposed in a vacuum frame with the color separation film (halftone positive) placed on top. The exposed areas of the film lose their adhesive nature due to polymerization. A finely grained powder toner (in the same shade of the color separation film used before) is then applied onto the film in the automatic proof press. The toner adheres only to the unexposed (tacky) areas. An image of the color separation is produced. A second film is then laminated, which is again exposed in the vacuum frame with the positive film of the next color separation exactly in register; this is then treated with powder in the corresponding color and so on up to the final color separa-

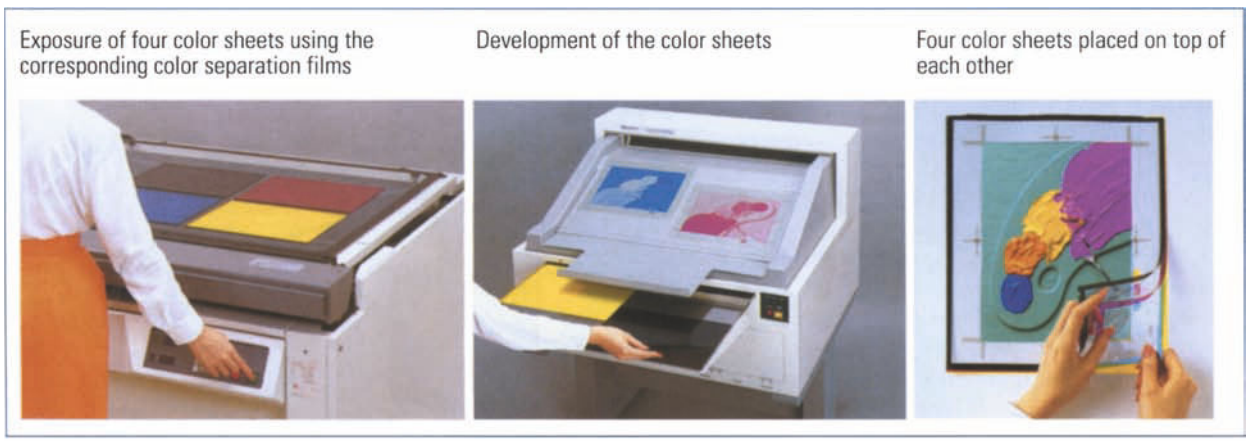


Fig. 3.1-42
Analog proof: color sheets that have been produced from the corresponding color separation films are fastened on a white background in accurate register (Color Art System/Single Sheet type, Fuji)

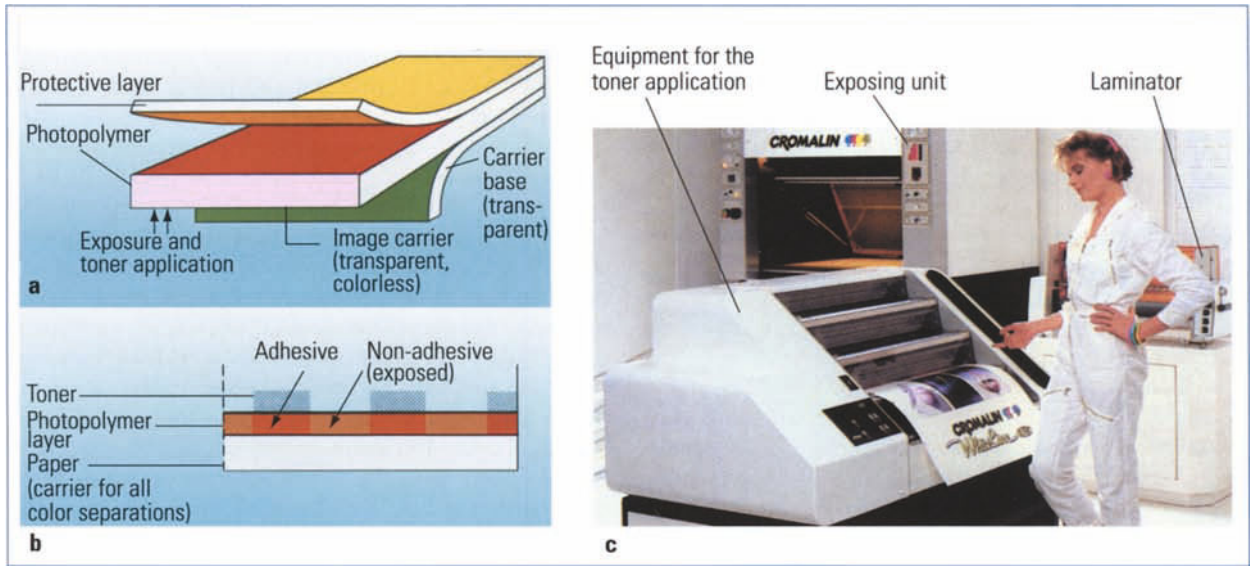


Fig. 3.1-43 Analog proof using a toner-based process.
a Layer structure of the sheets with an adhesive layer (photopolymer) that loses its adhesive property during exposure with a positive film (the protective layer is removed prior to laminating onto the substrate/paper, for exposure the film is placed on the carrier base, then the carrier base is removed to apply the toner);
b Toner adheres to the unexposed areas;
c Devices for the analog Cromalin color proof (Cromalin, DuPont)

tion. This produces a complete color proof. Dot gain in the standard range is also simulated in this process by the properties of the film and toner materials.

With the *Cromalin-StudioSprint* (fig. 3.1-44) the coloring of the exposed Cromalin Proof sheets laminated onto the film is not performed with a dry toner, but each sheet has an even layer of color distributed over the entire sheet, which is then brought into contact with the proof. When the color sheet is removed from the proof sheet the color will only adhere to the tacky areas of the proof sheet. The image of the color separation has formed. After that the next proof sheet is laminated, exposed, and treated as described above. The work steps of laminating, exposure, color film application, and the color films in the proofing system are illustrated in figure 3.1-44.

These color proofs produce colored images similar to prints without the need to prepare a printing plate, by using the films used for producing the plates. In the case of simulating offset printing, the limits of the process are in simulating the substrate with respect to its color, opacity, light scattering properties including



Fig. 3.1-44
Analog proofing: after exposure, color transfer films are applied to a special carrier substance (Cromalin StudioSprint, DuPont)

light entrapment ("light gathering"/optical dot gain) and gloss, and also regarding the actual "mechanical" dot gain occurring, ink acceptance, and the related effect of the color sequence in printing. These color proofing processes are not effective for screen rulings of greater than L = 100 cm^{-1}.

Press Proof

This proofing process has the best achievable correlation with the subsequent printing of the job, especially if the printing press used is the same one that will be used to print the job. This requires a full set of printing plates. The printed proof is produced on the paper and with the ink used for the job. The effort for producing such a printed proof is considerable and only justified for very high quality requirements. To keep high speed production machines available during the time it takes to produce the printed proofs, special proofing machines are available. Figure 3.1-45 shows an *offset proofing press in flat-bed design*. This flat-bed press is equipped in succession with the printing plates of the color set. The plates are fixed on a flat table with a register system. The paper is placed and held in position on a second flat table. Dampening and inking rollers are arranged in a moveable inking system as is the blanket cylinder. After the plate has been dampened and inked, the dampening and inking rollers are moved away from the plate, and while the carriage reverses, the blanket cylinder is brought into contact with the plate and the image is transferred. Next the image is transferred from the blanket cylinder onto the substrate, which is located on the table behind the table with the plate. Each color separation is transferred in this way; in between the printing of individual color separations, the inking form rollers and the blanket must be cleaned.



Fig. 3.1-45 Flat-bed offset proofing press (Korrex 2000, FAG).
a Proofing press;
b Plate fixture on the table;
c Printed sheet on the flat-bed table

Figure 3.1-46 shows the diagrammatic view and a photograph of a *multicolor offset proofing press* in satellite configuration. These machines have not found widespread use for economic reasons.

Section 2.2.1 (fig. 2.2-9) describes proofing presses for gravure printing. The printed results of the production machine may be simulated in the proofing machine by specially altering the consistency of the ink.

Section 3.2.11 explains digital proofing processes, which are based on the use of the digital data for the print job and do not require the use of previously produced films. "Color management" plays a particularly important part in this process, to enable creation of a proof that is faithful to the job to be printed.

In conventional prepress the proofing processes explained earlier for color printing and checking text, graphics, and images regarding content and position represent the basis for giving the "ok" to proceed with platemaking.

3.1.7 Platemaking and Quality Control

3.1.7.1 General Information

Printing plates vary according to the individual technology – offset, letterpress/flexographic, gravure, and screen printing. The following sections contain a description of the different platemaking methods used for the individual technologies. This section summarizes the operational sequences forming the basis of all processes.

During platemaking itself, the master copy (generally a film) is transferred optically onto the unexposed printing plate. This is done by means of either a contact copy or projection. In the former process a film is

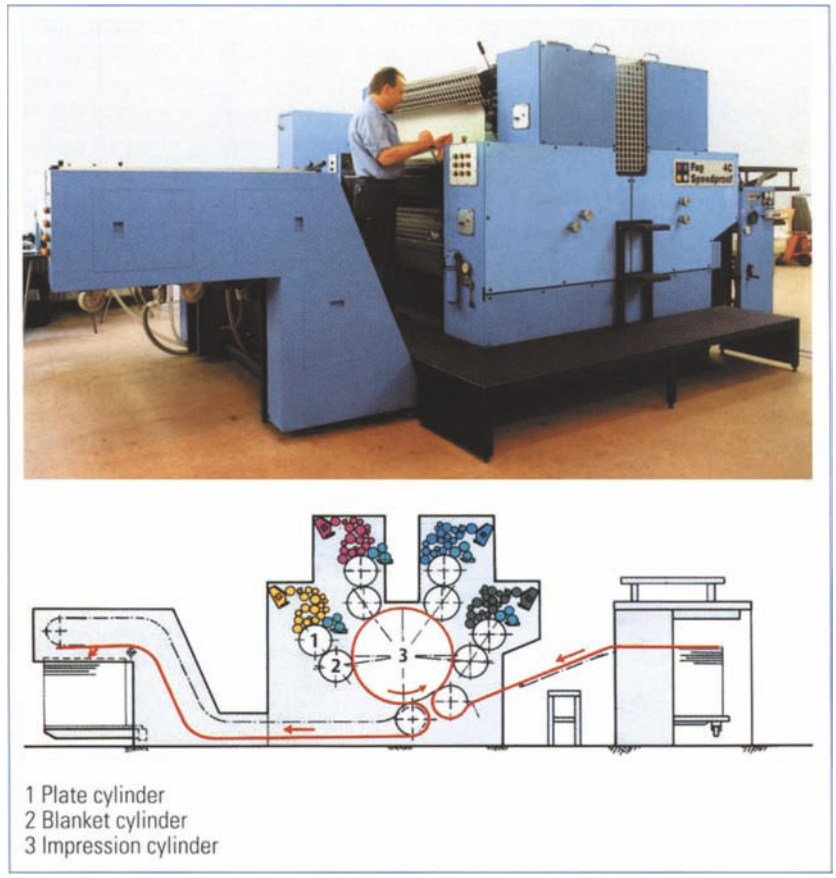


Fig. 3.1-46
Satellite sheet-fed offset proofing press (Speedproof 4C, FAG)

used whereas projection is done either from film or a reflection copy, that is, a paste-up. A printing plate is produced for each primary color of the intended print on the basis of the corresponding color separation.

With a *contact exposure*, the developed film layer emulsion lies on top of the light-sensitive layer of the unexposed printing plate; very often a vacuum is used to intensify the contact. Transfer is performed on a scale of 1:1, a wrong-reading copy becoming a right-reading copy and the other way round.

Projection platemaking is flexible with respect to both the reproduction scale and to right-readingness and can therefore be applied universally.

Radiation or exposure of the unexposed printing plate in accordance with the image may be followed by an intermediate step (such as heating) before the printing plate is developed using the chemical/physical processes appropriate to its material. This is followed by the final treatment of the plate, in which the latter undergoes after-treatment (e.g., baking to increase possible run length) or preservative measures (e.g., gumming-up to improve storage properties and printability) and is prepared for fitting in the press (e.g., punching, beveling).

3.1.7.2 Offset Printing

On an offset printing plate (fig. 3.1-47) the printing and non-printing areas are virtually planar.

The platemaking process using positive film and an appropriately designed positive-acting plate is called *positive platemaking*. The light-sensitive coating of the plates is usually composed in such a way that during processing all exposed areas are removed, as a result of which the printing plate is ink-repellant in those areas (see also fig. 2.1-4).

Accordingly, *negative platemaking* is the name given to platemaking processes using negative films. Printing plates with a negative-acting light-sensitive coating are

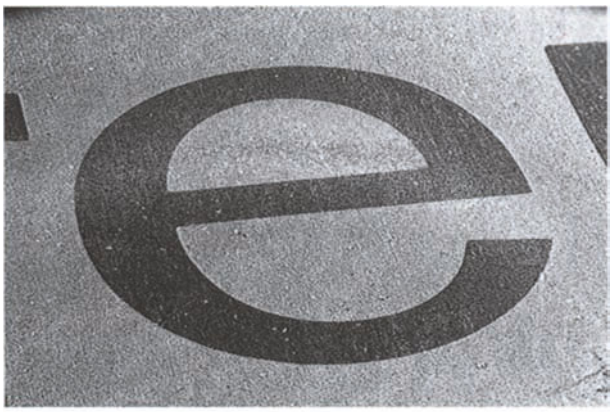


Fig. 3.1-47 Microphoto of an offset plate surface



Fig. 3.1-48
Projection exposure system (transmission technology) for offset and screen printing platemaking (Proditec Projektionssysteme)

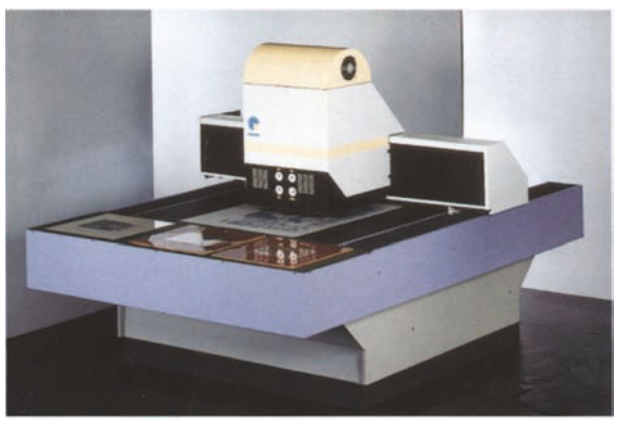


Fig. 3.1-49 Step-and-repeat copying machine (Krause-Biagosch)

used for this purpose. During processing the coating is removed from all areas that have not been sufficiently radiated. Radiation curing takes place in the ink-accepting areas.

Before the printing plates for the individual colors are exposed or irradiated, they are first punched for fixing the film/master copy. Very often the plate is also prepared with appropriate register holes for mounting it in the printing press. Alternatively, this can be done after processing, then the punching tool can be aligned (possibly automatically) to the register marks.

In conventional prepress a lithographic printing plate may be produced by projection or contact exposure.

Projection exposure systems (reflection or transmission) are used in black-and-white book printing and in newspaper printing (as well as in screen printing), with less stringent requirements on quality. A projection imagesetter works on the same principle as an epidiascope (for reflection copies) or as a slide projector (for transmission copies). The page-size master copy in the form of paste-up on paper or of film (fig. 3.1-48) is projected onto a computer-controlled traversable printing plate; consequently sheet assembly takes place during the exposure of the printing plate.

With the *step-and-repeat copying machine* (fig. 3.1-49), a complete assembled sheet/plate-size film is not required. With this machine the pages of film inserted in a film magazine are exposed according to a preset program onto the printing plate by the contact exposure method.

For exposure in a *vacuum frame* (fig. 3.1-50), a film in the full format of the printing plate is required. The film/sheet assembly is fixed on the plate in accurate register with register pins and placed in the vacuum frame. It is located between a flexible blanket and a glass plate. The space in between is evacuated with the result that the air pressure presses the blanket against the glass plate, thus ensuring satisfactory contact between assembly and plate. This is followed by exposure with UV radiation.

The photochemically reactive layer of the printing plate reacts to the actinic light of the radiation source. To ensure good processing performance a minimum energy per area must act on the printing plate. As with



Fig. 3.1-50 Vacuum frame with inserted dispersion sheet (Sack)

film producing, the timing of the exposure process depends on the radiation source and the plate material.

The radiation is mostly generated by a burner with a metal halide lamp. The radiation comprises parallel and a variable portion of diffusely oriented rays. The latter can be increased considerably by interpositioning a dispersion sheet/film. This is used in positive platemaking to prevent film edges and dust showing on the plate. Undercutting might be an unwanted effect occurring where too much irradiation reaches below the blackened parts of the film (see also sec. 3.1.5).

Processing (wet/chemical) is done manually in its simplest form, but preferably in an immersion tray or a plate processor. This is an integrated device, in which the printing plates pass through the developing, rinsing, and preserving stations.

Before preservation, the plate can be checked for errors and corrected manually if necessary. For a so-called "*minus correction*" the unwanted printing areas are etched with a deletion fluid, which is applied with a correction pen or a brush. The "*plus correction*" is more difficult. Only very simple changes can be made, such as filling in holes and reverse characters in solid areas. To do so correction varnish is applied to the areas concerned after any already existing preservative layer has been washed off.

The *correction* and *preservation* stages, as well as *baking*, form part of the after-treatment. In the preservation process, the plate is covered with a thin solution of "*gum arabic*" or similar chemical, which gives the non-printing areas storage-resistant hydrophilic properties. The hardness of the light-sensitive coating is increased during *baking*, and higher print run stability is achieved as a result.

For correct exposure the following requirements must be met:

- The entire tone value range that is usual for the printing process must be transferred to the printing plate.
- The tonal change from the film copy to the printing plate should lie within narrow tolerances.

For positive plates the control of the plate is done in accordance with a microline patch on a *control wedge*. The finest microlines shown on the printing plate should normally belong to the 12 µm or 15 µm steps (for business forms: 20 µm). An example is shown in figure 3.1-51 [3.1-13]. Especially the continuous-tone patch, in conjunction with the microline patches, is used as a means of control for the negative copy. The following specifications and/or standards give more detailed rules:

- standardization of the offset printing technology in accordance with BVDM/FOGRA (see sec. 13.2.3), [3.1-14],

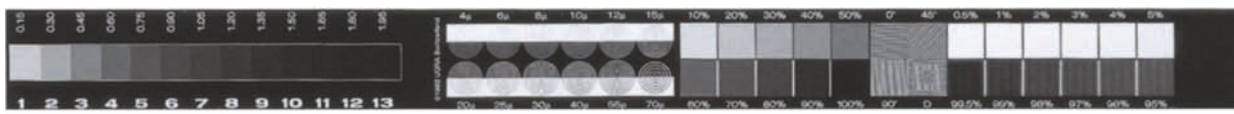


Fig. 3.1-51 Control wedge for positive and negative-acting offset plates (Ugra Plate Control Wedge 1982, UGRA)

- standardization of multicolor newspaper printing [3.1-15],
- standardization in the printing of business forms (see sec. 13.2.3), [13.2-28],
- DIN 16620 Part 2 (see sec. 14.4) or the subsequent ISO standard,
- ISO 12218 for offset printing in general (see sec. 14.4), [3.1-16].

Measurement of the tone values on the printing plate is not necessary if they can be determined from the pertinent FOGRA copy table once the microline reading is known (fig. 3.1-51). For conventional plate materials with a diazo layer, the copy table corresponds to the microscopic results. This is not always the case for digitally imaged plates (computer to plate).

As a result of the intended slight *undercutting* of the blackened sections of film there will be a decrease in tone value from film to printing form with positive platemaking and a correspondingly large increase in tone value with negative platemaking. The tone value difference is approximately 3% in the middle tone. This difference is usually taken into account in prepress. It has also been considered in the process standards for lithographic printing (ISO 12647 Part 2; see sec. 14.4), and for newspaper printing (ISO 12647 Part 3; see sec. 14.4).

For film-dependent platemaking the exposure process is controlled by means of a "light integrator." This is a device that automatically calculates the product of radiation intensity and time during the exposure process. The radiation is terminated as soon as the set value has been reached.

The coating of the printing plate in accordance with the image is a *special platemaking process* used for small formats in offset printing. The image on the film or paper original is transferred to the plate (very often it is made of a material similar to paper having suitable offset properties) by means of toner as in an electrophotographic printer. After the toner image has been fixed, the plate can be used for simple printing work, mostly for single-color jobs or together with spot colors.

3.1.7.3 Letterpress Printing, Flexography

On letterpress printing plates (fig. 3.1-52) the printing areas are higher than the non-printing areas. A right-reading negative film that is subjected to ultraviolet radiation in contact with a carrier plate coated with a polymerizable layer serves as the copy master for *direct letterpress printing*. The polymer layer cures in the radiated areas, unexposed areas are then washed off (see also sec. 2.3.2). This produces a distinct relief, the side wall slope of the halftone dot or line must be controlled by the well-defined addition of diffusive light.

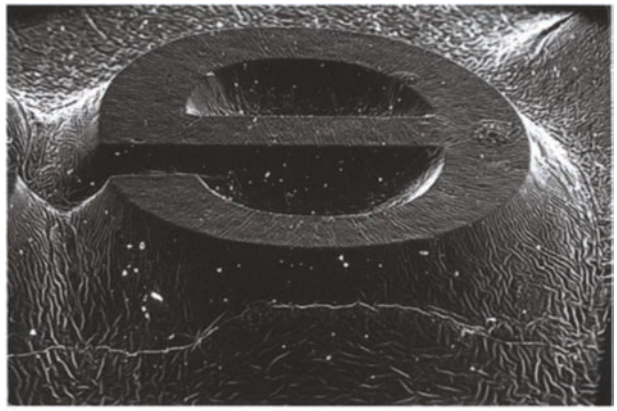


Fig. 3.1-52 Microphoto of a letterpress plate

In *indirect letterpress printing*, the printing ink is first transferred from the printing plate to a printing blanket and then to the substrate. The technology is frequently encountered in business forms printing and is referred to as "letterset" (or "dry offset," which is sometimes confused with waterless offset).

The fundamental difference between direct and indirect letterpress printing regarding film and platemaking lies in the condition of the copy master. Since the intermediate blanket reverses the orientation, right-reading films are required for direct letterpress printing. The term right-reading always refers to a condition where the emulsion side faces the viewer.

In recent years *flexographic printing* has increased, particularly in package printing (see sec. 2.3.3). Unlike the letterpress described above, in which a relatively hard printing form is used to print onto a substrate with a soft impression cylinder, the flexographic printing plate is itself flexible, and it prints against a hard impression cylinder. Flexographic printing plates are produced as already described for letterpress printing; once again a right-reading negative film is used.

For the production of *rubber relief plates*, a mold is made of a metallic relief plate into which a rubber sheet is pressed. However, these types of printing plates are made use of less and less.

Since the light-sensitive coatings used in letterpress printing are negative-acting coatings, the radiation should be monitored by a continuous-tone wedge. In this way it can be checked what multiple of the basic

exposure has been applied. The photochemical reaction depends on this parameter. The photochemical reaction, however, is not the only decisive factor for tonal transfer; it is also affected by the degree of divergence of the radiation (specular or diffuse).

In flexographic printing the tonal transfer can be determined on the inked printing plate using special densitometers. Another measuring method is the analysis of the microscopic image, for instance, using the "Photoshop" software program. There are also special tone value measuring instruments on the market that record the microscopic halftone image with a CCD camera and analyze it automatically.

3.1.7.4 Gravure Printing

In gravure printing (see secs. 2.2 and 1.3.2.2) the printing areas of the printing form, the "cells", are lower than the non-printing areas (fig. 3.1-53).

Determined by the shape of the cells there are three variants:

- In traditional (conventional) gravure printing the cylinder is imaged by etching. The cell area remains constant but the cell depth varies according to the tone value. Dark tones are produced by deep cells, light tones by flat ones.
- In variable area gravure printing the cell depth is kept constant. Different tone values are achieved by changing the cell diameter during etching. This type of tone value manipulation is also applied in other variable area printing processes, such as letterpress and lithographic printing, where the tone value is determined only by the size of the halftone dot on the printing master and not by the different amount of the transferred ink.
- With the third variant, variable area/variable depth gravure, the cells vary both in area and in depth. This can be achieved through mechanical generation of the image carrier using an engraving stylus. Its consistent quality is a particularly distinctive feature of this variant. Since gravure printing presses are controlled directly by means of electronic data, gravure printing has almost completely superseded the etching processes.

To ensure the quality of the engraving, the quality and thickness of the electroplated copper and chrome coatings are checked. After engraving the size of the cells is metered microscopically, on the basis of which the cell volume is determined. Of course it must also be ensured that the stylus used is neither worn nor broken.

3.1.7.5 Screen Printing

As the name implies, the printing ink is pressed onto the substrate through a screen or a stencil (fig. 3.1-54). For this a squeegee is drawn across the printing form, which forces the ink through the screen's open mesh (see sec. 2.4.1).

In the screen-making process the screen that serves as an image carrier is opened in accordance with the image to be printed. The main methods applied are as follows:

- In the *direct process* the screen is covered with a light-sensitive stencil emulsion and exposed with a film



Fig. 3.1-53 Microphoto of a gravure cylinder

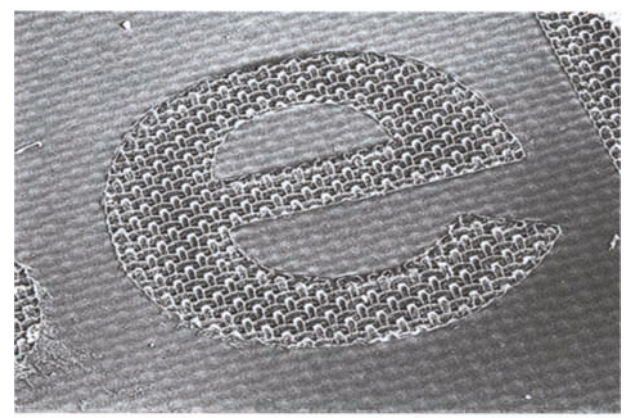


Fig. 3.1-54
Microphoto of a screen printing master/plate (stencil shown at the top/squeegee side, printing substrate underneath)

positive. The exposed parts of the coating then cure and the unexposed parts of the coating are washed off. This method is preferred for halftone jobs.

- In the *indirect process* a special screen printing film is first exposed with a positive film and developed, and only then transferred to the screen. After drying the film base is removed; the printing form is ready.
- Finally, it is also possible to combine the above methods into a *direct-indirect process*: the special screen printing film is first applied to the screen, additionally covered through the screen, and only then exposed and developed.
- A special form of screen printing (rotary screen printing) is applied when printing *textiles or wallpaper*. Here cylindrical metal stencils are used that have been produced – for example – in an electroplating process (like the metal foils used in some electric razors).

There are detailed recommendations for quality control in halftone screen printing that may be considered as standard. The quality of the print is not only affected by the actual copying process, but also by the selection of the screen frame, the screen fabric, and the preparation of the process. Of absolute importance is the correct dimension of the screen frame considering the printing format and the tension of the fabric. Checking the fabric tension with a screen tension meter is important for good register in multicolor printing.

The evenness of the stencil thickness across the entire print format and the repeatability of the coating process are essential criteria for the quality. This is only achievable with an automatic coating machine or when direct films are applied. It is advisable to carry out routine checks of the roughness value of the printing side and of the thickness of the stencil. (The roughness value R_z [see e.g., ISO 4287] should be between 4 µm and 10 µm.)

The most important control device for the production of screen printing forms is the UGRA Plate Control Wedge 1982 (see fig. 3.1-51), well-known in offset printing. If in the microline target the finest positive lines reproduced on the printing plate are 10 µm, the copy is correct. The tone value decrease in the middle tones is then approximately 4% for frequencies of 24/cm or 30/cm. This value corresponds to the circumstances in offset printing for 60/cm and positive platemaking. Once the copy has been calibrated together with the test wedge, that is, the optimal light sum has been determined for a certain type of stencil with a specified thickness, the contone wedge is a simple means of control for other copies, the solid step of the contone wedge on the ready-to-print screen forms must correspond to the value determined in the calibration. If a different step is shown a new calibration procedure must be initiated.

3.1.8 Color Management

A range of measures involving color management are required at the prepress and print stage to produce a multicolor print that gives the best possible reproduction of the original.

The reproduction must be correct for tone and color values. The "*correct tone value*" means that the observer cannot determine any difference in tonal progression compared to the original or that the desired reproduction curve for tone value is adhered to. A print has the "*correct color value*" if the reproduction gives the best match for color to the original. If the color space of the original differs from that reproducible in print, then appropriate adjustments must be made. In special cases, the use of special inks or "house colors" provides an alternative.

The requirement of the proof is to simulate the expected result of the printed job (not to produce the best possible reproduction using the selected proofing process, which may be better than that of the job).

Color values over the whole job must provide a consistent match to the ok-sheet within the chosen ΔE visual tolerances (see sec. 1.4.1).

Deviations in tone and color values during prepress and print are caused by deviations from the ideal in the actual transfer characteristic curves. For example, a print shows a characteristic dot gain in comparison to the film or the printing plate caused by an enlargement of the halftone dot due to the printing process and by light entrapment ("light gathering"). To avoid producing a distorted print as a result of this dot gain, tone value must be reduced at the prepress stage by exactly the same amount, thereby compensating for the effect.

Dot gain is recorded quantitatively in the print characteristic curve. It is dependent predominantly on the printing process, the press, the printing conditions, the ink, screen ruling, the halftone process and the substrate. Consequently, if a job is to be printed on a different press than originally intended, new printing plates might need to be produced if the print characteristic curves deviate too much from one another. The same is particularly true when changing to a different printing technology.

Similar effects to the print characteristic curve, albeit over a different range and sometimes to a much lesser extent, are produced by the characteristic curves of the spectral light sensitivity and gradation of film material for color separations, the spectral absorption and transmission properties of real printing inks and color filters, the whiteness of the substrate, its opacity and light scattering properties, and so forth.

Measures to compensate for all of these effects may be taken if the type and degree of deviation are known and the means to counteract them in a defined manner are present. For example, the system of characteristic curves (see sec. 3.1.3.5) allows the required repro characteristic curve as well as the printing and platemaking curves to be produced from the target reproduction curve, resulting in a reproduction with the correct tone value on the printed sheet.

The type and degree of deviation of the print from the original are determined with the aid of gray scales, halftone squares and colorimetric areas, which are produced during platemaking and printed out and then measured using a densitometer or spectrophotometer.

Correction of tone value is necessary to:

- reduce the density range of the original to that which can be reproduced in print,
- compensate for the dot gain appearing in the print by accurately measured dot loss in prepress,
- compensate for variations in tone value associated with platemaking,
- simulate the dot gain of the print at the proofing stage.

Influencing color value in the sense of color correction is necessary to:

- compensate for the uneven spectral distribution of the illuminant light used in the production of color separations,
- take account of the irregular spectral light sensitivity of the film material,
- counteract the effect of unacceptably low main reflectance (faulty transmission, grayness) and secondary reflectance (faulty absorption, desaturation) of the individual printing inks in the colored image,
- take account of the imperfect transparency of the printing ink,
- compensate for the spectral deficiency of the filter color,
- produce gray balance across the whole tonal range,
- take account of the conditions for ink acceptance in the print for a prescribed color sequence,
- simulate the optical properties of the substrate in the proof.

Mastering the large number of influencing parameters is achieved by broad standardization of materials and processes including the control processes (Europe Scale for printing inks, recommended color sequence for multicolor printing, suggested values for solid tone densities of the standard process colors in the print for different types of substrate, etc., see sec. 13.2.3).

3.1.8.1 Processes for the Correction of Tone Values and Color Values

The following measures and processes are suitable for correcting deviations in tone and color values [3.1-10]:

Prepress (Production of Films and Plates)

- *Gray balance.* Printing the standard colors cyan, magenta, and yellow together does not produce a neutral gray but a brown tint. To counteract this, the positive cyan color separation is produced with a 5–10% higher area coverage than the magenta and yellow separation.
- *Masking the original.* Color transparencies usually have a wide density range, for instance 2.80 optical density units, which is detrimental to the reproduction process. If a slightly blurred negative (mask) is produced from the transparent positive on very slow reacting panchromatic continuous-tone film that has a density range of 1.00, the combination of transparency (original) and mask will now have a density range of only 1.80 (2.80 – 1.00 = 1.80) density units, which is closer to the range reproducible in the print. Additional color filters used during the production of the mask allow color values to be corrected at the same time (e.g., correction of desaturation when the color of the filter is the complimentary color of the color separation being corrected).
- *Masking to correct color separations.* An auxiliary recording (mask) is produced photographically for each color separation and has the opposite errors to those in the separation. The color separation and mask are copied together so that the errors cancel themselves out.
- *Alteration of dot size by controlled over-exposure (dry dot etching).* When copying halftone screened color separation films in the contact copier, an enlarge-

ment of the dots can be achieved by over-exposure caused by light scattering effects in the light sensitive coating. There is a systematic relationship between the degree of increase in dot size and the exposure time. When copying from a negative to a positive, over-exposure will give a positive correction. Over-exposure will give a negative correction when copying from a positive to a negative (fig. 3.1-55).

- *Reducing or intensifying halftone dots on the film.* The aim is (also known as "halftone etching") to reduce the size of the halftone dots without "dry dot etching". The developed and dried film is treated with an aqueous reducing solution that gradually converts the black silver of the image to a water soluble silver salt, which is then washed away. This process occurs mainly outwards from the edges of the blackened areas of the film coating. Halftone dots with a flat blur edge react particularly well to the reducer. Halftone dots are intensified on the film by dyeing the coating with a dye that attaches itself only to the blackened areas of the coating, or by increasing the quantity of black silver in the image as a result of a physico-chemical process.
- *Undercolor removal* (UCR; see sec. 1.4.2). Electronic color separation devices allow gray values in the colored image to be produced by the black color separation alone, instead of by overprinting the three process colors. Tertiary colors are made up of black and only two of the process colors. The advantage of this system of color separation correction is that the gray of the image is reproduced correctly, even if there are deviations in color of the process colors, which would show up immediately as tints in a gray produced from the three colors.

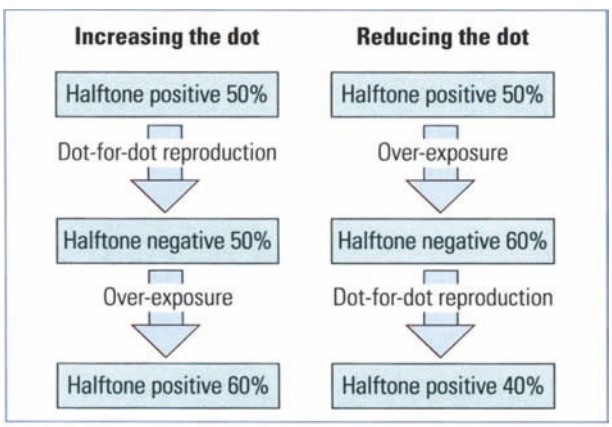


Fig. 3.1-55
Changing the dot size/halftone value on positive films by well-balanced over-exposure and the use of positive and negative copying ("dry dot etching")

Proof (see sec. 3.1.6)

- *Simulation of the dot gain of the printed job.* Analog color proofing processes start with the films of the separated colors. In order to produce a proof that corresponds to the expected printed result, the dot gain produced by the printing process must be simulated. For example, in the toner-based proofing process (see fig. 3.1-43) dot gain may be controlled within certain limits by varying the exposure time and toner supply.
- *Simulation of the substrate.* The optical properties of the substrate have a large influence on the printed result. These may be approximated in the proofing process by the use of various carrier materials available or by laminating translucent films with different diffusion factors due to different surface roughnesses.

3.1.8.2 Offset-Gravure Conversion

Gravure engravings are scanned from non-screened opal film masters (when engraving is not carried out directly from the digital data base). However, it is also possible to use screened film for offset platemaking as a master for producing the cylinder for gravure printing.

This technology is known as offset-gravure conversion and involves adjusting the scanning head of the scanner on the engraving machine (fig. 1.3-14) to give an integral scanning of the screened film and a conversion to a gravure cell volume-related value ("descreening").

The process allows the production of analog proofs or printed proofs using the offset film whose tone value reproduction provides a good match to the gravure print. A particular advantage of the offset-gravure conversion process is that it simplifies the production of a proof or printed proof within the gravure workflow, since the proof can be produced, as is usual in offset printing, using the screened films; that is, it is possible to avoid the much more time-consuming printed proof with a gravure proofing press using the engraved cylinders.

In general, analog color management processes in conventional prepress are sometimes very costly in terms of materials, equipment, and time; they are complicated to use, and depend on the accuracy and ability

of an expert, hence the modern use of electronic color management processes (see sec. 3.2.10).

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3.2 Digital Prepress

3.2.1 Structure of Digital Printed Products

The printing industry is without a doubt on its way to becoming a multimedia industry where printing itself might no longer be the dominant sector, but will nevertheless remain an important component in the long term. Printing will not be the only media and means of outputting information. Today's trends are decentralized production, print on demand, and diversified printed products, as well as the development of a new print media market, which is establishing its place between the printing industry, desktop publishing, and online media, themselves constantly growing and developing new applications.

Printed products and online media have a common prepress stage (premedia), which only diverges just before the functional output as electronic media or as printed media respectively (see also fig. 1.1-3). Lately, changes have been observed in the working processes as well as in the relationships between the customer and the service provider.

The printing industry has become aware of the potential of the multimedia market and has started synergies. A good example of this is the use of efficient workflows. In these, the data that have already been edited once, need not be edited again. Rather, the existing data file can be directly transmitted to different media.

3.2.1.1 Technological Capabilities and Workflows

The fact that the printing industry has to permanently adapt to new technologies has become almost a tradition. This has led to a new development in prepress (fig. 3.2-1).

- *Text capturing* has been reallocated from commercial typesetters to offices and agencies. Prepress companies are only responsible for "embellishing" the delivered text.
- *Image reproduction* is also increasingly carried out by agencies. Due to the low prices of scanners and a few other factors, image processing is available virtually to everyone, even in the high-end range. However, repro studios are entrusted with reproduction tasks of increasing complexity (major enlargement of 35 mm slides, duplex reproductions, etc.).
- Agencies have virtually taken over the *layout tasks* and integration of text and image, as well as the generation of the digital page. They also deliver ready-to-print data files to prepress or to the printer.
- Powerful *networks* and *global data exchange* allow for an easy interchange of data, even over long distances. On the other hand local or regional customer relationships are tending to disappear.
- *Output processes* have become the core business of prepress companies. Even though many agencies image individual pages themselves (up to a DIN A3 format), more specialized tasks, such as *full-sheet exposure* or *computer to plate*, are entrusted to prepress companies. The production of printed matters with computer to plate, computer to press, and computer to print is in practice and is available in most printing companies.
- New powerful *screening and color separation technologies* are becoming the main business of prepress and printing companies.
- *Database-handling* is becoming an important part of the work of prepress.
- Output media, such as the CD-ROM and online publications on the *Internet,* are becoming more prevalent in certain applications as an alternative to the printing process and as a complement to paper.

The concept of the prepress company has gained a new meaning in the past few years. The typesetting house and the repro house used to take care of most of the work. Now, however, former customers are taking over large parts of this work. The modern prepress company usually takes care of the integration of these data, consults, and carries out high-quality tasks.

H. Kipphan (ed.), *Handbook of Print Media*
© Springer-Verlag Berlin Heidelberg 2001

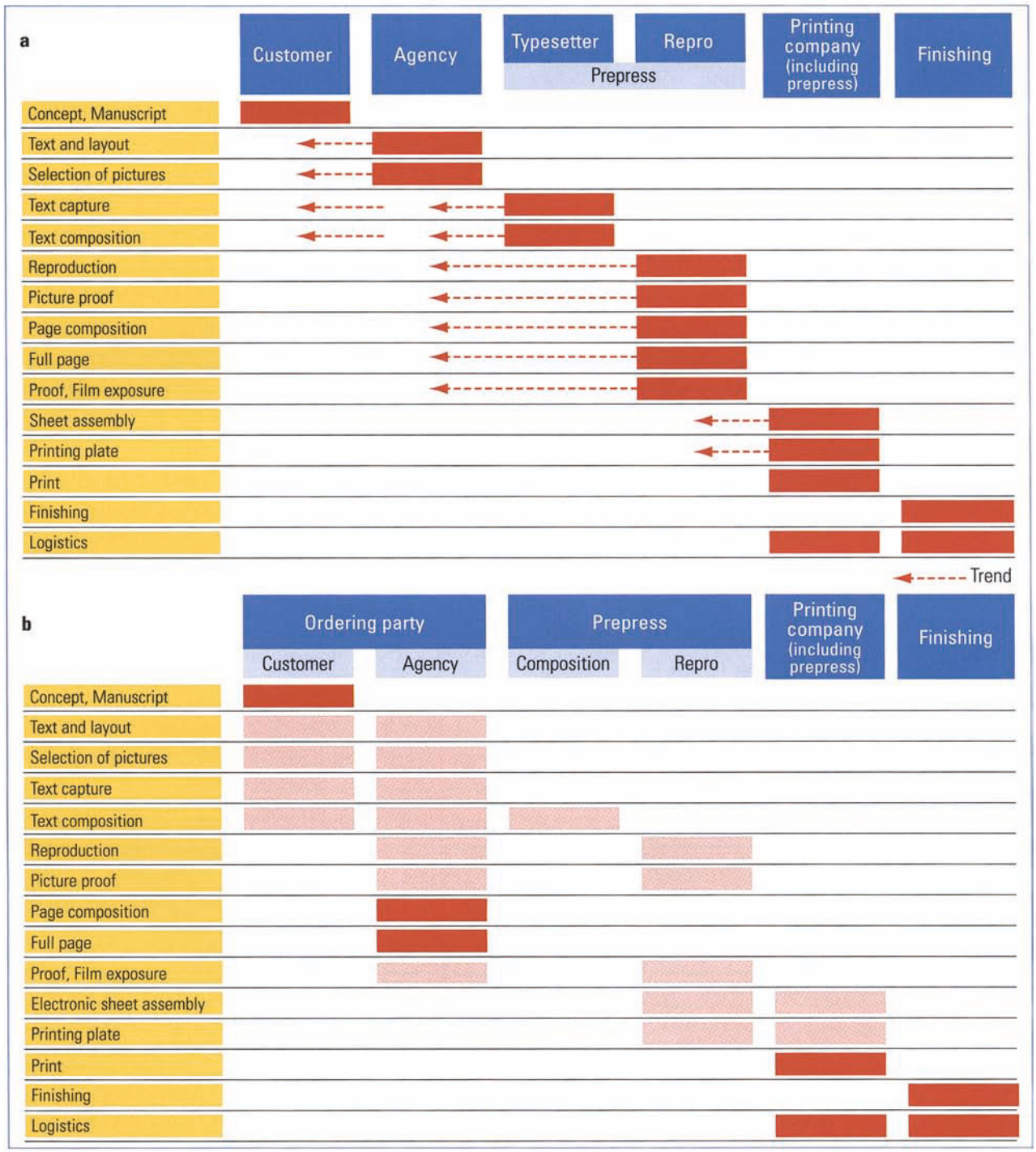


Fig. 3.2-1 Division of tasks in the production of printed media.
a Traditional, with references to trends;
b New, using digitization, particularly in prepress

This transformation highlights the fact that activities such as typesetting, reproduction, and text and image integration no longer need to be carried out exclusively by the printing industry. Thanks to digital technology, all captured text and image data can now be used for *multimedia purposes.*

What now constitutes the core of the possible workflow is a database containing all the data required for production. This development will become even more prevalent in the future. It is irrelevant whether this later leads to the production of printed media, or to electronically distributed information.

To understand this change in the printing world, it is important to realize that the individual stages have not become obsolete through rationalization, but have rather been moved to other locations. Indeed, layout, text, graphics, and pictures are still the main components of printed information and must be made available in edited form.

3.2.1.2 Digital Description of the Printed Page

The extensive standardization and compatibility between systems (e.g., PC or Mac/Apple), software, and data formats (see sec. 3.2.9) used by the customer, the agency, and the prepress company allow for a division of the workflow. As shown in figure 3.2-1b, text, images, and layout can be prepared either by the customer, the author, or the agency. This division of work is also applicable to the jobs carried out within a printshop with a prepress stage included. The basic stages in the *creation of a digital page* and a complete *digital print sheet* are shown in figure 3.2-2.

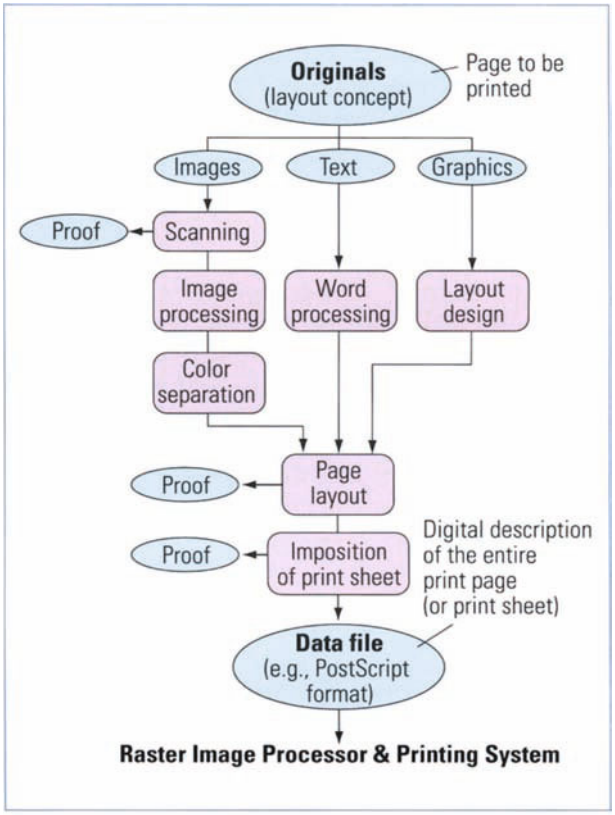


Fig. 3.2-2

The purpose of the page layout is to create a digital page from individual elements such as text, graphics, and images, which contains all the information relevant for further processing.

Text

The possibilities of word capturing and processing, as well as the generation of a typesetting product, are described in section 3.1.1.1. The method of working has not been changed by the introduction of digital production, only the place of execution has changed in most cases: that is from the departments of typesetting and reproduction to the corresponding departments at the customer's or at the agency.

The text data are primarily prepared in "Word" format, which has virtually become the word processing standard, since it is most widely used and offers many professional tools. The text data are very rarely edited directly in Word; instead they are positioned and typographically edited in a layout program (e.g., QuarkXPress, InDesign, or PageMaker).

Images

The picture objects of a printed product are usually available as *photograph*, *slide*, or *reflection copy*, and are scanned in, or digitized, for publication. The digital data (see secs. 3.1.4 and 3.2.4) are then available at a workstation for further processing (i.e., corrections of the image contents or geometry).

In the mean time, further alternatives have been added to this classical procedure: for instance the principle of the *Photo CD*. This procedure still includes the use of a camera and the development of the film. However, very often the result is not a slide, but a data file, for example stored on a Photo CD, containing original pictures that are already digitized. As for the scanned image, these data can also be processed directly onto the workstation.

Another alternative for image capturing is *digital photography* (see sec. 3.2.3). This technology also avoids the traditional procedure of film development and image scanning. As soon as the data have been recorded into a digital camera, its contents can be processed at the workstation.

Further, it is also possible to input image data directly from *image archives* (PhotoDisc, Bavaria, ImageBank, or Mauritius, to name just a few). These image archives have hundreds of thousands of pictures available and, increasingly, deliver the archived slides in digital form. Whenever you need a picture from an agency, for instance, you can download it onto your workstation to edit it in less than half an hour via ISDN data transfer.

All these picture data are generally saved in TIFF format or – to save data transfer times – are compressed in JPEG format (cf. sec. 3.2.9 on data formats and sec. 11.2.3).

In many cases, a *proof* of the set of image data is already prepared to check the reproduction quality before the generation of the full page.

Graphics

Graphics constitute the third main element of a printed page. They are generally generated in so-called *illustration programs* such as Freehand, Illustrator, or CorelDraw. These data are usually saved in the form of vector-based data files, which cannot be edited or positioned in a layout program. Therefore, these software programs offer an opportunity to save graphics or drawings in EPS format (see sec. 3.2.9) and make them available in the layout for geometric processing (scaling, cropping).

Layout

Layout programs are software packages allowing for flexible, creative work and for integrating the elements (text, images, and graphics) on pages or a sequence of pages, or to position them on the page depending on the current job. Thus they have taken over a significant function of production. One particular layout program has virtually become a standard application: QuarkXPress. In 1999, a competitor appeared on the market: InDesign from Adobe. Another popular layout program is PageMaker (formerly by Aldus, today Adobe), which is mostly used in offices.

The page components text, images, graphics, and layout, must be prepared and organized for further stages in processing (e.g., film production, platemaking, or printing), in order to avoid errors or breakdowns in the workflow. Although it is very important for the layout program to display all the components of the page (low resolution is sufficient), it is particularly vital for the system to be able to access the original resources for imaging.

Therefore all the main files required for a job must be supplied in their original formats. For production, a layout file is supplied that contains the definitions of special colors, or information regarding color separation, or regarding spreads and chokes (trapping, see sec. 3.2.2.6). The pictures are available with it as high-resolution files (e.g., 300 dpi scanning resolution) or at least as JPEG files and linked graphics as EPS files. Another important factor is that the original fonts (Type 1 fonts) of the layout file must be sent as type fonts (fig. 3.2-3).

To clarify the concept: the data generated with the different layout programs are not PostScript files. Rather, they contain all the information required, in line with PostScript conventions.

All these application programs offer the opportunity to create PostScript files or separated component files. This procedure has both the advantage and the disadvantage that the contents of the data can no longer be modified. On the one hand, unwanted changes can be prevented. On the other hand, faulty files can no longer be corrected and must be created anew.

In this context, a distinction is made between "separated" and "composite" files. Composite files offer the advantage that data can be corrected or complemented at any time; above all when used in *PDF workflows*, they guarantee a higher degree of flexibility.

The Digital Page used as a Basis

All the procedures described earlier can be carried out at the author's, at the contractor's, or in the agency. They can also be implemented at the prepress stage in a printing company. Thus the job containing layout data, pictures, graphics, and fonts can be sent directly for imaging (film production, platemaking) or can be stored on production servers for further processing. To optimize their workflow, printing and prepress companies use production servers, which can store and make available all the data required for imaging.

Newer workflows also incorporate a practical utility for further processing foreign data; they use so-called *preflight checks* in order to recognize errors before imaging or at another stage of processing, or to detect missing elements (see also sec. 3.2.11.5). In the mean-

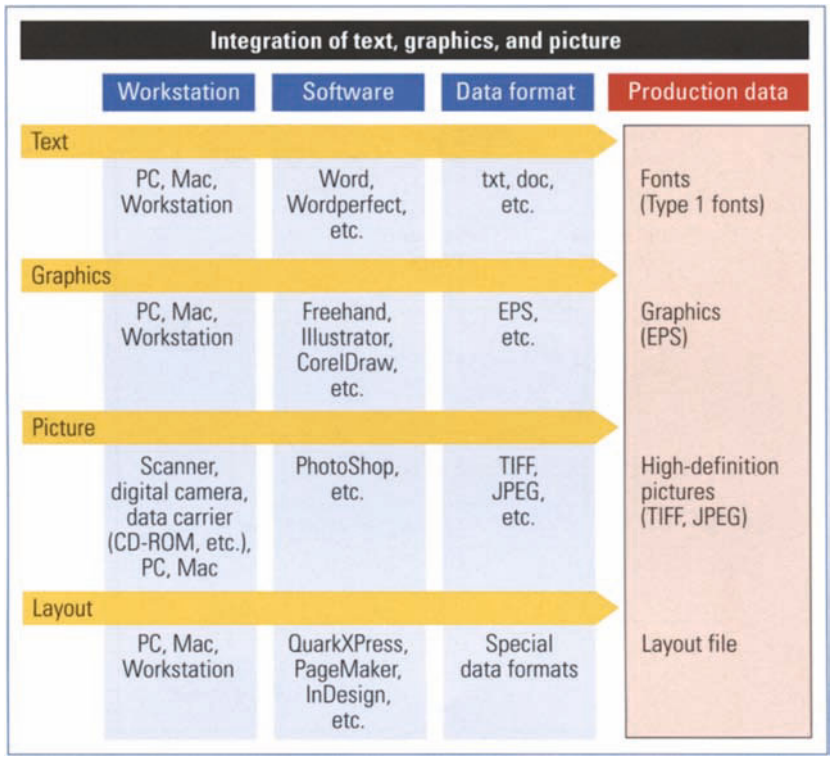


Fig. 3.2-3
The composition of the individual page segments using typical means such as hardware, software, and data format, as well as the generation of the necessary data files.

time, programs are so advanced that mistakes can be automatically detected and corrected. (Example: if a printed product is only printed in the low-resolution 34 lines/cm screen, very thin lines are recognized in the layout and replaced by printable elements.) The different workflow concepts are explained even more in detail in the section entitled Film Production and Platemaking (sec. 3.2.12).

The data delivered, which contain relevant information for the remaining process, are prepared on the production server for RIPing (see sec. 3.2.6).

The automatic procedure controlling the workflow plays a significant role in this context. When reading data, many servers generate so-called *low-res files* (files with a lower resolution) from high-resolution pictures, in order to limit the size of the data transferred via the network to a minimum. The picture can be saved into the image database either manually or automatically. When reading "fine image data", many servers generate a low-res file with OPI comments. *OPI (Open Prepress Interface)* means that the user only works with low-resolution files, which allow for fast image processing, scaling, and so on. Generally, the user only works with low-resolution pictures or graphics (equivalent to a monitor resolution of 72 dpi) at the workstation, in order to prevent any unnecessary overloading of the production process through the transfer of large amounts of data of high-resolution images and graphics. The *fine image data* are only recalculated during imaging and high-resolution original data required for a quality output are automatically substituted in place of low-res data.

From the Digital Description of the Page to its Printing

In many cases, production servers make it possible to prepare data for output on different output systems such as film imagesetters (computer to film systems), computer to plate, computer to press/direct imaging or computer to print systems (fig. 3.2-4). The data to be made available do not really differ from each other. The settings for the resolution, screen frequency, and so on, are defined in or by the RIP. For conventional workflows, that is, for workflows based on the PostScript file (the newer workflow management systems are based on PDF technology), all the settings required for imaging are defined on the server or at a workstation and

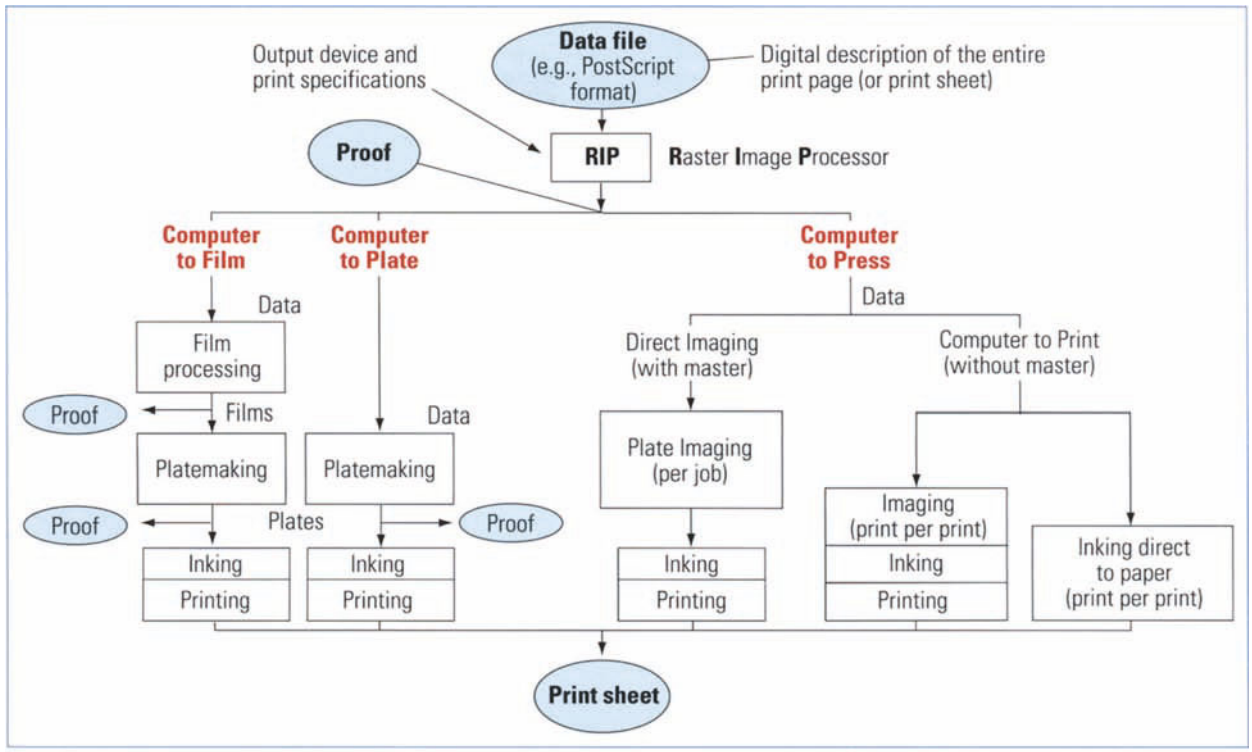


Fig. 3.2-4
The data file (e.g., in PostScript format) of the job is processed in the RIP to meet the specific requirements of the output device and is transmitted to it.

this information is transferred to the RIP. This is also the case when selecting the screening method to be used.

All PostScript devices have default settings, which ensure a continuous-tone representation even when no special screen parameters are set. If special screening requirements are imposed, the values must be set manually.

The screen parameters within a PostScript file can be changed as often as required. In the following hierarchy, if settings are absent, the next lower level determines the output:

- settings for individual objects of the file,
- settings for embedded EPS files,
- settings for the application software,
- settings for the driver,
- values for the screen filter (the screen filter is the only level that can overwrite other settings),
- default values of a device.

3.2.1.3 Digital Screening Processes

In the early years of distribution of PostScript (starting in 1985), the first criticism was directed towards screening processes. Problems were observed, particularly with high-end imaging systems, in the form of unwanted moiré patterns. These were caused by detrimental combinations of screen frequency and screen angle, a phenomenon already well known in the printing world (see secs. 1.4.3 and 3.1.3.6). The reasons for this could be found in the definition of repro screens.

When the usual *screen angles* for *moiré-free overprinting* and standard screen frequencies for the repro technology were defined and standardized in DIN standard 16547 (cf. sec. 14.4.1), electronic screening did not exist as yet. This standard is based on the angles 0°, 15°, 45°, and 75° for Yellow, Cyan, Black, and Magenta, which could be realized with engraved glass and contact screens without any difficulty. Practice has shown that this DIN standard had its weaknesses; indeed Black is not always set at 45° and the distance of 15° from

Yellow to Cyan is not ideal, but rather a compromise, which can be improved by the elliptical dot shape.

Finally, the problem with electronic screening is the implementation of specific screen systems (screen angle, screen frequency) in the pixel matrix imposed by the imagesetter. Since each type of digitizing causes so-called quantizing effects (digital sizes can only accept defined values in increments, but not intermediate values), inaccuracies arise that are normally not visible to the naked eye but may cause moiré patterns to form when printing with four colors.

RT Screening (Rational Tangent Screening)

The origin of these increments can easily be explained. Until now, we considered the screen cell as a simple square that could be rotated to any angle. In actuality, however, the screen cell must be aligned to the pixel grid because partly cut pixels are not possible. Even the square shape of the screen cell only exists in a few special cases, such as the 0° screen angle (fig. 3.2-5). For each rotation of the screen cells, their corners must "engage" with a pixel boundary. Therefore the only acceptable angles are the ones for which the corners of the rotated screen cell keep both a vertical and horizontal integral pixel distance to the lower left cell (fig. 3.2-6). Since the ratios of both these distances are designated in mathematics as tangent and the quotients of integers are labeled rational, the usual screen process used by PostScript is also called rational tangent or *RT screening*. Its characteristic features are that all screen cells have the same shape, and that only a few different screen angles and frequencies are allowed (fig. 3.2-7).

This becomes evident in figure 3.2-8: by positioning the screen cells on the intersections of the imagesetter matrix (as in fig. 3.2-7), the step sequence of three pix-

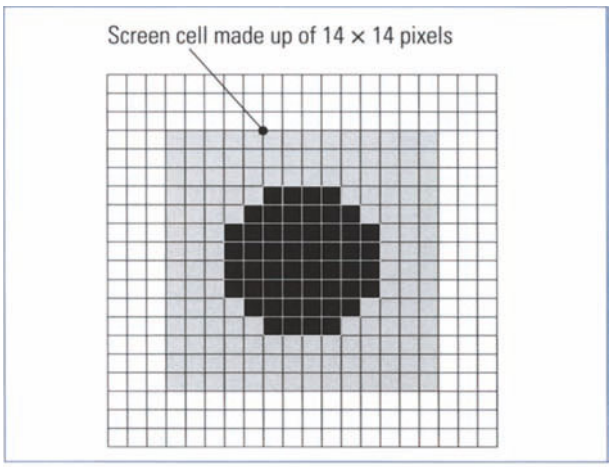


Fig. 3.2-5
Screen cell of 14 x 14 = 196 pixels (like in the image) with an area coverage of 52 pixels (approx. 26.5%), aligned at an angle of 0°. This angle can easily be implemented in the imagesetter matrix.

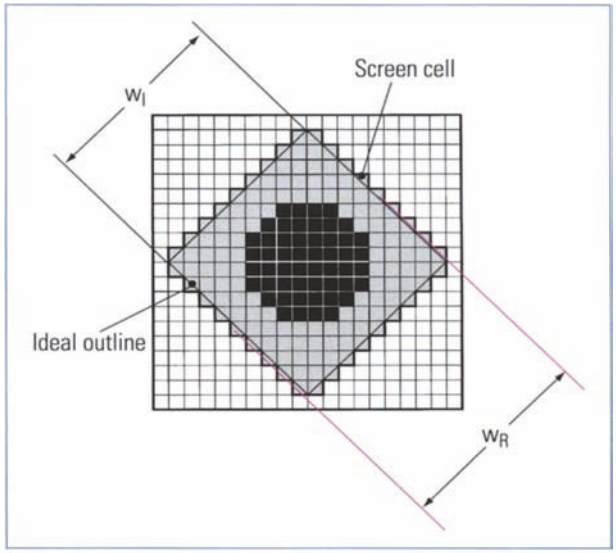


Fig. 3.2-6
Screen cell under 45°; the outline of the screen cell deviates from the ideal outline (screen width $w_R > w_I$)

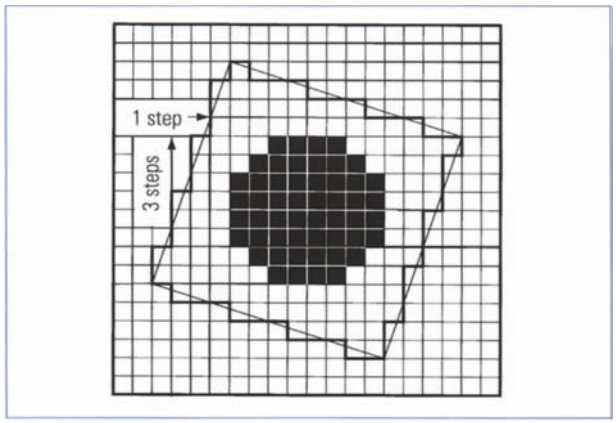


Fig. 3.2-7
Structure of a screen cell with rational tangent. It results in angles of 18.4° or 71.6° instead of the standard angles of 15° and 75°.

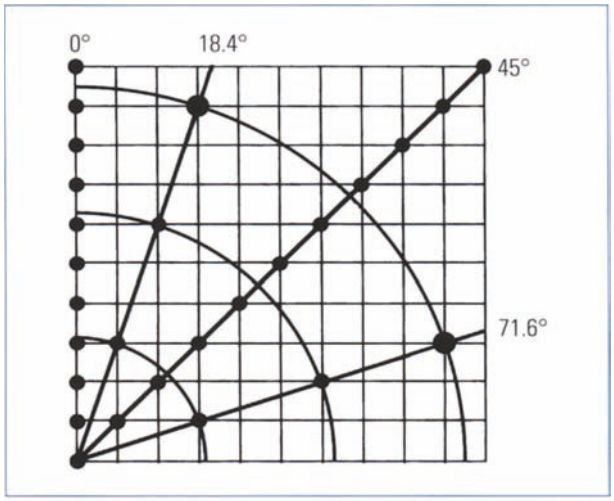


Fig. 3.2-8
The screen angle and screen frequency of rational screens deviate from the ideal screen (18.4° instead of the ideal 15° and 71.6° instead of the ideal 75°; screen frequency see table 3.2-1)

Color	Angle	Screen frequency
Yellow	0.0°	50.0 lines/cm
Cyan	18.4°	52.7 lines/cm
Black	45.0°	47.1 lines/cm
Magenta	71.6°	52.7 lines/cm

Table 3.2-1
Example of different screen frequencies as a function of the screen angle with rational tangent screening (RT screening)

els vertically and one pixel horizontally results in an angle of 18.4° (while one pixel vertically and three pixels horizontally result in an angle of 71.6°). The connection of the root points with quarter circles shows that the intersections for the angles of 0° and 45° are way off the angles of 18.4° and 71.6°. This causes different screen frequencies within a set of color separations, as illustrated in table 3.2-1.

Supercells

Larger screen cells offer a more accurate compliance with the angle, but they are undesirable since they create structures that are visible to the naked eye, and above all cause a loss of detail resolution. Thus, the principle of *supercells* does not simply magnify cells, but rather merges several individual cells into a larger unit (fig. 3.2-9). Individual cells can have different sizes and shapes. These differences are compensated for within the supercell. Altogether, supercell screening keeps to the required screen angle much more accurately (fig. 3.2-10).

While RIP only calculates the shape of the halftone dots once for RT screening (all screen cells have the same shape), the calculation of supercells is far more intensive: each screen cell has another shape, which implies the calculation of each cell by the interpreter. This requires processing time and storage space. Adobe has incorporated the supercell technology into some PostScript Level 1 interpreters ("Emerald-RIP") and into all PostScript Level 2 interpreters under the name *Accurate Screens*. Yet, because Accurate Screens drastically increases processing time and improved accuracy is not required by all users, this functionality is not activated as a default setting.

Accurate Screening technology is activated by means of special PostScript instructions, which must be generated by the application software. In addition to its longer processing times, Accurate Screening also requires more storage space. Adobe has got round the difficulty of the computation complexity with supercells

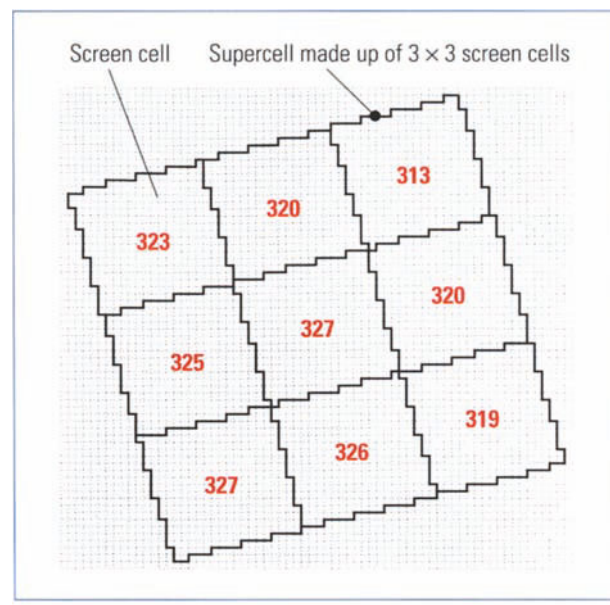


Fig. 3.2-9
Several different screen cells (3x3) are merged into a supercell. The numbers indicate the number of pixels available per screen cell

using specialized hardware solutions (the coprocessor "PixelBurst" relieves the main processor of the RIP and takes care of the screening as well as special tasks, which are directly implemented in the hardware, thus speeding up the process).

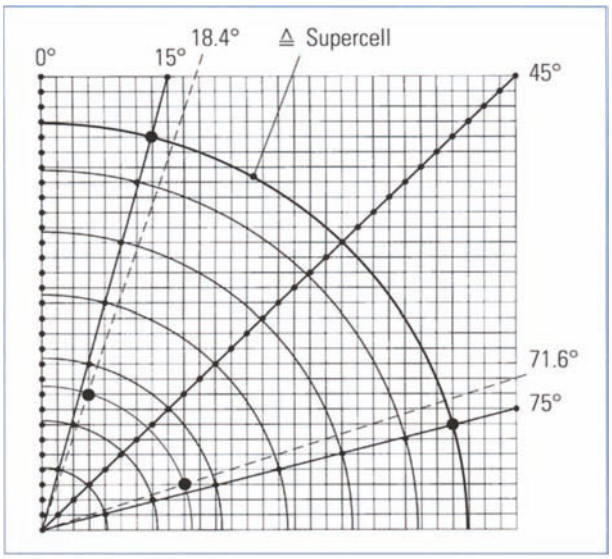


Fig. 3.2-10
The ideal angle and virtually corresponding screen frequencies can be achieved when calculating with a supercell.

Other manufacturers are also working on supercell solutions: Linotype-Hell (now Heidelberg) called its own solution "HQS Screening" and Agfa called its own system "Balanced Screening".

Irrational Screening

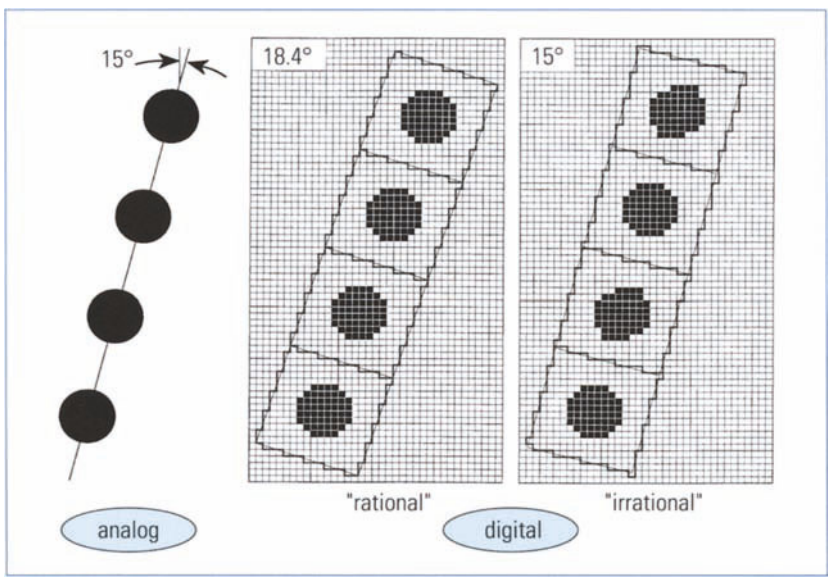
Linotype-Hell (now Heidelberg) further developed the principle of the supercell and gave it the name *irrational screening*. This technology uses those screen angles and frequencies that have already given optimal quality on the former Hell repro-scanners.

The main difference between rational and irrational screening lies in the mathematical difference between rational (rational numbers are numbers that can be expressed as the ratio of two integers) and irrational (real numbers that cannot be expressed as the ratio of two integers).

The basis of irrational screening is a screen matrix, on which the distance from one dot center to the next dot center corresponds exactly to a specified value, for instance, 166.66 µm for a 60 lines/cm screen. Irrational screening conforms to ideal angles, but the shape of the halftone dot is deformed due to the varying sequences, for instance, a step sequence of alternately three or four pixels vertically and one pixel horizontally (fig. 3.2-11).

Figure 3.2-11 makes the differences between analog, rational, and irrational angles very clear. The left-hand figure shows the analog screening with a 15° angle and constant screen frequency. The rational screen (figure

Fig. 3.2-11
Comparison of analog screening with rational and irrational digital screening



center) results in an angle of 18.4°. Its screen frequency deviates within the color separation (Cyan, Magenta, Yellow, Black). With irrational screening, the ideal angle (15°) and a constant screen frequency are possible again.

Frequency-Modulated Screening

While supercell processes try to match the specified screen angles as closely as possible, *frequency-modulated screening* (FM screening) has no screen angle. This technology has already been explained in section 1.4.3. With this technology, small dots are distributed on a surface in such a way that the required gray value appears as an average value, whereas distribution is completely random compared to the normal halftone dots. For this reason, frequency-modulated screening is also referred to as random or stochastic screening. While with conventional screening (AM screen, *amplitude-modulated*) the individual dots are spaced at equal distances from one another and only the dot size changes (amplitude), the dots in FM screening have the same size, but are irregularly spaced (fig. 3.2-12).

In the mid-90s, manufacturers of imagesetters and RIPs developed alternative technologies, which vary in their approach towards spot size, stochastic distribution, and RIP process. Here are a few names of technologies and their manufacturers: Brilliant Screens (Adobe), CrystalRaster (Agfa), Diamond Screening (Linotype-Hell/Heidelberg), HiFi-Screening (Scangraphic); for further details, see also section 1.4.3.

In comparison to conventional screening, the small spot size of the laser beam (approx. 15 µm for 2400 dpi resolution) makes higher demands on the film imaging, platemaking, and printing process.

Output Options

It is now common practice to generate the entire printed, multicolor page or sequence of pages from a complete data set prepared by the prepress. The pages are then processed by the raster image processor in line with the screen processes mentioned above and transmitted to the output devices as bitmap information. In this instance, it is insignificant whether the output device is a printer equipped with NIP technology (e.g., electrophotography), a film imagesetter, a computer to plate system, or a direct imaging printing press. The different output devices and procedures are described in sections 3.2.5 (Sheet Assembly and Imposition), 3.2.11 (Digital Proof), and 3.2.12 (Film Production and Platemaking).

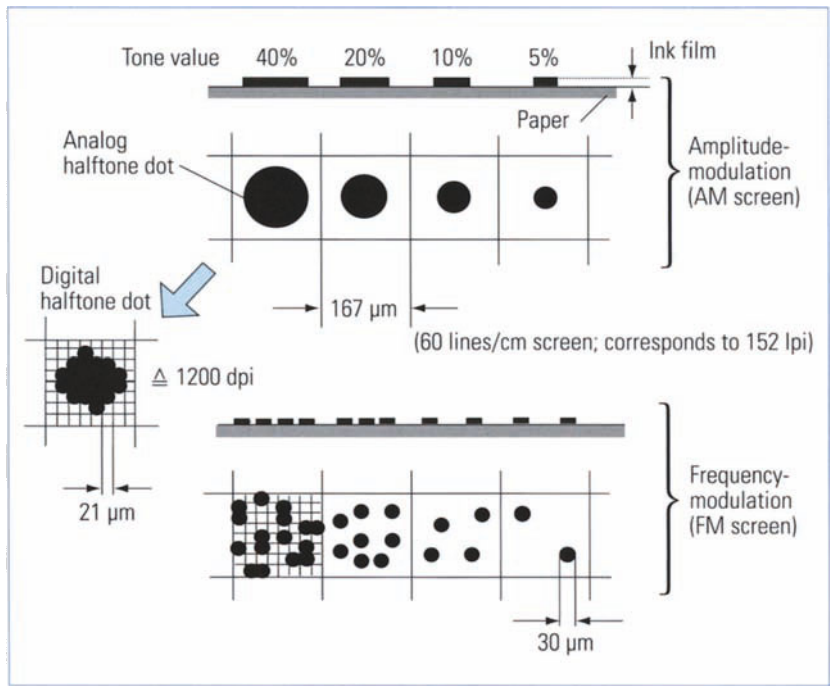


Fig. 3.2-12
Frequency-modulated (FM) screening in comparison with amplitude-modulated (AM) screening with a digital dot structure

The manipulation of digital data for the creation of printed products has led in many cases to completely new organizational forms (as already mentioned at the beginning of this section). These changes, which have been incorporated in different workflow management systems, have given a new meaning to proof and digital proof. These procedures will be examined in detail in section 3.2.12 (Film Production and Platemaking).

3.2.2 Quality Requirements

The definition of quality in terms of printing is a difficult issue. Quality-determining characteristics have already been dealt with in some detail in section 1.4, particularly with respect to coloring and screening.

The numeric evaluation of quality in prepress is also especially problematic. This is because it is not only a matter of the complete and correct reproduction of text, but over and above this, of the visual impression of images or whole pages, which makes it a matter of personal taste. Even the comparatively simple setting of a color TV, involving only the variables brightness, contrasts, and chroma, often leads to arguments because everyone perceives something different as correct. It is all the more difficult to evaluate quality in the area of conflict arising from the high level of expectation of the print buyer, the vision of the artist, the cautious optimism of the prepress expert, and what is actually feasible under industrial conditions with the different qualities of paper/substrates.

A product's quality is usually defined in terms of its suitability for the anticipated purpose. It would be unwise to conclude from this that a printed product's quality level could be geared to the requirements of the average end-user. The single decisive factor is the product's suitability in the client's eyes. However, the client's idea of quality usually lies far above what the end-user expects or could even perceive.

It is an undeniable fact that only a fraction of the approximately two million colors that can be distinguished by the human eye can be reproduced on a substrate and that the final product often shows visible differences compared to the test print (proof), or the ok sheet. Even with color management, none of this can be changed.

In addition to this, there are quality requirements on the prepress product of a purely craft-like nature. These apply for a data record with digital proof (see sec. 3.2.11) and likewise for a set of films with analog proof (see sec. 3.1.6). Examples of the typical errors affecting the quality of a prepress product are listed below:

- incorrect data format: application program format instead of data exchange format such as PS, EPS, PDF,
- unsuitable resolution (too coarse, too fine),
- unsuitable screen frequency (too high, too low),
- insufficient edge sharpness,
- special colors are separated as process colors or not defined,
- important parts of the image are outside the renderable tone value range,
- with non-periodic (FM) screens: the smallest dot is below the transferable tone value range,
- unsuitable dot shape,
- tone value sum too high (over prints),
- wrong gray balance,
- image is missing or is only available in monitor resolution,
- lines done as hairlines or created several times,
- missing or unsuitable types (only outline, reverse types too fine),
- missing or unsuitable proof or test print ,
- error in the word processing program (wrong version, wrong separation program, formats missing),
- wrong color management input profile (see sec. 3.2.10),
- unsuitable color management output profile,
- missing or unsuitable choke/spread (trapping),
- imposition: trim or fold lines missing,
- moiré effect as a result of incorrect screen angling.

Quantitative determination of the quality of a reproduction can only begin when the flowery verbal critique of the artist ("the jacket must look more sporty" or "this sausage doesn't look appetizing enough") has been converted into precise correction information. In the case of tone values, for example, "reduce cyan by 5% in selected areas" or in the case of color values "reduce chroma C^* by 1/5, make lightness L^* lighter by 5."

Originally prepress worked solely with CMYK data from the input device to output of the film. However, there has been a noticeable trend towards a media-independent workflow. The idea here is to retain the color gamut of the original for as long as possible and to compress it to the color gamut of the relevant printing process just prior to the output. A problem here is that the gamut must be reduced in order to transform the

process-independent CIE data into CMYK data, and that the perceptual rendering of the ICC profile produces different results depending on the profiling tool vendor. The results will only be unequivocal if a decision on a certain profiling tool is made or if the gamut of the CIE data has already been tailored to a certain type of substrate, so that conversion has only to be made between printing conditions or processes within the same gamut.

3.2.2.1 Input and Output Resolution

One obvious quality feature is the *image definition*, which can be determined at a deliberately low level in the original for artistic reasons, or it is limited by the resolution when scanning the original and transferring it to the film, plate, or substrate.

The original is scanned by either a digital camera (see sec. 3.2.3) or an input scanner (see sec. 3.2.4). The image information is not transferred entirely, but only in accordance with a scanning pattern of a specified resolution and number of *tone value levels* or *gray levels*. The pattern consists of the smallest image elements resolved by the scanning device, the *pixels*. This word is a neologism created from "picture" and "element."

In a similar way to radio and television, where the number of vibrations per second (i.e., a time frequency) is specified, the resolution of the pixel pattern can be specified by its *(spatial) frequency*, that is, the number of pixels per centimeter or inch. This is the *scanning frequency* (spatial frequency), also known as scanning *resolution* (see fig. 1.4-32).

The pixel pattern must be noticeably finer than the image detail. Figure 3.2-13b shows a section of the test diapositive "Bajazzo", which is, for example, to appear on the printed product in the size shown in figure 3.2-13a. There is another important aspect for the selection of scanning frequency: the image data should use the minimum of memory space. It is a waste of time and money to pass unnecessarily large quantities of data through the production process. Doubling the scanning frequency quadruples the size of the file. A good compromise is reached between the reproduction of fine details and the size of the file, if the factor F in the following equation is given a value of two:

Scanning frequency (f_s) =
F × magnification factor (M) × screen frequency (L).

If, for example, a 5.3 cm × 8 cm diapositive is to be printed the same size with a 60 lines screen (i.e., with a screen frequency of 60 lines/cm), the resultant scanning frequency (resolution) will be

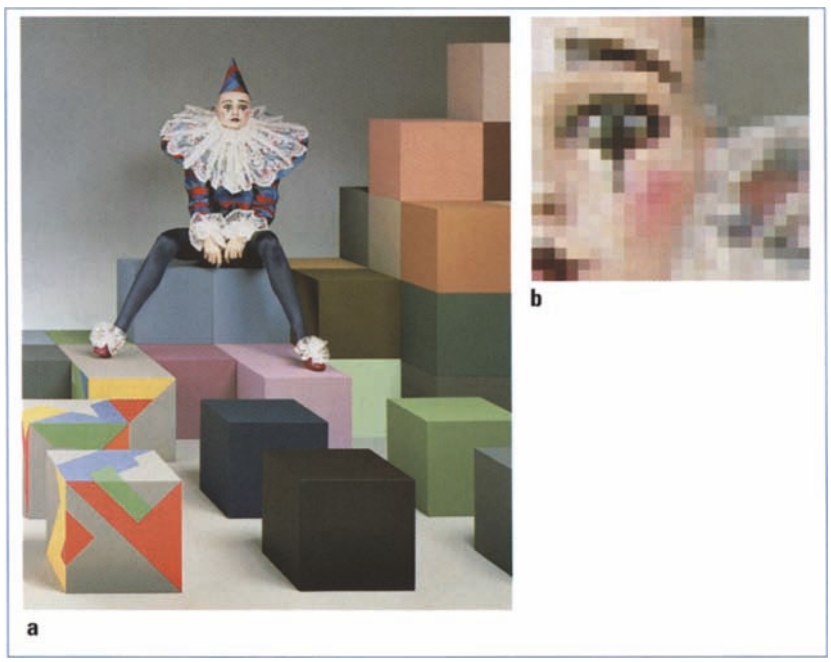


Fig. 3.2-13
Illustrations with various resolutions.
a Original size in the print;
b Detail from the data record used as the basis, displayed on the color monitor [3.2-1]

$f_s = 2 \times 1 \times 60/cm = 120/cm$ (approx. 300 dpi).

The ratios are illustrated in figure 3.2-14. Under normal circumstances, each screen cell on the output side is assigned four input pixels, one pixel covering a quarter of the area (due to F = 2). The mean is found from the tone values (gray levels) recorded from the scanning of the four input pixels and the result is stored in the memory. The mean produced in this way balances the slight, equipment-related variations of the light sensor in the input scanner, and brings about a more even representation of smooth tint areas.

Scanning resolution must not be too fine, otherwise unnecessarily large files will have to be processed, leading to unnecessarily increased production time.

The "*screen frequency*" is sometimes referred to as *screen ruling*. The standard screen frequencies of the most important printed products are listed in table 3.2-2.

The metric unit of scanning or screen frequencies is usually 1/cm or cm^{-1}, more rarely dpcm. Often used is the US-based "dpi" as an abbreviation of "dots per inch."

If the demands imposed on the image definition are not very exacting, and it is rather minimal memory requirement that is being striven for, a lower value than F = 2 can be used in the equation mentioned above (e.g., F = 1.4), and a lower resolution is used for scanning.

If an image is to be output on film, plate, or directly on a print substrate, the *dot shape, screen frequency,* and *screen angles* must be specified first. Since the dots to be written are made up of individual pixels (except in gravure printing), the pixel size must also be specified. Like scanning resolution for the input, we speak of *output* or *addressing frequency* (in short: *addressability*). Depending on the output device, values ranging from 197 cm^{-1} (500 dpi) to 1000 cm^{-1} (2540 dpi) and above are typical; the output resolution of simple electrophotographic office printers is usually only 118/cm (300 dpi).

Several considerations must be taken into account when the *output frequency is being selected*:

- The value must be chosen so that it is high enough to be able to reproduce the desired dot shape at an adequate accuracy.
- The number of reproducible tone value levels must be sufficiently large for no stages ("breaks") to become visible with extended banding.
- The imaging time (output time) should be as short as possible; too high an output frequency extends it unnecessarily.

As is illustrated by the three examples in figure 3.2-15, about 10 × 10 pixels are needed to create an acceptable *dot shape*. This means that the output frequency should be approximately 10 times larger than the frequency of the periodic screen.

The factor of 10 also results from a second consideration: the *number of reproducible tone values* increases considerably in line with the output frequency. It is obvious that it is only possible to plot as many tone value levels as output pixels fit in a screen cell. If the blank paper is taken into account as a tone value, the number of reproducible tone values (gray values) is:

$$\left.\begin{matrix}\text{Number of}\\ \text{tone values}\end{matrix}\right\} = 1 + \left(\frac{\text{output frequency}}{\text{screen frequency}}\right)^2$$

It was assumed that only one gray level (i.e., two gray values) can be represented per picture element (pixel) (see also sec. 1.4.3, in particular fig. 1.4-39).

The eye cannot distinguish many more than 100 tone value levels. Therefore it is sufficient for the screen cell to contain 10 × 10 pixels. This then produces 101 different values with a hundred steps of 1% each.

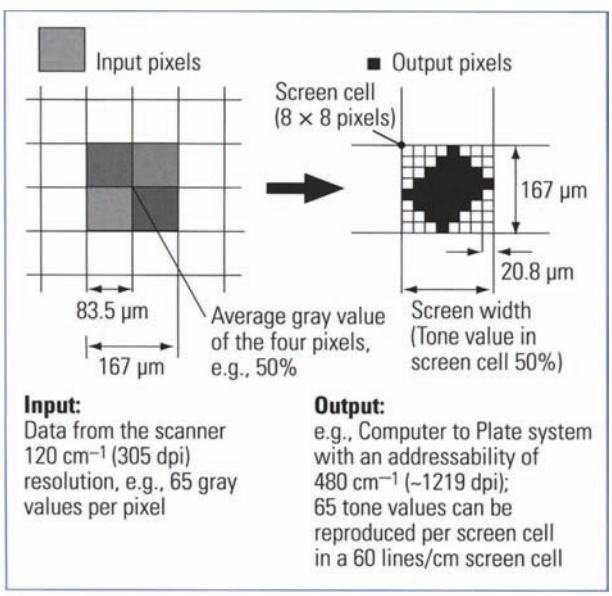


Fig. 3.2-14
Transformation of scanner data into halftone dots for digital film or plate imaging

Table 3.2-2
Screen frequencies, tone value ranges and minimum dot diameters for typical printing conditions and processes

	Screen frequency (smallest dot)	Tone value range
Commercial offset Europe	60 cm^{-1} (152 lpi) (20 µm)	3% to 97%
Commercial offset Japan	70 cm^{-1} (178 lpi) (20 µm)	3% to 97%
Web offset periodicals USA (SWOP)	52 cm^{-1} (132 lpi) (around 20 µm)	2(4)% to 97%
Newspaper printing (offset)	34 cm^{-1} to 48 cm^{-1} (25 µm to 40 µm)	3% to 85%
Business forms printing	52 cm^{-1} to 60 cm^{-1} (20 µm)	3% to 97%
Gravure printing	70 cm^{-1} (178 lpi)	5% to 95%
Flexography	40 cm^{-1} to 60 cm^{-1} (around 30 µm)	5% to 95%
Screen printing	30 cm^{-1} to 40 cm^{-1} (80 µm)	3% to 94%
	6 cm^{-1} to 29 cm^{-1}	10% to 90%

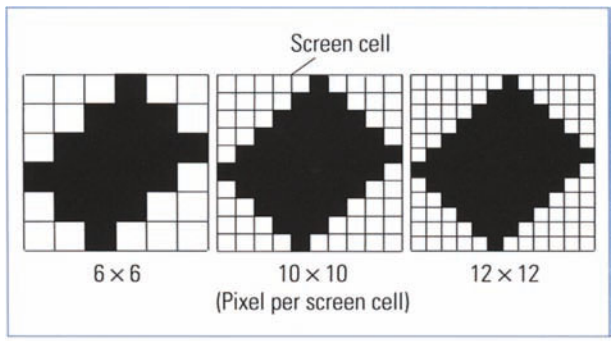


Fig. 3.2-15
Dot structure with varying addressability (output frequency) of the output device (tone value 50%)

In the example, the screen is imaged with a screen frequency of 60/cm, therefore the output frequency does not have to be higher than 600/cm (1524 dpi).

The screen frequency should not be higher than is absolutely necessary. Extremely *fine screens* (e.g., with 120 cm^{-1}, 305 lpi) are often required on the creative front, since photo-like reproduction holds its own fascination. However, very fine screens may also entail a loss of quality, because the transfer to the printing plate is more unstable and the variations during the print run are higher, not to mention the higher costs of platemaking.

If the output frequency is restricted to a low value by the equipment, e.g., to 600 cm^{-1} (240 dpi), there are less than 100 reproducible tone value levels for screen frequencies greater than 60 cm^{-1}. Accordingly an imagesetter would only be able to reproduce 26 tone values for an extremely fine screen of 120 cm^{-1}. To be able to reach 100 levels here, an output device with an output frequency (addressability) of at least 1200 cm^{-1} (480 dpi) would be needed. Figure 3.2-16 gives an overview of the dependencies produced by the equation mentioned earlier. Depending on the image, losses of quality may occur if there are less than 100 tone value levels (table 3.2-3), and the gradations may show visible steps (also known as banding).

3.2.2.2 Transferable Tonal Range

As a result of more recent interpretations (see also ISO 12647-1 [3.2-2]), the tone value of a print is defined by the Murray-Davies formula (see also sec. 1.4.4), regardless of whether or not the printing process is based on a halftone screen. This also applies for image carriers without contrast reversal such as positive films and most printing forms. In the case of negative films and printing forms with contrast reversal (e.g., polyester films for offset printing), the tone value is defined as the complement of the value to 100%. Correspondingly, the tone value of a numeric datum in a CMYK data set is defined by the opaque dot area, that would

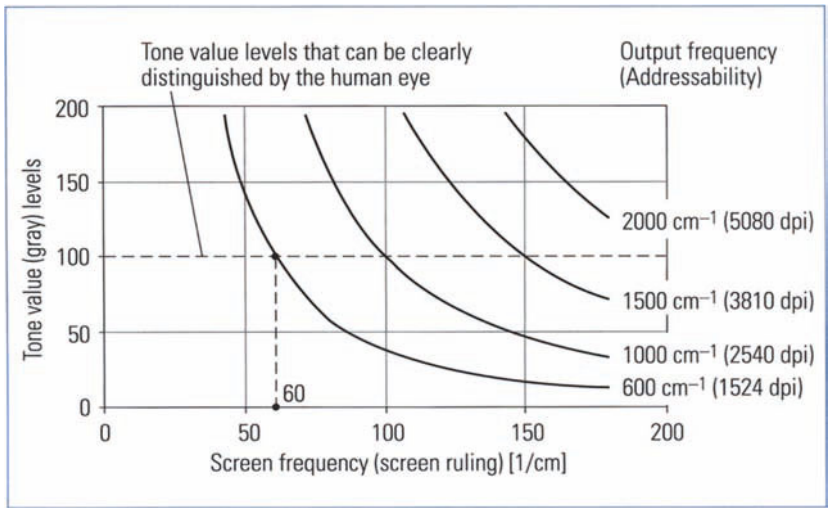


Fig. 3.2-16
Number of tone value levels as a function of the screen frequency ("screen definition"); the parameter of the curves is the resolution (output frequency or addressability) of the output system

	Output frequency (addressability)		
	600 cm⁻¹ (1524 dpi)	1000 cm⁻¹ (2540 dpi)	2000 cm⁻¹ (5080 dpi)
Screen frequency	Tone (gray) values		
60 cm⁻¹	101	279	1112
80 cm⁻¹	57 (*)	157	626
100 cm⁻¹	37 (*)	101	401
120 cm⁻¹	26 (*)	70 (*)	279
300 cm⁻¹	5 (*)	12 (*)	45 (*)

Table 3.2-3
Tone values (gray values) for different output and screen frequencies. Combinations marked with an asterisk (*) involve a loss of quality.

have been produced with output onto a positive film [3.2-2].

With periodic screens (amplitude-modulated), the *reproducible tone value range* is restricted by the fact that printing processes are unable to reliably reproduce dots below a certain minimum diameter. This applies both for "positive" dots in the extreme highlight range and also the "negative" dots in the shadow range. Screen tints of significance for the image or image contours must not be outside the given tone value range. This does not mean that an image may have no tone values outside the given range, this is in fact desirable to avoid visible steps. The transferable tone value ranges for a series of printing conditions are given in table 3.2-2.

With the non-periodic (frequency-modulated) screens, there are, theoretically, no restrictions on the transferable tone value range, because the dots can in principle be set at any distance, though even here, the dot diameter must not fall below a minimum value, which is also given in table 3.2-2. Specifications of this kind for printing processes without master (NIP technologies) do not yet exist.

3.2.2.3 Dot Shape

Whereas with gravure printing the shape of the cells is more or less predetermined because of the mechanical engraving process of the gravure cylinder with a stylus, with the other printing processes, the shape is generated as a pixel pattern and is therefore variable. At a continually increasing tone value, the individual dots touch when a certain area-coverage value has been reached. This leads to an erratic increase in tone value. With conventional amplitude-modulated screening the dots can be given a particular shape so that they begin to touch at different values (= *first and second dot contact*). The resulting tone value steps in the print can be shifted into the three-quarter tone by giving the dots a *particular shape*. Good reproduction results of light motifs can be achieved with screens of this type, but they are not suitable for general use. The reason is that these screens produce undesirable effects, such as the formation of a line screen. *Line screens* are extremely direction-sensitive, and they are prone to abnormal dot gains. For this reason it has been specified in ISO 12647-2 [3.2-3] for offset and business forms printing and ISO 12647-3 [3.2-4]

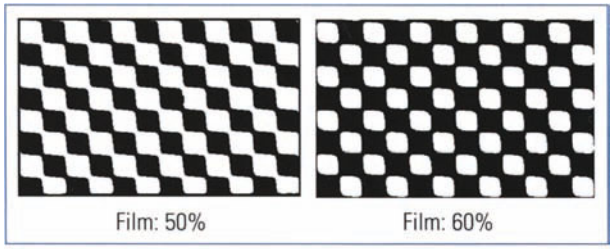


Fig. 3.2-17
Dot pattern (positive film) with first (left) and second (right) dot contact.
Note:
First dot contact: diamond-shaped dots touching in the direction of their longer diagonal
Second dot contact: diamond-shaped dots additionally touching in the direction of their shorter diagonal

for newspaper printing that both dot contacts should occur between tone values of 40 and 60%, separated by not more than 20%. Figure 3.2-17 shows a screen with *diamond-shaped dots* that meets these conditions: first dot contact at 50% and second dot contact at 60%.

Circular halftone dots are prescribed for facsimile reproduction in newspaper printing and for *print control bars*. Since the tone value somewhat depends on the dot shape, all types of control bars should use the same dot shape (i.e., circular) in order to maintain comparability. This shape has the advantage that it can be checked by simple means, it also shows the lowest dot gain. The dot contact does not play a role since control bars should not be used for the recording of print characteristic curves. These strips are rather intended for monitoring certain tone values during the production run.

For flexographic [3.2-5] and screen printing, the first dot contact must not be under 35% and the second not above 60%. The dot contact phenomenon does not exist in gravure printing, accordingly there are no such specifications for reproduction. For printing technologies that do not require a printing plate such specifications do not yet exist.

3.2.2.4 Tone Value Influences in Printing

Tone Value Sum

For some multicolor printing processes the sum of the tone values of all colors (normally four) involved in the composition of the image and with it the maximum application of ink must be restricted, because heavier ink loads do not dry fast enough. The *tone value sum* is calculated from the tone values of the *separated colors* (color separations) specified in the data file (or on the films); i.e. the tone value sum is a reproduction related parameter, changes of tone value at subsequent stages are not considered. A value of 100% corresponds to a solid tone, 400% means the four inks have been overprinted. For commercial sheet-fed offset the tone value sum should not exceed 350%, for web offset the value is 300% [3.2-3]. For newspaper printing the tone value sum should preferably remain below 240% and on no account exceed 260% [3.2-4]. There are no such restrictions in gravure publication printing, because the web is dried after each printing unit.

In flexographic printing the tone value sum should range between 280 and 320% [3.2-5]. The cardinal advantage of screen printing are thick ink films, 400% is possible. However, it is often required that the screen printing data be interchangeable with other printing processes. Therefore, the maximum values are usually lower. There are no specifications of this kind for printing processes without a master (NIP technologies). (In sec. 1.4.2, fig. 1.4-24, the tone value sum is also discussed in connection with different color separation techniques.)

Dot Gain (Tone Value Increase), Print Characteristic Curve

The print characteristic curve or the absolute tone value increase (see fig. 1.4-47; both calculated from the CMYK data in relation to the print), are used as the basis for generating the separation data. They should also be incorporated in the CIP3 data (see secs. 1.2.5 and 8.2.3). Neither property is a quality-deciding attribute of a separation. In particular, it is not true that the quality of a print will improve if the tone value increase is unusually low, because the image would then be "lighter" than the proof. It is also not possible to neutralize this by choosing a higher solid tone coloration than that of the original (master copy, proof). This is because the chromas and hues of the solids no longer match the proof. An extremely low tone value increase is only good for the image, if, as was generally the case decades ago, the proof, for technical reasons, had a tone value increase that was well below that of the normal production run.

It should be a generally applicable rule for industrial production that after completing the production stage of "reproduction", no further interventions on the image content are to be undertaken. There must be no

manipulation of the coloration of the solids and print characteristic curves during printing.

The quality of a reproduction in terms of tone value rendering will only be appropriate if it is based on the standard print characteristic curves of the designated production run. With regard to color management (see sec. 3.2.10) this means that the output profile used to generate the CMYK values should be calculated from a characterization table that applies to the designated printing conditions. The output profile used must be sent along with the data. Alternatively, the name and the source of the characterization data as well as the parameters determining black must be given. This enables the recipient to calculate the equivalent CIELAB data from the CMYK data.

If the system used for output accepts CIE color data, they must be matched to the gamut and tone value rendition of the designated production run.

To verify that settings are properly aligned with the output process, an off-press proof (see sec. 3.2.11) or an on-press proof (the same printing process and materials are applied as for producing the job) is carried out; the characteristic values of the production run (within the given tolerances) are specified on the print control bars. They comprise the CIELAB coordinates for solid tones (only for auxiliary purposes: their ink densities) and the tone values of the primary colors C, M, Y, and K. The color control devices of digital off-press proofs must also contain a number of typical mixed colors, the color coordinates of which must have specified values for each printing process and printing paper type. The Ugra/FOGRA Media Wedge CMYK [3.2-6] is an example of such a device.

If the color control bar for the off-press (see sec. 3.2.11) or on-press proof has the correct values, the *gray balance* will also be correct, that is, achromatic parts of the image on the original will be represented without a color cast under printing conditions. In this case, the tone values of the chromatic primary colors C, M, and Y must be in a certain ratio, that is, determined by the printing process, the inks, and the substrate (see also fig. 1.4-42). Therefore, if a general specification is given for the gray balance of a certain printing process this must be regarded as approximate [3.2-3].

More detailed information on the conditions for on-press and off-press proofs (see sec. 3.2.11) for the various printing processes and conditions are given in the standardization directives of the German Printing and Media Industries' Federation (BVDM, [3.2-7]) and the ISO 12647 series of standards [3.2-2 to 3.2-5 and 3.2-8]; see also section 14.4.

Standards for printing processes without a permanent printing master (NIP technologies, Computer to Print) are being developed (ISO 12647-7) [3.2-8]. Since offset printing is the prevailing method, at least for short/medium and long print runs, it is economically beneficial for NIP technologies to accept data originally intended for offset printing. A press with digital input like gravure printing, by the way, can also simulate various print characteristic curves.

3.2.2.5 Color Management Profiles

When applying color management (see sec. 3.2.10) in prepress production, the profile created for the relevant combination of input device and photographic material must be used. The relevant profiles must likewise be used for display on the monitor and output onto plate or proofer, otherwise quality loss must be expected. The profiles used should be sent along with the data. They should contain a reference to the source of the characterization data. Based on this information or, if available, on the color values of the proof, it can be checked whether the data is suitable for the intended production run conditions. Generally acceptable characterization tables are preferable for the production run, rather than those that are only suited to special conditions. A printing company that can adapt and maintain all its presses to its own in-house standard will also be able to bring itself into line with the industry's standard.

3.2.2.6 Image-dependent Effects and Corrections

Chokes/Spreads (Trapping)

When a substrate passes through the press at high speed, paper distortions, register differences, or other factors may cause "geometric, local shifting" of separated colors, which become visible to the human eye as unsightly "white gaps". On sharp contours in particular (e.g., a red dot on a black background or in a black surrounding) this may lead to the white substrate showing through.

These "gaps" are not a problem specific to printing, but to prepress. Whenever colored elements with a sharp edge definition are combined, this effect can occur. For this reason, the *adjacent color areas are spread* (made larger). It is usually the lighter form that is spread. The programs used here draw a (virtual) line around the object. Since the extent of spreading needed also depends on the substrate and screen used, the values mentioned

below can only be approximate values. With a 60 lines/cm screen, trapping should be between 0.1 and 0.2 mm, with a 33 lines/cm screen between 0.2 and 0.4 mm. Since the extent of trapping depends on the respective printing conditions, it should take place as late in the process chain as possible (the same applies to the decision on the screen program for output).

Trapping must unconditionally not be done twice, once in prepress or at the customer's and a second time at the printer's. Fine elements would fill in and detail rendering would be impaired.

Choking is used when the background is lighter than the foreground. To make a black area appear "deeper," the black area is often printed on a 40% cyan screen. If this area is broken by a reverse type (white on black), cyan might become visible in the edge areas. To counteract this effect, the corresponding area is "choked"; that is, the cyan area is made smaller. The term "trapping" is also used to describe the ink acceptance behavior when printing one ink film on top of another ink film (see sec. 1.4.4).

Moiré

Moiré effects can occur wherever two or more *periodic screen patterns* are unfavorably superimposed resulting in coarse regular patterns (see sec. 1.4.3).

One of the most common reasons is that a regular structure was already present in the original, as is the case with already screened originals or the patterns of fabrics (from which the word moiré originates). These interference patterns are avoided by selecting a suitable angle during the screening process or by using special filters when editing the image.

However, moiré effects may also occur during exposure, depending on the screening program used. Usually the latter shortcoming has nothing to do with the data supplied but must be attributed to the output unit (see sec. 3.2.1).

With frequency-modulated screening no moiré effects occur (see also sec. 1.4.3).

3.2.3 Digital Photography

3.2.3.1 Origins of Digital Photography

Modern digital photography has been developed from various technologies, all of which share *film-free image recording* as a common denominator. The most important base technology is undoubtedly the television and its line-by-line recording of moving pictures, whereby it is important to note that the television signal is only quantized line-by-line and represents an analog signal within the line. It was in an endeavor to make this kind of image recording accessible for home use that video technology came about. The difference between this video technology and television does not merely lie in the simplified camera design but also in the standardization of the signal recording on magnetic tape cassettes. The VHS (Video Home System) format, introduced in 1975, and the Video-8 format, introduced in 1984, have established themselves as standards.

In 1981 Sony introduced a video camera for still images (individual images as in photography). The term *Still Video Camera* was created to describe this. This camera had all the attributes of a normal photographic camera for the user but used a CCD area sensor (CCD: charge-coupled device) in place of the film, whose signals were saved onto a 2 inch floppy disk. Sony called this camera "Magnetic Video Camera" or MAVICA for short. This idea of recording still images instead of moving images could not really be classed as an new invention. What can be classed as an independent development, however, is its technical realization. The following five components were newly developed to record still video images:

- a form of data carrier that permits faster access than a magnetic tape, namely a mini-diskette;
- a camera that is modeled very closely on the 35 mm reflex camera;
- a printer for producing paper copies;
- a reader for the diskettes;
- a device for remote transfer of the images via telephone lines.

One thing that did not differentiate the recording of still images from moving images was the resolution, as this was based on the television picture standard. Since the television standard in the United States is different than that in Europe, the still video camera had to be compatible with both of these standards. This meant that both the American NTSC (National Television Standards Committee) standard with 525 lines and 30 images per second and the European PAL (Phase Alternation Line) system with 625 lines and 25 images per second had to be processed for playback. The *data carrier*, which could perhaps be classed as the most innovative component of this system, had a format only slightly larger than a framed 35 mm slide and could store 25 images each at approximately 400 000 pixels. Assuming

that 120 pixels/cm are required to print an image in offset printing, the data set of a still video image is only suitable for an image around the size of a passport photograph. This is the main disadvantage of the technology, namely the limited picture resolution. The link to the limited television standard also negated any further development in this regard. By 1989 more than ten companies had presented or at least announced prototypes of still video cameras. In Europe, however, only very few of these cameras were on the market, with Canon and Sony offering the best known models.

An area array of sensors, which offer significantly better *resolution*, could not be used to improve the picture resolution prior to 1990 as they were too expensive and not available in the required numbers. Efforts therefore had to be concentrated on scanner technology, where inexpensive line sensors were already being used before 1980 for image scanning. The first line-by-line CCD scanners could only be used for less demanding tasks such as optical character recognition and document scanning in fax machines. Not until later did CCD elements find use in flatbed scanners for photographic originals. It was around this time that the same scanning principle was adopted for use in digital cameras, with the limitation that no moving pictures could be taken. Yet as it turned out, this did not prove to be a decisive disadvantage.

The actual photographic camera did not have to be newly invented for digital photography but rather adjusted to meet the requirements of the digital recording technology. This allowed several companies to make use of existing camera casings and offer just an attachment unit fitted to the back of the camera for digital photography. The advantage of this concept is that this kind of attachment unit can usually be used on several camera casings. We must therefore differentiate between two design concepts, namely digital cameras that come as a complete unit and the *digital camera backs*, which are components for *conventional camera casings*.

3.2.3.2 Image Scanning with Digital Cameras

The object is mapped onto the sensor surface via the lens of the camera for image scanning, as shown in figure 3.2-18.

The basic kinds of digital image scanning are shown in figure 3.2-19.

The most important criterion is the type of scanning, which can take place either dot-by-dot (individual sensor), line-by-line (numerous sensors arranged in a line), or by area (area sensor, matrix of sensor elements). Dot-by-dot scanning is not significant for digital cameras. *Line-by-line scanning* is closely related to the scanner principle, and cameras using this principle can be classed as scanners with a built-in lens system (fig. 3.2-20).

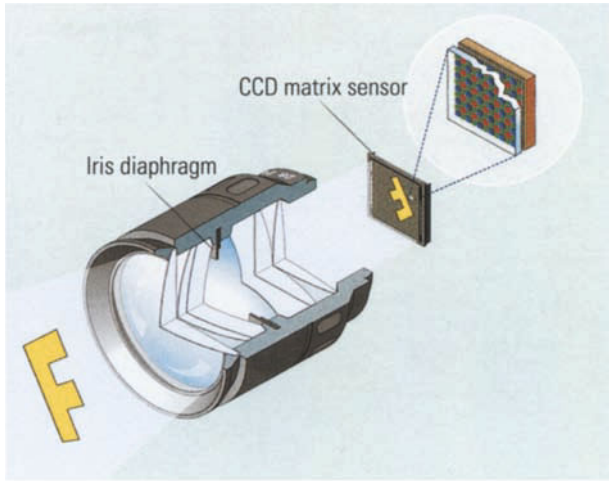


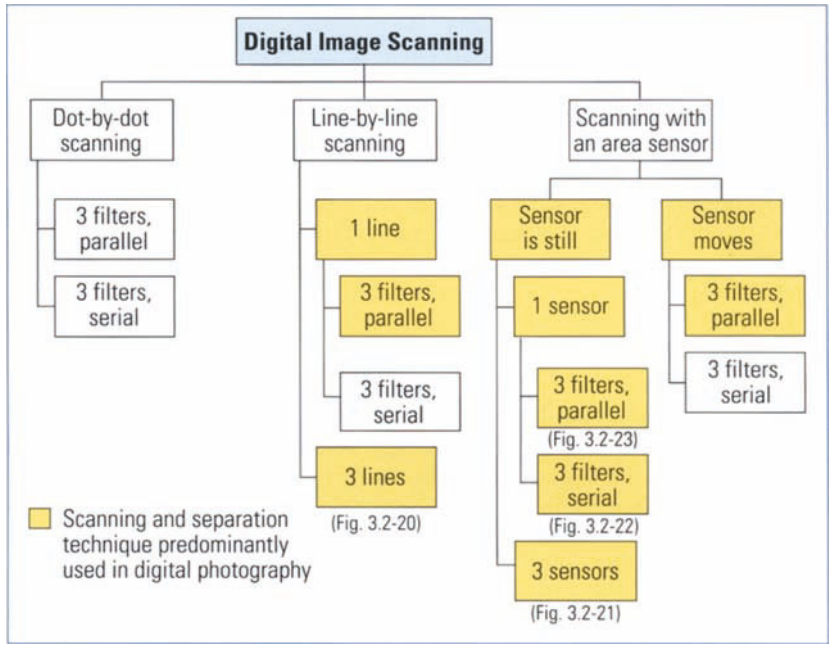
Fig. 3.2-18
Optical imaging onto a sensor element via a camera lens, using the example of a CCD matrix/area sensor (AGFA)

To capture colored objects the light is split into the three color channels (RGB) using *color filters*. In the linear *three-line sensor* (trilinear sensor) shown in figure 3.2-20, the three color channels are alongside one another so that the color information for each sensor position is captured simultaneously. For area image capture, the CCD lines are moved in increments. If an increment size is selected that corresponds to the gap between the CCD lines of the color channels, the color information for one line of the picture is complete after three increments. Due to the *sequential image scanning*, line scanning cameras require constant lighting conditions. In addition to this, the object to be imaged must not be moved while the photograph is being taken – that is, during the scanning procedure. These basic conditions limit the field of application to so-called *still-life photography* in the studio.

While the line sensor moves when scanning, the *area sensor* normally remains still (fig. 3.2-21). Area sensors are available with specifications such as 3060 × 2036 = 6230160 pixels with a pixel size of 9 µm × 9 µm, that is a sensor receiving range of 27.5 mm × 18.3 mm.

The kinds of *color separation* in area sensors are shown in figures 3.2-21, 3.2-22, and 3.2-23. Color separation can

Fig. 3.2-19
Principles of image scanning and color separation in digital photography



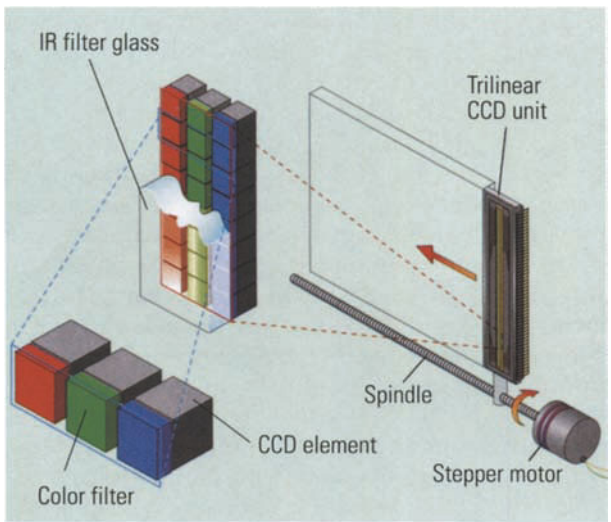


Fig. 3.2-20
Color image scanning using three sensor lines with RGB color filters; scan motion for image recording via stepper motor and spindle (AGFA)

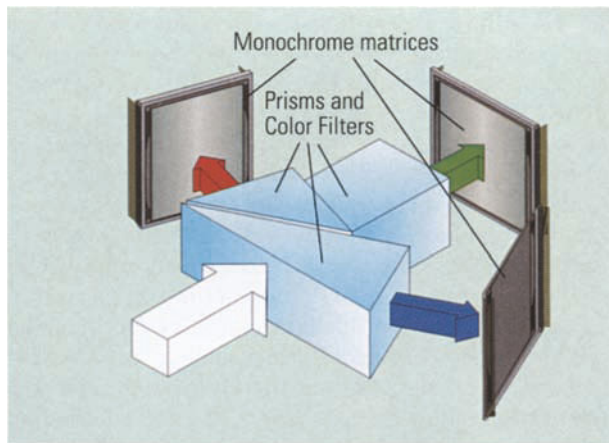


Fig. 3.2-21
Color image recording (RGB parallel) using three area sensors and beam splitting using prisms with color filters (AGFA)

basically take place either with three sensors (fig. 3.2-21) or with just one sensor (figs. 3.2-22 and 3.2-23).

When working with three area sensors, color separation can be achieved using *prisms* and color filters. With this process photographs of moving objects can be taken.

When working with just one area sensor, the color separation either takes place via serial scanning with filters, for instance, via a *filter wheel* (fig. 3.2-22) or by scanning via a *mosaic filter* consisting of R, G and B filter elements on the sensor array. The filter can be designed

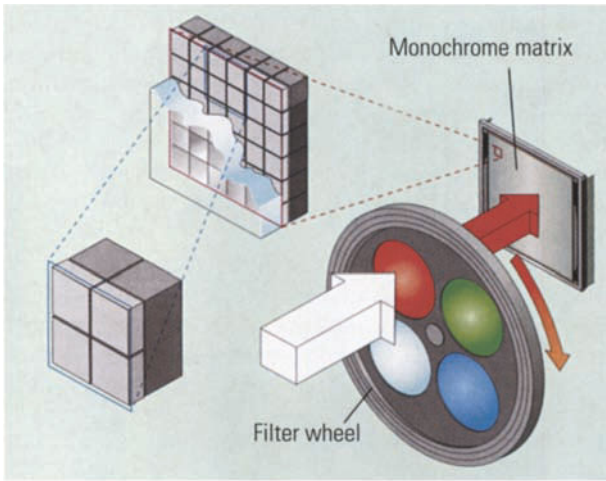


Fig. 3.2-22
Color image recording with an area sensor; RGB color separation using three separate shots, each with alternating color filter via filter wheel; neutral filter for black and white shots (AGFA)

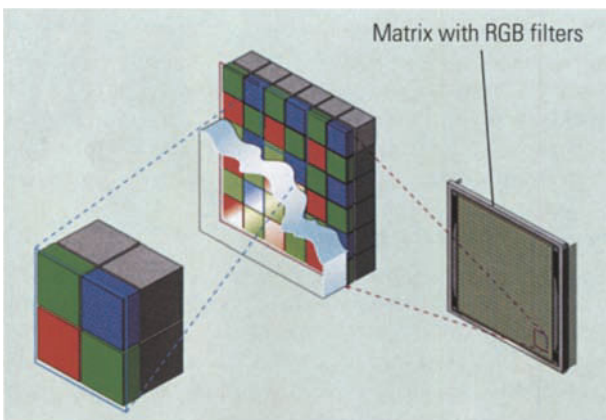


Fig. 3.2-23
Color image recording with an area sensor; color separation using RGB mosaic filter on the sensor array (AGFA)

in either a strip form or with pixel-related individual elements, as shown in figure 3.2-23. One method is for the area sensor to move in micrometer increments. In this way even more pixels can be written between the pixels already recorded (higher resolution). This principle was first applied by Kontron and is found in several cameras today. The sensor movement used is called *micro-scanning*. Resolution can be increased by up to a factor of about fifty using this method.

The greatest flexibility for the user is achieved when the photographs are taken either simultaneously with three area sensors or with just one area sensor, equipped with a mosaic filter. Here, shots from moving objects can also be taken, which is why the term *one-shot camera* is used. In contrast to this, serial cameras with filters are called *three-shot cameras*. From a purely mathematical standpoint, three shots with three filters offer three times the amount of information compared to an individual shot with a combination filter. However, this does not lead to three times the resolution since those images that are captured in a single pass with a mosaic filter are also split into three partial pictures with the full number of pixels during the color separation. One area where the resolution is not improved, for instance, is where all three partial colors are present in one picture element. Elements of a picture that consist of just one partial color do, however, have a better resolution with three separate exposures.

3.2.3.3 Demands on the Resolution

The efforts to continuously increase the resolution of digital cameras lead to the question of what resolution the human eye actually requires when looking at pictures. The resolution of the human eye is determined by the distance between the light receptors and the retina. This creates a viewing angle, below which the eye can still just barely differentiate between two lines (fig. 3.2-24). This minimum viewing angle comes to about 1.5 angular minutes. In order for the human eye to be able to dif-

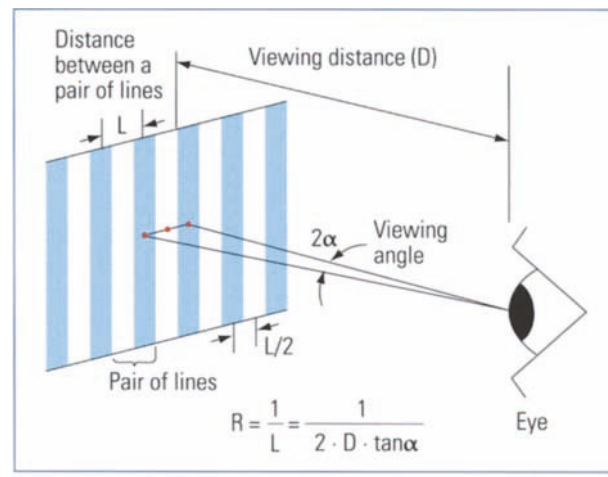


Fig. 3.2-24 Definition of the resolving power (R) of the human eye

ferentiate between two lines, there needs to be a gap between the lines, that is, a *pair of lines* consisting of one black and one white line. The resolution of the eye (or also of a photographic layer) is therefore not given in lines/cm but more precisely in pairs of lines/cm.

From the aperture angle of 1.5 angular minutes (α) the resolution can be calculated in pairs of lines by assuming a certain viewing distance (D). A typical value taken for this distance from the object when looking at pictures in books or newspapers is 40 cm. For this distance a resolution/resolving power for the eye (R) of 28.7 pairs of lines/cm is calculated using the equation:

$$R = \frac{1}{2D \tan \alpha},$$

that is, black/white line structures spaced about 0.175 mm or black lines (with white interspace) with a distance of 0.35 mm (line width is the same with black and white stripes) are easily recognized when viewed normally, this is not the case with finer structures.

When determining the number of distinguishable pairs of lines experimentally, it becomes apparent that this value depends to a considerable extent on the contrast between white and black lines. To gain a precise description of the resolving power, therefore, it must be calculated in relation to the contrast. This produces a curve, known as the modulation transfer function (see also fig. 1.4-26 in sec. 1.4.3). Significant for the eye in this context is that the given value of 29 pairs of lines/cm only applies to black-white contrasts. With color contrasts (e.g., red-green or yellow-blue) the resolution is significantly lower. Television transmissions, for example, make use of this by transmitting the black and white signal with a higher resolution than the color signal.

To be able to reproduce 29 pairs of lines/cm using a digital image process, 58 (2 × 29) pixels/cm are required. For a data set printed in offset printing, however, more than 58 pixels/cm are usually required since the number of pixels should be adapted to the *screen ruling* and the number of required gray/tone values. A good rule of thumb is that the *scanning detail* (scanning frequency) should be twice that of the screen ruling (screen frequency). This applies to screen rulings in the range from 40 to 70 lines/cm in particular. For larger screen rulings this ratio is normally reduced to 1.5 in practice to avoid overly large image data volumes (see also sec. 3.2.2.1). How many pixels a data set should have can now be calculated for a certain screen *ruling* and a preselected print image format so that the image can be reproduced. For a screen ruling of 60 lines/cm (and aligned to this, a scanning resolution of 120 pixels/cm) the required number of pixels for image capturing for the DIN A3 format (420 mm × 297 mm) comes to about 18 million per color (the number of pixels changes linearly with the size of the surface area; the number of pixels for digital plateimaging for offset printing is much higher (approx. 30 times) through the creation of tone values per screen cell!).

Comparing these values with the scanning capacity of digital cameras available in mid 1999 makes clear that the resolution needed for a DIN A3 image, for example, cannot be achieved with an area sensor and that a scanning camera is still required.

3.2.3.4 Special Features of Digital Cameras

Tone Value Quantization

Alongside resolution, the tone value quantization also has an influence on the potential image quality. The lower limit for a good *tonal graduation* for the image capture is 256 gray levels, corresponding to 8 bits. How many bits are required for all three partial colors is often also given, coming to 24 bits (or 3 bytes) in this example. With the availability of faster computers and better storage capacity, cameras with a higher tonal range are also offered. Values above 12 bit/color (4096 gray levels) do not, however, offer any further improvement in graduation even for "difficult" scenes.

Focal Length of the Lenses

In conventional photography the focal length of the lenses is normally set to the format of the film. With 35 mm cameras the shot area is 24 mm × 36 mm, 50 mm is viewed as a standard focal length. Mathematically, this corresponds to the shot area diagonal multiplied by a factor of approximately 1.2. Many digital cameras in the lower price category possess an area sensor with a diagonal of less than 10 mm. The standard focal length of these cameras is then less than 12 mm. At the other end of the focal length scale are cameras with an attached digital unit, whose standard focal length can be in excess of 70 mm. Since users of analog photography are used to handling standard focal lengths of 50 mm and above, they must often revise their thinking when using a digital camera, which may have a standard focal length of just 10 mm. For a portrait photograph a focal length of 15 mm is sufficient, and 50 mm represents a "telefocal length." With these short focal lengths it is difficult to make wide-angle lenses with even shorter focal lengths as shortening the focal length is not always possible.

Aspect Ratio

Having used 35 mm cameras, most people are used to the aspect ratio of 2:3. Yet many digital cameras, especially those in the lower performance bracket, tend to use the television format of 3:4. With higher resolution cameras (over a million pixels), however, there is virtually no standard aspect ratio. Several manufacturers use sensors with an aspect ratio of 1:1 while others offer the photographic format of 2:3. Between these two, practically every permutation is available, including the television format of 3:4.

Link-up to a Computer

The clear advantage of digital photography is that the image data can be digitally processed immediately. This means the data must be transferred to a computer, either directly when taking the picture or at the latest for processing. There are two basic possibilities here, either intermediate storage on a data carrier fitted in the camera or direct transfer to a computer after each shot. The PCMCIA card (Personal Computer Memory Card International Association) has become established as a good means of data storage for cameras. It is an electronic storage device in the shape of a credit card with a standard interface for transmission to the computer. For direct transfer, a standard interface such as SCSI (Small Computer System Interface) or a plug-in card is suitable. A serial interface offers a slightly slower data transfer. For the following image processing, special image processing programs or plug-ins are available for standard applications.

3.2.3.5 Digital Photography and Color Management

A digital camera can basically be characterized with a *color profile* in exactly the same way as a scanner or other input or output devices (see also sec. 3.2.10). However, the significant difference between a digital camera and a scanner is that the type and density of light are fixed values in scanners, while in digital photography they are variable. The consequence of this for digital photography is that a different profile is needed for each different kind of *lighting condition* used. While the lighting can be standardized for use in a studio, this is clearly not possible with outdoor photography.

The fact that a *test form* (test image) is required to produce an *input profile* poses the question of how this can best be achieved in the case of digital photography. It is well-known that with scanners the test form represents the colors of the original photographic material used. But what colors should a test form for digital photography contain when the diversity of colors found in nature is so great?



Fig. 3.2-25
Digital camera with PC Card (PCMCIA card) and color management software (including test image) for integration into the digital workflow of the prepress stage

Investigations have shown that in cases where digital cameras have a sensitivity corresponding to that of the human eye, the problem of finding the "correct" model colors can be disregarded for the most part. For this reason it is acceptable to use the same test image for *producing the profiles* in digital photography as is used for scanners. With low resolution digital cameras, however, this can lead to problems as the format of the test form is usually too small.

To integrate digital photography into the digital *workflow* of print media production, more and more special computer programs are being created and implemented to make it possible to work with ICC profiles (see sec. 3.2.10 and fig. 3.2-25). Alongside this, several camera manufacturers are beginning to move over to a system that allows the image data to be connected with ICC profiles during image capture.

3.2.4 Digitizing Originals (Scanner)

As late as about 1970 repro cameras of varying construction (horizontal and vertical) were still regarded as the only devices that could be used for repro jobs (see also sec. 3.1.3.4). Supplies of different film materials were stocked for this purpose: masking films and continuous-tone films for four-color separations, fast reacting films for screening color separations and direct screening, duplicating and

contact material for converting the exposed negative to film positive for platemaking, etchable films for color lithography, and finally, stripping films that allowed final corrections to be made without the need to recopy whole pages.

Since the entry of electronics into repro technology "expertless repro" has become a discussion point. Following the introduction of electronically controlled vertical repro cameras in the early 1970s, industry experts were already forecasting that from then on anyone could be trained to operate a camera in next to no time and would be able to produce the same results as highly trained experts. However, in the first phase of electronic reproduction these forecasts came to nothing, as the diversity of repro work still required too much know-how from the camera operator.

This was all the more true for the powerful repro scanners which dominated color reproduction in the '70s and '80s. Working with these scanners required just as much experience as thorough training. This technical development did have a massive influence on the personnel structure, however. As scanners replaced cameras, the need for repro photographers diminished by the same amount; a new type of profession arose: scanner operators. As electronic image processing gradually became established, lithography also took place at the computer, followed in the mid-'80s by the integration of text and images.

Since then the market has come to be dominated by a totally different generation of scanners. Reproduction or "scanning-in" became just as popularized as typesetting had already become through desktop publishing. The possibility of using software to integrate the knowledge of whole generations of repro experts and lithographers into the hardware and software components of so-called "one-button scanners" and their driver programs has been accompanied by a change not only in the qualifications required of the operators but also in the work processes in this area. There has also been a shift in the places where repro is carried out. In an era of rapid communication, scans or image data bases emanate from the repro department as well as the customer, agency, CD-ROM, or the internet. In this "mixed company" there is an even greater need for a functioning color management system (see sec. 3.2.10). This means that all the scanners and image-processing stations should be calibrated and the profiles for subsequent processes should be known.

3.2.4.1 Scanner Designs and Models

Scanners

For years, and almost decades, the choice of scanner for the graphic industry was limited to *drum scanners*. Today there is a range of technologies available. *Flat-bed scanners* predominate in terms of number, and increased demands have resulted in a renewed proliferation of scanners. Today there are good value flat-bed scanners for DIN A4 format, powerful flat-bed scanners for formats significantly larger than DIN A3, drum scanners ranging from table-top units to high-end vertical scanners, as well as so-called "*copy dot scanners*" for redigitizing analog and screened originals. Besides these there is an increasing number of special scanners for transparencies (slides and larger format transparent originals) and OCR scanners (Optical Character Recognition) for reading in text data.

Scanners may therefore be differentiated according to design and technical performance as well as special functions (table 3.2-4).

Suitability of Scanners

	Scanner type		Function			
Type of Original	Drum scanner	Flat-bed scanner	Color (generally)	35 mm slide	Redigitizing	OCR (documents)
Reflection	●	●	●		●	●
Transparent	●	●	●	●	●	
Color	●	●	●	●	▲	
Continuous tone	●	●	●	●	▲	
Black and white	●	●	▲		●	●
Line art	●	●	▲		●	●
Printed original	●	●	▲		●	
Flexible original	●	●	▲			
Rigid original		●	▲			
3-D original		●	▲			
Format > A3	●	●	▲		●	

● applies ▲ possible

Table 3.2-4 Scanner types and their use

Scanner Types

- drum scanners (horizontal, vertical, or inclined drum arrangement)
- flat-bed scanners (desktop scanners, XY scanners)

Functions

- color scanners
- slide and APS scanners (Advanced Photo System)
- OCR scanners (OCR Optical Character Recognition)
- redigitizing scanners

Designs

Figure 3.2-26 gives an overview of examples of scanners of various constructions.

The various types of scanner are suited to a greater or lesser extent to a particular task. Which type of device is suitable for which task must be determined with the aid of an individual requirement profile:

- What type of original is to be processed?
- Are the originals flat or three-dimensional?
- Are the originals flexible or rigid?
- What is their format?
- By how much do the images need to be magnified?
- Are the originals mainly transparent or reflective/opaque (slides or photographic prints)?
- Are the originals predominantly black and white or colored?
- Do the originals have clearly defined lines and areas (line art originals)?
- Are they continuous-tone images, such as photographs, with gray tones or colors that merge smoothly into one another?
- Are the originals already printed?
- How are the recorded data going to be used and further processed?

The matrix in table 3.2-4 answers these questions and assigns the relevant device, showing which device is most often chosen for which job. Important factors in this decision besides the device's function are its user-friendliness, software functions, robustness, and reliability.

In the printing industry the choice falls mainly on scanners offering great versatility of application as well as high quality. Besides having the capability of reproducing *transparent and reflective originals*, the format is also important, as is the capability to record a wide tonal range (especially shadow areas of color slides) and den-

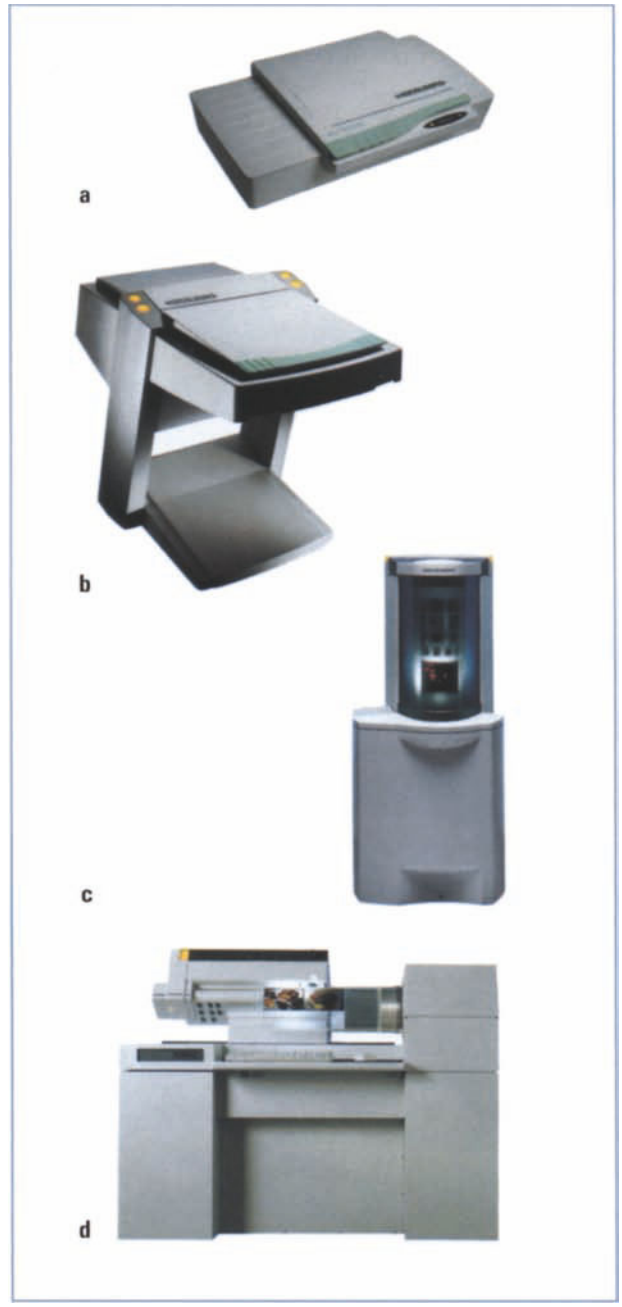


Fig. 3.2-26 Scanner designs.
a Flat-bed scanner as a table-top unit (Quickstep, Heidelberg);
b High performance flat-bed scanner (Topaz, Heidelberg);
c Drum scanner with vertical drum arrangement (Tango, Heidelberg);
d Drum scanner with horizontal drum arrangement (ChromaGraph, Heidelberg)

sity ranges of at least 3.5. Well-designed software may also offer interesting functions such as the conversion of color negatives into positive images or the direct transformation of RGB data into CMYK for four-color printing. The ability to produce a considerable enlargement of colored images that are rich in detail without any visible loss of quality is reserved largely for the professional high resolution flat-bed or drum scanner.

Redigitizing or *copy dot scanners* are particularly suitable for redigitizing already screened films by scanning a bitmap of the existing halftone dots at suitably high resolution.

Transparency scanners are mainly used to scan large numbers of color slides (framed or unframed). This type of scanner is made exclusively for this purpose (or also for scanning color negatives).

OCR flat-bed scanners with the appropriate software are eminently suited to scanning printed text into a word processing program. Even though there are only a few black-and-white scanners, such scanners are designed primarily for recording gray scale images (continuous-tone images), line art originals, or documents.

Scanner Technology

Modern digital input processes such as scanners, digital cameras (see sec. 3.2.3), or photo CDs allow flexible editing and processing of images on a computer. In this respect digital data have the indisputable advantage of being able to be copied as often as required without loss of quality.

Digital images consist of an arrangement of small squares known as picture elements or pixels (fig. 3.2-27). When scanning in, the input devices reduce the visible color spectrum to the RGB color system, for which one color set is allotted to each pixel.

The resolution of scanners is usually quoted in pixels per inch (ppi) or dots per inch (dpi). At a reproduction scale of 100%, scanning in a continuous-tone image is normally done at a scanning resolution of 300 dpi (see also sec. 3.2.2), while a line art original ought to be scanned in with at least 600 dpi. (As a comparison: the maximum resolution of output devices is quoted as the number of printable or exposable dots per inch (dpi).)

Scanners offering higher resolution need this degree of resolution for enlargements. The true optical resolution of a CCD scanner is determined by the optical system and the number of dots per inch that can actually be registered by the CCD cells. It is advisable when comparing scanners to determine whether the optical resolution is improved by means of the software (interpolation). It is true that this process avoids visible pixels in enlarged images but it is unable to record any extra detail.

The increasing proliferation of flat-bed scanners may be attributed primarily to technical improvements that allow up to 8000 or even more CCD elements in a single chip. Up until just a few years ago CCD arrays contained only 2000 elements per chip. Flat-bed scanners allow various originals to be scanned in, some-

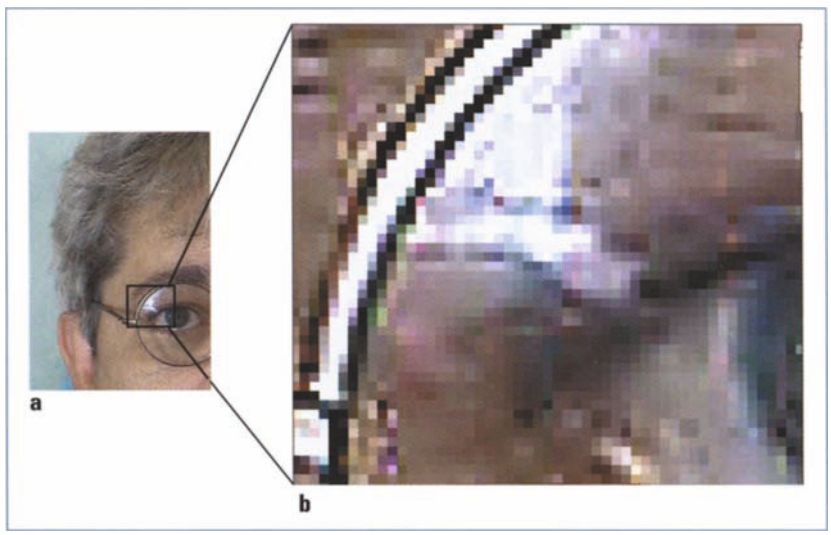


Fig. 3.2-27 Scanner resolution.
a Detail from a color photograph;
b Digitized color image, detail after scanning and displaying on the color monitor

thing that cannot be achieved with drum scanners because the original is affixed to the curved surface of the drum.

3.2.4.2 Drum Scanners

Drum scanners of the old design (see sec. 3.1.4, repro scanners, fig. 3.1-35) were stand-alone systems or input devices that were part of an EIP system (electronic image processing). The *photomultipliers* used to register RGB color values in drum scanners result in high quality reproductions. Drum scanners remain the image recording devices that satisfy the highest demands of resolution and quality (figs. 3.2-28 and 3.2-26c and d).

Drum scanners are based on highly sensitive photomultiplier technology, which scans the light reflected or transmitted by the original and separates it into red, green, and blue (RGB) component colors. Drum scanners have a xenon or tungsten halide light source that is focused on to a small area of the original by means of glass fiber optics and condenser lenses.

Only flexible originals may be mounted on transparent drums. Processing can normally be carried out on negative or positive transparent or opaque originals. Transparent originals are illuminated from within the drum, while opaque originals are illuminated from the outside. The light transmitted or reflected from a tiny point of the image enters the sensor unit, which passes along the external surface of the fast rotating drum (fig. 3.1-36). The light is directed on to mirrors arranged at an angle of 45° to the light beam. Part of the light is reflected by each mirror/beam splitter while the rest is transmitted to the next mirror. The reflected light passes through a red, green, or blue filter and then reaches one of the three light amplifiers, the so-called photomultipliers. Analog/digital converters digitize the analog voltage signals of the photomultiplier. A fourth photomultiplier unit can supply information to immediately produce a high-definition image.

Photomultipliers (just as charge-coupled devices, CCDs) convert different brightness values into continuously changing, analog voltages. These are split up by an analog-digital converter (A/D converter) into a distinct number of steps using a process described as "sampling." The purity of the signal concerned may be affected by electrical interference leading to the possibility of noise.



Fig. 3.2-28 Drum scanner (ICG 360, ICG)

3.2.4.3 Flat-bed Scanners

CCD elements (charge-coupled semiconductor elements) are used in flat-bed scanners. The performance of these elements is so high that flat-bed scanners are beginning to achieve the quality of drum scanners. Up until just recently flat-bed scanners were clearly at a disadvantage compared to drum scanners, particularly in converting high density values. CCD scanners are still not able to achieve the resolution and density values of drum scanners – in particular they do not pick up the finest nuances of color in the very dark shadow areas of transparent originals – but in practice today's flat-bed scanners can easily satisfy the quality and productivity requirements of many applications (fig. 3.2-29).

Flat-bed scanners contain a linear CCD array consisting of several thousand CCD elements (e.g., 8000 per color channel) arranged on a chip. The originals to be scanned are placed on a copy glass and illuminated with a fluorescent or halogen light source. Transparent originals are illuminated evenly from above, while opaque originals are illuminated from below.

When scanning with flat-bed scanners, the light source and sensors move across the image in order to measure and record the color values. The scanned line of the image is projected via optical elements (lens



Fig. 3.2-29 Flat-bed scanner as table-top unit (PFU)

systems) onto the light sensitive CCD array and recorded.

Powerful flat-bed scanners for the professional market function according to so-called *XY technology*. This means that the projection characteristics of the optics are adjusted to the size of the original to make maximum use of the receiver unit in the CCD so that the best possible resolution is achieved (figs. 3.2-30d and 3.2-31). Optimized beam direction systems during scanning reduce the number of optical components and thus the system-dependent tolerances which occur. Figure 3.2-30c and d shows beam direction without deflecting mirrors.

CCD flat-bed scanners are used for both DTP applications and professional prepress. Apart from placing the originals in the scanner, the operation of a flat-bed scanner involves using a standard image-editing program or a special workstation containing the scanner software. Operator-friendly software user interfaces for controlling flat-bed scanners require only minimal

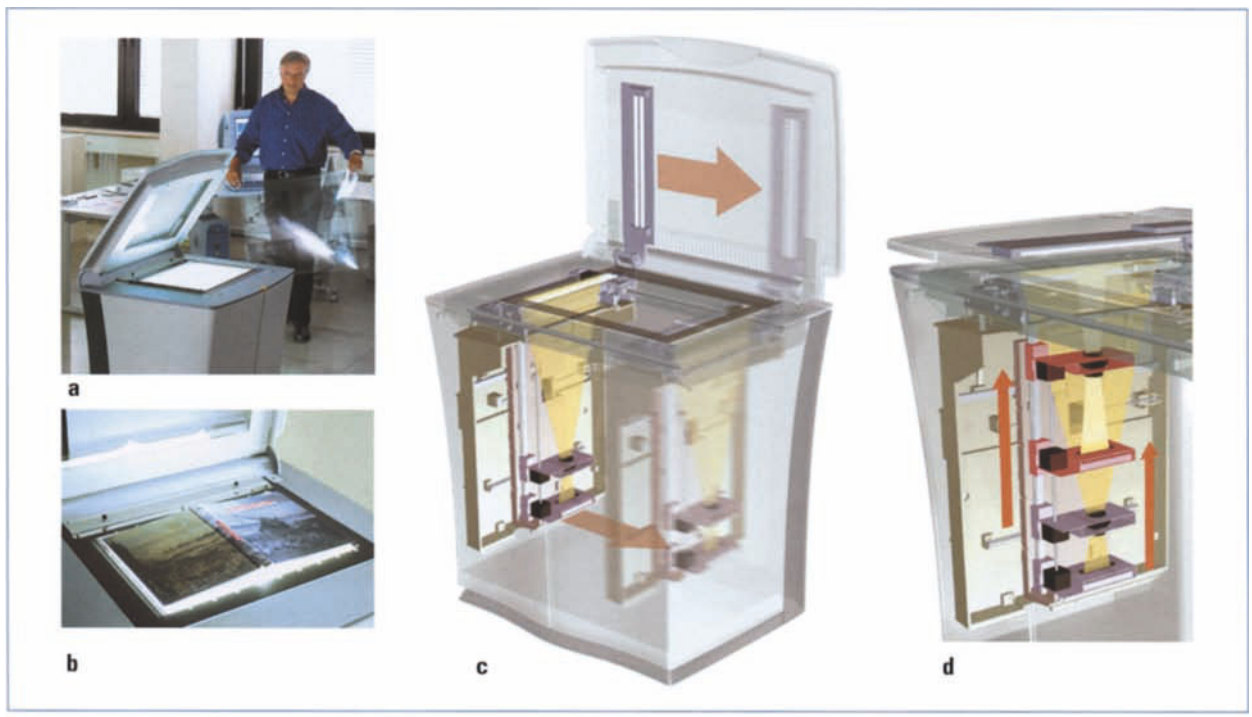


Fig. 3.2-30 Flat-bed scanner.
a Flat-bed scanner for reflective (opaque) and transparent originals;
b Scanning an original from a book;
c Scanning process (resolution, e.g., 5080 dpi max. at 8000 CCD elements);
d Setting the optics for two sizes of original (Nexscan F4000, Heidelberg)



Fig. 3.2-31
Flat-bed scanner with adaptive optical system for scanning different formats with the best resolution (XY–15, AGFA)



Fig. 3.2-32 Scanner for redigitizing halftone films

training, since the optimal color balance and image density are calculated automatically. High-end flat-bed scanners are available with a wide range of performance and can capture both opaque and transparent originals, while simpler equipment often requires peripheral devices in order to scan transparent originals.

An important advantage flat-bed scanners have over drum scanners is that originals on rigid materials of any thickness may be scanned, such as books or page layouts mounted on board.

3.2.4.4 Digitizing and Redigitizing

Scanners play a central role in all digital processes in prepress. The redigitizing scanner is particularly important in computer to plate workflow since it is only with the aid of such scanning systems that existing analog films can be converted into data files for digital processing. It is true that redigitizing is an additional expense requiring the utmost precision, yet it is not normally appreciated by the customer. So that this processing step, which is absolutely essential for end-to-end digital production, is cost effective, it is mainly businesses with mixed production that use color separation scanners (drum and flat-bed) with a special added function (fig. 3.2-32). Often films for possible repeat jobs, which were produced with computer to film units, are archived, and the data are no longer available. In this case scanners are used to digitize these analog data carriers, for example to drive a computer to plate unit or to amend the content at a workstation.

Various *redigitizing techniques* are employed for the different types of film masters supplied:

- *Copy dot* gives a high resolution scan for line structures, where the halftone dots present in the master are scanned 1:1 as a bitmap. Manipulations of the image content are not possible with this technology.
- *Descreening* is reverting a screened master into a continuous-tone file. This method gives good color quality and allows corrections to be made to color and content. It must be noted that the edges of text or graphics in the design tend to appear unclear.
- The so-called *mixed mode* allows the two processes above to be combined: the color information for the cyan, magenta, and yellow is stored as a continuous-tone file, while the black separation, which gives the contrast, is computed at the output stage as a bitmap file.

Both drum and flat-bed scanners are used for redigitizing.

Figure 3.2-33 shows an example of a flat-bed scanner scanning originals.



Fig. 3.2-33
Flat-bed scanner for digitizing large-format reflective originals (Purup-Eskofot)



Fig 3.2-34
The usual work environment of an A4 desktop scanner. With a direct connection to the computer all scanner adjustments are activated from this workstation, image processing is undertaken and the image placed in a layout program (AGFA)

Scanner Operation and Image Processing

The operation of today's scanners has been considerably simplified by operator guidance, self-adjusting components, automation, and powerful software. It is possible to start the scanning process using "one-button operation." Consequently the wide range of settings that may be selected no longer depends on the physical presence of potentiometers and control knobs, but is contained in the software. Basic settings made available by today's software provide an opportunity to achieve rapid and good results at the first attempt (figs. 3.2-34 and 3.2-35).

This has made scanning at the push of a button a common reality.

Processing the data base is done using image processing programs. However, the operator must first define the way in which his original is to be reproduced. An example of a standard image processing program is Photoshop (Adobe). There is still considerable potential for further development in the provision of easy-to-use, powerful image-processing programs together with high-quality monitors for displaying intermediate and final processing results.

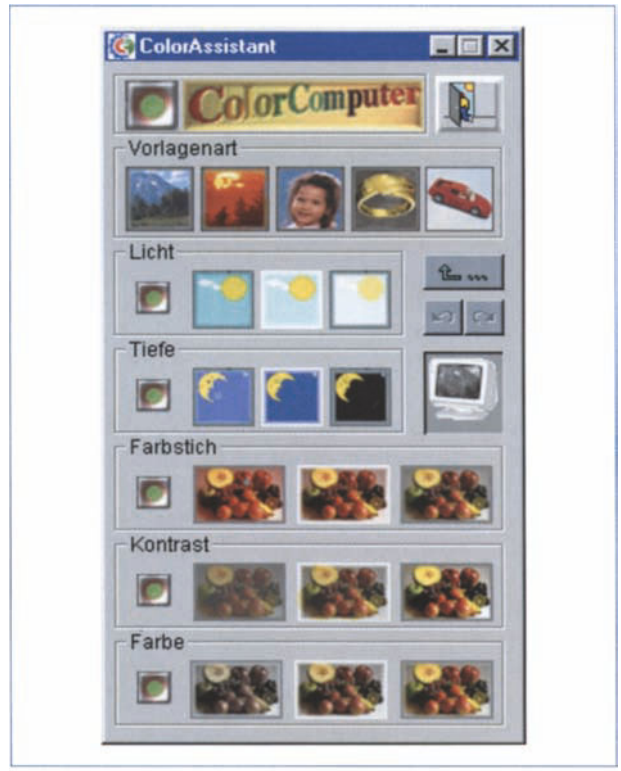


Fig. 3.2-35
Image processing functions and operation via the workstation monitor (Heidelberg)

3.2.5 Sheet Assembly and Imposition

The manual assembly of a sheet from page sections and page elements, as well as the combining and positioning of several pages on a print sheet in the format corresponding to the press, is a time-consuming, cost-in-

tensive, and sometimes uncertain stage within the production chain from conception to print. Cost-efficiency and a high level of production certainty are important in all areas of printing production.

The move from the manual light table to sheet assembly on the digital screen, assisted by imposition software, should both reduce costs and streamline the workflow. It makes no difference to the workflow whether the imposed pages are then placed on a large-format film imagesetter or transferred directly to image an offset printing plate (computer to film or to plate).

3.2.5.1 Page Make-up and Sheet Assembly

Only a few years ago, editorial staff, authors, or agents still glued paper and image proofs onto assembly sheets (*page composition*/layout with text, graphics, and picture elements, see sec. 3.2.1) and gave them to the composition room with page proof corrections. At this stage it was not just the line spacing that changed. Images had to be enlarged, reduced, and reproduced again.

At the beginning of the 1980s, text and picture integration was introduced and reduced the amount of manual work. Going backwards and forwards with masks, positives, negatives, copying in, and copying out quickly came to an end, and manual composition lost ground. The composition of complete pages was increasingly carried out on Macs and PCs but the process did not yet extend to whole sheets.

Assembly copying machines did, however, rationalize some stages of *sheet assembly* (arrangement of several pages on the print sheet) in the '80s. The machines were equipped with imposition programs that were exceptionally capable for their time. These machines positioned the full-page film (and also the assembled page film) automatically and in the right sequence on the printing plate and then exposed this plate section. This equipment, which is still in use today, is also used in *step-and-repeat copying*. Only a single film is needed in these step-and-repeat copying systems to produce x number of identical copies (multiple-ups) on the plate.

3.2.5.2 Full-Sheet Output

Modern *imposition* programs offer virtually any imposition pattern in prepress. Communication and consultation from accepting the order up to the binding is as essential as ever in spite of all the automation.

The technological development that has taken place in the area of film imagesetters and computer to plate systems has rendered the working methods outlined unnecessary. Powerful output devices, coupled with special software programs have made it possible to have an integrated process for single-color and multicolor jobs. The move towards large-format film and plate imagesetters, which has been increasing since the beginning of the '90s, is becoming ever stronger. The market for *imposition software* has also grown accordingly.

Producing entire sheets through large-format laser imagesetters is not only of technological interest but is also of economic significance as a result of rationalizing the workflow and saving material. For example, when printing eight made-up pages it is not necessary to expose the individual pages. The use of material is consequently more effective and more economical (fig. 3.2-36).

The ability to image entire sheets onto film or plate raises questions not only of technical feasibility but also of economically viable production methods. It will be some time before computer to... systems and technologies become fully established in the market, since it is the organizational problems, and not technical feasibility, that play the decisive role in the restructuring of workflows.

It is not so much the reluctance of businesses to use the computer to plate technology but rather the inconsistency of the workflow that is holding up the process. Computer to plate and computer to press require a completely digital workflow but the original copies are still being delivered to the industry in different forms and formats and only very few in digital form.

In practice it is impossible to do without a mixed process in the short-term. This means that businesses cannot fully utilize the cost savings associated with a computer to plate system and still have to rely on conventional production for the time being.

Full-Sheet Production in the Workflow

For businesses that are in a position to set up a digital or analog/manual workflow and have an influence on the nature of the original copy, there is potential for rationalization. By employing powerful multi-page imagesetters it is possible to adopt the method of using impositioned films or imaged printing plates.

In view of the wide variety of equipment and materials available, businesses have to decide which technologies to invest in for the short or medium term:

- Large-format film imagesetters (*computer to film*), which require the use of film material and the necessary chemicals: With this system only complete

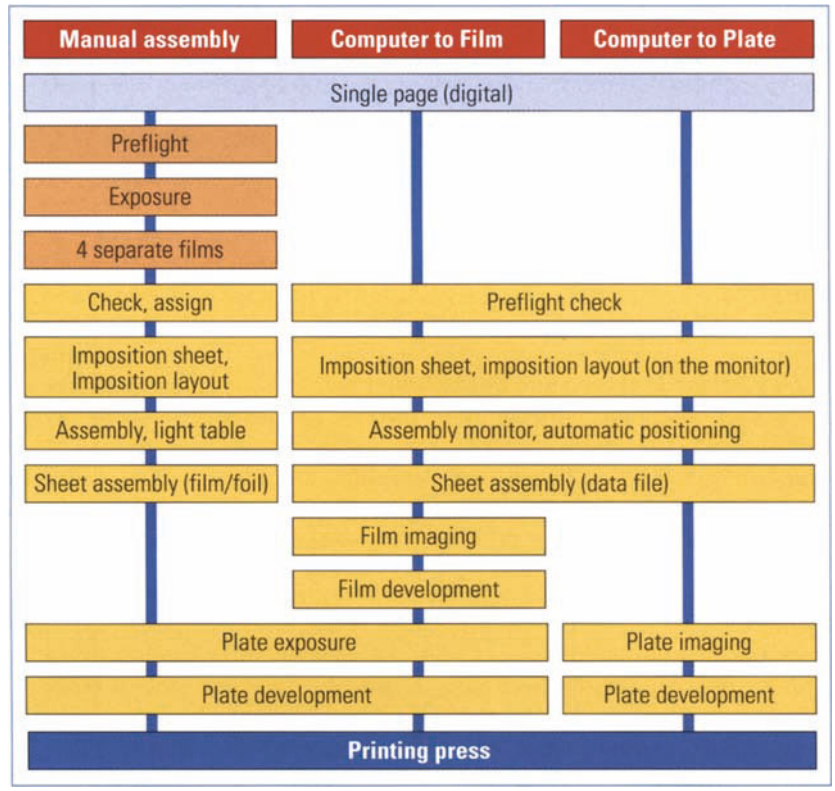


Fig. 3.2-36
Manual sheet assembly compared with digital assembly techniques for computer to film and computer to plate

sheets are made up and copied onto the printing plate.

- *Computer to plate* systems (CtP), where film developing and assembly are not necessary.

There is a whole range of jobs that can use the complete CtP workflow. Periodicals are an often mentioned exception, where all editorial pieces can be assembled into complete pages and sheets as digital data. Imposition can also be carried out digitally for these pages. However, pages or page sections (e.g., advertisements) that are delivered as films have to be assembled manually. Computer to film (CtF) is the ideal procedure for this application.

There are alternative solutions for this *hybrid method* (analog and digital production or digital and analog originals for the whole sheet) through so-called *copy-dot scanners* (see sec. 3.2.4), which enable a *digitization* or *redigitization* of sets of film. They allow the data, which is stored analog on film, to be integrated into the digital process chain. This does mean additional investment in an appropriate scanner and it takes time, which can rarely be charged for separately in the customer's bill. If, however, the workflow can be guaranteed by redigitizing the film and a cost saving is achieved, then an investment can very quickly pay off.

3.2.5.3 Imposition through Software

With manual working methods, sheet assembly of standard products and complex assembly of multicolored products often cause bottlenecks during print production. Even if a great deal of time is spent on achieving a precise register and correct arrangement of page and sheet elements, it is difficult to avoid the usual imposition errors (e.g., slight movements of register due to parallax). Preparation jobs such as sorting and cutting the individual films also take up time and are potential sources of errors.

By contrast, *digital sheet assembly* on the screen offers a higher register precision. It also helps to avoid mistakes by program-supported assembly. Digital imposition raises the quality of the print production, reduces the costs of material, space, and machines, and helps to resolve bottlenecks in production.

The *imposition programs* available on the market make it possible to combine traditional manual sheet imposition with the user-friendliness of publishing software and to replace the manual procedure with a digital command chain. The first priority of programs is to simplify and safeguard repeated tasks. Libraries of *imposition layouts* that come with the programs can be used for standard jobs. After appropriate modification they can also be used for special orders. Almost all programs also take into account the finishing work to be carried out on the product. These programs automatically adapt the lip and the binder's creep occurring with saddle-stitching depending on the paper weight, and correct the lateral distortion caused by folding.

The Imposition Sheet and the Imposition Layout

Imposition means the correct assembly of pages for a layout with, for example, 4,8,16, or 32 pages. Two basic working materials are required to manufacture the printing plate: the imposition sheet and the imposition layout, which depends on the type of folding to follow. The imposition sheet and the imposition layout can only be employed when the most appropriate production method from a technical and economic viewpoint has been determined.

The *imposition sheet* (fig. 3.2-37) shows the positions of the sections to be printed, the distances between the pages, from the middle of the sheet, from the binding edge (fold), and from the edges of the sheet. It also takes into account information such as the position of the gripper edge and shows where the different markings should be made that are needed for printing and subsequent sheet finishing, such as lay markers, signature titles, collating marks (see fig. 7.2-52), or cutting marks as well as the register marks and print control strips that are required for printing. The imposition sheet must sometimes also contain information on the position of a numbering unit or perforation (see also sec. 3.1.5, fig. 3.1-40).

Signatures and collating marks (fig. 3.2-37) are indispensable for processing book blocks, to produce the correct sequence of sheets, sheet sections and binding sections. The alignment/lay marks are particularly important because they mark the direction in which the sheet runs into the folding machine. This establishes the location, alignment, and direction of the first fold and all the subsequent folds.

It is also important for electronic imposition for the imposition sheet to contain all the information on measurements.

The *imposition sheet* is the basis for preparing the print of a sheet. It is provided with information about the *imposition layout*, which establishes the division of the printed sides onto the front and back of the sheets and gives an overview of the number of printing plates (fig.3.2-38).

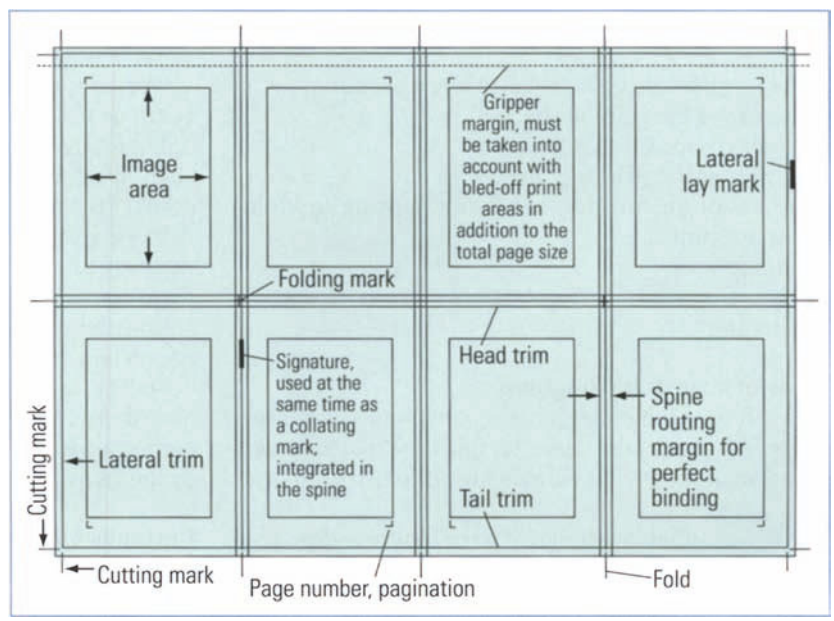


Fig. 3.2-37
Imposition sheet for 8 pages with information on page orientation, later printing, and finishing

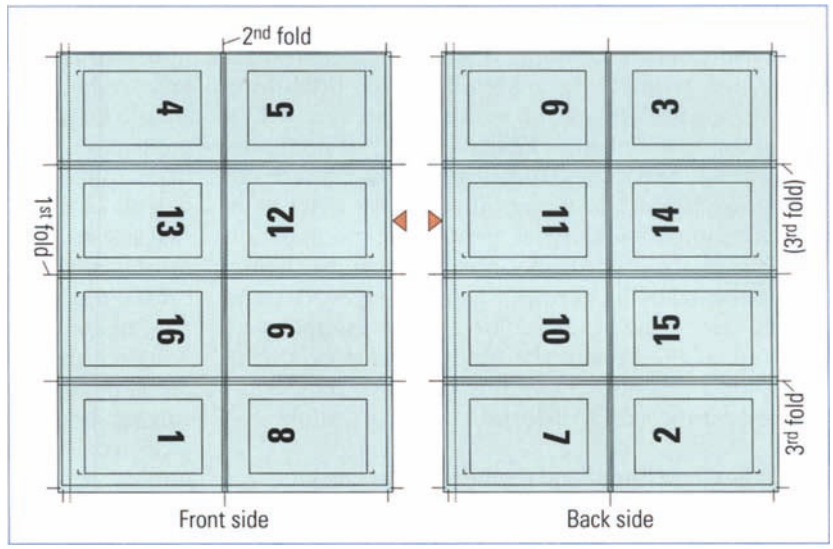


Fig. 3.2-38
Imposition of a 16-page brochure on the sheet for a perfecting job (the sheet is folded three times to produce the 16-page brochure)

While the imposition sheet establishes the position of the pages on the printed sheets, the imposition layout shows how the total number of pages of a printed product should be divided up. It also indicates how often and in which way individual sheets have to be folded. The imposition layout shows how a printed sheet in a format of 70 cm × 100 cm, for example, is folded into the required final format. In this respect the imposition layout adds to the imposition sheet and is the result of optimization by a number of factors, such as:

- the number of pages in the printed product,
- format of the printed sheet,
- paper composition and grain,
- format of the printing press,
- format of the finishing machines (cutting and folding machines),
- final format,
- type of binding (perfect binding, thread or wire-stitching).

Types of Imposition Programs

The software tools that have become known as imposition programs also have to fulfil the requirements mentioned above. They are divided into two categories:

1. Programs that are designed to be *device-independent* and can be used with every publishing equipment/system.
2. Programs that have been *integrated* by the manufacturers of prepress systems *into their own workflow.*

The first category contains programs such as: INposition (DK&A), Imposition Publisher (Farrukh Systems), Presswise (ScenicSoft), Strip It (One Vision), Preps (ScenicSoft), and Impostrip (Ultimate).

The second category of imposition programs are those that are offered by companies such as Agfa, Barco, Heidelberg, Krause, Scangraphic, and Screen as part of their workflow management in a product line. These programs include hardware configurations such as servers, imposition stations, RIP, and film imagesetters (CtF) or CtP systems.

There are also solutions available from companies such as Scitex, which has integrated a standard program (Preps by ScenicSoft) into its own workflow. Heidelberg also enables the integration of the software mentioned above into the Prinergy workflow as do the firms Creo, Fuji, Intergraph, Scitex, and Xerox.

Businesses that decide on the last two variants know for certain that the workflow will follow a logical concept. The responsibility for the individual processes is also then controlled by one party. Otherwise, companies have to implement the digital sheet assemblies by themselves and adapt it to the existing configuration.

Demands on Imposition Programs

Imposition programs have to fulfil requirements of the kind listed below. From the technical point of view they

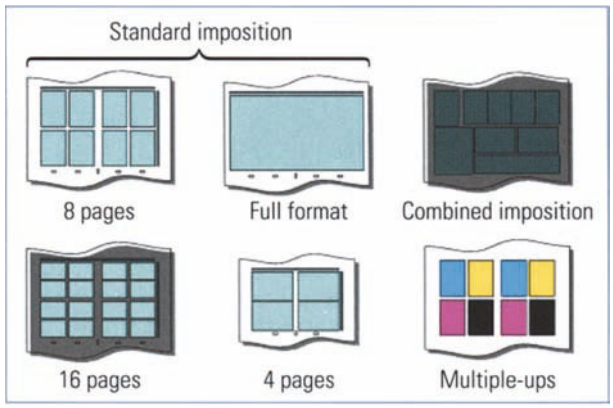


Fig. 3.2-39
Imposition of pages with standard, multiple-up, and combined forms

must, for example, be in a position to (see also fig. 3.2-39),

- make and store imposition sheets,
- process the number of pages per plate, their format and alignment, together with defined gutters, margins, and imposition patterns,
- produce several imposition patterns for each imposition sheet, including multi-page printing and partial sheets,
- take perfecting, work and tumble, and work and turn procedures into account,
- process bled pages and double-page spread,
- produce combined forms and multiple-ups,
- impose according to the type of binding (stapling, wire stitching, or perfect binding),
- take trim allowance, paper thickness etc., into account,
- automatically equalize the binder's creep,
- take the creep and format increases, folding and register marks, and much more into account (in accordance with the installation defined above).

Apart from their purely technical functions imposition programs must be in a position to

- fulfil the Adobe PostScript Document Structure Convention (DSC),
- interpret EPS, TIFF, PDF data, and Pict pages/files,
- integrate different types of data from layout programs within a particular job,
- show the pages on the screen in certain modes in reader-view,
- call up the pages for editing, adding, or removing, as well as for changing the sequence,
- show the sheet as a job in imposed sheets.

Programs that create a new PostScript data file after each step are disadvantageous because more storage space is needed. An example is the calculation for a 16-page brochure: Every A4 page needs about 40 MB of memory (corresponding approximately to a full four-color page) which means 640 MB for a 16-page brochure. If this data file is stored permanently in the memory, the storage space of standard configurations can quickly run out.

3.2.5.4 Imposition Workflows

The manufacturers of prepress systems are constantly working on solutions that avoid slowing down the workflow with overly large memory requirements and that produce a continuous workflow including imposition.

Most manufacturers of imagesetters (computer to film systems) and computer to plate systems have made it their job not to offer the output units as an isolated system, but rather to configure the imagesetter (whether as film or platesetters) as a complete system. However, they often abandon the ready-prepared and targeted standard solutions in order to make their systems faster, more stable and, above all, more economical. The workflow from the individual digital page to the imposed eight or sixteen-page sheet requires special data management. Considerably more is needed than just the output of digital text and image information.

In comparison to standard programs it is often much more interesting to use complete workflows of the manufacturers that have compatibility, reliability, and speed as their goal. In addition to preflight-checks, RIPing, imposition, spreads and chokes, job-management, and the actual output belong to the system solutions. The manufacturers also often offer an interface to CIP 3 (see also sec. 8.2.3), to be able to provide printing presses with prepress data for procedures such as ink key presetting (see sec. 2.1.5).

Some *imposition workflows* are described in more detail in the following:

Apogee (Agfa)
Apogee-Workflow is a system that uses the *PDF format* (Portable Document Format) and consists of the

Apogee Pilot Production Manager, a PDF-RIP, and the Apogee PrintDrive Output Manager. In contrast to systems that convert the PDF format into their own formats during processing, the PDF format is maintained in the Apogee system. As a result, all PDF performance features can be used, editing can still be done and page independence can be maintained. Apogee optimizes the output because completed jobs are automatically stored, managed, and made available for output on different media. The system also has at its disposal functions for last minute corrections and an imposition tool before output to film or plate.

Impose (Barco)
The imposition programs Impose! and Auto-impose! are part of the fast-lane concept in which the imposition of pages also takes place. The imposition data files only contain the relevant data for imposition. The pages and pictures themselves are on a separate server. The creation of a ready-to-process imposition data file can consequently be postponed until the last minute before the exposure. This offers the advantage of incorporating correction of data files and inclusion of page sections that arrive late until just before exposure. The program also checks at regular intervals which pages of a job are available. If the pages of a particular imposition sheet are ready, the signature (full-sheet) data file is generated (fig. 3.2-40).

Signastation (Heidelberg)
After selecting a defined imposition layout for the print job from the library and the input of the corresponding printing parameters, the required number of sheets including all marks and symbols are automatically calculated. Creeping and bottling for the whole printing process is also taken into account. The user can also produce individual folding schemes with an editor. To optimize the workflow, Signastation supports OPI. The high-resolution image data which is stored on a server will only be used for exposure in the full sheet assembly. For a form proof or reduced-size print-out on an electrophotographic or ink jet printer, lower resolution versions are used. Signastation processes PostScript-data files from different applications and also takes the "Delta lists" into consideration in connection with *Delta-Technology* (Heidelberg). These have already been through the RIP-process and are page-independent. Signastation is also used in the PDF workflow *Prinergy* (see sec. 3.2.12.3 and figs. 3.2-41, 3.2-42).

Fig. 3.2-40
Imposition sheet on the screen (Impose, Barco)



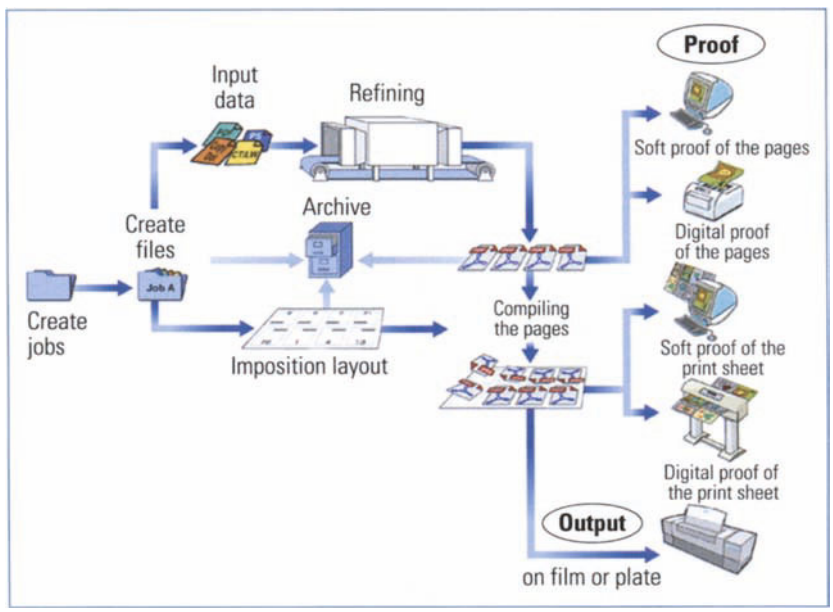
Bit-Impose (Scangraphic)
The Scangraphic imposition program is part of workflow-management system's *Scantext Combo*, a combination consisting of file and printserver, software RIP, imposition software, and output control. PostScript data files of any application (Adobe Document Structure Convention required) are fed into Bit-Impose without using special drivers or filters. They are analyzed and checked for completeness by the program. The page displays that are produced are attached to the imposition scheme, the sheet is imposed and stored for exposure. The sheet assembly itself takes place with access to the low-resolution files produced by the RIP with Bit-Impose. Finally, BitmapControl checks whether the high-resolution bitmaps needed for the exposure are present or still need to be produced by the RIP. If all bitmaps of the pages are present, Combo automatically starts the output process, which then always runs at the maximum imaging speed of the output device.



Fig. 3.2-41
Imposition sheet of an 8-page plate, created on the Signastation using Prinergy workflow (Heidelberg)

Brisque-Impose (Scitex)
Two different procedures are offered here for the production of digitally imposed signatures/sheets and to image them on Scitex imagesetters. There is the ScenicSoft *Preps* imposition program, which has already been mentioned, and in addition the qualities of Preps have been combined with Brisque technology to produce the imposition solution Brisque-Impose. It is a part of Brisque-Workflows. Individual pages or parts of a job run through a preflight check, the OPI, and the RIP process, as well as trapping, and are stored on hard disks. Finally they can be proofed on an ink jet proof system (Iris-Realist). If the pages are ready and the imposition is set, Preps is used for positioning the sheet layout. Since the pages available on Brisque-Impose are

Fig. 3.2-42
Imposition layout and sheet assembly in the Prinergy workflow (Heidelberg)



already ripped, the information where the relevant data files are is enough for the imposition program. Since the RIP'd data files are available as individual pages, only the changed sheet has to be RIP'd again when a page is amended. All other pages remain unaffected by this (fig. 3.2-43).

Workflow Management. It does not matter whether *computer to film* or *computer to plate systems* are to be installed in the operation: In both cases *workflow management* is essential for economical and smooth production. This should be taken into consideration at the stage of investment planning. Among the necessary items, the most important are *functional and product supervision functions* for taking over digital data such as the OPI function, trapping (see sec. 3.2.2.6), digital imposition, preflight, job supervision, print controls, costing, contract, and data and production management. The modified data and job structure in the company should not to be forgotten. Digital imposition is only a relatively small part of the whole procedure.

In both computer to film and computer to plate (see sec. 3.2.12) there is a production sequence that starts with the composition of individual pages. It involves *digital proofing* (see sec. 3.2.11) and electronic imposition and extends through imaging (in computer to film), digital blue print through to platemaking. With computer to plate the stages of film exposure and plate copying are omitted. Otherwise both procedures are the same (fig. 3.2-36). The workflow can be ideally set up in such a way that either computer to film or computer to plate systems can be used to expose the data file of the imposed sheet.



Fig. 3.2-43
Positioning of pages: the pages are positioned and displayed in accordance with the imposition layout shown in the background (Brisque, Scitex)

3.2.6 Raster Image Processor (RIP)

Raster Image Processors (RIPs) have been around for as long as there has been digital, electronic prepress. There have also always been (very diverse) page description languages in the digital world with which the information from the application program is brought via the interpretation to the page. Practically every manufacturer had his own page description language and therefore also had an RIP set up to handle this.

The term "Raster Image Processor" (RIP) has come to be very closely associated with the *PostScript* page description language (see sec. 3.2.9). To run computer programs that have been written in a higher programming language such as C, Pascal, or PostScript, the language must be translated into the individual, binary program structure of a computer system.

Modern computer technology uses two basic principles: in the first, the command written in the higher programming language can be translated into a machine-compatible binary structure by a "*compiler*" immediately after program generation. In the second, the program can remain in the higher language and is transferred into the machine-compatible code on the final computer system by an "*interpreter.*"

The advantage of the interpreter-based system is that the computer program remains coded regardless of which computer system is later used while remaining universally compatible. A few examples of interpreter-based programming languages are BASIC, JAVA, and particularly PostScript. Since PostScript is not merely a programming language but also principally a page description language and a device-independent data exchange format for documents, a PostScript interpreter is of great importance in prepress.

RIP Structure and Functions

A *Raster Image Processor* comprises all function modules that are required for the translation of a complex page description into a device-specific data format, normally to address an output system (fig. 3.2-44).

The most important module of a *PostScript*-RIP is the *interpreter*. This first translates the commands of the page description language into the so-called "*display list.*" It is here that all the calculated objects of a

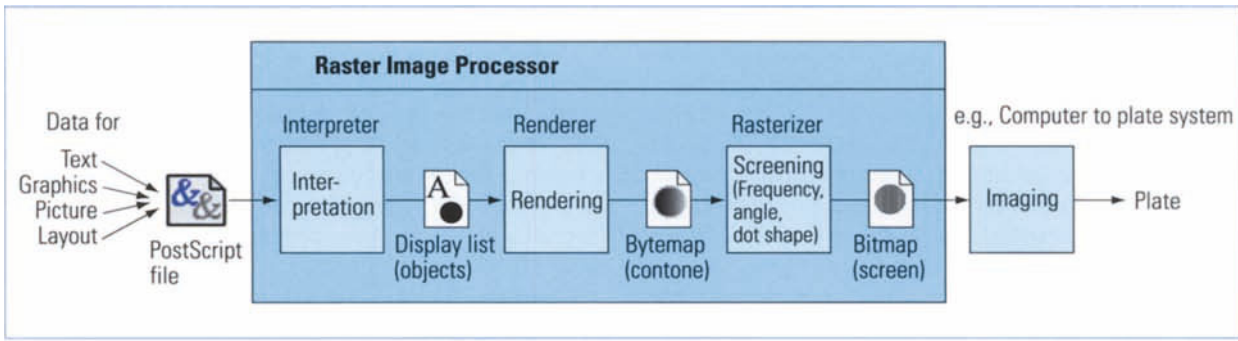


Fig. 3.2-44 PostScript-RIP in the prepress workflow

page are buffered in a uniform format. In a second step the objects of the "display list" are converted by the *renderer module* into the device-specific resolution of the output device – for instance, the smooth contours of a typeface font are emulated by stepped gradients. The resulting *continuous-tone* image (contone) is then divided up by the *rasterizer* into *halftone dots* and translated into the original data format (normally bitmap) of the output device. In most RIP environments of electronic printing systems a "controller" follows after the processing of the page data and this ensures that the *bitmap data* is transferred correctly to the actual printing unit.

Interpreter Interactions

A *PostScript-RIP* controls the output of a printer or imagesetter (film, plate) in conjunction with a PostScript program that has been generated by an application (e.g., QuarkXPress). The RIP executes the PostScript program and generates a data flow for a printer, imagesetter, or monitor. The *PostScript interpreter* can communicate with the application in three ways (fig. 3.2-45).

In *conventional output-only printing mode* the application generates a page description, that is, a complete PostScript description of the document. The file that results from this can either be saved or transmitted directly to a PostScript interpreter. The interpreter treats the sequence of page descriptions as "print jobs" and produces the desired printouts.

In *interactive display mode* an application interacts with the PostScript interpreter to address a monitor. In place of the "one-way communication" with conventional mode, an interactive "session" takes place between the application and the interpreter. In accordance with user actions the application generates commands for the interpreter and also receives information returned by the interpreter.

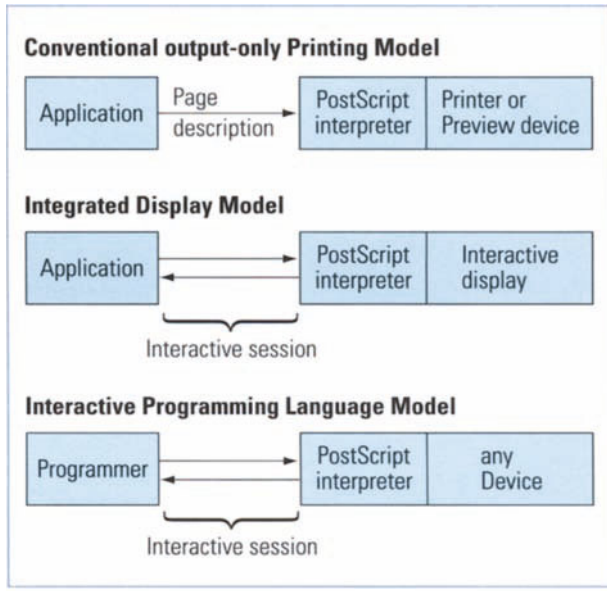


Fig. 3.2-45
Interaction between PostScript interpreter and application (excerpt from PostScript Language Reference Manual 1999, Adobe Systems)

In *interactive programming language mode* direct communication takes place between the PostScript generator and the interpreter. This mode permits direct "feedback" between an application as a "PostScript generator" and the RIP, for example to check the existence of certain resources (e.g., typefaces) in the RIP unit.

Color Data

During the processing of *image data and color information* in a PostScript interpreter the key parameters can be set for the "rendering" process of the PostScript data and the actual screening by PostScript commands (the so-called operators). An example of the controllable basic functions and the sequence of their execution when rendering a image file into a *PostScript interpreter* is given figure 3.2-46.

The *color data* is either located in a device color model (*RGB, CMYK*, or gray) or in the colorimetrically defined CIEXYZ color space (see sec. 1.4.1). Color transformations can also be used to convert other color systems (e. g., CIELAB) to CIEXYZ. After the colorimetrically defined data has run through the "output profile" of the PostScript language (the "color rendering dictionary," see sec. 3.2.10) and has received its final color model, a further correction of the gradation curve can be addressed in the RIP via the "sethalftone," "settransfer," and "setcolortransfer" (transfer functions per component) operations. After that, the screening process (halftoning) takes place before the data leaves the interpreter. It is controlled via the "sethalftone," "setscreen," and "setcolorscreen" operations (fig. 3.2-46).

Although so-called "in-RIP separation", namely the color transformation during the interpretation procedure of a PostScript file, has been possible since the introduction of PostScript Level 2, Adobe had not taken into account the special case of a CMYK→CMYK color transformation for addressing *proof printers*. As of interpreter version 2017 an add-on for four-channel,

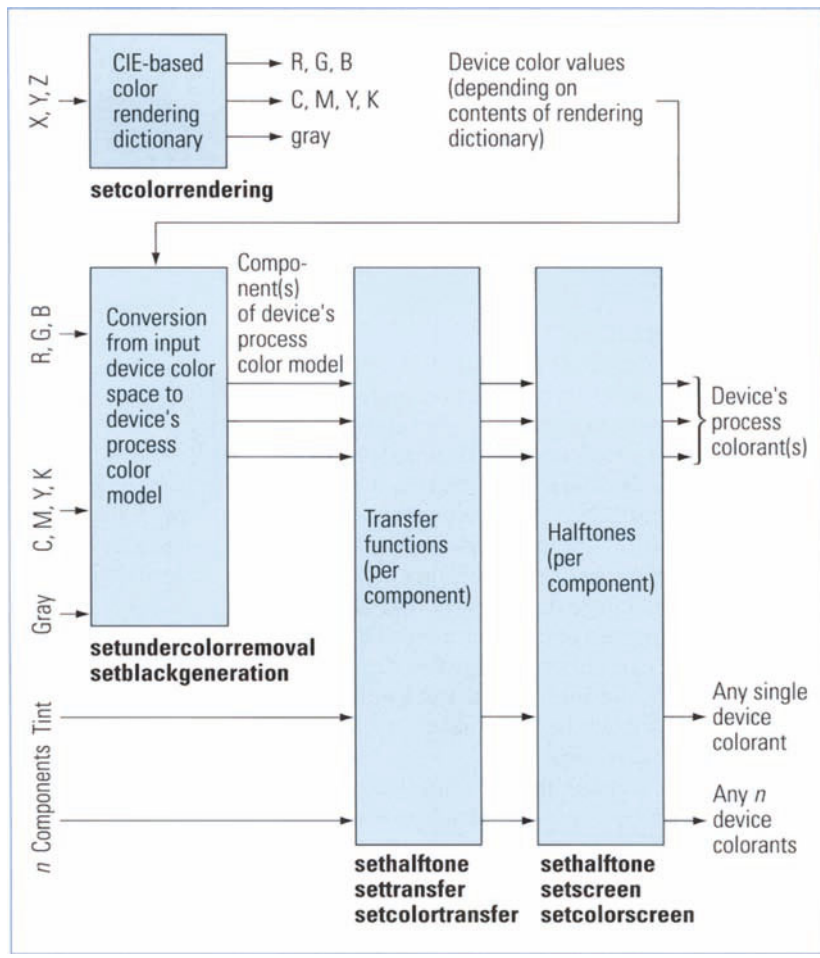


Fig. 3.2-46
Basic functions/operations of a PostScript Interpreter (excerpt from PostScript Language Reference Manual 1999, Adobe Systems)

colorimetrically defined color models has been available on the input side of the RIP.

RIP Integration/Execution

The core innovation of PostScript lies in the fact that it is *device-independent*. Due to the interpreter-based approach and the contour-based data structure, a PostScript file can be reproduced ideally on different output devices making use of their own particular illustration properties. This is assuming that the PostScript-generating application (normally in conjunction with a system driver present in the operating system) is available on the user workstation and the *RIP* is integrated *in the output device* (fig. 3.2-47).

For special applications it can be useful for PostScript driver and interpreter to be both on the same computer. This is true, for example, if a printer that is not PostScript-compatible is addressed by the PostScript driver (*Software RIP on a workstation*, fig. 3.2-48). In this case no device-independent print file is generated for addressing the printer or the imagesetter.

The *Acrobat Distiller* represents a special variation on this RIP configuration, which normally interprets a PostScript file on the generating workstation and converts it into a *PDF file* (PDF Portable Document Format). However, since the PDF data format is based on the same basic graphic elements ("imaging primitives"), the resulting PDF file keeps its device-independent properties.

In the first few years after the 1985 market introduction of PostScript, the RIP software was almost always used on specially developed computer hardware for performance reasons. As PCs and workstations became more powerful, *software applications* of PostScript RIPs were used more and more on *standard computers* (fig. 3.2-49). To do so, a standard computer is connected via a rapid interface directly to the controller of the printing system. Most RIP software applications are today equipped with the standard RIP by Adobe, the "*Configurable PostScript Software Interpreter*" (CPSI).

For particularly computation-bound tasks, Adobe developed special hardware modules equipped with co-processors (e.g., "Type 1 Co-Processor," "Pixelburst") that improve the performance of the RIP system.

RIP in the Prepress Workflow

Raster image processors are integrated in the *workflow concepts* of prepress systems in different ways. In modern *prepress workflows* the desire for media-independent, high-performance, and automated production is increasingly becoming the main focus of attention. This means that no adaptation to the final output system should be necessary after the individual pages have been generated in a layout program. This characteristic concerns the color mode of the file (not CMYK!), the screening, trapping (see sec. 3.2.2.6), and the imposition to a complete page/sheet for plate exposure. The page data is generated at a preliminary stage, yet the data is not prepared for the output system "printing press" until it undergoes further, if possible, automated processes of color transformations, spreading, full-sheet layout, and screening.

In the classic *PostScript-RIP concept* (fig. 3.2-50) trapping already takes place in the CMYK color mode of the

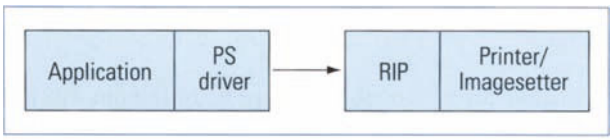


Fig. 3.2-47 PostScript "standard configuration"

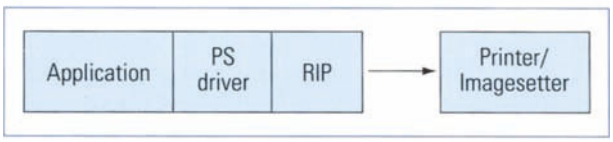


Fig. 3.2-48 Software-RIP on a workstation

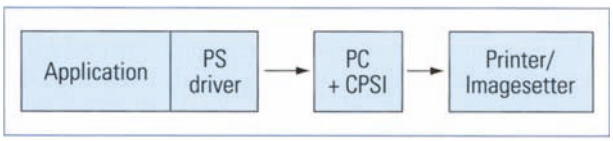
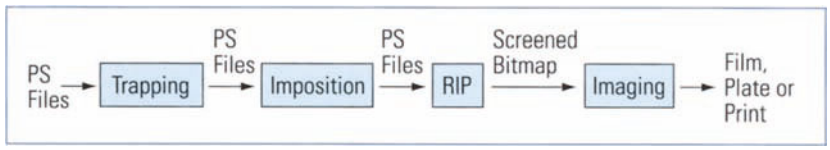


Fig. 3.2-49 Software-RIP (CPSI) installed on Personal Computer

Fig. 3.2-50
Conventional PostScript workflow



layout program. The data normally leaves the layout tool in the form of pre-separated PostScript files. For full-page/sheet assembly, special software products are used that impose the PostScript color separations separately. In this case the PostScript-RIP simply has the task of generating the data structure for the controller format of the output system and screening the continuous-tone data.

For several years, virtually all the traditional suppliers of prepress equipment have been offering an extended *PostScript workflow concept* that enables an earlier conversion of the PostScript data into a proprietary intermediate format (fig. 3.2-51).

The (ideally media-neutral) PostScript file is converted just once into a less complex intermediate format (normally contone or contone/contour format) by the PostScript-RIP. The resolution of the intermediate file is oriented towards the greatest real output resolution. All characteristics that are specific to the printing process are calculated following the PostScript interpretation in downstream trapping, imposition, color transformation, and screening function modules by processing the proprietary intermediate format.

The advantages of this concept lie in the one-off interpretation of the PostScript data. This enables the computation-bound PostScript interpretation procedure to be reduced as far as possible and a "safe" intermediate format to be generated. In this context, "safe" means that the risks of abnormal termination when interpreting a complex PostScript file are relatively high but a reduction of the complexity through format conversion generates production stability. A disadvantage is the dependence on a single system manufacturer that comes about due to the proprietary data structure. The workflow advantages of this RIP concept can only be achieved with those products that are compatible with the data structure.

Similar advantages can also be attained by replacing the proprietary intermediate formats with a PDF-based workflow concept in connection with PostScript Level 3 (PostScript 3)-RIPs (fig. 3.2-52).

In this case PDF files are created instead of the proprietary intermediate formats after the interpretation of the PostScript data by a standard interpreter (CPSI). Since a PDF file has already been interpreted, a subsequent rendering process can take place much more quickly and safely than with the original PostScript file. At the same time the device-independence of the PostScript data structure is maintained.

Since the *PostScript Level 3*, trapping and imposition functions can also take place in the RIP. PostScript-based color transformations were already possible prior to this. PostScript 3 was, nevertheless, enhanced by useful color functions, in particular for addressing proof systems and supporting more than four output channels.

In Adobe's *"Extreme" architecture*, developed for high-performance printers and prepress workflows, the PostScript data is interpreted in its entirety and converted to PDF by the "*normalizer.*" The rendering processes can then be carried out in parallel so that a "simple" PostScript file can be generated again at a later date for addressing the printer (fig. 3.2-53).

The manufacturers of computer to plate systems were looking for a way of sequentially automating and accelerating the process flow for the output of pages. This lead to a special "Extreme" version for prepress developed by Adobe in 1998, which is, for example, used in the "*Prinergy*" *system* (see fig. 3.2-42). This RIP/workflow version, which is based on the PDF standard, represents the state of the art.

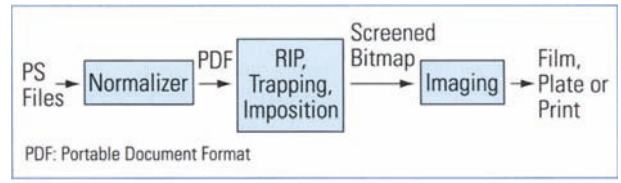
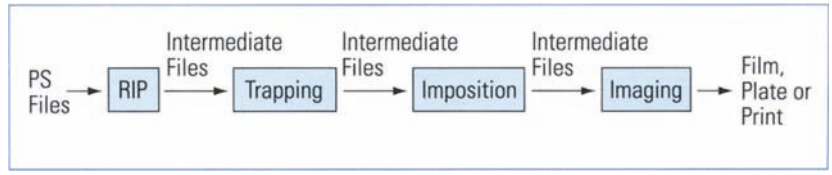


Fig. 3.2-52 Combined PDF/PostScript-3 workflows

Fig. 3.2-51
Converting to intermediate formats



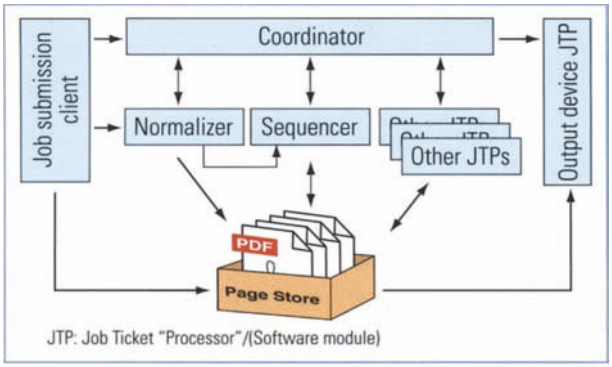


Fig. 3.2-53
Adobe "Extreme" architecture (excerpt from "vision+work", PDF Workflow/Basics, Heidelberg)

Storage Medium	Capacity
Floppy Disk	1.44 MB
SuperDisk (LS-120)	120 MB
SyQuest	44, 88, 200, 270 MB, 1 GB, 1.5 GB
ZIP	100, 250 MB
JAZ	1 GB, 2 GB
CD (compact disc)	650 MB
DVD (digital versatile disc)	4.7–17 GB
CD-MO (magneto-optical disc)	1.3, 2.6 GB
Hard disk drive	up to 80 GB

Table 3.2-5
Storage capacities for different data carriers (apart from hard drives, all data carriers are portable), status: 1999

3.2.7 Storage Media

Prepress places particular demands on storage media (see also sec. 11.3). Such demands do not only result from the constant need for increased data storage capacity when producing printed matter; memory also is of extreme importance for the regular backup of data within networked work stations, and for the secure transportation and archiving of data. In spite of the increasing possibilities for data transfer via public networks or the Intranet, storage media will continue to play a significant part in the exchange of data between the customer and the print shop (see also sec. 3.2.8).

New technologies for storage and data media develop relatively quickly. Up to about 1990, 5¼ inch diskettes were the number one in mobile storage media. Possessing 360 kB of memory, such disks were adequate for many applications (usually text-based). However, after around 1990 the 5¼ inch diskette lost much of its importance and has since been replaced by the 3½ inch, 1.44 MB diskette.

At the present time, two major *trends* are constantly encouraging the development of storage media.

The first *trend is purely technical*, developing rapidly and comparable to the evolution of processors and other computer components. At the end of the 1980s, 80 MB hard disk drives were still an acceptable size-even in computers for professional use. Ten years later this value has increased by almost a thousand times. The enormous expansion of memory capacity has enabled software developers to write increasingly extensive and complex programs. Memory and processing times do not play such an important role anymore.

The second trend stems from *workflow changes* in prepress. The task of uniting and editing text, image, and graphics in one file necessitates ever larger memory capacities. Normally, the text for a sixteen-page brochure with four-color separation for fonts or color areas will still fit on a standard 1.44 MB floppy disk. However, a document like this with graphics requires more memory and, therefore, another type of storage media with higher capacity. The data for a sixteen-page brochure including exposure data with graphics and fonts can easily add up to 600 megabytes. The changes in image reproduction procedures, therefore, have especially affected the demands made on storage capacity.

Storage capacities are constantly increasing due to new technologies and manufacturing procedures – there are predictions that it will increase by up to about 80% per year. The key to increasing capacity lies in the proper combination of the following factors: write density, track density, and optimized use of the medium's surface. The SuperDisk with 120 MB of memory clearly achieves this goal: although its outward appearance is almost identical to that of a typical 3½" floppy disk, the SuperDisk offers 83 times the storage. An overview of the storage capacities of various data carriers is given in table 3.2-5.

Classification of Storage Media

At the present time, the storage media available on the market can be classified according to different criteria. First, differentiation should be made into *volatile memories* (main memory) and non-volatile memories.

Non-volatile (permanent) memories, which are suitable for archiving and securing data, are listed below and categorized according to:

- *recording methods*:
  - magnetic memories (hard disk, floppy disk, exchangeable disc),
  - magneto-optical systems (MOs), and
  - optical processes, such as those used by CD-ROM (compact disc read-only memory) or DVD (digital versatile disc);
- *design*:
  - rotating disks (hard disk, floppy disk, removable disk, CD, DVD, or MO),
  - tape media in various formats,
  - storage without moving parts (e.g., FlashCard, RAM/Random Access Memory; compared with the previously mentioned data carriers, however, these types of memory have relatively low storage capacities and therefore only have limited use).

Media with a rotating disk offer a good solution if fast-access, temporary storage or data transport are priorities. For regular backups, on the other hand, tape drives are preferable. For a comparatively low price, tape media have a large storage capacity, although the relatively low data transfer rate is a drawback.

The following applications represent three possible *uses* for storage media:

- data distribution: pre-recorded media such as the CD-ROM or DVD-ROM;
- archiving: once-only recordable media such as the CD-R or DVD-R (R recordable);
- Backup or transport: rewritable media such as floppy disks, hard drives, MOs, CD-RWs (RW rewriteable), and tapes.

CD and DVD (ROM, R, RW)

The CD-ROM was originally designed to distribute large quantities of data (e.g., music) at a low price. In the meantime it has become a popular storage medium for relatively low data volumes (650 MB) such as for private use. In the foreseeable future the new DVD-ROM technology could eclipse the CD-ROM. DVD has a storage capacity of 4.7 GB up to 17 GB. The DVD-ROM is suitable for the distribution of software, multimedia, databases, and also for movies. DVD makes this increase in memory capacity possible by using dual-layer technology: Two memory layers can be applied to the top and bottom of the disk with a semi-reflective, intermediate layer in between. When reading the data, the laser "jumps" back and forth between the two memory layers.

The CD-recordable, in short CD-R (or DVD-R) is a once-only writable, 5¼" optical disk with fast access times. After burning a "blank" in a special drive, the recorded data can be read in a normal CD-ROM drive. CD-Rs are very practical when distributing data for a small number of recipients.

The CD-RW (rewritable) has shown itself to be flexible but is still not in widespread use. This form of exchangeable media can be rewritten up to 1000 times. When recording, the crystalline coating of the CD-RW is converted into an amorphous structure in a thermo-optical process. This action alters the reflexive behavior of the recording layer. The light intensity (bright or dark) that corresponds to the reflections is converted into the binary numbers 1 or 0.

Exchangeable Memory

Exchangeable memories are based on magnetic layers and are rewritable.

Exchangeable Disks (SyQuest). The manufacturer SyQuest increased the capacity of their first exchangeable disks from 44 MByte to up to 1.5 GByte – whereby each increase in capacity required a new disk drive. These magnetic exchangeable disks are a well-established storage *medium* in prepress.

Data Cartridges. Since the 1970s these types of magnetic tape storage media have asserted themselves as one of the leading forms of backup. They are chiefly used to backup PC hard drives or networks. For the backup within networks very often a robot system automatically operates several cartridges in *tape libraries* or *jukeboxes*. The formats for cartridges are 5¼ and 3½ inches. Various vendors supply individual PC drives as built-in or external units. Compared to floppy disks the data transfer rates for cartridges are high, but low in comparison with hard disks.

With the ever-growing popularity of networks, data back-up becomes more and more important. In order to meet the requirements for automatic storage systems, various manufacturers (such as Imation, Exabyte, or Tandberg) developed tape-libraries. *Streamers* use cartridges with capacities of up to 32 GB on a single tape. Data can be transferred at 180 MB/min and NetWare, Unix, and Windows NT operating systems are supported. Streamers are suitable for data back-up, archiving, and memory management on servers.

Data Tapes (width: 4 mm or 8 mm). Among the 4 mm and 8 mm data tapes there are a few new developments that have reduced static loading and, therefore, provide for more secure data storage. Four millimeter data tapes are available with uncompressed capacities of up to 4 GB. The 8 mm versions attain a 5 GB capacity. These storage media can be used in libraries where large amounts of data need to be automatically saved on tapes.

SuperDisk, ZIP, JAZ. The 3½" floppy disk is the most common storage medium worldwide. At the moment there are two systems racing to provide a successor medium: the ZIP technology from Iomega and Imation's SuperDisk (previously LS-120).

The *SuperDisk* offers a storage capacity of 120 MByte and hardly differs from the traditional 3½" disk in appearance. The medium is economically priced and is "downward compatible", that is, the new drives can read and write the classic 1.44 MByte disks, too.

The *ZIP disks* from Iomega provide 100 or 250 MByte of storage space and are in the same price range as the SuperDisk. ZIP disks have become very widespread in the publishing scene, suggesting that such a desire for removable media does exist. ZIP is not downward compatible, and only ZIP media can be processed with ZIP drives. However, ZIP's access times are shorter than those for the SuperDisk.

The 3½" disks "JAZ" from Iomega offer a storage capacity of up to 2 GByte.

Magneto-Optical Disk (CD-MO). Magneto-optical storage media, in short MOs, have become widely popular. The storage capacities clearly speak for this technology: 640 MB on a 3½" disk and 2.6 GB on a 5¼" medium. The development never stops. Even today manufacturers such as Sony or Philips are talking about capacities of 2.6 GB in the 3½" and 10.4 GB in the 5¼" format. MO drives achieve a data transfer rate of over 4 MByte/s and an average access time of under 25 ms. Using a laser, magneto-optical drives place and store data in the magnetic layer of the medium.

When writing to the optical disk, the laser heats up a tiny area of this layer to around 150 degrees centigrade. Only in this way can the alignment of the magnetic particles on the medium be altered with the aid of a magnetic field. During the reading procedure, the laser light is polarized depending on the alignment of the magnetic particles on the medium. The receiving electronics converts the signals into binary information.

Hard Disk Drives. Last but not least is the hard drive – a standard component in practically every computer. The storage capacities of these data carriers are constantly on the increase and are on the threshold of around 80 GByte for the 3½" disk size.

More information on data storage can be found in section 11.3 (see also fig. 11.3-1).

3.2.8 Networks

The installation of networks and network computing are two examples of the forward-looking working methods and concepts of prepress technology. System and network functionality and applications nowadays ensure that business processes are dealt with efficiently in most companies. For this reason network technologies are taking on an increasingly important position in the graphic arts industry. After all, the move towards networking of all prepress components (for "networked printing companies" even on an interdepartmental level) represents an ever greater challenge (see sec. 8.2.1).

The collective term "net" stands for the routing equipment used for linking together several systems. This includes lines, network nodes, servers, routing computers, and, where appropriate, multiplexers and cluster controllers. The following is only a basic description of the subject, offering a general overview (see also sec. 11.4).

3.2.8.1 Network Concepts and Components

Networks are classified under the following categories:

- local networks (LAN Local Area Network), such as Ethernet, Token Ring,
- external networks, wide area networks (WAN), such as ISDN (Integrated Service Digital Network), the Internet, Intranets, and so on.

Network Topologies

In *distribution networks* a single network user sends information to all other users. This kind of network (topology) mentionend *star structure* (fig. 3.2-54). This form of information sharing is used in classic data processing networks.

In *group networks* several participants send their information to a single recipient (fig. 3.2-54). The combination of distribution networks and group networks typifies a data bank system with open access.

In *switching networks* everyone can communicate with one another. Here both *bus structure* (fig. 3.2-55) and *ring structure* (fig. 3.2-56) are common. Switching networks are mainly used in private and public data communication.

Along with the operating mode (distribution, group, and switching), networks are divided into networks with widely distributed nodes, such as public networks (WAN) and local, in-house networks (LAN). In contrast to open networks, private networks can mostly not be connected to the public data network. Public networks consist of both analog telecommunication networks for telephone and fax and the digital data network (ISDN Integrated Services Digital Network) for telephone, fax, and other services.

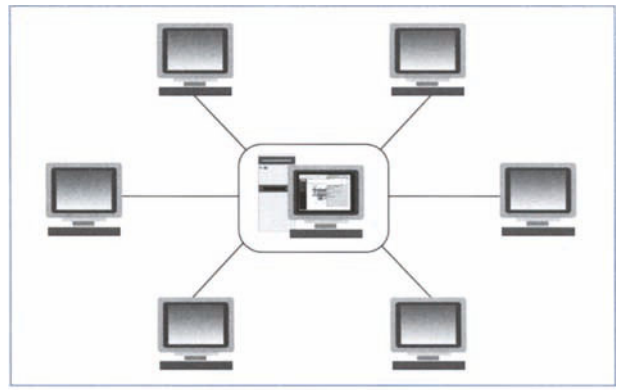


Fig. 3.2-54 Star structure of a network

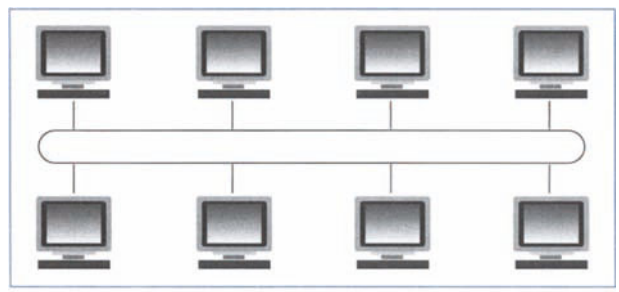


Fig. 3.2-55 Bus structure of a network

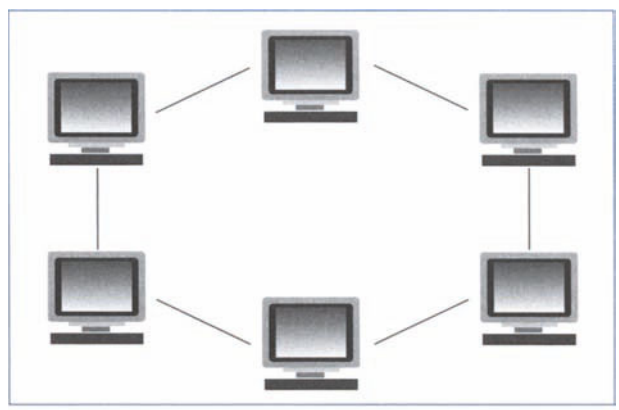


Fig. 3.2-56 Ring structure of a network

Data Transfer

Data transfer is understood to be any sort of data transmission within the central processing unit, between peripheral units (printer, memory, etc.) or between data stations, for example via local networks or public networks. The term data transfer also stands for long-distance data transmission.

Data transfer can be achieved either directly, that is, *on-line* or else indirectly, that is, *off-line* via a buffer/an intermediate storage.

Where communicating computer systems are run with the same clock frequency, this is a *synchronous* transfer. Otherwise it is an *asynchronous* transfer.

The bit-serial transfer of data is referred to as *serial* transfer. Bit-parallel transfer is classed as *parallel* transfer.

Ethernet

Ethernet is the most widespread network used in prepress. These *local networks* follow the bus principle (fig. 3.2-55). The *segment* length of each Ethernet, for instance, from workstation to workstation, is 500 m, although in the total network it can link distances of up to 2.6 km. So-called *repeaters* assist segment connection and signal boosting. Via bridges and gateways, crossings to other local networks are also possible. Each segment can be accessed by up to one hundred users. A total of 1024 workstations can be operated on the network. The *transfer rate* is 10 Megabit/s or 100 Megabit/s with "fast Ethernet". Cable types used are coaxial, glass-fiber, and so on.

Network Components and Services

A diverse range of network systems, network components, and network services have made their way to the market. Demands on the network have kept pace with the increasing capabilities and efficiency of servers. A large proportion of solutions and components support standardized communication protocols and interfaces. The same applies to formats in the represen-

tation of information, for example for the exchange of documents in electronic form. To this end, the industry standard PDF "Portable Document Format" from Adobe (see also sec. 3.2.9), which ensures conformity with the original across all communication methods and different platforms in respect to layout, font, graphics, video images, and language, is leading the way forward.

The significant expansion of *public networks and private commercial networks* and communication services also reflects the rapid progression and increasing integration:

- LAN connection to public dial up networks, notably ISDN,
- Internet Service Providers (new software solutions for Internet access),
- mailbox services, which are also gaining significance in the exchange of directly processable data through all means of communication,
- connection of mobile radio systems to stationary computers and networks, whereby on this occasion first and foremost we refer to modems and other peripherals for the use of mobile radio system services that support this communication.

High-Speed Networks

Many businesses and network services have already begun the launch of their networks, to handle the ever increasing data traffic between local and regional networks via *ATM protocols* (Asynchronous Transfer Mode) or *Fast Ethernet* with a network capacity of more than 100 Megabit/s.

Meanwhile, the costs of data transfer by ISDN have dramatically fallen. Moreover, investment in fast broadband services is becoming increasingly cost effective. Correspondingly, this cuts down on time expenditure to such a degree that the question of where data is stored geographically no longer seems to enter into the equation. Both access and transfer time as well as costs will be so insignificant in the future that an entirely new data infrastructure will result, along with other ways and means of producing documented and printed information (print on demand, distribute and print, etc.; see chap. 9).

3.2.8.2 Working with Networks

The rapidly falling network and access costs are of great significance to public and general *data banks* and *on-line services*. In the coming years they will enter into greater competition and cooperation with influential or information-selective publishers, above all in print media, since they can compose messages quicker, which in turn are more up to date and comprehensive. That publishing companies set up their own information services of this kind is a logical consequence.

While in today's sense a message is a piece of information that is prepared in advance, network and online service users can engage in "*data mining,*" the individualized composition of information by means of "sifting through" data banks and the finding and selecting of necessary information.

For *offices* and their *organization*, networks offer clear advantages in the transmitting of information and changing business processes and working methods. The fact that people need no longer meet in the same place to exchange information and documentation has given rise to completely new opportunities.

Video conferencing could be an improvement on telephoning, and have the greatest significance in replacing many of the time-consuming and expensive conversations in person. *Machines can be controlled and diagnosed and databases can be accessed from workstations.* Distances and national borders are losing more and more significance.

The *function of paper* as a general (and for a long time the only) data carrier and information transfer medium over large distances can in part be replaced. This is possible because electronic data transfer is faster and cheaper than the use of paper. Printing is then done locally, on the spot, on demand. Each company and office acts similarly to a publisher, tracking down and composing, printing, restructuring information, transferring it into data banks and storing it, all autonomously, and using it *over and over* at its discretion. Information on paper is far more difficult to prepare but easier to use than electronic data. The desired information can be composed from this data and quickly customized in a very flexible manner.

In figure 3.2-57 the setting up of a *LAN within a printing company* is illustrated. The network connects prepress, press (printing), and postpress (finishing). Via a modem, internal networks can be connected to ISDN or to other networks, for instance, for communication and cooperation with external partners.

In figure 3.2-58 another example of networking and data transfer for print media production is illustrated. From this it is clear that *print media and electronic me-*

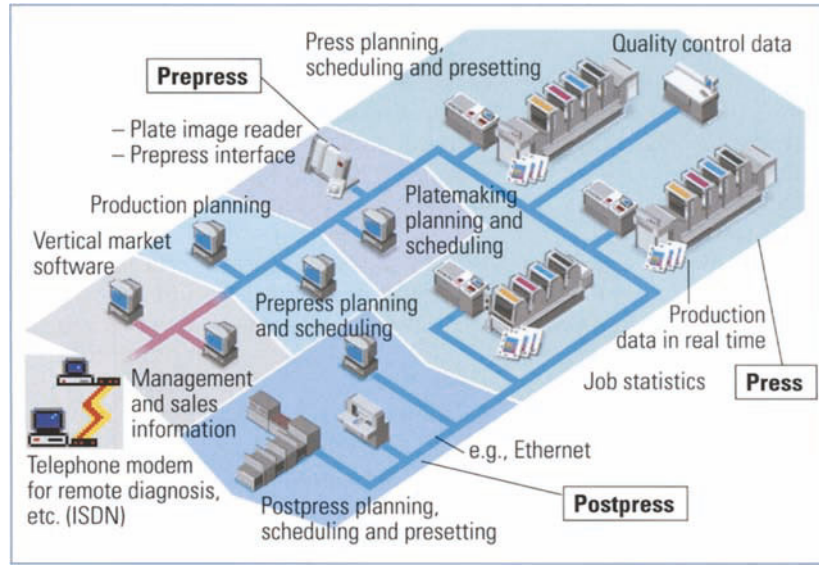


Fig. 3.2-57
The networked printing company (DataControl, Heidelberg)

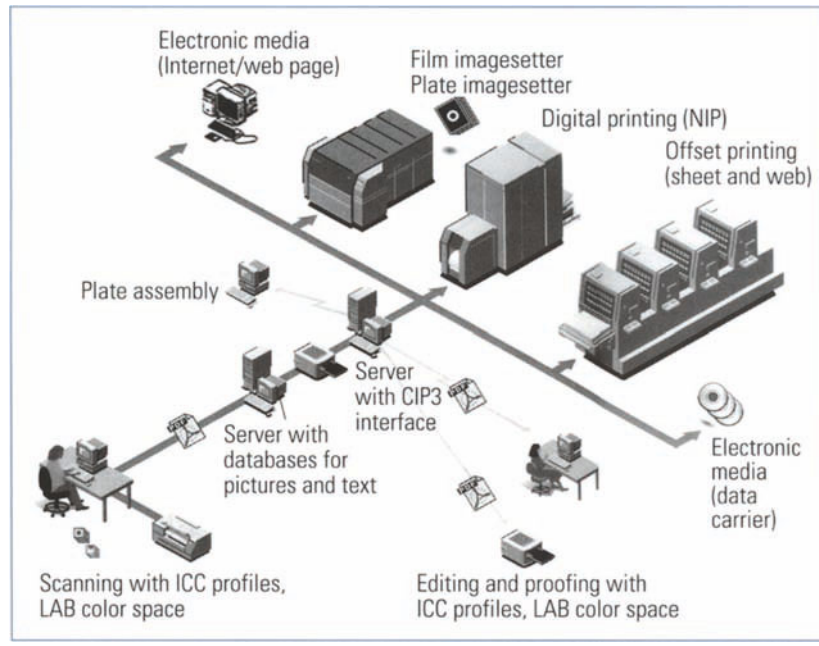


Fig. 3.2-58
Data transfer and network components for the production of print media and electronic media (AGFA)

dia can be produced – depending on the company's structure and business areas – from a common pool of information, all under "one roof".

Figure 3.2-59 illustrates how *networks* with the various transfer systems and services can be operated *on a global scale.*

3.2.9 Data Formats

Digital prepress technology is confronted with a multitude of data formats. While the job data delivered by the customer can sometimes include rather exotic data structures, the limited number of formats used within



Fig. 3.2-59 Structure and components of a global network (Internet) for data transmission and communication (EnBW/Zbigniew Sroga)

the production cycle itself is of particular significance. This section will discuss the most prevalent data formats used in *open prepress systems*. In other words, closed, *vendor-specific formats* will not be taken into consideration. In many production systems, open data formats are converted into company-internal data structures for processing purposes. As long as this data is converted back into *standard data formats* directly after processing, such a solution is definitely recommended.

In a *modular prepress system*, the device components can only be combined together because there are interface standards at the different levels of communication between these devices. These standards are official standards (e.g., ASCII, American Standard Code for Information Interchange) as well as recommendations from companies that at some point in time took over the role of the "de facto-standard" (e.g., PostScript, [3.2-9]).

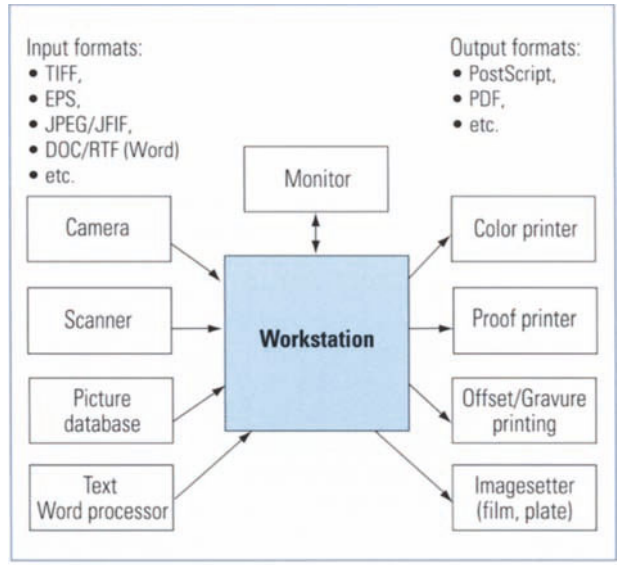


Fig. 3.2-60 Modular publishing system

Input/Output

Figure 3.2-60 shows a few device components of a digital, modular publishing system. The *data formats* used

on the *input side* of the system generally result from the very diversified requirements of the text, graphics, and picture coding. The *output side* is dominated by the page description language PostScript. Being device-independent, the data structure of PostScript can be used to control the complete range of output devices.

Data from text, graphics, and picture-capturing devices form the stream of input data.

Text

The classic data structure used for the exchange of *text documents* is the ASCII character string. However, ASCII (*American Standard Code for Information Interchange*) is not a data format in itself but rather describes the structure of the stream of data. More sophisticated formats can be coded both as ASCII character strings and as binary data. The advantage of ASCII coding (especially the internationally standardized, 7 bit coded ASCII) is that it enjoys a large, international acceptance and compatibility in all operating systems. Both word processor documents and PostScript files are coded in ASCII. The data format dominating the Internet, HTML (*Hypertext Mark-up Language*), is also based on ASCII character strings.

Practice has shown that the structure of "MS Word," which has become the standard (de facto) word processor, with the file extension ".doc," is suitable for entering data in virtually all application programs. This is particularly true when the texts are saved in the ".rtf" (*Rich Text Format*) data exchange format. This format allows for a virtual cross-platform work. It can be opened in Word for PC or Mac and can be directly imported into programs such as QuarkXPress.

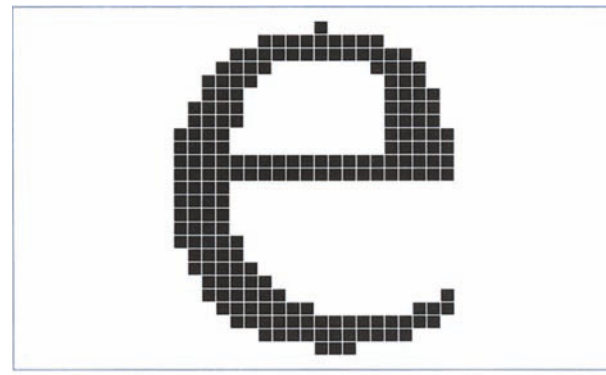


Fig. 3.2-61
Bitmap-based (pixel-based) representation of a character (pixel structure)

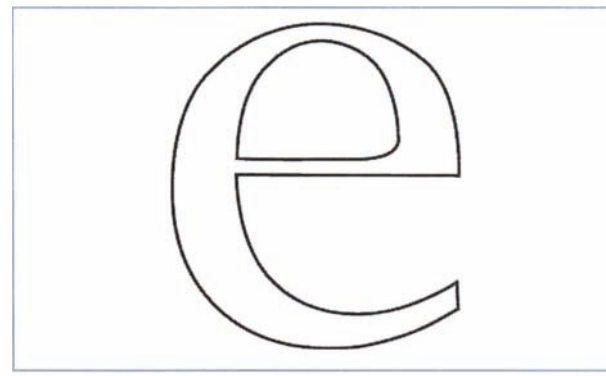


Fig. 3.2-62
Outline-based data coding (e.g., by means of splines or vectors) of a character

Graphics, Pictures

For *graphics and picture coding*, pixel and outline-based data formats are used. A *pixel-based* data format (bitmap) means that the graphics or picture is split into a series of dots in a defined resolution (fig. 3.2-61).

With the other format, the *coding of outline-based data* involves the description of the information content in outlines (fig. 3.2-62). This data structure was introduced mostly by the *PostScript* page description language. It is often incorrectly described as a vector format and uses mostly parametric splines for the description of outlines (see sec. 3.1.1.4, fig. 3.1-2). Although the generation and decoding of an outline-based format involves intensive mathematical calculations, this format has the advantage of ensuring a resolution-independent result in the digital prepress world. A PostScript file can be transferred to any output device, independently of the final resolution. It is only during the *interpretative process* of the output device that a discrete pixel structure will be generated from the functional outline description in the RIP (*Raster Image Processor*, see sec. 3.2.6) with the parameters of the output device. A secondary advantage of the outline-based data formats is that considerable data compression rates can be achieved.

Many modern data formats *combine* pixel- and outline-based data structures. This is also true of the PostScript page description language and of the "*Portable Document Format*" (PDF) [3.2-10]. Since complete documents are coded with text, graphics, and picture contents, their original data structure should ideally be

transported, too. This should particularly be the case when these are device-independent (e.g., Bézier curves for graphics; see fig. 3.1-2). The pixel-based "*Tag Image File Format*" (TIFF) and the storing of the picture in "*Encapsulated PostScript*" (EPS) allow the saving of vectors, for instance cut-out paths (e.g., contour around the motif to isolate it from the background), in addition to the pixel-based picture.

Bitmap formats are generally used to exchange and save picture data. They are mostly saved in the TIFF, EPS, and JPEG/JFIF formats.

TIFF

TIFF is a classical, pixel-based data format. It was originally developed by Aldus (now Adobe Systems) and Microsoft. The basic parameters of a picture (e.g., resolution) are saved in standard "tags", which are documented in the TIFF Reference Manual [3.2-11]. "Private" tags can also be defined. Their contents can only be read by specific applications. Due to its freely definable tags, TIFF is a strong, extendable data format, which has become a de-facto industry standard. It is based on the "*Lempel-Ziv-Welch*" compression method (LZW), making it a simple, no-loss data compression option.

EPS

Graphics data files are mainly stored as outline-based data. The main graphics application programs already generate spline data structures internally; these can be directly converted into EPS data for further processing. Being directly derived from PostScript, EPS can be used to transport alternatively or combined outline and pixel-based data. For the coding of graphics, EPS mainly implements outline-based coding. EPS stands for "*Encapsulated PostScript*". This means that an EPS file contains embedded information that cannot be changed.

EPS is a special file version of the PostScript page description language. Internally, it uses the same operators as PostScript, yet it can be imported as a file into other documents. To avoid the interpretation of the entire PostScript data set to simply visualize the contents of the file (which would require the interpretation of the complete file by a PostScript RIP), a low-resolution "*preview*" image is added in the file header during the creation of the file. When an EPS file is loaded, for example, in a page layout, the preview image is used for the screen display. An EPS file can contain both outline and bitmap-based data. As a transport format for picture data, EPS is generally only used with its own bitmap-saving capacities. Moreover, cut-out paths can be used to complement outline-based data. Like PostScript files, EPS files cannot be edited without first being fully interpreted by a RIP. They can be positioned, rotated, and scaled, but their content cannot be altered. This property is particularly useful when unwanted manipulation of an EPS file by applications later in the workflow is to be avoided.

JFIF (JPEG)

The *JPEG File Interchange Format* (JFIF) is used particularly for large data sets, optimized prepress workflows (e.g., newspaper production), and for Internet solutions [3.2-12]. The data compression mechanism developed by the *Joint Photographic Expert Group* (JPEG) includes several combined *compression methods*. The so-called "baseline" process offers a series of successive compression modules with defined parameters as a standard application. The JPEG picture data compression is based on a discrete cosine transform. This method which is more prone to data loss can achieve very high compression rates (up to *1:100*), depending on the parameters selected. However, the loss rate of this method depends on the content of the picture. It is not possible to predict the exact data loss. The JPEG format is specified both for RGB and CMYK data, but not for CIELAB data.

PostScript

The page description language *PostScript* presently still plays the dominant role in the output of a digital publishing system. PostScript is a general, interpreter-based computer programming language, which was developed by Adobe founders John Warnock and Charles Geschke. It is typically used to describe the appearance of a document page and to transfer it to an output system. PostScript can code all elements of a document, including text, graphics, and pictures. Since its introduction to the market in 1985, PostScript has become the most important standard for controlling electronic printing and imaging systems, due to the high flexibility of its internal data structure.

After the creation of the original version, *PostScript Level 1*, the page description language was further developed. A major improvement made to *PostScript Level 2* was the embedding of the screening algorithm "Accurate Screening." Nowadays, the latest generation, PostScript 3, is used. *PostScript 3* includes long-awaited improvements, such as integration in Color Management Systems and the interpretation of PDF data.

PostScript, as a language, is virtually invisible for the user. It is generally generated in the driver of the computer system, transferred to the printing device via a network, and translated by the interpreter (RIP) into the language of the output device, for example, a printer – usually bitmap-based. *Device-independence*, which is the outstanding innovation of this page description language, is ensured by the internal data structure (vectors and Bézier curves).

PostScript includes both device-independent and device-specific components. The device-specific part of a PS file is generated in the driver by selecting the so-called "*PostScript Printer Description*" file (PPD), which is often incorrectly called a driver. A PPD contains all the individual properties of a printing or imaging system (e.g., number and control version of the paper trays, PostScript-Level of the interpreter). If no individual PPD file is selected, a universal PostScript code is generated, which can be also run on interpreters of the first generation.

"*Adobe Type 1*" *fonts* are another major innovation of PostScript [3.2-13]. This type format was the first that was scalable and resolution-independent, not on account of its data structure, but because it could be generated by means of so-called "*hints*" and could ensure a typographic, high-quality font rendering. Like all other elements of PostScript, the "Type 1" fonts are also device-independent and can be used on a wide range of output devices. Although laser imagesetters can mostly produce a far higher resolution than most printing systems, when used on another output device a "Type 1" font can be reproduced with the maximum resolution of this device.

Another variant of the PostScript file is the "*Desktop Color Separation*" format (DCS). If a single color separation of a previously color-separated PostScript file (i.e., existing in CMYK color mode) is sent to an imagesetter, this would normally imply that the entire file has to be sent to the imagesetter, including all the other color separations. In the case of large volumes of data of a high-resolution CMYK page file (in DIN A4 format about 40 MB), it would be more useful to send (via the network) only the part of the file that should be imaged to the imagesetter. This would reduce the size of the file to be sent via the network to 25% of its original size. In DCS files, the four color separations are saved separately in four separate files, included in a PostScript file. Moreover, a fifth file containing a low-resolution, non-separated version of the image is used for layout purposes ("*preview*").

Through the introduction of the DCS format, the use of pre-separated PostScript files is becoming prevalent. In the so-called "*separated workflows*," the color separations and their trappings are calculated completely, saved separately, and transmitted via the network as separate files. The other approach is the "*composite workflow*," in which the CMYK files are always handled coherently in the production environment. Processing the pre-separated data would not make sense in the new, media-independent production environments and workflows.

PDF

The PostScript page description language is closely related to the *Portable Document Format*, PDF [3.2-10]. This format is primarily used to describe documents. While PostScript constitutes a complete programming language like BASIC or FORTRAN with which the programmer can write application programs, the so-called "Portable Document Format" (PDF) is a data format, comparable with EPS or any other outline-based data format. PDF is mostly based on the *imaging primitives* of the PostScript language and is also suitable for the description of a document page. PDF can also include additional information regarding the document page, for example to link its contents to other parts of the document. A PDF file is superior to an EPS file in many respects. It can contain fonts, graphics, printing instructions, special keywords for search and index functions, "*job tickets*," interactive links (*hyperlinks*), video clips, and much more. Contrary to PostScript, a PDF document stores each page of a publication separately. This means that the file need not be completely interpreted in order to print or display the contents of a page.

A PDF file is actually a PostScript file that has been interpreted in an RIP and divided into clearly separated objects. These objects can be represented on the screen, and not simply in their ASCII code, as in a PostScript file. Since PDF files have already been RIP'd, they can ensure a far more reliable result when printing or imaging. Additionally, the user can display and check the file after the interpretation, as well as before the output of the file onto the printer or the imagesetter. To speed up the interpretative process for fast printing systems, Adobe's "*Extreme*" *concept* (see sec. 3.2.6) converts each PostScript file into PDF for later output in parallel interpretation processes.

Internal/Open Formats

Besides the specific data exchange formats, other "*internal formats*" for some key applications (e.g.,

QuarkXPress, Photoshop) play an important role. The so-called "*open formats*" are a good alternative, especially when data that still needs to be edited several times is passed between cooperation partners. These formats are mostly problematic since the file itself is missing some elements (e.g., no fonts are embedded). Another problem is that these formats are often incompatible in different versions of application programs.

3.2.10 Color Management

Why Color Management?

When a prepress expert produces files for offset printing in his usual environment, that is, using his familiar scanner and screen, he generally achieves a quality of color reproduction that can scarcely be improved upon by employing color management. However, if this expert is asked to produce images once a year for newspaper printing, he is no longer likely to achieve the desired color quality at the first attempt. His skill in controlling color quality also suffers if he suddenly has to work with a different monitor. He would also not find it possible to deliver optimum images immediately if he was told that a poster is going to be produced on a large format ink jet printer. Color management comes into play at precisely that point where the accuracy of the expert in controlling color reproduction ceases. Color management ensures optimum color reproduction irrespective of the input device, monitor, and output device used, as long as the device is characterized by an *ICC profile* (International Color Consortium). Therefore, an important reason for using color management today is the certainty that the correct output result will be achieved at the first attempt.

What is Color Management?

Color management is the calibration of all input and output devices within an image processing chain with the aim of always achieving the desired color reproduction independent of the devices used.

3.2.10.1 The Image Reproduction Process using Color Management

We will begin by considering the process without color management: The original image is scanned, giving RGB values that are converted into CMYK values using an image processing program or the RIP of the output device (see sec. 3.2.6).

When using color management, there are now several intermediate steps inserted between the output of the RGB values and calculation of the CMYK values (fig. 3.2-63). This appears at first sight to be lengthening (and hence slowing down) the process. However, these intermediate steps ensure that the weaknesses of the conventional system mentioned earlier are eliminated.

Details of the additional steps involved in the color management process are as follows:

1. The RGB values of the input device are converted into *device-independent color values* (e.g., CIE XYZ) with the aid of the color profile for the input device and conversion software (often described as *color management module* or CMM for short. Input devices that supply CMYK values directly are not suitable for color management). In this form the image values may be used for any output processes or devices. This becomes important when the process to be used to output the image has not been firmly established at the image recording stage, or when the image is to be output using different processes in parallel (e.g., by offset printing and on a CD-ROM or on the Internet).
2. When the *process for outputting the image* has been established, the color values of the image are converted into the process-specific output values (CYMK for printing) with the aid of the *color profile* of the output process and the same conversion software (CMM). The *output profile* from this process acquires universal significance since the color profile also contains the specifications for image make-up (under color removal, black definition) and the desired rendering intent in addition to the color gamut and the gradation characteristic of the output process.

Before applying the process shown in figure 3.2-63 the profiles for the input and output devices involved must be produced.

3.2.10.2 Production of Color Profiles

A color profile is understood to mean a numerical connection between the values of the image input or output devices and the CIE (Commission Internationale de l'Eclairage) color values XYZ or L*a*b*. The color profiles produced for the input or output device are not only device-specific but are also determined by the

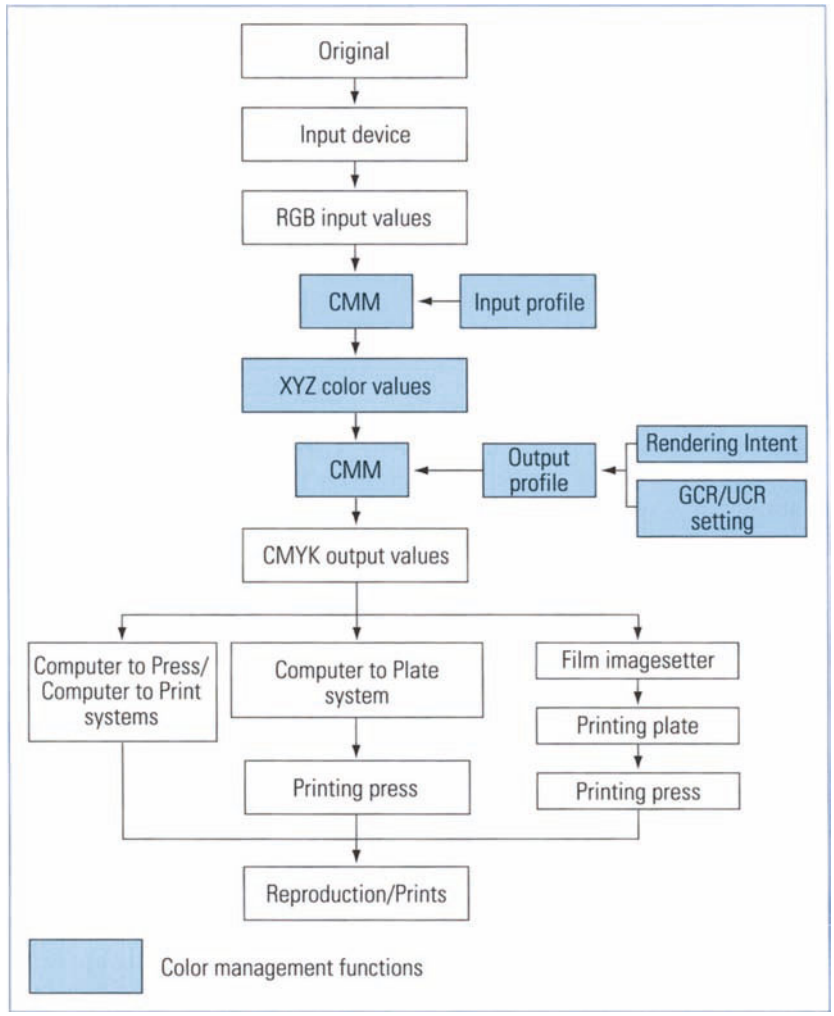


Fig. 3.2-63
Image reproduction process using color management (CMM = Color Management Module, i.e., software; GCR = Gray Component Replacement; UCR = Undercolor Removal)

chosen operating conditions of the device as well as its calibration. Hence each of these profiles contains different information (see table 3.2-6), which also means that a new profile must be created each time one piece of information changes.

A crucial prerequisite for the color management concept to function properly is for the profiles to be interchangeable. To achieve this it was necessary to standardize the make-up and content of color profiles, which was set in motion in 1993 by the *International Color Consortium* (abbreviated to ICC). An important principle used in the standardization of profiles is the connection of the device-dependent data with a device-independent *standard color space*, known in ICC terminology as *Profile Connection Space* (PCS) and based on the XYZ color space introduced in 1931. Metaphorically speaking, the device-independent standard color space acts as an "adapter" between the profiles of the input and output devices. When an input and an output profile are connected to one another, RGB values can even be converted directly – and invisibly to the user – into CMYK values.

Software is needed for the production of profiles and this is nowadays included in the purchase of professional input and output devices. Measurable *test images* are also required and there is a distinction made here between input and output test images. An output test image should be available in the form of digital data to avoid changes to the content by an already established input process. An *input test image*, on the other hand,

Information contained in an input profile	
Device characteristics	– Separation behavior (separation filter) – Spectral sensitivity – Dynamics (signal/noise ratio)
Characteristics of the originals	– Spectral properties of the object colors – Reflective/transparent – Contrast range
Image input conditions	– Light source (color temperature) – Illumination intensity – Illumination contrasts (for studio shots)
Information contained in an output profile	
Device characteristics	– Characteristic curve (gradation) – Inking (color saturation) – Printing sequence of colors
Selected combination of primary colors	– Gamut
Selected substrate	– White point – Gloss
Selected image make-up	– Definition of gray scale – Proportion of component colors in gray tone reproduction (UCR, GCR)
Selected type of reproduction	– Rendering intent
Information contained in a monitor profile	
Device characteristics	– Color spaces of the primary colors – Gamma value (gradation)
Selected monitor setup	– Brightness (luminance) – White point
Surroundings	– Brightness (illumination)

Table 3.2-6 Information for the generation of color profiles

needs to be present in physical form. Today the ISO 12641 test image is used almost exclusively as an input test image and contains 252 test patches (fig. 3.2-64). Since input profiles must be produced for both opaque and transparent originals, the test image must be available in opaque and transparent form. Moreover it must also be specific to various types of film and photographic paper. This means that ISO 12641 does not consist of only one single test image but of as many variations as there are film and paper materials used for photographic masters. A data set containing the CIE color values is supplied by the manufacturer with all test images purchased. The production of *input profiles* is simple and rapid since the CIE color values of the test image are already contained in the profile production software.

However, when producing an *output profile*, it is necessary to print a test image under the printing conditions chosen for the image output and to *measure it colorimetrically*. The ISO 12640 test chart is a test image in common use for output profiles (although not the only one) and includes 928 color patches (fig. 3.2-65). Nowadays it is usual to use a colorimeter with a scanning table to measure these color patches (fig. 3.2-66). This color measurement means that the production of an output profile takes correspondingly longer than that of an input profile.

Besides self-produced profiles there are also *ready-made* (so-called *generic*) *profiles*, which are supplied for standardized processes, such as in newspaper printing according to ISO 12647-3 or offset printing on specific papers according to ISO 12647-2. In addition to this, manufacturers of non-impact printing output devices, which can only be operated using a certain type of paper, provide ready-made device profiles that refer to a standard calibration. If the calibration of the device changes during operation, then this kind of generic profile can no longer be used.

The profile alone still does not allow any image data to be calculated. This requires a conversion program described in ICC terminology as a *Color Management Module* (abbreviated to CMM). It would actually be desirable for the CMM to be standardized to ensure uniformity of the conversion process. Unfortunately, this has not yet been achieved but work is being carried out to this end.

3.2.10.3 Structure of Color Profiles

A color profile represents a list of color values that are attributed systematically to the corresponding device-specific color values. The technical term for such a list of attributed values is a *look-up table*. In the simplest case the series of measurements given in table 3.2-7 would provide a starting point for a color profile (in this case a *monitor profile*).

Here, color patches with the given RGB values were produced on a monitor and measured on the monitor surface using a colorimeter suitable for phosphores-

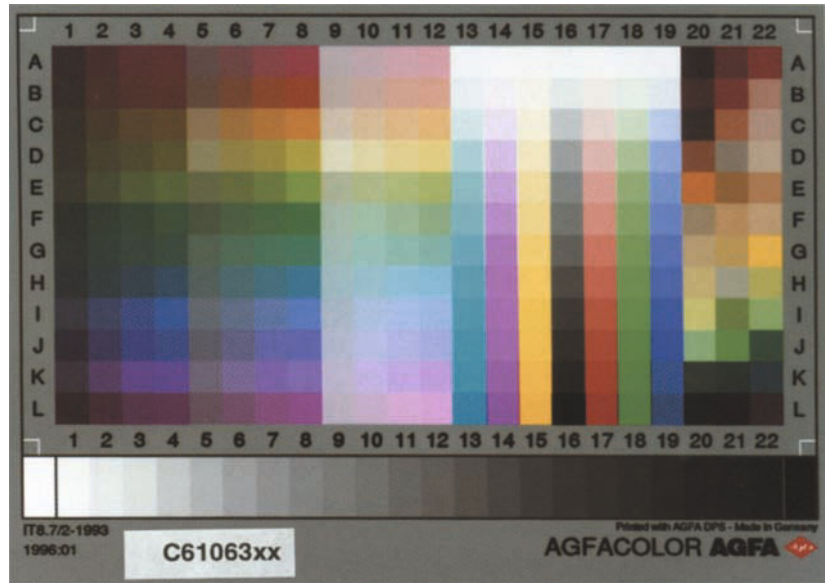


Fig. 3.2-64
Test image according to ISO 12641 (input test image)

cent colors (see also fig. 3.2-67). The measurements in this case refer to a D50 light source as the white point and a gamma value of 2.0.

The profile production software now calculates intermediate values so that the RGB color space is filled with values at geometrically equal distances (this process is known in mathematics as linearization). In the present case, values for the combination of two and three primary colors are also calculated whereby these combinations – again in the simplest case – are only given for RGB values of 50 and 100. Here, the color profile would have 27 combinations of RGB values. However, a color profile should contain more intermediate values, for instance, values for RGB = 20, 40, 60, and 80, meaning that such a profile would already include 216 combinations (namely 6 values each between 0 and 100 for each of the three primary colors).

As already mentioned the production of *output profile* chromaticity diagrams requires the measurement of 928 color patches, it makes sense to calculate the profile using still more intermediate values. According to ICC specifications this may be up to 256 values per primary color, which represents 16.8 million combinations for the three primary colors. At the present time, however, it is not usual to go beyond 32 values so that the amount of data contained in a profile is still manageable, even though this still means almost 33000 combinations for the three primary colors.

The CMM software is used to interpolate from the color profile in sequence those intermediate values that correspond to the pixel values of the image to be reproduced. It can be assumed that a monitor image (which consists of the RGB values listed above) must be calculated back into XYZ. For a pixel having the values R = 30, G = 80, B = 60 the following color values would then be calculated from the previously discussed monitor profile: X = 31.4, Y = 48.9, Z = 32.3. The CMM software can also calculate in the opposite direction, that is, RGB values based on CIE XYZ values.

L*a*b* values may also be calculated simply from the XYZ values of the color profile. These are required if color spaces need to be matched (see sec. 3.2.10.5).

3.2.10.4 Connection of Color Profiles

For the processing of images which are to be printed it is important to have as accurate a picture as possible of the printed result to be produced, either on a screen or a digital output device. It is true that digital *proofing devices* have been created for this purpose but, unfortunately, they do not always produce a result that is identical to the printing process subsequently used. This must be achieved using a step-by-step approach that brings the proofing system repeatedly closer to the production result. In the case of newspaper printing, for example, this means reducing the color density and increasing the dot gain. The

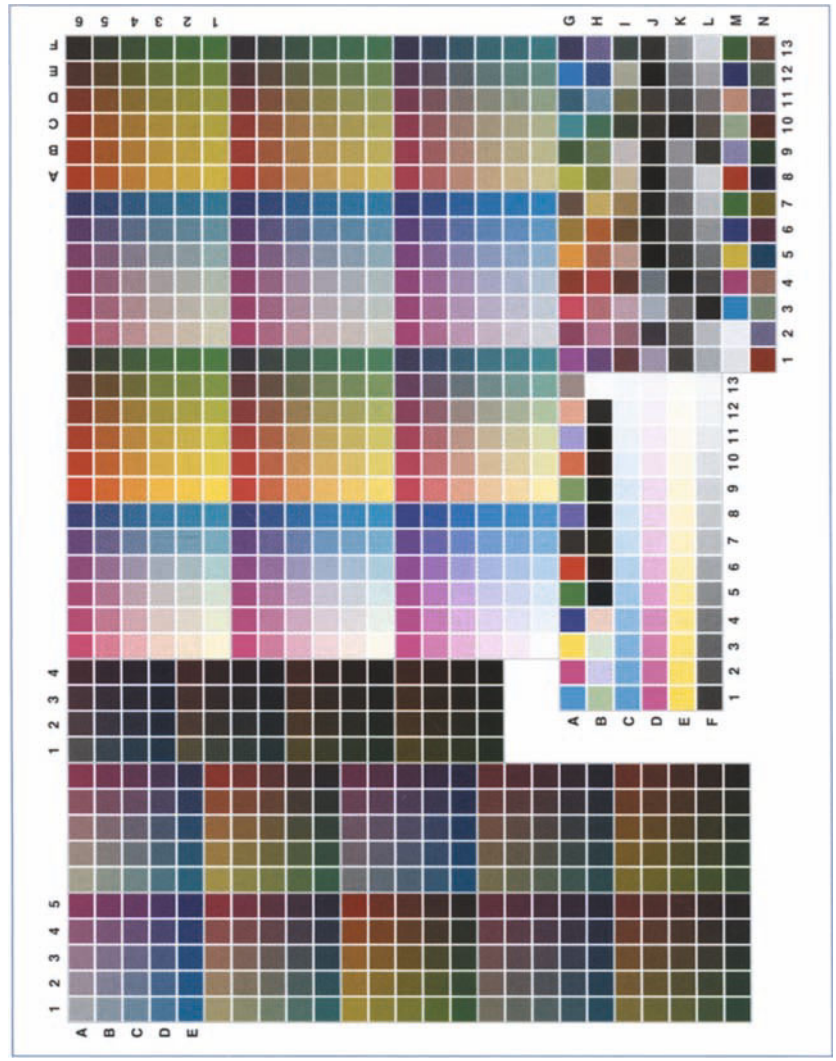


Fig. 3.2-65
Test chart according to ISO 12640 (for producing output profiles)



Fig. 3.2-66
Spectrophotometer with programmable x-y positioning for measuring a calibration test chart used for Color Management (SpectroScan, Gretag-Macbeth)

R	G	B	X	Y	Z
100	0	0	48.5	25.0	2.3
0	100	0	34.9	69.8	11.6
0	0	100	13.0	5.2	68.6
100	100	100	96.4	100.0	82.5
50	0	0	12.1	6.3	0.6
0	50	0	8.7	17.4	2.9
0	0	50	3.3	1.3	17.1

Table 3.2-7 Look-up table for the color profile of a monitor
Note: RGB values: setting at the monitor (max. value 100%)
XYZ values: CIE color space coordinates



Fig. 3.2-67
Monitor color measuring system for the calibration of color screens (Vipview, FAG)

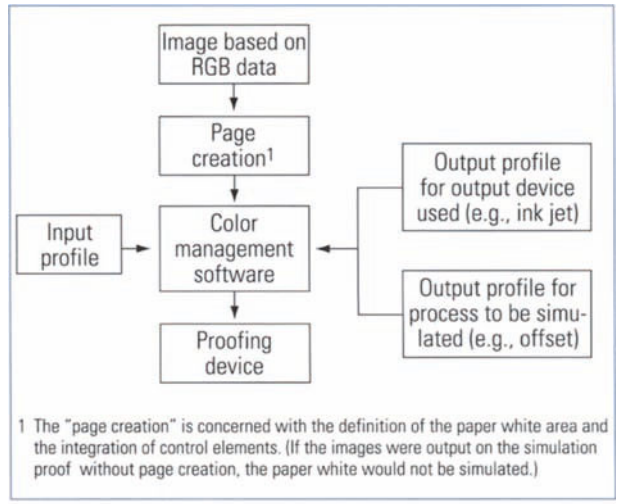


Fig. 3.2-68 Making a proof including the linking up of output profiles

color of the newsprint must also be simulated on the substrate. If the primary colors of the proofing system do not match those of the newspaper print with respect to hue, there will always be a variation in color when matching "manually."

It is here that color management helps to improve the simulated result dramatically by connecting the color profile of the printing process with that of the digital output system (proof system). This *profile connection* is a special function that can be called up when working with a color management system. Figure 3.2-68 shows an example of the procedure. A printed image may also be simulated on a monitor in a similar manner. In section 3.2.11.4 various color management concepts are explained, including details on how they are used to generate digital proofs.

3.2.10.5 Rendering Intent

The term *rendering intent* is a new term introduced by the ICC and means that the reproduction of colors may be chosen specifically depending on the intended purpose of the reproduction. The ICC has defined four types of rendering intent, namely:

- colorimetrically absolute,
- colorimetrically relative,
- perceptual,
- optimized for saturation.

Colorimetrically absolute rendering defines the case in which the colors of the output image are required to be identical to the colors of the original. In many cases this requirement cannot be fulfilled since the original may, for example, have a wider color gamut than the reproduction process. There may, however, be occasions when difficult house or product colors demand an absolutely identical reproduction. In a case like this, colors that lie outside the color gamut are simply cut away.

Colorimetrically relative rendering differs from the absolute rendering in that the white point of the original is rendered equal to that of the reproduction process. This makes sense if, for example, a transparency with a relatively high gray veil is reproduced on brilliant white paper. If the color gamut of the transparency is still greater, then even here the colors with greatest saturation are cut away.

The type of rendering used most frequently is *perceptual rendering*, which actually corresponds to the rendering the repro expert aims at instinctively without relying on theoretical considerations. Perceptual rendering implies that the color gamut of the original is matched to the one of the reproduction process. In ICC terminology this process is known as *gamut map-*

ping. The most frequent form of gamut mapping is gamut compression, that is, the reduction of the gamut of the original to that of the reproduction. This is important when, for example, a color slide is reproduced in newspaper printing (fig. 3.2-69). A different instance would be when the color gamut of the original is wider only in certain areas than that of the reproduction. This is the case when, for example, an opaque photographic image is reproduced in offset (fig. 3.2-70). The third, less frequent case is when the color gamut of the original is smaller than that of the reproduction process. In this case it is a question whether it is not better to increase the color gamut or to reproduce it identically by colorimetry. Gamut mapping is currently a non-standardized process and one that is left to each supplier of color management systems to define. However, there are already attempts underway to produce an international standard for this important processing stage. This would then make even perceptual rendering no longer dependent – as it is today – on the software used.

Saturation optimized rendering has been defined for the case when the colors of the original are to be reproduced as saturated as possible. Not all originals are suitable for this rendering intent, but only those where highly saturated colors are important, a classic example being color graphics that only contain steps of high saturation. This rendering intent is also non-standardized at the present time.

It is important for the user of color management to establish that the color rendering intent is calculated during the creation of the output profile. This gives four different profiles for a given output process if the system offers all four rendering intents. If the rendering intent is not specifically selected, the profile applying to perceptual rendering is automatically selected.

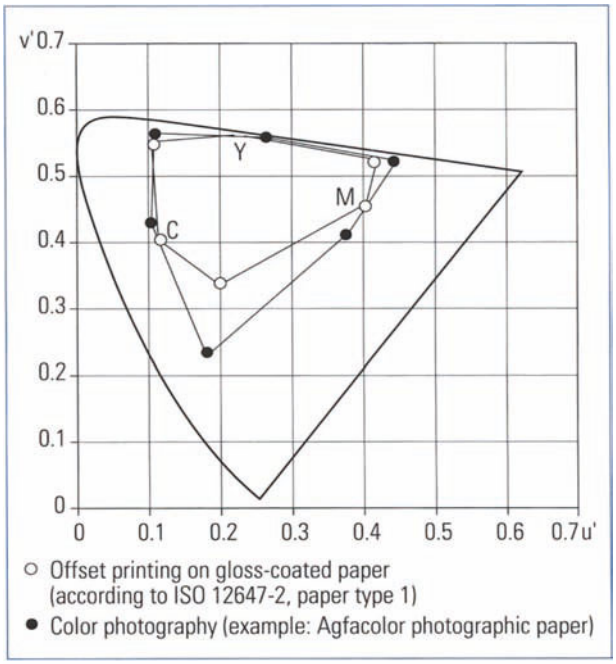


Fig. 3.2-70
Gamut in the CIELUV color space (Offset printing and color photography)

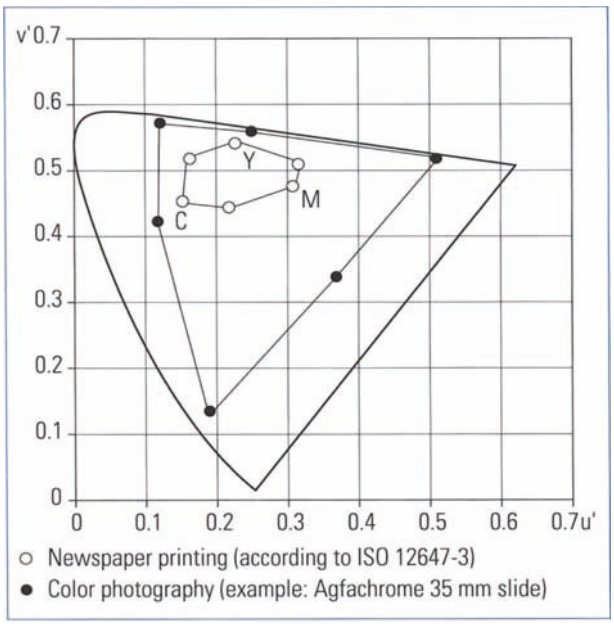


Fig. 3.2-69
Gamut in the CIELUV color space/chromaticity diagram (newspaper printing and color photography)

3.2.10.6 Color Management and the Production of Proofs

It is absolutely essential for a reliable color management that each image file be accompanied by a *proof*. Color management allows the same set of data to be sent to several printing companies even if they are printing under different conditions or with different setups. In this case the data provider produces a proof using his preferred output profile, which means that

the receiver does not get an exact simulation of his print job. A printed *control strip* allows the receiver to identify the conditions under which the proof was produced. The following procedure may be carried out in practice:

- The data provider produces a proof using an agreed standard CMYK profile, which might, for example, be the offset profile for coated paper according to ISO 12647-2.
- The data provider passes RGB or XYZ data to the receiver/company. For RGB data the input profile must be inserted into the images. (For different input devices the profiles of all devices involved must be supplied.)
- The data provider must demonstrate that the proofing device is correctly calibrated for color with respect to the proof. This can be measured using CIELAB control units.
- The data receiver may now proceed in two possible ways:
  - He prints according to ISO 12647-2 and converts the received XYZ or RGB data to CMYK using the same standard profile. For him the proof received is perfectly valid.
  - He does not print according to ISO 12647-2 and uses his own output profile for conversion to CMYK data. In this case he must produce a new proof from his CMYK data and have it approved by the customer.

3.2.10.7 Color Management for Images on the Internet

In principle, color management may also be used on the Internet, since the image input and output must be matched to one another in the same way here as in the printing industry. So that the observer of Internet images does not have to produce a color profile for his home monitor, the images from the information provider are transformed with the aid of an input profile into a *standard color space*, which is based on the primary RGB colors of television and is device-independent. This color space is described as *sRGB (where s stands for standard)*. The base colors of this color space are identical to the color standard defined for the new high-resolution television (HDTV) in 1995. These base colors are also extremely similar to each of the current European and American television standards as well as to those of most PC monitors. Hence, when Internet images are defined by sRGB data, they appear to be fairly accurately matched for color on most PC monitors as well as on today's television screens. The prerequisite for this is that the monitor is set to a gamma value of 2.2.

3.2.10.8 Color Management and Standardization

It has been the doctrine for many years that, for input and output processes containing a large number of variable process parameters, certain parameters should be agreed upon in order *to standardize the process*. Offset printing is quoted as an example where the variables are not only the paper, printing ink, characteristic curve, and printing plate but also the screen ruling, screen angle, and image composition. ISO standard 12647-2 represents the current specification for standardizing offset printing, which is valid worldwide.

At first sight the concept of color management appears contrary to the attempts at standardization since color profiles may be individually created for chosen process parameters. Nevertheless, color management has in fact a good deal to do with standardization, since each input or output process controlled using color management makes it absolutely necessary to keep to the selected process parameters. Standardization contains a second requirement, however, in that as many users as possible agree on the selection of the same process parameters. It is easier to fulfill this requirement, however, than to keep the selected parameters constant over a long period of time. In this respect color management continues to support attempts at standardization.

In a situation where image output does not proceed via a chain of individual steps, but with a single device, such as a simple (medium quality) non-impact printer (on an ink jet basis, for example), we use the word *calibration* rather than standardization. Calibration means that the parameters that define a device's operating conditions are chosen correctly and kept constant. In this respect color management also requires each input or output device to be correctly calibrated and the calibration to be regularly checked.

3.2.11 Digital Proof

Just as with on-press proofs, which are printed on production presses or on special presses based on the same printing technology as production presses, proofs (printed on special proofing printers and presses) have the task of visualizing originals to examine layout, text, image, and color. The proof should be a per-

fect sample of the later print run. Various paper qualities and printing processes should be taken into account. The ideal conditions for a proof would be to use the same press, same paper, and same ink. However, the question of cost and time constraints severely limits the demand for this perfect scenario.

The broader the range of application of a proof, the more comprehensive the requirements. Such demands often stretch from the presentation through color-reliable proofs right up to the proof that serves as a "contract proof" (it can be used as evidence in legal disputes).

The demands on a proof therefore vary quite significantly. For this reason, the market offers proof systems that can reproduce an original at various rendering qualities in accordance with the color print of the production run. Selecting the optimal system means balancing costs and benefits and analyzing what is to be expected from a proof:

- reproduction of the complete page contents and/or sheet,
- color reliability (visually similar or color-true),
- reproduction of the screen structure (and the halftone dot arrangement) which is used for the production run,
- same substrate surface and sheet size as used for production,
- time required to produce the proof is acceptable,
- job-specific cost situation.

3.2.11.1 Digital Proofing Processes

Digital proofing processes are used to output a digital data set to create the most accurate possible simulation of the printed product to be produced. In most cases the most important factor is that the proof visually matches the later print quality (color proof, see below for definition). Special printing parameters (e.g., dot structures) can only be reproduced in line with the print run using special proofing processes (true proof, screen proof).

The digital proof is of central importance for digital imaging printing systems (e.g., Direct Imaging System: Quickmaster DI, Heidelberg, fig. 3.2-71). Films, which usually form the basis for proof manufacture with analog proofing processes, are no longer produced during the course of production. Prior to imaging the printing plates within the press (see also sec. 4.4) a check must be performed to assess whether the quality of the data is in line with the commissioned product. In the example given, a thermal sublimation printer is used for the proof (see sec. 5.6). The entire format (A3+, + means: a little larger than the DIN/ISO standard size A3) is reproduced in true colors with a powerful color management system.

Digital proofing systems can at the outset be classified into two basic process variants based on intended use and quality required (fig. 3.2-72):

- soft proof,
- hard proof.

3.2.11.2 Soft Proof

Soft proof describes the simulation of the print result on a *monitor*. If previous soft proof applications were simply a display of the image in color to check for completeness and the status of the print file, a significantly improved color reliability has been achieved since the arrival of the PDF data format and additional software applications (Viewer) in combination with *color management systems* (see sec. 3.2.10.3). The color reliability of images on the monitor depends heavily on the viewing conditions, and colors do not always match those of the printed copies. While the color-reliable representation of the image on the screen normally requires a darkened room, a sample print must be viewed under standard light conditions close to daylight (e.g., D50). Although a few compromises have to be made from the virtually perfect simulation of the later print quality on the monitor, soft proofs offer interesting, forward-looking solutions for the cooperation between customers and service providers in reproduction technology.

In so-called "*remote proof*" applications, files can be sent rapidly via global networks and later print runs simulated on site with the customer. Color management systems perform a key function when implementing this kind of production scenario.

Solutions that have already been realized, such as those shown in figure 3.2-73, display the trend towards image assessment on the monitor. The next print job can be inspected on the press monitor, where it is possible to zoom in to the level of the halftone data for checking the dot structure (screen proof).

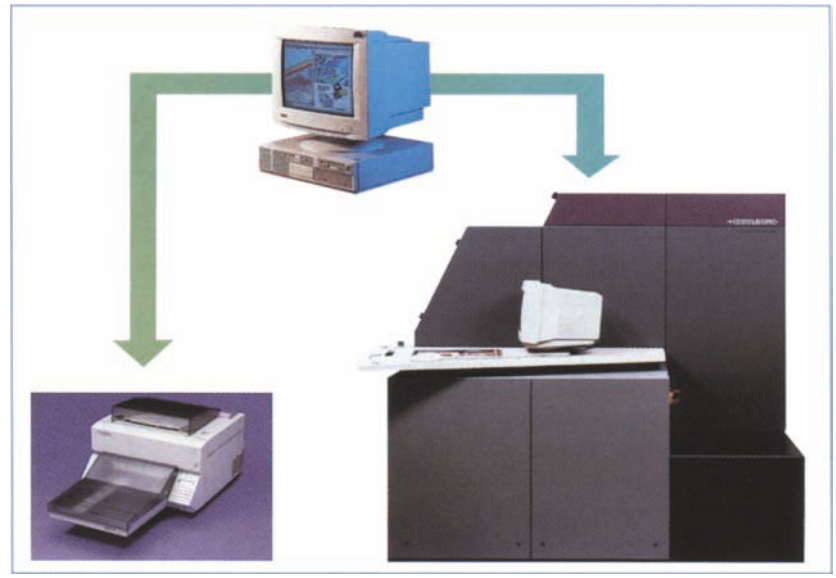
3.2.11.3 Hard Proof

Hard proofs can be further divided into five general classifications, which are described below (fig. 3.2-72).

Blueprint

To gain an initial overview of the *contents, imposition layout, and completeness* of a data set to be printed, a *single-color* blueprint can be created. The term, which

Fig. 3.2-71
Digital proof system (thermal sublimation) connected to a computer to press/direct imaging printing press (DCP 9500/QM-DI, Kodak/Heidelberg)



		Rendering quality										Expenditure	
		Content (text and image) black and white	Content (text and image) Color (visual impression ok)	Content + Color (color-true)	Content + Color + Screen structure	Type of ink: Special	Type of ink: Production run	Type of paper: Special	Type of paper: Production run	Sheet size: Individual pages (A3, 2 pages A4)	Sheet size: Entire print sheet (8 pages)	Costs	Time
Classification	Soft proof (on color monitor)	X	X	X	X	X				X		"free of charge"	immediately
	Hard proof												
	Blueprint	X				X		X		X	X	low	reasonable
	Imposition proof		X			X		X		X	X	ok	reasonable
	Color proof			X		X	(X)	X		X	X	acceptable	slow
	Screen proof (true proof)				X	X	(X)	X	(X)	X	(X)	high	slow
	Press proof				X		X		X		X	high	very slow

Fig. 3.2-72 Digital proofing processes (Rendering quality and expenditure)

is confusing in this context, originates from conventional platemaking. Here a so-called "Ozalid/diazo copy" (which is monochrome and blue due to the process involved) is produced after assembly and offers information about the completeness of the pages, their position on the sheet, and the imposition layout. In digital printing technology this technical context no longer exists. Blueprint has become a generic term.

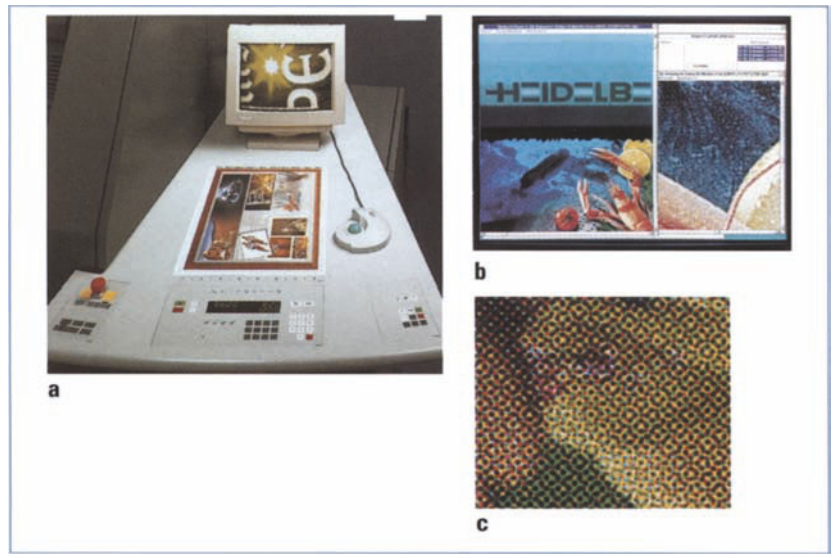


Fig. 3.2-73
Soft proof on the control console of a computer to press/direct imaging printing system (QM-DI, Heidelberg).
a Monitor on the control console;
b Image details of the print job on the monitor;
c Checking the dot structure on the monitor

Imposition Proof (Layout Proof)

In order to gain a *color impression (but not color reliable)* of the file with the same aim as a blueprint (checking the contents and position of the image elements), a layout can be created. Today, blueprint and layout proofing are applications ideally suited to reasonably priced *large-format printers* and are normally equipped with ink jet printing units (fig. 3.2-74). Due to the universal and device-neutral addressability with the PostScript page description language (see sec. 3.2.9), the original printing data can be output via a multitude of printing systems (typically assigned to the "large format printer" category) with the most diverse of quality parameters (resolution, gray levels, type of paper, quality of color).



Fig. 3.2-74
Imposition color proof with large-format ink jet printer (Sherpa, AGFA)

Color Proof

In practice, the process most commonly understood under the term digital proofing is "color proof."

In the printing industry and in the context of high-quality prints, this proof provides the *color-reliable/color-true reproduction* of the contents of the file intended for printing. More and more standard printing systems are being used for this, such as ink jet printers (fig. 3.2-75, four-page (A4+) format) or thermal sublimation printers (fig. 3.2-71, two-page format) in combination with powerful color management systems (see also sec. 3.2.10). The color proofs created in this way serve as a guideline (reference) for the printer in charge of the production run.

While it is possible to work predominantly with small page formats in the creative phase, it is desirable both for printing and for finishing to carry out an inspection of the full-size original or the original digital file in the full-size print format. Reliability is the most important aspect here. As a rule, robust systems with low follow-up costs are obviously preferred in such circumstances. The decision as to whether the proofing system is toner-, ink-, or foil (color donor)-based must be made on the merits of each individual case.



Fig. 3.2-75 Ink jet system for color proofs (Iris 4 Print, Scitex)

Screen Proof (True Proof)

If the *screen structures* of the later printing procedure can also be simulated using a digital printing process, the term *screen proof* is used (also true proof since, with this level of quality, reproducing the dot structure too, this proof is the closest to that in the print run). Among other things, information about the screen structure enables the printing expert to recognize changes to the tone value and the color shifts associated with this or to see the effects of color register deviations early on. Targeted access to the transfer characteristic curve can be made if necessary. The effects of halftone dot, screen angle, and screen frequency are reproduced in the screen proof and show the print quality of multicolor overprinting.

Raster-dependent effects such as smoothness, grade and range of tonal gradations, and *moiré or rosette patterns* can be recognized prior to print production and, if necessary, be assessed together with the customer.

The use of PostScript databases for screen proofs represents an inherent source of error. Since the dot structure is generally not yet a component of the PostScript file, the electronic dot generator in the PostScript interpreter (see sec. 3.2.6) of the proof device must create the same halftone dots as the RIP of the imaging unit for film or plate exposure. This means that the RIP of the film or plate imagesetter or of the computer to press system also controls the proof printer (see fig. 3.2-71). Only in this way can identical dot shapes and screen angles be guaranteed.

Several vendors offer special *proof systems* for creating a "true proof"/screen proof. The examples shown in figures 3.2-76 and 3.2-77 work with the process colors C, M, Y, K. The proof is produced via color donors and thermal transfer (ablation) onto *intermediate carriers* (fig. 3.2-76) or onto the *substrate* used for the print run (fig. 3.2-77). Both systems are imagesetter-like devices with which the image motifs can be reproduced in every detail including their color, screen definition, and screen angles. The systems are designed for four A4+ pages (A2-oversize) as well as for eight A4+ pages. The unit shown in figure 3.2-76 is a *multi-function system*. It can be used to create screen proofs and for digital printing to image plates (computer to plate) when using the same RIP.

The true proof systems named use color foils that are to be processed in separate units (laminators), transferred from intermediate carriers onto production paper and/or laminated, either to protect the proof or to give it the appearance of the surface structure of production paper.

Press Proof

A *press proof* is a *test print* of the data directly in a printing press. This can be the press for the production run or a comparable press (using the same print technology) prepared especially for proof purposes (see also sec. 3.1.6, figs. 3.1-45 and 3.1-46). Short runs of 50 or 100 copies can be produced more cost-effectively than with other color proof processes. The individual proof is, however, hardly economically justifiable.

3.2.11.4 Color Management Concepts

The principal difference between a *digital* and *analog proof* (see sec. 3.1.6) lies in the need to use *special paper* (with ink jet or thermal sublimation) and in the *colorants*, which, in many digital proof systems, are either not at all or insufficiently adapted to the scales used in printing. Electronic printing and proofing systems with inks/colorants and substrates that have not been optimized must therefore be adapted as well as possible into the workflow.

Since the spectral characteristics of the colorants used and the reproduction characteristics of digital, non-impact based printing systems are generally not identical with those of the print process to be simulated, the reproduction characteristics of a printing press

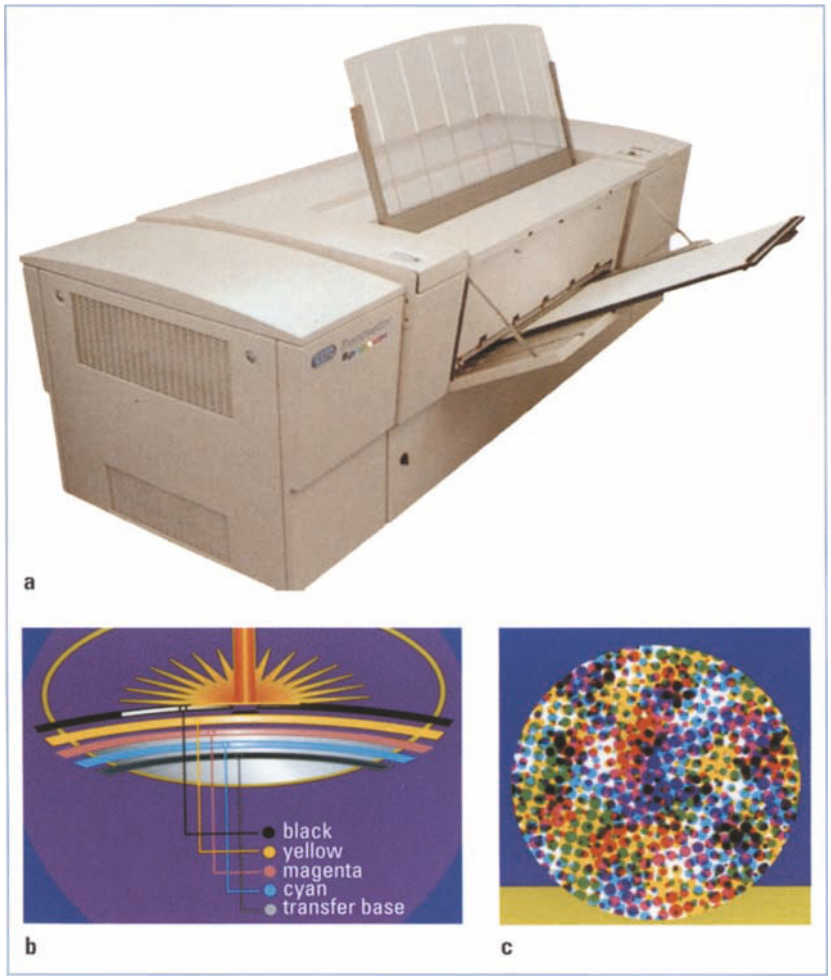


Fig. 3.2-76
"True proof" (screen proof) with thermal transfer system via intermediate carrier.
a Multi-function system for computer to plate and for screen proof production;
b Superimposed printing with color foils on intermediate carriers using thermal laser ablation;
c Screen structure of the proof (Trendsetter Spectrum, Imation/Creo/Heidelberg)

$(CMYK)_1$ should be reproduced for all high-quality proofing processes with the aid of a previous *color transformation*: the inks, toner, and coatings as they are used in digital printing systems $(CMYK)_2$ must be taken into consideration (color management, connecting color profiles, see sec. 3.2.10.4). In addition to the previous section 3.2.10, a description of the procedures and potential applications of color management with digital proofs is given below.

The following is an explanation of color transformation methods for calibrating proof systems.

The previous $(CMYK)_1 \rightarrow (CMYK)_2$ color transformation, which is often wrongly classed as a "*calibration*," is a characteristic of high-quality, digital proofing systems. Other device components are not involved in this special color management application (fig. 3.2-78).

Due to the nature of the process it is only possible to use the original job paper (production paper) in a few digital printing systems. A further task of a digital proofing system or the color management system, therefore, often lies in the simulation of the job paper. The *white dot* of the job paper (colorimetric specification of the color of the production paper) to be proofed must be reproduced in the digital proofing system in this case and the file projected onto the new white dot (in ICC-based color management systems this function is achieved by selecting the rendering intent "absolute colorimetric," see sec. 3.2.10.5 and fig. 3.2-68).

The $(CMYK)_1 \rightarrow (CMYK)_2$ *color transformation* for the simulation of the reproduction characteristics of the press (output profile), which is necessary for all dig-



Fig. 3.2-77 Screen proof ("True proof") with thermal transfer on production paper (job paper).
a Proof system with laminator and workstation/RIP;
b Screen proof on drum of the proofing unit;
c Color foil set with proof
(PolaProof, Polaroid Graphic Imaging)

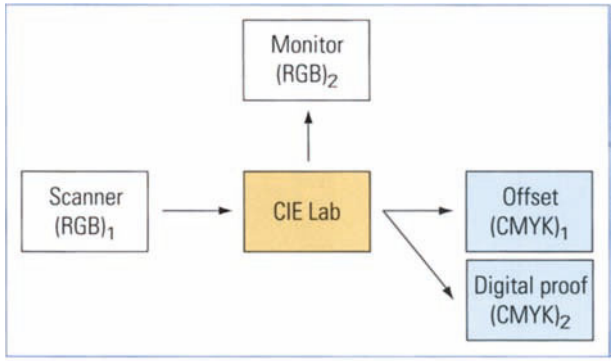


Fig. 3.2-78
Color management/color transformations for adapting the colors of soft proof (monitor), digital proof (e.g., thermal sublimation) to the print production press (e.g., offset process)

ital proofing systems, is normally carried out in the data set prior to the actual print.

Determined by the *configuration of the devices and workflows* used and also the availability of a suitable *color transformation mechanism, five separate cases* can be differentiated. These are described as follows.

Case 1. Since the introduction of the first system-independent color transformation environment based on the profile standard of the International Color Consortium (ICC), namely "*ColorSync*" by Apple Computers in 1994, color matching can now, theoretically, be carried out in the operating system of the controlling computer (fig. 3.2-79).

The data set adjusted for the printing press in color mode $(CMYK)_1$ is, for example, sent by a layout program (e.g., QuarkXPress) to *conversion software (driver)* in order to generate the PostScript data stream. The driver has access to the color transformation routines in the operating system (here Apple ColorSync). When two ICC-compatible color profiles are entered, the file is converted into the color mode $(CMYK)_2$ of the proof printer in the driver and then coded in PostScript and sent in color-converted form via the network to the printer. Assuming that the color profiles describe the reproduction characteristics of the printing press and proof printer ideally, a color-reliable proof is produced.

Case 2. In a similar fashion, color transformation can alternatively be carried out in the PostScript interpreter of the proof printer. This function, also known as "*in-RIP separation*" is theoretically possible on all PostScript RIPs as of version 2017 (fig. 3.2-80).

In this case the data set adjusted on the printing press in color mode $(CMYK)_1$ is also sent to the PostScript driver of the creating computer system. The two ICC-compatible color profiles are converted by the driver software into special PostScript "color profiles" (so-called "*color space arrays*" and "*color rendering dictionaries*") and sent with the file over the network to the proof printer. The desired $(CMYK)_1 \rightarrow (CMYK)_2$ color transformation then

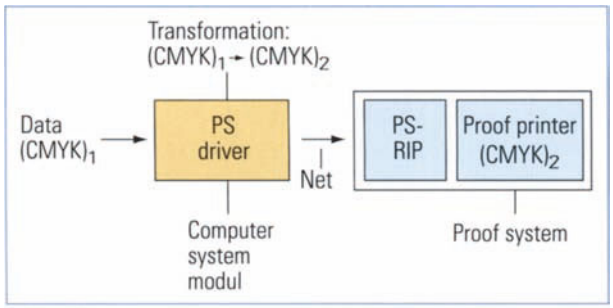


Fig. 3.2-79
Color transformation via ColorSync for adapting the proof printer (case 1)

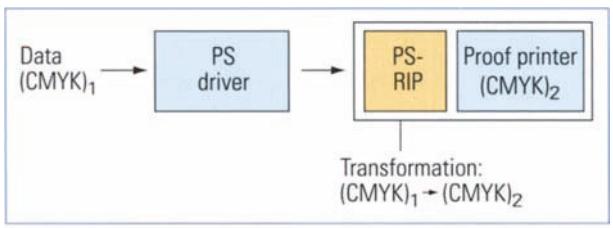


Fig. 3.2-80
Color transformation via PostScript for adapting the proof printer (case 2)

takes place in the RIP software of the proof printer during the interpretation of the PostScript data.

Case 3. In many digital proofing systems proprietary (*vendor-specific*) color transformation routines are used for color matching in the control unit of the printer. These are normally high-grade $(CMYK)_1 \rightarrow (CMYK)_2$ color transformation modules that are not, however, in line with the ICC standard and whose "color profile structures" are not published (fig. 3.2-81, example TekColor by Tektronix).

Here the creation of the PostScript control data takes place without any access into the color data. In the RIP the PostScript data is interpreted in full and forwarded to the color transformation unit. The color data is converted from $(CMYK)_1$ to $(CMYK)_2$ on the basis of the color transformation table previously loaded in the RIP software and then transmitted to the printing unit of the proof printer.

Case 4. Instead of the proprietary color transformation units, ICC-compatible *color management modules* (CMMs) can also be imbedded in the RIP software (fig. 3.2-82).

The processing of the data takes place as in the previous example (case 3) but the color transformation is controlled by standardized ICC color profiles. This type of solution is not dependent on system resources, has optimized performance, and can be set up on various computer platforms. These solutions are predominantly used by purely software-driven RIPs that run on standard computers and allow access into the proof process via the monitor screen (e.g., for loading color profiles).

Case 5. When setting up any PostScript color printer as a proof printer if none of the possibilities previously described are available, $(CMYK)_1 \rightarrow (CMYK)_2$ color transformations can also be made via a *PostScript parser on the network* independently of the controlling computer and the RIP of the printing system (fig. 3.2-83).

With this concept a computer on the network behaves like a virtual printer and loads the PostScript file (whose color has not been manipulated) generated for the proof printer. A special software module (parser) searches for and extracts all the color information from the PostScript data stream and feeds them to an ICC-compatible color transformation unit (CMM). After the color transformation to $(CMYK)_2$ via color profiles, the converted color information is put back into the PostScript data stream originally generated and sent over the network to the actual proof printer.

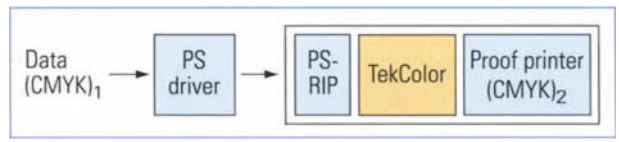


Fig. 3.2-81
Color transformation via RIP extension (vendor-specific, e.g., TekColor, Tektronix) for adapting the proof printer (case 3)

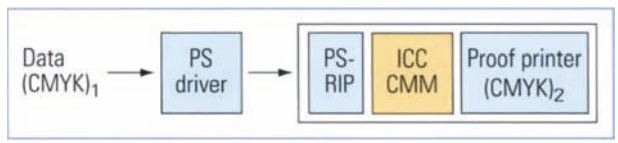


Fig. 3.2-82
Color transformation via RIP extension with color management module (ICC-compatible) for adapting the proof printer (case 4)

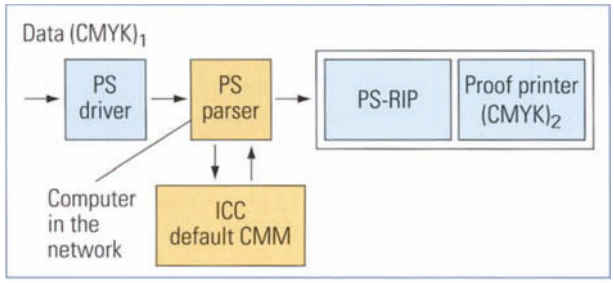


Fig. 3.2-83
Color transformation with PostScript parser technology (PS parser software module within the computer) for adapting the proof printer (case 5)

Conclusion. When using high-performance color management components and systems, a large number of NIP technology-based printing systems can be used for the creation of high quality proofs (test prints), (see secs. 5.2, 5.5, 5.6, and 5.8).

3.2.11.5 Preflight Check

So-called "*preflight checkers*" represent a special version of proofing. To avoid the risk of incorrect imaging, above all of PostScript files, preflight checkers carry out a consistency inspection of the files prior to forwarding them to production. Missing type and defective files, which could lead to incorrect imaging or a system crash, are recognized early in this way. The importance of preflight checkers is likely to increase with the growing complexity of the modern data formats. Some software products falling under this category have the function of interpreting PostScript files with a complex structure and converting them into "simple" PostScript data, which, in the majority of cases, can be processed quickly and reliably in any RIP software.

Preflight checking has become a special service function for contractors of numerous operations in the graphic arts industry and has also become successful in business models as an additional business for the benefit of all parties (checking the data of the contractor and, if necessary, correcting instead of sending back).

3.2.12 Film Production and Platemaking

Throughout the second half of the twentieth century, film occupied a central position within the printing industry. It was used for the production of color separations and proofs as well as for the combination and assembly of all the elements in a page/sheet necessary for platemaking. Besides all this, it was an ideal medium for long-term storage. Film will continue to play a significant role in the coming years and will only gradually be replaced by directly imaged printing plates.

The following observations exemplify both digital film imagesetters (computer to film) and plate imagesetters (computer to plate systems) in combination with the offset technology and are largely applicable to other printing technologies. Other models regarding computer to film can be found in sections 3.1.2 and 4.2 and regarding computer to plate in section 4.3.

3.2.12.1 Computer to Film Systems

Imagesetters were originally used as output devices for typesetting or repro systems. In the 1970s it was still inconceivable that a typesetting imagesetter (for text) could also record images. Not until the arrival of laser imagesetters and the rapid progress made in text and image integration by desktop publishing did imagesetters gradually become the universal output medium for text and image.

Essentially, three types of devices have become established in the imagesetter field: *capstan imagesetters*, *external drum imagesetters*, and *internal drum imagesetters* (see also sec. 3.1.2 and figs. 3.1-4 to 3.1.-7). The capstan imagesetter originates from the technology developed for photosetting. The external drum imagesetter is based on the technology of color scanners. Internal drum recording is the most common technology and is especially suited to large formats.

The types of imagesetter differ in the way the recording material (film, coated paper, or foils) is placed in the unit and the positioning of the optical system in relation to the material during exposure. The large number of imagesetters available shows the many different methods of incorporating these design characteristics.

Drum imagesetters are considered to be the devices best suited to high-quality color work on account of the stability and repeatability of the drum design. Capstan imagesetters are preferred for black-and-white jobs or less demanding color work and are good value for money and simple to use.

Imagesetters receive image data (a matrix of dots or pixels transferred, e.g., from a PostScript-RIP) and output these line by line onto highly sensitive material. During this process each individual dot is written to the material using a laser beam. At the end of each imaged line either the recording material or the optical system is moved on until the page is recorded. This allows text and graphic

line work as well as halftone dots to be recorded. The data supplied by a RIP is in bitmap format, which determines the position where a dot is to be recorded (laser beam on/off). All elements of the page (text, graphics, image) are composed of a number of laser spots whose size is determined by the resolution of the imagesetter.

The laser impulses must be timed and positioned extremely precisely since deviations of only 1 µm may give rise to visible errors in the print, especially when the error is amplified during overprinting.

Drum Film Imagesetters (External and Internal Drum Principle)

The construction principles are shown in figure 3.2-84 and also described in sections 4.2 and 4.3.

The underlying concept of *external drum imagesetters* is based on the fundamental technologies of scanners/imagesetters that were already being used earlier for color separations. In a drum imagesetter the material is placed around (external drum) or inside a concave curved surface (internal drum, trough).

The optical system of an *internal drum* imagesetter is located inside the drum. As with the external drum principle the reflected laser beam is at a constant distance to the film throughout the entire exposure process. In a typical construction (fig. 3.2-84b) the laser beam is directed onto a mirror rotating about the central axis of the drum. This means the optical system moves along the axis and records one line after another.

In the *external drum* system the optical system is located on the outside of the rotating drum (fig. 3.2-84a). The drum with the film revolves past the optical system, which records one line after another and is itself guided along the axis.

Drum imagesetters are able to transport the recording material in two ways: either with a feeder device from a roll of film or by placing cut film manually. The photographic material must be placed accurately in position and held in exactly the right place over its total area. It is particularly important that the material is evenly attached and fits the contour of the drum exactly, usually via a vacuum system.

The advantage of an internal drum is that the moving parts of the optical system have a relatively small mass and can therefore rotate at a very high speed and be moved quickly along the axis.

There are large differences in quality and precision between the devices that are currently available on the market and the choice should be based on the application. In general, drum imagesetters are used in production-intensive environments where predominantly color separations have to be produced. Figure 3.2-85 shows an example of the construction and components of an internal drum imagesetter.

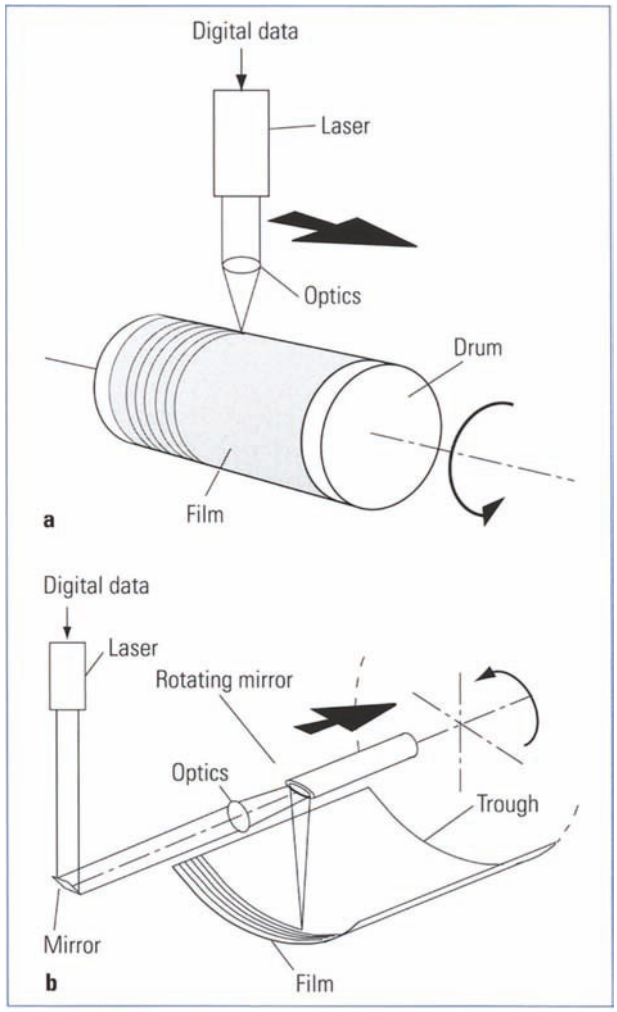


Fig. 3.2-84
Principles of drum imaging systems for computer to film.
a External drum imagesetter: the film is fastened over the drum;
b Internal drum imagesetter: the film is held in a cylindrical trough

Internal drum imagesetters work mostly with one laser beam, while external drum imagesetters generally image using several beams simultaneously.

The productivity of imagesetters (imaged area per minute) depends not only on their individual mechanical-optical features but also on the specifications of the preceding RIP.

Capstan Film Imagesetters

Figure 3.2-86 shows the principle of a capstan imagesetter. Capstan imagesetters were developed from photosetting units. The first PostScript imagesetters were basically photosetting devices combined with PostScript RIPs. This resulted in the early models having tolerances that were sufficient for black-and-white photosetting but not for color work.

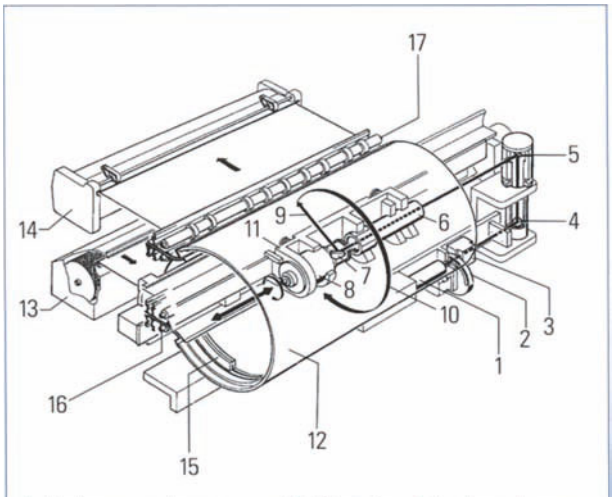
In a capstan imagesetter a film is pulled from the supply roll along a fixed rail, around the capstan roller, and past the optical system of the imagesetter. A critical factor is the precision with which the film is transported from scan line to scan line in order to be imaged line by line by the laser beam. Contrary to the way the material is transported by drum imagesetters, the capstan transport system is continuous. Factors such as the tension of the material are critical because they may cause extremely small variations in the positioning of the material and thereby losses in quality.

The transport system is the most critical component of a capstan imagesetter. In the early imagesetters stepper motors were used to transport the material from one imaging line to the next. A stepper motor normally works on a start/stop principle. The stepper motor transports the recording material to the next imaging line, stops until the imaging line has been recorded, and then continues moving the web to the next imaging line. This starting and stopping causes variations in torque that can lead to vibrations that reduce quality. In addition, each stepwise switching limits the speed at which the recording material can be transported.

There are systems with continuous film transport in use today that have highly precise synchronization between the laser beam and movement of the film. Even though drum imagesetters still offer advantages with respect to greater resolution (finer halftone screening) and productivity, capstan imagesetters are today capable of producing colored pages with high resolution that satisfy the quality demands of many applications.

Expansion of Film Imagesetter Equipment

The differences between individual models of imagesetters on the market concern mainly the range of resolution available, the recordable formats, speed, type of light source, and so on. It is only the areas of application that should still determine whether a film imagesetter works according to the capstan, or the internal or external drum principle. All three designs are fully developed. Capstan imagesetters, with which the spread



1 Helium neon laser
2 Continuous gray filter
3 Modulator
4 First deflection mirror
5 Second deflection mirror
6 Collimator
7 Rotating mirror
8 Rotating mirror drive
9 Laser beam
10 Direction of the laser beam
11 Carriage for axial direction
12 Internal drum
13 Material supply cassette (film)
14 Material take-up cassette
15 Material width stop
16 Material infeed rollers
17 Material outlet rollers

Fig. 3.2-85
Technical diagram of an internal drum film imagesetter (Scangraphic)

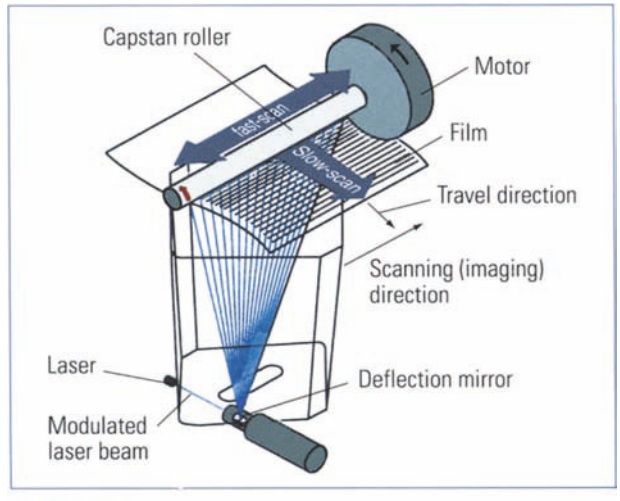


Fig. 3.2-86 Basic principle of the capstan film imagesetter (AGFA)

of PostScript began, are renowned for their interesting price-performance ratio but are still only supplied by a few large companies. The market is clearly dominated by internal drum systems, which make up far in excess of half the products and installations available. External drum devices (with multi-beam imaging systems) are used predominantly for imaging large format films at high production speeds.

3.2.12.2 Computer to Plate Systems

Computer to plate systems also work according to the internal and external drum construction principles described above as well as the flatbed principle (similar to capstan recording) as discussed in section 4.3. The vast majority of computer to plate units use external drum systems. Figure 3.2-87 shows a computer to plate unit with external drum, which operates automatically via a cassette plate feeder and remover (the picture shows the cassette loaded with new plate material). The state of the art is the use of thermally imageable plates (laser wavelength around 830 nm), which can be handled in daylight and do not require a special UV protected room as is the case with conventional plates. Capstan imagesetters are only used for computer to plate applications in combination with polyester-based printing films (the recording material must be processable from a roll). A detailed explanation of computer to plate systems technology follows in section 4.3. The following section will therefore look more closely at workflow when using digital imaging systems.

3.2.12.3 Computer to Film and Computer to Plate in the Prepress Workflow

If CtF or CtP systems can be directly compared due to their technical specifications, the workflow concepts of the individual manufacturers are considerably more difficult to compare (fig. 3.2-88). The workflows should therefore be very closely analyzed and the larger the imagesetter format, the more carefully they should be scrutinized, since the more pages there are on the sheet the larger the quantity of data to be transferred, processed, and archived. This all increases the need to organize an efficient and secure flow of data.

The use of computer to film and especially computer to plate is something for the future. It is virtually beyond a doubt that computer to plate is superior to the conventional production method, but there are still a number of technical and organizational problems to be overcome before film can be discarded on a large scale for producing printing plates.



Fig. 3.2-87
Computer to plate system (external drum principle) with cassette for automatic plate infeed and removal (Trendsetter, Heidelberg/Creo)

When considering the possibilities of rationalization, large format film imagesetters and CtP systems (see sec. 3.2.5) offer the possibility of offsetting the large cost factor, namely manual sheet make-up. The difference is that a film imagesetter means considerably less expenditure, allows flexibility with respect to the plate material, and can easily process originals that are not fully digital. Besides this, it is still easier to carry out a final check and last minute corrections as well as post-exposure of individual printing plates, and it is also possible to manage the induction of employees in to computer to film without a great deal of retraining as the first step towards digitization of the production process. A benefit of CtP is that another processing step, namely photographic platemaking (plate exposing via the film), becomes obsolete and direct imaging of the plate leads to an obvious increase in quality.

Therefore it is often recommended that printing houses that are about to set up their own digital prepress start with a large format film imagesetter so that they can more easily move to CtP recording after they have gained experience with digital production. Benefits of this way of working are not only the lower entry and running costs but also the advantage of being able to work with familiar plate materials.

Since computers work more accurately than humans, digitally imaged films and particularly imaged plates have a more accurate registration, which allows a reduction in print wastage as well as machine setup times.

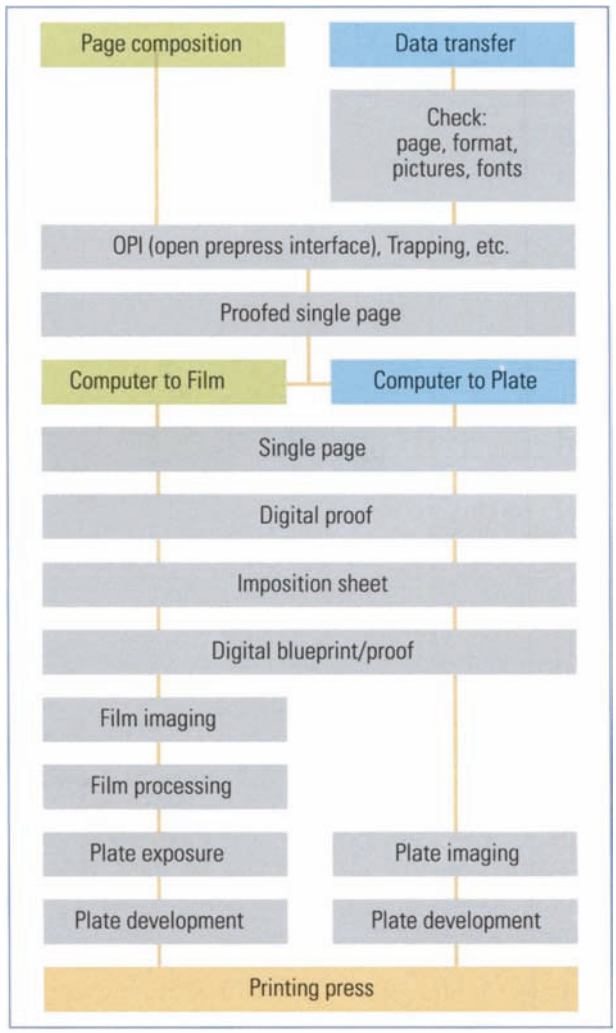


Fig. 3.2-88 Workflow in computer to film and computer to plate

Just by the exclusion of manual assembly a degree of automation is achieved that brings about considerable savings in time and labor. CtP means additional savings on film materials and chemicals and this also has positive environmental repercussions.

In addition, the quality of halftone dots of a digitally produced plate is superior to analog, since each recording stage inevitably brings about quality limitations. The range of tone values that can reliably be reproduced using CtP is from 2 to 98%. CtP systems are an ideal system for frequency-modulated screening with its well known advantages (see also sec. 1.4.3).

The success of the automation step with CtP is strongly influenced by complete prepress technology. Since plate recording now occurs using digital data without any intermediate analog steps, not only must each step that was previously analog be mastered digitally (assembly, imposing, trapping), but computer to plate also requires the handling of quantities of data unheard of up to now. A company must therefore have not only a good, electronic prepress technology available, but also a powerful network together with data servers, the respective workflow management, a digital and layout proof with established RIP technology, and a powerful, efficient *preflight check*.

The development of RIPs in particular has largely influenced modern prepress systems, and to a similar extent the output technologies of computer to film, computer to plate and computer to print.

If the tasks of printserver, OPI (Open Prepress Interface), and RIP integrated on one computer had already started to emerge, the trend since then has been towards integration of process steps such as assembly, trapping, and color management in a dynamically scaleable software RIP mostly based on the Windows NT operating system.

Other tasks are also performed. Strictly speaking, proof and final output can only give identical results if the *plate imaging* and *proof* are produced via a technologically identical RIP. The ideal is if the same RIP can be used for both tasks. The RIP must also master various output formats as well as have the capability of so-called "rip once, output many." This means that data, once ripped, can be made available to the various output media.

Both films and plates must, of course, be punched for further processing (before or/and after imaging) and, depending on the material used, undergo a developing process after recording.

Workflow Management

Besides the output devices and their RIPs, workflow management systems constitute another significant factor for productivity and quality assurance in the process of film production and platemaking.

In this context, productivity depends more on the ability of the total system to control the imagesetter (regardless of whether it is a plate or film imagesetter) than on the speed of the recording itself. A whole range of requirements must be satisfied in order to guarantee productivity.

This includes a powerful network, supported by a powerful data server to ensure the required through-

put rates for recording several hundred megabytes of data. RIPing, imposing, proofing, and imaging must be able to take place in various locations at the same time. Changing the page contents, the imposition scheme, and the choice of output unit should be possible right up to the very last minute.

This can be realized by using modern workflow management systems. The various systems may be divided into single-stage and multi-stage workflows, and the latter sub-divided into typical RIP workflows and PDF workflows. We can therefore distinguish between:

- conventional workflow (single-stage workflow),
- static workflow (RIP workflow, multi-stage),
- dynamic workflow (PDF workflow, multi-stage).

Conventional (single-stage) workflows require completing individual steps that must be initiated manually (e.g., input, RIPing, output).

Static workflows are processes that line up and automatically complete individual workflows (e.g., input, trapping, imposing, RIPing, output).

Dynamic workflows are workflows that receive data to be edited, convert it into another format, and complete the various workflow steps automatically (e.g., input, normalizing, PDF, OPI, color management, imposing, trapping, RIPing, and output).

Figure 3.2-89 shows the essential difference between the *RIP and PDF workflow* concepts. Workflows of these types start with the transfer of single digital pages (see sec. 3.2.1) and control them as far as outputting on

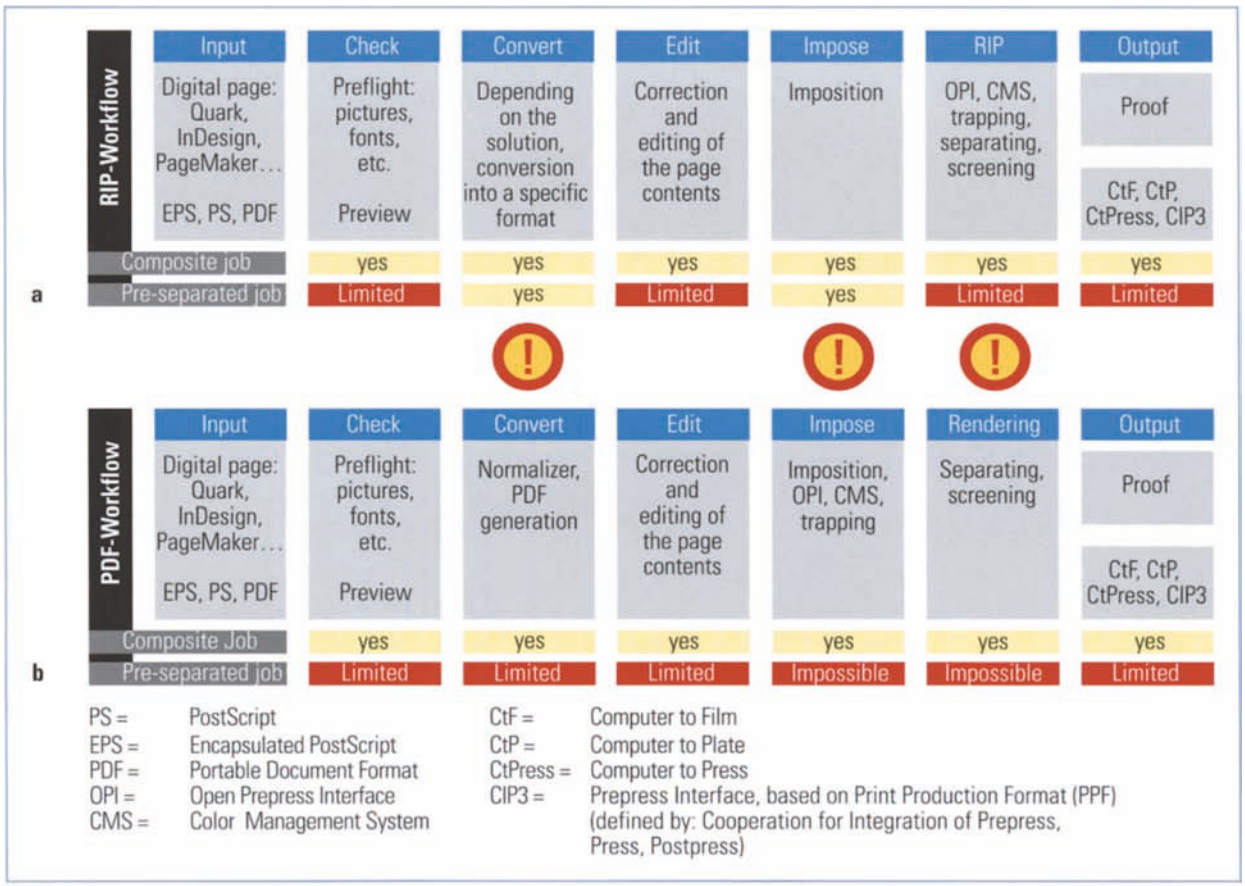


Fig. 3.2-89 Workflow concepts.
a RIP workflow (static workflow);
b PDF workflow (dynamic workflow)

an imagesetter, for instance, a CtP system, or a digital printing system for computer to press/print.

Two typical "dynamic workflows" of different structure are given as examples. In the "Brisque" workflow (fig. 3.2-90) the data is first standardized in the "normalizer," ripped, and then followed up in a Scitex own format as far as output. The "Prinergy" workflow (fig. 3.2-91) normalizes the ingoing data in a so-called

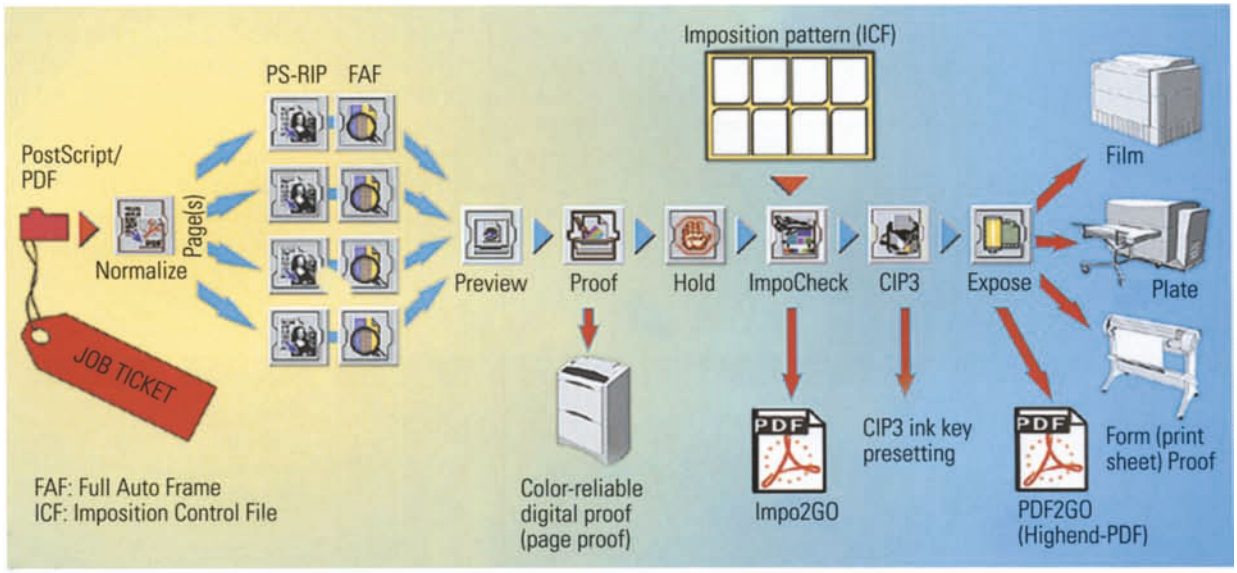
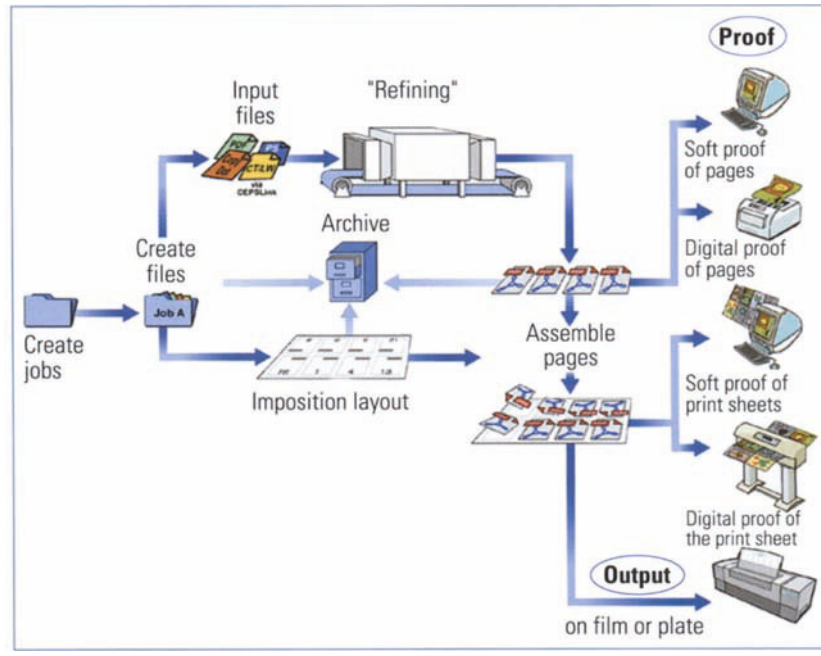


Fig. 3.2-90 Example of a dynamic workflow: Brisque, Scitex

Fig. 3.2-91
Example of a dynamic workflow: Prinergy, Heidelberg/Creo



"refiner" and produces (if not already present) standardized PDF files (see sec. 3.2.9). All of the necessary steps for film and plate production or digital printing, such as color management, trapping, and so on, take place in the refiner. The result of the "refining" process are individual pages in PDF format, which are imposed in a further step and then, after an initial check, sent to the CtF or CtP system.

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4 Computer to … Technologies

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4.1 Survey of the Technologies

Digital Description of the Print Job

Thanks to the opportunities offered by prepress digitization, in particular methods and procedures for providing images, text, and graphics of a page to be printed entirely in digital form, it has become possible to supply an entire page for print, or even a printing sheet containing several pages, as a data file.

Figure 4.1-1 shows schematically how such a data file for the information to be reproduced is prepared using original image data and a layout draft. The image has been processed in a preliminary stage comprising color separation, text processing, and creation of graphics. Images, text, and graphics are then assembled to form the layout of the page. By means of the imposition system, the individual pages are subsequently combined to create the complete printing sheet. The result is a data file accurately describing the monochrome or multicolor printing sheet with all images, graphics, and text elements.

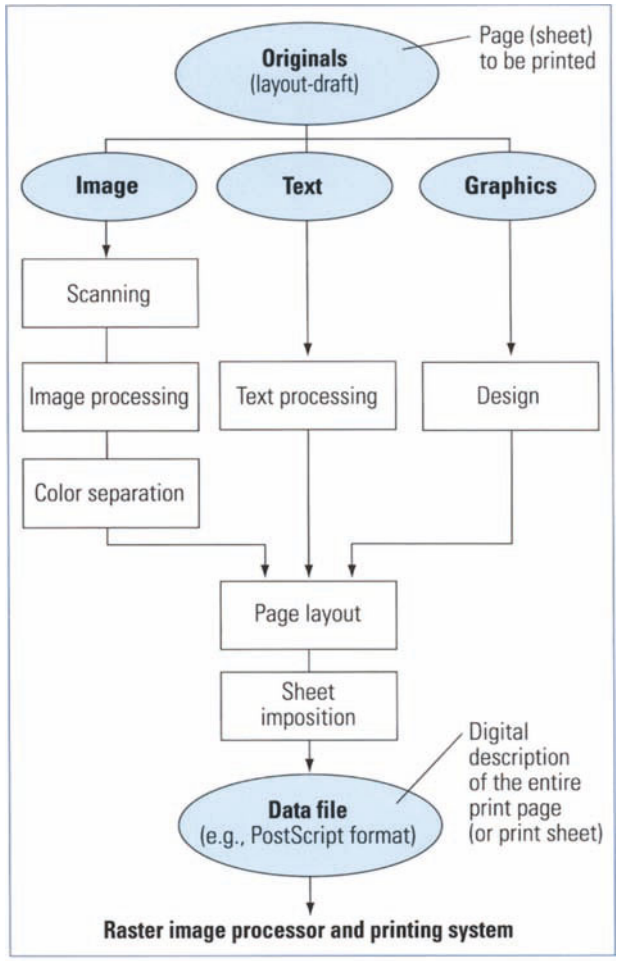


Fig. 4.1-1 Digital composition of a printed page

The System of Computer to ... Technologies

As shown in figure 4.1-2, there are several ways of processing these data, which give a digital description of the page (or sheet) to be printed.

There are basically three options:

- computer to film,
- computer to plate,
- computer to press.

What these different methods have in common is the control of the various devices and pieces of machinery by means of an adapted raster image processor. For each print job, the raster image processor (RIP) transforms the data that has been organized, for example in the page description language PostScript, into what is called a bitmap. Regarding color separations, screening, and resolution, on the one hand the bitmap adapts the print job to the quality requirements and the capabilities of the output device and on the other prepares the specifications and control signals for further processing in the production machine.

H. Kipphan (ed.), *Handbook of Print Media*
© Springer-Verlag Berlin Heidelberg 2001

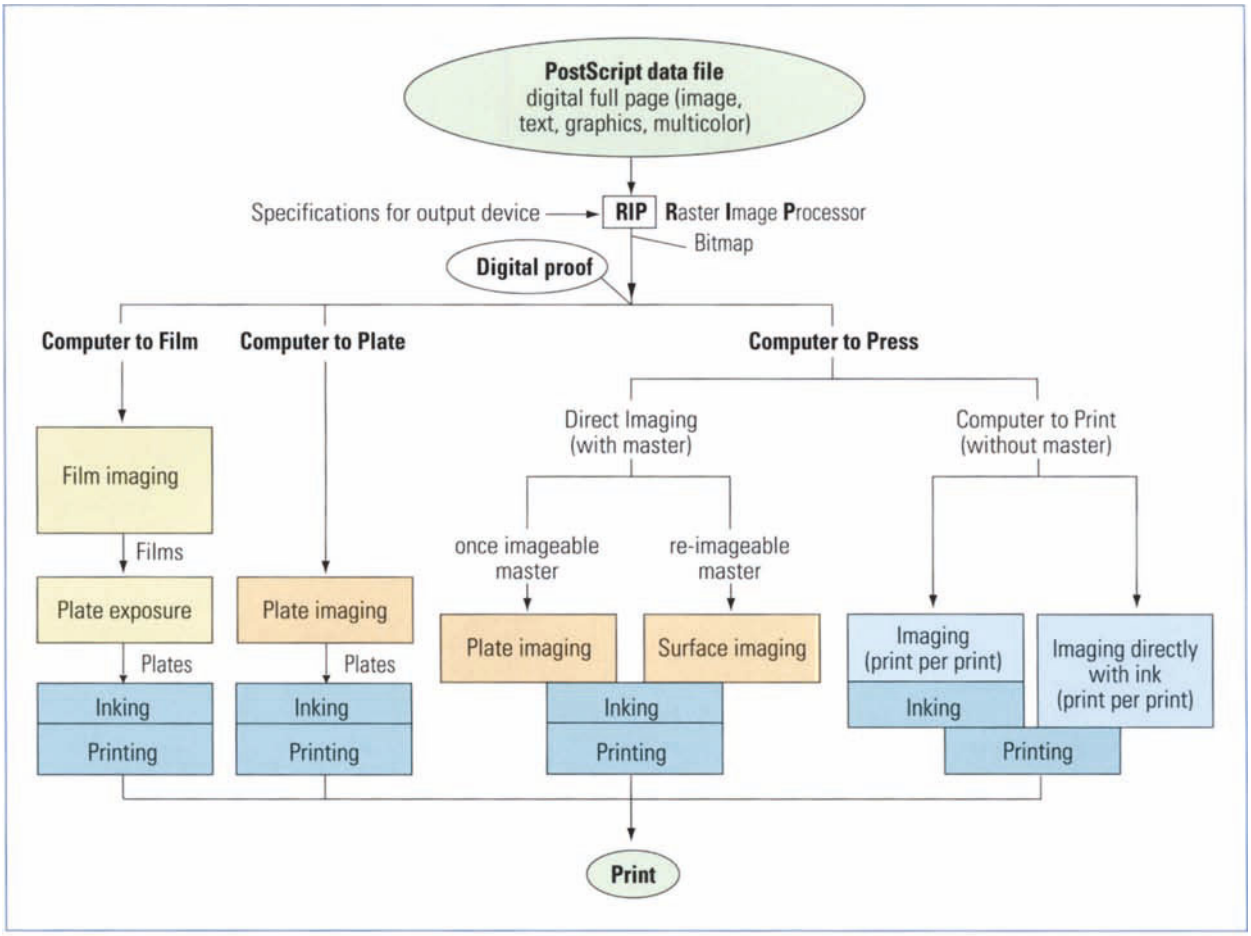


Fig. 4.1-2 Computer to ... technologies (Heidelberg)

The quality of the data file must be ensured before the digital data is transmitted to the selected output device, which may be film imagesetter with computer to film, or a device for directly imaging an offset printing plate with computer to plate, or a printing system for imaging the printing plate directly in the printing press (e.g. direct imaging) with computer to press, or a printing system working without a printing plate with computer to print. For this purpose, digital proofers are available. It is useful to have a proofer that can proof the entire printing sheet, consisting of, say, eight individual pages, with respect to its contents, the positioning of the components, the required colors, and the selected screening: in short, to have a proofing device relying on data that has been transformed by the raster image processor and that can then be used directly to produce the printed product (fig. 4.1-2).

The diagrams in figures 4.1-1 and 4.1-2 are based on [4.1-1] and are generally employed for descriptions of the relatively new, and innovative computer to ... technologies in the printing and publishing industries. On the following pages, the various computer to ... technologies will be briefly explained, together with selected examples. A detailed description is given in following chapters.

The sections on digital prepress (see sec. 3.2) dealt with the preparatory stages of providing the data file for the production of the printed product, together with the RIP technologies and the digital workflow.

4.1.1 Computer to Film

As shown in the figure 4.1-2 block diagram, computer to film systems produce the film for the entire sheet, for example in an internal drum system (see sec. 3.2.12.1), by imaging with a laser beam. Each film of the full-color set of a multicolor print are copied conventionally onto a printing plate, and the set of printing plates is then used in the normal way to produce the print job, as, for example, in a sheet-fed offset printing press. Thanks to such computer to film systems, the workflow in the prepress stage has become shorter, since it is no longer necessary to cut, assemble, and glue individual pieces of film as required in the conventional process. In addition, the system provides for more accurate positioning. Consequently, production of films, and thus of plates, has become quicker and more reliable.

Figure 4.1-3 shows a computer to film system for producing films for entire sheets including an adjoining device for further processing. This system processes a special type of film material that does not require chemical development.

4.1.2 Computer to Plate

Since the film material is highly sensitive, imaging in computer to film systems can be done with laser systems of comparatively low power. In order to image printing plates directly, cost-effective, multi-beam, high-performance laser systems had to be developed. In addition, the system comprising a laser imaging unit and coating material for the image layer of the printing plate had to be optimized to make computer to plate profitable and efficient.

This process which began around 1993 has now been successfully completed, so that today a wide variety of high-performance systems is available.

As shown in figure 4.1-2, the computer to plate method of producing printing plates eliminates films from the production process, thus reducing costs and shortening production times. Since several intermediate film-handling stages in the production of printing plates can also be dispensed with, tolerances have been reduced, and it has become easier to meet the quality requirements of a print job. In computer to plate systems, digitally controlled imaging systems create the printing image pixel per pixel on the printing plate. In general, the plate that has been imaged in this way has to be introduced into the conventional development process. The printing plates are then used in a conventional printing press for printing the print job as in a sheet-fed or web offset printing press.

Figure 4.1-4 shows one of the earliest high performance computer to plate systems, which was introduced onto the market around 1995. As can be seen in the illustration, in this system the printing plates have to be guided to the imaging unit in cassettes that protect them from ambient light. The printing plate is mounted on a drum and imaged by a laser system. The imaged printing plate is then fed to the developing unit via a connecting bridge between the developing unit and a further processing device. The system shown provides a completely automated workflow. By means of the cassettes, the printing plates for ten four-color



Fig. 4.1-3
Computer to film system for outputting full-sheet films corresponding to the sheet size (DrySetter, Heidelberg/PGI)

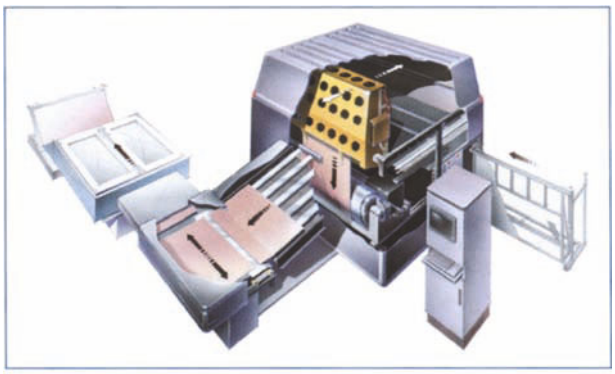


Fig. 4.1-4
Computer to plate system for automatically imaging and developing printing plates (Platesetter 3244, Heidelberg/Creo)

print jobs can be automatically imaged, developed, and fixed. (With more recent printing plate systems (materials), for example thermal plates, it is no longer necessary to work in rooms protected from light.)

4.1.3 Computer to Press (Direct Imaging and Computer to Print)

The computer to film and computer to plate processes described above still rely on traditional, conventional printing presses for producing a print job. It is, however, a technologically fascinating idea to transfer the digital data describing the print job directly to the printing press, dispensing with the intermediate steps of producing films and/or plates off-line and with manually mounting the printing plates in the press. Even in the computer to plate process mounting the imaged plates in the press is still at least partially a manual process, which is time-consuming and can cause register errors when printing multicolor images. In the computer to press process, by contrast, the imaged plates no longer have to be handled manually, since the printing plate is produced in-line, that is, within the printing press, and in register.

There are two different computer to press technologies. With *computer to press/direct imaging* technology, a printing plate as is required, for example, in conventional offset printing, is produced directly in the printing press. For instance, four printing plates for multicolor printing can be imaged inside the printing press. The register alignment that can be achieved in this manner depends only on the quality of the press and of the imaging process and is no longer subject to operator-related influences (see fig. 4.1-5).

Another computer to press technology is *computer to print* (also referred to as computer to paper). This technology does not require production of printing plates for each print job. The technology of the printing method used (non-impact printing) makes it possible to introduce job data directly into the replication process without a printing plate, as, for example, in electrophotography. In this non-impact printing process, a laser creates a charged image corresponding to the printing image on a unit comparable to a plate cylinder. The charge image attracts an appropriate medium, for example, powder toner, and is subsequently transferred to the paper (see fig. 4.1-8).

Figure 4.1-2 includes another computer to print process in which imaging takes place without any intermediate image carrier, as is the case in ink jet systems. In these processes, the ink is applied directly to the printing sheet via electronically controlled nozzle systems (see fig. 4.1-9).

In the following section, the computer to press technology is described by means of several examples. Later sections give more detailed explanation, including a variety of implementations (see secs. 4.4, 4.5, and 5).

Computer to Press/Direct Imaging (with a printing plate that can be imaged once)

Figure 4.1-5 depicts a direct imaging sheet-fed offset printing press. The printing press, shown in diagrammatic form, comprises four offset printing units (each with a plate cylinder, blanket cylinder, inking unit), which transfer ink in four different colors to a paper sheet held by grippers on a common impression cylinder (satellite design). The printing method used is waterless offset printing, which, unlike conventional offset procedures, does not require the application of dampening solution, thus no dampening unit is needed. The characteristic feature of the printing press shown is that each printing unit is equipped with its own laser imaging unit. Controlled by a raster image processor, which processes the job data for the *direct imaging* process, the laser imaging units create the printing plates in all printing units simultaneously. This printing press thus works on a "computer to plate on press" principle. In other words, the printing plates are produced *in-line*. Another specific feature of this printing press (which will be described in greater detail in sec. 4.4.1) is that the printing plate material is provided on a reel stored in cassettes located within the plate cylinder. Before each new print job, the already used printing plate is wound on further, so that a new, unused section of the printing plate roll is arranged on the plate cylinder, ready to be imaged by the laser unit for the next print job. Thanks to available technologies and appropriate machinery design, production of the printing plates for all four printing units in this example can be completed in less than 5–10 minutes and the printing process can start.

Computer to Press/Direct Imaging (with re-imageable printing plate)

Following from the direct imaging concept described above, in which the printing plates must be changed for each print job, another fascinating technical idea is to use printing plate material that can be neutralized by erasing the printing image after completion of one print job and then re-imaged with the image of the next one.

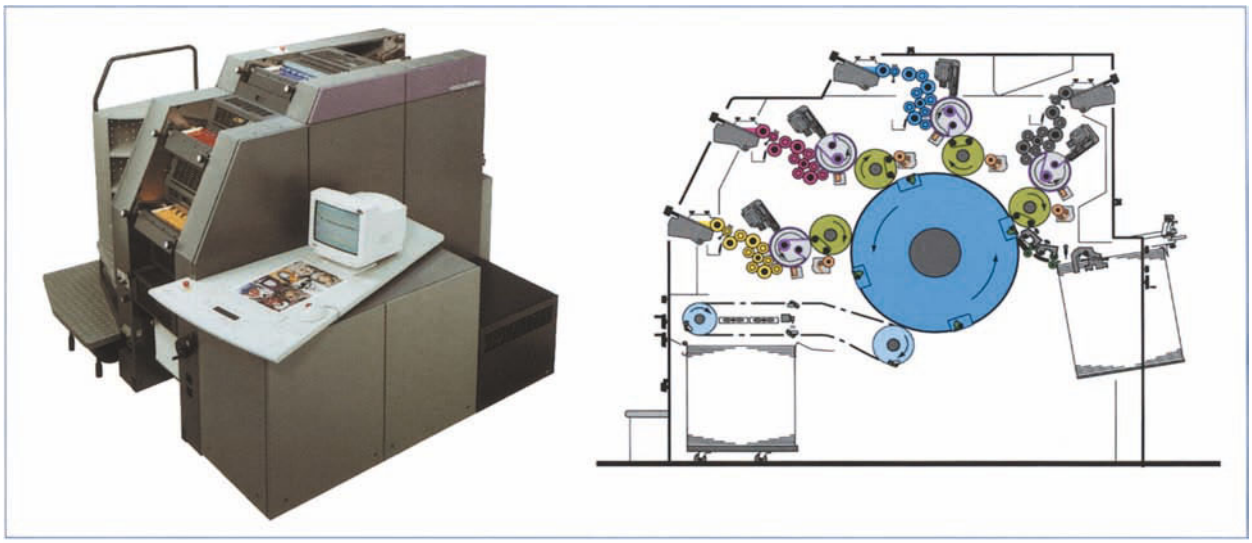


Fig. 4.1-5 Computer to press/direct imaging system for multicolor waterless offset printing (Quickmaster 46-DI, Heidelberg)

Patent literature and several technological studies conducted in the laboratories of individual companies and institutes propose various solutions to this technological idea. As yet, there are no systems used in printing practice. Statements of intent and technological presentations have given rise to the hope that such ideas will be put into practice within the next few years (see also sec. 4.4.2).

Figure 4.1-6 shows a computer to press/direct imaging system of this kind. As can be seen from the individual illustrations, the ink-accepting and ink-repellent sections of the image carrier required in offset printing are created by means of thermal laser imaging. In a thermal imaging process a special type of ink is applied via a ribbon to a cylinder base (water-receptive, ink-repellent) to create the ink-accepting sections of the printing plate. After imaging has been completed and the image on the plate cylinder is fixed by heat, the offset printing process, including dampening, inking, and printing via a blanket, can be performed. The picture shows the laboratory arrangement of a four-color web-fed narrow-web offset print-

Fig. 4.1-6
Computer to press/direct imaging system for re-imaging the printing master (cylinder) in the press (DICOweb Litho/laboratory prototype, MAN Roland)



ing press as it was presented at a trade fair (1995). When the print job is finished, the cylinder surface can be cleaned chemically and mechanically and the printing image can thus be removed. The cylinder surface can subsequently be re-imaged with the printing image for the next print job. No plate change is necessary between print jobs, since the plate cylinder surface can be used many times. Section 4.4.2 (figs. 4.4-24 and 4.4-25) gives a more detailed description of the process, together with alternative processes and technological options.

In practice, the stronghold of the computer to press/direct imaging technology is the field of high-quality, multicolor print jobs of at least three hundred prints per job. To image the printing plates the imaging systems might work at a relatively low speed compared to the print production speed (for example, depending on the design concept cylinder speed (revolutions per hour) for imaging is 80% of the cylinder speed when printing). The printing process itself can be carried out at a high productivity rate on the basis of existing printing systems and well-established machine technology. The printing plate serving as a master guarantees a permanently high level of quality print by print.

Computer to Press/Computer to Print

As explained above, this technology does not require a printing plate. The technologies used in this field are called *non-impact printing technologies* and are based on certain physical effects.

Figure 4.1-7 shows a printing system for *electrophotographic* multicolor printing using liquid toners. The main feature of this system is that a single printing unit is sufficient to produce a four-color print. Multicolor printed products are produced in that the paper sheet is held on the impression cylinder during four rotations. During these four rotations, the color separations cyan, magenta, yellow, and black are subsequently applied to the sheet by means of a cylinder that, as in offset printing, is covered by a blanket. This intermediate cylinder receives the individual color separations from a photoconductor drum that has been imaged by means of a laser to carry the particular color separation. The liquid toner is applied to the photoconductor drum by means of a special type of inking unit. From the intermediate cylinder, the individual color separations are transferred directly to the paper sheet. The different process colors of liquid toner are transferred to the sheet subsequently, by means of the same ink applicator system and imaging system. In the process described above, four or six different color separations can thus be subsequently printed onto the paper. (Such systems are also referred to as multipass systems, since the printing sheet passes the printing nip several times.)

The multicolor computer to print press described above can be used to produce high-quality print jobs

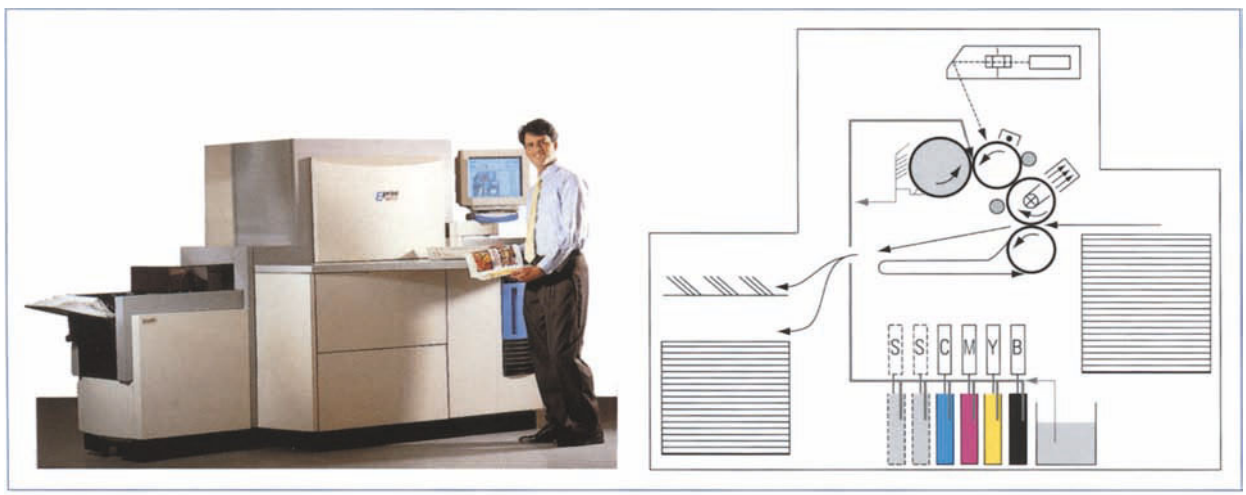


Fig. 4.1-7
Computer to press/computer to print system for multicolor printing using electrophotography (NIP technology) with liquid toner in "multipass design" and an integrated booklet maker for stitching and folding (E-Print 1000 (see also fig. 4.5-4, 5.2-12), Indigo)

of medium run length but is also appropriate for short-run print jobs or productions in which subsequent sheets are printed with different information and can be collated in a further processing unit to form a finished booklet. Such booklet makers produce one finished product after another (fig. 4.1-7).

The computer to print system shown in figure 4.1-8 does not require a printing plate either and also employs the principle of electrophotography. Yet, in this version, powder toner is used and the printing units are arranged in a row one behind the other to produce multicolor prints. Thus the sheet only needs to pass each unit once ("singlepass design"). The system shown in figure 4.1-8 is appropriate for medium print quality and is less expensive than the system described previously.

As explained above, *computer to print* makes it possible to print a different image on every sheet. There are no printing plates with a permanent, fixed image. The image carrier must be re-imaged for every sheet, even if the images to be printed are identical. This has negative effects on the printing speed and causes variations in printing quality from sheet to sheet. With the *computer to press/direct imaging* method, a stable printing plate is produced that to a large extent guarantees an identical quality for every sheet and allows higher production speeds after imaging, since it is not necessary to produce a new printing plate for every printed product. What is impossible, however, is changing the printed image for every sheet.

Digital Proofing

As already indicated, for the operation of systems using computer to … technologies, it is particularly important to test the data before starting the production run (fig. 4.1-2). To produce a digital proof, technologies are used that are similar to *computer to print systems* (i. e., non-impact printing methods that do not require a printing plate).

Figure 4.1-9 represents a proofing system using *ink jet technology*. Eight colors are employed to simulate what will later be a four-color print. This system corresponds to the computer to print principle in figure 4.1-2, in which the ink is directly transferred to the paper without any intermediate carrier. Figure 4.1-10

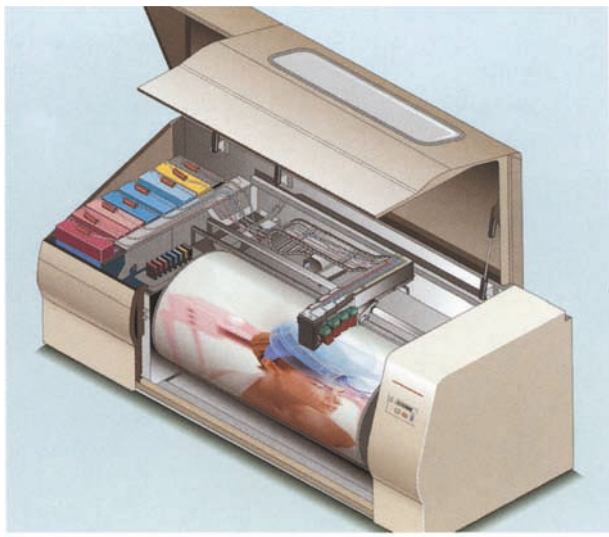


Fig. 4.1-9
Ink jet printing system for digital multicolor proofing (AGFA Jet)

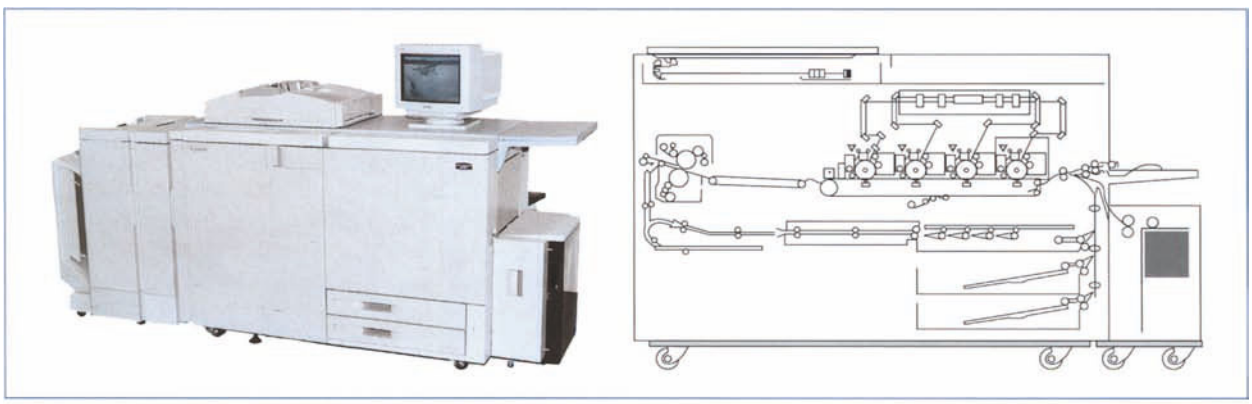


Fig. 4.1-8 Computer to print system for multicolor printing (electrophotography, powder toner) in unit design (CLC 1000, Canon)

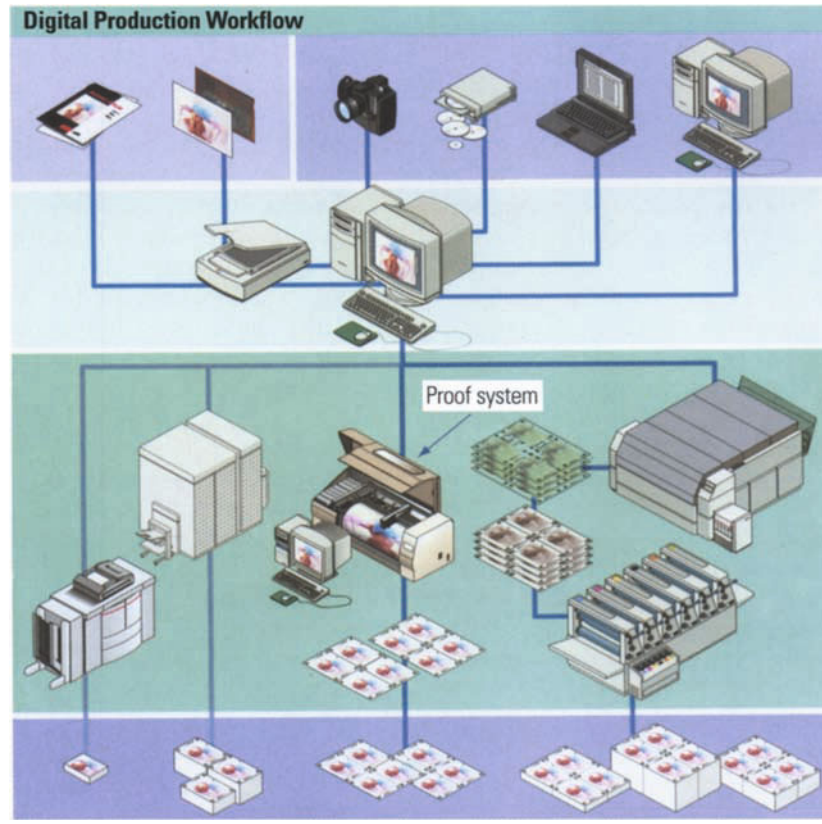


Fig. 4.1-10
Proof system in the print media production workflow (AGFA)

shows that digital proofers are of vital importance in the production *workflow* for print media.

4.1.4 The Use of Computer to ... Technologies and Networking for the Production of Print Media

Figure 4.1-11 shows how an identical data file of a digitally defined print job can be used to operate various devices in varying stages of digitization in order to produce print media. The figure also shows that the different technologies can be used quite efficiently and successfully within one printing company.

The use of the different components is summarized on the basis of this installation example.

By means of *digital proofers* (as in fig. 4.1-9) the data file is tested before a full-sheet (full-flat) film is produced in the *computer to film* system (e.g., using a system as shown in fig. 4.1-3). If a *computer to plate system* is available (e.g., an external drum system as in fig. 4.1-4), printing plates can be produced without using films. The printing plates can then be used in a *sheet-fed or in a web-fed offset printing press.*

In *computer to press/direct imaging systems* (e.g., as in fig. 4.1-5), the printing plates can be produced in the printing press. Manual plate feeding and clamping is no longer necessary.

Short-run or moderate-run print jobs can also be handled without printing plates by transmitting the digitally defined print job directly to a *computer to print system* (e.g., as shown in figs. 4.1-7 and 4.1-8).

For all computer to ... systems a *raster image processor* (RIP) must be provided to convert the digital data supplied in the PostScript format (or in the PDF format) into a bitmap so that the data can be processed by the printing systems. Either the RIP is directly integrated into the production system or conversion takes place offline. In the latter case, the bitmap data may be

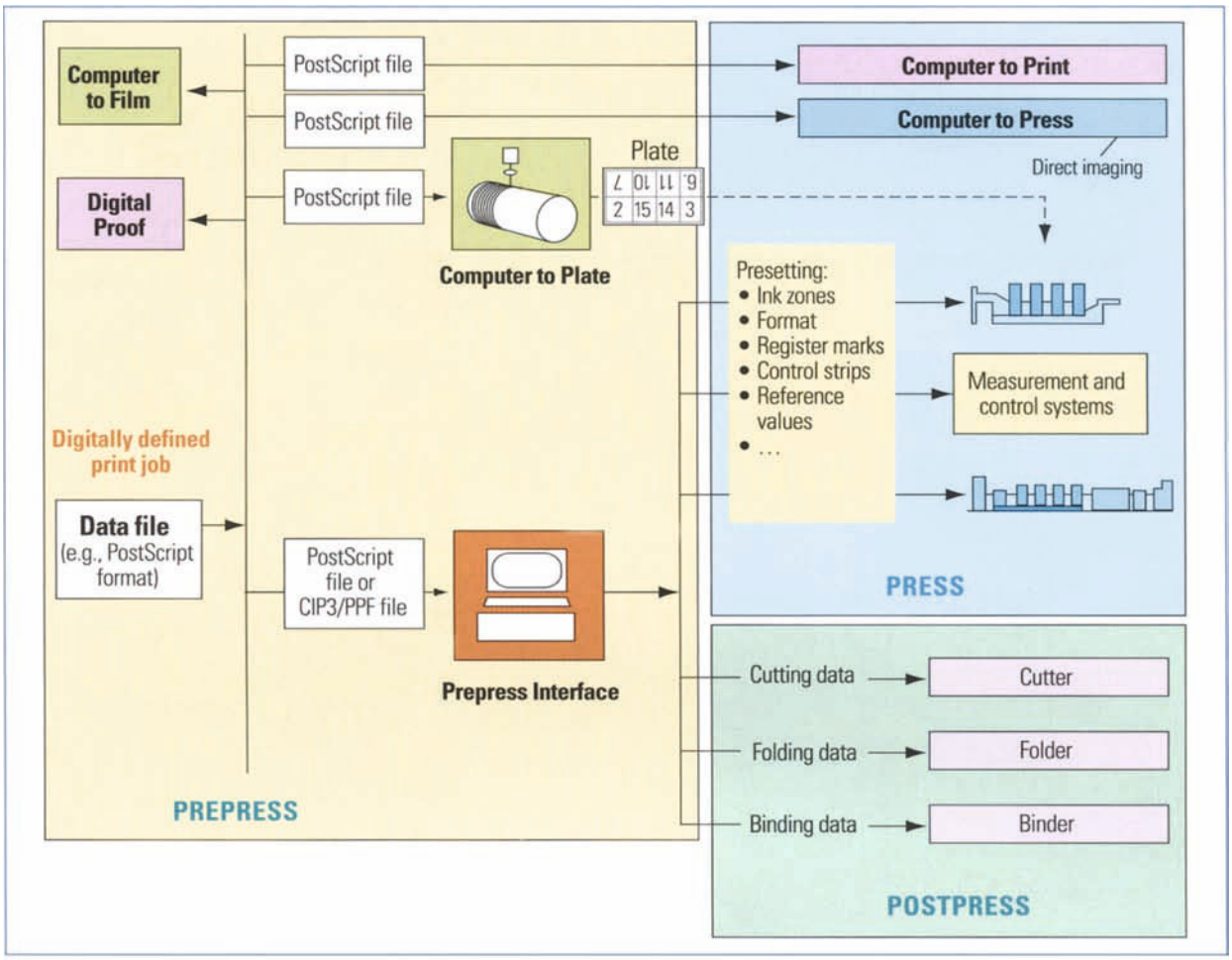


Fig. 4.1-11
Networked production based on application of computer to ... technologies using digital data and a prepress interface for operating conventional printing systems and finishing equipment (Heidelberg)

stored in a temporary memory and be transmitted to the production system later.

Figure 4.1-11 additionally shows that a *prepress interface* can be employed to take data extracts out of the data file describing the entire print job and so provide information on *presetting* conventional printing systems. This information may relate to presetting the ink zones of sheet-fed or web-fed offset printing presses or to presetting further processing devices such as cutting, folding, or binding machines, which depend on the size of the products to be processed.

In addition to figure 4.1-11, figure 4.1-12 gives specific examples of devices and systems, showing that all devices used in the fields of prepress, press, and postpress can be operated employing a common data file for the print job (*computer to print* is not illustrated).

Computer to ... Technologies within the Production Flow and for Different Printing Technologies

Figure 4.1-13 again gives a summary of the different printing technologies (see fig. 1.3-26). At the same time this diagram emphasizes those components that are of

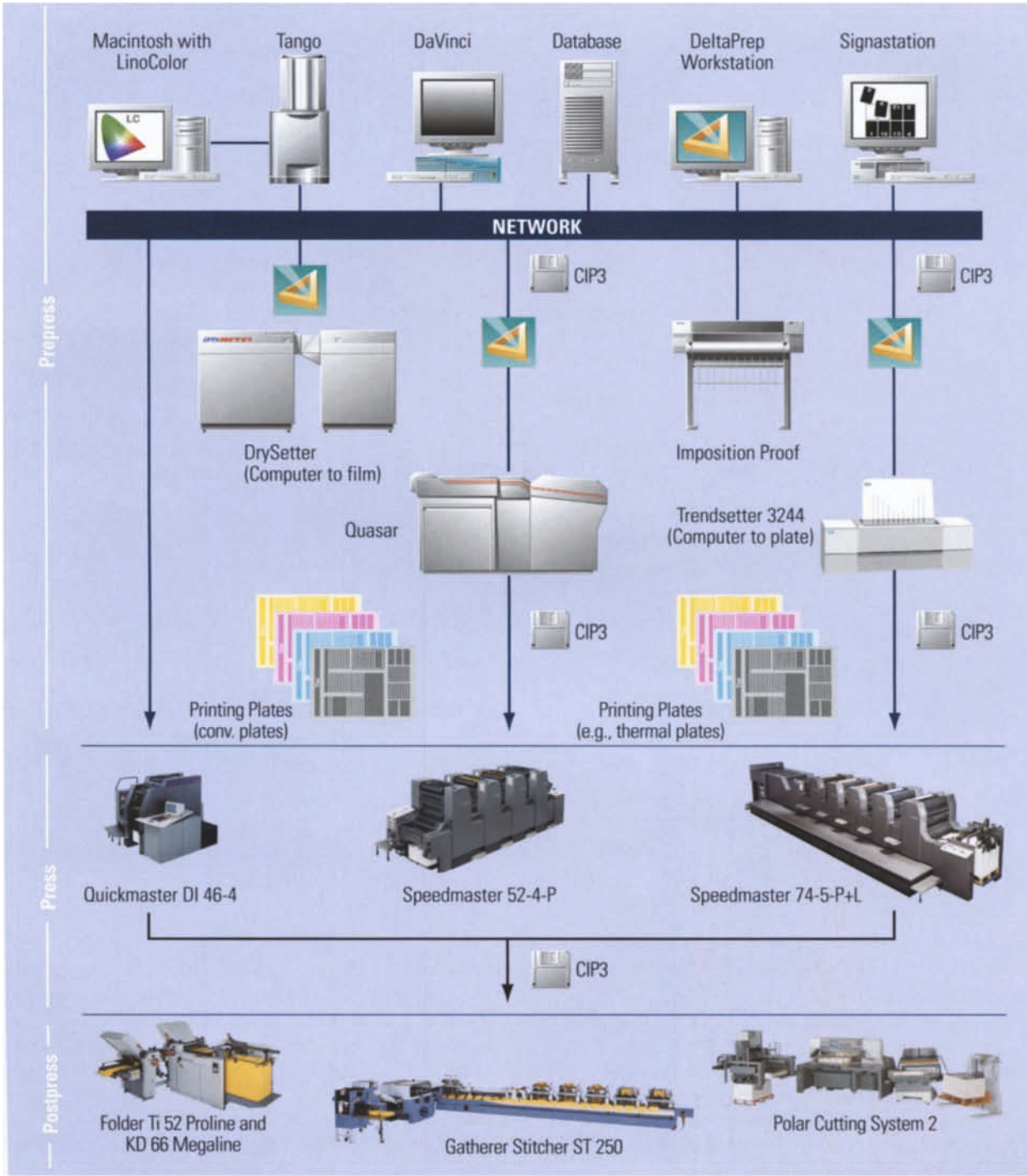


Fig. 4.1-12
Production options and printing systems using computer to ... technologies in a networked production with digital workflow (Heidelberg)

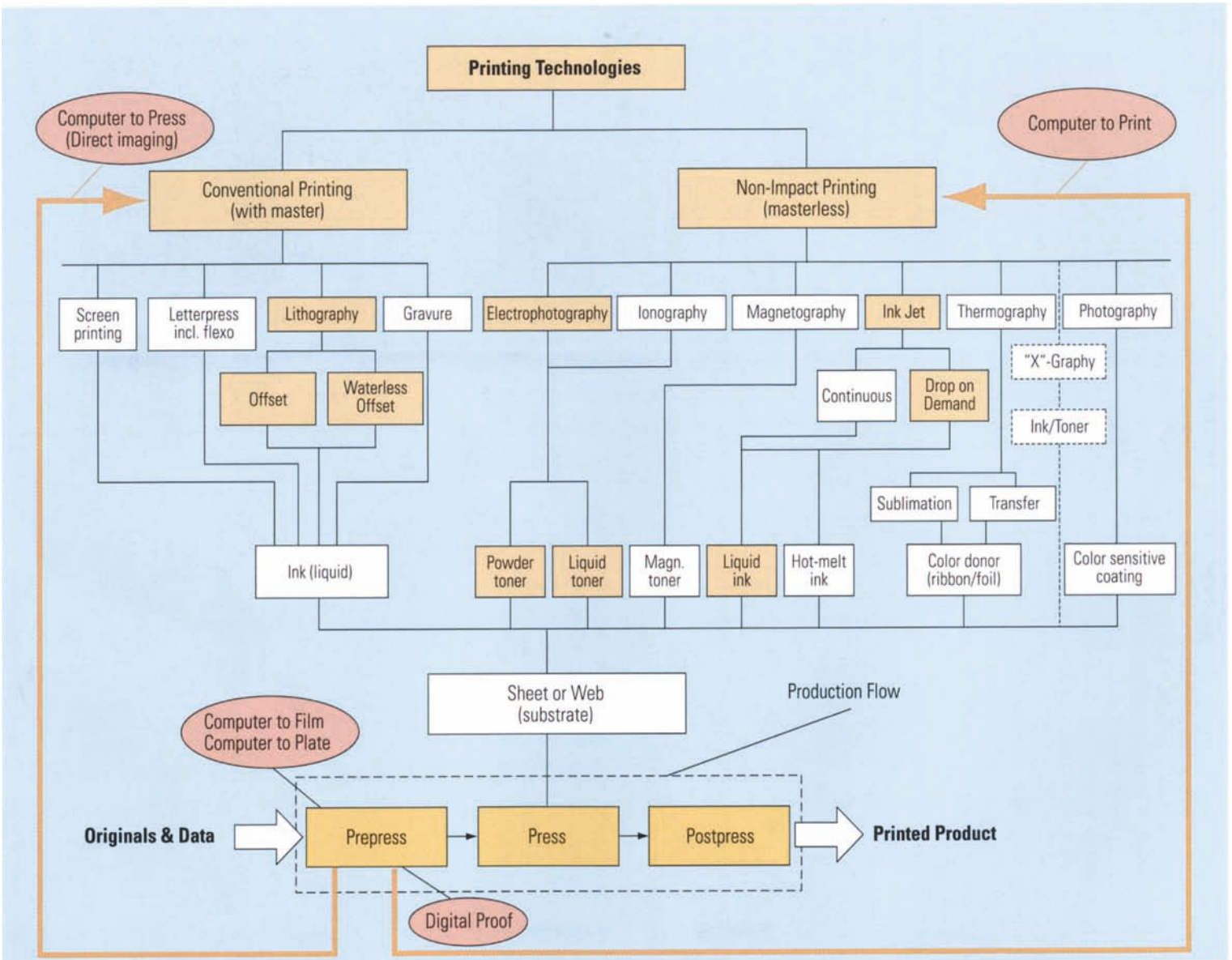


Fig. 4.1-13 Digitization for producing multicolor printed products by applying computer to … technologies with conventional and NIP printing technologies

particular importance for the description of the different computer to ... technologies mentioned above.

Computer to film and computer to plate belong to the field of prepress. The data of the digitally described print job based on given originals or data can be transmitted to computer to press/direct imaging systems relying on conventional printing technologies such as offset printing.

If computer to print systems that work on the basis of non-impact printing technologies are available, no printing plate is required. The digital data can be directly transmitted to produce the print media. By way of example, a description was given above of systems applying the principle of electrophotography, using liquid toner or powder toner as well as a digital proofer, employing ink jet technology. Digital proofing largely belongs to the field of prepress, but is also important at the production equipment itself, especially if computer to press technologies are employed. (In computer to print systems, proofing can be done by the printing system itself, if the press is not running to capacity.)

Decentralized Production of Print Media

Owing to the availability of the print job in a completely digital data file and thanks to the different computer to ... systems, it has become possible to *decentralize* the production of a print job. This means that data can be transmitted to printshops located close to the customer and that the print job can partially be produced there.

Depending on the production system employed and the degree of digitization of the workflow, various production methods can be used, as shown in figure 4.1-14 on the example of printshops at different locations and with varying machinery. The minimum requirement for handling digitally transmitted print job data is a *digital prepress* section/department. At least computer to film or computer to plate technology should be available. If computer to press/direct imaging systems or computer to print systems are used, it is possible to use the data transmitted via the network directly to start the production run. As shown in figure 4.1-14, the use of computer to print (computer to paper) systems for in-line processing is particularly advantageous for the production of "*books on demand*," where the printing system delivers a single finished and bound book by processing special data received "on demand" from a data library.

After this general survey of the different computer to ... technologies, detailed descriptions of the various options are given in the following sections of chapter 4. An entire chapter (5) is dedicated to non-impact printing technologies as used in computer to print systems. In this chapter 5, particular attention is paid to the working mechanisms of these non-impact printing (NIP) technologies.

References in 4.1

[4.1-1] Kipphan, H.: Color Measurement Methods and Systems in Printing Technology and Graphic Arts. SPIE – The International Society for Optical Engineering, Vol. 1912, Bellingham (WA) 1993, pp. 278–298.

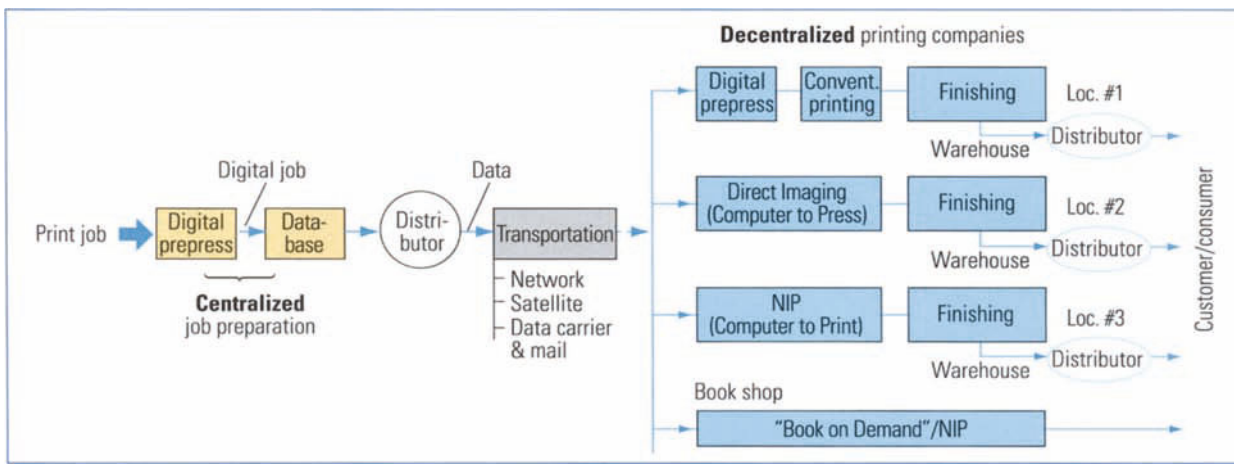


Fig. 4.1-14 Decentralized production of print media by applying Computer to ... technologies

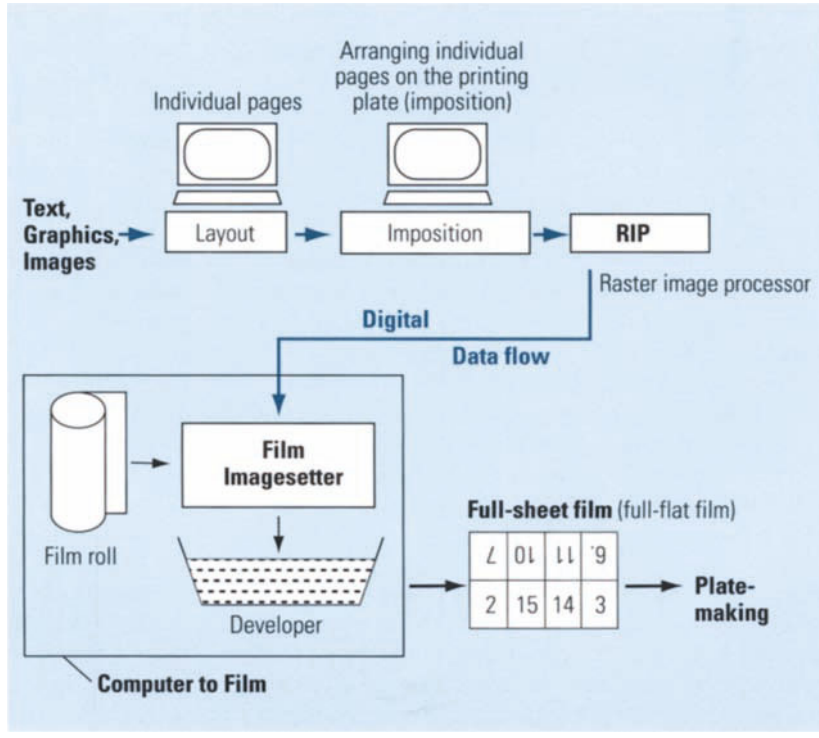
4.2 Computer to Film

4.2.1 Principles and Equipment

"Computer to film" describes the *complete* imaging of films based on digital data and is controlled by the computer. Here, emphasis is placed on the word "complete" because the digital output on film is not, in itself, new and has already been described in detail in section 3.1.2.1. However, if a full-flat (full-sheet) film is exposed, the term "computer to film" is used, analogously to "computer to plate." The special feature of the full-flat film is that manual assembly is no longer necessary. The full-flat film already includes all the pages as well as all the print control elements and marks for finishing.

Figure 4.2-1 shows the characteristic workflow of computer to film. After the layout of the individual pages is complete, digital "imposition" takes place in the computer. This imposition is the central prerequisite of computer to film and the decisive factor for cutting down on costs and time. It is detailed fully in section 3.2.5. After imposition, the data is transferred to the raster image processor (RIP), which converts it for output on film. In section 3.2.6 there is more information on how a RIP functions. The full-flat film is created in the film exposure device, together with series-connected developing equipment, the full-flat film can then be copied in the copying frame onto the printing

Fig. 4.2-1 Workflow with Computer to Film



H. Kipphan (ed.), *Handbook of Print Media*
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plate material without need for any further manual assembly operations.

Compared with conventional manual sheet assembly, computer to film – and therefore the output of a full-flat film – offers the following *advantages*:

- As compared to manual assembly of numerous individual elements (films), *work time* can be reduced considerably, depending on the complexity of the elements.
- *Productivity* in the prepress area is thereby increased; during the same time, more films can be produced than previously. On average, it can be assumed that productivity is increased by a factor of three.
- There is a *saving in materials* (base material, copy and print control strips, adhesive strips, intermediate film).
- Drawing the *layout sheet* is no longer necessary.
- With repeating imposition patterns, in particular with *repeat jobs*, the imposition data is available and can be called up at the touch of one button.
- *Operators learn* to handle digital data and digital methods of production in general, and gather experience for use later with computer to plate. With computer to film, flexibility is maintained, even for (analog) films supplied by the customer, which can then be integrated. Digitization of these analog films is, of course, also possible and advantageous, but with this hybrid method of working, as described, it is not necessary.
- If needed, *proofs* can be produced using analog equipment (sec. 3.1.6).
- The *plate copy* requires less time. Cut edges for positive plate imaging systems, which would have to be removed, are no longer present on the plate (cut edges can occur when film pieces are stuck on top of one another while using analog plate exposure).
- There are even advantages in time and quality at the *printing press*. Register accuracy of the individual full-flat films is better than it could be with manual assembly. In this way, the time needed for ink register setting at the press is reduced for multicolor jobs.

Numerous film exposure devices (imagesetters) contain an *integrated punch* to ensure that the register accuracy of the films for copying to the printing plate is as great as possible and that no additional manual operation is necessary. Figure 4.2-2 shows examples of large format internal drum film imagesetters with full-flat film output.

The workflow in computer to film as described in figure 4.2-1 requires a wet chemical development process after imaging in the film imagesetter. The technical procedure of such a wet-chemical development does not differ from the one applied for ordinary (analog) production of films and is described in more detail in section 3.1.3.4. The properties of these film materials are described in sections 3.1.2.2 and 3.1.3.3. The physical/technical fundamentals of film exposure are dealt with in section 3.1.3.2.

The vast majority of computer to film applications use *conventional films* that require a wet chemical development. Apart from this, there is another interesting technology available: the use of so-called *dry films*, which do not use wet-chemical development. By this means, the workflow with computer to film (fig. 4.2-1) can be even further reduced.

The technologies and products for *dry films* are summarized in table 4.2-1. The *DryTech* film from Polaroid has a multi-layered structure; it consists of a base material (receiver) and a donor (fig. 4.2-3). Between the polyester foil and the base material there is a laser-sensitive layer and a carbon layer. When imaging takes place, the carbon particles fuse with the laser-sensitive layer and can then be peeled off with the polyester foil. The particles that have not been irradiated remain in place on the base film. Film exposure works in the same way as with conventional negative films: wherever the film is hit by laser light, it becomes transparent as a result of the carbon being removed. In order to protect the film from abrasion and scratching, it is necessary to seal it using a thin acrylate protective layer. It was exactly for this special dry film that the computer to film system "DrySetter" (Linotype/Heidelberg), with its directly connected peeling unit, was developed.

The *DryView* dry film is based on a silver diffusion process and requires extra heat treatment after imaging has taken place. DryView was developed by Imation and taken over by Kodak Polychrome Graphics (KPG). Kodak has also developed a dry film (*LTI-Film*; table 4.2-1) for which no heat treatment is required; however, during this process the dissolved ink substance has to be vacuumed off.

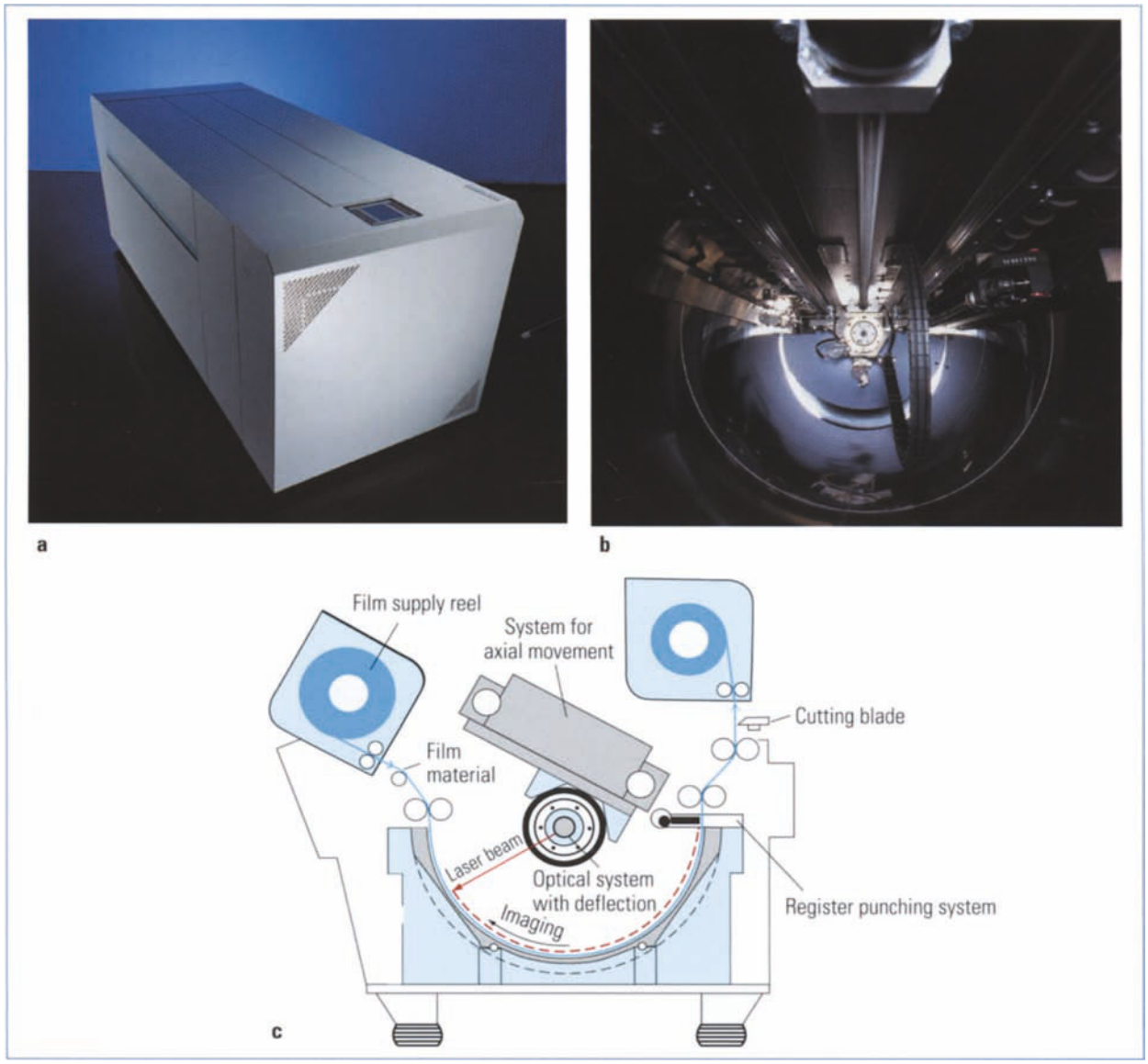


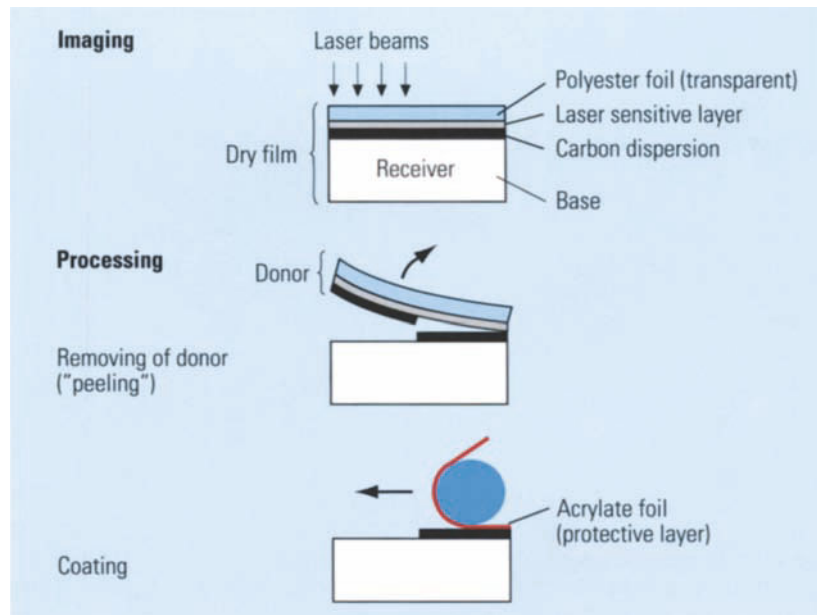
Fig. 4.2-2 Computer to film equipment for full-sheet film output.
a External view of a filmsetter for the 70 cm × 100 cm (28" × 40") format (Signasetter, Heidelberg);
b Internal drum system (Signasetter, Heidelberg);
c Structure of the internal drum film imagesetter (Quasar, Heidelberg)

The *thermo-contact process* is another technology used in dry film imaging. In this process the film is heated by a thermal imaging head whereby a thermochrome substance is permanently discolored. The thermal writing head usually contains several writing elements in one line that can be controlled individually. The distance between these elements is fixed and does not permit great resolution (approximately 600 dpi). For this reason, the printing quality that can be achieved using such films is limited to a screen width

Table 4.2-1
Dry films: technologies and products

Technology	Product	Manufacturer	Imaging with	Process stage (after imaging)
Thermal transfer	DryTech	Polaroid	IR laser (5 W, 1050 nm), e.g., YAG laser	1. Peeling (removing of donor foil) 2. Coating
Silver diffusion ("dry silver")	DryView	KPG (formerly Imation/ 3M)	IR laser diode (780 nm), as with conventional film imagesetters slightly higher output (40 mW)	Heat treatment, heat sensitive
Ablation	LTI film (laser thermal imaging)	Kodak	IR laser (550 mW), heat solubilizes the green colorant, which is exhausted during imaging	none
Thermo-contact	ThermalRes	Laser Master (USA)	Thermal, with touching tips; thermochrome substance turns black	none

Fig. 4.2-3
Film imagesetting based on the thermal transfer technique with dry film (DryTech, Polaroid)



of approximately 54 lines per centimeter (135 lpi). Thus, thermo-contact films are predominantly suitable for single-color offset but are also used for printing spot colors, and in screen and flexographic printing. In the case of thermo-contact processing, there is clearly potential for further development; this is especially true for the design of imaging equipment.

Further Reading for 4.2

Wilkesmann, C.; u.a.: Naß- und Trockenfilme unter ökonomischen, technischen und ökologischen Aspekten. Hrsg.: Bundesverband Druck e.V., Abt. Umweltschutz, Wiesbaden 1997.

4.3 Computer to Plate/to Cylinder/to Screen

4.3.1 Introduction

"Computer to plate" is the term used to describe the computer-controlled direct imaging of printing plates from digital data. It refers to the production of printing plates for offset printing as well as to the production of plates for flexographic printing. "Computer to cylinder" is the term used for the direct imaging of printing cylinders, thus for engraving gravure printing cylinders directly from digital data. "Computer to screen" is the corresponding term used in the production of stencils for screen printing.

The general basic sequences and principles applied in producing these computer-generated plates are described below. A separate description of computer to cylinder and computer to screen is given later.

A wide range of computer to plate technologies and systems was introduced on the market at the end of 1993 (IPEX 93, trade fair for the graphic arts industry); and since then, it has been one of the great themes at all of the subsequent trade fairs and events for the graphic arts industry (e.g., DRUPA 95 and IPEX 98). There was more hesitancy in putting this type of printing plate production into practice than manufacturers had expected, however. The essential prerequisite for computer to plate, that the complete printing plate images be available as digital data files, had still not been adequately met. The digitization of prepress has moved forward slowly, since the entire organization of work and sequences (workflow) has to be converted to the digital process. This is a big challenge for a company and its employees as regards education and training and a change of tasks. Another hurdle in the path of its introduction is the volume of investment required. However, it is to be expected that this technology will be used more and more and that there will be more than five thousand systems in operation in the year 2000 (there were approximately six hundred in early 1997).

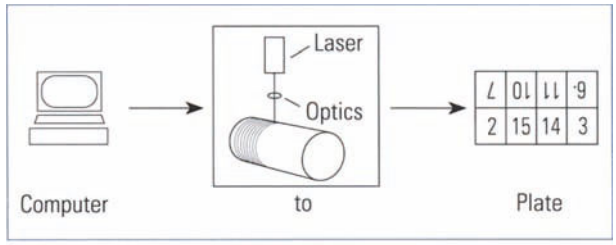


Fig. 4.3-1 The three elements of computer to plate

Computer to plate (CtP) comprises three basic components: computer, imaging system, and printing plate/plate support (fig. 4.3-1). All components have now reached a suitably advanced technological state for practical application.

Computer

The computer rightly has first place, because it influences the entire workflow. Electronic imposition (see sec. 3.2.5) on computer, in particular, results in fundamental savings in the time and cost of platemaking compared to manual assembly on light tables. The overall system usually comprises several computers dedicated to various functions such as imposition, a raster image processor (RIP), intermediate data storage, and a control computer for the equipment.

Imaging System

The transfer of digital data from the computer to image the plate surface is performed by the central element of the computer to plate system, the *plate imagesetter*. In most systems lasers are used for this purpose. The power and wavelength of the laser beams have to be matched to the sensitivity of the plate surface.

Printing Plate

A large number of plate types is available for computer to plate applications. *Offset plates* vary with respect

H. Kipphan (ed.), *Handbook of Print Media*
© Springer-Verlag Berlin Heidelberg 2001

both to the base, namely aluminum, polyester, or paper, and to the coating. In the current state of the art most plates still have to be developed by means of a solvent or water-based process after imaging.

4.3.2 Technology of Computer to Plate Systems for Offset Printing

4.3.2.1 Design Principles

There are three major design principles for the design of plate imagesetters: internal drum, external drum, and flat-bed imagesetters. The most important characteristics of drum plate imagesetters are compiled in table 4.3-1 (see also [4.3-1]).

External Drum Design

The plate is mounted on a drum, on the same basic principle as with the plate cylinder of a printing press (fig. 4.3-2). The imaging head focuses one or more laser beams on the plate surface. The imaging head moves along the axis of the drum while the drum rotates. Feed may be continuous, so that one individual laser beam writes one sweep, or in stages if the gap (the area of the drum in which the clamping device is located, not the plate) rotates past the imaging head.

The crucial advantage of the external drum method over the internal drum imaging method is that both structurally and optically it is relatively easy to focus several laser beams on the plate surface simultaneously. This leads to a corresponding reduction in imaging time for the entire plate. The imaging heads of the Canadian company Creo, for example, operate with about 240 parallel, independently controlled beams. Figure 4.3-3 shows the drum and the imaging unit of an external drum CtP system. The imaging head moves along the entire axial length of the drum. This is quite different from the carrier bar design with separate laser

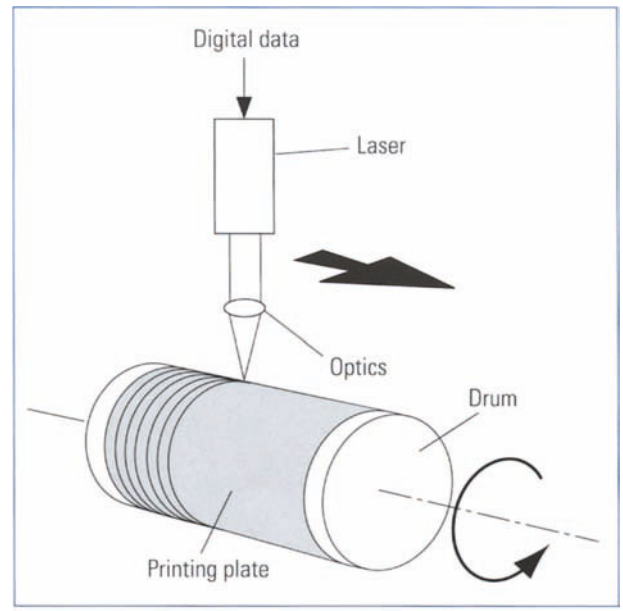


Fig. 4.3-2
Design principle of an external drum plate imagesetter: The printing plate is mounted on the drum

Table 4.3-1
Characteristics of internal and external drum plate imagesetters

Internal drum	External drum
Stationary printing plate	Rotating printing plate (risk of unbalance, centrifugal forces)
Punch can be integrated in the drum	Easy plate handling (as with plate cylinder in the printing unit)
One laser beam (several laser beams with more recent developments) for the complete plate: – uniform beam intensity throughout – longer imaging time – very short radiation time per pixel → greater accuracy, with thermal plates less loss of energy	A large number of parallel laser beams (e.g., 200) possible: – risk of uneven beam intensity – shorter imaging time
Large optical depths of focus	Optics very close to the plate, short optical path



Fig. 4.3-3
Computer to plate system based on the external drum design.
a General view;
b Drum with imaging unit (Trendsetter, Heidelberg/Creo)

diodes arranged at intervals (e.g., Presstek about 20 mm apart). The carrier bar is nearly as long as the drum and only needs to be moved within the distance of the laser diodes (see fig. 4.4-6). This principle is also applied in the computer to press/direct imaging system "Quickmaster DI" (see sec. 4.4.1).

Up till now the external drum method has been the one normally used in the design of computer to plate systems for the imaging of flexographic plates (fig. 4.3-4).

Internal Drum Design

The internal drum concept derives from the design of film imagesetters. The printing plate is placed in a cylindrical trough (fig. 4.3-5). Most devices use angles greater than 180°. The plate exposure in such a system, the beam path, and the laser optics are shown in figure 4.3-6.

There is a rotating mirror on the geometrical axis of the internal drum/trough. The laser beam is reflected into the axis of the drum and deflected by the rotating mirror onto the plate surface, which it scans in a circumferential direction. The optics with the rotating mirror move slowly in an axial direction. The rotating mirror rotates very fast: the number of rotations may be more than 40 000 rpm (revolutions per minute).

Some manufacturers who have decided in favor of the internal drum principle construct the trough with a granite base, so that it is as solid, geometrically stable, and vibration-proof as possible. The plate support is

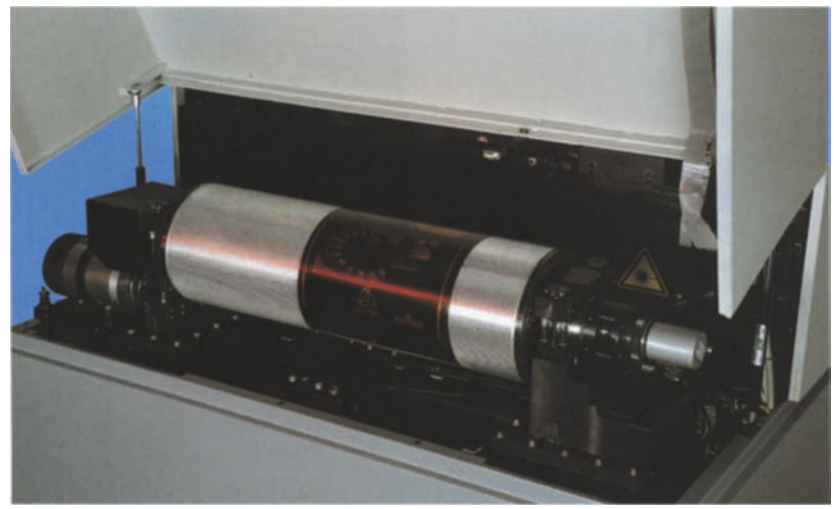


Fig. 4.3-4
External drum system for the digital imaging of flexographic printing plates (Flexo Lasersetter, Wetzel)

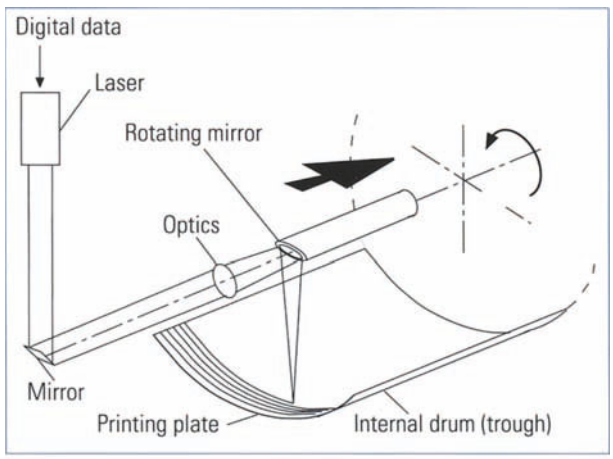


Fig. 4.3-5
Design principle of an internal drum plate imagesetter: The printing plate is held in a concave cylindrical support

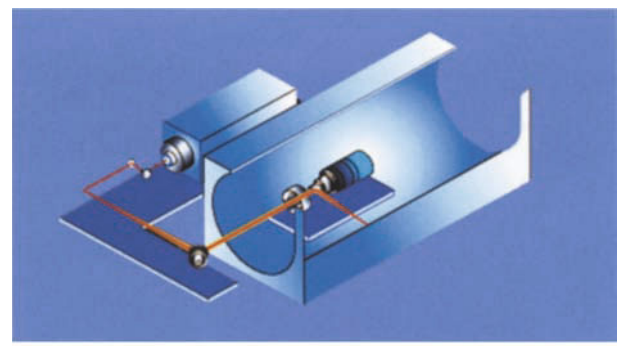


Fig. 4.3-6
Internal drum and beam path in a plate imagesetter (PlateRite PI-R2080, Dainippon Screen)

usually fixed in position. In one of the first computer to plate systems from Krause-Biagosch (former Hope) the entire trough with the printing plate was moved in a direction parallel to the axis, while the imaging optics was fixed in an axial direction. The Gerber company, now Barco, should be mentioned as a pioneer of internal drum technology.

It is more difficult to work with several beams in parallel using the internal drum method. But there are even solutions to this. In 1997 the CtP system "XPose!" was introduced by Lüscher. In this system there are sixty-four laser diodes in the rotating module. This array of diodes is close to the plate surface. Deflecting mirrors are not necessary. There is fast contactless image data transfer, the data being transferred to the rotating imaging head. (Other multibeam concepts are demonstrated by Fuji Film, ECRM, and Cymbolic Sciences).

Flat-Bed Design

In the flat-bed concept, the printing plate is held flat on a level base during the imaging process (fig. 4.3-7). In the simplest and most commonly used example of imaging technology, the laser beam is deflected line by line across the plate by a rotating polygon mirror with imaging and correction optics. Here, the problem arises

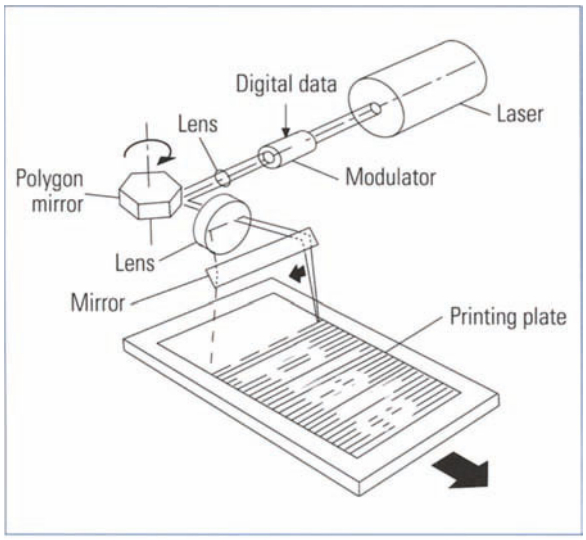


Fig. 4.3-7
Design principle of a flat-bed plate imagesetter: The printing plate is held on a flat table

that in spite of the complicated optics, the laser dot at the edges of the plate is of a different geometry than that in the center area of the plate (the projection is less sharp and round). Because of this optical distortion, which increases with the format, flat-bed imagers are more suitable for smaller formats and less stringent quality requirements (e.g., in newspaper printing). There are actually technical solutions for avoiding the imaging errors with the design methods used in fig. 4.3-7 (special optics, etc.), but they are not yet used in serial production devices and can only be implemented at greater expense. However, developments in this direction are in progress.

A great advantage of the flat-bed method is the very easy handling of the plate. High-quality devices that use the flat-bed method are therefore fitted with several special imaging heads working in parallel (e.g., "LithoSetter" from Barco) or they have an imaging head that moves across the plate in several consecutive strips ("Titan 582 Combination Platesetter" from ICG).

There is a relatively high number of flat-bed systems in the 50 cm × 70 cm format range and in newspaper printing. The ease of plate handling makes this method particularly favorable for newspapers, because a high throughput, and consequently a short production time, is particularly important here.

4.3.2.2 Imaging Methods and Plate Punching

Laser Imaging

Laser technology is used for imaging in most computer to plate systems. Outputs in excess of 1 watt per beam may be necessary, depending on the type of plate used and the design method applied. This relatively high power is needed, because the laser beam only has an affect on an individual dot on the plate for a few microseconds at a high imaging speed, and therefore has only a short time in which to produce the desired effects.

Gas lasers (argon-ion or helium-neon) are found in all design types (external and internal drum, flat-bed). *Solid-state lasers* of a smaller structure are being used increasingly instead of large gas lasers, especially those made from Neodymium (Nd): YAG (YAG yttrium aluminum garnet). The YAG crystal is doped with optically effective Nd atoms. Nd:YAG lasers emit radiation with a wavelength of 1064 nm. By doubling the frequency, this radiation can be transformed from the infrared range to the visible green range (532 nm), and by trebling the frequency it can even be transformed into the UV range. Because of this frequency doubling, the abbreviation FD-YAG is often used for the frequency-doubled Nd:YAG lasers. Nd:YAG lasers are currently the most commonly used solid-state lasers (not only in the printing industry). They offer good optical quality and can cover a power range from a few milliwatts to some 100 watts at an acceptable price/performance ratio [4.3-2].

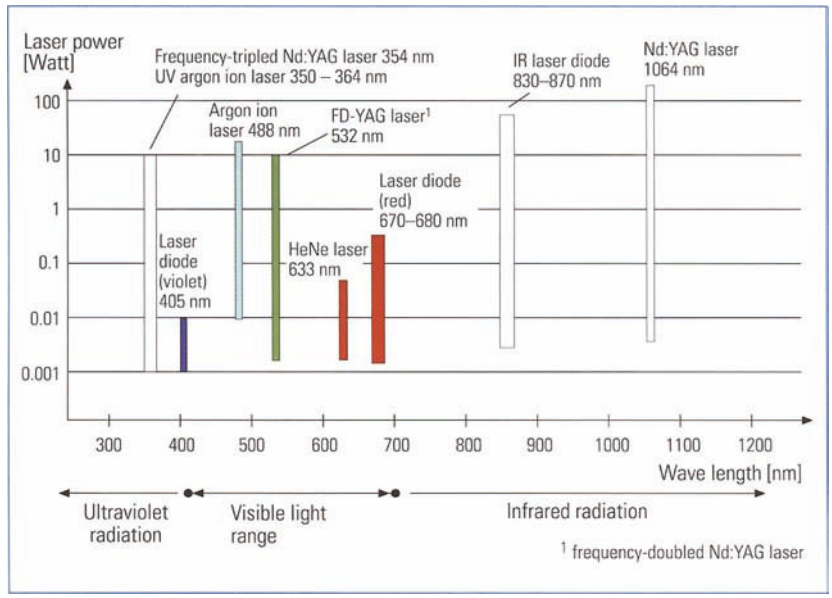
Laser diodes are more economically efficient than gas and solid-state lasers, and they also have a longer life cycle. Red light laser diodes are particularly economical and common (630 and 670 nm). They have a life cycle of two to four years. Thermal laser diodes (e.g., wavelength of 830 nm) can operate at considerably higher power, such as is needed for thermal-sensitive plates.

Figure 4.3-8 shows the major lasers for computer to plate technology with their power range and radiation wavelength. Printing plates suitable for digital imaging and laser imaging systems are not usually developed independently of one another, but as a system.

Imaging with UV Light

Digital imaging of conventional UV-sensitive plates is also possible. BasysPrint, for example, has developed the so-called "Digital Screen Imaging (DSI) process" for this purpose. The light originating from a strong

Fig. 4.3-8
Laser sources for use in computer to plate systems with their wavelengths and power ranges (approximate values)



UV lamp is, for example, directed onto a digitally controllable, two-dimensional light matrix, which consists of about 500 × 500 separate LCD elements (LCD Liquid Crystal Display–light valve matrix). They can be controlled individually, thus letting light pass through or blocking it out. As a result of this, a pixel-form image is produced from the light matrix, which is projected in the same way as with a projector, through the optics and onto the printing plate (fig. 4.3-9). An exposure operation always images only part of an entire plate, a square with side lengths of about 0.3 to 2.5 cm, depending on the resolution selected. An accurate drive system and a positioning mechanism make provision for the exact assembly of the partial images. They move the imaging head over the printing plate in stages. The plate imagesetter is designed on the basis of the flat-bed concept (fig. 4.3-10).

In 1997, the company Purup-Eskofot also introduced a plate imagesetter for UV-sensitive plates. The "Mografo" plate imagesetter can expose plates with a format of up to 1850 mm × 1300 mm and uses a UV argon-ion laser with a wavelength of 351 nm. Further systems will follow.

Ink Jet Imaging

Computer to plate systems using an ink jet technology for imaging were also introduced for the first time at DRUPA 95. In the ink jet process, a mask (the equivalent to a film) is applied to a pre-coated conventional plate. This is followed by exposure with flood-lighting and developing. An ink jet process, which works without developing, was introduced for the first time in 1997 by Iris/Scitex, as a device close to being ready for series production. In this process, a special aqueous ink is used to spray an image onto an uncoated, electrolitically grained, and anodized aluminum plate in an external drum device. After drying and thermal aftertreatment the image applied carries the printing ink as an oleophilic coating (see fig. 4.4-28). Table 4.3-2 gives an overview of systems based on ink jet technology.

Multipurpose Systems

Since about 1995 systems have also been available that can image the plate using both *digital data and film*. This involves a combination of a conventional step-and-repeat machine and digital technology (CtP). Both devices, the "Digital Page Stripper" of the American company Cortron and the "Laserstepper" of the Swedish company Misomex, are designed on the flat-bed principle (table 4.3-3). They have two different light sources/exposure systems, one for digitally controlled imaging and the other for the exposure of normal films by floodlight.

Numerous CtP systems can now be used for the digital imaging of *both plates and films*; the imaging system varies according to the method of exposure and the

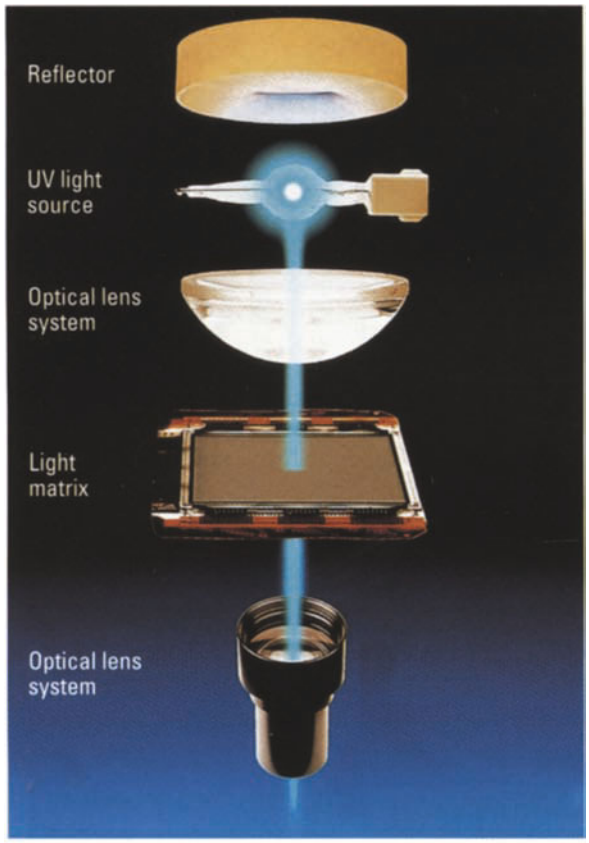


Fig. 4.3-9
Design of the "Digital Screen Imaging (DSI)" system for computer to plate systems for the exposure of conventional UV-sensitive printing plates (basysPrint)

material to be exposed, especially as regards exposure intensity and speed.

Punching

Distinction can be made, in principle, between two operating sequences for punching in CtP systems: on the one hand, the imaging of plates that have been pre-punched and fixed correspondingly in the system; and, on the other, the positioning of the plate with pins as aligning stops for imaging, the plate is punched until imaging has taken place. In the first case, *pre-punching* either occurs in a separate punch or is integrated into the CtP system. It is particularly easy to integrate plate punches into plate imagesetters of internal drum and flat-bed design. Some CtP systems are fitted with several punching tools, so that printing plates of different formats can be made for different printing presses. In some cases, punching tools also serve directly as register pins for the CtP system.

In systems *without pre-punching*, the plate is positioned in-register by means of pins. There are usually three pins, against which the plate is aligned on two sides and then fastened. In some CtP systems, the plate is automatically pressed against the pins with great precision during alignment by means of sliding bars. The contact between pins and plate is also monitored electronically to avoid incorrect positioning. If punching is not done within the CtP system, the plates are punched in a separate punch after imaging and developing, the punch preferably having the same system and the same arrangement of alignment pins as the CtP system.

Fig. 4.3-10
Computer to plate system (flat-bed design) for conventional UV-sensitive printing plates (UV Setter 710, basysPrint)



Model (design)	Company (or cooperation)	Plate size mm × mm (max. addressability)	Imaging time for maximum format	Plate processing
IJP-1000 (flat-bed)	Alpha Merics, Kodak Polychrome Graphics	1422 × 1422 (1200 dpi)	11 min/900 dpi (1220 mm × 1220 mm)	1. UV flood light 2. wet-chemical
Extrema (flat-bed)	Lastra (Italy)	1024 × 816 (914 dpi)		1. UV flood light 2. wet-chemical
Solid ink jet printer SJ02A (flat-bed)	Dataproducts (Hitachi Group)	670 × 560 (1200 dpi)	5 min (fast mode)	No development
Iris2PLATE (external drum)	Iris/Scitex	711 × 533 (600 dpi)	7 min/600 dpi	No development, ink-accepting areas for offset printing are created by ink jet ink sprayed onto aluminum

Table 4.3-2 Computer to plate systems using ink jet technology (Status: 1999)

Model (design)	Company	Plate size mm × mm, (max. addressability)	Market launch
Laserstepper (flat-bed)	Misomex (Sweden)	1700 × 1150 (2540 dpi)	1995
Digital PageStripper (flat-bed)	Cortron (USA)	1676 × 1100 (2540 dpi)	1995

Table 4.3-3
Computer to plate systems which can also image the plate via films (selection)

4.3.2.3 Computer to Plate Systems for Offset Printing

Printing Plate Format Categories

There are computer to plate systems for all format categories and ranges of applications in accordance with the customary formats of offset printing. The systems mainly to be used for commercial and book printing are given in table form here, classified by format category, together with their most important technical data. The selection does not claim to be comprehensive.

Table 4.3-4 gives an overview of the systems in the *small format range* (smaller than 70 cm × 100 cm or smaller than eight pages of A4). Some systems are marketed by other companies, sometimes even under other names, as OEM products (OEM Original Equipment Manufacturer). This is indicated in the second column under the term "cooperation." The great number of possible raster image processor (RIP) configurations on the one hand and automation systems on the other produces a great variety of system solutions.

Table 4.3-5 contains a corresponding overview of systems in the *larger format range* (70 cm × 100 cm or eight pages and larger). Figure 4.3-11 shows an example of a very large format system.

There are numerous systems available in *various stages of automation*, such as the "Trendsetter" system (fig. 4.3-3) outfitted for manual plate feeding, or for automatic plate feed via plate cassette (figs. 4.3-18 and 3.2-87, e.g.).

Computer to Plate for Newspaper Printing

Compared to commercial printers, quite different circumstances apply in the workflow for computer to plate systems in newspaper printers. Platemaking is not distributed more or less evenly over the whole day but that a large number of plates has to be made in the shortest possible time just before printing starts. The shorter the time needed for platemaking (and printing too, of course), the later the editorial deadline can be set, which in turn leads to the greater immediacy of the newspaper. On the other hand, high requirements for printing quality, such as exist in commercial printing, do not apply. This means that the plate imagesetters have to produce a lot of plates very quickly, but addressability need not be so high. These two basic conditions go well together and accommodate each other: Lower addressability, and so low dpi values, favors higher throughput because the imaging time is shorter.

Model (design)	Company (or cooperation)	Plate size mm × mm (max. addressability)	Imaging time for maximum format per plate	Laser	Market launch
Antares, PlateJet (internal drum)	Cymbolic Sciences, Agfa	940 × 660 (4000 dpi)	3.9 min/2000 dpi	Nd:YAG, FD-YAG	1995
FlateRite 1050 (flat-bed)	Dainippon Screen, Mitsubishi Paper	745 × 620 (3000 dpi)	44 s/1200 dpi	Laser diode 630 nm	1997
AIR 75, PI 3000CTP (internal drum)	ECRM, Fujifilm	749 × 616 (2540 dpi)	50 s/1270 dpi	Argon ion 5 beams	1998
Crescent 3030 (T) (internal drum)	Barco (Gerber)	762 × 762 (3810 dpi)	3 min/1270 dpi	Laser diode 670 nm (Nd:YAG)	1996
Trendsetter 3230 (external drum)	Heidelberg/Creo	813 × 762 (3200 dpi)	2 min/1200 dpi	Thermal laser diode 240 beams (830 nm)	1997
Platinum 2230 (flat-bed)	HighWater Designs	813 × 660 (2540 dpi)	1.6 min/1270 dpi	FD-YAG 532 nm	1996
Aurora Electra (external drum)	Optronics	900 × 745 (4000 dpi)	1.5 min/1000 dpi	Argon ion, Nd:YAG	1998
Pearlsetter 74, 52 (external drum)	Presstek, Shinohara	749 × 616 (2540 dpi)	7.4 min/1270 dpi	32 thermal laser diodes	1995
Futuro (internal drum)	Scangraphic	770 × 650 (3810 dpi)	7 min/1270 dpi	Nd:YAG 1064 nm	1997
Topsetter 74	Heidelberg	830 × 645 (4000 dpi)	3.75 min/2400 dpi	32 thermal laser diodes (830 nm)	2000

Table 4.3-4
Computer to plate systems in the smaller format range (smaller than 70 cm × 100 cm or smaller than 8 pages; selection, status: 1999)

European newspaper printers that installed a CtP system before 1998 produce an average of two hundred plates a day [4.3-3]. This mostly involves newspapers with fairly small and medium-sized circulation, which often use only one or two web presses per circulation and therefore have less need for multiple plates per page. Large newspaper operations, which frequently require multiple plates per page for several web presses, must invest in several plate imagers.

On top of this there are the extremely varied circumstances and conditions in the newspaper printing industry world-wide. There are great differences in this sector between North America and Europe; only about a quarter of the large North American newspapers produce their pages in full-page make-up [4.3-4]. In Japan double-length plates (in print direction) are predominantly used in newspaper printing because printing is always done in double production (see fig. 8.1-4) there. Therefore this market requires special, large-format CtP systems adapted to these conditions, though by the end of 1997 there were only two Beta test installations in the Japanese newspaper sector [4.3-4].

Computer to plate systems designed for newspaper printing can be found in table 4.3-6. Many of these systems are available with highly-automated plate feed systems and, of course, with online developing units. Automation increases system throughput, but this also raises the system price. Many CtP systems for newspapers are designed on the flat-bed principle because plate handling is relatively simple on that basis and can be done quickly. Some systems have also been designed so that two suitably small plates are imaged simultaneously alongside each other. All systems designed for newspapers use laser sources with beams in the visible range, and therefore no thermal technology. The reason is that at present thermal-sensitive plates require

Model (design)	**Company** (or cooperation)	**Plate size** mm × mm, (max. addressability)	**Imaging time** for max. format at ~ 1200 dpi	**Laser**	**Market launch**
Galileo (internal drum)	Agfa	1130 × 820 (3600 dpi)	2 min/1200 dpi	Nd:YAG (1064nm), FD-YAG (532nm)	1997
LithoSetter III, V (flat-bed)	Barco Graphics	2 formats III:1100 × 810 V: 1650 × 350 (4000 dpi)	1.7 min/1270 dpi (1100 × 810)	FD-YAG 3 resp. 5 heads	1996
Crescent/42 (HS) (T) (internal drum)	Barco Graphics (Gerber)	1067 × 813	3 min/1270 dpi (3600 dpi)	Argon ion	1992 (T: Nd:YAG)
Crescent 68 (T) (internal drum)	Barco Graphics (Gerber)	1727 ×1320	3 min/1270 dpi (3600 dpi)	Laser diode (630 nm)	1997 (oder T: Nd:YAG)
Trendsetter 3244T (external drum)	Heidelberg/Creo	several formats starting from 1117 × 813 (3200 dpi)	2 min/1200 dpi (1117 × 813)	thermal laser diode 240 beams	1995
Platesetter 3244 (external drum)	Heidelberg/Creo	1117 × 813 (3200 dpi)	2 min/1200 dpi	FD-YAG 480 beams or thermal laser diode 240 beams	1994
PlateJet8, Antares 1600 (internal drum)	Cymbolic Sciences, Agfa	1100 × 910 (4000 dpi)	4.8 min/2000 dpi	FD-YAG, Nd:YAG	1997
PlateRite 2080 (internal drum)	Dainippon Screen, Mitsubishi Paper Mills	1068 × 820 (4000 dpi)	2.7 min/2000 dpi	Argon ion 488 nm	1997
PlateRite PTR 8000 (external drum)	Dainippon Screen	1160 × 940 (4000 dpi)	5 min/2400 dpi	32 thermal laser diodes	1998
Celix 8000 CTP (internal drum)	Fujifilm	1045 × 900 (3658 dpi)	4 min/1219 dpi	Argon ion 488 nm	1995
Titan 582 (flat-bed)	ICG	1120 × 840 (3396 dpi)	4 min/1270 dpi	FD-YAG	1997
LaserStar 110 C, 140 C, 170 C (internal drum)	Krause Biagosch	3 formats LS 110C 1050 × 850 (2540 dpi)	1.5 min/1270 dpi	Nd:YAG or FD-YAG	1995
XPose! 120, 160 (internal drum)	Lüscher	120: 1100×900 (2540 dpi)	5 min/2540 dpi	64 thermal laser diodes	1997
OmniSetter 4000 (external drum)	Misomex, Kaber	1219 × 914 (2540 dpi)	varying according to medium	thermal laser diodes 20 beams	1997
Aurora (semiautom.) Eos (automatic) (external drum)	Optronics	1130 × 900 (4000 dpi)	1.5 min/1000 dpi	Argon ion or Nd:YAG 16 beams	1995

Table 4.3-5 Computer to plate systems in the larger format range (70 cm x 100 cm or 8 pages and larger; selection, status: 1999)
(continuation on next page)

Model (design)	Company (or cooperation)	Plate size mm × mm, (max. addressability)	Imaging time for max. format at ~ 1200 dpi	Laser	Market launch
Merlin (internal drum)	Purup-Eskofot	1080 × 820 (3175 dpi)	2.3 min/1270 dpi	Argon ion 488 nm	1997
Lotem 800 V (external druml)	Scitex	1130 × 900 (3556 dpi)	4 min/2540 dpi	24 thermal laser diodes	1998
UVSetter 710 (flat-bed)	basysPrint	1120 × 820 (1800 dpi)	1 head: 8 min/1270 dpi	1 or 2 heads with UV lamps	1996
Topsetter 102	Heidelberg	1160 × 940 (4000 dpi)	5 min/2400 dpi	32 thermal laser diodes (830 nm)	2000

Table 4.3-5 (Continued)
Computer to plate systems in the larger format range (70 cm x 100 cm or 8 pages and larger; selection, status: 1999)



Fig. 4.3-11
Computer to plate system (internal drum design) for large formats
(Laser Star LS 170 C, Krause-Biagosch)

more energy and therefore cannot be imaged as quickly as CtP plates that are sensitive in the visible range.

Computer to Plate for Small Format Offset Printing

Computer to plate solutions are available for small format, above all single-color offset printing (typically: approximately A3 format) that do justice to the limited investment potential of this predominantly small and medium-sized sector.

The most cost-effective solution here lies in *using electrophotographic printers*, in which *special polyester or paper-based printing plates* are imaged. The distinctive feature of electrophotographic printers specially designed for imaging printing plates compared to normal electrophotographic printers is the modified fixing unit. Toner must be particularly firmly anchored on the base material and this is achieved with a higher fixing temperature, and without fixing rollers wetted with silicone oil. With respect to tone values some of these electrophotographic printers can be calibrated in the same way as film imagesetters.

Whereas polyester plates to be imaged in electrophotographic printers with toner are mainly suitable for single-color printed products or, at best, for spot colors

Model (design)	Company (or cooperation)	Plate size mm × mm, (max. addressability)	max. throughput (plates/hour)	Laser	Market launch
Ozasol LE 100 (in USA: "Polaris 100") (flat-bed)	Agfa, Strobbe	900 × 650 (2400 dpi)	128	FD-YAG 532 nm	1996
NewsJet, Antares (flat-bed)	Cymbolic Sciences, Agfa	940 × 690 (2000 dpi)	60	FD-YAG 532 nm	1995
APS 3850 CtP (flat-bed)	Autologic	660 × 474 (2540 dpi)	100	Argon ion or red laser diode 670nm	1998
EG-2300 (flat-bed)	Escher-Grad (Polychrome)	736 × 585 (2400 dpi)	41	Argon ion 488 nm	1995
MagnaSetter 650 CTP (flat-bed)	Fujifilm	635 × 457 (1828 dpi)	40	Argon ion 488 nm	1993
PI 3000 CTP, AIR 75 (internal drum)	Fujifilm, ECRM	749 × 616 (1540 dpi)	74	Argon ion 5 beams	1997
Digital Plate Maker (flat-bed)	Kodak-Polychrome, Versitec	640 × 500 (2304 dpi)	60	red laser diode 670nm 256 beams	1995
LaserStar/N (internal drum)	Krause Biagosch	1030 × 800 (2540 dpi)	50	FD-YAG 532 nm	1995
LaserExpress CTP (flat-bed)	K&F Manufacturing	2 × 650 × 400 (1270 dpi)	> 100	FD-YAG 532 nm	1998
Panther FasTRAK (flat-bed)	Prepress Solutions	914 × 610 (2540 dpi)	42	Argon ion 488 nm	1996
DMX 2737 (internal drum)	Purup-Eskofot	940 × 690 (2032 dpi)	120	FD-YAG 532 nm	1997
DiamondSetter (flat-bed)	Western Lithotech, Mitsubishi	2 × 610 × 355 (2540 dpi)	> 100	FD-YAG 532 nm	1996

Table 4.3-6 Computer to plate systems for newspaper printing (selection, status: 1999)

and for short print runs, higher printing quality can be achieved using *polyester plates* that have a light-sensitive coating on a silver base. These plates can be imaged with *film imagesetters*. With polyester-based plates, exposure primarily takes place as the material is unrolled and in most cases the imaged plate material is transferred directly to the chemical developing unit. Some plate imagesetters that have been specially developed for imaging polyester plates in a film imagesetter can be found in table 4.3-7.

A device that operates on the *Capstan principle* (see fig. 3.1-4) is shown in figure 4.3-12. Figure 4.3-13 shows a device in this small-format range especially designed for aluminum plates. The device originally developed by the German company Opto-Tech is now available in partially modified form from several suppliers. At the end of 1998 Toray Industries announced an external drum device for two-page format, especially for waterless offset plates with thermal laser imaging. The introduction of other products in this field can be expected.

4.3.3 Computer to Plate for Flexographic Printing

As explained in detail in sections 1.3.2.1 and 2.3.3, flexography is a letterpress printing technology, in which a flexible (soft) printing plate is pressed against a hard impression cylinder. Three different imaging systems

Model (design)	Company	Plate material	Plate size mm × mm, (max. addressability)	Remarks
Various electrophotographic printers	HP, Lasermaster, Printec, Xanté...	Polyester, paper	up to 635 306 (1200 dpi)	Powder toner
Propis (external drum)	Digital Graphics	ZnO paper	520 × 457 (2304 × 1152 dpi)	Liquid toner
Digital Platemaster 2000	ABDick	Polyester (silver diffusion), paper	551 × 419 (1200 dpi)	Digital imaging: red laser diode 670 nm; also for reflection originals
Quicksetter (Capstan)	Heidelberg	Polyester (silver diffusion)	406 mm wide (3386 dpi)	Imaging: red laser diode 670 nm
Silver Digiplater (internal drum)	Mitsubishi Paper Mills	Polyester (silver diffusion)	660 × 550 (4064 dpi)	Imaging: red LED multi-beam line
DPX (internal drum)	Purup-Eskofot	Polyester (silver diffusion)	550 × 420 (2540 dpi)	Imaging: red laser diode 670 nm
CTP 0520 (external drum)	Sack, Opto-Trade, Litronic	Aluminum (e.g., photopolymer)	525 × 459 (2032 dpi)	HeNe laser 543 nm (green)
Platinum 2218 (flat-bed)	HighWater Designs	Aluminum (e.g., silver diffusion)	558 × 460 (2540 dpi)	Laser diode 400 nm (violet)

Table 4.3-7 Computer to plate systems for small format offset printing (max. format A3+; selection, status: 1999)

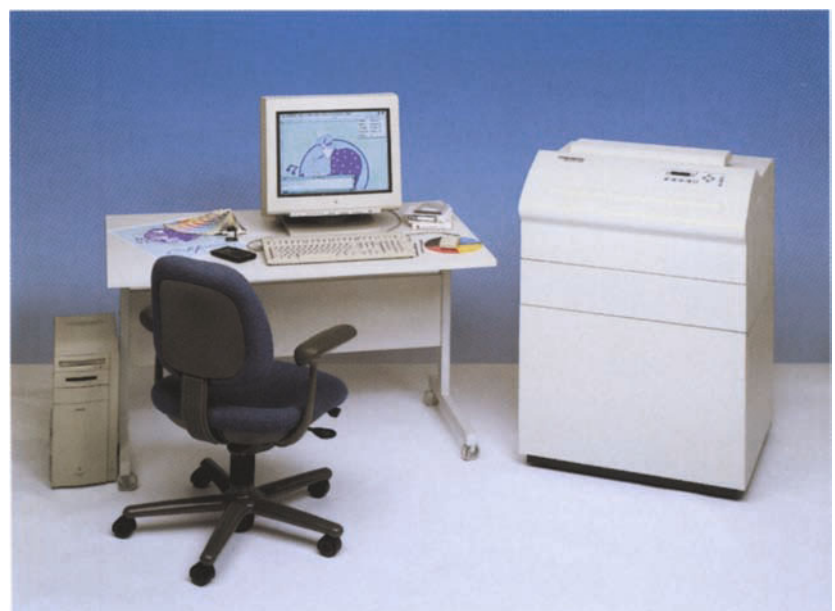


Fig. 4.3-12
Computer to plate system (Capstan principle; see also fig. 3.1-4) for polyester printing plates (Quicksetter, Heidelberg)



Fig. 4.3-13
Computer to plate system for aluminum printing plates for small formats up to 459 mm × 525 mm, external drum design (CTP 0520, Sack)

are available for computer to plate in flexographic printing:

- laser imaging of the mask (high quality),
- laser engraving/ablation (up to approximately 600 dpi, mostly used for rubber plates),
- direct imaging with very high energy UV light (quality suitable for newspaper printing).

The first computer to plate systems for flexographic photopolymer plates were shown at DRUPA 95. They work on the external drum imagesetter principle and a Nd: YAG laser is used for *imaging the mask*. The plate is held on the drum by vacuum. The Barco company's "Cyrel Digital Imager" system may be taken as an example (fig. 4.3-14). This system is suitable for DuPont Cyrel plates with a format of up to 1067 mm × 1524 mm. In full format with 48 lines/cm screen, imaging takes approximately 35 minutes. Addressability is a maximum of 4000 dpi.

Low laser power suffices to image the laser-sensitive black coating on the photopolymer plate. The black coating is vaporized in areas corresponding to the image, consequently serving as a film for the subsequent UV exposure (details of the composition and function of these plates are given in sec. 4.3.9, see fig. 4.3-30). After imaging, these plates undergo conventional exposure on the reverse and image side (main exposure) with UV light and are then developed or further

Fig. 4.3-14
Computer to plate system for flexographic printing plates up to a format of 1067 mm x 1524 mm (Cyrel Digital Imager, Barco/DuPont)



processed. In 1997 a computer to plate system suitable for both flexographic and some thermal-sensitive offset plates was introduced for the first time by Misomex, the "Omnisetter." A light source consisting of twenty thermal laser diodes (wavelength 830 nm) is used as the imaging system here.

In flexographic computer to plate systems for producing relatively soft rubber printing plates, the recessed, ink-free parts of the printing plate are removed directly by laser energy (*laser engraving*). The ablated particles are removed by suction. High-power lasers (such as 1–2.5 kW CO_2 lasers) are used for this activity. The laser engraving of gummed rollers for continuous printing has been possible since the seventies. With the maturing of computer technology, computer to plate became available as early as the end of the eighties.

UV direct imaging is available as the "UV Laser Platesetter" from Napp Systems. By means of high-power UV laser light the polymerisation needed for producing the flexographic plate is carried out directly pixel by pixel.

4.3.4 Computer to Cylinder for Gravure Printing

Direct digital control of mechanically *stylus engraving devices* has been possible since about 1985 in gravure cylinder production. This means that the data comes directly from the computer and not from a scanned analog copy (bromide), (see fig. 1.3-14). Thus computer to cylinder technology is far more widespread in gravure printing than computer to plate technology in offset printing. Figure 4.3-15 shows a digital engraving machine for rotogravure printing.

Electrons or laser beams have been tested in conjunction with various base materials for *direct engraving* by applying heat energy to the base material. Electron beam engraving has worked very efficiently. However, it is too expensive as a result of the costly vacuum technology. Thus, for economic reasons, no system has yet been marketed. A fully automated gravure system using laser beams, the "Laserstar" from Max Dätwyler, was presented at DRUPA 95. In this, however, the cylinders have to be coated with zinc (instead of copper) because of its better absorption capacity, particularly at 1064 nm (Nd:YAG). This entails high expenditure on conversion of the other cylinder preparation processes (see sec. 2.2.1.1).

4.3.5 Computer to Screen for Screen Printing

A detailed description of screen printing is given in sections 1.3.2.4 and 2.4.1. Computer to screen is the digital production of image carriers for screen printing in which the print image data, controlled directly via the computer, are output onto the stencil or screen [4.3-5]. Most computer to screen systems work using the ink jet technology, in which either heated wax or ink is applied to the screen.



Fig. 4.3-15
Computer to cylinder for gravure cylinder stylus engraving (HelioKlischograph K406, HELL Gravure Systems)

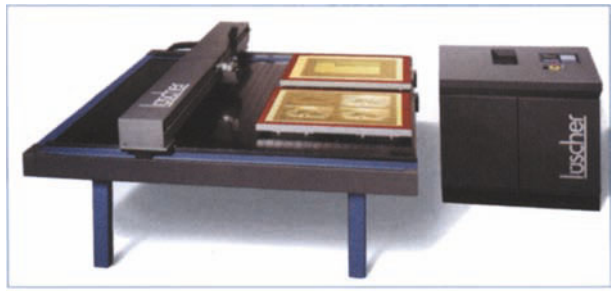


Fig. 4.3-16
Computer to screen system for imaging with ink jet (mini-JetScreen, Lüscher)

First the screen must be lined with a closed layer/emulsion (stencil material). The print image is applied to this coating using ink jet ink (as a film substitute). This is then followed by the usual exposure to cure the stencil material. The uncured ink-covered areas of the coating are then washed off with water. After drying, the stencil/screen plate is ready for printing. Addressability is about 600 dpi (systems with 1000 dpi are being developed). In large format applications (e.g., 2 m × 3 m, which is now about the maximum format for computer to screen) a resolution of 150 dpi usually suffices, with screen ruling of 18 to 20 lines per cm becoming possible. An example of an ink jet-based computer to screen system is shown in figure 4.3-16.

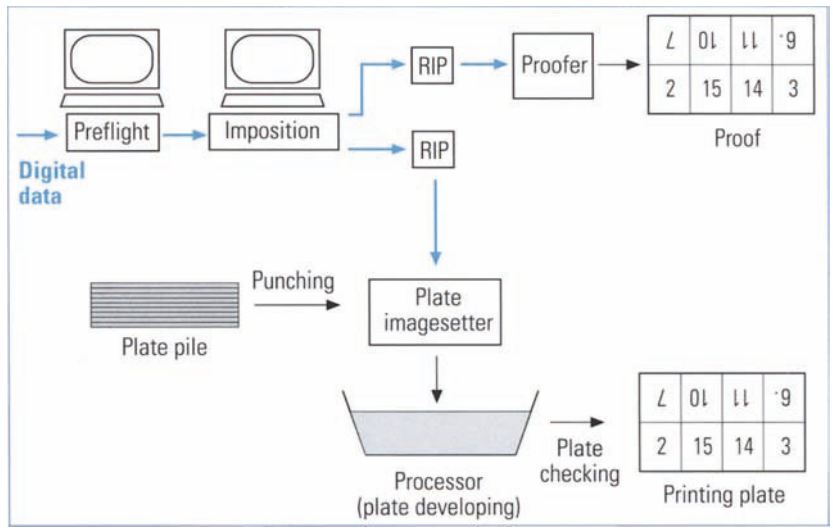
The shortest stencil production method is the direct exposure of the emulsion-coated screen by laser beam. The laser beam destroys the emulsion in the image area. The emulsion is cured on the non-printing areas (UV light). This method is only suitable for metal mesh and not for the customary polyester mesh. It is only used in exceptional cases, mainly in textile and tile printing.

4.3.6 Computer to Plate Workflow

The digitization of the workflow entailed by the introduction of computer to plate necessitates adaptation and possibly a complete conversion of previous workflows. These changes present both a technical and an organizational challenge (see also [4.3-6]). The required employee qualification profile changes considerably: The computer to plate system operator must have understanding and experience of computer processing. Literature is available (e.g., [4.3-7]) with "Instructions on Courses of Action" for the selection of technology, the training of employees and the organizational structuring in which the latter occupies the most space. In fact the reorganization of work content, interfaces, and responsibilities must not be underestimated. The successful conversion of a company from a conventional to a digital workflow is a process that may quite possibly take some years.

The most common *workflow* is shown in figure 4.3-17. This assumes that there is a printshop that receives digitally printing data from outside and first of all checks

Fig. 4.3-17
Workflow with computer to plate



it for completeness, correctness, and printability in the so-called "*preflight check*." After imposition, the entire sheet, now available as a PostScript data file for example, is usually sent to the raster image processor (RIP) for transforming into the bitmaps to be used.

There are very varied *data processing concepts* (see also secs. 3.2.5 and 3.2.6). For example, in some configurations, imposition is not done until after the raster image processor (RIP), and hence on the basis of bitmap pages.

There are also various solutions for transferring bitmap data from the RIP to the plate imagesetter. In many CtP systems the imaging unit is directly connected to the RIP. There is no intermediate storage for the bitmaps, but the data is transferred directly "on the fly" from the raster image processor (RIP) to the imaging head. In other configurations the imaging data (bitmaps) generated in the RIP is first stored on hard disk in a buffer memory.

In figure 4.3-17 the digital data flow is indicated by blue arrows, while black arrows are used to indicate the route that the plate takes.

Not to be ignored is the *quality control* of the finished plate, irrespective of whether this is done automatically or visually by an employee. For example, the Krause company supplies a so-called "Plate-checker," a camera system that simulates the expected print image of the four plates on the monitor and makes possible inspection by the operator.

There are devices for *plate handling* with varying degrees of automation, such as those in which the plates have to be inserted in the safelight and removed from the plate imagesetter individually, and at the other extreme those that grip the individual printing plate from the light-proof magazine automatically, remove the separating paper, and, after exposure, pass the plate *inline* to plate developing. Many devices with "*autoloading*" operate from several cassettes, in which various plate formats, models (e.g., aluminum plates and polyester printing plates) or films can be loaded. The "Platesetter 3244" system, for example, (fig. 4.3-18), can be loaded with aluminum plates in one cassette and with polyester printing plates in the other. After leaving the

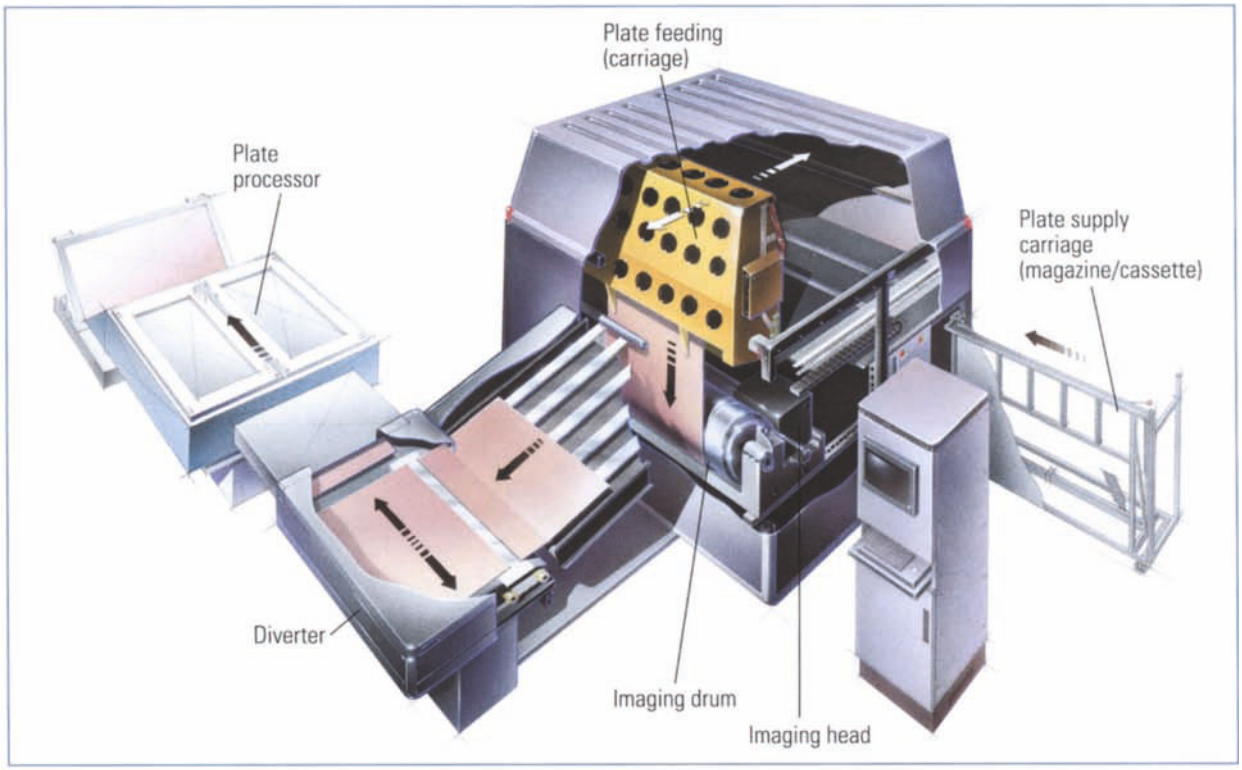


Fig. 4.3-18 Diagram of a fully automated computer to plate system (Platesetter 3244, Heidelberg/Creo)

platesetter, a diverter routes the plates into the corresponding plate processor (plate development).

4.3.7 Rise in Quality as a Result of Computer to Plate

In principle, computer to plate offers potential for substantial improvement in print quality. The print image quality attainable with computer to plate is affected by all components of the entire production line. Users agree unanimously that the plate imagesetter, the central unit in the production line, is the most stable and reliable component with regard to print quality. The halftone screen and the quality of the raster image processor (RIP) are the rather more decisive factors for printing quality in prepress. Chemical plate developing after imaging represents another operation that brings a certain measure of uncertainty to the process. There are numerous parameters, like the chemical composition of the baths, their cleanliness and temperature in particular, that have to be kept constant within narrow limits for a reproducible result to be achieved.

Essentially, computer to plate supplies plates that are very good in terms of accuracy of register and in all cases better than plates exposed from fully imposed films (computer to film), because film material is not as dimensionally stable as aluminum. If aluminum plates are used in conjunction with automatic plate clamping devices in the printing press, register control is scarcely necessary. Moreover, in computer to plate, the plate exposure operation with its possibilities of error (e.g., undercutting) is completely unnecessary. However, dust on the plate cannot be ruled out in computer to plate and can prove to be a reason for waste sheets.

Quality assurance and control of the finished plate is necessary even with computer to plate. The occasional exposure errors originating from software and hardware defects must be detected: partially mixed-up color separation, sometimes missing images or areas of text, incorrect photographs, and so on. Such errors can often be neither explained nor reproduced. Experience shows that their frequency is between 1 and 5%. Careful inspection of the plates by means of imposition sheets or *digital proofs* is important, so that these errors are detected before printing. The calibration of the production line must also be monitored, particularly the plate imagesetter, using an imaged control wedge.

One example here is the *digital plate control wedge* shown in figure 4.3-19 [4.3-8]. It has several control patches with various functions, which make possible visual inspection of the plate with the naked eye or using a densitometer and/or a magnifying glass. If a control wedge is used, it is inserted in the document to be output and sent to the output system together with the page and sheet parameters. It can be used to find the causes of loss of quality in the output due to changed parameters. The densitometer measurement on the printing plate supplies relative measured values that are suitable for day-to-day production control.

Stable plate developing is only possible within a narrow tolerance field of temperature and chemical composition of the developing bath. Deviations from the desired values detract from plate quality, for instance, by the individual halftone dots becoming sharper or gaining dot size. With *polyester-based printing plates* (see sec. 4.3.9) there are limitations on the quality of register accuracy. The poor stiffness of the material, especially in larger formats, has a somewhat negative effect here.

Print quality can likewise be substantially increased in *flexographic printing* (see sec. 2.3.3) by means of computer to plate systems, because the raised image has a

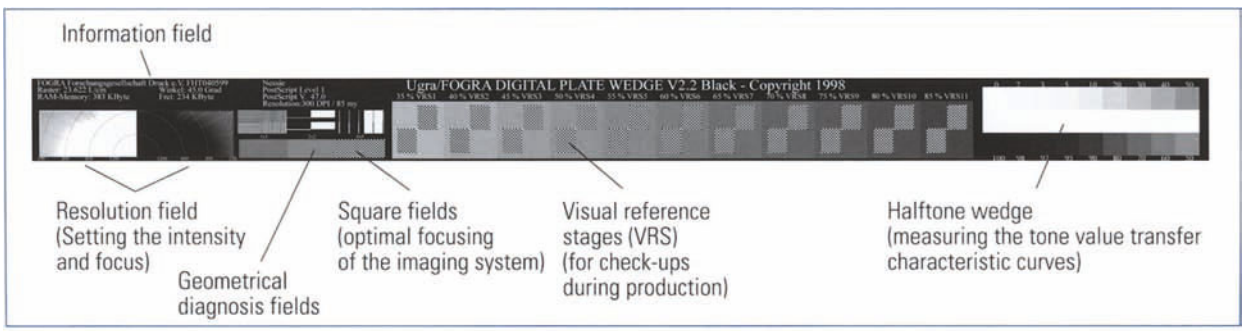


Fig. 4.3-19 Digital plate control wedge (Ugra/FOGRA)

stiffer basic structure (see figs. 2.3-8 and 4.3-29). As a result of this, the much greater dot gain that is specific to flexographic printing can be markedly reduced using CtP. Moreover, the print results distinguish themselves by better differentiation and smoother tonal gradations. The screen frequency can be increased to 60 lines/cm (a resolution of 1200 dpi is possible) and more. The simultaneous use of thin-plate technology and UV inks can contribute to a further increase in quality.

4.3.8 Productivity and Economic Efficiency

Automation and the associated chances of reducing time and cost constitute a central aspect in favor of the introduction of computer to plate technology [4.3-9]. The effects in the printing room are a fundamental factor in this. The printing press makeready times can be greatly reduced with the introduction of CtP.

The greatest time-saving potential with computer to plate lies in prepress, that is to say in digital imposition. The potentially very time-consuming assembly of the films for imaging the printing plates is no longer necessary (see sec. 3.2.5). Users of computer to plate systems report that up to three times more plate output can be achieved than with conventional assembly and platemaking.

Productivity, that is, the number of printing plates produced per unit of time, is determined by the entire processing time and by whether the individual processes occur simultaneously or overlap, for example, developing of the first plate in the processor and simultaneous imaging of the next plate in the imaging unit.

The exposure and imaging time within the computer to plate system is a central factor in productivity. Imaging time increases with addressability and/or resolution. The shortest imaging times for a 70 cm × 100 cm plate at 1200 dpi are less than two minutes.

The duration of the entire platemaking cycle is also an important parameter for estimating how quickly a replacement plate can be made up for a plate that has been damaged in the printing press. All stages of work must be taken into account, from removal of the plate from the cassette (taking off the intermediate layer of paper, if necessary) through mounting the plate in the imaging unit, to transportation to the plate processor (after imaging) and chemical developing.

Some computer to plate systems may be so *highly automated*, that with an adequate supply of data and plates they can operate throughout a shift with no operator. In some high-output installations, the computer to plate system is run for two shifts with staff and for the third shift without staff. An example of such a highly automated system is shown in figure 4.3-18.

Commercial and book printing on the one hand and newspaper printing on the other put quite different requirements on platemaking productivity. In newspaper printing a large number of plates have to be made within a few hours. The quality requirements are lower than in commercial printing. Newspaper printing plates are imaged with lower addressability, usually in a range between 800 and 1400 dpi. This leads to relatively short imaging time. Some CtP systems achieve productivity of more than 100 plates an hour (see table 4.3-6). In the commercial sector an even workload throughout the day or a shift is more likely. In this case, the usual figure for plates is at least 10 per hour. Some systems even achieve a throughput of 20 to 30 plates an hour. In practice about 200 plates a day are currently being made on plate imagesetters in the format of 70 × 100 cm² (in two or three-shift operation).

To increase productivity there are even designs for combining several plate imagesetters. For example, at DRUPA 95 Presstek displayed a *duplex CtP system*, in which the two imaging drums are arranged alongside each other, controlled by a common computer, the raster image processor (RIP), and the server, but can be imaged independently of each other (fig. 4.3-20).



Fig. 4.3-20
Computer to plate system with two imaging units, external drum design (Pearlsetter Plus, Presstek)

In both prepress and press makeready time, computer to plate generates higher productivity, combined with a great saving on cost. The shorter production time, the accuracy in register of printing plates, and the automatic ink key presetting come into their own, especially if digital prepress data are used for the ink key presetting. The CIP3 Consortium has agreed on a data exchange format for transfer of data from prepress to the press control system (see sec. 8.2.3; also figs. 4.1-11 and 4.1-12).

Since the trend in the printing industry is towards ever shorter run lengths, the advantages mentioned favor the development potential of this technology and therefore lead to the assumption that there will be even wider use of CtP in the future.

4.3.9 Printing Plates for Digital Imaging

Special plates have had to be developed to use computer to plate for *offset* and *flexographic* printing; they are described in the following sections.

For *gravure* cylinders, on the other hand, there have been no changes to the printing plate, as long as engraving is done mechanically with digitally controlled styluses. However, laser engraving requires a material that can absorb the laser beam's energy well. For this application zinc is used instead of copper (sec. 4.3.4).

The usual polyester mesh can in most cases be used for stencils for *screen printing*, and only the coating material had to be adapted to the requirements of an image application using ink jet or laser imaging. New inks and waxes have been specially developed for this.

Electrophotographic CtP Plates

Electrophotography (see sec. 5.2) is used for the production of offset printing plates with organic photoconductor coating. OPC is the oldest technology in CtP development. Back in the 1980s this technology was also beginning to be used digitally through laser imaging. The plates for the newspaper sector were produced by the company Polychrome. However, the technology did not gain general acceptance.

Aluminum-based Printing Plates

After DRUPA 90 there were initially only two plates on the market suitable for digital imaging for offset printing: the "Ozasol N 90" from Hoechst Kalle (now Agfa) with a photopolymer image layer and the "Silverlith" from DuPont with a silver halide image layer. Figure 4.3-21 shows the imaging and developing of *photopolymer plates*. Exposure in accordance with the image, causing a cross-linking of the photopolymer (polymerization), occurs in the areas that are ink-receptive later in printing, because the cross-linked polymer is ink-accepting (oleophilic). This type of plate has been called negative working, by analogy with plate exposure using negative film, in which the areas of the plate that are later ink-receptive are also exposed. The letter N in "N90" is also derived from this.

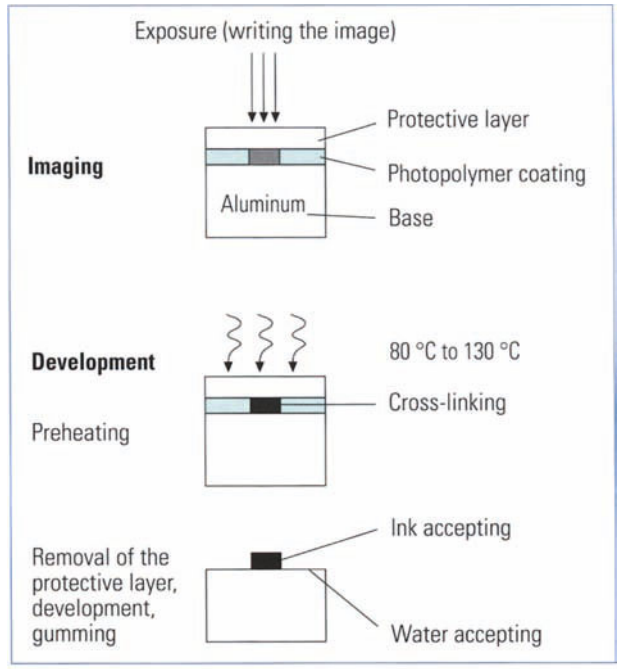


Fig. 4.3-21
The imaging and developing of printing plates by photopolymerization (imaging results in ink-accepting areas; negative-working plate)

Figure 4.3-22 shows the imaging and developing of aluminum plates with *silver halide coating*. Silver-halide-coated printing plates have a considerably higher sensitivity to light than photopolymer-coated plates. Both types of plates are also available from other suppliers by now. Because of their high sensitivity to light, silver halide plates such as "Lithostar" (Agfa) can also be exposed via films in a copy frame. Unlike the imaging described earlier, non-image areas (hydrophilic) are exposed (as in fig. 4.3-22); by analogy with platemaking via film it is now a matter of "positive-working plate."

As a development of the conventional offset printing plate, a third type of plate was introduced by Polychrome

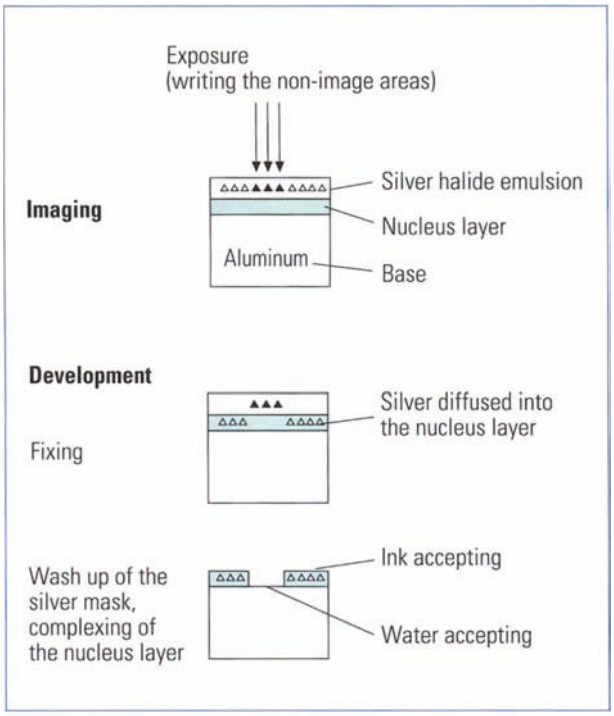


Fig. 4.3-22
The imaging and developing of printing plates (aluminum-based) by diffusion transfer (imaging results in ink-repelling areas; positive-working plate)

in 1993–the CTX *sandwich plate*. It can be exposed directly with CtP systems. In principle this new type of plate consists of two coatings on the aluminum base material, namely a silver halide coating with a conventional diazo coating beneath it (silver hybrid, fig. 4.3-23). The silver halide coating is exposed in the areas that are later ink-accepting and is then used virtually as a mask (with positive image) or film for subsequent conventional floodlighting with UV light of the diazo layer underneath.

Table 4.3-8 gives a selection of available plates. Table 4.3-9 shows the advantages and disadvantages of the plate technologies described in an overview, and also compared to the second generation of CtP plates, the thermal-sensitive plates described below.

Thermal-sensitive Aluminum Plates

Thermal-sensitive plates were first introduced at DRUPA 95. They react not to visible light but to thermal radiation. They have a distinctive threshold characteristic during imaging: as soon as the thermal energy goes over a certain threshold during imaging, the surface changes completely, and any further increase in energy remains of insignificant effect with regard to dot quality. The danger of under or overexposure does not exist.

The beam profile of the light source (laser) is also important in connection with thermal plates. In addition to "Gaussian intensity profiles," as being typical for

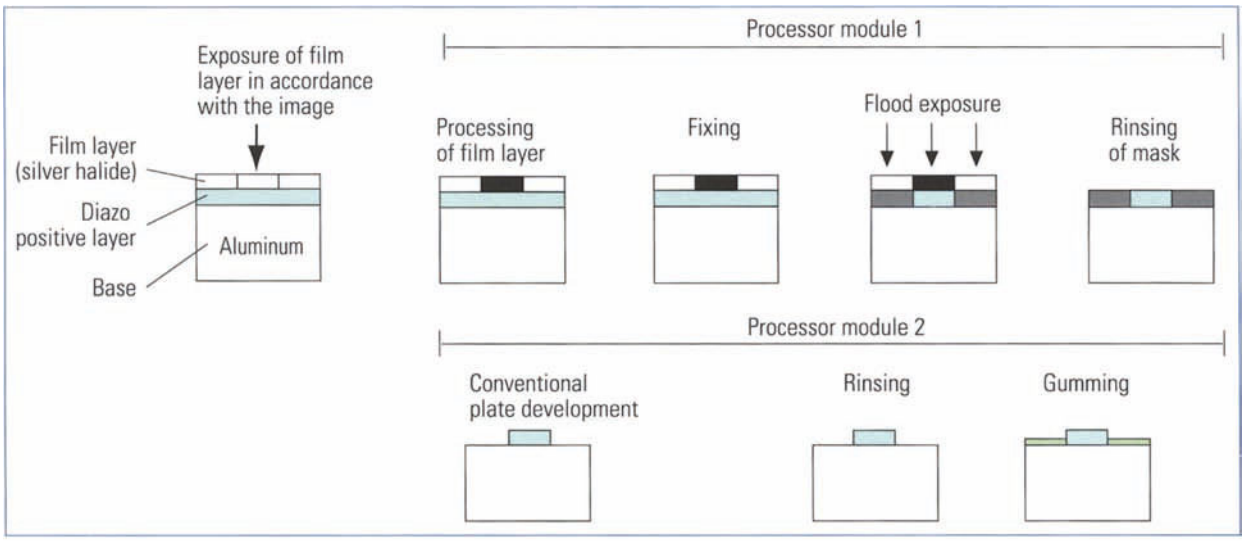


Fig. 4.3-23 The imaging and developing of multi-layer printing plates (sandwich plates), for example, Polychrome CTX plates

many lasers there are also intensity profiles with steeper edges (e.g., imaging via light valves as, for example, implemented in the Heidelberg/Creo "Trendsetter" and elsewhere). Steeper edges produce a dot size with less fluctuation, which can occur as a function of the plate material (sensitivity, i.e., the threshold level) and light source (fluctuation in intensity). Figure 4.3-24 shows the principle, which is also applicable in a generalized way to non-thermal exposure processes.

Thermal-sensitive plates do not need a safelight because they are essentially insensitive to visible light.

Among the first CtP plates of this type is Kodak's "Digital Plate/IR," which has a thermal-sensitive polymer coating. This coating is heated locally during imaging, in the course of which cross-linking is initiated. Complete cross-linking is accomplished by heating the entire plate to temperatures of about 125°C immediately after imaging. This so-called "preheating" process is followed by aqueous/alkaline developing. Figure 4.3-25a shows the imaging and developing of polymerizing plates. The contrasting process, namely thermal decomposition, is shown in figure 4.3-25b. There are other differences in the detail of the individual products (table 4.3-10); particularly with respect to the Agfa "Thermostar" we would like to refer to [4.3-10], which gives a detailed overview of this and other types of thermal-sensitive plates. A good collection of microphotos of various plate surfaces is available in [4.3-11].

Technology	Products
Photopolymer	Agfa: Ozasol N 90 A Fujifilm: LPA, LPY, Brillia LP-II Mitsubishi Chemicals: Diamond Plate
Silver halide	Agfa: Lithostar, Silverlith (formerly DuPont) Mitsubishi Paper Mills: SilverDigitalPlate SDP
Silver hybrid (sandwich plate: silver film, beneath Diazo)	Kodak Polychrome Graphics: CTX (in various variants for the different types of laser)

Table 4.3-8
Aluminum-based CtP plates with sensitivity in the visible range (wavelength 488 to 670 nm); (selection, status: 1999)

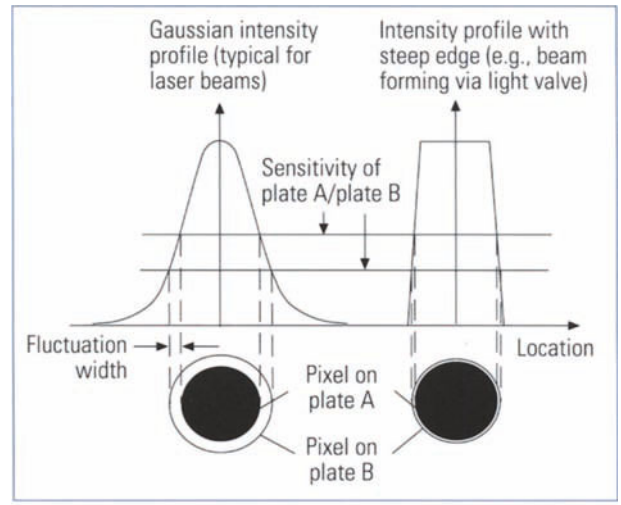


Fig. 4.3-24
The edge steepness in the intensity characteristic of the light beam affects pixel sizes on the printing plate: steeper edges (on the right), for example, using light valves, produce less fluctuation in the pixel diameter in the event of different sensitivities of plates A and B

Table 4.3-9
Advantages and disadvantages of the common aluminum-based CtP plates

Technology	Advantages	Disadvantages
Silver halide	Very high resolution, Analog or digital imaging, Low laser power required	Waste containing silver, Requires safelight environment
Photopolymer	Conventional development	Requires safelight environment
Hybrid (containing silver halide + Diazo)	Plate behaves like a conventional plate during the printing process, Low laser power required	Multistage development Requires safelight environment
Thermal	Steep threshold characteristic, Well defined dots, Insensitive to daylight	High laser power required

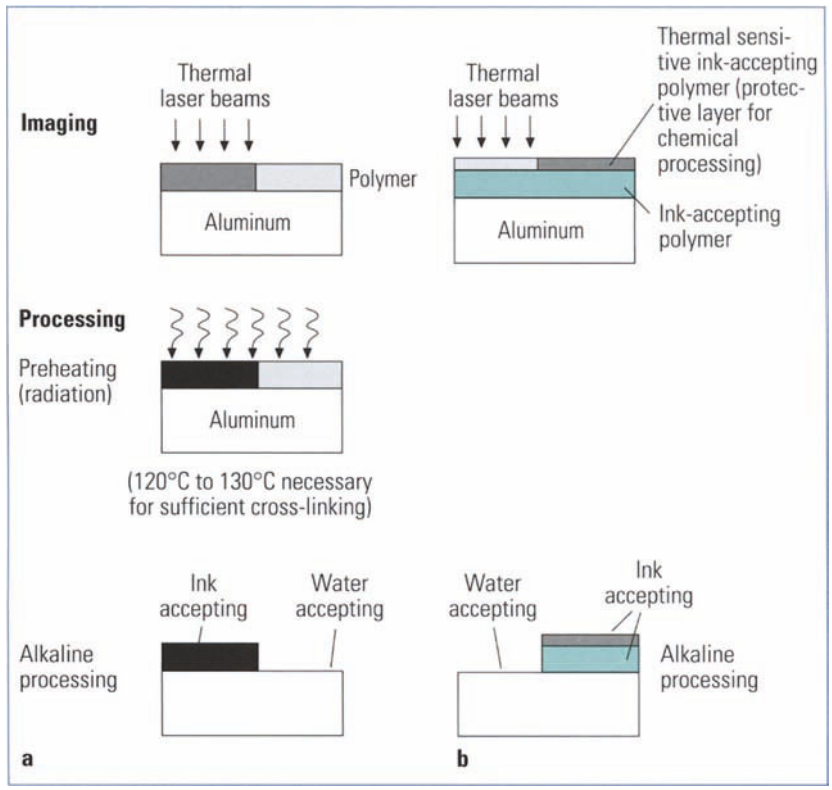


Fig. 4.3-25
Technologies for thermal-sensitive plates with polymer coating for offset printing.
a Polymerization (cross-linking);
b Thermal decomposition

Figure 4.3-26 shows technologies for the *thermally ablative imaging* of CtP plates. Ablation means that the top layer of the plate being developed is removed under the effect of heat energy. Relatively high energy densities (approximately 500–1000 mJ/cm²) are necessary for thermal plates working on the principle of ablation. Presstek first introduced plates using this method in 1993, initially for waterless offset. The "Pearldry" plate has an oleophobic (ink-repellent) silicone coating on the surface, which is removed in the image areas by the thermal energy of the laser beam, so that the underlying surface of the ink-accepting plate coating is exposed (see also figs. 4.4-6 and 4.4-9). This plate is obtainable both with an aluminum and a polyester base.

Presstek has also developed digital plates for conventional wet offset ("Pearlwet"). Already on the market is the second generation, the "Pearlgold," in which only a very thin layer is removed in accordance with the image.

The principle demonstrated in figure 4.3-26b is used in the plate developed by DuPont "SDT" (Silver Dry Thermal). It has an ink-accepting coating containing silver. With adequate removal by suction of the ablated (silver-containing) particles during imaging, no other separate cleaning operation is necessary. Unlike Presstek's "Pearl" plates, in this case those areas of the plate that are water-accepting during printing are irradiated by laser, so that the hydrophilic aluminum substrate is disclosed.

For thermal-sensitive plates there is a trend towards *processless plates*, which no longer need chemical or "wet" developing. However, as long as ablation is the applied method (which means that particles are removed from the surface) cleaning the plates is necessary. Cleaning may possibly even be done in the printing press, if the plate has been mounted and imaged on the plate cylinder. Wiping off can be done by dampening rollers. This process is called *On Press Development* (*OPD*) and is also familiar from analog plates, such as the Polaroid "DryTech Express."

Figure 4.3-27 shows a technology introduced by Polaroid in 1995 under the name "Laser Ablation Transfer" (LAT). A donor film is mounted firmly on the aluminum plate. Ink-accepting polymers are transferred in accordance with the image from this donor film onto the plate. Incidentally, digital color screen proofs (true

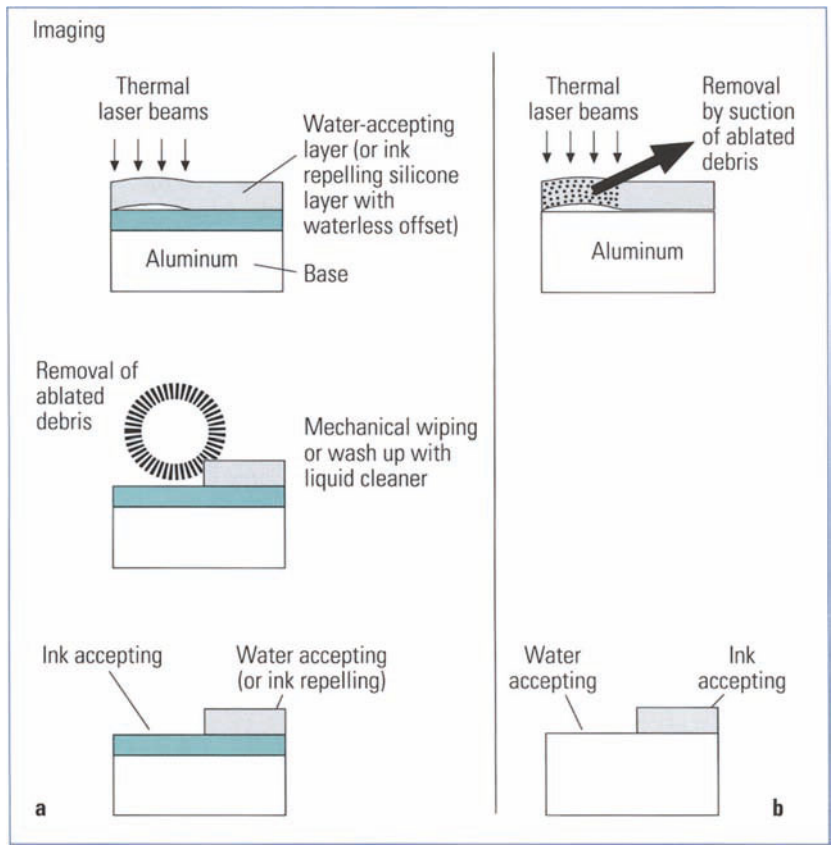


Fig. 4.3-26
Ablative imaging technologies for offset printing plates (the absorbers for the thermal laser radiation are embedded in the top layer or in a layer beneath it, not shown here, depending on the plate technology used).
a Cleaning after imaging;
b Cleaning by suction during the imaging process

proofs) can also be produced using this technology, where colorants are transferred from the donor film (one color per film) to the production (job) paper, as explained in section 3.2.11 (see fig. 3.2-77). Table 4.3-10 gives an overview of thermal-sensitive plate technologies.

It must be expected that in the years ahead some plate manufacturers will offer *completely processless plates*, in which material will not be removed by ablation, but rather, surface wettability characteristics will be changed in accordance with the image. Processless plates are incorporated into table 4.3-10 with "Change of the surface property" and "Ablation transfer," and technological differentiation is made.

Paper and Polyester Printing Plates for Offset Printing

The first signs of computer to plate appeared in the early 1980s, but not under that name. *Paper print masters* were used for this, that is, "printing plates," the base material of which is special paper. Paper print masters of this type are imaged by means of electrophotographic procedures (see sec. 5.2). Paper print masters are mainly used for short print runs, in the production of single-color printed matter with low quality requirements. They are also used in printing with spot colors. They are limited in format to a maximum A3.

Polyester-based plates are also available for computer to plate (table 4.3-11). For high print quality, there are also polyester plates that work on the diffusion transfer principle. The Japanese company, Mitsubishi Paper Mills, introduced them as a new product under the name of "Silver Digiplate" in 1985. Because of the relatively low energy requirement, this plate can be imaged using computer to film systems. Figure 4.3-28 shows the structure and function of this material, which is now widely used. Unlike aluminum-based silver plates (fig. 4.3-22), the nucleus layer is on the surface. The developing agents are already embedded in the silver halide layer beneath it. During developing the silver halides exposed by light become black. The unexposed silver halides diffuse in the nucleus layer, are fixed, and accept ink.

Technology	Products	Remarks
Polymerization		Image areas (ink accepting) are exposed during the imaging process.
	Kodak Polychrome Graphics:	
	– Digital Plate/IR (Kodak)	Requires preheating, also suitable for UV exposure
	– Quantum 830	Requires preheating, no protective light needed
	Fujifilm: Brillia LH-N	LH-N with preheating and baking for long run lengths
Thermal decomposition		Non-image areas are exposed during the imaging process; conventional alkaline development
	Agfa: Thermostar	
	Kodak Polychrome Graphics:	
	– Electra DC	Electra DC originally from Horsell-Anitec; no preheating required
	– Quantum NPP	NPP: No Process Positive, the decomposed layer is washed off by the dampening unit of the printing press (concept by Polaroid)
	Fujifilm: Brillia LH-P	LH-P without preheating, without baking, also for UV inks
	Mitsubishi Chemicals: DiamondPlate LT-1	
	Lastra: Extrema 830	
Ablation	Presstek:	With Presstek plates, the image areas are exposed.
	– Pearldry	Pearldry for waterless offset (aluminum and polyester-based).
	– Pearlgold	Pearlgold is the successor plate for Pearlwet.
	– Anthem	Market launch in 2000
	Agfa: Silver Dry Thermal (SDT)	With Silver Dry Thermal (SDT, originally from DuPont) non-image areas are exposed and the ablated debris (containing silver) is exhausted during the imaging process.
	Anocoil: T-Plate	The ablated debris is washed off with water in a separate module
Ablation transfer	Polaroid: Laser Ablation Transfer (LAT)	Transfer of ink-accepting material from the donor film to the aluminum plate (material deposition). Burning in is required for anchoring. (Presented as a concept by Polaroid in 1995)
Physical phase change	Heidelberg: Saphira Thermoplate PL	Ink-accepting areas are created by melting/fusing thermoplastic particles of the coated plate. Water-accepting areas emerge in the non-exposed areas (the dampening solution activates non-fused material, which is taken away by the ink). Particularly suitable for direct imaging applications
	Agfa: Thermolite (announced)	
Change of the surface property		Various manufacturers have development projects for plates which change their surface property directly to the desired manner under thermal radiation (no follow-on development, therefore processless).
		The term "switchable polymers" originates from a patent document from Creo (see also sec. 4.4.2 and fig. 4.4-23).
	Asahi: Thermal CTP (through micro capsules)	Microcapsules within the coating substance burst under thermal radiation and release ink-accepting particles, that is ink-acceptance of imaged areas; no development stage required (presented by Asahi as a technology study at IGAS 1997 and announced for launch on the market since IPEX 98, see also fig. 4.4-18).

Table 4.3-10 Technologies for thermal-sensitive aluminum-based CtP printing plates (wavelength 750 to 1200 nm)

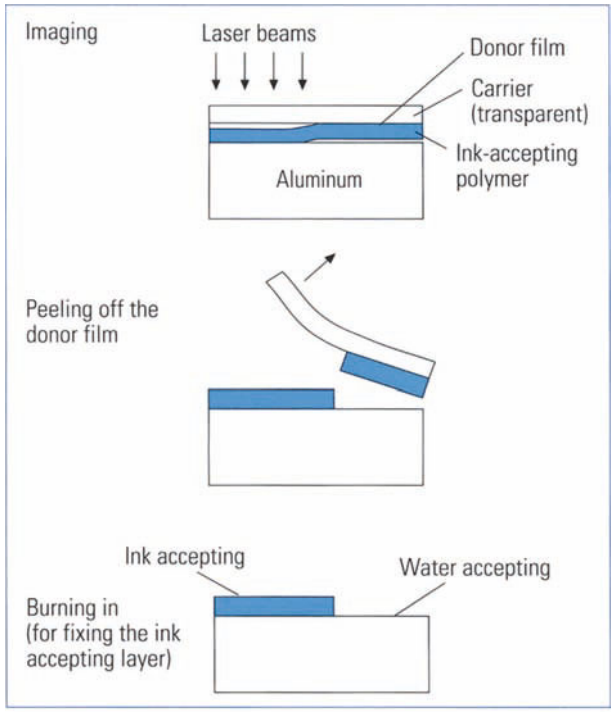


Fig. 4.3-27
The principle of ablation transfer (LAT Laser Ablation Transfer) for the imaging of offset printing plates (Polaroid)

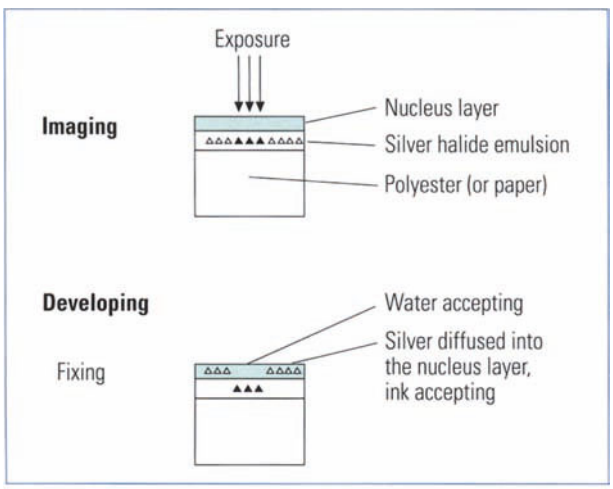


Fig. 4.3-28
The imaging and developing of polyester-based printing plate using the diffusion transfer method
(Silver Digiplate, Mitsubishi Paper Mills)

The use of these "instant printing plates" does not require great investment because they can be imaged with normal film imagesetters. Only the chemistry in the developer has to be changed. The plate is developed in a two-bath process consisting of activator and stabilizer. These plates are normally used in the small format range (A4 and A3), also for multicolor printing. Some printing companies also use these plates for larger formats in four colors. Most printing companies for producing large-format print jobs only use these plates for single-color printing, for example, in book printing. Polyester printing plates are available as reels or sheets.

Plates for Flexographic Printing

Digital imageable plates for flexographic printing can be divided into photopolymer plates and rubber plates. *Photopolymer plates* give better print results than rubber plates because they are more stable and they can also be used for printing fine screens. Figure 4.3-29 shows how "sharp" the halftone dots can be on a plate, using the example of a "digiflex" plate from BASF. For printing and stability reasons, the screen dot diameter should not be less than 25 µm. With *rubber plates* the non-image areas can be engraved directly by laser.

Photopolymer plates can only be imaged by laser and not engraved (fig. 4.3-30). For this purpose they receive a black, thermal-sensitive coating. The laser beam causes ablation of the black layer in accordance with the image; the remaining part of this layer forms a mask for the subsequent main exposure of the photopolymer coating in the UV floodlight. This main exposure triggers the photopolymerization process; the corresponding areas cure. The plate is then washed off by the conventional chemical method, dried, post-exposed and post-processed (fig. 4.3-30). This laser imaging technology can be used not only for flexographic plates, but also for letterpress, gravure, and offset printing.

In 1997 a new technology was introduced in cooperation between BASF Drucksysteme, Schepers Druckformtechnik, Saueressig, and AKL Warburg under the name of "*Direct to Sleeve*" (brand name "digisleeve"). Sleeve in this case means a sleeve-shaped carrier for the actual printing plate, which wraps completely round the sleeve and is joined together at the seam. Sleeve and plate then form a sleeve-shaped unit. More than 90% of flexographic print runs are now printed using plates mounted on cylinders or sleeves. Only individual areas of continuous decoration printing, such as wallpapers

Technology	Product	Manufacturer	Max. screen ruling and life cycle (printed sheets)	Remarks
Imaging with film imagesetter, silver copy layer			*high quality in small formats, medium quality for the medium format range*	*after imaging two-bath processing: 1. Activator, 2. Stabilizer*
Red light diodes or IR diodes	SetPrint Plus	Agfa	70 lines/cm 20 000	
Variants for all wave lengths	Silver Digiplate	Mitsubishi Paper Mills	70 lines/cm 25 000	
	Goldmaster	Fujifilm	70 lines/cm 20 000	Not available in Europe
Imaging with electrophotography (powder toner)			*for small print volumes, single-color and decorative (spot) colors*	*special fixing unit with higher temperature improves fixing and print run stability*
	LaserLink LLP Omega Plate ParagonPlate	Agfa Autotype LaserMaster	15 000	Since 1998 on the market
	NovaDom Kimoplate	TechNova Kimoto	3000	
	Plazerplate Policel	Plazer PolicromScreens	15 000	Sandwich plate (paper/polyester)

Table 4.3-11 Polyester plates for computer to plate

or floor-coverings, require seamless sleeves, as shown in figure 4.3-31 (see also sec. 2.3.3, fig. 2.3-10).

During production of this type of plate-bearing sleeve, the plate with pre-exposed reverse side is firstly stuck onto the base (sleeve), the sleeve is then imaged in the computer to plate system. There is also the option of seamlessly fusing the plate, which is not yet blackened but already pre-exposed on the reverse side of the sleeve. This is then followed first by surface treatment and application of the laser-sensitive black coating and always (after imaging) by all-round exposure as well as all-round removal of the black coating, and then by the usual measures such as all-round washing, drying, post-exposure, and after-treatment in variable fixtures.

Which sleeve technology for endless printing will prevail is still an open question. On the other hand it is certain that sleeve technology in general will be used more and more, because seamless sleeves save long assembly work and produce very high register accuracy.

4.3.10 Trends in Computer to Plate

On the one hand, the current wide range of *computer to plate systems and plates* makes many potential customers insecure, but on the other hand, the variety of available technologies enables an operation-specific introduction to computer to plate.

The question of how and with what specifications a *digital proof* can be produced has still not yet been satisfactorily answered for many people. Since with computer to plate there are no films from which analog proofs can be made, the "proof" topic is highly debatable. The possibilities and areas of application of digital proof technology are summarized in section 3.2.11. Users understandably demand that the same raster image processor (RIP) should be used both for the digital proof and for plate exposure in order to avoid different interpretations of the PostScript format, and above all to create proofs which match the later pro-

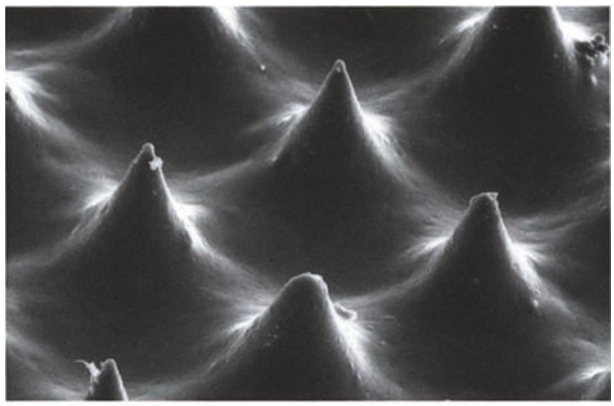


Fig. 4.3-29
Microphoto of a section on a flexographic printing plate for printing halftone dots (digiflex, BASF)

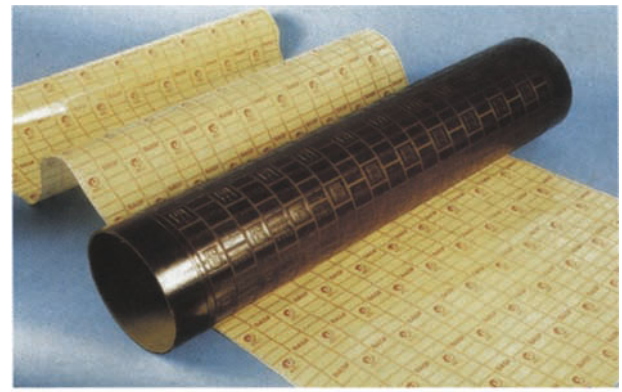


Fig. 4.3-31 Sleeve (seamless) for flexographic printing (BASF)

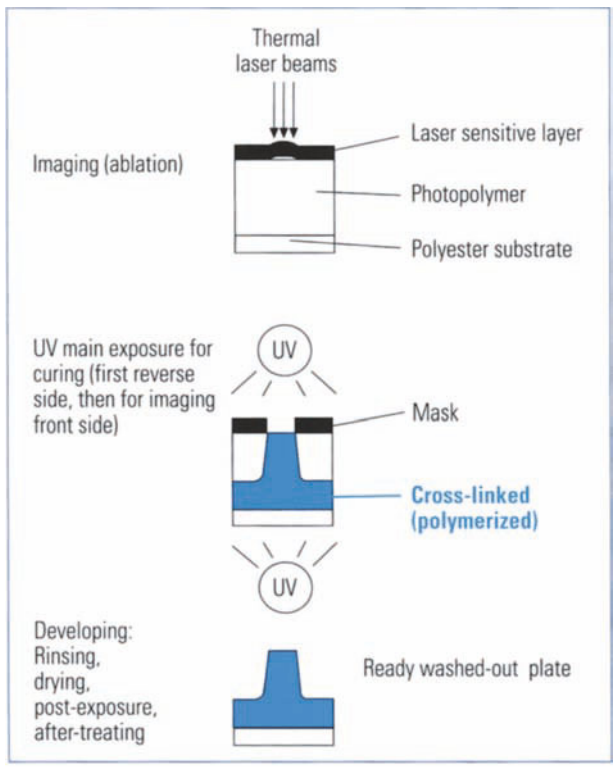


Fig. 4.3-30
The imaging and developing of photopolymer plates for flexographic printing

duction (*Screen Proof, True Proof*). There are various designs for this purpose, which are dealt with in detail in section 3.2. The combining of RIPs for digital proof and plate imaging is explained in diagrammatic form in figure 4.3-32 by the red line around both RIPs.

The broken red line represents an even more far-reaching concept, namely combining the output of *digital proof and plate in a single device*. This is perfectly feasible technically, but it remains to be seen whether any particular case is economical. This certainly makes it possible to output a rasterized digital proof with identical bitmaps just as it is imaged on the plates, but it must be anticipated that there will be a pass for each basic color, so that producing the proof will become very time-intensive. A device available on the market for the combined outputting of plates and digital proofs is the "Trendsetter Spectrum" (fig. 4.3-33, see also fig. 4.3-3).

Another trend that can only be realized with thermal plates is to avoid the chemical developing of the imaged printing plates, indicated by the red arrow in figure 4.3-32. The first printing plates no longer needing chemical developing were the "Pearldry" plates from Presstek for waterless offset printing. In this case only a cleaning process is required after imaging, to wipe off the particles ablated from the plate surface. In the end, though, the declared objective of numerous plate manufacturers is to develop and bring about the widespread use of *completely processless thermal plates*. As long as printing plate technology is based on ablation, this objective has not yet been fully accomplished. Other technologies such as "switchable polymers" are therefore being tested (see also table 4.3-10).

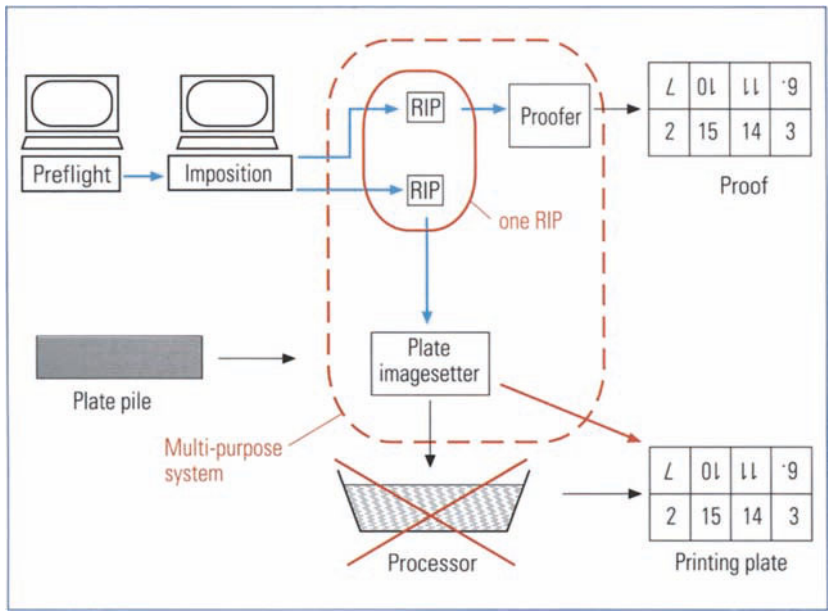


Fig. 4.3-32
Trends in computer to plate: processless printing plate, multi-purpose system for plate imaging and proof, only one RIP

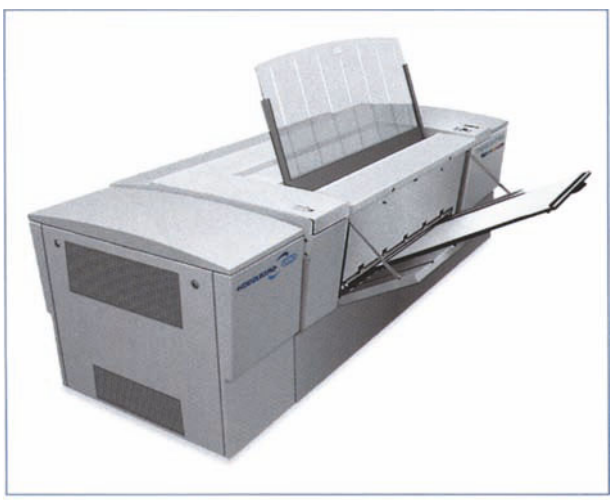


Fig. 4.3-33
Multi-purpose system for plate imaging and for producing digital proofs (Trendsetter Spectrum, Heidelberg/Creo)

If chemical developing and cleaning of the imaged plates are no longer necessary, a work cycle that presents problems as regards process reliability will be eliminated. There will also be savings on chemicals and energy.

Other alliances of manufacturers are emerging for computer to plate and the variety currently available will be reduced as a consequence. In 1998 the number of computer to plate systems installed worldwide was more than 2000; in the year 2000 the figure is risen to more than 5000 installations (for comparison: at the beginning of 1997 about 600 computer to plate systems had been installed). It is expected that in the coming years more and more systems will be installed.

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Further Reading for 4.3

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4.4 Computer to Press/Direct Imaging

Introduction

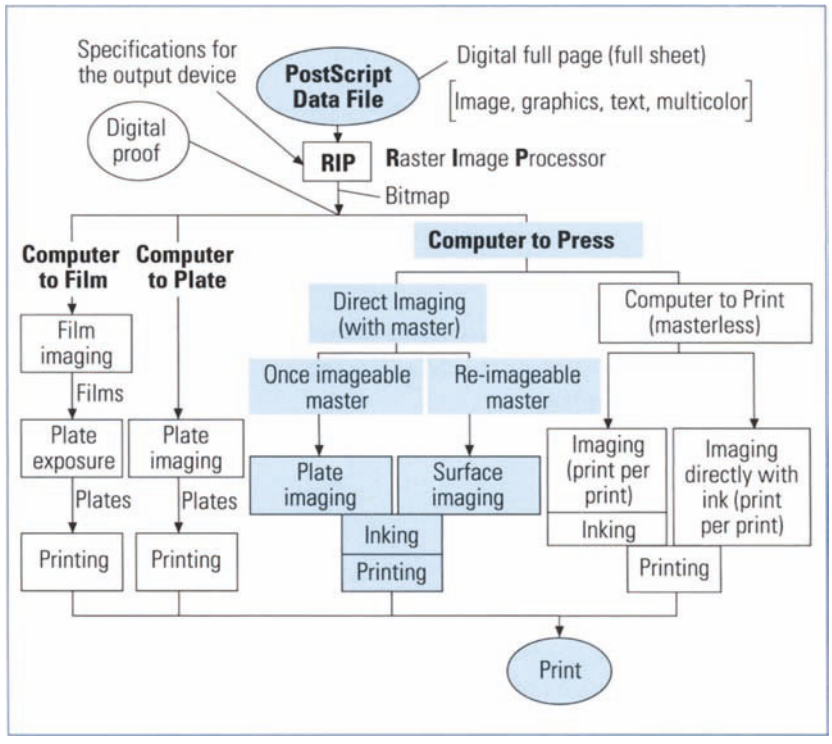
In the last section computer to plate was described including numerous examples of the technology in use; in this case the plates were produced off-line, that is, outside the press. In this chapter, however, technologies and systems are depicted in which the plate is produced in-line, that is, inside the press. The data for the print job is used to generate the printing plate via a *direct imaging process* with the appropriate imaging system and plate materials.

A summary of the computer to ... technologies is shown in figure 4.4-1 with special emphasis on *computer to press/direct imaging variants*. Described is the type where the plate is produced directly in the press with a once imageable plate and the variant where the plates are re-imageable.

Figure 4.4-2 is the *technological comparison* of these computer to press/direct imaging technologies with conventional platemaking outside the press as well as with computer to press/computer to print technologies where no plate is required.

It is evident from the illustration that with the increasing degree of automation some special additional equipment is necessary inside the printing unit. In the case of direct imaging with the once usable plate, the imaging unit must be installed inside the press; if a technology comes into play where a plate can be used several times, then additional erasing and preparation systems are

Fig. 4.4-1 Computer to ... Technologies



H. Kipphan (ed.), *Handbook of Print Media*
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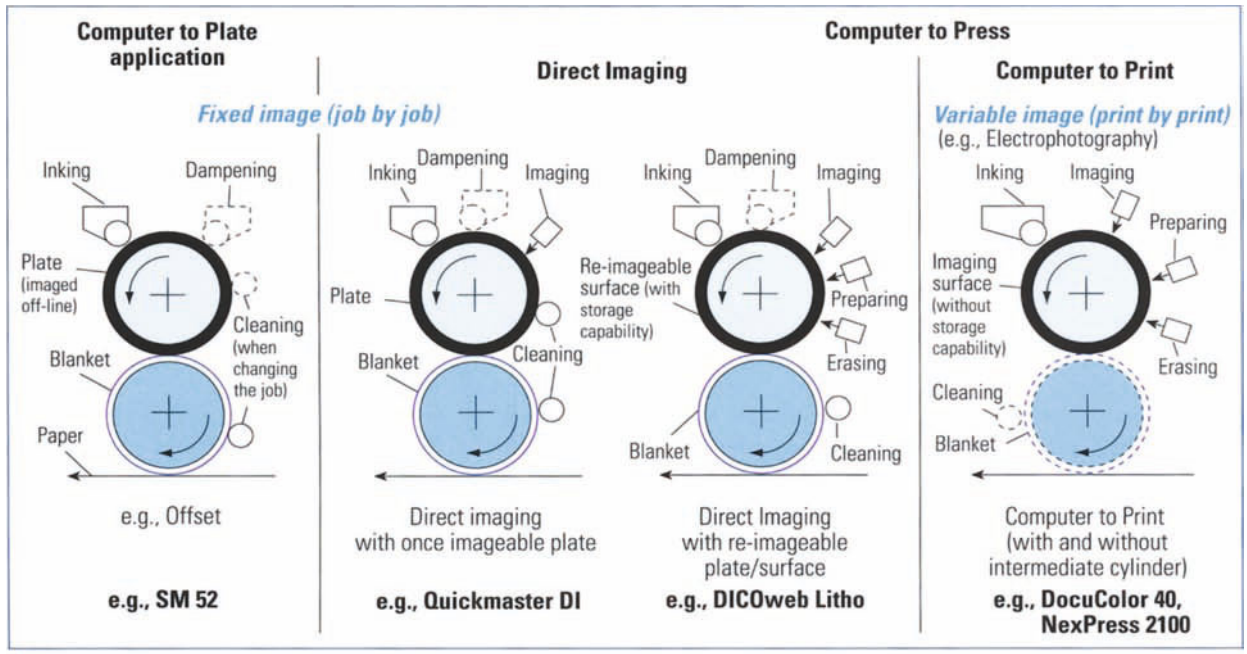


Fig. 4.4-2 Printing unit equipment in computer to press/direct imaging systems compared to off-line platemaking and computer to print

needed in addition to the imaging unit. The printing process itself is not different, that is, direct imaging technologies and systems can be realized in various printing processes.

So far direct imaging technology has been used in *offset printing*; however, there are also attempts to employ direct imaging in gravure printing. For screen printing simple single-color printing systems using direct imaging technology exist. These systems are described in detail in later sections.

4.4.1 Computer to Press/Direct Imaging with Removal of the Master for each Print Job

4.4.1.1 Computer to Press/Direct Imaging Printing Systems

GTO-DI/Sparc

The first computer to press/direct imaging offset press was launched on the market in 1991. The four-color sheet-fed offset press shown in figure 4.4-3 is a conventional offset press in *unit design* based on a *waterless offset printing process*. Each printing unit of this press is equipped with a digitally controlled system for in-line platemaking.

The method of function of this direct imaging press is explained in figure 4.4-4.

It can be seen from the press diagram that an imaging unit has been installed instead of the dampening unit (the press works with waterless offset).

Figure 4.4-4b shows how this imaging unit is arranged so it can be automatically shifted in the axial direction on each printing unit. The imaging procedure is effected with a revolving plate cylinder and an imaging system that moves axially. As can be seen in figure 4.4-4c, several electrodes (16) have been arranged in the circumferential direction, by means of which the plate is imaged for the print job using the technology of *spark erosion*. In figure 4.4-4d the printed image is shown on the plate with the printed image on the blanket of the blanket cylinder in the offset printing unit.

With the configuration shown here it was possible to achieve an addressability of 1016 dpi. Approximately twelve minutes were needed for imaging all four plates. The press is designed for format A3+ (two pages A4 per plate, sheet alignment: "landscape format"). The time required for imaging a print job including the necessary wash-up processes after spark erosion was about twenty minutes. A precise color register is given from

Fig. 4.4-3
Four-color sheet-fed offset press with direct imaging technology (GTO-DI/Sparc, Heidelberg)



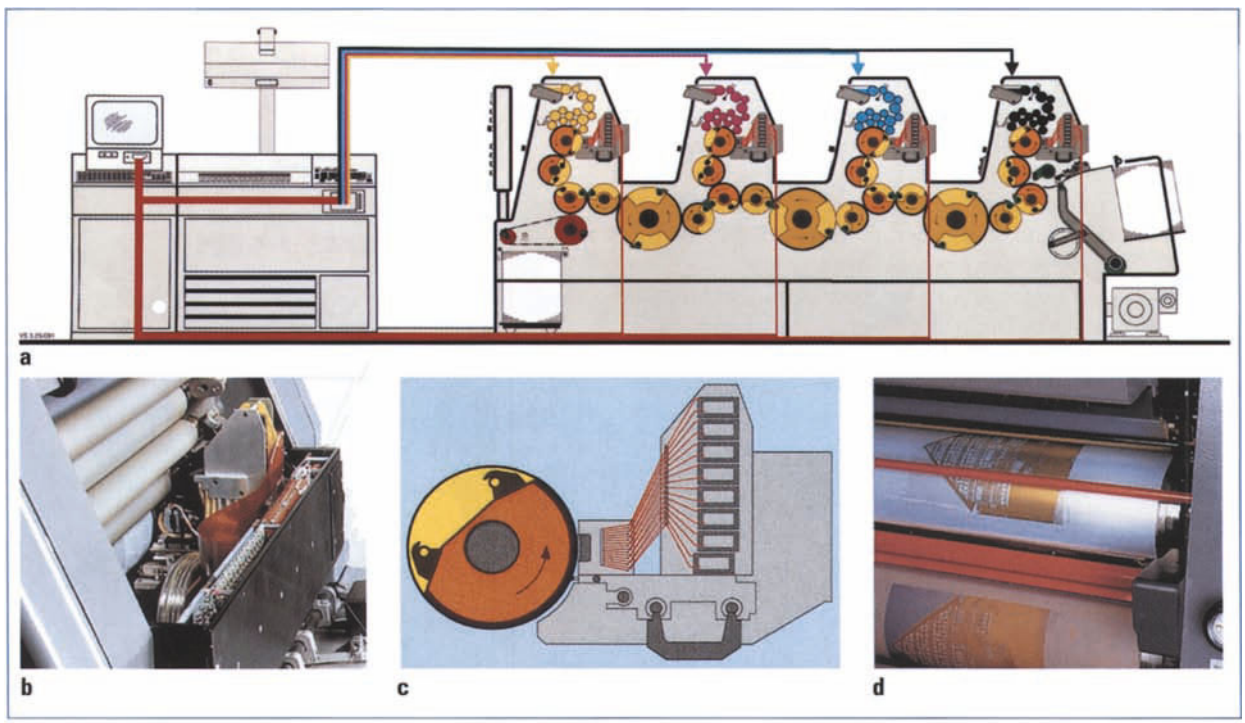


Fig. 4.4-4 Computer to press/direct imaging multicolor press.
a Press diagram for multicolor offset printing (waterless offset);
b Imaging system on the printing unit (spark erosion);
c Diagram of the imaging system with 16 imaging electrodes;
d Imaged plate on the plate cylinder (with printed image on the blanket of the blanket cylinder) (GTO-DI/Sparc, Heidelberg/Presstek)

the very beginning through imaging in the press. Only fine adjustments might be necessary if the image gets out of register during the sheet pass due to the type of substrate or ink.

In figure 4.4-5 the *imaging process* is explained in more depth. In a high-voltage field the plate is so altered via the electrodes of the imaging head at the ink-accepting points due to *spark erosion* that the ink-accepting layer beneath the ink-repellent surface is laid bare. Figures 4.4-5b and 4.4-5c are high magnifications of the printed image. It can be seen that an irregular dot shape arises through this process of erosion in the high voltage area. In principle this does not need to be of disadvantage in the multicolor halftone image, though with sharp-edged structures in the printed image there are clear deficiencies in comparison with the usual high quality of offset printing.

This press technology was launched in 1991 at a time when the digitization of prepress with a link-up to the print stage was still in its infancy. Some pioneering printshops took advantage of the new direct imaging technology and were successful in *short-run color printing* capturing a new market segment for short/medium print runs in relatively high quality and with short throughput times ("*print on demand*"). The classical prepress was then no longer required in the printshop, the print job could be done with digital data. This led to shorter makeready, especially when printing in waterless offset, and to the elimination of setup work needed to attain an exact color register.

As shown in figure 4.4-5 the print quality achieved with the direct imaging technology of "spark erosion" did not meet the high standards of offset printing quality, in which sharp-edged structures can be reproduced and halftone dots have a defined reproducible shape.

GTO-DI/Laser

By using *laser technology* for creating plates a reproducible, defined halftone dot can be generated, as well as a higher resolution than with spark erosion, which only achieves 1016 dpi.

Laser technologies for imaging systems for each printing unit were, of course, expensive at the initial stage. Developments focused on the use of laser diodes with a wavelength in the thermal range (about 830 nm) together with newly developed plate coatings that enabled very efficient laser exposure processes for heating and *ablating* the material for platemaking.

Figure 4.4-6 shows the laser system as it was used in the direct imaging press illustrated in figure 4.4-3.

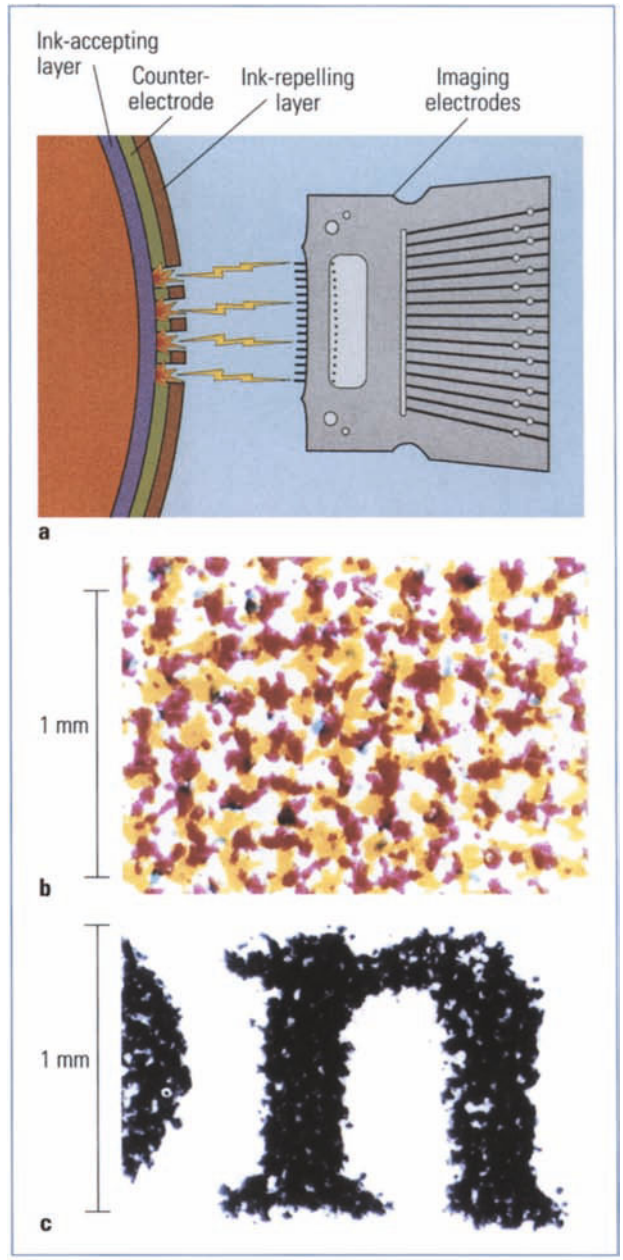


Fig. 4.4-5
Imaging of the offset printing plate (waterless offset) through spark erosion.
a Imaging method;
b Detail of a multicolor print (60 lines per cm/1016 dpi);
c Detail of a printed text (GTO-DI/Sparc, Heidelberg/Presstek)

This system replaced imaging units based on spark erosion.

The imaging system shown in figure 4.4-6 consists of sixteen imaging modules arranged next to each other in the axial direction; they comprise a laser diode, optical fiber, and beam forming optics. The optics are focused so that at a resolution of 1270 dpi, the pixel on the plate has a diameter of about 30 µm. During the revolution of the plate cylinder the imaging system is axially shifted having a path that corresponds to the distance from imaging optic to imaging optic. The great distance between imaging modules requires shorter imaging travel in comparison to imaging systems using sparc erosion, where the writing elements are arranged in the direction of turn. The connection from zone to zone in the image, however, requires an extremely precise adjustment mechanism/ procedure.

As illustrated in figure 4.4-6a, in order to achieve the *ablation procedure* for imaging, the *printing plate* is coated with a special heat-absorbing layer; this is heated up so intensively by the laser pulse that an evaporation or ablation process is achieved with efficient energy transfer from the laser onto the material.

Figure 4.4-7 shows how much improvement in printing quality was achieved by laser imaging in comparison with spark erosion (fig. 4.4-5). The *quality* attained is comparable with usual offset quality and as expected led to much greater acceptance and use of direct imaging technologies.

QM DI 46-4

In 1995 the third generation of direct imaging presses came onto the market, the Quickmaster DI (fig. 4.4-8). The press concept is based on a *satellite design*, in which four offset printing units transfer the printed image of the respective color separations on paper sheets to a common impression cylinder; the sheets are held at the impression cylinder by means of gripper systems.

Compared to the modular configuration (unit design), the satellite design needs much less space, which made installation easier and opened up new operational opportunities.

The printing process is *waterless offset*, and imaging occurs by means of *laser ablation*. In contrast to the concepts referred to above, in which the plate has to be removed after the job and a new unimaged plate manually mounted by the operator on the plate cylinder to be imaged for the next job, the Quickmaster DI has a plate cylinder that contains a supply reel with *plate material*. After completion of a job the used plate material

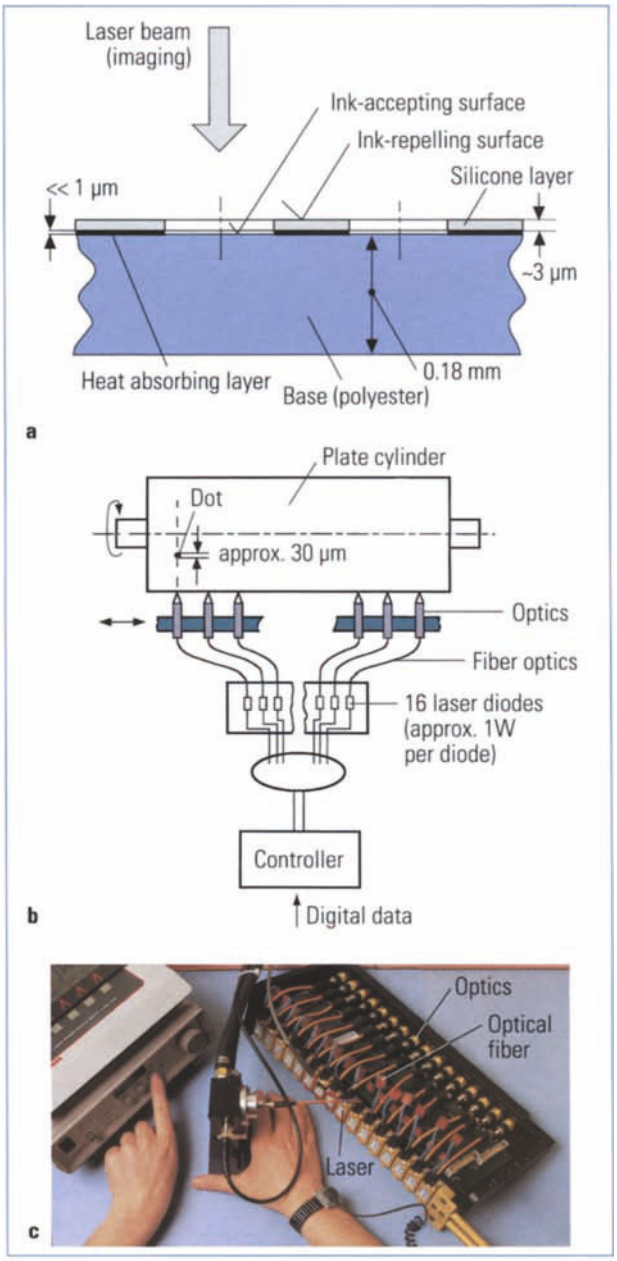


Fig. 4.4-6
Laser technology for imaging the plate in computer to press/direct imaging.
a Printing plate for waterless offset and imaging using the laser ablation technique;
b Structure of the imaging system;
c Imaging unit with laser diodes, optical fiber, and beam forming optics to generate the dot shape and size (on the quality test;
GTO-DI/Laser, Heidelberg/ Presstek)

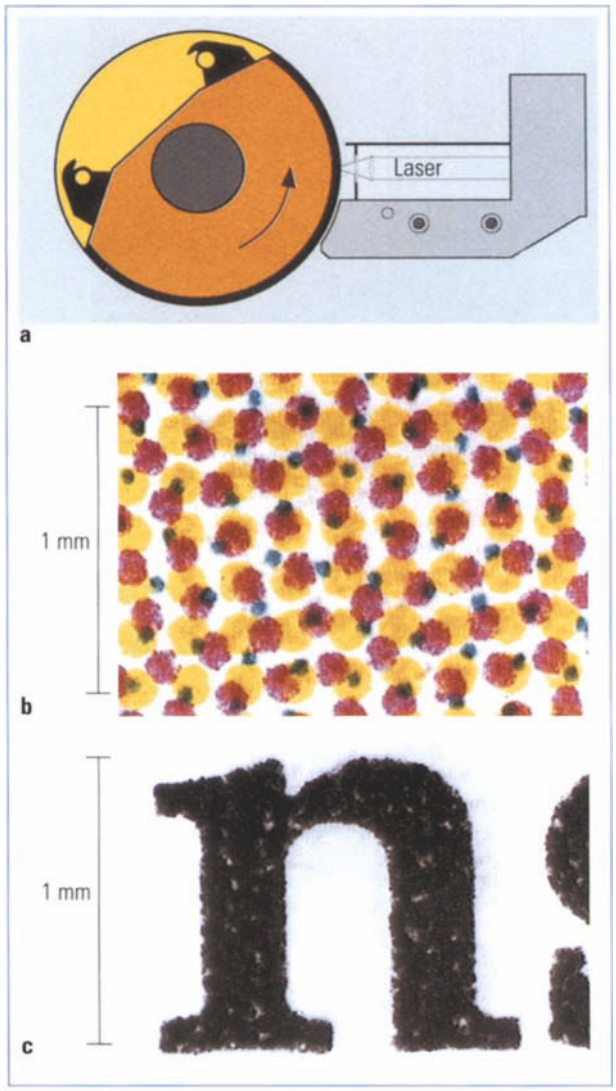


Fig. 4.4-7 Imaging the plate by means of laser ablation.
a Imaging method;
b Detail of a multicolored print (60 lines/cm, 1270 dpi);
c Detail of a printed text (GTO-DI/Laser, Heidelberg)

is automatically rolled up and an unused section is unrolled from the supply reel and fastened on the plate cylinder. Imaging for the next job can start without manual change of plate. It can be seen in figure 4.4-8 that a wash-up device has been installed at the plate cylinder. The cleaning process (using a cloth saturated in liquid) is necessary in order to eliminate the fine material particles that are released from the plate surface through thermal imaging.

The press was designed for sheet format A3+, format orientation is "portrait," that is, the long side of the sheet travels in direction of the print. Imaging takes place at a cylinder revolution of about 4.4 revs/sec. (maximum printing speed is 10 000 sheets per hour). This leads to a time requirement for producing the plate for the new job together with the necessary cleaning process of about ten minutes at an addressability of 1270 dpi. The *cassette* with plate material is designed so that there is enough capacity for thirty-five print jobs. When the plate material has been used up the cassette is replaced; the used material enters a recycling process.

Figure 4.4-9a shows a laser imaging system inside the printing unit in the press; figure 4.4-9b is a shot of a *plate section* made by laser ablation taken by a scanning electron microscope. It can clearly be seen that the halftone dot consists of individual pixels created through laser ablation. The upper layer is the ink-repelling silicone layer; the area that is bared inside the dot form accepts ink. Because the dot size of the smallest individual halftone dot is 30 µm imaging can also take place on the basis of frequency-modulated (FM) screening. For a multi-beam imaging system this demands a most precise level of adjustment and great stability in the individual imaging channels.

The components of a *direct imaging system* are shown in figure 4.4-10b. The data for the job are transmitted to the raster image processor (RIP), which is linked to the control console. The bitmap with the color separations of the desired screening and resolution generated in the RIP controls the imaging unit in the digital multicolor press. Simultaneously the plates in all four printing units are imaged. Now the printing of the job can begin directly. As shown in figure 4.4-10a, the direct imaging press is the output system for a digital prepress, in which the job is completely digitally represented through varying input systems for text, image, and graphics by means of page layout and imposition systems. The raster image processor (RIP) then controls the press. Proofing of the data file can occur in a *preflight check*, for instance, on the color monitor of the direct imaging press (see also fig. 3.2-73) or in connection with *digital proofing equipment* as is shown in figure 3.2-71. This proofing system is based on the NIP technology of thermo-sublimation and generates an optimized *color proof* for the whole format through *color management*.

The *pre-adjustment of the ink zones* of the individual inking units can be calculated from the print job data

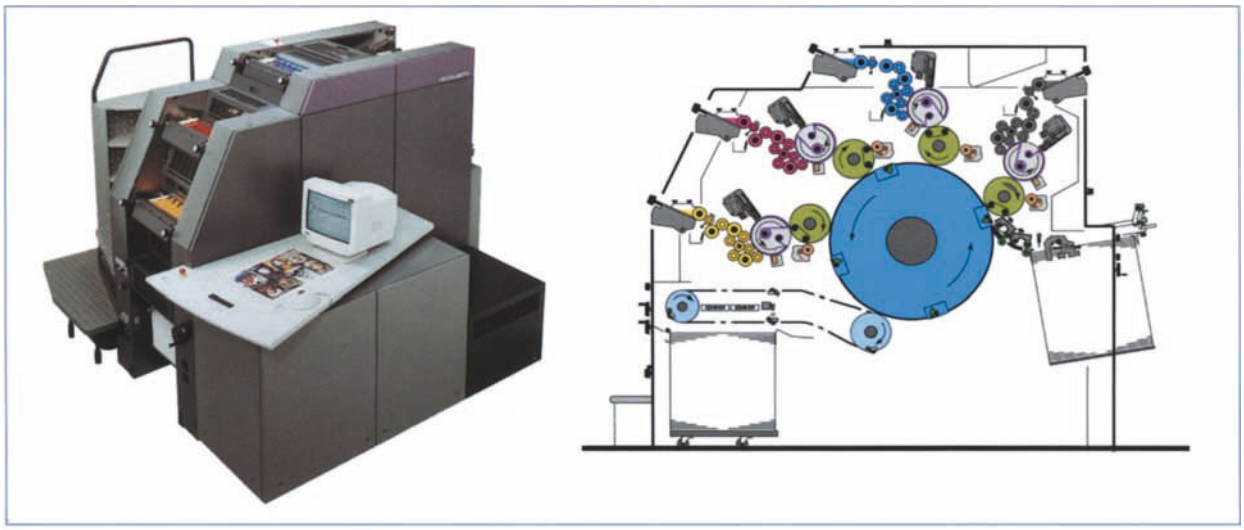


Fig. 4.4-8 Quickmaster DI computer to press/direct imaging system for multicolor printing in waterless offset (QM DI 46-4, Heidelberg)

with a high degree of accuracy; these are automatically adjusted by remote control during the imaging process taking into account press and process characteristics, and also supported once again by a color management system.

Direct Imaging Presses for Larger Sheet Formats

The direct imaging presses described above are designed for the print format A3+ (two A4 pages per sheet side). Presses with a larger format require either a more complicated imaging unit or they need more time to image the plates. Printing plates working in waterless offset are more expensive compared to plates for conventional offset; this also leads to higher production costs for large print formats and short runs. In the beginning phases of direct imaging, digitization of the print jobs was not so advanced that there were enough jobs in digital form to fully utilize a large-format press; in addition, the data quality for the whole printed sheet often revealed deficiencies that led to delays in production. The evolutionary development both in digitization and in the availability of high quality and inexpensive components for constructing imaging systems in the last few years has caused direct imaging presses to become both possible and attractive for larger formats.

SM DI 74

Figure 4.4-11 shows a multicolor offset press in modular design together with a direct imaging system in the format A2+ (four A4 pages per side of a printed sheet). The press concept is so designed that plates for waterless offset as well as conventional offset (dampening and inking up) can be used. The imaging unit is so installed in the printing unit that space is available for the dampening unit, and allows for access to the printing unit, for instance, for cleaning or changing the plate. In figure 4.4-11 the imaging system in the press is based on laser technology; around 220 beams perform the imaging simultaneously, while the imaging head moves parallel to the axis of the plate cylinder. Imaging and cleaning requires approximately twelve minutes.

Dominant DI

In addition to Heidelberg other manufacturers have also launched products for computer to press/direct imaging technology on the market. Figure 4.4-12 shows a sheet-fed offset press in the format A2+ from ADAST (Czech Republic), which is also based on thermal laser imaging technology (in accordance with fig. 4.4-6) using a waterless offset process.

Further Concepts for Computer to Press/Direct Imaging Printing Systems

Evolution of DI Technology. Computer to press/ direct imaging presses were already available in 1991, before computer to plate systems became established on the market. Computer to plate systems were offered in sev-

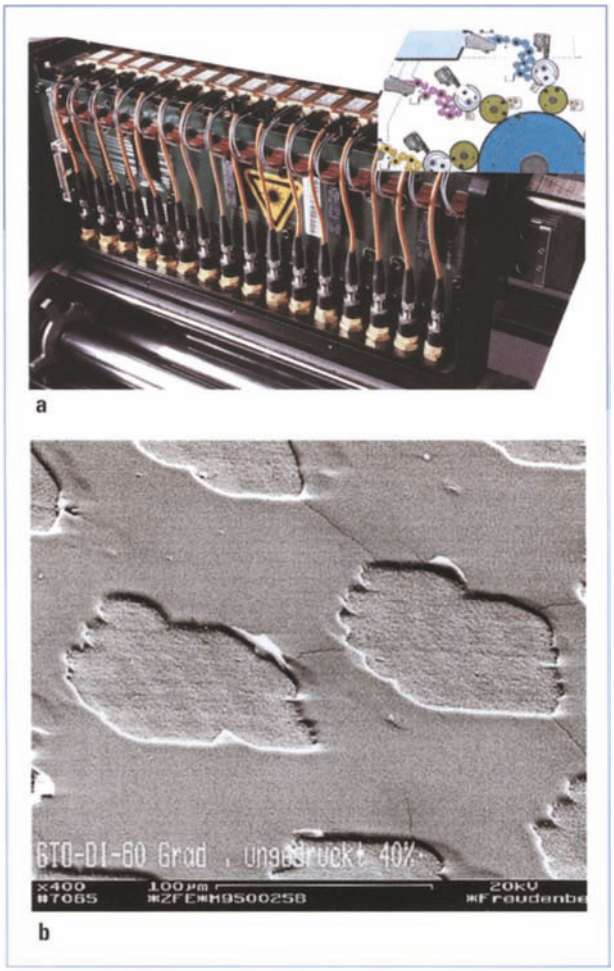


Fig. 4.4-9 Laser imaging with computer to press/direct imaging.
a Imaging system in accordance with the printing unit diagram in figure 4.4-8;
b Detail of a plate after imaging using the laser ablation technique (QM DI 46-4, Heidelberg/Presstek)

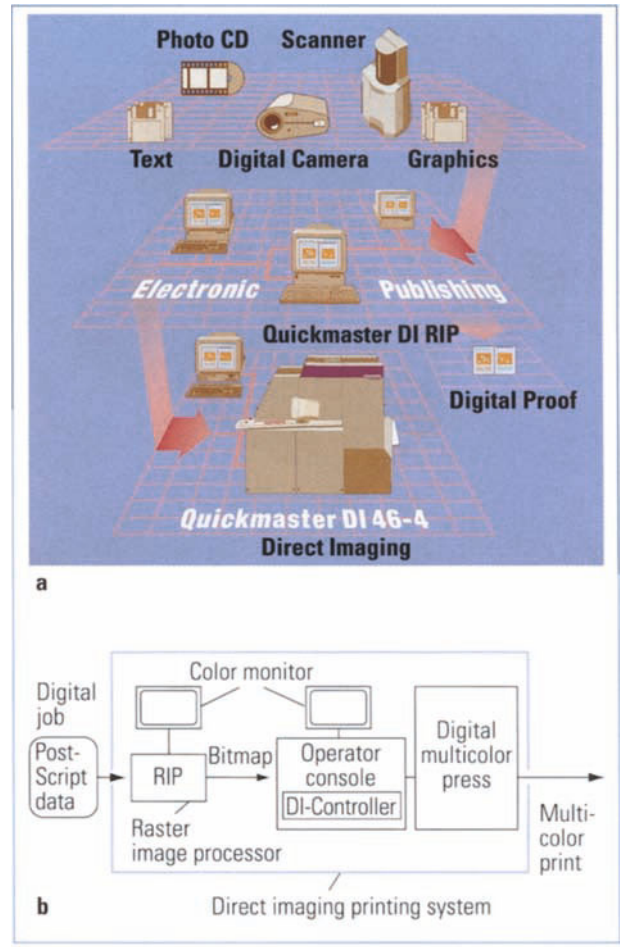


Fig. 4.4-10 Computer to press/direct imaging printing system.
a Digital job preparation and direct imaging printing system in the digital workflow;
b System components of the direct imaging multicolor printing system (QM DI 46-4, Heidelberg)

eral variations from about 1993 and installations began in prepress; however, it took until 1995 before one could really talk about penetration into the graphic industry. This was accompanied by the introduction of high-performance systems for various print formats as well as the development of economically feasible and efficient imaging systems and adequate plates that could be exposed by means of thermal imaging.

With the introduction of the direct imaging press *Quickmaster DI* in 1995 based on the experience with two previous models, *GTO-DI/Sparc (spark erosion)* and *GTO-DI/Laser*, practical experience was consolidated and installations increased all over the world. Small printshops were founded based on this press technology such as prepress companies that integrated the technology so as to extend their service offer in the direction of print media production. After *ADAST*, which came on the market in 1996, other press manufacturers appeared with additional offers of direct imaging systems.

More Recent Concepts. In 1997 KBA in cooperation with Scitex presented their direct imaging press *74 Karat* for the format A2+. Then in 1998 the com-

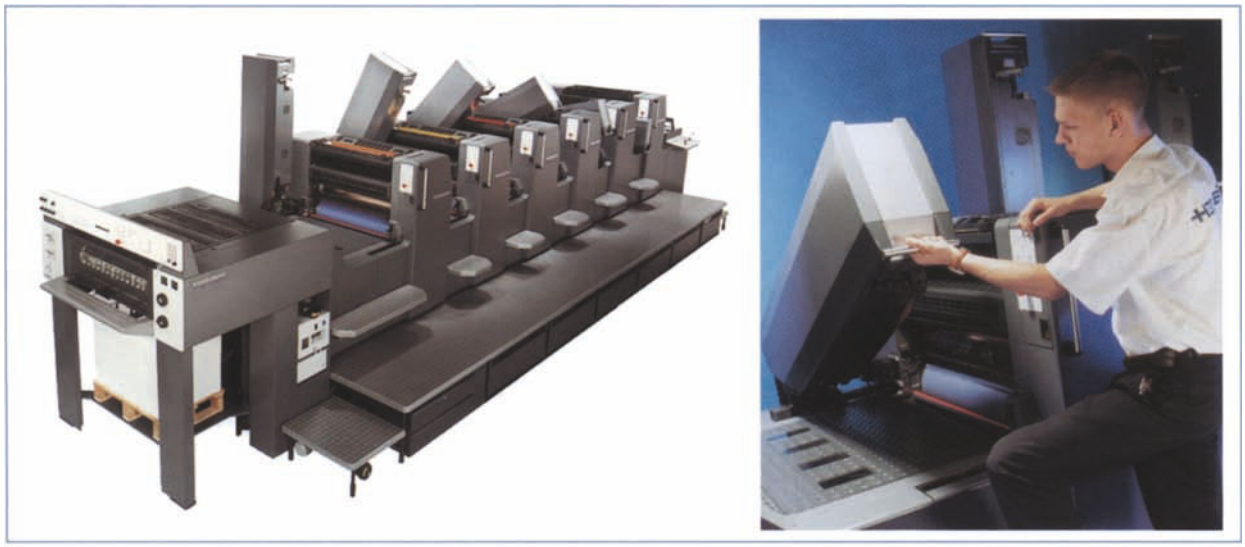


Fig. 4.4-11
Computer to press/direct imaging multicolor printing press (straight printing and perfecting) with laser imaging system for conventional and waterless offset; scanning imaging head of 220 laser beams, thermal (830 nm) (Speedmaster DI 74-6, Heidelberg)



Fig. 4.4-12
Computer to press/direct imaging printing press for waterless offset (Dominant 745C PDI, ADAST/Presstek)

puter to press/direct imaging four-color press *TruePress 544* (format: A3+) was presented by Screen and in 1999 this was followed by a press with a similar design, the *TruePress 742* (two-color printing for the A2+ format range). The three presses mentioned above are in fact in their introductory phase, they nevertheless clearly confirm and underline the trend that printshops want to employ direct imaging technology, to be able to exploit the advantages of generating plates within the press with direct data link-up to prepress. Further models will follow.

In the following, the three newer press concepts are explained. All the presses are based on *offset technology*; from a technological point of view there is the attempt to reduce the number of imaging systems for producing plates for the four-color separations; this is through the design of printing units and dimensioning of cylinders. Additionally the handling of the press should be designed to be as simple as possible through inking unit concepts and automatic plate loading and ejection.

74 Karat

Figure 4.4-13 shows the operating console near the delivery of the direct imaging press 74 Karat. Each plate cylinder of the press can take up two plates, and inking is performed by a keyless short inking unit in waterless offset (fig. 4.4-14). The technical details are described in the following.

It can be seen from the *press diagram* in figure 4.4-14 that only two plate cylinders are used for four-color printing. Two plates are mounted on each of the double-sized plate cylinders. The *two* plates are imaged with the desired image using only *one* laser system in a



Fig. 4.4-13
Computer to press/direct imaging four-color press (waterless offset) with keyless inking unit and two printing plates per plate cylinder (74 Karat, KBA/Scitex)

laser ablation process. Printing is effected in waterless offset. The keyless inking unit consists of an anilox roller and chambered doctor blade system; adjustment of the ink zones is not possible, which places greater demands on the quality of the original and color matching. Through adequate temperature control of the ink form rollers, it is possible to influence the entire ink film thickness slightly. As is shown in figure 4.4-14 the color separations for yellow, cyan, magenta, and black are transferred to the two double diameter blanket cylinders. The plates on each plate cylinder are inked by alternately engaging the two ink form rollers. For example, the cyan form roller is engaged for the first plate when the second plate comes in, the cyan inking unit is disengaged and the ink form roller for yellow is engaged.

The short inking unit shown (short ink train, only two rollers) has the advantage that it can react quickly, which means in principle that there is a better control of the start-up (makeready) waste. The ink supply takes

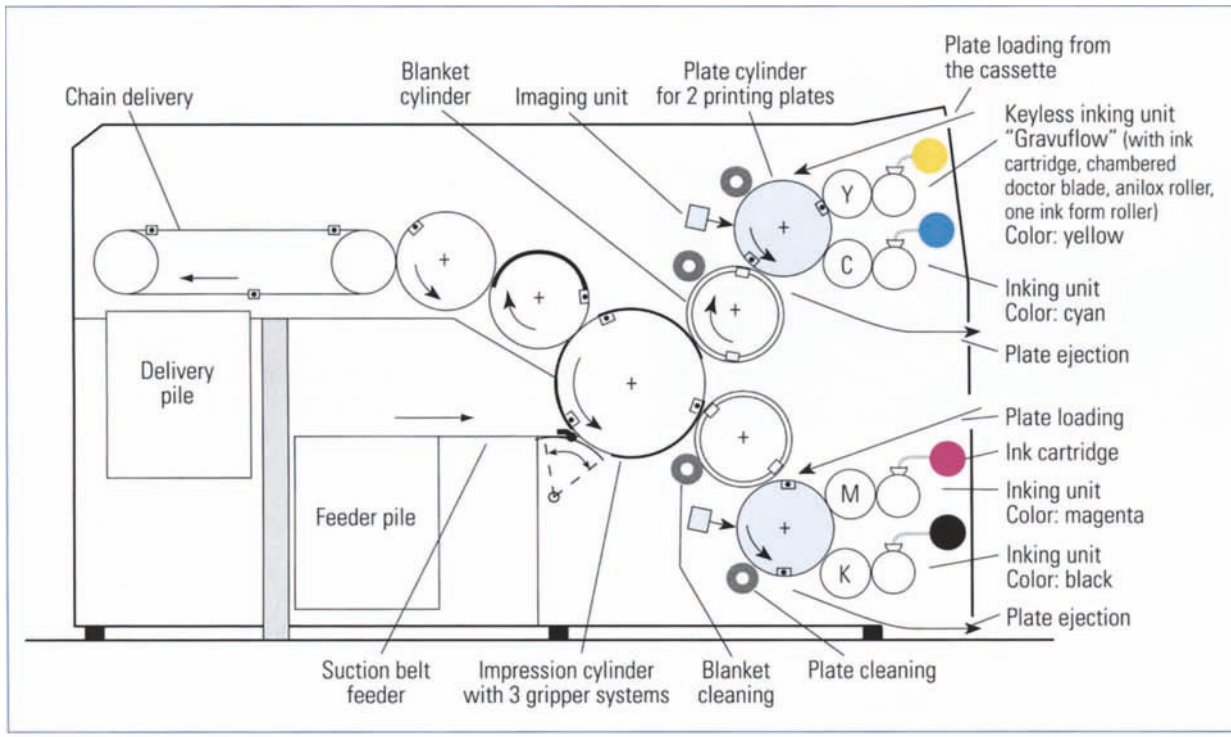


Fig. 4.4-14
Computer to press/direct imaging printing system with two printing plates per plate cylinder (74 Karat, KBA/Scitex, diagram based on various sources, status: 1999)

place via ink cartridges similar to the ones used in conventional sheet offset presses.

The imaging system of the direct imaging press 74 Karat presented in 1997 is a laser system moving axially and having thirty-two beams; imaging can range from 1524 to 3556 dpi (600 dpcm and 1400 dpcm; dpcm: dots per cm). A resolution of 1524 dpi (600 dpcm) is typical. In the case of very high resolutions for reproducing very fine details, a resolution of 2540 dpi (1000 dpcm) is used. The press is designed for A2+ (four-page) format. The sheets pass through the press in "landscape form", that is, the long side of the sheet lies in the axial direction of the cylinder groups, the short side of the sheet moves in the direction of print, which is generally the normal constellation with larger format presses. As shown in figure 4.4-8 the direct imaging press for A3+ format, the Quickmaster DI, prints format A3+ with the sheet passing through in "portrait", that is, the short side of the sheet is in the axial direction to the cylinder and the sheet pass occurs in the longitudinal direction of print; this results in more favorable, larger diameters of cylinders for small formats, and permits a more efficient laser imaging system that stretches over the entire page width.

In the diagram shown in figure 4.4-14 it is illustrated that plate loading and ejection are carried out automatically by means of cassette systems. The plates are imaged through thermal laser ablation; similar plate material is used to that used in the direct imaging presses described above.

The direct imaging press 74 Karat has an output of 10 000 sheets (max. A2+) per hour. The time from the beginning of plate imaging with 1524 dpi to printing/paper run takes about 15 minutes. A print run of 1000 sheets is thus completed in about 30 minutes on the basis of ripped data.

TruePress 544

The TruePress 544 from Dainippon Screen (Screen, for short) is based on a concept where all four color separations for offset multicolor printing are generated with a single laser imaging device.

As shown in the diagram of figure 4.4-15, *imaging at a separate station* is carried out inside the press for each of the two plate cylinders. To do this the plate cylinder is separated from the blanket cylinder and automatically positioned in the imaging station. At this station the plate material is fed into the clamping system of the plate cylinder from a supply roll. The length of plate and the diameter of the plate cylinder are matched in such a way that two color separations fit onto one plate. The plate material is based on polyester having a light-sensitive layer for the wavelength of approximately 633 nm; this requires special wet-chemical develop-

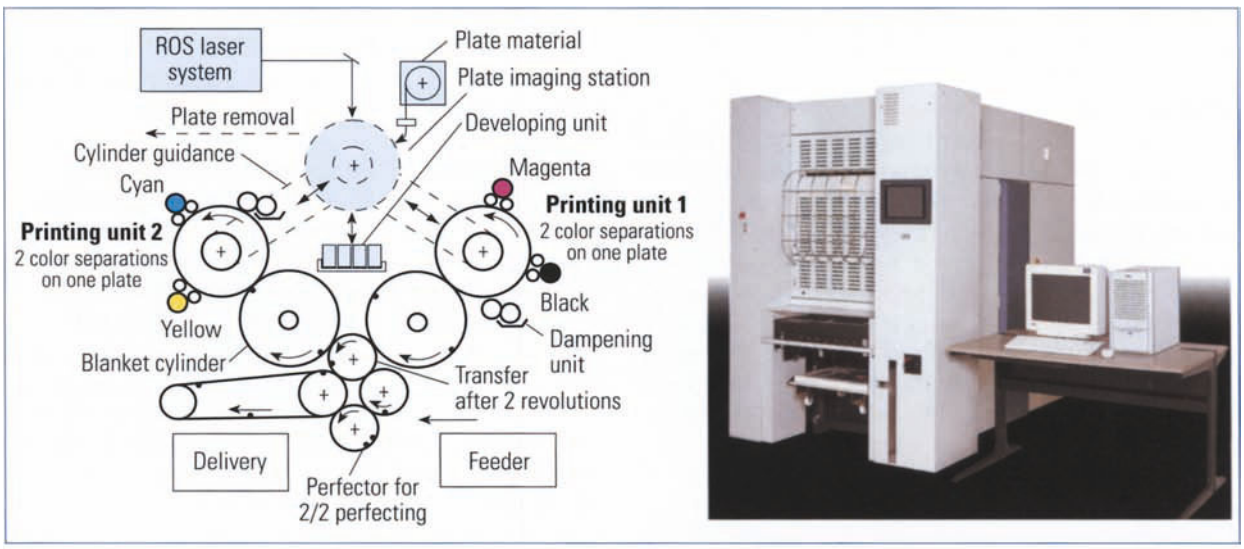


Fig. 4.4-15
Computer to press/direct imaging four-color offset press with two color separations per plate cylinder/printing plate and a central plate imaging station in the press (TruePress 544, Screen; diagram based on various sources, status: 1999)

ment after exposure. The plate material is cut off the supply reel and clamped onto the plate cylinder, then it is imaged using a ROS (raster output scanner; see fig. 5.2-5) laser imaging system. This system images the plate line by line via a fast-turning polygon mirror as the cylinder rotates. The laser imaging can have a resolution of 1000 to 3000 dpi. After imaging, the plate is wet-chemically processed in a developing unit which is moved into the imaging station (see fig. 4.4-15).

Subsequently the plate cylinder is automatically moved to printing position; the second cylinder is moved into the imaging and developing station for the plate exposure for printing the two other color separations. In an automated process the used plate is removed from the imaging station and a new unused plate section is cut off the roll and automatically loaded.

Printing is done in *conventional offset*. Each of the two plate cylinders needs only one dampening unit for dampening the one plate with the two color separations; there must be a controlled engagement and disengagement of inking units.

The press is designed for A3+ (two-page) format. Production speed is 4000 sheets per hour for four-color printing. (If the same master is used in both printing units), 8000 sheets per hour can be printed in two-color. Set-up time from the beginning of imaging to printing is stated as being about 25 minutes. A device for perfecting is planned (two colors per sheet side). This press was presented on the market at the end of 1998.

TruePress 742

At the end of 1999, Screen presented a further computer to press/direct imaging press (fig. 4.4-16). This press is designed for *two-color* printing in A2+ (four-page) format. The concept for the press will be similar to the one shown in figure 4.4-15. For two-color printing only one cylinder group is required, similar to printing unit 2 in figure 4.4-15. The imaging unit is aimed directly at this plate cylinder and the wet-chemical developing system is arranged underneath the cylinder. Imaging is done with a resolution of 1200 or 2400 dpi at a printing speed of 8000 sheets per hour.

Jprint DI

More recent announcements in the market indicate that computer to press/direct imaging techniques are set to be used more and more with sheet-fed presses for four-color and multicolor perfecting. Figure 4.4-17 (diagram, above) shows a sheet-fed press for perfecting without sheet reversal. Here, there are two levels, each having five offset printing units – five units for multicolor printing on the top side of the sheet and five for multicolor printing on the reverse side. The plate cylinders are equipped for laser imaging similar to that carried out with the Quickmaster DI (fig. 4.4-8). The plate material is on reels inside the plate cylinders and imaging is carried out by means of a multibeam laser system moving axially. Plates for conventional offset are used, that is the plates are inked using dampening and inking units.

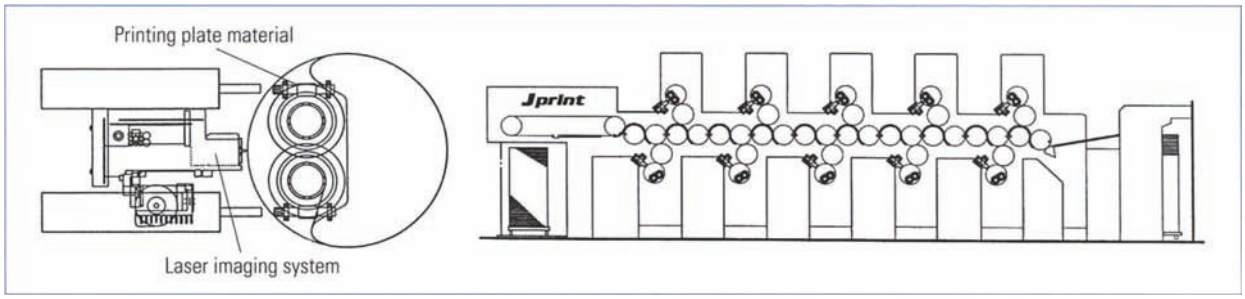


Fig. 4.4-16
Computer to press/direct imaging two-color offset press (with a printing unit similar to the printing unit 2 in the system shown in fig. 4.4-15) (TruePress 742, Screen; status: 1999)

4.4.1.2 Expansion and Comparison of Systems

As has become clear from the preceding explanations, 1991 was the start of an *evolutionary development* in computer to press/direct imaging printing systems. These systems are already in widespread use in numerous companies with varying portfolios of printed products. Several press models are offered, new types have been announced and others are set to follow. The presses are focused on *multicolor printing* in higher quality. *Print formats* mainly still focus on A3+ (two-page) formats. Presses for the larger A2+ (four-page) formats are still in their infancy and they will be used more and more in connection with the ever expanding technology of prepress to image jobs in digital form.

With the exception of TruePress from Screen, with computer to press/direct imaging, *thermally imaged*



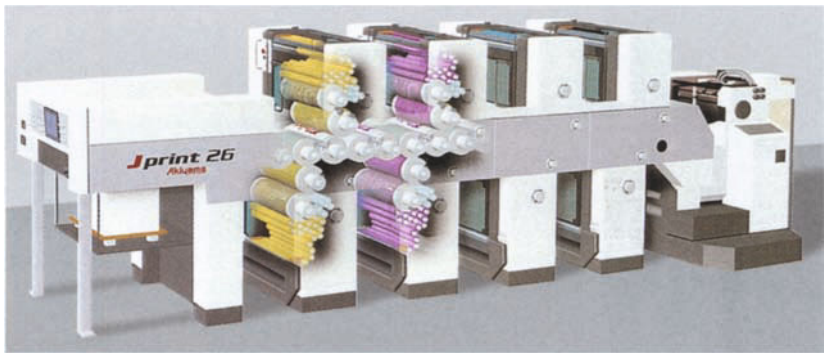


Fig. 4.4-17
Direct imaging multicolor sheet-fed offset press for printing both sides (perfecting) with laser imaging (Jprint DI, Akiyama/Presstek; announced: September 1999)

plates are used that, for the most part, work with *waterless offset processes*. However, thermal plates for conventional offset printing are also available.

Multi-functionality of the printing system is particularly important in the case of larger format presses, where the investment costs are correspondingly higher. This means that the press design must enable both conventional and waterless offset and must also be able to use plates that can be produced off-line by means of computer to plate or conventional platemaking methods. This ensures an economically efficient employment of high-grade capital goods such as a large-size multicolor offset press.

Table 4.4-1 gives an *overview of the technical specifications* for the printing systems described above that are already available on the market, or that are in launch or field test phases.

Due to the expenditure required for laser and imaging technology in each printing unit in a multicolor press equipped with laser imaging technology, the manufacturers are concentrating on the development of small- and medium-format presses (format range: A3+, A2+). These printing systems are designed for the production of short print runs (medium *run length* typically of about 1000 prints, cost comparisons with computer to print systems are favorable for job sizes greater than 300 copies in addition to the better printing quality resulting from the printing process).

Although direct imaging presses are mainly used for short to medium print runs, the available plate materials permit print runs of up to about 20000 copies. This feature increases the flexibility of computer to press/direct imaging systems.

New Types of Plates for Direct Imaging

The development of further computer to press/direct imaging printing systems goes hand in hand with the availability of innovative plate systems offering easy handling during imaging that are also less expensive (see also sec. 4.3.9). With thermal plates, where the ink-accepting (oleophilic) layer is stripped by *laser ablation* and for which no chemical developing is required, yet where the fine, loosened particles resulting from this thermal ablation process have to be cleaned off, cleaning is carried out using a liquid with plate contact. Nowadays, times required for cleaning and for imaging are about the same. Special efforts should therefore focus on the development of plate materials where the cleaning process can be considerably shortened or even eliminated.

Asahi Chemical Industry has announced the development of such a plate. The principle of this new plate

	GTO-DI/Laser (Heidelberg)	QM DI 46-4 (Heidelberg)	Dominant DI (Adast)	74 Karat (KBA/Scitex)	SM DI 74 (Heidelberg)	TruePress 544 (Screen)
Format/Orientation	A3+/landscape	A3+/portrait	A2+/landscape	A2+/landscape	A2+/landscape	A3+/landscape
Printing speed (sheets/h)	8000	10000	10000	10000	15000	4000 (8000, 2 colors)
Offset process	waterless	waterless	waterless	waterless	conventional (and waterless)	conventional
Press design (number of printing units)	unit design (4–5)	Satellit (4)	unit design (4–5)	2 plates/ plate cylinder	unit design (4–6), perfecting 1/4 or 2/4	2 plates/pl.cyl. perfecting 2/2
Inking unit (ink fountain zones)	conventional (16)	conventional (12)	conventional (20)	keyless ("Gravuflow")	conventional (23)	conventional (12)
Plate base material	Aluminum	Polyester	Aluminum	Aluminum	Aluminum	Polyester
Resolution (dpi)	1270.	1270/2540	1016/2540	1542–3556	up to 2400	up to 3000
Pixel size on plate	∅ approx. 30 µm	∅ approx. 30 µm	∅ approx. 30 µm	∅ approx. 10 µm up to 24 µm	approx. 11 µm × 11 µm	∅ approx. 12 µm
Imaging system	16 IR laser diodes (large width array)	16 IR laser diodes (large width array)	32 IR laser diodes (large width array)	32 Beam IR laser scanning head	220 Beam IR laser scanning head	ROS: laser beam scanning system (633 nm)
Plates ready for print in:	approx. 20 min.	approx. 10 min.	approx. 20 min.	approx. 15 min.	approx. 12 min.	approx. 24 min.
On the market since (presentation/ launch in):	1993 [to replace GTO-DI/Sparc]	1995 [to replace GTO-DI]	(1996), 1997	(1997/2000)	(1998), 1999	(1998/2000)

Table 4.4.-1 Comparison of computer to press/direct imaging printing systems for multicolor sheet-fed offset printing (status: 1999)

type is shown in figure 4.4-18. The plate is coated with a material system in which *microcapsules* are embedded in a polymer. When imaged using infra-red radiation these microcapsules release a substance that triggers a chemical process. The areas of the offset plate imaged in this way change their surface property from ink-repelling to ink-accepting (see also table 4.3-10).

This and similar plate concepts will certainly contribute to the expansion of direct imaging printing systems. They will naturally also positively influence the use of computer to plate equipment for digital production (off-line) of plates by avoiding chemical and mechanical cleaning processes. The development and supply of "*truly processless*" plates, where neither development nor separate cleaning is necessary, is a challenge for plate manufacturers and at the same time a requirement of printing companies. This is because the setup times for production of the print runs become shorter with these plates, and the production process is safer and friendlier to the environment and resources. In total this leads to a better cost structure and success for all partners in the printing industry, especially for the users of print media.

This brief discussion about plate materials also leads us to the topic of computer to press/direct imaging with *re-imageable plates or surface systems*. This should make it possible to prepare the subsequent job without changing the plate. To do this the previous printing image would have to be erased and the neutralized surface imaged with the information for the next print job. As was described before, this should take place without any additional cleaning. Concepts referring to this method are described in the following section 4.4.2.

Direct Imaging for Screen Printing

The computer to press/direct imaging printing systems described previously focused on offset printing. This was for technological and economic reasons. On the

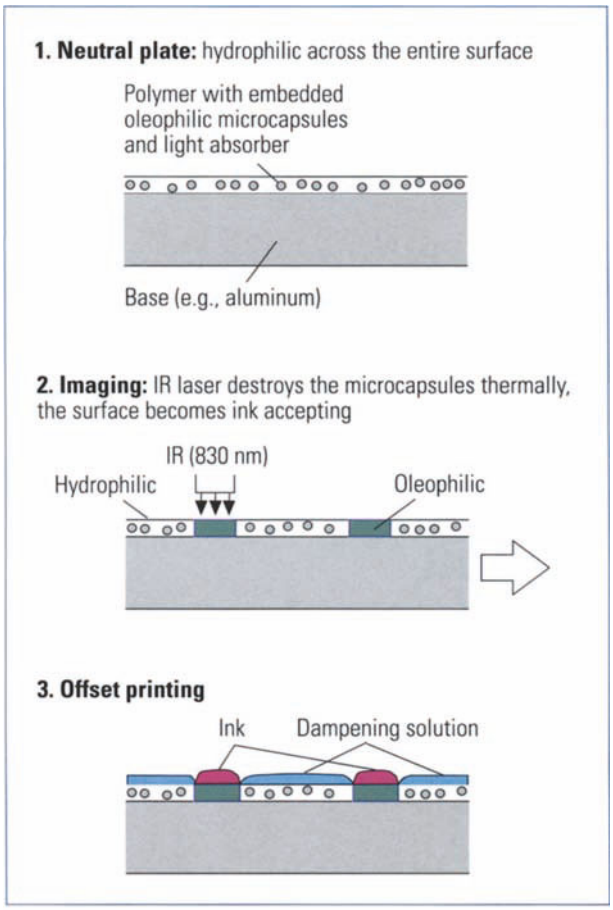


Fig. 4.4-18
Functional principle of a processless thermal offset plate for computer to plate or direct imaging printing systems (Thermal CTP, Asahi Chemical Industry)

technical side this has to do with the quality requirements for multicolor printing and with the fact that the provision of plates for computer to plate systems is focused on offset printing technologies (applications for flexographic and gravure printing are in preparation). The profitability of these digitally imageable plates goes hand in hand with the propagation of digitally imageable plates in offset printing. This leads to a correspondingly large market volume and thus to a reduction of manufacturing costs.

It was about 1988 when systems (so-called stencil printers) were first introduced by RISO from Japan, in which the stencil is produced using direct imaging technologies. Printing systems based on this are available nowadays on the market for single-color printing and for printing in special colors (spot colors).

Processes and printing systems are shown in figure 4.4-19. The stencil material is kept on rolls inside the press and is imaged by a thermal imaging head. Openings are burned into the stencil material in accordance with the image. Nowadays, there are thermal imaging systems available for this with which the image carrier/stencil can be imaged across the whole width of the page (e.g., 310 mm) with a resolution of 600 dpi. The attainable quality for single-color prints is very high, yet these systems are not in use for high quality multicolor prints. For prints with special colors, cartridges containing the respective ink are used. The printing process described in figure 4.4-19 is a direct imaging rotary screen printing process. The thermally imaged stencil is automatically mounted on a cylinder (screen). The ink is fed from the interior of the cylinder through the openings of the stencil onto the substrate (see also sec. 2.4.3.3). Ink feeding takes place via cartridges.

Printing systems for the A3+ (two-page) format are available (fig. 4.4-20b). Printing speeds are about 60 A3 sheets per minute. Several special color tones are offered. Printing systems for halftone multicolor printing in high quality are not yet available. For imprinting one or several special colors, the whole screen printing unit is generally exchanged. Additional information or creative image elements are imprinted in the special color during a new sheet pass of the preprinted sheets. Figure 4.4-20a shows a direct imaging screen printing system in a workflow for generating printed products.

4.4.2 Computer to Press/Direct Imaging Printing Systems with Re-imageable Master

The flowchart in figure 4.4-21 describes the sequence for processing several print jobs when the surfaces of the plates used permit a *permanent storage of the image* which is *erased again after completion of the job*, that is, neutralizing the plate and re-imaging it for the next job.

Figure 4.4-21 also shows a comparison with computer to press/direct imaging where the plate has to be replaced after each print job. It also shows the contrast to computer to print where the master (e.g., electrophotography) must be imaged again after the printing of each sheet.

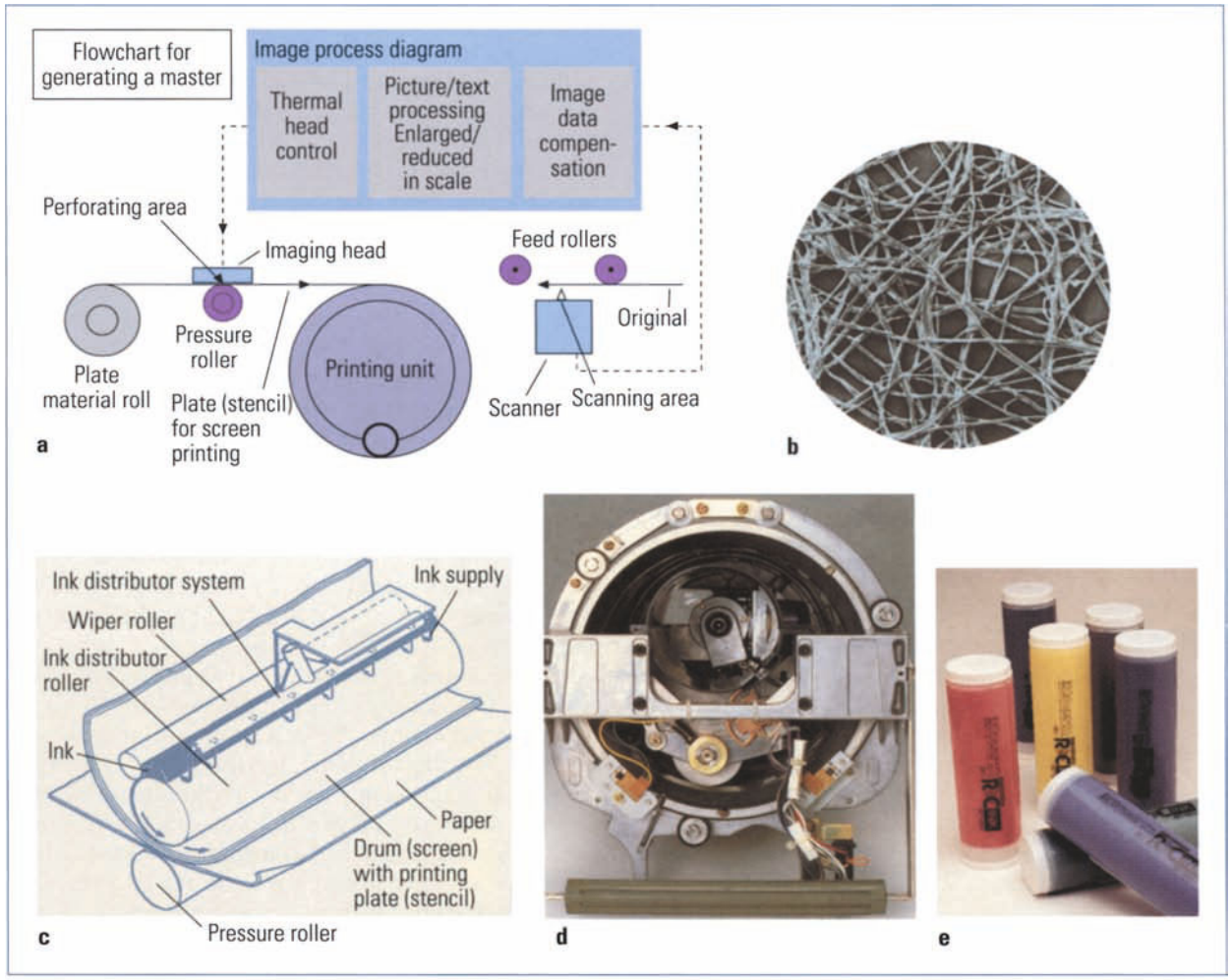


Fig. 4.4-19 System concept and functional components for computer to press/direct imaging screen printing systems.
a Concept of direct imaging screen printing system (stencil printer) as per fig. 4.4-20;
b Fiber structure of the stencil material;
c Principle of rotary screen printing;
d Design structure of the printing unit (ink drum);
e Ink cartridges (RISO)

The fascination of computer to press/direct imaging with re-imageable masters is that material consumption is reduced, change-over times and workflow from one job to another could be shortened and, at the same time, an identical master is available for the entire print run ensuring consistent printing quality. For computer to print systems based on non-impact printing technologies with imaging surfaces, the image must be newly generated for each print, even if identical prints are to be produced. This can lead to more or less visible fluctuations in the printing quality from one print to another.

Figure 4.4-22 shows a further illustration for comparison of the computer to press process variants together with an evaluation regarding efficiency, quality, and typical fields of application. This comparison refers to relatively early attempts and first ideas for direct imaging technologies with image carriers which,

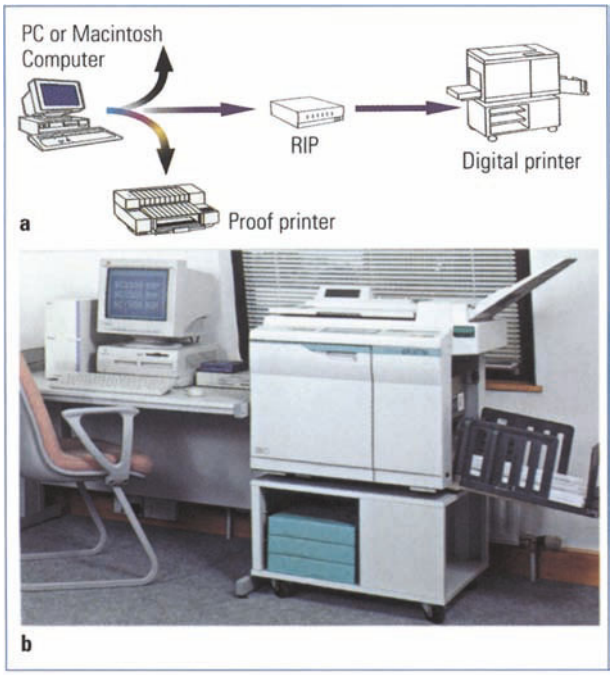


Fig. 4.4-20 Computer to press/direct imaging in screen printing.
a Workflow;
b Printing system (Risograph GR 3770, RISO)

on the one hand, have storing characteristics for the printed image and, on the other, can be deleted. In the following section the processes are described in detail. Additional variants and possibilities are detailed.

The term "*switchable polymer*" is frequently used in connection with re-imageable plates. This term is explained in figure 4.4-23. "Switchable" refers to the fact that the surface properties of a material can be switched from one state to the other for printing. In reference to the offset technology, this means that a surface that in its basic state is water-accepting, hydrophilic, and as such ink-repelling (oleophobic) can, for example, be "switched" into another state in respect of its interfacial physical characteristics by certain physico-chemical influences. The oleophobic surface is turned into an oleophilic surface, that is, ink-accepting surface. The vital point is that this state is permanently stored in the material and the entire print run can be produced with the same quality without any visible disturbances in the printed image. The printed image of the plate can be deleted after completion of the job, that is, it can be brought back to the original. This erasing process can again be obtained by physico-chemical effects. The interfacial physical transition now takes place, for example, from the oleophilic (ink-accepting) state back to the oleophobic (ink-repelling and accepting dampening solution) initial state. Thus the conversion processes must be reversible. The surface properties must be switchable. At the same time, other materials instead of polymers can be used and the term "switchable polymer" can therefore be misleading.

Material properties determine this erasing, re-imaging, and storing behavior of the material, yet they also determine the useful life of a printed image for the production run as well as the number of possible cycles for deleting and re-imaging the material.

It should be pointed out that the material properties and the imaging system must be coordinated, that is, the physico-chemical processes within the plate are released by different physical effects when imaging. Thermal, electric, or ionographic imaging can therefore take place, but so can a multistage process with application of material such as the thermo-sublimation of certain inks on the plate or application of material via an ink jet system and subsequent image fixing.

Given this background, it is possible to distinguish between processes, materials, and imaging systems where the master is either imaged by *application/removal of material, or without application of material solely via interfacial physico-chemical effects* with reversible deletability and rewritability.

So far (early in 2000) there is no system for computer to press/direct imaging with a re-imageable plate on the market/used in practice. However, intensive research and development is being carried out. Published patent applications clearly indicate this, individual technology presentations from laboratories have been published, and contributions in meetings confirm this (e.g., [4.4-1 to 4.4-3]).

4.4.2.1 Concepts for Re-imageable Masters with Material Application/Ablation

Offset Platemaking by Means of Thermal Transfer

DICOweb Litho. Figure 4.4-24 shows how a plate suitable for offset printing is fused on the metallic surface of a plate cylinder by thermally transferring a suitable polymer. The polymer material, stored on a roll, is fused on the metallic cylinder surface by a thermal laser to create the *image* via laser ablation (fig. 4.4-24a). Depending on the laser imaging head, the image can be

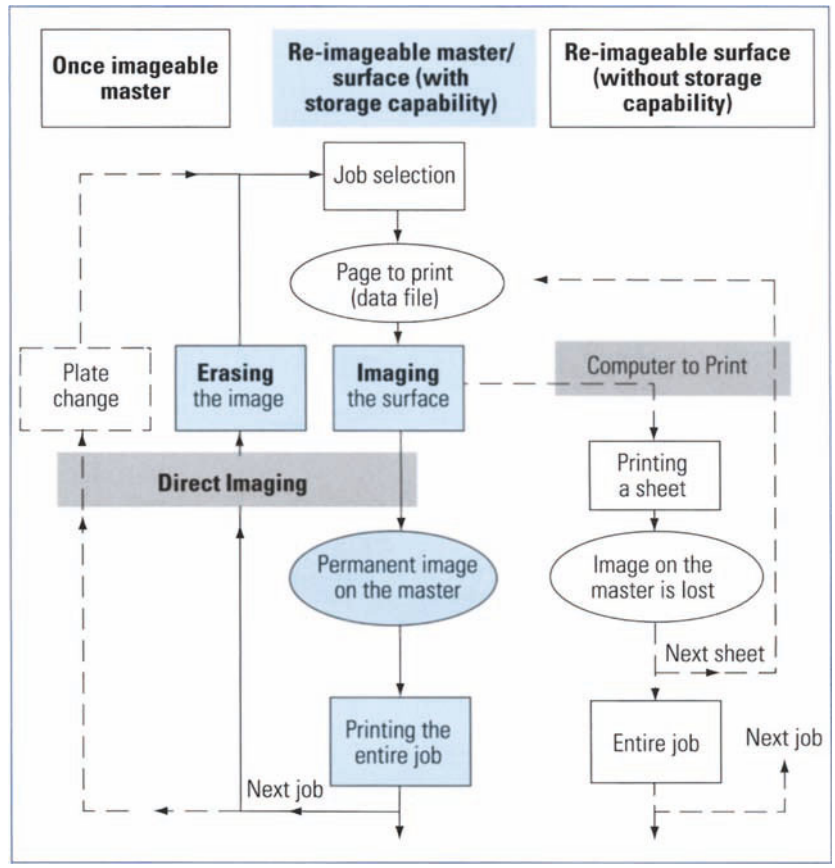


Fig. 4.4-21
Properties of the printing plate/master and process stages with computer to press/ direct imaging and computer to print technologies

burned in, e.g., by 64 beams simultaneously, at a resolution of up to 2400 dpi. While the cylinder rotates, the plate is imaged across the entire press width through axial shifting of the imaging system and the storage unit for the polymer material (width of the ribbon material about 15 mm).

After the imaging process the material is fixed on the cylinder by supplying heat (e.g., hot air, 150 °C).

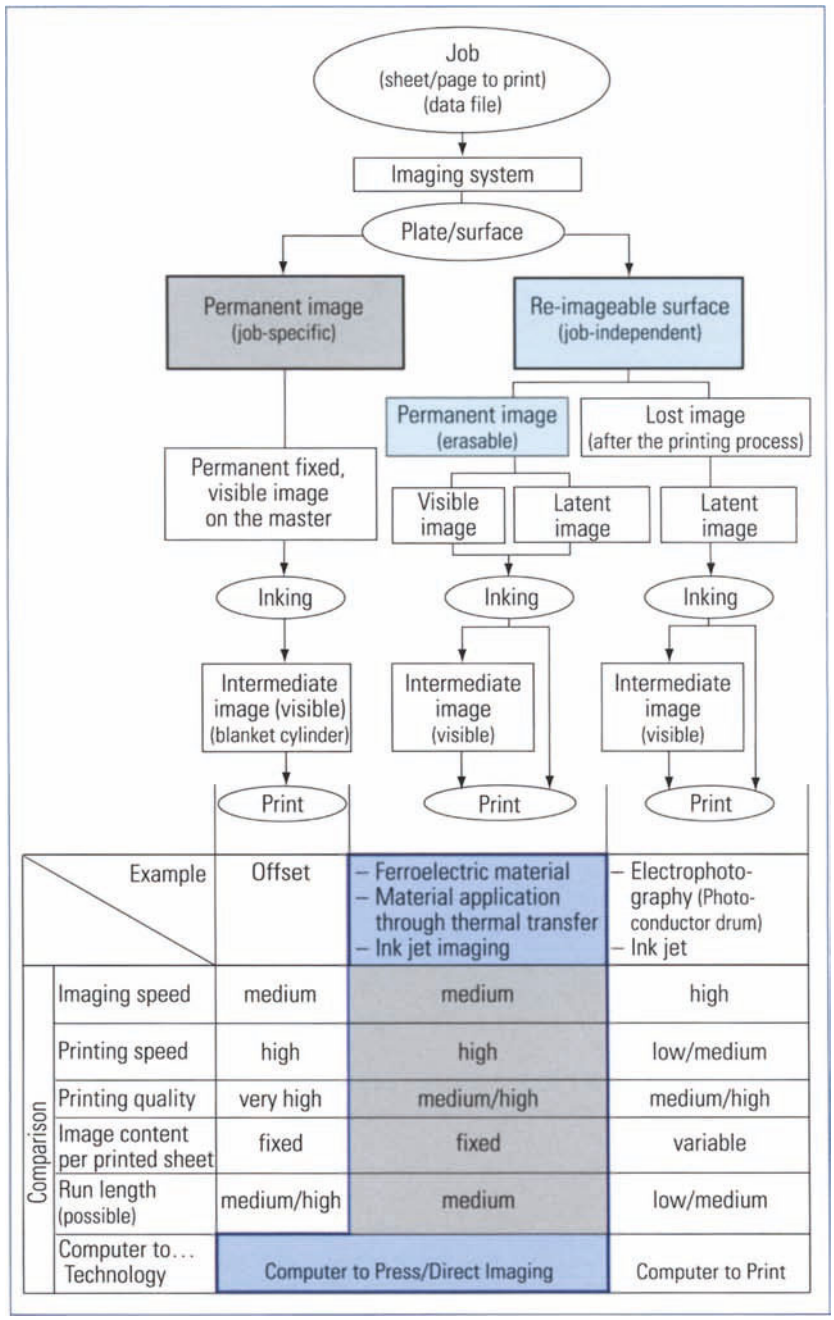
One such master (imaged plate cylinder surface) is used in the printing unit illustrated in figure 4.4-24b where the image is printed in a web offset process (dampening and inking via the blanket cylinder) on the paper web.

After the print job is completed the ink-accepting polymer material is removed from the cylinder surface in a chemical and mechanical *cleaning process*. After this cleaning process the water-accepting/hydrophilic base cylinder is neutralized and ready for imaging the next job.

The difficulties here are the basic material properties of the base cylinder required for offset printing, the stability and quality of the ink-accepting surface areas that are thermally transferred to the base cylinder, and the additional equipment needed within the offset printing unit.

Figure 4.4-25b shows *a two-stage thermal transfer* process for comparison with the process (direct thermal transfer) described above where the imaging process takes place inside the press (fig. 4.4-25a). In this case the transfer material is imaged in a special imaging system and several jobs can be prepared one after the other on the roll material (similar to computer to film equipment using internal drum or capstan imagesetter design). The material roll with the prepared image(s) can now be stored in the press on a cassette and thermally transferred onto the metal surface of the neutral plate cylinder. This means that the press only needs a cylinder-wide heat source for material transfer

Fig. 4.4-22
Printing plates/surfaces with varying storage capabilities and visibility of the image on the plate/master for computer to press technologies



	Example	Offset	– Ferroelectric material – Material application through thermal transfer – Ink jet imaging	– Electrophotography (Photoconductor drum) – Ink jet
Comparison	Imaging speed	medium	medium	high
	Printing speed	high	high	low/medium
	Printing quality	very high	medium/high	medium/high
	Image content per printed sheet	fixed	fixed	variable
	Run length (possible)	medium/high	medium	low/medium
	Computer to... Technology	Computer to Press/Direct Imaging		Computer to Print

as opposed to the laser system required for the direct thermal transfer. The corresponding fusing/fixing and cleaning units are illustrated in figure 4.4-24a. (In principle the transfer material can be imaged inside the press using a special module, yet off-line imaging would probably be more advantageous.)

Figure 4.4-25c shows the diagrammatic view of a test installation in which both thermal transfer processes

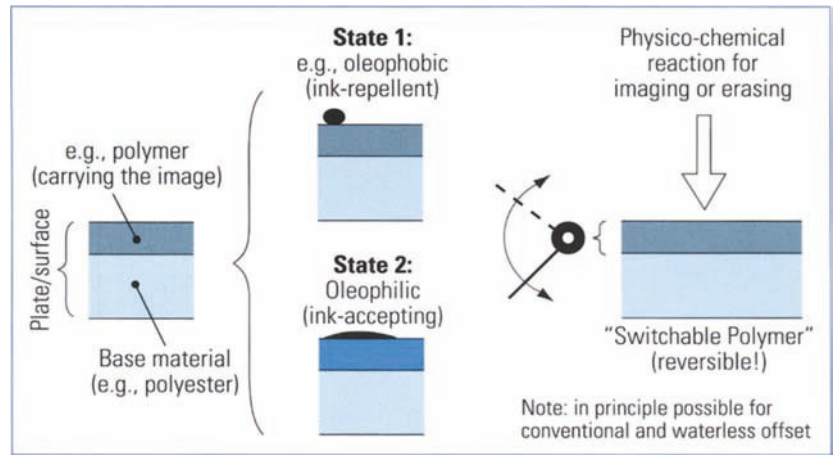


Fig. 4.4-23
"Switchable Polymer", change of the interfacial physical properties of the plate surface by reversible "switching" by means of adapted imaging and erasing systems for offset printing

are tested and further developed. This diagram corresponds to the printing system shown in figure 4.1-6 for the technology presentation in 1995 of the DICOweb Litho system (Digital Change-Over for lithographic, offset printing technology) from MAN Roland.

Gravure Cylinder Production through Ablation

DICOweb Gravure. As described in sections 1.3.2.2 and 2.2.1, in the gravure printing process the ink fills cells that are engraved into the gravure cylinder in accordance with the image and is then transferred onto the paper by means of the impression roller/cylinder. In contrast to offset presses the printing unit technology of rotogravure presses is of a relatively simple design, yet the manufacture of the gravure cylinder is time-consuming and cost-intensive. The attainable printing quality is of a very high standard. In particular the high manufacturing costs for gravure cylinders explain why gravure printing is only used for very long print runs (in the range of millions).

Figure 4.4-26 shows a technology that might also make gravure printing profitable for shorter runs and enable practical computer to press/direct imaging systems for gravure printing.

Figure 4.4-26a shows how a *polymer is filled* into an evenly *engraved gravure cylinder* (e.g., with 70 cells per cm, or 178 dpi, which means a cell spacing of about 140 µm). A blade is used to attain an even surface with bared cell walls. The polymer hardens in the cells and is partly evaporated in accordance with the printing image using a *thermal laser*. Smaller cells of varying volume originate within the given cell structure. Resolutions of about 1200 dpi can be achieved with this method; due to the varying cell depths, that is, varying filling volumes, several tone values per pixel can be generated, which enables a correspondingly higher quality in the color image.

To *erase* the image on the gravure cylinder a *high pressure water jet* (fig. 4.4-26a) is used that washes out the polymer from the cells. The base structure of the gravure cylinder is revealed again and the polymer for imaging the next print job can be applied again by the *filling equipment*.

The technical realization of such a printing unit is shown in figure 4.4-26b. The basic components include a polymer filling system, a thermal laser imaging unit, a chambered doctor blade system to supply the ink, and a device for erasing the image by means of a high pressure water jet. The gravure printing process in the example shown is an *indirect gravure printing* process where the image is transferred to the web via a transfer cylinder (with rubber coating).

As in the case of the DICOweb Litho, the DICOweb Gravure test installation was presented to the public in 1995. The printing system and press diagram are illustrated in figure 4.4-27.

Platemaking by Applying Material in an Ink Jet Process

An obvious approach is to coat an *uncoated aluminum offset plate* (as used in conventional offset) with ink-accepting image segments using a non-impact imaging system. A possible solution is ink jet systems using a *special ink* such as a hot-melt ink suitable for offset printing. In the ink jet process this ink is applied to the hydrophilic, electrolytically oxidized surface of the offset plate for imaging. The cooled ink cures on the plate

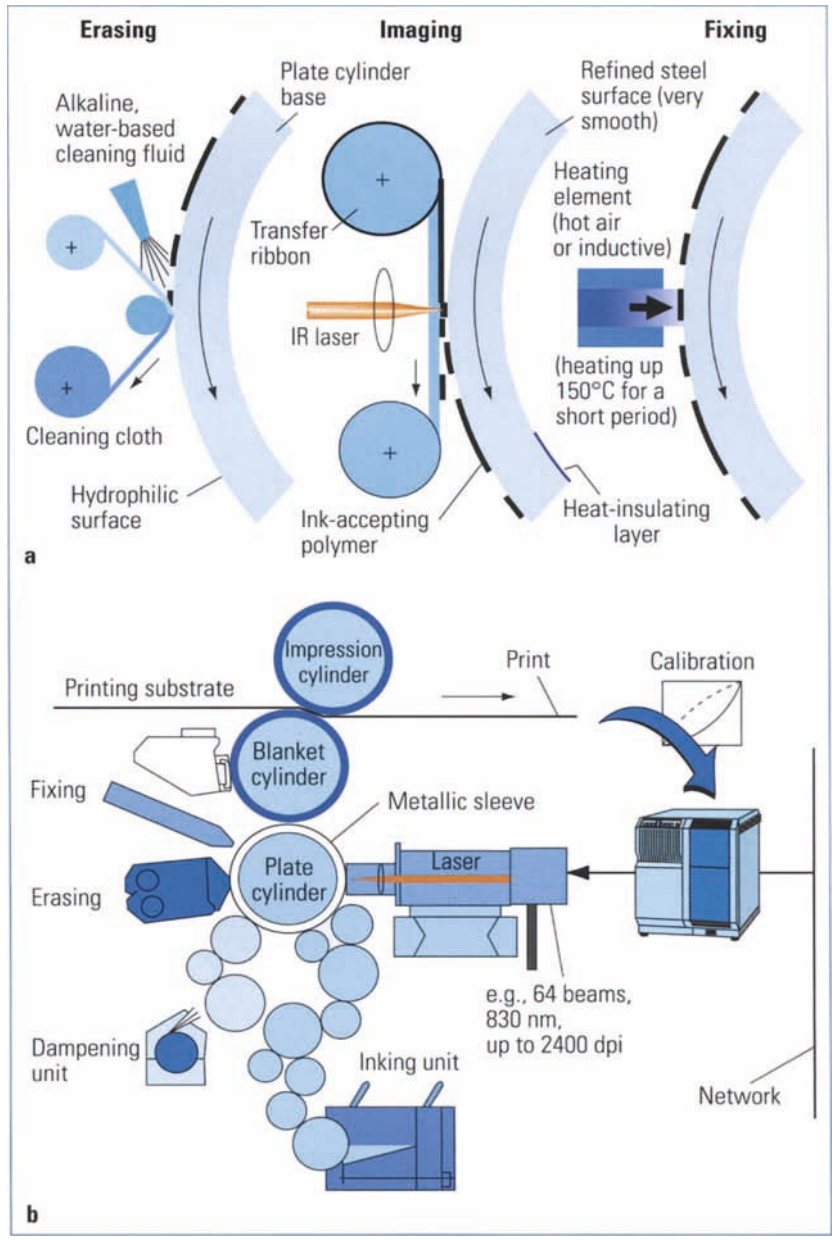


Fig. 4.4-24
Computer to press/direct imaging offset with re-imageable plate.
a Stages in the process: erasing, imaging, fixing;
b Web offset printing unit with components for imaging and erasing the plate (DICOweb Litho, MAN Roland)

surface. In order to achieve more stability and longer running times, it might need to be fixed through heating or other physico-chemical processes.

Section 4.3 also dealt with computer to plate systems based on ink jet processes. Such a system, where offset plates are made off-line, is illustrated in figure 4.4-28. Computer to press/direct imaging systems based on ink jet imaging means that the offset printing unit is equipped with this sort of system.

Setting up such a direct imaging system with re-useable plates means that the *ink-accepting layer must be removed* from the plate after completion of the print job. The basic difficulties in implementing this include developing a system with which the surface can be cleaned

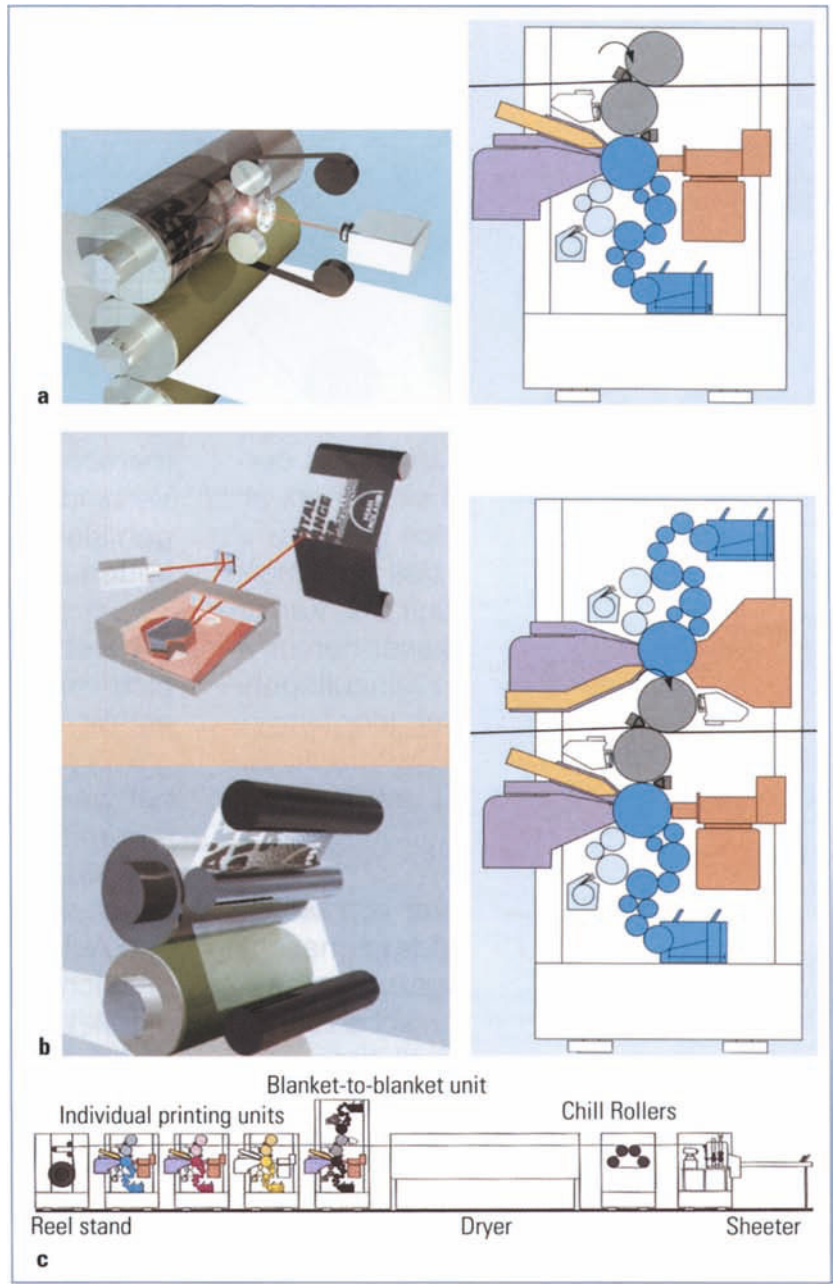


Fig. 4.4-25
Imaging systems for computer to press/direct imaging with re-imageable offset plate cylinder.
a Principle of thermal transfer of ink-accepting material to the metal cylinder and printing unit diagram of a lab prototype;
b Principle for two-stage thermal transfer with external imaging on webs with subsequent in-line transfer to the plate cylinder for offset printing and diagram of the printing unit of a lab prototype;
c Schematic drawing of the test press (lab prototype) in accordance with fig. 4.1-6 (DICOweb Litho, MAN Roland; status: 1995)

economically. At the same time the hydrophilic, water-accepting properties of the plate base must remain intact.

It is to be expected that research and development efforts will involve the development of new types of ink jet inks and plate surfaces suitable for offset, to bring this technology closer to reality.

Platemaking with Magnetography and Toner Application

Magnetography as a variant of the non-impact printing technologies is described in section 5.4. Here, a magnetic pattern is applied to the imaging cylinder in accordance with the image. The magnetic fields at-

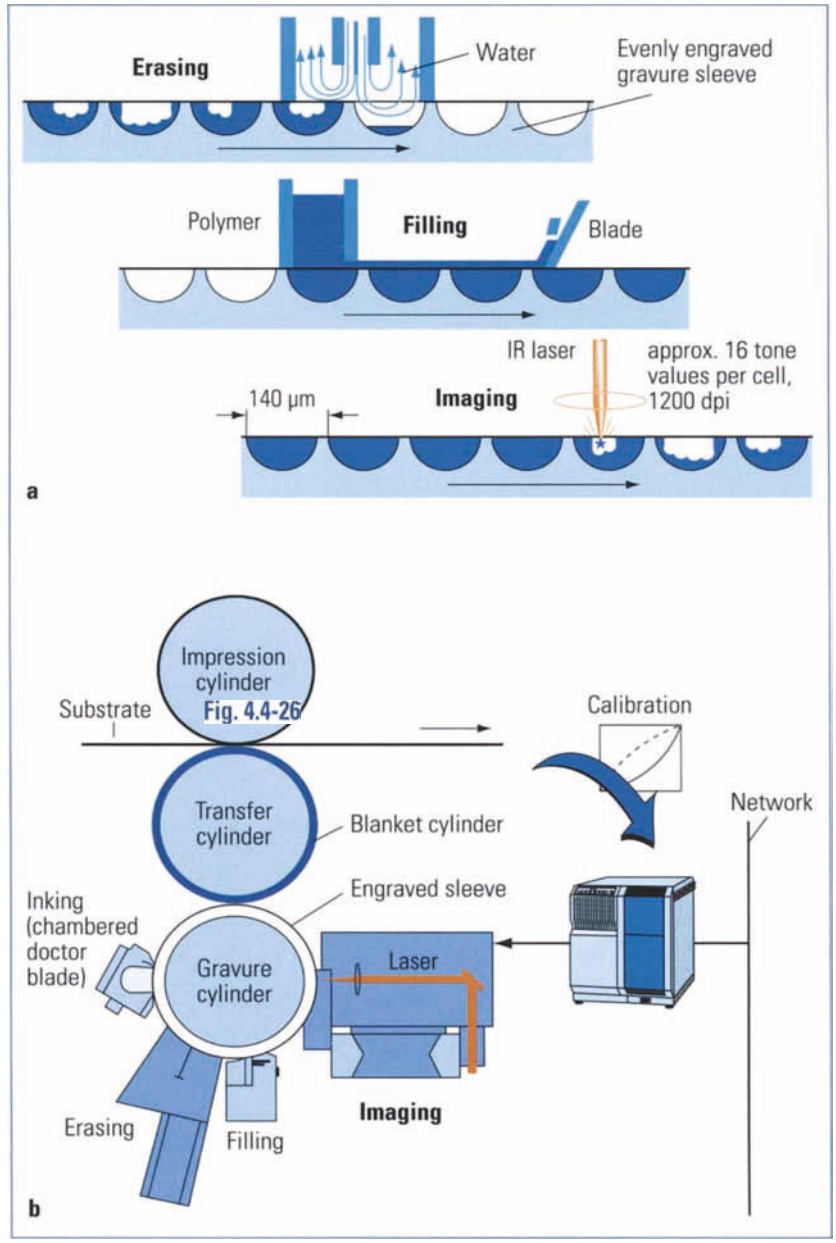


Fig. 4.4-26
Computer to press/direct imaging gravure printing system.
a Stages in the process: erasing, filling, and imaging;
b Printing unit for indirect gravure printing with erasing and imaging systems (DICOweb Gravure, MAN Roland)

tract ferrous magnetic powder toner particles via a special inking unit, and the particles are then transferred onto the paper. In principle the magnetography imaging drum is capable of storing a magnetic pattern generated on the surface so that images with the same image content can be printed on paper without re-imaging. In working practice this variation has not yet been put into action, since the circumference of the imaging cylinder is generally smaller than the image-length, but above all because the magnetic pattern is not sufficiently stable to ensure constant print quality.

Figure 4.4-29 shows a concept of generating a plate suitable for offset printing on the basis of the imaging

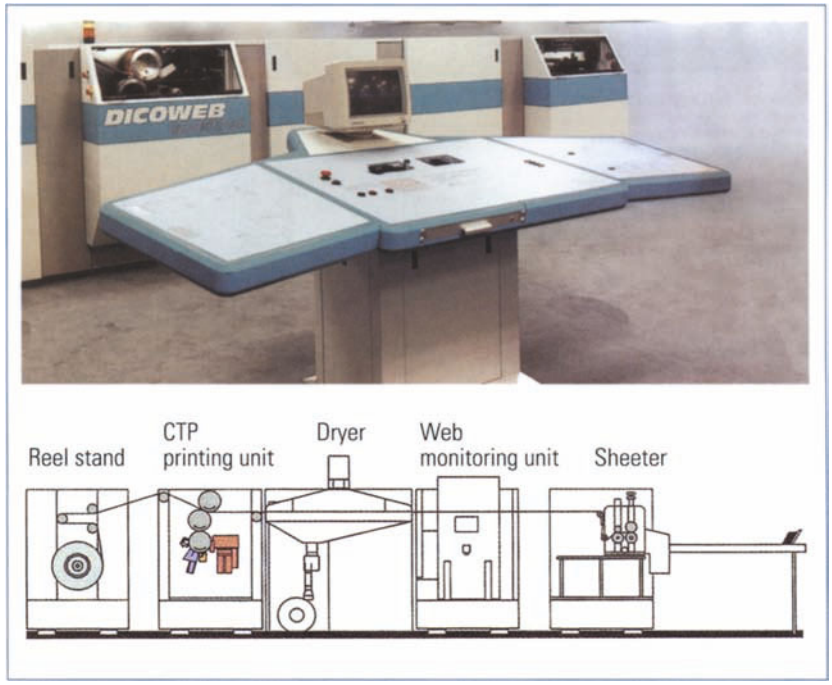


Fig. 4.4-27
Lab prototype for computer to press/direct imaging gravure printing system with re-imageable master (DICOweb Gravure, MAN Roland)

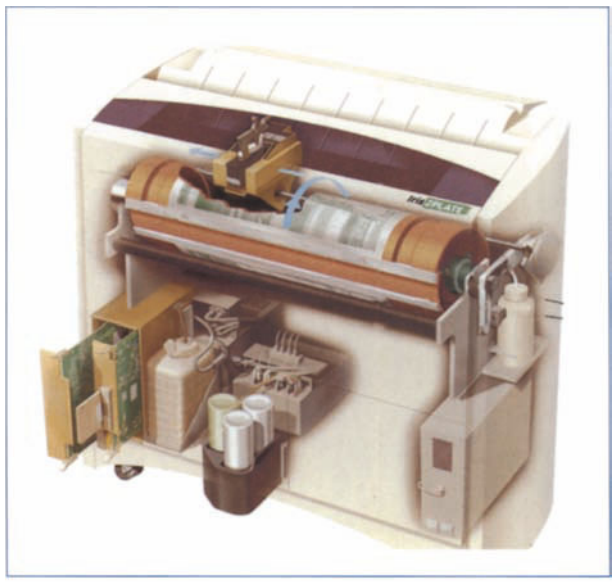


Fig. 4.4-28
Computer to plate equipment for making an offset plate with ink jet imaging technology (IRIS 2 Plate, Scitex/IRIS)

cylinder with its hard metallic surface. The magnetographical imaging occurs via an imaging system with micro-magnet heads (fig. 4.4-29a). Then the magnetic toner is applied, which is fused in order to attain a permanent image. The materials on the imaging cylinder surface and the fused toner have to be conditioned so that they are suitable for offset printing, that is, the image is transferred via the blanket cylinder onto the paper using dampening solution and inking up with offset inks. The illustration does not include the cleaning equipment, which must basically consist of mechanical and chemical cleaning components in order to remove the fused toner. Nipson, a leading company in magnetographic printing, calls this concept/technology "*Magnetolithography*." Figure 4.4-29b shows the individual process stages as they occur in a direct imaging offset press (the erasing process is not included). This approach has so far got no further than the laboratory phase, although awareness of it has increased through reports at technical conferences.

Generating Re-imageable Offset Printing Plates using Photo-Electrolytic Effects

Figure 4.4-30 shows a schematic diagram of a photoelectrolytic platemaking process of an offset plate.

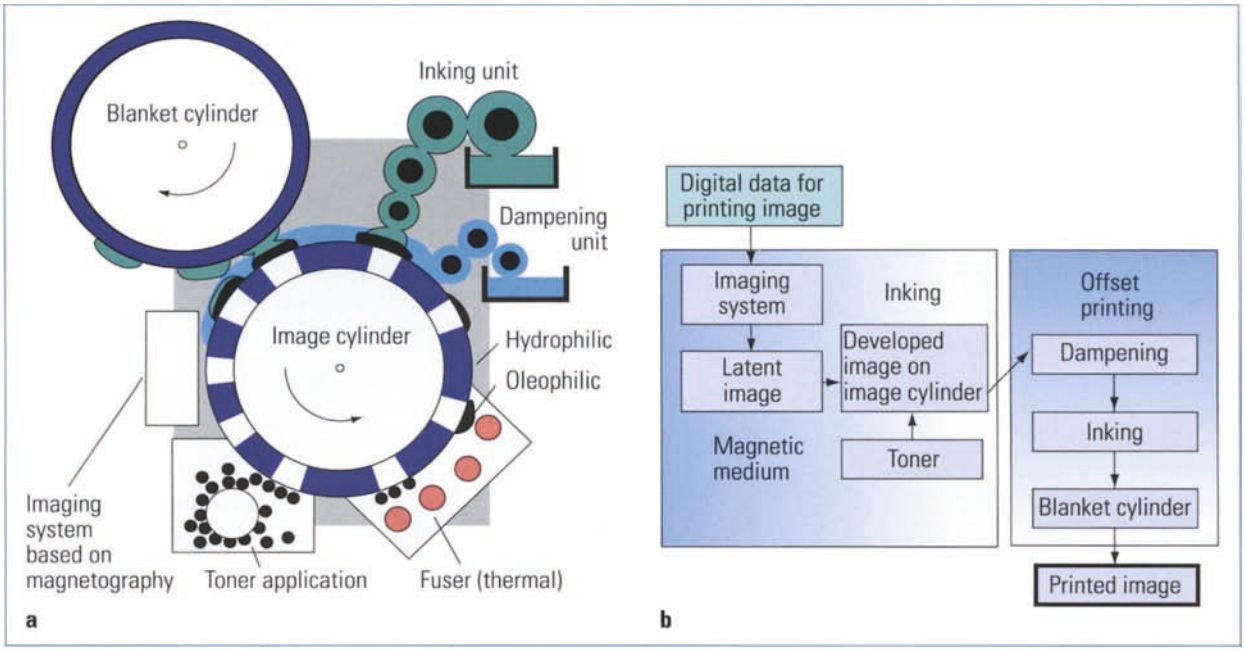


Fig. 4.4-29 Magnetolithography: concept for imaging an offset plate through magnetic fields, powder toner, and heat fusing.
a Principle for platemaking (erasing system is not shown);
b Block diagram for a direct imaging system with magnetolithography (NIPSON)

The plate cylinder is coated with nickel oxide. This nickel oxide has semiconductor properties and becomes conductive through light, and is coated with a liquid electrolyte containing copper ions. The copper ions are deposited in an image-wise pattern in connection with imaging via a laser light source. The base cylinder surface is hydrophilic, the copper oleophilic. In this way a suitable surface is created for offset printing.

Decoating the cylinder surface for erasing the image can occur on an electro-chemical basis, simply by means of voltage reversal. This means that the copper is separated from the cylinder surface and remains in the electrolyte bath.

The structure of an offset printing unit based on this imaging and erasing principle is described in figures 4.4-30b and 4.4-30c shows the first public presentation in a web offset test installation (although the offset plate was imaged outside the press). In this case it is designed as a sleeve and can be slipped onto the base cylinder, supported by air pressure coming out of the base cylinder.

Without a doubt this is an interesting technological approach, but here too, the problems lie in the realization of an appropriate cylinder surface on the basis of the semi-conductor effects and in the system for the electrolyte application and the imaging.

In-line Coating of the Printing Plate

Concepts have been in discussion for a long time that involve coating of the printing plate processes inside the printing unit to set up re-imageable printing systems.

Corresponding to the extract from a patent document (Creo), figure 4.4-31 describes how the ink-accepting surface of a special image carrier material is transformed into a hydrophilic ink-repelling state by means of laser exposure, and an offset printing plate on a hydrophilic base is produced. Through the subsequent dampening and inking, the polymer can be ablated in the exposed areas of the plate.

After completion of the print job the imaging layer must be removed in a mechanical and chemical process (fig. 4.4-31d). The "switchable polymer" must be applied in an in-line process, e.g., sprayed on as shown in figure 4.4-31e.

In addition to this patented method there are also concepts from the patent applicant in which a major ablation and re-application of material is not necessary

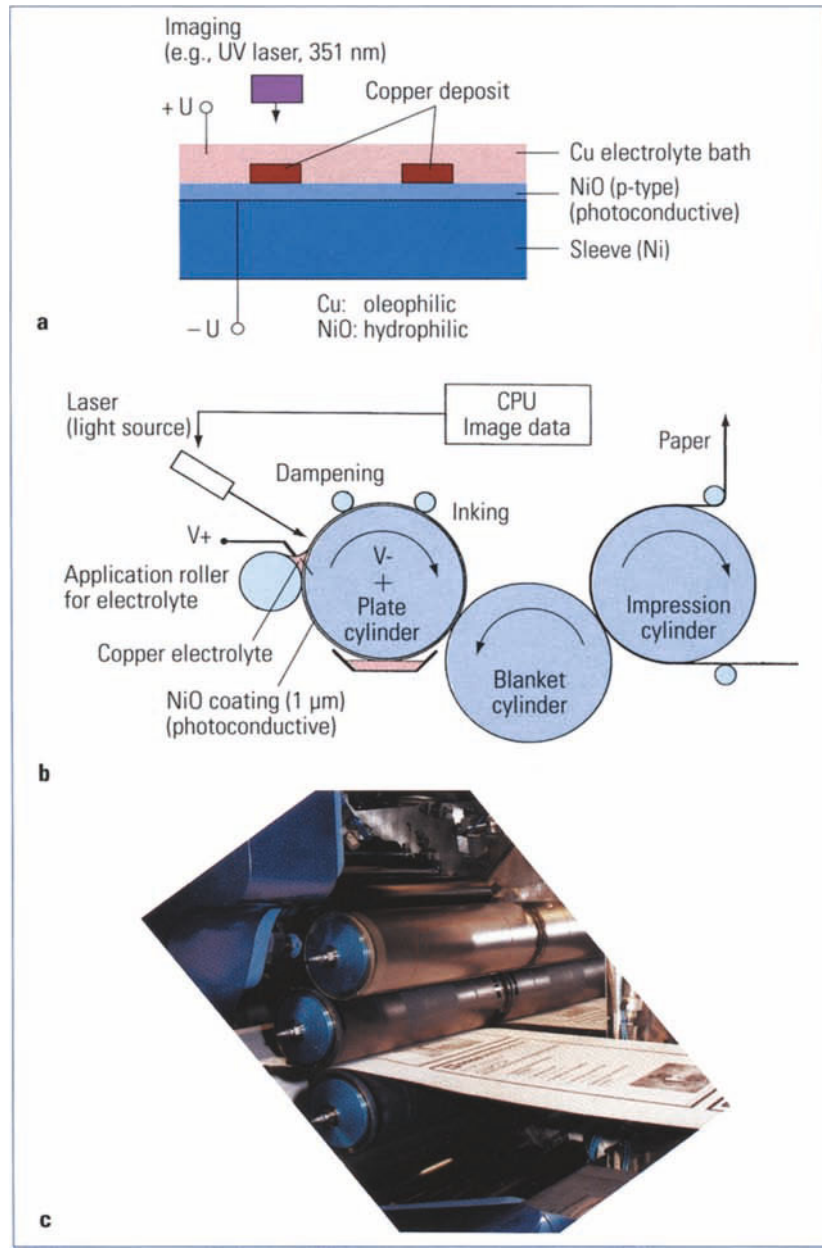


Fig. 4.4-30
Re-imageable offset plate based on photoelectrolytic copper deposition/decoating.
a Function principle for photoelectrolytic imaging of the surface;
b Direct imaging system in the offset printing unit (US patent 5.206.102);
c Print presentation on the lab prototype of a web offset press (ADOPT/CP, Goss Graphic Systems)

but only a "refreshing" of the imaging layer in order to achieve the switchability.

This results in the ability to image and produce an image carrier that is suitable for offset printing without the need to apply a new material coating ("switchable polymer" in accordance with figure 4.4-23).

4.4.2.2 Re-imageable Printing Plate Systems without Material Application

There are various approaches for creating re-imageable surfaces that do not require the application of a new material coating. These materials could be, e. g., oxidic ceramics or polymers. At the present time none of these technologies is available in practice.

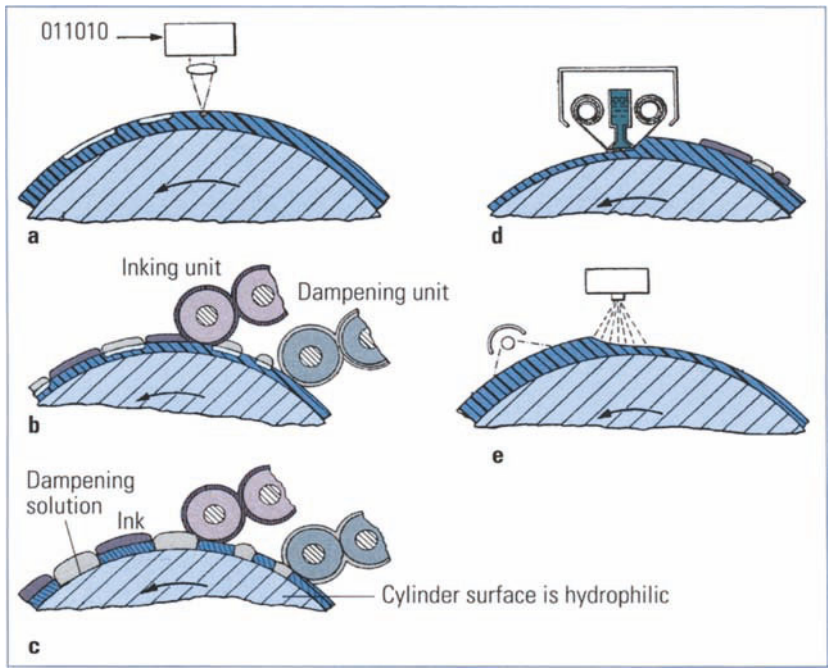


Fig. 4.4-31
Process for generating a re-imageable plate suitable for offset printing.
a Laser imaging of the ink-free areas of the print image;
b Dampening and inking of the plate, gradually washing out the non-image areas;
c Dampening and inking up in offset printing after longer print runs;
d Erasing the printed image through removal of material (based on the status shown in sequence b);
e Coating with material to prepare imaging next print job (US patent: 5.713.287, Creo)

Ferroelectric Materials for Re-imageable Plates/Surfaces. In the following, the possible applications of ferroelectric, ceramic materials for direct imaging systems are described.

The structure and effect of ferroelectric material for re-imageable surfaces with storage capability are illustrated in figure 4.4-32. In the mixed crystal (fig. 4.4-32a) titanium can be at two different positions which leads to a varying polarity. Figure 4.4-32b shows the structure of ferroelectric ceramic materials with their typical domains and particle sizes. The orientation of the various domains differs. As can be seen from the hysteresis curve shown in figure 4.4-32c, the domain orientations and thereby the polarization of the material can be changed by applying varying electric field intensities. The individual domains can also be arranged in such a way that the material is electrically neutral. Accordingly, ferroelectric material can exist in three states: electrically positive, electrically negative, and neutral. The material can be switched back and forth between the states as required and the states themselves are stable, that is, they do not change until they are influenced by electric fields or heat.

The principle structure of a *printing unit* based on ferroelectric surfaces is shown in figure 4.4-33a. The following is a description of possible imaging and erasing systems.

Image information can be transferred to the surface of ferroelectric materials by using the various states (positive, negative, neutral) to store the image information.

If the *initial state* of the entire surface is *neutral* (as in fig. 4.4-33c), an image can originate through a selective polarization of the image areas. This image is permanently stored, as the material was changed in the microscopic orientation of the electric dipoles and the structure is only lost when the orientation of the dipoles (erasing process) is destroyed, for example by heat. An *ionographic imaging system* can be utilized for selective polarization (see sec. 5.3.2 and figs. 4.5-12 and 4.5-13) and the surface is selectively charged by a system having no physical contact with the surface. As shown in figure 4.4-33c this results in the dipoles being oriented in the ferroelectric material.

Another alternative for imaging is to use *electrodes*, which are in contact with the material surface, to polarize the material in accordance with the image data. The hysteresis curve (fig. 4.4-33c) shows that the dipoles can be brought back into a random state (electrically neutral) through the application of *heat (erasing process)*. Depending on the polarity of the voltage source or of the ionographic imaging system, both a positive and negative orientation of the dipoles in the material can be

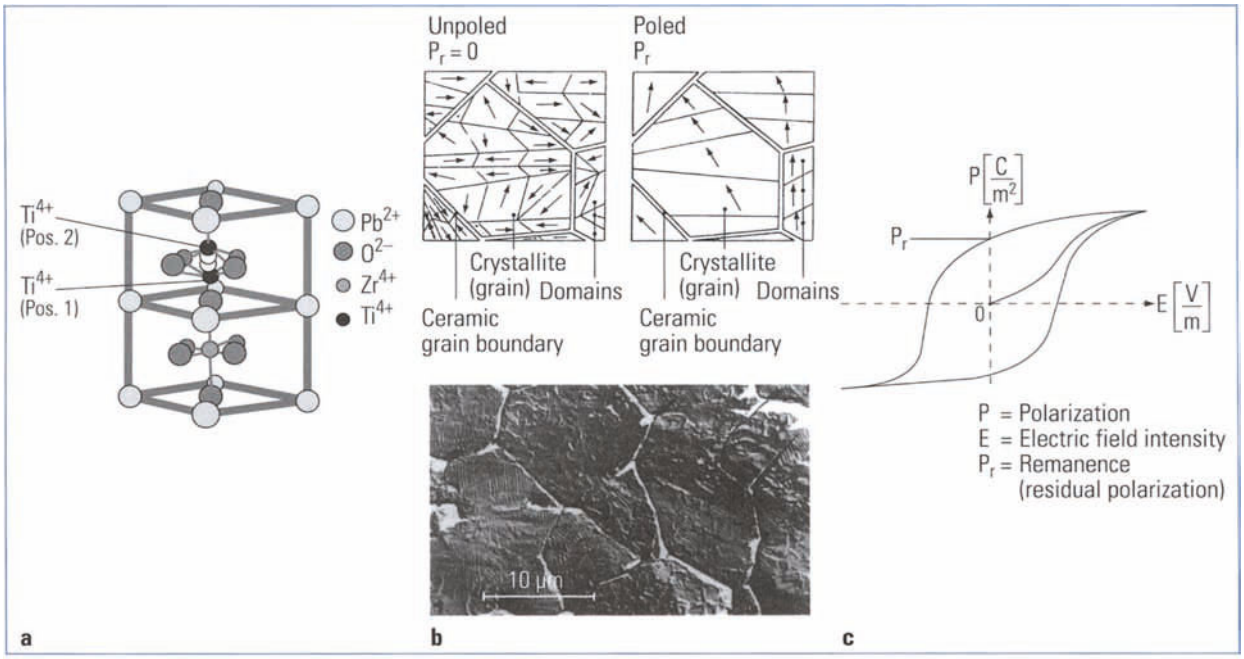


Fig. 4.4-32 Ferroelectric material for use as re-imageable surfaces with storage capability for direct imaging printing systems.
a PZT (lead-zirconate-titanate) mixed crystal for building up ferroelectric coatings;
b Polarization in ferroelectric material;
c Hysteresis loop (polarization dependent on the electric field intensity) [4.4-4]

achieved. The choice of polarity depends on which type of ink is used to ink up the latent image in order to transfer it to the substrate/paper (fig. 4.4-33a).

Another possibility to image ferroelectric materials is shown in figure 4.4-33b. Here the *initial orientation of the dipoles may be uniformly* positive or negative. Imaging can occur through reversal of polarization in accordance with the image either without contact via an *ionographic* imaging system, or with contact using *imaging electrodes*.

A further imaging variation is depicted in figure 4.4-34. Here the *initial state* is once more *uniformly* positive or negative. In this case, however, a thermal system is used for imaging. This system produces a random, electrical neutral orientation in the material. A *thermal imaging head* with direct contact to the surface can be used for this, as can a thermal non-contact laser beam.

Direct imaging concepts based on ferroelectric materials have been around since about 1993. MAN Roland has applied for numerous patents and has presented reports on lab tests in this field at several conferences.

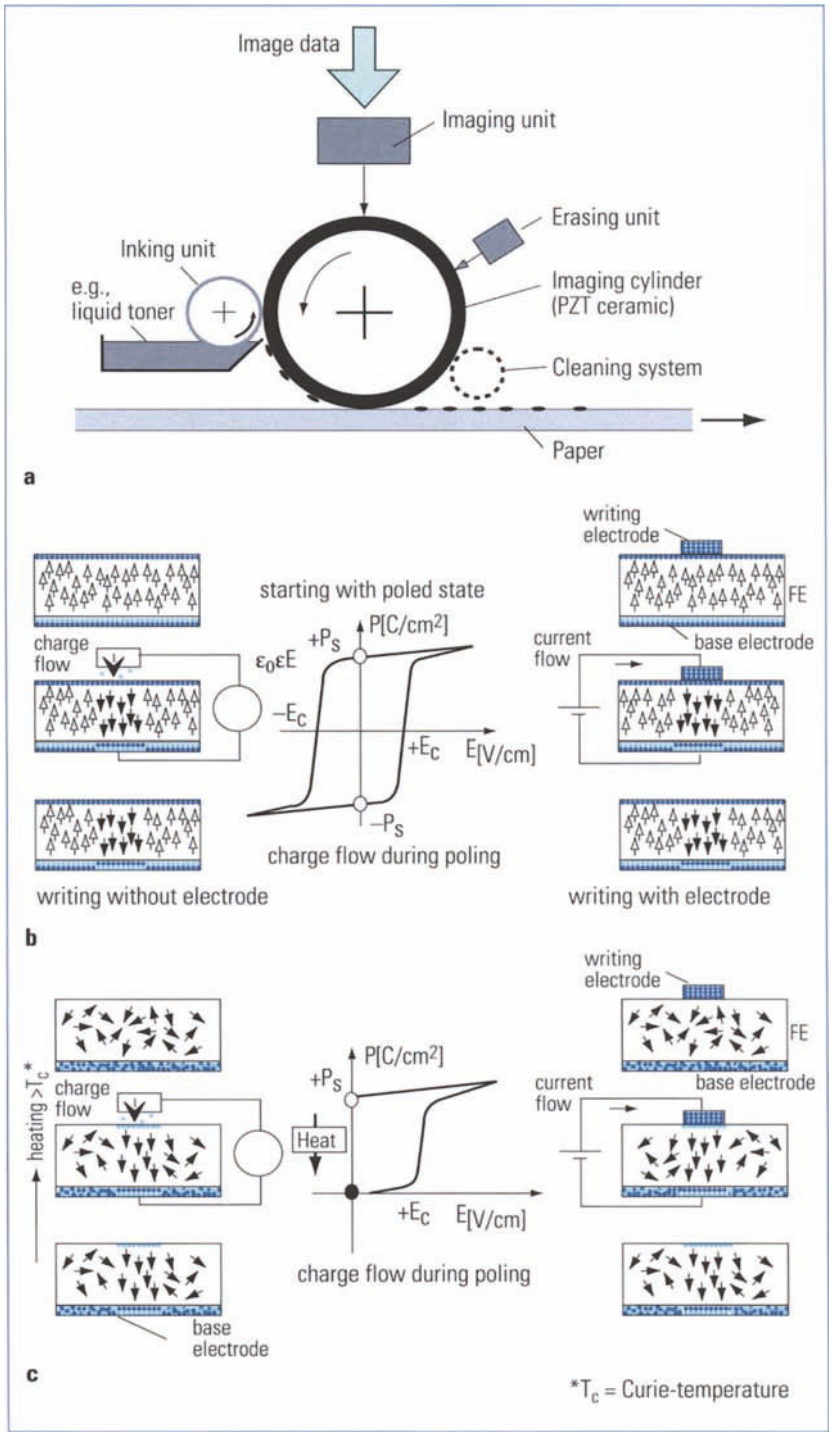
The concepts for these systems with regard to their application in print production focus primarily on liquid toners and their exploitation for offset is likewise a topic of discussion (see also [4.4-1] to [4.4-3]).

Chemical Material Systems for Generating Re-imageable Surfaces

From patent literature, individual scientific publications, and lectures at conferences research and development work exploring re-imageable materials is known. These can be used in offset and made available for practical application.

They are concerned with physico-chemical processes in which reversible changes of material states lead to a transformation in surface properties. An example of this is the different concentration of oxygen in metal oxides, such as zirconate. The material possesses different wetting properties with different concentrations of oxygen. With a normal concentration of oxygen the material surface is hydrophilic and laser irradiation can be used to reduce the concentration of oxygen, thereby making the material surface oleophilic. Through

Fig. 4.4-33
Structure of a printing unit for re-imageable plates with imaging and erasing equipment.
a Basic principle of the printing unit (functional components);
b Imaging through reversal of polarization by means of ion source or electrodes; erasing the image through uniform, homogeneous polarization;
c Imaging through aligning random microdipoles by means of ion source or electrodes; erasing the image through depolarization of the microdipoles with heat (MAN Roland)



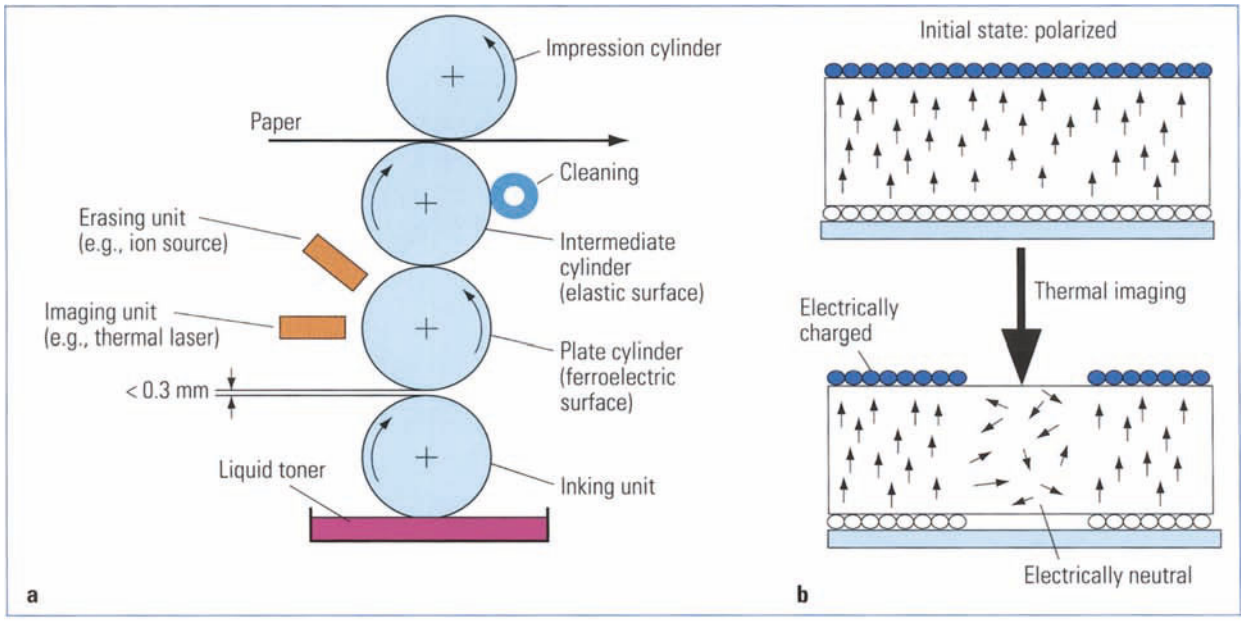


Fig. 4.4-34 Direct imaging with re-imageable plate cylinder.
a Structure of a printing unit for testing plate cylinders with ferroelectric surface for printing with liquid toner;
b Imaging through supply of heat, erasing the image by means of electric fields (MAN Roland)

thermal treatment a normal oxygen level can be attained again, that is, it becomes hydrophilic.

Likewise, it seems possible for photo-catalytic material such as zinc oxide or titanate to be turned hydrophilic or hydrophobic by means of the appropriate irradiation.

Special reversible, interfacial physical phenomena are also known in polymers with functional side chains, as is the case with fluoro-polymers. These substances – some of which are related to PTFE ("Teflon") – could be considered for use as re-imageable surfaces in offset printing.

For this type of material the expression "switchable polymer" (fig. 4.4-23) is appropriate.

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[4.4-1] The 9th International Congress on Advances in Non-Impact Printing Technologies/Japan Hardcopy '93 (Proceedings). The Society for Imaging Science and Technology (IS&T), The Society of Electrophotography of Japan (SEPJ), Springfield (VA) 1993.

[4.4-2] IS&T's Tenth International Congress on Advances in Non-Impact Printing Technologies (Proceedings). The Society for Imaging Science and Technology (IS&T), Springfield (VA) 1994.

[4.4-3] IS&T's Eleventh International Congress on Advances in Non-Impact Printing Technologies (Proceedings). The Society for Imaging Science and Technology (IS&T), Springfield (VA) 1995.

[4.4-4] Ruschmeyer, K. et al.: Piezokeramik. Expert Verlag, Renningen-Malmsheim 1995.

Further Reading for 4.4

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4.5 Computer to Print

Introduction

The following deals with those *computer to press technologies* that do not require a master (fig. 4.5-1). So-called non-impact printing technologies (NIP technologies) form the basis for printing systems of this kind. A brief description of computer to print systems, systems based on electrophotography or ink jet technology, has already been given in section 4.1.

The overview of the printing technologies is given again in figure 4.5-2. The printing technologies that operate without a fixed master, namely the *non-impact printing technologies*, are highlighted. This chapter will explain the NIP technologies highlighted in color in figure 4.5-2.

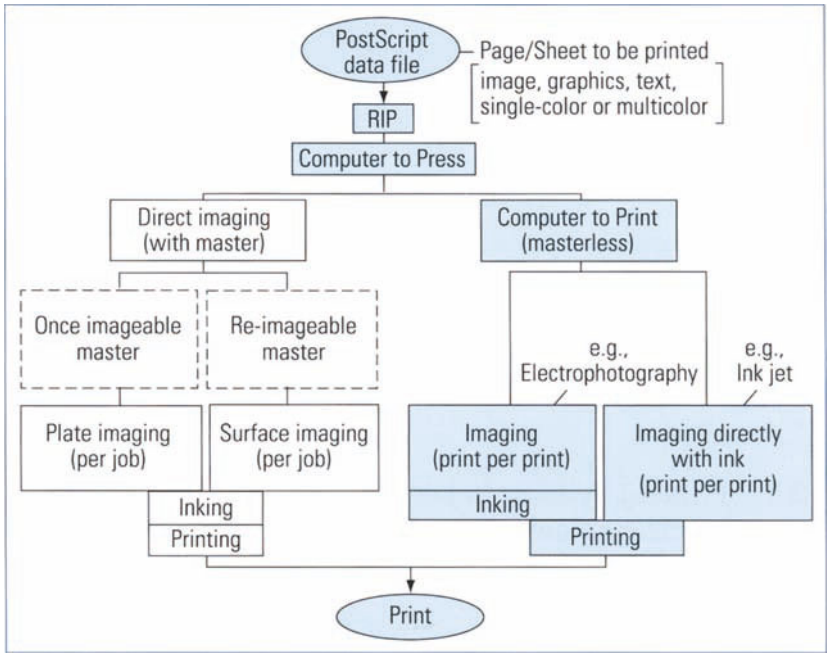
In chapter 5 a detailed description of the physical and technological principles of these NIP technologies will be given, accompanied by examples of practical printing system applications using these techniques.

Multicolor printing systems based on NIP technologies (e.g., thermal sublimation and drop on demand ink jet) were also explained in section 3.2.11 (digital proof). These are also computer to print technologies but are not dealt with here on account of their relatively low productivity.

Selected practical examples of computer to print systems in industrial use and designed for *relatively high productivity* are detailed in the following section. These are systems for multicolor printing, single-color printing, and printing with special colors.

As highlighted in figure 4.5-2, NIP technologies can be used for printing with *sheet-fed and web-fed systems*. Since the NIP technology normally requires a fixing

Fig. 4.5-1
Computer to print technology compared to computer to press/direct imaging



H. Kipphan (ed.), *Handbook of Print Media*
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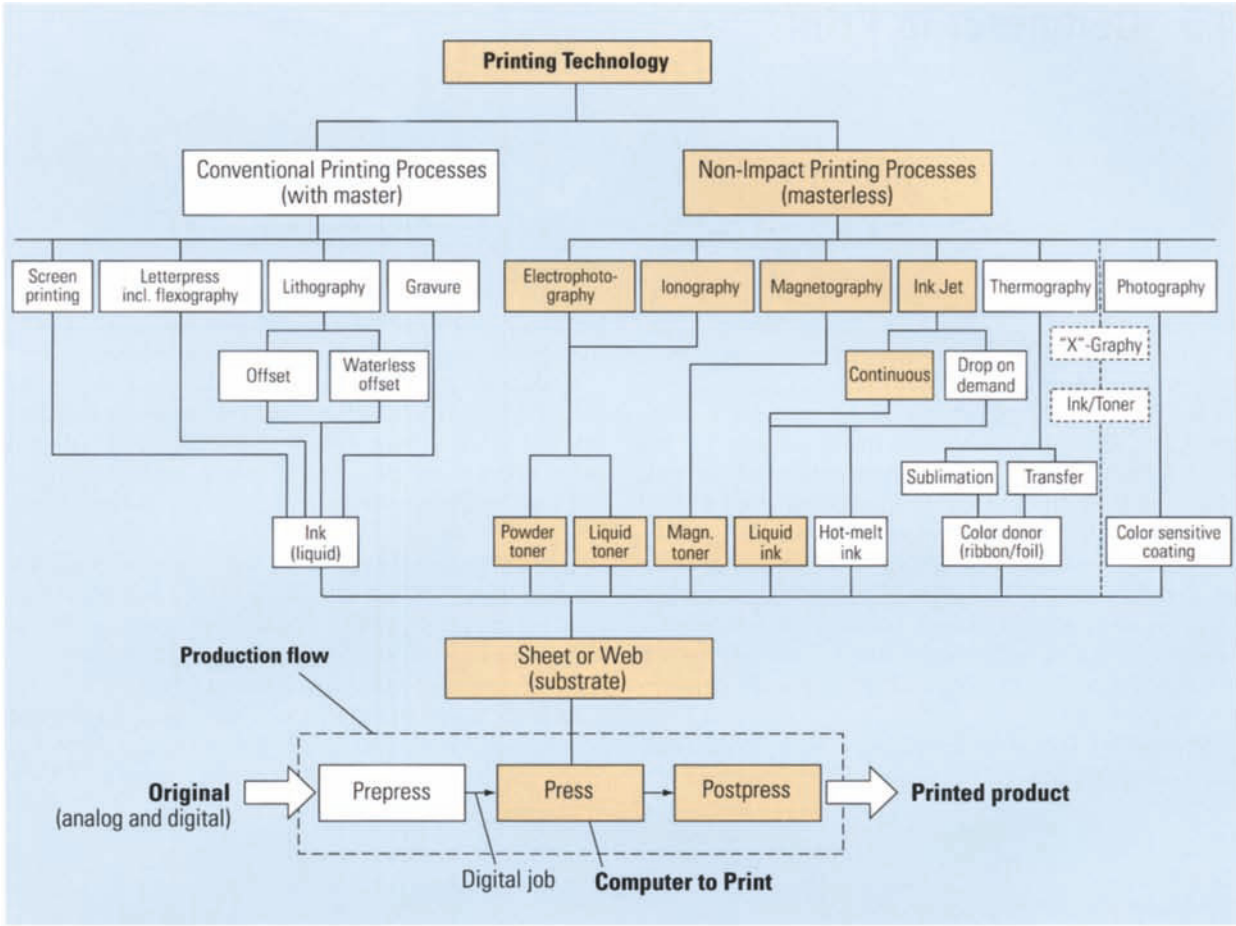


Fig. 4.5-2 Non-impact printing technologies for use in computer to print systems

of the print image for process reasons (a separate drying operation is therefore not necessary), the press can be directly connected to *in-line finishing systems*. Computer to print systems therefore enable in-line production of complete printed products, such as wire-stitched brochures or even books with perfect binding (see also sec. 9.2).

4.5.1 Printing Systems based on Electrophotography

The printing systems described below are a selection used to explain the various technologies. The descriptions, supported by outline diagrams of the printing systems, are based on diverse product information from the manufacturers and have, to some extent, been summarized by the author.

Several variants and expansion options are generally available for a base printing system. The explanations given focus on one example, with references to variants.

DCP/32

Figure 4.5-3 shows a multicolor printing system that is used to print *web material* with *powder toners*. An *LED system* with a resolution of 600 dpi is used for imaging, and toner is transferred directly onto the paper web. Different charge intensities, and thereby different ton-

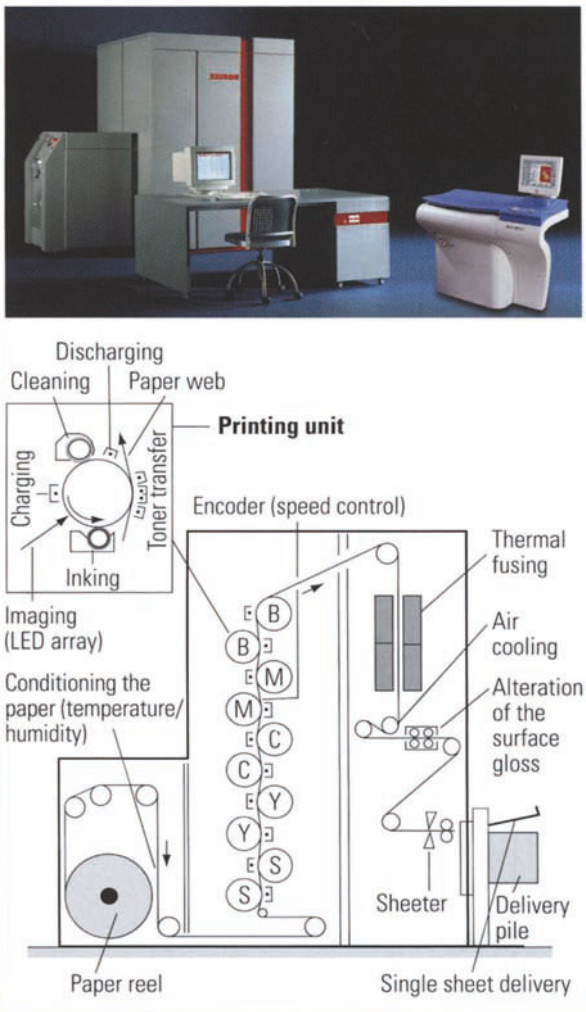


Fig. 4.5-3
Computer to print multicolor printing systems for double-sided printing on web material (electrophotography, LED imaging, powder toner) (DCP/32D, Xeikon; diagram drawn up using company literature)

er transfer per pixel (approximately nine gray values), can be generated by controlling the individual light-emitting diodes during exposure of the photoconductor drum. This enables reproduction of a larger range of color than with only two gray values per pixel.

The printed image is fixed by heat processes (thermal fusing). An additional device that affects the *surface of the printed image* by the application of pressure and heat transfer in a similar way to a fixing/fusing system can also be employed to influence the surface quality of the printed image after the web has cooled down. After printing, the web material is cut into sheets by a sheeter.

This printing system has the advantage of being able to print both the *front and reverse side* of the web simultaneously. An extremely wide range of formats can also be created in the direction of printing.

The printing system is available in two widths, model DCP/32D for a maximum web width of 320 mm and DCP/50D system for a maximum web width of 500 mm. Systems are also available for printing on one side of the web only (see table 4.5-1). The printing speed is 35 A4 sheets per minute (equivalent to 0.13 m/s) or 70 A4 page impressions per minute if printing is done on both sides of the web. This printing system was introduced to the market in 1993 and is available from several companies under various names and with different front end systems (hardware and software). The use of the printing system for label printing is explained in section 2.5.3 and in figure 2.5-30.

In figure 4.5-3 a flat-bed scanner has been installed next to the printing system's operator station. With this system (Pressport by Portalis) or similar equipment, analog originals can be digitized and either added to a print job already available in digital form or produced separately.

E-Print 1000

The E-Print 1000 machine from Indigo was detailed in section 4.1.3 (see fig. 4.1-7). This computer to print system forms the basis of a series of models for 4-color printing on sheet material (E-Print Pro) and six-color printing including a powerful front-end system (TurboStream). A model with increased productivity (UltraStream) has been presented in the year 2000 with a modified printing unit design as well as a model for printing on web material (Publisher).

The TurboStream model is illustrated in figure 4.5-4, together with an outline view of the E-Print 1000 and a more detailed explanation of the components. The system works with *liquid toner*. The printing unit is designed as a "*multipass system*" and an *intermediate cylinder* that is fitted with a blanket is used for the ink transfer onto the *substrate* (sheet material). Imaging takes place via a scanning, multi-beam *laser system*. The printing system can also be used for duplex printing. A finishing unit can be connected (see also fig. 4.1-7).

For four-color printing the productivity is 33 A4 pages per minute (equivalent to approximately 0.15 m/s;

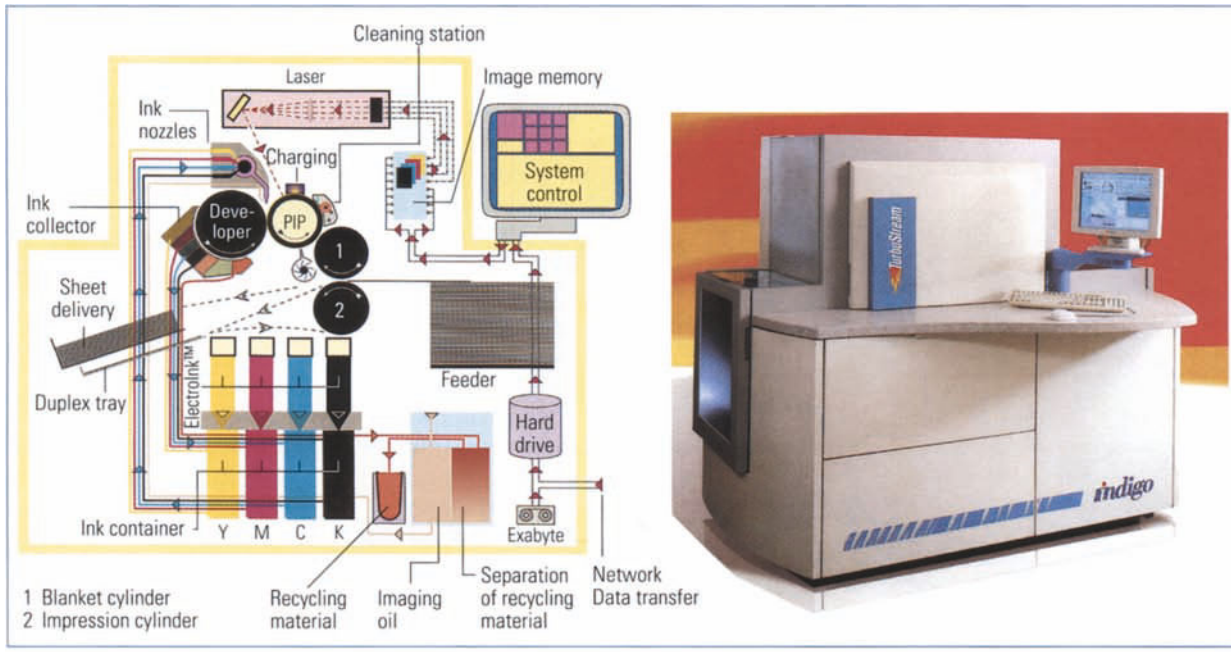


Fig. 4.5-4
Computer to print system for multicolor printing (electrophotography, ROS laser imaging, liquid toner, intermediate cylinder) with the option of sheet turning for double-sided (duplex) printing (E-Print 1000/TurboStream, Indigo; see also fig. 4.1-7)

the speed for a color separation is approximately 0.6 m/s). The system's method of operation has already been explained in section 4.1.3 (fig. 4.1-7).

Figure 4.5-5 shows a variant derived from this printing system, the Omnius model, for printing on *web material*. The printing method corresponds to that of sheet-fed multicolor printing and is similar to the system illustrated in figures 4.1-7 and 4.5-4. The basic difference is that the color separations are not collected on the printed sheet by quadruple rotation (or six-fold rotation for printing with six colors) of the impression cylinder on which the sheet is held by grippers, as was previously the case. Here, all the color separations are collected on an intermediate carrier, a cylinder covered with a flexible blanket, before the entire multicolor print image is transferred to the web material in a single printing contact. This enables flexible materials to be used since register accuracy is determined solely by the quality of the transfer to the intermediate carrier. In this system the imaging also takes place by electrophotography and laser systems with a resolution of 800 dpi. The printing speed for four-color printing is 33 A4 pages per minute.

The web transport must be intermittently controlled because of the special ink transfer system (which the manufacturer calls "*one shot technology*").

DocuColor 40

Xerox's computer to print system, illustrated in figure 4.5-6, is an example of another electrophotography-based system for multicolor printing (see also sec. 1.3.3.1, fig. 1.3-28). It was first introduced to the market by Fuji Xerox around 1995. This machine's productivity in *tandem or unit construction* is 40 A4 pages (four-color) per minute (equivalent to a printing speed of approximately 0.17 m/s). Imaging is done at 400 dpi by using *ROS laser imaging systems*. Printing is done with *powder toner*. Key features of these systems are the unit construction and the *gripperless conveyance* of the printed sheets by means of electrostatic forces and a conveyor belt (the Ricoh company introduced the first design of this type on the Japanese market around 1990).

The printing system is also designed for *multicolor printing on both sides* (duplex printing) and productivity in this mode of operation is 30 A4 pages per minute

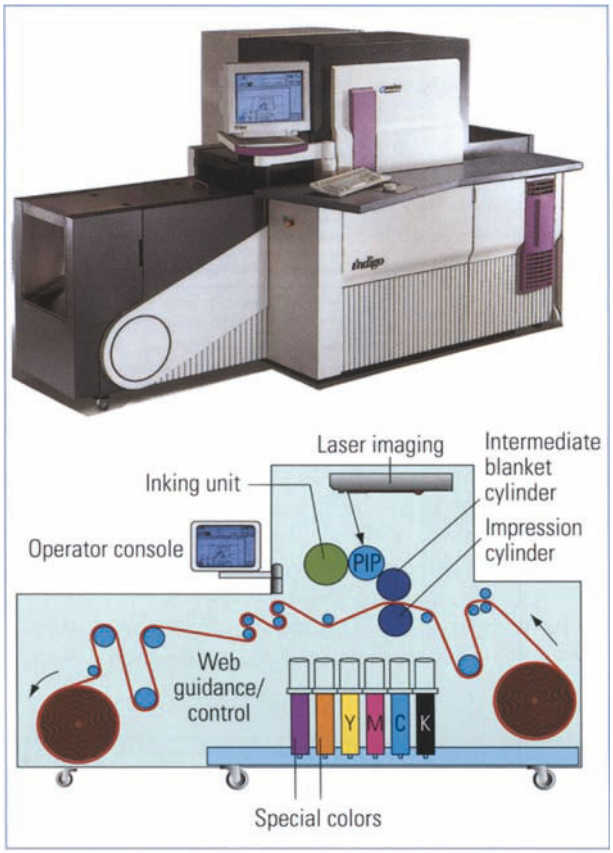


Fig. 4.5-5
Computer to print system for multicolor printing on flexible web materials by collecting color separation images on intermediate cylinder and the subsequent transfer onto the web in one printing contact ("one shot" technology), (Omnius, Indigo)

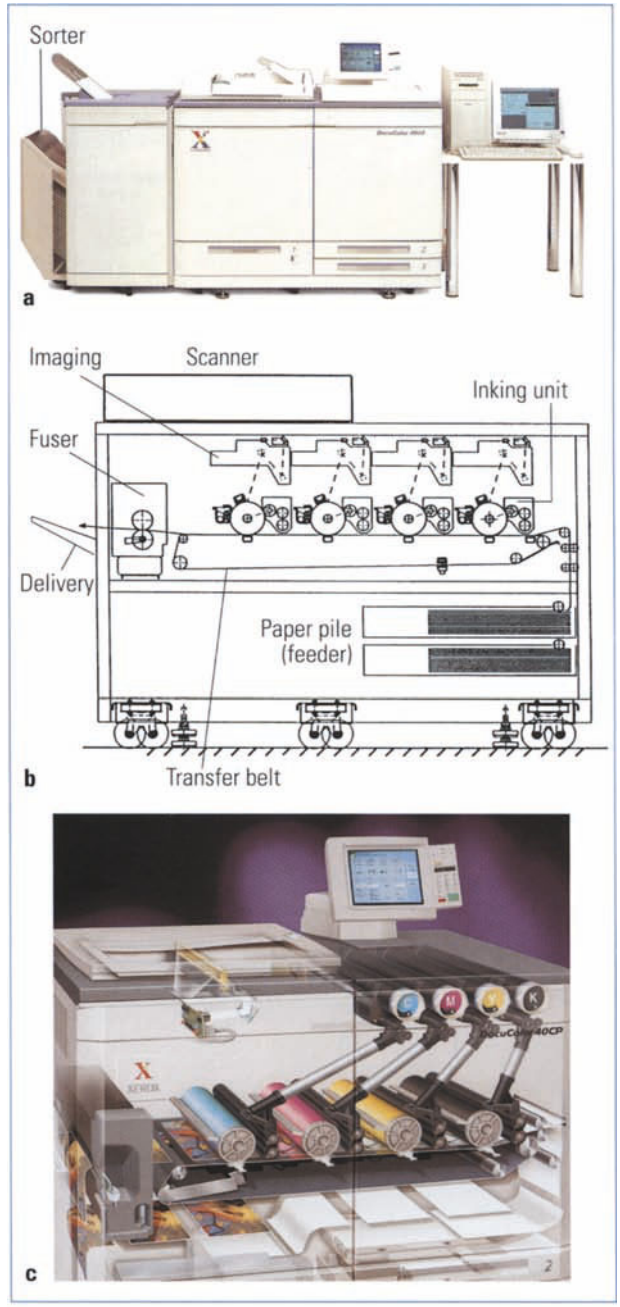


Fig. 4.5-6
Printing system for four-color printing in unit construction (electrophotography, ROS laser imaging, powder toner) with equipment for duplex printing (4.5-6c).
a Printing system (with sorter);
b Unit construction;
c Paper transport and ink transfer (DocuColor 40, Xerox)

(reduced due to the return transport of the sheet after the initial printing on only one side). The transport mechanism is illustrated in figure 4.5-6c.

Figure 4.5-6a shows the printing system equipped with a *sorter*. Eight A3 sheets, for example, with different page content (with two A4 pages each on the front and on the reverse side) can be collated successively in the individual sorter trays for subsequent finishing operations (e.g., stitching, folding). The eight A3 sheets for a thirty-two-page brochure then lie in the correct order in the individual sorter trays, that is, if twenty sorter trays were used, there are 20 copies.

Comparison of the Printing Systems. The specifications of the *computer to print systems for multicolor*

printing detailed above are listed in table 4.5-1. The CLC 1000 system by Canon, discussed in section 4.1.3 (see fig. 4.1-8), has also been included. Figure 9.2-7 (see sec. 9.2) illustrates the system link-up for the CLC 1000 printer to a finishing system for the production of stitched booklets.

DemandStream

The DemandStream 4000 DI printing system for *sheet material* and the DemandStream 8000 DI for *web material* are shown in figures 4.5-7 and 4.5-8 as examples of relatively *high productivity* electrophotography-based *single-color printing* (110 or 158 A4 pages/min. depending on the press width). In both of these systems by Océ, the front and reverse side can be printed in one pass.

The system shown in figure 4.5-7 has two printing units and can produce single-color prints on both sides using a duplex turner, after which the sheets are routed to the delivery. Colored overprinting can also be done by the second printing unit. If only one side is to be printed, the two printing units are used in parallel. In the system illustrated in figure 4.5-8 perfecting is carried out on web material using turning bars located between the two printing systems.

In order to ensure accurate positioning of the print image, web printing systems also process webs with *tractor feed holes* along the right and left sides. The webs are perforated in an in-line process prior to printing. Pre-perforated web material and perforated web material *fan-folded* into stacks of continuous sheets are also processed (e.g., business forms printing).

The DemandStream 6000 DI system is shown in section 9.2 (fig. 9.2-8) as an example of a "book on demand" production system (like the system illustrated in fig. 4.5-8, this system also prints on web material).

The printing systems listed operate with *powder toners* and imaging is done using an *LED array* with a resolution of 600 dpi. The structure of the LED array is shown in figure 4.5-8b. The high resolution (600 dpi) and high printing speed (approximately 0.5 m/s) call for a very accurate and powerful system.

The printing speed of the systems for sheet-fed printing (fig. 4.5-7) is approximately 0.5 m/s, which is equiv-

Model (manufacturer)	**DCP/32 D** (Xeikon)	**TurboStream** (Indigo)	**Omnius** (Indigo)	**DocuColor 40** (Xerox)	**CLC 1000** (Canon)
NIP processes	Electrophotography Powder toner	Electrophotography Liquid toner 6 colors	Electrophotography Liquid toner 6 colors	Electrophotography Powder toner	Electrophotography Powder toner
Printing format, substrate	320 mm wide, web	A3+ (portrait), sheet	308 mm wide, 432 mm long; web	A3+ (portrait), sheet	A3+ (portrait), sheet
Duplex printing	Yes	Possible	No	Possible	Possible
Imaging method	LED Array	ROS System	ROS System	ROS System	ROS System
Addressability (dpi)	600	800	800	400	400
Gray values/pixel	approx. 9	2	2	approx. 9	approx. 9
Productivity:					
– A4 pages/min	70	33	33	40	31
– A4 sheets/min (dupl.)	35	16.5		15	15
– printing speed (m/s)	approx. 0.13	approx. 0.6	approx. 0.6	approx. 0.17	approx. 0.14
Market launch	1993	1993 (1st model: E-Print 1000)	1995	1995	1996
Variants	DCP/32 S: printing on one side only; DCP/50 D and S: 500 mm wide	e-Print Pro: 4 colors; UltraStream (announced)	Omnius Card: printing on sheets; Omnius Canery: printing on containers		

Table 4.5-1 Computer to print systems for multicolor printing (selection, status: 1999)

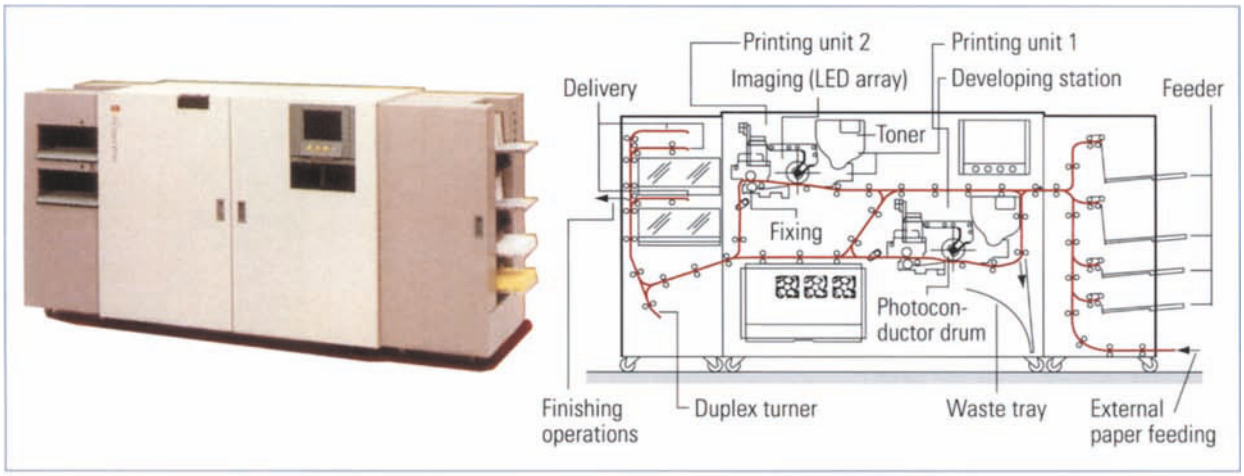


Fig. 4.5-7
Printing system for double-sided single-color printing on sheet material (electrophotography with LED imaging, powder toner) with two printing units (DemandStream 4000 DI, Océ)

alent to 110 A4 pages per minute (the format layout of the A3 sheet being "portrait," the A4 layout is therefore at right angles to the direction of travel), or 158 A4 pages per minute with the model having a larger press width, using the "landscape" format layout for A3 (two A4 pages adjacent to each other with the longitudinal sides parallel to the direction of travel).

The interlinked printing system in figure 4.5-8 produces 290 (or with the format variant, 470) A4 pages per minute when perfecting (printing on both sides).

InfoPrint 4000

The InfoPrint 4000 printing system (model IS2) by IBM is illustrated in figure 4.5-9. Single-sided printing is done on web material using the electrophotographic method with a resolution of 300 dpi and a printing speed of approximately 1.1 m/s (equivalent to approximately 470 A4 pages per minute). Printing can be carried out on both sides by linking up two systems using a perfector/turner bars as illustrated in figure 4.5-8.

DocuTech 6180

The DocuTech 6180 system by Xerox is illustrated in figure 4.5-10a. This system can produce 180 A4 pages/min (equivalent to approximately 0.8 m/s) with a resolution of 600 dpi. The printing format is A3+ (portrait).

The electrophotographic imaging is carried out with a *laser scanning system* (ROS: raster output scanner, see fig. 1.3-29 or part 2 of fig. 4.5-17) using two independently controllable laser diodes simultaneously on a polygon mirror inside the raster output scanners. This enables a printing speed of approximately 0.8 m/s. With this printing system the imaging is done on a *photoconductor belt*, as illustrated in the DocuTech 135 system in figures 4.5-10b and 9.2-9 of section 9.2.

In a special variant of electrophotographic imaging (*Trilevel technology* by Xerox) two partial images can be applied to the surface of a charge carrier/image carrier (e.g., a photoconductor belt) as the charge pattern. Consequently two 300 dpi print images can be created on the same section of the surface as a latent image instead of one 600 dpi print image. The two partial images can then be inked using differently configured toners. This method is often applied for printing in the *highlight color process*. A new hue is reproduced from two colors in this way, depending on the screening of the respective individual colors, although at the cost of the reduced resolution (see also sec. 5.2.3, fig. 5.2-16/ DocuPrint 350-HC).

Digimaster 9110

This high-speed printing system by Heidelberg is shown in figure 4.5-11. Printing is done by means of electrophotography and imaging via an *LED system* with a resolution of 600 dpi and a printing speed of approximately 0.5 m/s (110 A4 pages per minute) on sheet material.

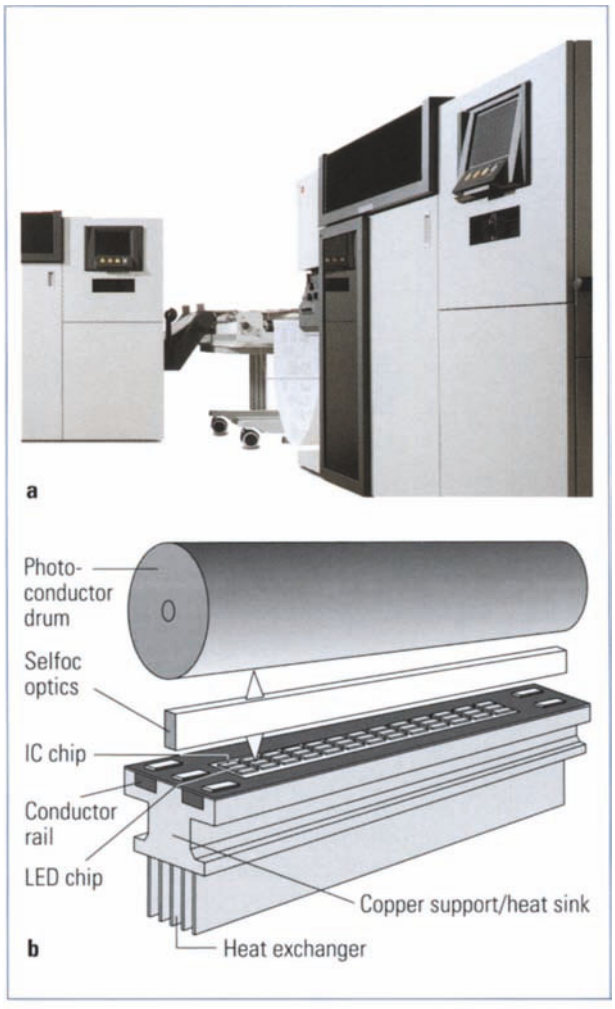


Fig. 4.5-8
Printing system for double-sided printing on web material.
a Twin installation of two systems for perfecting via turning bars;
b Underlying principle of LED array for imaging (600 dpi),
(DemandStream 8000 DI, Océ)

In figure 4.5-11b the underlying principle of the electrophotographic printing unit is explained. The latent charged image is transferred via the LED array to a *flexible belt coated with photoconductive material.*

Further details on the Digimaster printing system are given in sections 1.3.3.3 (fig. 1.3-34) and 9.2 (fig. 9.2-10). In figure 1.3-34 system components for the transfer and digitization of analog originals and a finishing unit for booklet production have been added to the system configuration shown in figure 4.5-11.



Fig. 4.5-9
Printing system for single-color printing (one-sided, electrophotography, LED imaging, powder toner) on web material (InfoPrint 4000, IBM)

4.5.2 Printing Systems based on Ionography, Magnetography, and Ink Jet

ImageFast 180 (Ionography)

While with electrophotography the latent image is created on the charge carrier by imaging via light/photons, in *ionography* imaging is done by transferring the charge using a controlled ion source (see sec. 5.3 for details of this).

A printing system from Delphax (now Xerox) is shown in figure 4.5-12. The *ion source* is designed for a resolution of 240 dpi and the system operates with *powder toner*. The printing speed is approximately 0.55 m/s, which is equivalent to 90 A4 sheets per minute (further developments by Delphax/Xerox have been announced with systems having 600 dpi and printing speeds of up to approximately 1 m/s). In the configuration of the printing system illustrated in figure 4.5-12, 90 sheets are printed on both sides per minute, yielding a productivity of 180 A4 pages per minute with this tandem configuration of two systems with perfector.

Figure 5.3-6 shows another printing system based on the NIP technology of ionography (instead of the drum as shown in fig. 4.5-12c, a dielectric belt is imaged with ions).

VaryPress T700 (Magnetography)

Figure 4.5-13 shows a printing system based on the NIP technology of *magnetography* from Nipson/ Xeikon. In this system, as shown in figure 4.5-13b, the print image is



Fig. 4.5-10
Printing system (electrophotography, ROS laser system, powder toner) for the production of single-color printed media using digital printing methods.
a Printing system (DocuTech 6180; 180 A4/min);
b System design (DocuTech 135; 135 A4/min, Xerox)

created as a latent magnetic field pattern on a magnetizable cylinder using an imaging system consisting of individually controllable miniature magnets (fig. 4.5-13c and for details see sec. 5.4). The magnetic *powder toner* is transferred in accordance with the magnetization pattern. Fixing is done by heat transfer, and in special designs by a "*flash-fusing system*" in which pulsed, non-contact heat is transferred to melt the toner. The printing system shown produces around 700 A4 pages a minute (two adjacent A4 pages; A3, landscape) at a resolution of 480 dpi and a printing speed of 1.75 m/s.

VersaMark MPS4 (Ink Jet)

Figure 4.5-14 shows a computer to print system that uses *ink jet* non-impact printing technology. The four imaging systems work on the continuous ink jet principle (see fig. 1.3-30 and sec. 5.5). The system produces at a resolution of 300 dpi and a printing speed of up to 2.5 m/s, equivalent to 1000 A4 pages per minute for a web width corresponding to A3 (landscape: two A4 pages configured vertically alongside each other).

The system is fitted with four 9" (229 mm) wide ink jet imaging modules, which enables two-color printing of two adjacent A4 sheets (no overprinting). With a web width equivalent to A4 width, two colors can first be printed on one side of the web and, after the side printed first has dried and the web has been turned, two-color printing can also be done on the reverse side of the web using two other ink jet imaging systems. If the web is only diverted and not turned, a third and fourth color could be overprinted on the A4 page after the first and second colors have been printed. Other ink jet systems for printing on web material are shown in figures 1.3-32, 5.5-7, and are announced for multicolor printing.

The specifications of the computer to print systems for single-color or special color (spot color) printing described are summarized in table 4.5-2.

4.5.3 Design Principles of Computer to Print Systems

The examples of printing systems dealt with above clearly show that various components are used for *imaging*, for example, LED systems or laser scanning (ROS) systems. They also, however, clearly show that

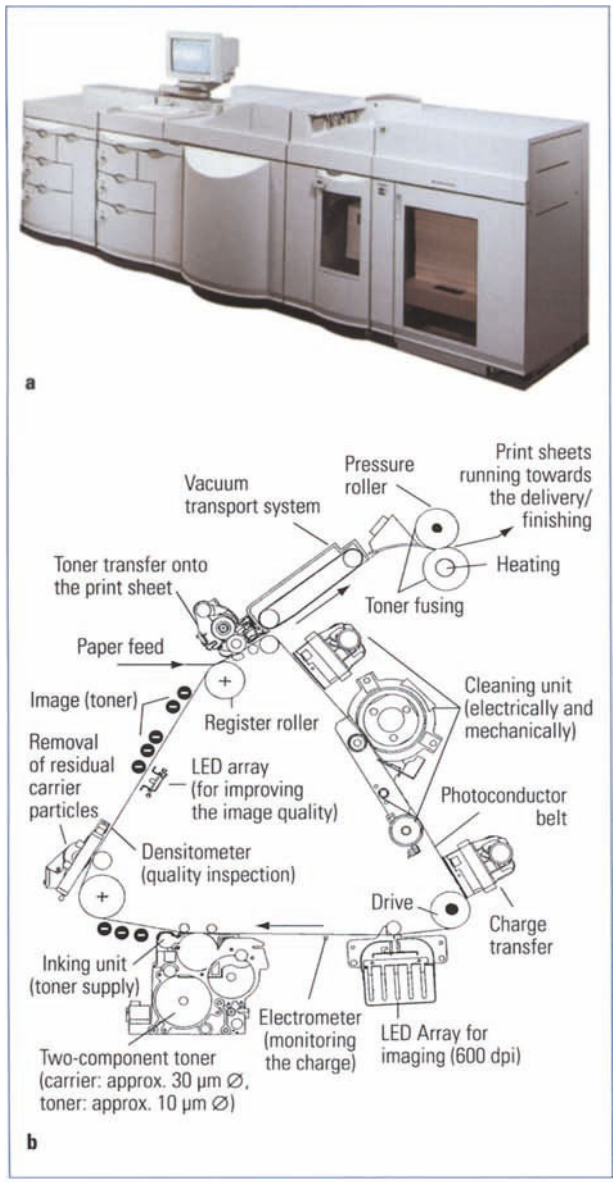


Fig. 4.5-11
Computer to print system for single-color printing and in-line production of print media (electrophotography, LED imaging on photoconductor belt, 110 A4 pages per minute).
a Example of system configuration (add-on see figs.1.3-34 and 9.2-10);
b Basic principle of the electrophotographic printing unit (Digimaster 9110, Heidelberg)

the *superimposed printing* of screened color separations for multicolor images can be carried out using different methods, such as collecting the color separations on an intermediate carrier or directly on the paper.

The examples of systems were also used to explain that with systems based on NIP technologies it is relatively easy to design *complete systems* for single-color and multicolor printing that link together prepress, press, and postpress production stages in-line (also on account of the generally low production speeds compared to those technologies requiring a master and equivalent systems).

Prepress functions are integrated into the printing system via the digitally defined print job and, for example, using an integrated flat-bed scanner. Since the print image is usually dry immediately after printing, as NIP technologies require fusing, finishing can be done in-line. The postpress (finishing) process can therefore also be integrated into the system.

There are numerous *finishing* options. The systems are usually modular in structure so that production systems for different end products can be set up. The system can usually be converted by the operator for different types of products.

In-line production is illustrated in the form of a block diagram in figure 4.5-15. "*Data in*"-"*Product out*" is an apt description of this digital print media production system.

It is essentially the design of the multicolor printing process and the imaging system specifications that determine the productivity and quality of the printing system.

Multicolor Printing Systems. Several *options for collecting color separations* for multicolor printing are shown in figure 4.5-16. Distinction is made between collecting on the paper, collecting on an intermediate carrier (drum or belt), and collecting directly on the imaging surface.

The image can be transferred to the paper with or without an *intermediate image carrier system.*

Systems in which color separations are collected on an intermediate carrier and transferred to the paper in one printing contact (as shown in fig. 4.5-5) can also be described as "*singlepass*" *systems*, such as those used for multicolor printing systems in unit design (e.g., fig. 4.5-6) where the multicolor print is produced by sheet transfer in one pass through the press. In "*multipass*" *systems* the multicolor print is transferred to the substrate in several print contacts with the intermediate image carrier or the imaging system in one printing unit (e.g., fig. 4.5-4).

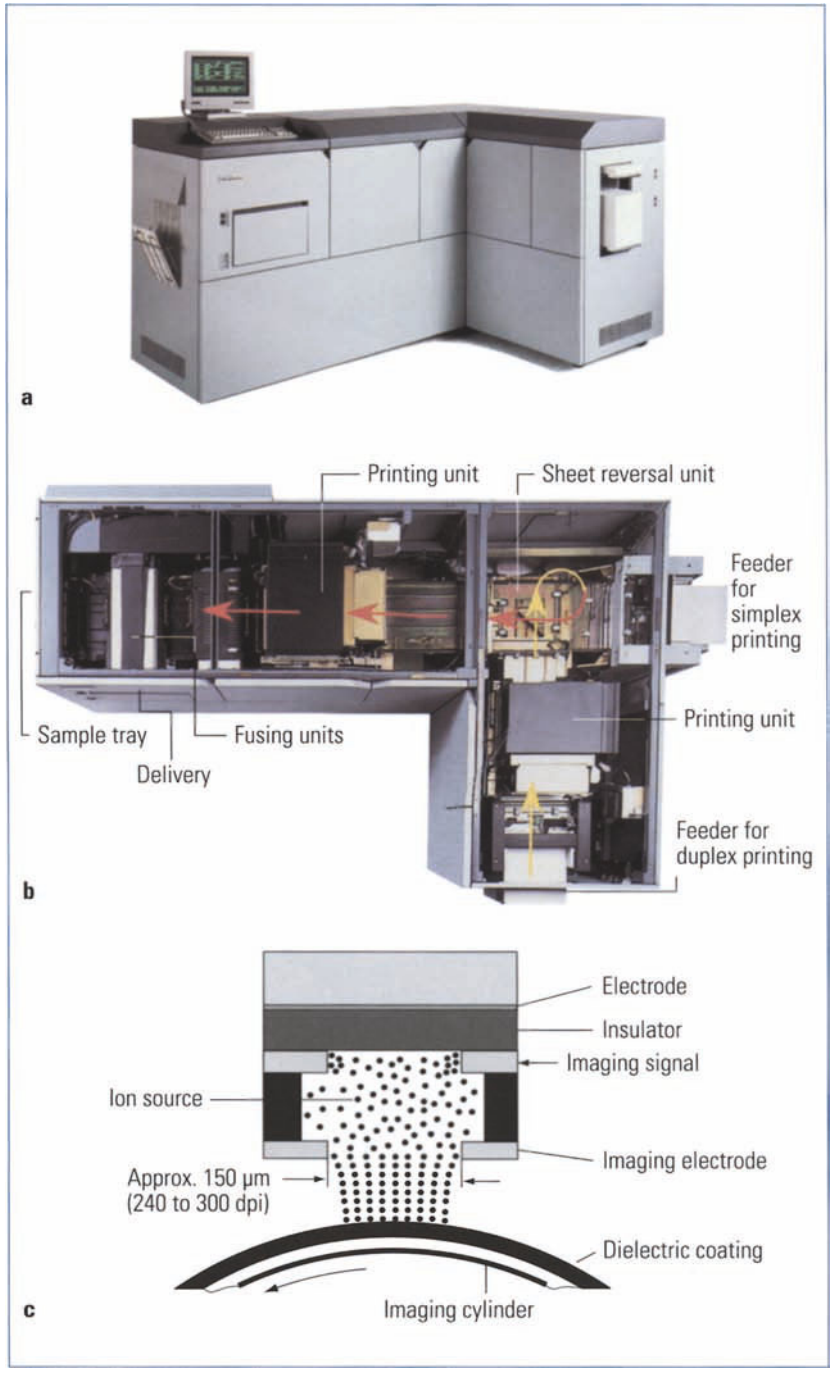


Fig. 4.5-12
Digital printing system for single-sided and double-sided printing on sheet material (ionography, 240 dpi, 90 A4 pages per minute, single side).
a Printing system;
b Paper guidance and system components for double-sided printing;
c Ion source for imaging (component of the page-wide imaging system)
(ImageFast 180, Delphax/Xerox)

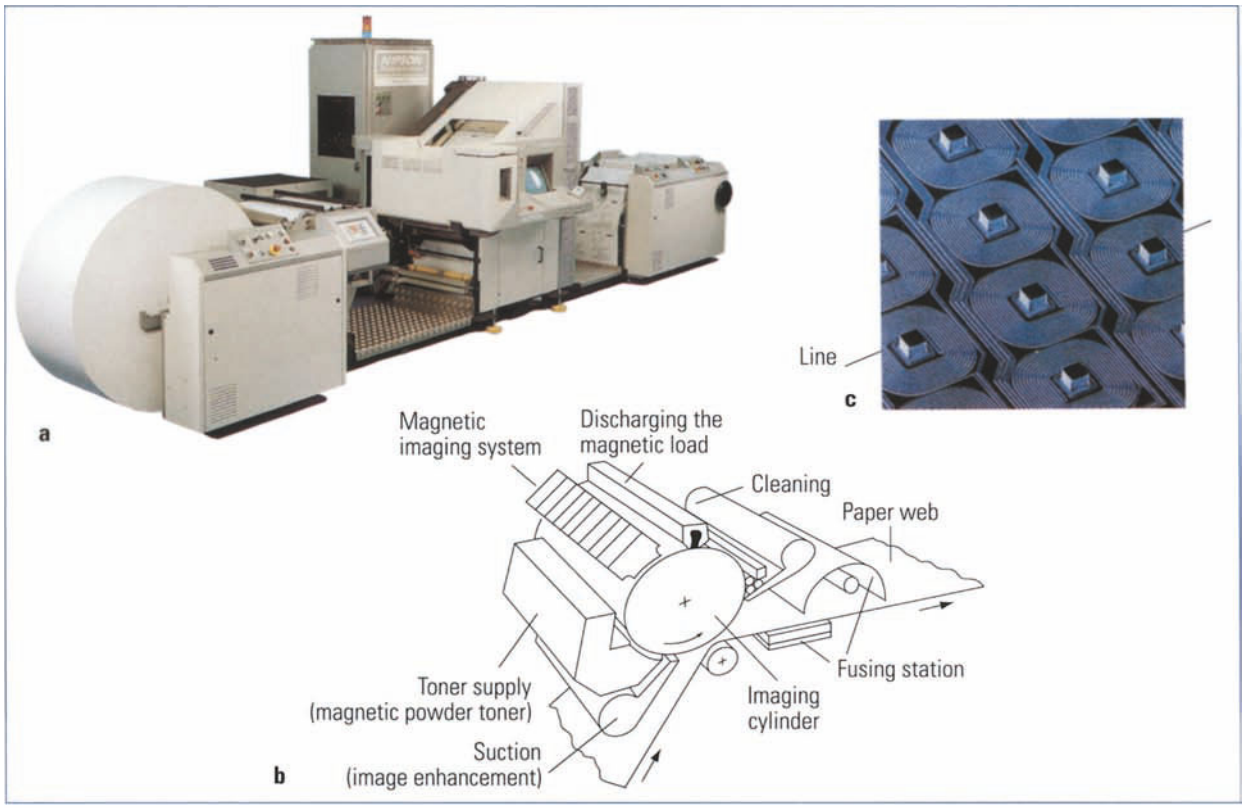
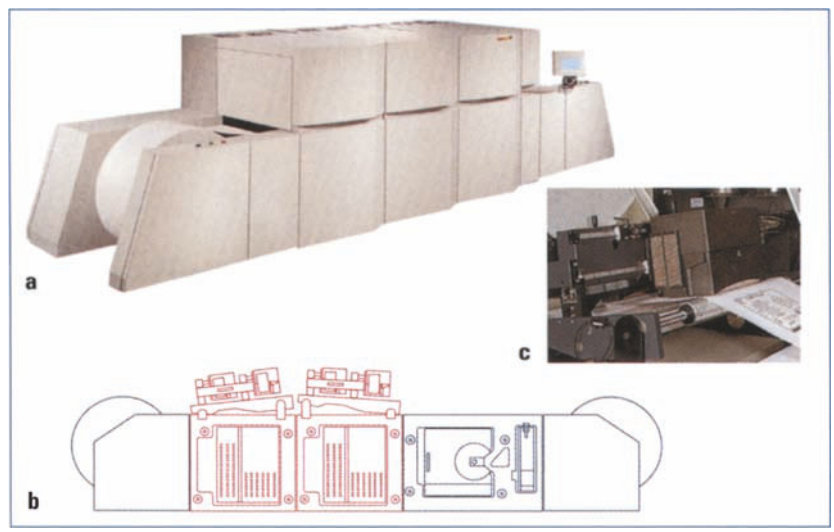


Fig. 4.5-13 Digital printing system (magnetography) for printing on web material.
a Printing system;
b NIP printing unit (magnetography);
c Miniaturized magnets for imaging (detail of array for 480 dpi, six-line structure with 80 dpi per line) (VaryPress T700, NIPSON)

Fig. 4.5-14
Ink jet printing installation with four printing systems and drying equipment for printing on web material.
a Computer to print system;
b Diagram (two printing units each having two printing systems, drying unit);
c Ink jet module in printing unit (VersaMark MPS4, Scitex Digital Printing)



Model (manufacturer)	**DemandStream 4000 DI** (Océ)	**DocuTech 6180** (Xerox)	**Digimaster 9110** (Heidelberg)	**ImageFast 180** (Delphax)	**Varypress T 700** (Nipson)	**VersaMark MPS 4** (Scitex)
NIP processes	Electrophotography	Electrophotography	Electrophotography	Ionography	Magnetography	Ink Jet (cont.)
Printing format, substrate	A3+ (portrait), Sheet	A3+ (portrait), Sheet	A3+ (portrait), Sheet	A3+ (portrait), Sheet	approx. 457 mm wide, web	e.g., A3+ (landscape), web
Duplex printing	possible	possible	possible	possible	possible	possible
Imaging method	LED array	ROS system	LED array	Ion sources array	Magnetic head array	Nozzle array
Addressability (dpi)	600	600	600	240 (300)	480	300
Gray values/ pixel	2	2	2	2	2	2
Productivity: – A4 pages/min	110	180	110	180 (90 sheets duplex)	700	1000
– printing speed (m/s)	approx. 0.5	approx. 0.8	approx. 0.5	approx. 0.54	approx. 1.75	approx. 2.5
Market launch	1997	1997 (DocuTech 135 since 1990)	1999	1996	1998 (previous models with 240 dpi)	1999

Table 4.5-2 Computer to print systems for single-color and special color printing (selection, status: 1999)

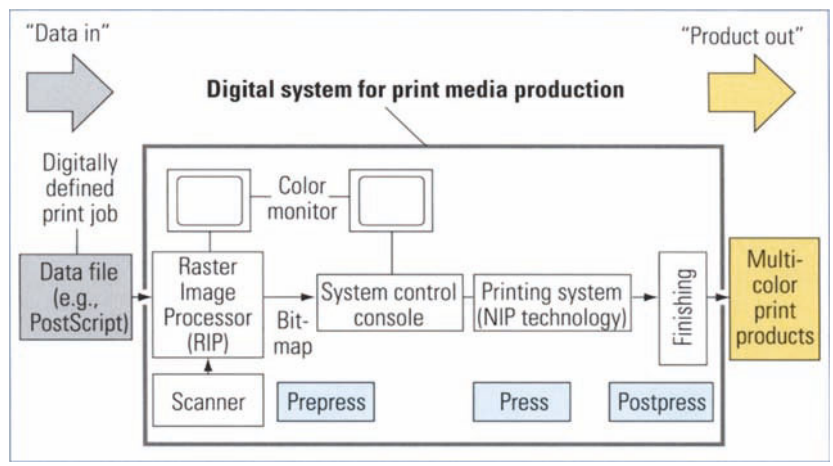


Fig. 4.5-15
Digital system for the production of print media with integration of prepress, press and postpress

In part 1 of figure 4.5-16 the color separations are collected directly on the *paper* using a system in *unit design* (cf. the system shown in fig. 4.5-6). This could also be achieved with the printing system illustrated in part 2, which is based on a *satellite design*. Here the four-color print takes place on a common impression cylinder.

In the year 2000 Heidelberg and Kodak (joint venture: NexPress Solutions) launched the new multicolor printing system (NexPress 2100) for sheet-fed printing. With

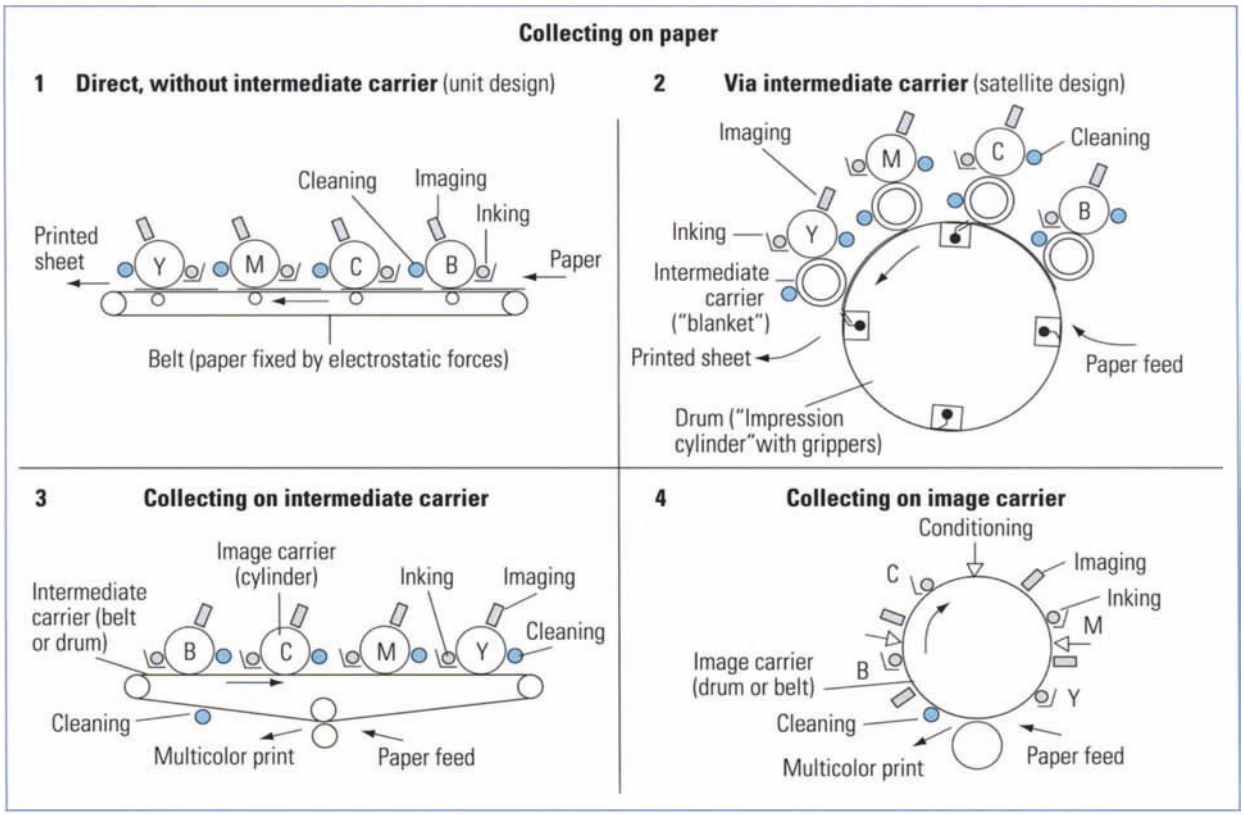


Fig. 4.5-16 Designs for collecting color separations in multicolor printing with computer to print systems (singlepass systems)

this production system the multicolor print is based on the method shown in part 1 of figure 4.5-16. However, to obtain better printing quality each printing unit is equipped with an additional intermediate cylinder that is covered with a rubber-like material (fig. 4.4-2 on the right). The printing system produces 2100 A3 pages (four-color) per hour (this corresponds to 70 A4 pages per minute) and is equipped for simplex printing as well as for duplex printing (perfecting). The NIP technique used is electrophotography; imaging takes place via an LED array with 600 dpi and numerous gray levels per pixel (see fig. 9.2-11).

Part 3 of figure 4.5-16 shows a variant in which the multicolor image is collected on an *intermediate carrier* in the form of an endless belt. The image is then transferred in a single contact with the paper. At the beginning of the year 2000 Xerox introduced a new printing system (DocuColor 2060). This system has a similarly structured multicolor printing unit as shown in part 3 of figure 4.5-16 (production speed: 60 A4 pages per minute, addressability: 600 dpi).

With the printing system from Indigo already described (see fig. 4.5-5), color separations are collected on an intermediate cylinder with a flexible, rubber-like surface. With the system shown in figure 4.5-4, on the other hand, they are collected on the paper by switching the toner supply four times while the sheet is held on the impression cylinder in a single printing unit (*single unit design, multipass system*).

In the concept shown in part 4 of figure 4.5-16 the color separations are collected directly on the *imaging cylinder (or belt)*, that is, imaging and inking take place in the same system. The "Trilevel" method for highlight color printing described previously is an example of this option.

In the middle of the year 2000 Xeikon (in cooperation with Agfa) has launched a multicolor system for printing on sheet material. In this system based on the

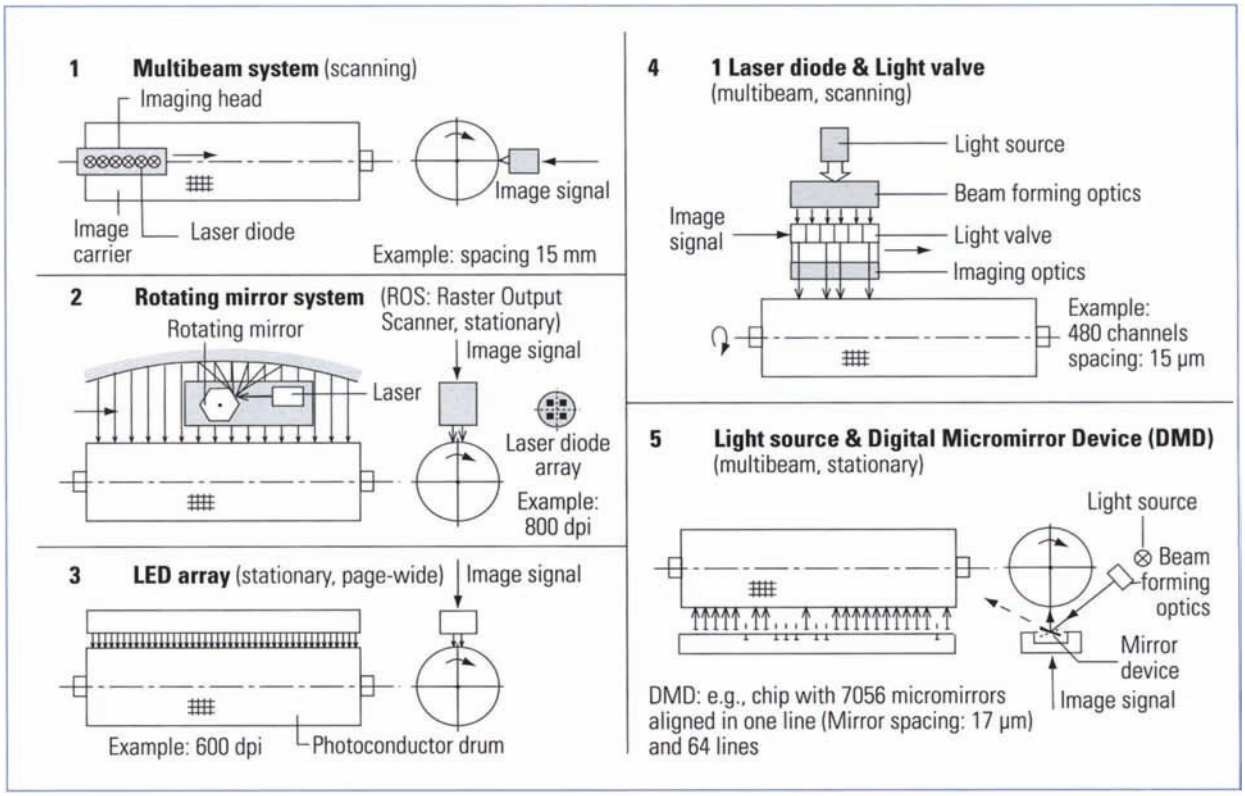


Fig. 4.5-17 Variants for the configuration of multibeam systems in optical imaging of computer to ... systems

NIP technology of electrophotography, the color separations are transferred successively onto a photoconductor belt via only one imaging system and inked one after the other in accordance with the separation. Overprinting takes place on the paper at four contact points with the imaged and inked belt. (In principle this concept is similar to the one shown in part 1 of fig. 4.5-16. The only difference is that the individual imaging cylinders were replaced by a photoconductor belt with just one imaging system.) Duplex printing on this system (CSP 320D/Xeikon and Chromapress Csi/Agfa) is achieved through two multicolor systems that are arranged in a line (productivity: 32 A4 pages per minute, addressability: 600 dpi).

Imaging Systems. Different *variants for the design of multibeam optical imaging systems* (which can also be used for electrophotography) are illustrated in figure 4.5-17. Most of these systems have already been presented in previous sections on computer to press/direct imaging, the design of computer to plate or computer to film systems and also in the examples in this chapter on electrophotography-based computer to print systems.

The system in part 1 of figure 4.5-17 is used in principle in the Quickmaster DI computer to press/direct imaging printing system (figs. 4.4-6 to 4.4-9). The concept shown in part 2 is, for example, used in electrophotography-based printing systems (figs. 4.5-4 or 4.5-10).

The multibeam imaging system illustrated in part 3 is used in the printing systems shown in figures 4.5-3, 4.5-8, and 4.5-11.

The multibeam imaging system as shown in part 4 is installed in computer to ... systems illustrated in figures 4.1-4, 4.3-3, 4.3-33, and 4.4-11 but could also be employed as a module for page-wide imaging in electrophotographic systems.

The system in part 5 represents a special concept. Here, the multibeam system can be set up for page-wide imaging using electrophotography via individually controllable micro-mirrors. In a mirror array provided by

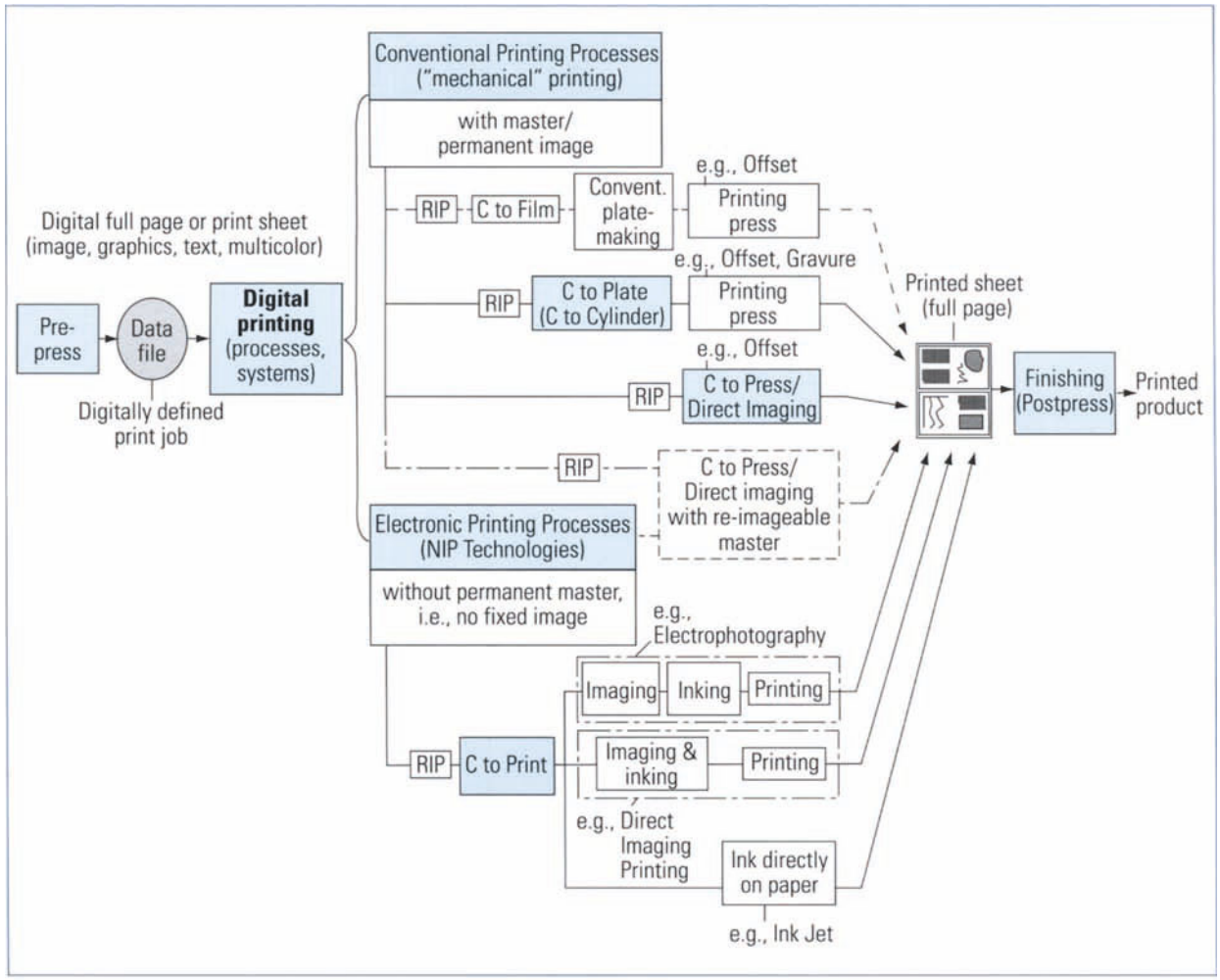


Fig. 4.5-18 Digital printing technologies, components, and systems

Texas Instruments the individual, micro-mechanically manufactured mirrors are only 17 µm apart and the line length is approximately 120 mm. Magnification by a factor of 2.5 produces an imaging width of approximately 300 mm with a resolution of 600 dpi. Practical applications for printing have not yet been implemented (for computer to plate there are some announcements).

4.5.4 Digital Printing

The computer to... technologies dealt with in chapter 4 are all based on a digitally defined print job. Various output devices (computer to film, computer to plate, computer to press/direct imaging or computer to print systems) are controlled via raster image processors (RIP).

The *levels of digitization* in the production systems and solutions available for printed media production *can vary greatly*.

Figure 4.5-18 explains how digital printing based on a digitally specified print job can be interpreted/understood. The basic starting point when using digital printing options is the single- or multicolor *digitally described full page or print sheet* with the entire image, text, and graphics information. As illustrated, different printing technologies can now be used. On the one

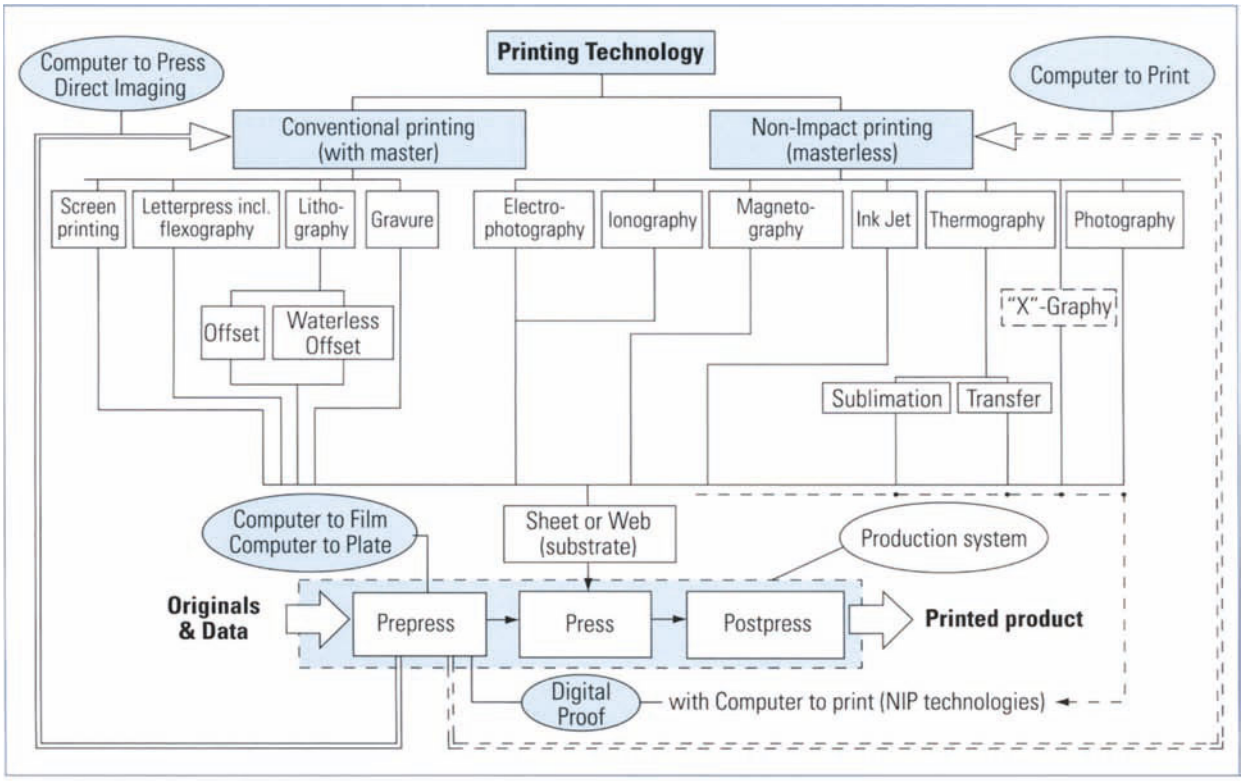


Fig. 4.5-19 Printing processes, computer to ... technologies, and workflow for the production of print media

hand, the conventional printing processes that operate with a permanent master ("mechanical" printing) can be used and on the other hand there are the "electronic" printing processes that do not require a fixed master (NIP technologies).

When *conventional printing technologies* such as offset printing are used, the lowest level of digitization for digital printing within the entire process chain is computer to film. A relatively high level of digital printing is the more direct linkage of prepress to press via computer to plate. When computer to press/direct imaging presses are used, the master is produced directly in the press from a digitally defined print job; since the film and mounting of the imaged plate have been dispensed with this version of digital printing represents a high level of digitization with a fixed master.

The introduction of *electronic printing processes* such as electrophotography or ink jet represents the highest level of the expansion of digitization within the entire production process, especially if in-line finishing is also carried out. With this digital printing variant, the multicolor printed product is produced in the press (without a permanent master) directly on the paper via the control of the imaging system solely by the transfer of ink via an intermediate carrier or, with the ink jet process, directly from the nozzle array.

In the case of computer to press/direct imaging technologies that use re-imageable masters, digital printing occupies a position between "mechanical" printing with a fixed, permanent master and "electronic" printing without a fixed print image. It represents the highest level of digitization of printing processes using a permanent master since with this process (computer to press/direct imaging with re-imageable master) the stored image can, in principle, be deleted and a new image built up on the plate or cylinder surface after each printing rotation (although this is not the aim and the strength of these kinds of processes).

It must be emphasized that this description and the illustration in diagram 4.5-18 show that digital print-

ing is not merely the production of printed products using non-impact printing technologies/systems, but that digital printing is realized by operating production equipment in the digital workflow that is controlled via the digitally defined print jobs using the various computer to ... technologies. The prerequisite is therefore digital prepress and an interface to the computer to ... system via a raster image processor (RIP). Digital printing is therefore practiced in companies with extremely diverse installations that are adapted to meet the requirements of the specific clientele and print orders.

Finally, figure 4.5-19 demonstrates once again the role that the various computer to ... technologies, production systems, and technologies play by way of a comprehensive overview of printing technologies and of the production flow of printed media production.

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5 Printing Technologies without a Printing Plate (NIP Technologies)

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5.1 Principles and Basic Components

Non-Impact Printing Technologies (NIP Technologies)
This chapter is dedicated to printing technologies that do not require a solid printing plate (master) with a fixed image and that can basically produce successive pages with different printed images.

These processes are referred to as *non-impact* printing technologies (NIP technologies), a designation that is based on the early digitally and electronically controlled printing systems for outputting data by means of a matrix printer in a computer center. In such matrix printers the type is controlled electronically. The information is transferred to the paper via an ink ribbon. Such systems have largely been superseded by electrophotographic technologies, in which the information is no longer transferred to the paper via type (for example a daisy wheel) or needles (matrix printer) hitting a transfer medium, but is transferred to an intermediate carrier, that is, a drum coated with a photoconductor layer, via laser, which provides for a *contact-free*, *non-impact* image transfer by photons. The (invisible) latent image is stored on the intermediate carrier, inked by a special type of ink (toner) and then transferred to the paper. Therefore, there really is contact between the inked carrier storing the information and the paper, but the information is not transferred by elements hitting a transfer medium. This is where the designation "non-impact printing technology" originates.

In sections 4.5, 4.1, and 1.3.3 some printing technologies based on non-impact technologies have already been explained.

In sections 5.2 to 5.9 the physical principles and possibilities for constructing printing systems will be explained. For each technology, at least one printing system is described as it is used in practice.

First there will be a general description of the functioning principle and the structure of NIP printing systems.

5.1.1 Computer to Press/to Print Technology

Computer to press systems applying non-impact printing technologies do not require a printing plate. As shown in figure 5.1-1, the printing system is controlled directly by a raster image processor on the basis of the print job described entirely in digital form. Depending on the applied NIP technology, the image is either transferred via an intermediate carrier/*imaging surface* (which, in the case of electrophotography, is the photoconductor drum from which the printing image is

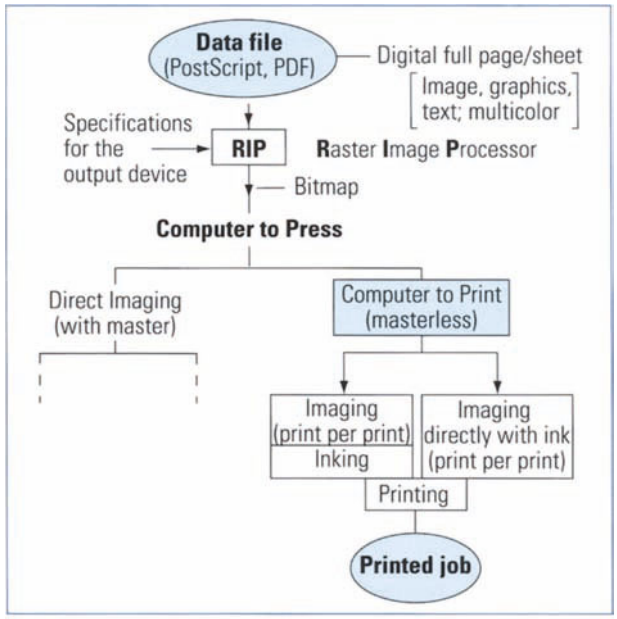


Fig. 5.1-1
Computer to press on the basis of non-impact printing technologies (computer to print)

H. Kipphan (ed.), *Handbook of Print Media*
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transferred to the paper after the drum has been imaged with the printing image by light and subsequently inked), or the image is transferred directly without an intermediate carrier (as is the case with ink jet systems).

In NIP technologies there is no printing plate carrying permanent information. As a consequence, different information can be printed on every sheet. This has given rise to new, efficient ways of producing printed media, such as print on demand, personalization, book on demand, and so forth. The productivity of these systems is lower than the productivity of printing systems based on conventional technologies, that is, technologies using solid printing plates. This means that computer to print systems based on NIP technologies cover particular market segments, for example, short-run jobs, proofing applications, personalization, office and DTP applications, and so forth.

One requirement for printing systems based on NIP technologies is the *description* of the sheet to be printed with all its image, text, and graphic components or of the entire print job, such as a thirty-two-page multicolor booklet, in an *entirely digital* form.

Figure 5.1-2 shows diagrammatically how the digital systems of the prepress stage are used to produce an exclusively digital data file describing the entire single-color or multicolor printing page (or sheet) with all its images, text, and graphics. The print job is then transmitted to a computer to print system via a raster image processor (RIP). In the computer to print system, imaging and printing operations are carried out according to the respective non-impact printing technology.

Figure 5.1-3 diagrammatically represents a *printing unit* within a digital printer (computer to print system). The imaging surface does not have a storage function, that is, after imaging, there is no stable, fixed printing image. After imaging, inking is carried out via special types of inking units. The printing image can either be transferred directly to the paper or via an *intermediate carrier* (e.g., a cylinder with a rubber-like soft surface). The imaging surface must be prepared/conditioned again and then re-imaged for the next print.

The actual design of the individual printing unit components depends on the physical effects that form the basis of the different NIP technologies.

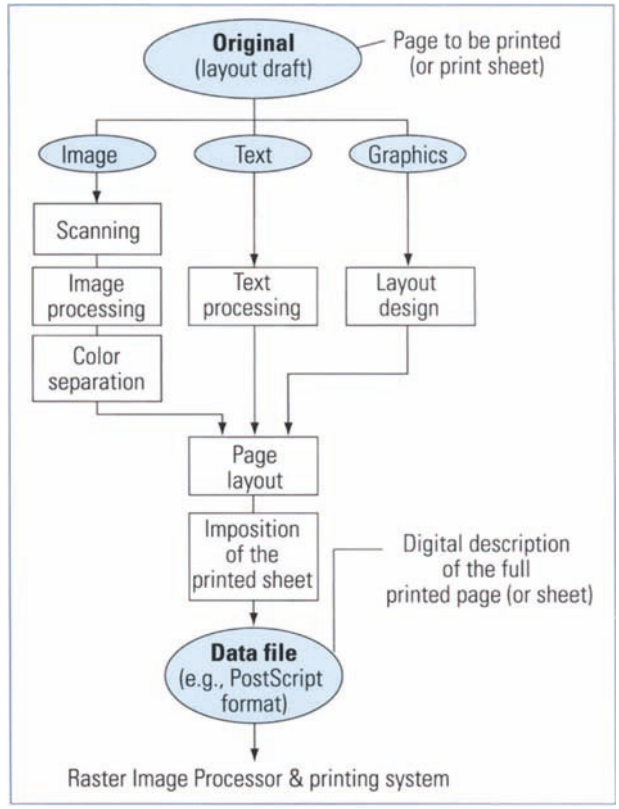


Fig. 5.1-2 Digital composition of a printed page

5.1.2 Non-Impact Printing Technologies (Overview)

In the *general survey* given in figure 5.1-4 a number of non-impact printing technologies are given. They are named after the physical or chemical principle they are based upon. With *electrophotography*, the imaging is carried out on the basis of photo-electronic effects. In *ionography*, charges are transferred to an appropriate surface in order to create the image. *Magnetography* is based on the creation of magnetic patterns on the surface of the image carrier that correspond to the image to be printed. In *ink jet* processes, the ink is transferred directly to the substrate by means of a jet system. *Thermography*, a printing process in which thermal effects are used to create the printing image via special types of ink carriers (such as ribbon material), can be subdivided into thermal sublimation (dye sublimation) and thermal transfer (wax transfer). *Photography* relies on special types of photo-sensitive papers, which are digitally exposed via light signals corresponding to the image. In this list, the *"X"-Graphy* is added as a collective designation for NIP technologies that do not belong to any of the technologies indicated above. These are tech-

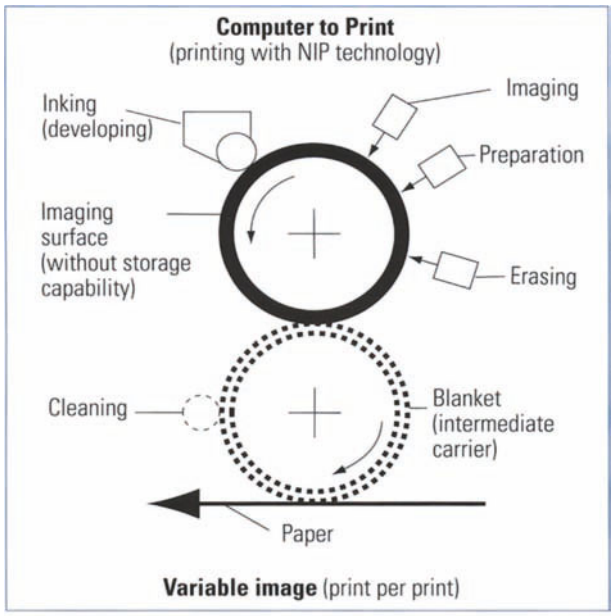


Fig. 5.1-3
Example of a printing unit for computer to print (NIP technology)

nologies such as "Direct imaging/inductive printing", "TonerJet", "Elcography", "Zurography", and so on, which will be explained in a later chapter.

In non-impact printing technologies, the physical effects for creating the image frequently require the use of special types of *ink*. In electrophotography, for example, powder toners or liquid toners are used. Ink jet technologies work with liquid inks of low viscosity as well as so-called hot-melt inks, and thermography uses ink that has been applied to ink donors.

Depending on the process applied, the printing unit represented in figure 5.1-3 can be equipped with many different functional components differing in terms of imaging, image carriers, and inking unit.

As shown in figure 5.1-4, NIP technologies can be applied to both *sheet-fed and web-fed* printing. The printing unit can be a component of in-line production of printed media in the digital workflow and production flow.

5.1.3 Printing Process and Functional Components in NIP Technologies

Figure 5.1-5 shows various *process steps* in printing processes based on NIP technologies. Depending on the process selected, it may not be necessary to perform all of them. Most processes include the functional components of *imaging* (creation of an invisible, latent image), *inking* the latent image (also called developing, based on the fact that the invisible latent image is visible after the transfer of toner onto the imaging surface), *ink transfer* to the substrate, *fixing/drying, and cleaning and preparing the surface (conditioning)* of the image carrier. In later chapters, the additional process steps required in various NIP technologies and included in figure 5.1-5 will be explained. Figure 5.1-5 also shows that it is, in principle, also possible for NIP system configurations to include an *intermediate carrier* for transferring the ink to the paper (as is the case in offset printing, where a blanket cylinder is used for this purpose). A decisive functional component in the process is the *image carrier* (image carriers, as well as intermediate carriers, can be constructed as stable drums or flexible belts).

5.1.4 Digitally Controlled Image Creation in NIP Technologies

In NIP technologies, the latent image on the image carrier is created by a digitally controlled imaging unit, for instance, by laser impulses in electrophotography or by charge application in ionography.

Print quality depends on the *addressability (resolution)* of the imaging systems (given as dots per inch or dpi), on the quality of the shape of the individual image elements (pixels), on the ability to transfer different amounts of ink per image element, and on the screening.

Figure 5.1-6 shows halftone dots in the printing image consisting of individual *image (picture) elements (pixels)*. Figure 5.1-6a shows how, at a *screen ruling* of 167 µm (60 lines/cm screen) and with varying addressability, an analog halftone dot is represented by digitally created pixels in a screen cell. The higher the resolution, the more accurate the contours.

Figure 5.1-6b shows *dot sizes* and *edges* with varying *resolution*. Figure 5.1-6b particularly emphasizes that in order to print solid areas, the diameter of an individual image dot must be greater than the width of the *pixel cell* (dot diameter = screen ruling $\times \sqrt{2}$). The smallest pixel screen ruling corresponds to the distance between the pixels (pitch).

If the respective process offers the possibility of inking individual image elements with different quantities of ink, the *optical density* of each image element *can be modulated*, that is, multiple *gray values* can be created *for each pixel*. In the example shown in figure 5.1-6c

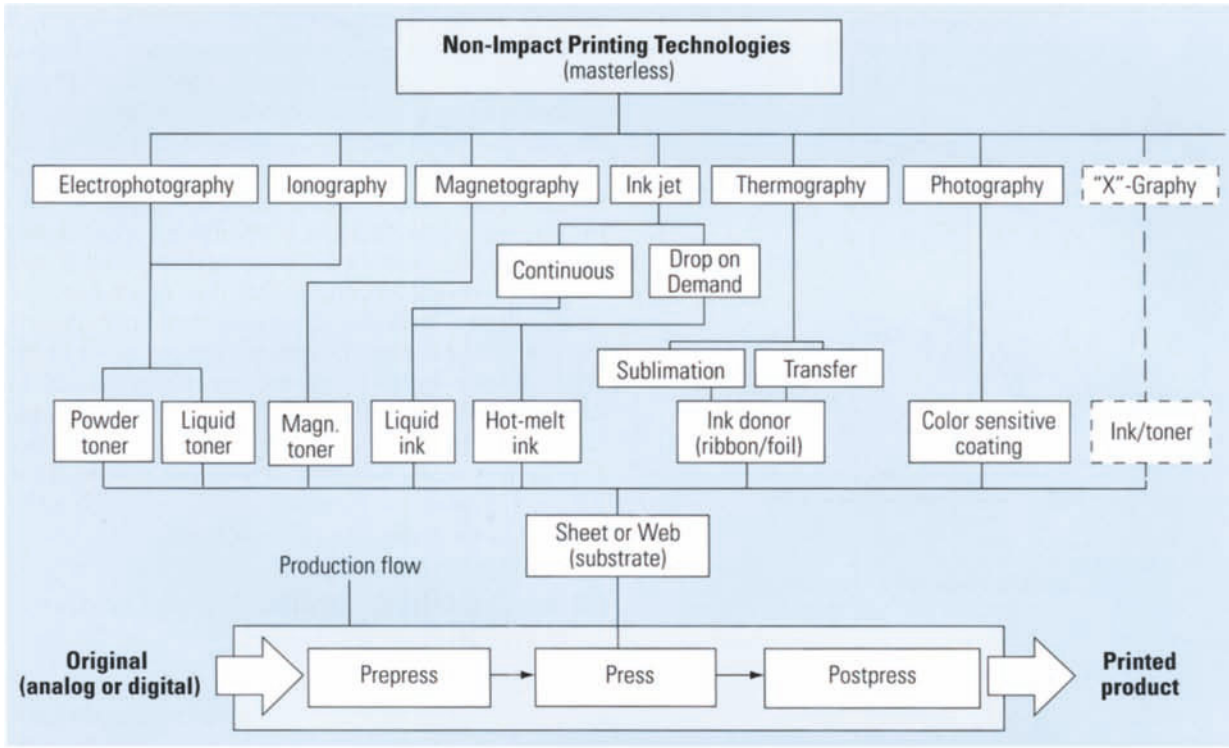
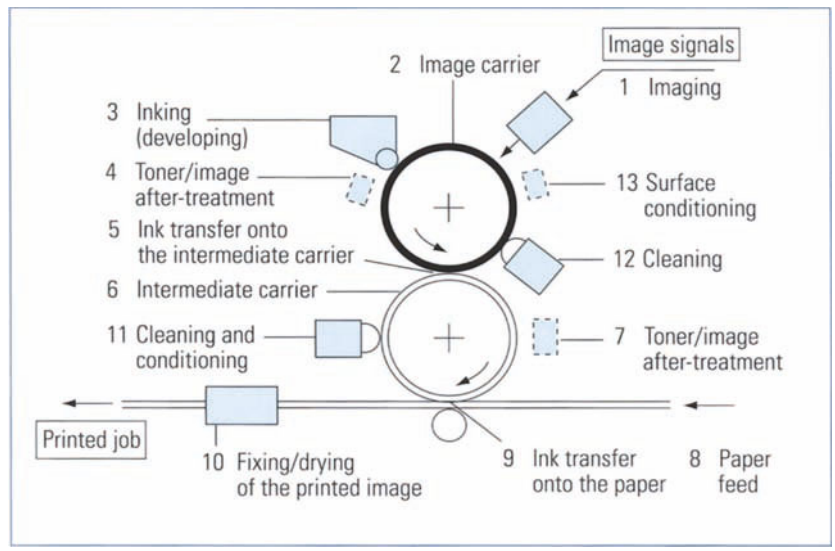


Fig. 5.1-4
General survey of the non-impact printing technologies with respect to the set-up of printing systems in the workflow for producing print media

Fig. 5.1-5
Functional components and process steps for a printing system based on non-impact printing technology



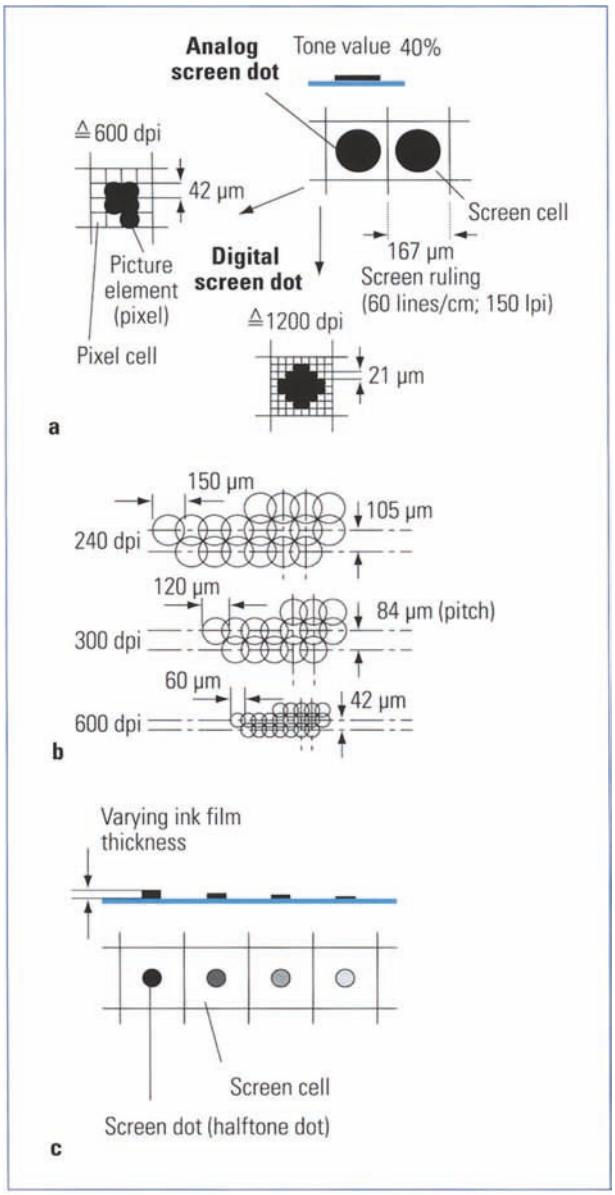


Fig. 5.1-6
Printed image generated from individual image elements in digital printing.
a Halftone dot consisting of pixels (picture elements) at different resolutions (addressability);
b Image structures generated on systems having different addressability/resolutions;
c Density modulation of the screen dots (pixels) by varying the ink film thickness

there are five gray values, that is, four different ink layer thicknesses plus non-printed image area (four gray levels, five gray values). Systems providing the possibility of *density modulation* (see also sec. 1.4.3, fig. 1.4-35) can reproduce a wider tone range and a wider color space (gamut) than systems that can only print with two gray values (ink or no ink on the paper). As shown in figure 5.1-6c the density modulation for a pixel of equal size is done by a varying ink film thickness. The creation of gray values within one pixel cell can also be achieved through variably sized pixels or through a combination of both effects (film thickness and pixel diameter).

Figure 5.1-7 gives a summary of the *relation between the factors of screen ruling (screen frequency), addressability (resolution), and gray values*, which determine printing quality in the case of digital imaging.

5.1.5 System Concepts/Architecture of Computer to Print Systems

Singlepass and Multipass Systems

Multicolor printing based on non-impact technologies can be carried out in multipass or singlepass systems. *Singlepass systems* comprise a separate printing unit (or a separate ink transfer from the intermediate carrier onto the substrate) for every color, whereas *multipass systems* have only one printing unit which is successively connected to several inking units corresponding to the different colors of the color separations. If the process colors cyan, magenta, yellow, and black are to be printed in a multipass system, just one imaging unit is used for successively creating the four color separations, while four inking units are provided for transferring the ink. Singlepass systems comprise an entire printing unit for every process color, so that the four color separations can be imaged simultaneously in the computer to print system.

System Concepts for Multicolor Printing on the Basis of one Printing Unit (Multipass System)

The following examples relate to electrophotography, the technology that has become most commonly used in various applications for producing printed media. Yet the examples are also valid and representative for most other NIP technologies.

In general, the image can be transferred to the paper either *directly* from the imaging surface or via an *intermediate carrier*. Imaging surfaces as well as intermedi-

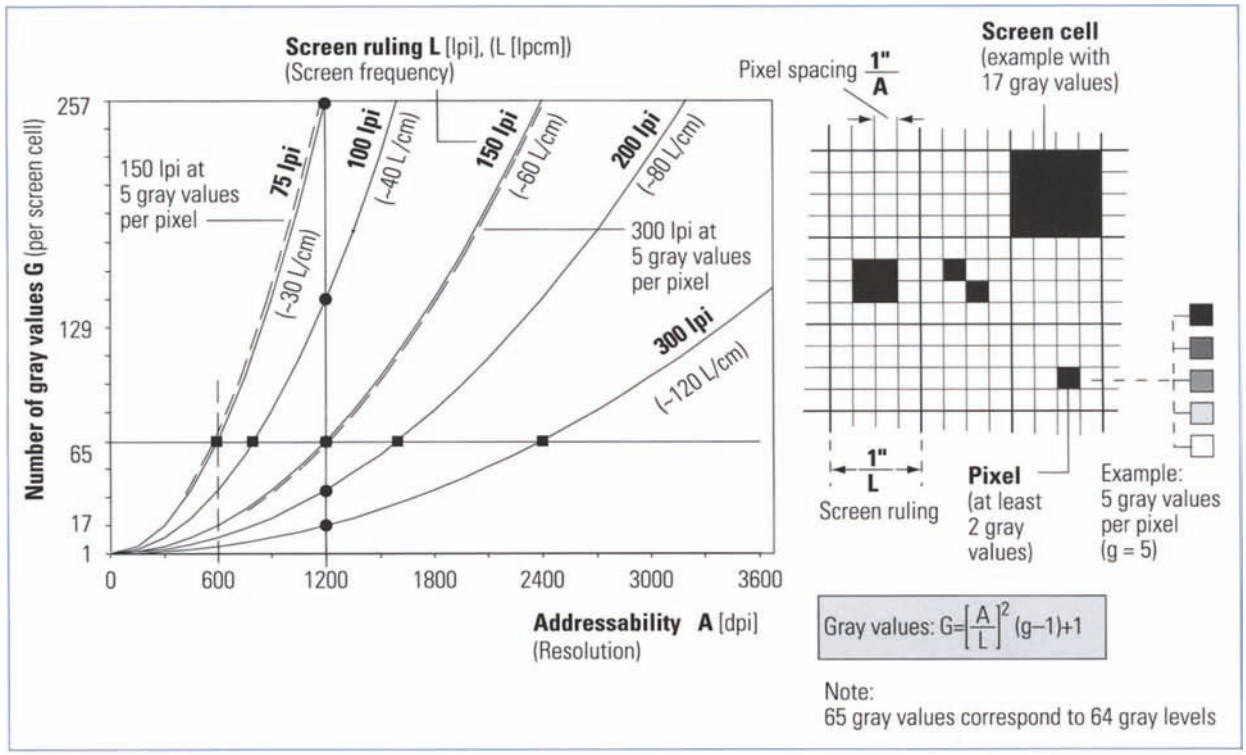


Fig. 5.1-7 Relation between screen ruling, addressability, and gray values in a digitally screened image

ate carriers can be constructed as a drum or as a *revolving belt*. The color separations for a four-color print can be collected in different ways: on the paper, on the intermediate carrier, or on the imaging surface of the imaging system itself.

Figure 5.1-8 shows a system in which the imaging drum is imaged by only one laser imaging system, but in which four inking units (developing units) for inking the imaging drum are fixed in their positions on the circumference of the imaging drum (*satellite configuration*). The color separations are transferred to the imaging drum one after the other, are inked with the corresponding color and collected on the intermediate carrier belt. The four-color printing image is transferred from the intermediate carrier belt in one contact to the paper.

The system in figure 5.1-9 shows inking units (developing units) arranged in a *carousel system*. The imaging is carried out on a photoconductor drum, which contacts the respective inking unit and the paper to be printed. The paper sheet is held on the impression cylinder (transfer drum) by electrostatic forces or, in

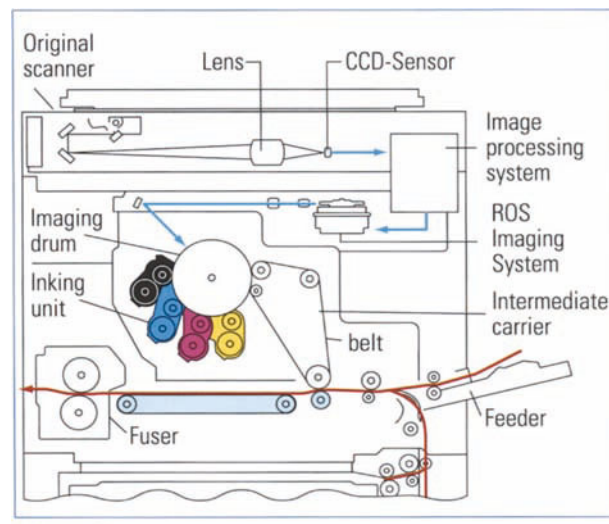


Fig. 5.1-8
Multipass system for multicolor printing (satellite arrangement of the inking units); color separations are collected on a belt acting as an intermediate carrier (NC 5006, Ricoh)

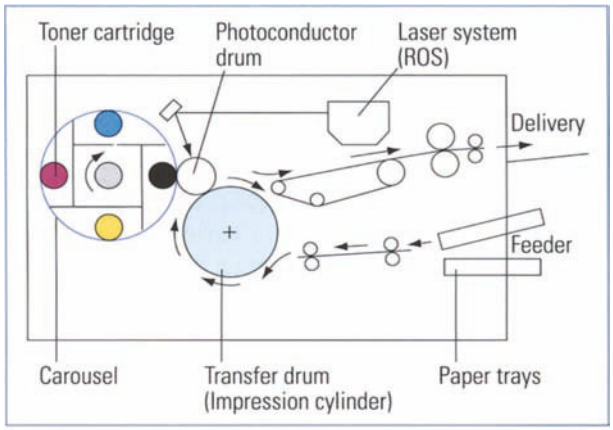


Fig. 5.1-9
Multipass system for multicolor printing (carousel configuration for switching toner feed); color separations are collected on the substrate during four rotations of the transfer drum for a four-color print (CLC 300, Canon)

some designs, by an additional gripper bar. After four rotations of the impression cylinder, the four-color print image is complete.

The system depicted in figure 5.1-10 works in a similar way. The paper sheet is held on the impression cylinder. In four rotations, the four color separations are successively transferred via an *intermediate cylinder*. The imaging is carried out by laser and a photoconductor drum. To develop the latent image, different color liquid toners are applied via a single switchable inking system (for a more detailed explanation see fig .5.2-12).

In the system shown in figure 5.1-11 the *image carrier* is constructed as a *belt* that can be imaged by a laser system. The individual inking units run in sequence, the four-color image is collected on an intermediate cylinder and then transferred to the paper in one pass.

The system in figure 5.1-12 is also based on electrophotography. The four inking units (developing units) can be successively connected to the photoconductor drum. The characteristic feature of this system is that color separations are collected directly on the *imaging drum* and transferred to the paper in one contact.

System Concepts Comprising Several Printing Units for Multicolor Printing (Singlepass Systems)

In the multipass systems described above, the printing sheet or the intermediate carrier has to be introduced to the same printing unit several times to receive ink. The result is low productivity.

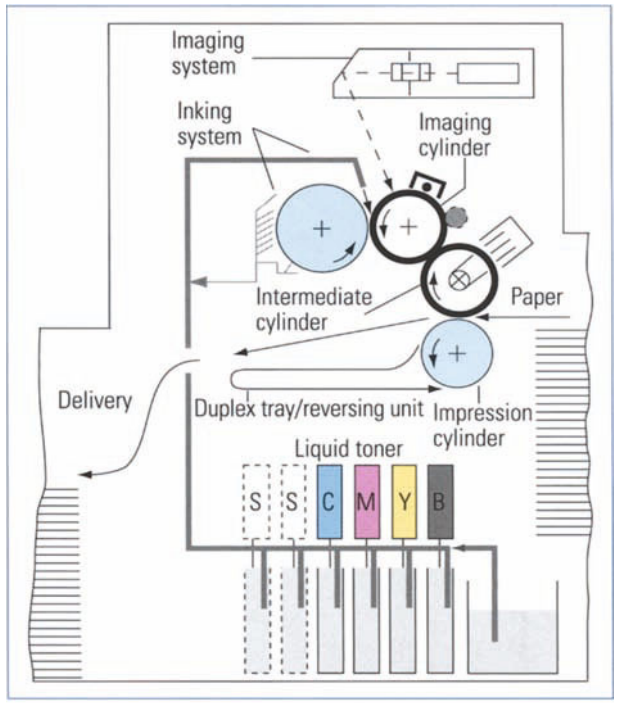


Fig. 5.1-10
Multipass system for multicolor printing with switchable feed of liquid toners; color separations are collected on the printing cylinder while the printing sheet is held in its position; toner transfer via intermediate cylinder (E-Print 1000, Indigo)

Singlepass systems comprise one imaging and printing unit for each process color. To print a multicolor image, the printing sheet passes through several printing units to receive ink and this happens in one pass, hence the designation singlepass system. The imaging speed corresponds to the printing speed.

Figure 5.1-13 summarizes the various possibilites of collecting color separations for a multicolor print. In the *sequential arrangement* (*unit design*) in figure 5.1-13a, the ink is transferred from the imaging unit via the imaging drum directly to the paper, as in the system shown in figure 5.1-9; in this case, however, four printing units are arranged in a row (fig. 4.5-6 depicts such a printing system). At the same imaging speed, the productivity of a singlepass system is four times as high as that of a multipass system (e.g., fig. 5.1-10).

Figure 5.1-13b shows a system in which, as in figure 5.1-10, the printing image is transferred to the paper via an *intermediate cylinder*.

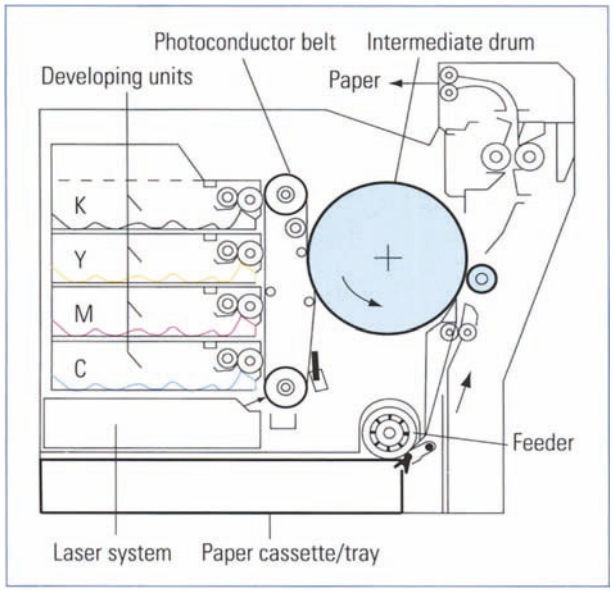


Fig. 5.1-11
Multipass system for multicolor printing with photoconductor belt as an image carrier; color separations are collected on an intermediate cylinder (BeamStar, Hitachi)

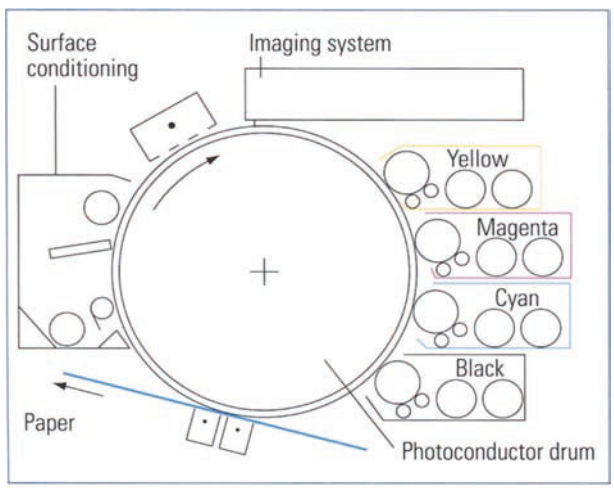


Fig. 5.1-12
Multipass system for multicolor printing (satellite configuration of inking units); color separations are collected on the imaging cylinder and then transferred to the paper (Matsuchita, Konica, HP)

In figure 5.1-13c the color separations are collected on an *intermediate carrier belt* and are then transferred to the paper in the same way as in figure 5.1-8.

In the system depicted in figure 5.1-13d the color separations are collected directly on the *imaging drum* but, in contrast to the system according to figure 5.1-12, the imaging and inking of the four color separations is carried out simultaneously and not during four rotations as required in the multipass system shown in figure 5.1-12.

Sheet Reversing Units/Possibilities for Printing on both Sides of a Sheet in a Printing System (Duplex Printing)

Double-sided printing is possible in computer to print systems without intermediate storage of the sheet after the first side has been printed. This is reinforced by the fact that in most non-impact printing technologies the *ink is already dry* after printing so that the sheet or web can be fed directly to a further processing unit. After the first side has been printed, the substrate can be reversed and fed to the same printing units once again. Alternatively, a second printing unit can be provided in-line for printing on the second side of the substrate. This is often the case in double-sided single-color printing systems of high productivity.

There are various concepts for duplex printing (double-sided printing or perfecting) that will not be dealt with in depth in this chapter. The reader is referred to illustrations of systems comprising perfecting options shown in earlier chapters. The printing system shown in figure 5.1-10 (see also fig. 4.5-4) for double-sided multicolor printing on sheets has a *duplex tray/reversing unit*, in which the sheet is temporarily stored in order to be *reversed* and picked up again for printing on its reverse side.

In the system illustrated in figures 4.5-6, 4.1-8, and 9.2-11 the sheet is fed back to the *transport belt* for another four-color print after the first side has been printed.

In the *twin arrangement* of the printing system in figure 4.5-8, the web reversal is performed by turner bars between two printing systems.

Figure 4.5-12 shows how a sheet reversal can be carried out in-line in a sheet-fed printing press with an angular arrangement of two combined printing systems.

In figure 5.4-7 there is a duplex option for *half-size webs*. The web is re-fed to the same printing unit (with the web being offset by half of its width) and printed on its second side. The system in figure 4.5-14 works in a comparable way.

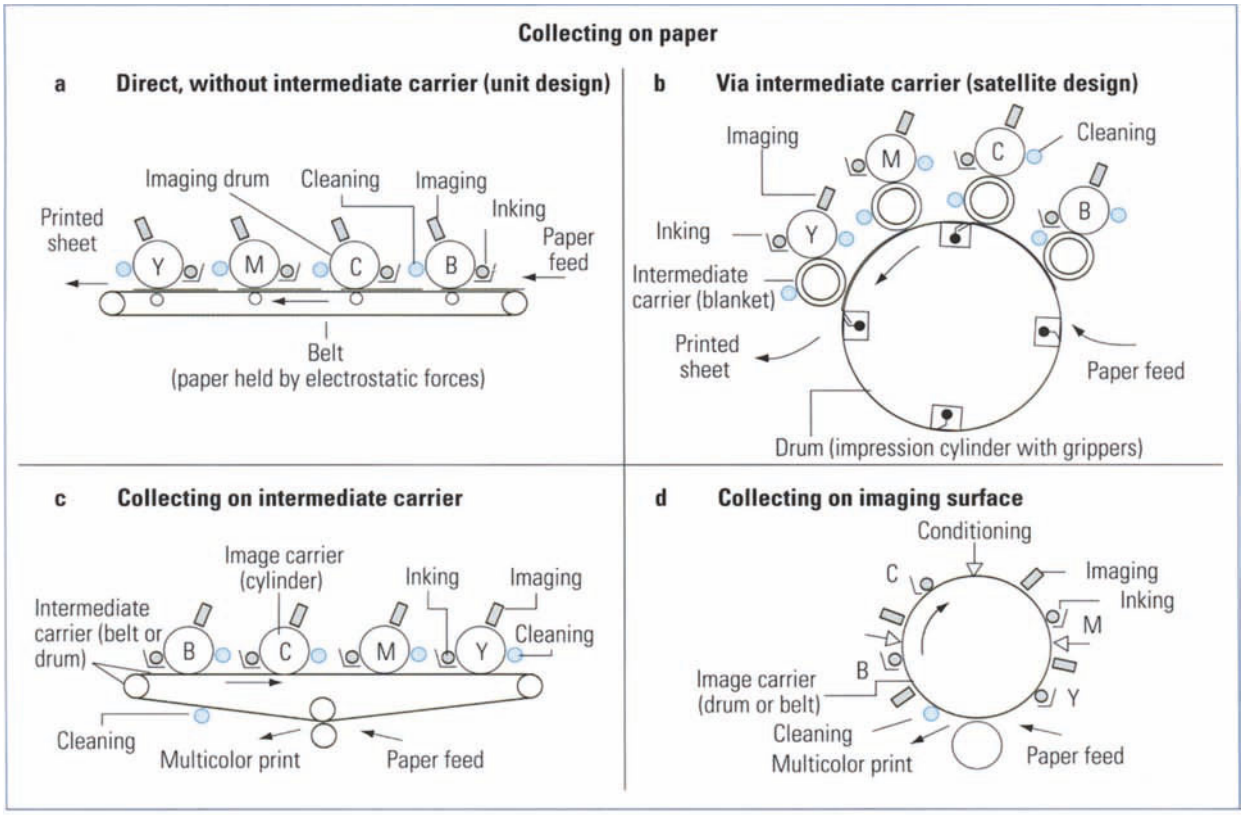


Fig. 5.1-13 System concepts with several printing units for collecting color separations for multicolor printing (singlepass system)

5.1.6 Inks for Non-Impact Printing Processes

In principle, non-impact technologies require specially suited inks. In most processes that do not require a printing plate a latent (invisible) image is created on the image carrier (this is not the case in ink jet processes). The image can be produced as a pattern of electrical charges or as a pattern of magnetic fields. The ink to be transferred to this image carrier must thus have physical/chemical properties corresponding to the physical effects creating the latent image. With electrophotography, where electric fields exist, toners with an adapted polarity must be employed to ensure successful transfer of toner from the inking unit to the imaging surface. If the charging patterns that form the image to be printed on the imaged surface are positively charged, the ink (toner) particles must be negatively charged (in a relative sense, that means on a lower voltage level).

Toner

As can be seen from figure 5.1-4, toners are used in electrophotography, ionography, and magnetography. There are two different types of toner: powder toner (dry toner) and liquid toner. Figure 5.1-14 gives a short systematic survey of the toners.

Powder toners are available as single-component or two-component toners.

Two-component toners are more commonly used than single-component toners. In a two-component toner system, the toner particles for inking the printing image are fed to the image carrier via carrier particles. The carrier particles (about 80 µm in diameter) convey the considerably smaller toner particles (about 8 µm in diameter) and feed them into the inking process at the surface of the image carrier (fig. 5.1-15c). Whereas the toner particles are consumed in the printing process, the carrier particles are recycled in the inking system (also called the developer unit).

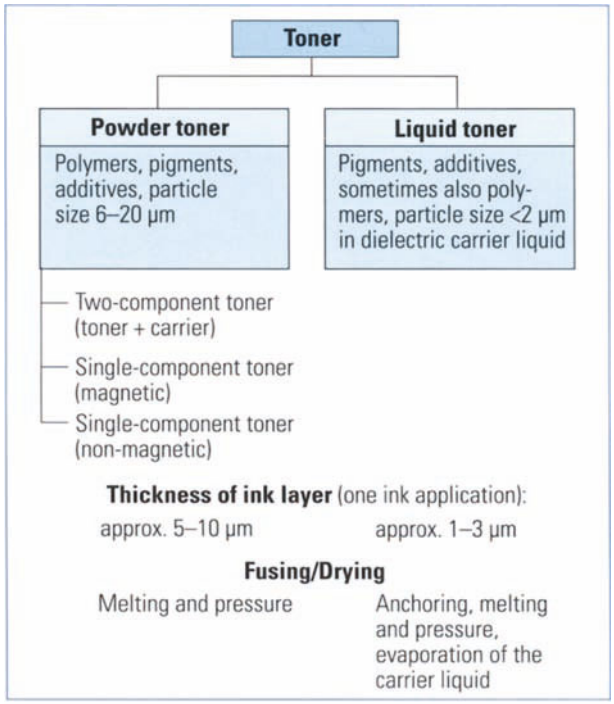


Fig. 5.1-14 Toner systems for NIP technologies

Single-component toners can be subdivided into magnetic and non-magnetic toners. *Magnetic* toners are particularly common for single-color printing with dark colors. *Non-magnetic* single-component toners are mostly used in systems working at a low operating speed.

Liquid toners comprise a carrier liquid for transporting the imaging pigments or toner particles. The carrier liquid must largely be removed before the printing image is transferred from the image carrier to the paper. In general, it is fed back into the printing process. In multicolor printing the use of liquid toners has not yet really caught on. The printing system shown in figure 5.1-10 uses liquid toners to produce multicolor prints, as does the system illustrated in figure 5.2-13. Numerous developments based on different chemical/physical concepts giving special consideration to the rheology of the carrier liquids and their impact on the environment are in progress (see also [5.1-1]).

In single-color printing, NIP technologies using powder toners create an *ink layer* on the paper that has a *thickness* of approximately 5–10 µm (compared to 1 µm in offset printing). If liquid toners are used, the ink layer thickness ranges between 1–3 µm, since the size of the toner particles is only 1–2 µm.

The use of powder toners implies that the *drying process* is automatically included in the printing process, since the printing image must be fixed by fusing the toner particles onto the paper. For this purpose, the printed sheet is exposed to heat and often also to pressure. If liquid toners are used, the drying process lies in evaporating or otherwise removing the carrier liquid, fixing the image by fusing the toner particles, applying pressure, and by anchoring the toner particles on the paper.

Figure 5.1-15 gives two examples of powder toners. Figure 5.1-15a shows the uneven structure of toner particles having been produced in melting and grinding processes. Several melting, grinding, and classification

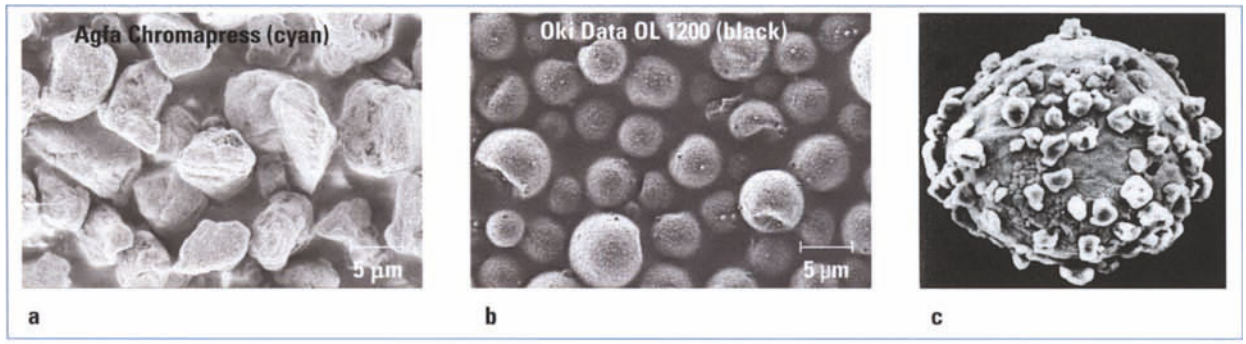


Fig. 5.1-15 Powder toners.
a Mechanically produced toner (AGFA);
b Chemically produced toner (OKI Data);
c Two-component toner system: toner particles on carrier particles (diameter of the carrier particle about 80 µm)

stages are necessary to produce toner out of the original granules. Figure 5.1-15b shows an example of spherical toner particles which can be produced from dispersions through direct chemical synthesis.

Figure 5.1-15c shows the positioning of toner particles on a carrier in a two-component toner.

Inks for Ink Jet Processes

Figure 5.1-16 gives a systematic survey of the different inks that can be used in the NIP technology ink jet.

As has already been shown in figure 5.1-4, a distinction is made between *liquid inks* and *hot-melt inks*. Both types of ink can comprise *dyes or pigments* as colorants. Different types of ink jet processes – which will be explained in chapter 5.5 – require different types of ink with respect to the ink carrier (e.g., water or solvents).

The type of ink to be used is also substantially determined by the properties of the *substrate* (absorbency, coating, foil, etc.), the surrounding conditions of use of the print media (light resistance, weather resistance, resistance to wear), and the drying process required during printing with different printing systems (productivity, multicolor printing, further processing, etc.).

If liquid inks are used, the *drying process* occurs through evaporation and absorption. The evaporation process can be accelerated by the application of heat. In the case of UV inks, the drying process involves UV light for radiation curing (cross-linking of organic molecules).

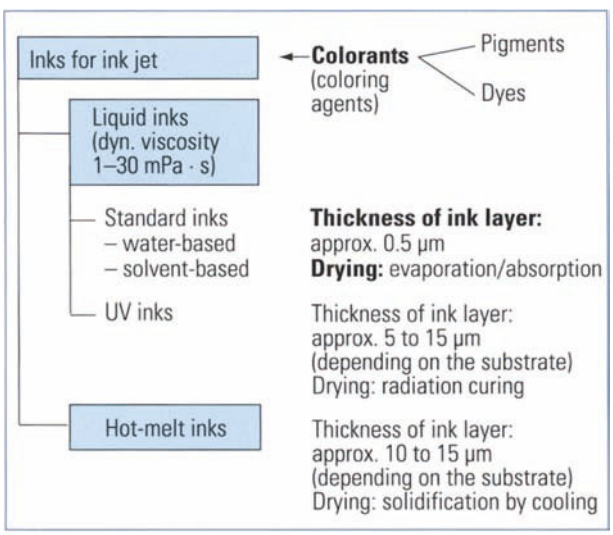


Fig. 5.1-16 Inks for ink jet processes

The use of hot-melt ink implies that the drying process is automatically included in the printing process: the ink that has been melted by heat prior to being processed cools down on the paper and becomes solid again.

The ink used and its interaction with the substrate determine the thickness of the ink layer on the paper and thereby the quality of the printed image, especially in multicolor printing. If liquid inks are used in the ink jet process, the thickness of the ink layer may be approximately 0.5 µm (rendering a high quality product). In the case of UV ink and hot-melt ink the ink layer thickness ranges between 10 and 15 µm, thus causing relief-like structures that can affect the visual impression. (The ink layer thickness in single-color offset printing is typically 0.7 µm.)

Inks for Thermography

The special types of ink used in the NIP technology thermography (thermal transfer and thermal sublimation) are dealt with in section 5.6. A characteristic feature is that in the thermal transfer and thermal sublimation processes the ink is applied as a thin layer to a *sheet or ribbon material.* In the printing process, the ink layer is transferred either in its entirety (*transfer* of the ink layer) or in part by controlled evaporation of the ink (*sublimation*).

In thermal printing processes, the paper to be printed may also comprise colorants that are activated to form the image by the application of heat. This is similar to technologies that are based on photographic processes.

In thermal transfer processes, the ink layer thickness typically is approx. 2 µm and in thermal sublimation the ink layer thickness ranges between 1 and 2 µm. The fixing process is automatically included in the process owing to the physical/chemical processes of thermography (melting/evaporation by heat and transfer by pressure, solidification by cooling down).

In section 1.5.2 (Printing Inks) the properties of inks for different printing technologies are summarized in table 1.5-6. The description of toners and inks for ink jet processes contains additional information.

5.1.7 Components for Computer to Print Systems

The block diagram in figure 5.1-17 represents components of a computer to print system based on NIP technologies. This system structure emphasizes once again that the printing system is controlled by a *raster image*

processor, which converts the digital data file of the print job into a bitmap for controlling the imaging and printing unit. In addition, figure 5.1-17 shows that originals can be digitized via a *scanner* to produce a data file that can be fed to the printing system. The data then obtained can be used either to complete the present data file of the print job or to directly reproduce the analog original, possibly after the image has been processed and corrected via the control console of the system. The system may comprise additional finishing (postpress) units as required.

The previous descriptions of *computer to print systems* using NIP technologies were based on the assumption that the print job was provided in an entirely digital form. In this case, the imaging unit in the printing unit is controlled via electronic, digital signals.

Most printing systems based on NIP technologies, however, also offer the possibility of producing a print on the basis of an analog original (scanner as shown in figs. 5.1-17, 5.1-8, and 4.5-6). In *conventional office copiers* based on electrophotography, the *original is optically transmitted* to a photo-sensitive surface in the printing unit (typically on a drum). For every copy, the original image must be scanned and transmitted again directly to the image carrier of the imaging system.

In contrast to this scanning of the image for a direct optical imaging process, many *scanners work digitally*, that is, they optically scan the original printing copy and digitize the image/content. To transfer the image, the image carrier is then imaged by a digitally controlled imaging unit (fig. 5.1-8). If, for instance, the original is to be copied ten times, the printing process can be conducted from the memory in which the digital image has been stored. Here, the *copier works like a digital printer* that, in general, receives the printing data from a network or data carrier.

It is therefore difficult to distinguish between printers and copiers in terms of printing processes. One distinction could, however, be that *copiers* are systems that produce every copy on the basis of an original which therefore has to be provided so that the system can optically rescan it for every copy. *Printers*, on the other hand, are systems that receive digital job data from a network via an interface and a RIP. If, for example, a digitally controlled printing system comprises a scanner for digitizing an analog original, and the printed product is then produced by means of the digitized data stored in a data memory, this system should be considered a printer and not a copier.

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Further Reading for 5.1

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Schein, L. B.: Electrophotography and Development Physics. Rev. 2nd ed. Laplacian Press, Morgan Hill (CA) 1996.

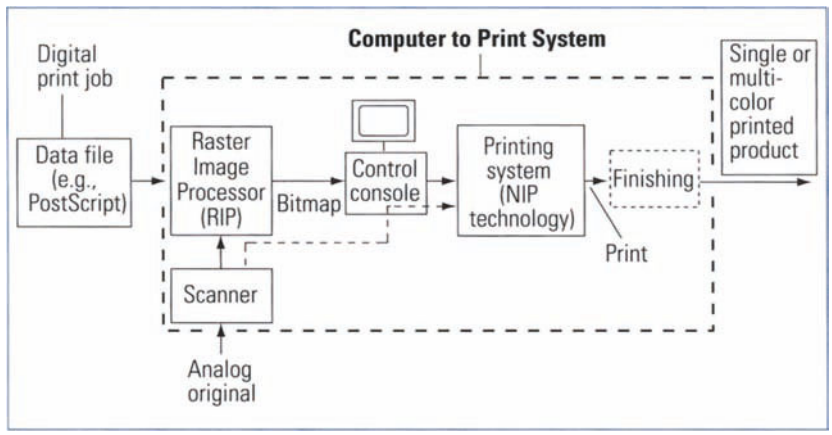


Fig. 5.1-17
Components for computer to press systems based on NIP technologies (computer to print)

5.2 Electrophotography

Electrophotography is the most widespread non-impact printing technology. It is based on an invention by Chester Carlson, who submitted it for patenting in 1939, and then finally obtained a patent in 1942. An overview of the technology and history of electrophotography is given in [5.2-1]. It also contains a comprehensive explanation of the basic physical effects. In the previous sections numerous examples on the areas of application of the NIP technology of electrophotography were given. Printing systems based on this technology can be found in particular in sections 1.3.3.1, 4.1.3, 4.5.1, and 5.1.

5.2.1 Principle of Electrophotography

The principle of electrophotography is shown in figure 5.2-1. The process of electrophotographic printing can be subdivided into 5 stages:

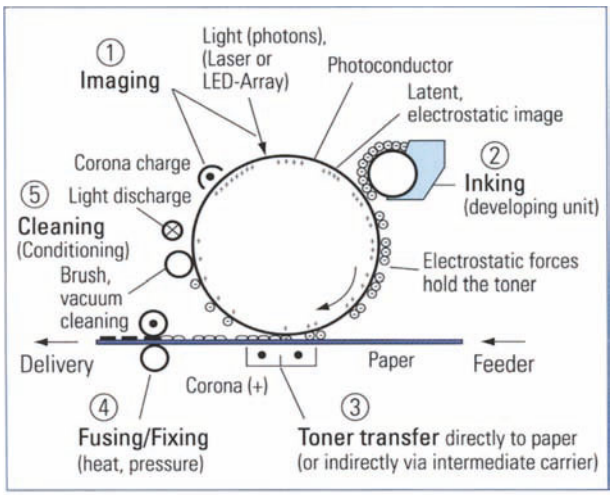


Fig. 5.2-1 Basic principle of electrophotography

1. imaging,
2. inking,
3. toner transfer (printing),
4. toner fixing,
5. cleaning (conditioning).

These five process stages are described in detail below.

Of prime importance for the electrophotographic process is the design of the *image carrier*. The image carrier can consist of a *drum* that is built-up on the basis of an aluminum body or a *flexible belt* with a suitable photoconductive coating.

There are three main possibilities for designing imaging drums or photoconductive coatings:

- coating with arsenic triselenide (As_2Se_3) or similar compounds containing selenium,
- organic photoconductor (OPC),
- amorphic silicon (termed as a-Si or α-Si).

Coating with organic multi-layer systems is the most widespread and the use of amorphic silicon (α-Si) is on the increase, while the use of compounds that contain selenium is in decline.

Figure 5.2-2 shows a simplified *design of the image carrier with OPC coating* having a homogeneous, negative charge. The light is absorbed in the charge-generating layer (CGL), thus generating positive charges. These charges are then compensated on the surface by the charge transport layer (CTL). The surfaces of the OPC coating have a negative charge as standard, while with α-Si or selenium coating they are positive. Compared to OPC coatings, a coating of α-Si has the advantage of a higher wear resistance, however this is obtained at a higher production cost. OPC coatings can also be improved by the application of wear-reducing coatings. Further developments are being made for both coating systems.

H. Kipphan (ed.), *Handbook of Print Media*
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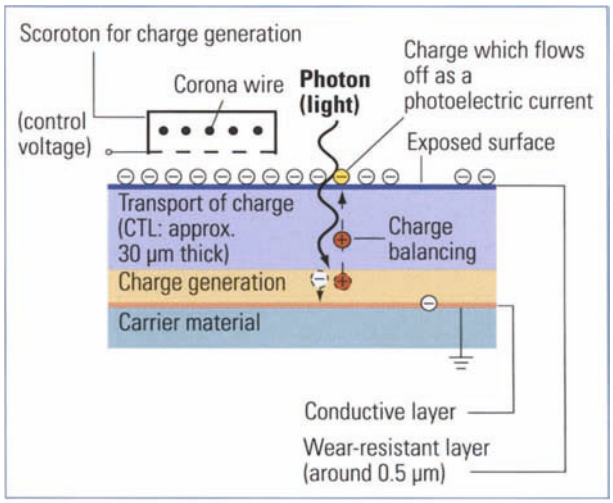


Fig. 5.2-2
Structure of a coating of organic photoconducting material (OPC); a scorotron unit is shown for applying a homogeneous charge to the surface

The above-mentioned five *process stages* in the printing process with electrophotography are explained below:

1. Imaging:
Imaging is achieved by charging a suitable photoconducting surface (i. e., generating a homogeneous charge image) and subsequent imaging via a controlled light source. This can be scanning *laser light* or light that is emitted by an *LED array*. (With simple copiers imaging is done by direct optical projection of the analog original.) The position of the light impulses on the photoconducting drum corresponds to the printed image. The homogeneous charge image on the surface is partly discharged by the exposure, that is, the required printed image is altered accordingly (since imaging in electrophotography can be produced by laser light as well as by LEDs, the frequently used term "laser printer" instead of "electrophotographic printer" is incorrect). For *direct imaging* by a copier, *halogen light* is used to illuminate the original. The white, image-free sections of the original reflect the light, expose the photoconducting drum, and the charges flow away accordingly. The sensitivity of the coating must be adapted according to the wavelength range of the imaging unit. For digital imaging, exposures are usually carried out in the wavelength range of around 700 nm.

2. Inking:
Special inks are used for electrophotography. These can be *powder or liquid toners*, which differ in their composition. The major element determining the printed image is the colorant contained in the toners in the form of pigments or dyes (see also fig. 5.1-14). Inking takes place by means of systems (inking units) that transfer the fine toner particles (around 8 µm) in a non-contact manner to the photoconducting drum through electric potential differences (electric fields). The toner charge is configured in such a way that the charged regions of the photoconducting surface take on the toner. (In the simplified representation shown in figure 5.2-1, imaging takes place with the negative image, since the positive charges have dispersed due to the exposure.) After inking, the latent charge image on the photoconducting drum becomes visible due to the toner applied (for this reason the inking system is also referred to as a developer or developing unit).

3. Toner transfer (printing):
The toner can be transferred directly to the paper, but also via intermediate systems, for instance, consisting of a drum or a belt. As figure 5.2-1 shows, transfer takes place mainly directly from the photoconducting drum to the substrate. To transport the charged toner particles from the drum surface to the paper, electrostatic forces are generated via a charge source (corona) in the *printing nip* (not to be mistaken for NIP!), which ensure the transfer of the toner to the paper. This transfer is assisted by the contact pressure between the drum surface and the paper.

4. Toner fusing/fixing:
A fixing unit is required in order to anchor the toner particles and thus generate a stable printed image on the paper. This is generally designed in such a way that the ink is melted and thereby anchored onto the paper using a *heat supply* and *contact pressure*.

5. Cleaning:
As figure 5.2-1 shows, after the printed image has been transferred from the photoconducting drum to the paper, residual charges and individual toner particles can remain on the drum. To prepare the drum for printing the next image, mechanical and electrical cleaning of the surface is required. Mechanical cleaning to remove toner particles can consist of brushing and/or suctioning. Electrical "cleaning" (neutralisation) is achieved by a homogeneous exposure of the surface (frequently al-

so by an alternating electrical field/AC corona). The surface is then electrically neutralized and free from toner particles. As in the initial process stage, the photoconducting drum is then charged with a homogeneous charge image for the complete surface via the corona (or for higher quality with a Scorotron, fig. 5.2-2) and subsequently imaged, in accordance with the required printed image.

Print Quality. It becomes evident from the process steps described that in electrophotography no *fixed image* on a printing plate is used and that a different charge image can be applied to the photoconductor drum revolution by revolution. This means that a completely different image (*variable image*) can be generated from one revolution to the next.

Where, for example, a print run of one hundred identical prints is to be produced with this process the same printing image consisting of a latent charge pattern must be repeatedly produced revolution by revolution in contrast to printing with a master. Due to the process involved this can result in fluctuations in the printed image, first due to the tolerances during imaging generating the charge image and secondly due to the tolerances that occur when inking the photoconductor with toner and the subsequent transfer to the paper where this is assisted by electrical forces. Therefore, with electrophotography and non-impact printing technologies in general, greater fluctuations can occur within the run than is the case with technologies requiring a printing plate.

The decisive factors influencing the quality and stability when printing with electrophotography are the quality of the imaging, the uniformity and precision during ink transfer by the developing unit, the transfer onto the paper or the intermediate image carrier, and the conditioning of the imaging surface (and where present, the intermediate image carrier) for the next printing process. This requires carefully devised and sometimes highly complex technological components. A more detailed description of the process components than in figure 5.2-1 is given in figure 5.2-3 (in this example, the ink is transferred to a paper web). In this diagram it is especially the various charge sources required that are highlighted: the charge corotron for the homogeneous charge of the photoconducting drum, the corona for transferring the toner from the drum to the paper, and the alternating current corona for neutralizing the surface prior to the cleaning process by means of toner suctioning and exposure with the discharge lamp. The illustration in figure 4.5-11 shows a printing unit with a photoconductor belt.

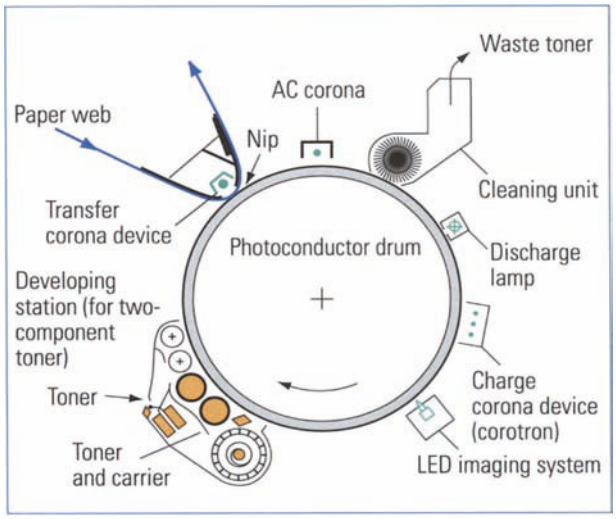


Fig. 5.2-3
Arrangement of the components for an electrophotographic printing unit (Océ, [5.2-3])

5.2.2 Imaging Systems

Principal ways of imaging in electrophotography are shown in figure 5.2-4.

Figure 5.2-4a shows the imaging by means of a rotating mirror system (*ROS: raster output scanner*), in which the beam of one or more laser light sources is deflected via polygon mirror and beam-forming lenses at high speed (e.g., 1000 m/s, polygon mirror speed about 500 revolutions per second). This optical system is explained in more detail in figure 5.2-5.

A page-wide, stationary imaging system is shown in figure 5.2-4b. It is set up as an *LED* (light emitting diode) *array*.

An example at work of a powerful LED imaging unit with an addressability/resolution of 600 dpi is shown in figure 5.2-6. This LED array is employed in the printing systems shown in figures 4.5-7 and 4.5-8. Several technical details on the actual design of the imaging system shown in figure 5.2-6 are also shown in figure 5.2-7 [5.2-2].

The light wavelength when using LED systems is generally in the range from 660 to 740 nm. An adaptation

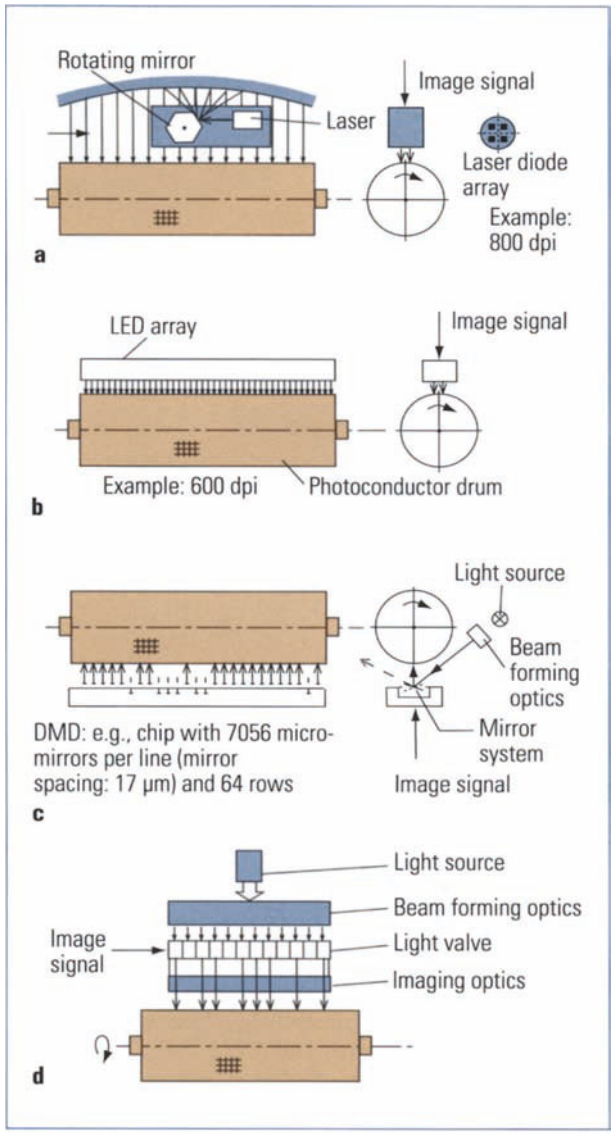


Fig. 5.2-4
Design variants of multibeam systems for optical imaging with electrophotography.
a Rotating mirror system (ROS: raster output scanner);
b LED array (stationary, across the entire page width);
c Light source and digital micromirror device (DMD) (multibeam, stationary);
d Light source and light valve (multibeam)

to the characteristics of the photoconductive surface of the image carrier is both possible and necessary.

Depending on the system employed, the laser scanning imaging systems previously shown operate in the wavelength range from 630 to 780 nm and here again in accordance with the characteristics of the surface.

More recently discussions have taken place, in particular on the use of *blue laser diodes* (wavelength about 430 nm, i. e., a very short wave light), especially in connection with advantageous optical properties to achieve as great as possible a depth of focus. This offers design advantages for the imaging system due to the greater permissible tolerances where the precision of the drum mount and the design of the imaging system, with their mechanical and optical components are concerned.

In line with figure 5.2-4c, figure 5.2-8 shows the design of an imaging system for electrophotography when using the *micromirror array* (DMD: digital micromirror device) from Texas Instruments [5.2-4, 5.2-5].

Figure 5.2-9 shows the design of an imaging unit based on *light valves*. Similar to the concept in figure 5.2-4d, a special light valve was employed here by using electro-optical ceramics. With this component, greater resolution together with a higher imaging velocity can be achieved.

Reference is made to the following figures giving *examples of application* of the imaging systems previously shown: For the rotating mirror system (ROS) see figures 4.1-8, 4.5-4, 4.5-6, 4.5-10, and 5.1-10. For LED systems see also figures 4.5-7, 4.5-8, 4.5-3, 4.5-9, 4.5-11, and 9.2-11 in addition to the examples already mentioned.

5.2.3 Inking Unit (Developing Unit) and Toner

The inking system for transfer of toner (developing of the latent charge image) to the image carrier is configured according to the charge process, the toner system used (single-component, multiple-component system, etc.), and the required print speed/inking velocity. Single-component and two-component toners in powder form as well as liquid toner are used.

With *powder toner*, the *two-component toner* is the most widespread. In this system, the so-called *developer* consists of a *carrier particle* and the *toner particle* (fig. 5.1-15c). The carrier particle (e. g., iron oxide with a size of around 80 µm) holds the toner particles, which may be colored for example by pigments, by means of elec-

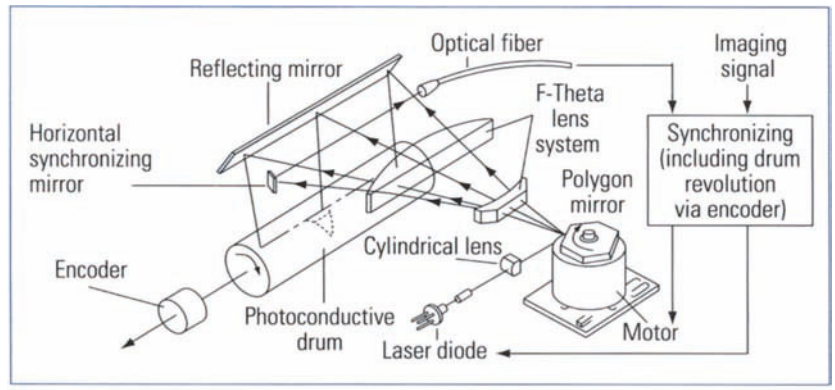


Fig. 5.2-5
Rotating mirror system (ROS: Raster Output Scanner) for imaging in an electrophotographic printing system (LBP-CX/1986, Canon)

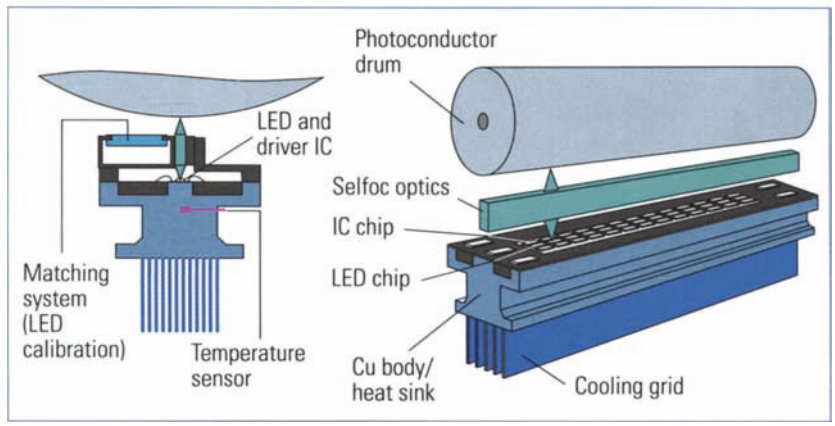


Fig. 5.2-6
LED array for imaging the photoconductor drum for the NIP technology of electrophotography, resolution: 600 dpi, array width: max. 520 mm (character generator ZG 2, Océ/[5.2-3])

trical forces. The diameter of the toner particles is around 5 to 20 µm, depending on the manufacturing process. High-grade toner systems have a mean particle size of around 6 to 8 µm with a very small particle size distribution.

In the *inking system* (developing unit), the carrier and toner particles must be blended together and fed to the application rollers (developer rollers). The photoconductor drum attracts the charged toner particles corresponding to their electrical charge (charged by friction), while the carrier particles are returned to the process. To transfer the toner to the photoconductor drum, so-called *magnetic brushes* are employed.

A developer station (inking system) is shown as an example in figure 5.2-10. The design and mode of operation of developer rollers for two-component toners (magnetic brush) is demonstrated in figure 5.2-11. By means of the structure of the magnetic brush, with contra-rotating movement of the multiple-pole magnetic core (magnetic roller) and the application roller (as shown in fig. 5.2-11b), the toner on the surface is offered for acceptance to the photoconductor by a dynamically moving thread structure in a sliding wave form. Surface sections with a charge attract the toner and the latent charge image is developed.

Single-component toner is available on a magnetic and a non-magnetic basis (see also fig. 5.1-14). In *magnetic* single-component toners, the core consists of iron oxide and the coloring toner constituents (pigments, binding agents, additives) surround this core. In a comparatively easy manner, inking of the photoconducting drum can therefore be carried out without the need for a circulating and blending system for carrier particles via the magnetic roller. The disadvantage of this magnetic single-component toner is that, if a high content of iron oxide is needed (see fig. 5.4-4), it is not possible to develop chromatic colors that meet the standard for the process colors of cyan, magenta, and yellow.

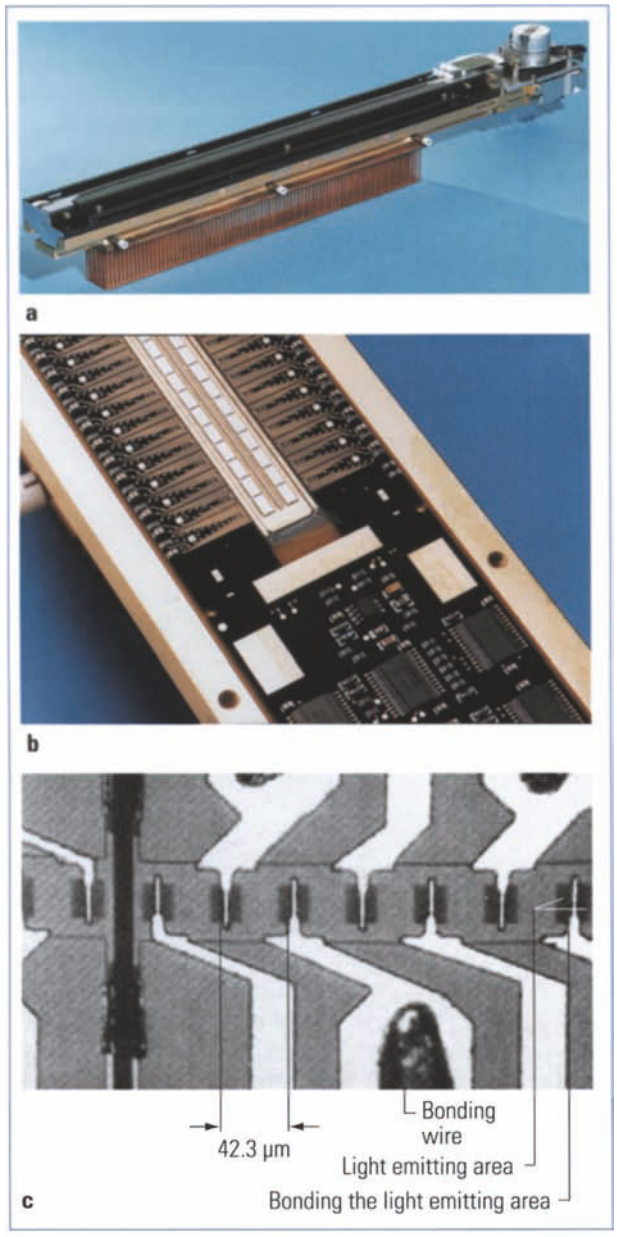


Fig. 5.2-7
Design of an LED array for imaging in an electrophotographic printing system.
a Imaging system as in fig. 5.2-6 (600 dpi, design length up to 520 mm);
b LED module (in the middle of the system) with IC chips, conductors, and electronic assemblies (ZG 2, Océ);
c Extract from an LED chip with a resolution of 600 dpi (Océ)

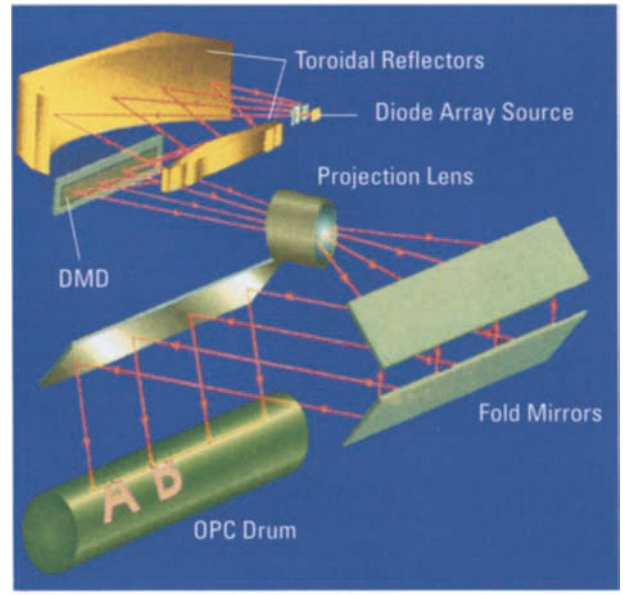


Fig. 5.2-8
Use of a micromirror array (DMD: Digital Micromirror Device) to set up an electrophotographic printing system (Texas Instruments, [5.2-4], [5.2-5])

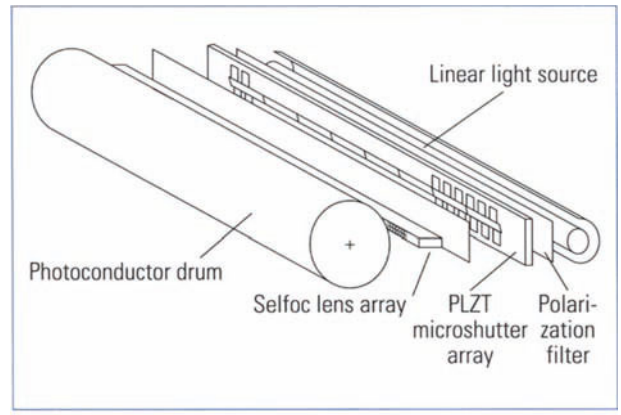


Fig. 5.2-9
Light valve array for imaging a photoconductor drum; PLZT: lead-lanthanum-zirconate-titanate, transparent ceramic material (Minolta)

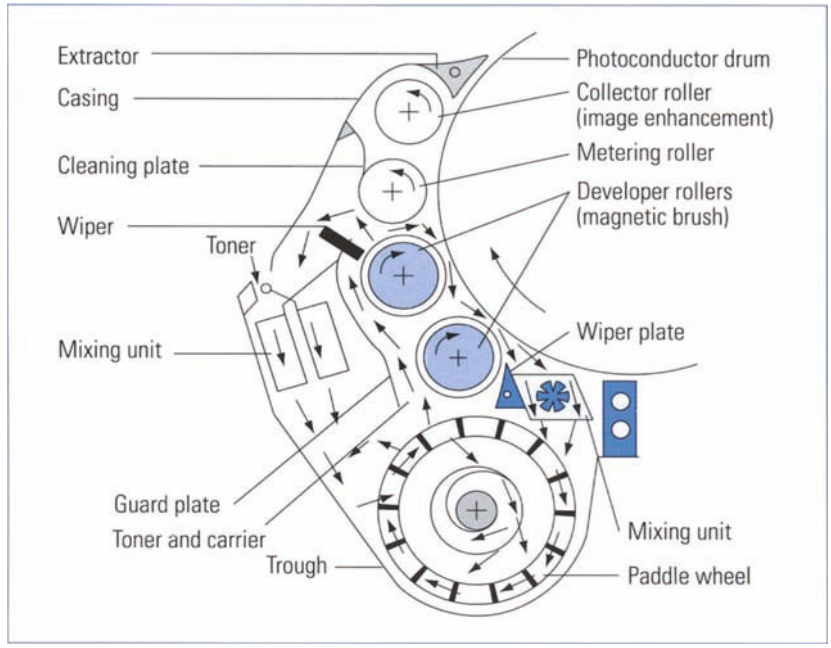


Fig. 5.2-10
High-performance developer station for two-component toner with two developer rollers for toner transfer (Océ; [5.2-3])

Non-magnetic single-component toners are used in systems with low print speed. A uniform toner transfer for inking larger areas is difficult and there is a tendency towards dusting, that is, uncontrolled toner particles can have a negative influence on the printing process and lead to a reduction in quality.

Liquid toners (see also fig. 5.1-14) consist of a carrier liquid containing very small toner particles (about 1 to 3 µm). During the developing (inking) process, the charged toner particles concentrate at the image areas and are extracted from the carrier liquid.

The transfer process requires sensitive thermal and electrical control. *Carrier liquid* that has also been transferred must be removed, for instance, by extraction and evaporation from the inked surface. The attainable print quality is comparatively high due to the small toner particles.

Printing Systems with Liquid Toner

In the multicolor printing system from Indigo, as shown in figure 5.2-12 (see also fig. 4.5-4), liquid toner is used together with an organic photoconductor on the imaging drum.

In the MD 300 system presented by Mitsubishi, liquid toner is also employed while amorphic silicone is used as the image carrier (fig. 5.2-13).

Ricoh has also reported on the use of liquid toners in the electrophotographic printing process.

Printing Systems with Two-component Toners

Two-component toners are employed in the common printing systems for *multicolor printing* of higher quality and productivity, for example, in the system from Xeikon (fig. 5.2-14; see also fig. 4.5-3), from Canon (fig. 4.1-8), Xerox (fig. 4.5-6), and in NexPress 2100 from Heidelberg (see also sec. 4.5.3 and fig. 9.2-11).

Printing Systems with Single-component Toners

Magnetic single-component toners are employed in single-color printing systems with higher productivity, in the systems shown in figures 4.5-12 (ionography), 4.5-13, and 5.4-7 (magnetography) and also in relatively simple electrophotographic copying and printing systems.

In low speed multicolor printing systems, such as the one shown in figure 5.2-15, printing is carried out with *non-magnetic* single-component toner, which can be easily changed by means of a cartridge. No additional consumables are required with single-component toners, such as those required when using two-component toners due to the carrier particles. The design of the developer unit is therefore simpler.

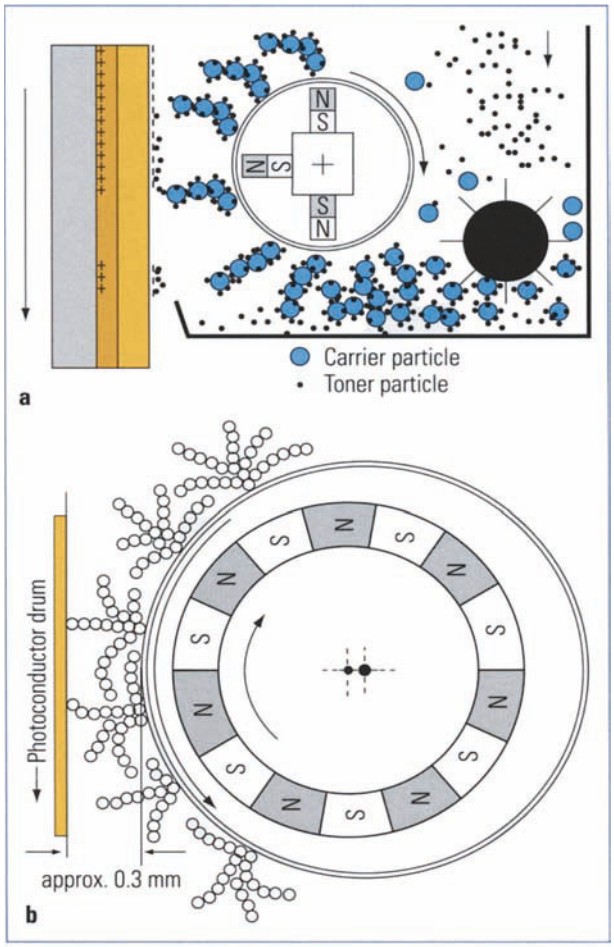


Fig. 5.2-11
Magnetic brush for toner transfer to the photoconductor drum.
a Carrier and toner particles in the developer station with transfer by magnetic roller; stationary magnets, roller shell rotates;
b Magnetic brush design for smooth transfer of the toner to the photoconductor surface; magnetic roller and application roller turn in opposite directions (Kodak)

Tri-Level System (Highlight Color)

As already briefly dealt with in section 4.5.1, there is a special method in electrophotography with which partial images can be generated on the image carrier with a differing charge level.

The principle is shown in figure 5.2-16b, as it is used in some equipment by Xerox.

Controlled by the exposure unit, charge images at various voltage levels are generated on the photoconductor belt with a resolution of 300 dpi, for instance, the color images with a high voltage potential and the black images with a low voltage potential. The mean voltage potential does not permit any toner transfer (hence three stages, "tri-level").

Accordingly, differently formulated powder toners are used and these are matched to the respective charges.

With this system it is possible to print so-called highlight colors. On a section of the OPC coated photoconductor belt, a black halftone image and a blue halftone image can be created next to each other, for example, in two different tone values. The two inking stations transfer the toner accordingly and a visual shade of color (hue) is produced from the mixture of black and blue (fig. 5.2-16c). This technology is especially suitable for imprinting an additional special color with only one printing unit, for instance, a free-standing, colored logo in a black text, or for emphasizing certain sections within a text with a second color.

5.2.4 Fixing and Cleaning

As shown in figure 5.2-1 *fixing* takes place after the toner image has been transferred to the paper. As indicated in this diagram, fixing is carried out by the application of *heat and/or pressure* (fusing/fixing). The task of the fixing unit is to firmly anchor the toner particles to the paper through fusing (melting) and (with optimum process control) an improvement can also be achieved in the *surface quality* of the ink application (influence of heat/melting and pressure). There are fixing units available that actuate the fusing and fixing process both without contact through radiated heat or by contact with the printed surface. In the system shown in figure 5.2-14 (see also fig. 4.5-3) fixing takes place through the admission of heat. The image surface can be selectively influenced via roller pressure and heat in a subsequent system.

An example of a fixing unit, which acts on the paper with the toner image by means of heat and pressure, is shown in figure 5.2-17.

Problems in the fixing process can arise through excessive heat and consequent drying of the paper as well as from unintentional changes in the surface structure of the color image. Fixing devices, which fix the toner under pressure between rollers, can also cause deformation (*curling*) of the printed sheet. The printed sheet is then no longer flat, which can cause delivery problems and can

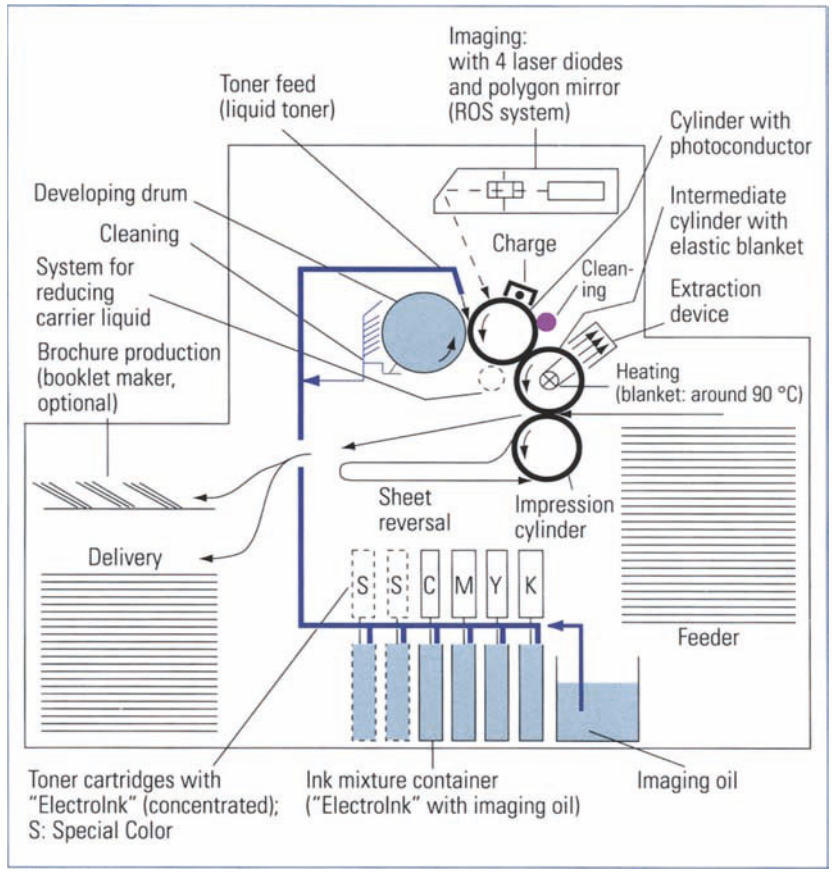


Fig. 5.2-12
Electrophotographic multicolor printing system with liquid toner (TurboStream (33 A4 pages/min), Indigo; diagram derived from company information, not confirmed; see also fig. 4.5-4)

be a particular disadvantage when collating a brochure.

On fixing units that come into contact with the paper and the toner image, toner may be unintentionally taken up by the fixing/fuser roller due to the *ink re-splitting* and this impairs the quality of the subsequent printed image sections. To prevent this type of toner acceptance, the fixing rollers are usually coated with a special oil (*silicone oil*) that can, however, also produce unwanted gloss effects in the printed image.

Fixing/fuser rollers and the facing *pressure rollers* are designed with differing levels of elasticity. This produces differing types of roller deformation at the point of contact (the "nip") between the rollers and paper. In the nip, the fixing process takes place with different gloss formation and smoothing of the ink application, depending on the nature of the material pairing of the roller system. The temperature in the nip is normally around 150 °C. Overall, the nip-forming fuser rollers have been able to establish themselves. These fuser rollers are provided with an elastic/soft coating while the pressure rollers are hard.

The development of effective fixing devices is a challenge for the manufacturers, especially with high-capacity systems. Further developments can be expected here, both functional and material-specific.

Cleaning

As shown in figure 5.2-1, cleaning of the photoconductor drum takes place after the toner image has been transferred to the paper. Cleaning is carried out using the effect of electrostatic forces, mechanical loosening and removal processes, and the effect of light on the area. Figure 5.2-3 shows the brushing and extraction devices that are available. There are also systems with rubber blades (see also fig. 4.5-11b) and devices for loosening the toner particles that adhere to the surface by the use of specific alternating electrical fields.

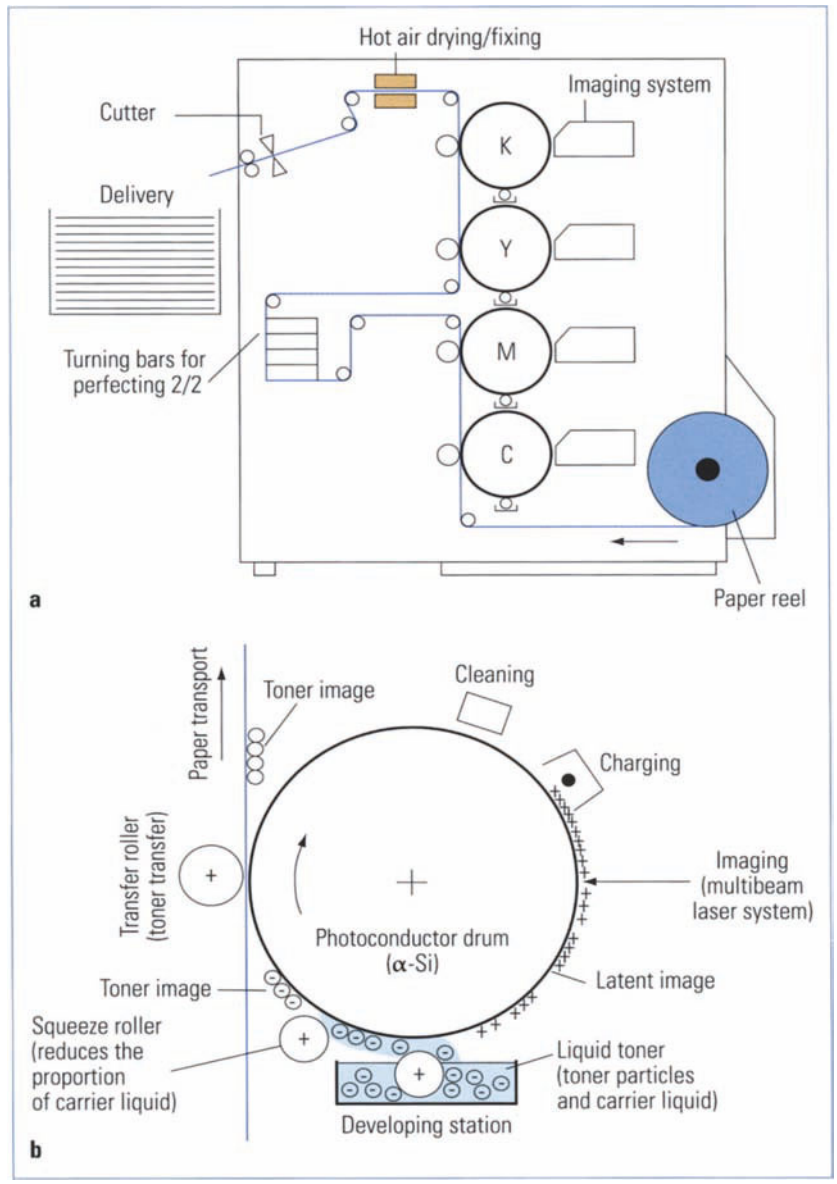


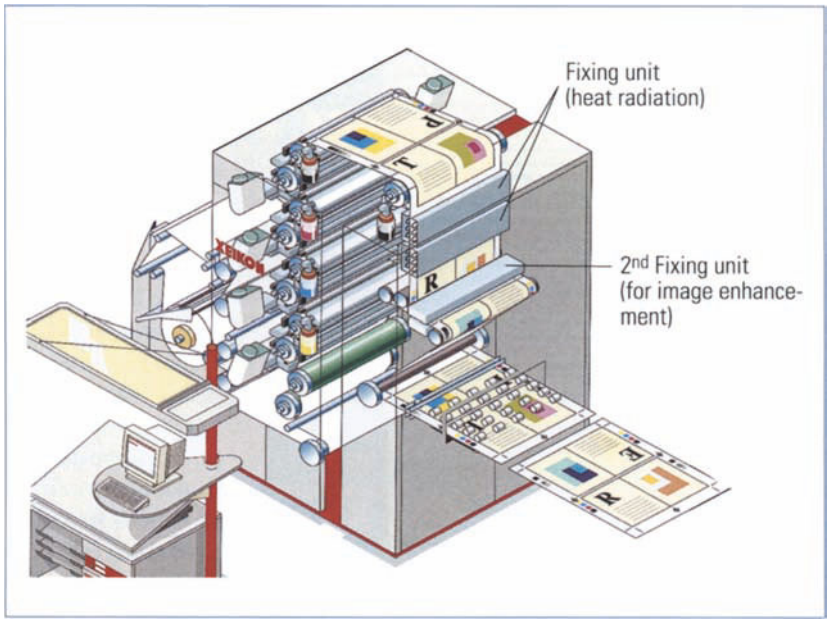
Fig. 5.2-13
Electrophotography with liquid toners and imaging drum coated with amorphic silicon.
a Concept for printing system (72 A4 pages/min);
b Printing unit with liquid toner developing and imaging drum, coated with α-Si (800 dpi, around 8 gray values per pixel) (MD 300, Mitsubishi; product announcement, diagrams derived from company information, not confirmed; status: 1999)

5.2.5 Conception of the Printing Unit

Matching the voltage of the components used in electrophotography for charging, discharging, and toner transfer from the inking station (developing station) to the photoconductor drum and from the photoconductor drum to the paper or the intermediate carrier requires precise, stable design of the system components, voltage control, and temperature and humidity stabilization in the vicinity of the printing unit. Similarly, when using fine-grained powder toner, which can produce a higher print quality, precautions must be taken to prevent the appearance of dust. Dust particles that circulate in the system can have a negative effect on the print quality and disturb the process itself.

The physical and chemical processes within a printing unit for electrophotography are far more complex

Fig. 5.2-14
Multicolor printing system based on electrophotography for two-component powder toners; 600 dpi, around 9 gray values per pixel, web width 500 mm, 50 A4 sheets/min (printed on both sides); see also fig. 4.5-3 (DCP/50D, Xeikon, status: 1999)



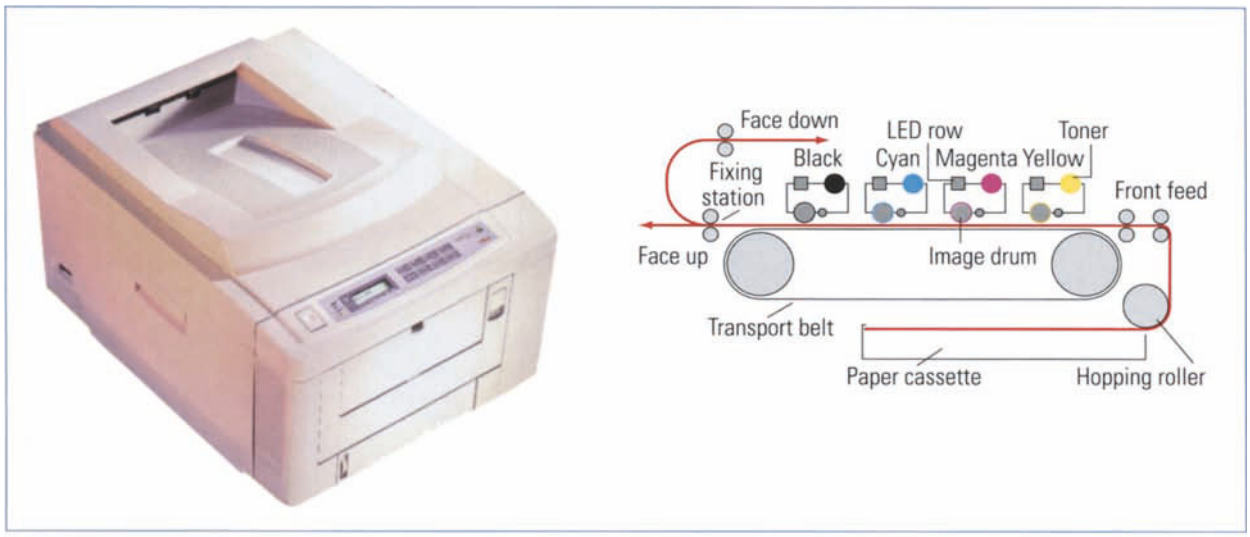


Fig. 5.2-15
Multicolor printing system (electrophotography, single-component toner, LED imaging, A4 format, tandem design/singlepass system); 600 dpi, 8 A4 pages/min (OKIPAGE 8c, OKI)

and diversified than those within a conventional printing unit operating with a printing plate, such as in offset printing. The operator of computer to print systems usually has less training and system know-how than the operator of an offset printing press. From the process, design, and control engineering aspects, all of this requires a complex design of the printing systems for computer to print to ensure reliable operation of these with a high level of quality and availability. The printing units are equipped with complex process compo-

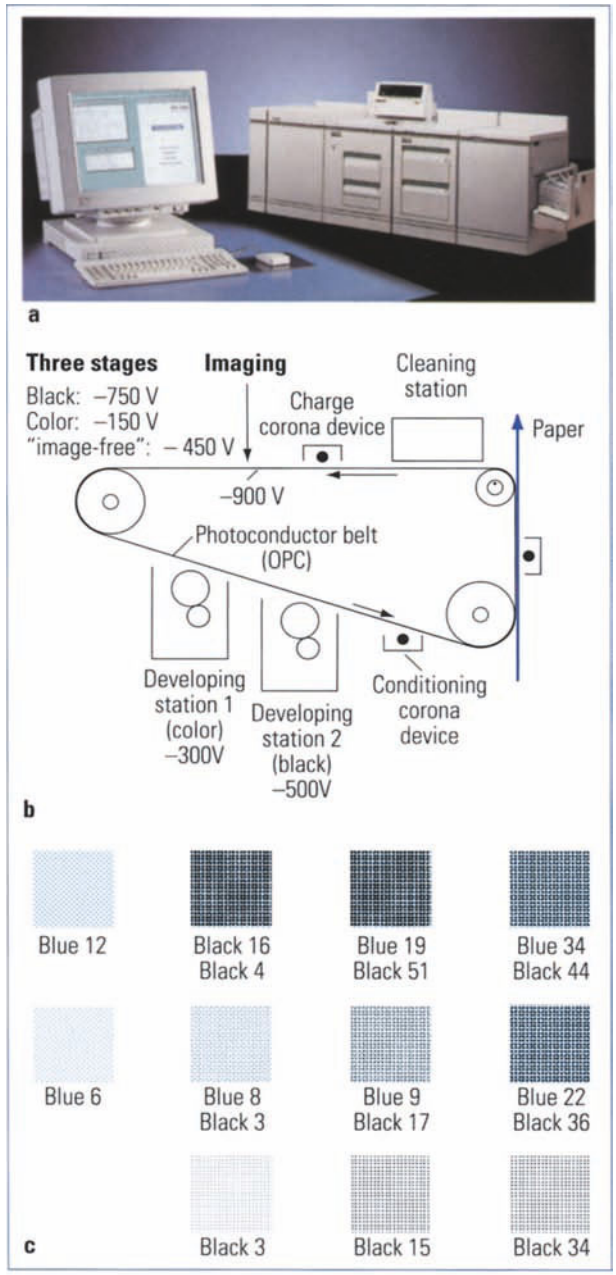


Fig. 5.2-16
Electrophotography with tri-level system for printing special colors and highlight color.
a Printing system;
b Tri-level process (stating the voltage potentials);
c Example: Black + Blue (highlight color), reproduction shown not printed in this technology;
(e.g., DocuPrint 350-HC, Xerox)

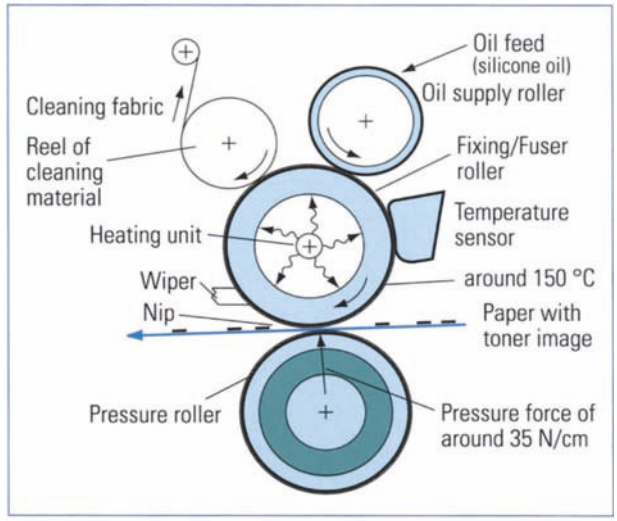


Fig. 5.2-17 Fixing unit (Océ; [5.2-3])

nents supported by measurement and control instrumentation.

Particularly important are self-service concepts and especially solutions for the easy replacement of consumables, such as toner and wearing parts, such as the photoconductor drum and cleaning systems.

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[5.2-5] Nelson, W. E.; Bhuva, R. L.: Digital Micromirror Device Imaging Bar for Hardcopy. Color Hardcopy and Graphic Arts IV, Vol. 2413. SPIE, Bellham (WA) 1995, pp. 58–65.

5.3 Ionography

In the previously described *electrophotography*, the latent charge image on the image carrier is generated using the photoconductivity of specific materials. To condition the imaging surface, in electrophotography a homogeneous electrical charge field is applied to the image carrier by means of a corona (corona device or scorotron). The image is then exposed with photons by the imaging unit, as a result of which the charge pattern changes in line with the image. In the following stage of the process, the latent charge image attracts the toner particles, so that the latent charge image becomes a colored visible printed image.

In *ionography*, the charge pattern is generated on the image carrier directly by the imaging unit and a previously generated redistributed homogeneous charge on the imaging surface is not required. In contrast to the principle shown in figure 5.2-1, the processes of charging and imaging are therefore combined.

5.3.1 Printing Unit

The basic structure of a printing unit for the NIP technology of ionography is shown in figure 5.3-1. Imaging takes place via an *ion source*, which can be set up with the currently available technology as a page-wide array (e.g., about 310 mm wide) for a resolution of 600 dpi.

Inking takes place with *toners*, such as those that are also used for electrophotography. Following transfer to the paper, cleaning of the drum surface with mechanical and electrical equipment is required. The non-conductive *dielectric coating* of the imaging drum has a very high mechanical hardness, so that cleaning by means of blade systems with surface contact can be carried out simply and efficiently (which, with electrophotography, is more expensive to achieve on the photoconductive coatings with OPC material; this is not the case with the harder coatings such as amorph Silicon/a-Si, see also sec. 5.2.1).

In figure 5.3-1 it is pointed out that a special fixing process is installed. *Fixing already takes place in the nip* during toner transfer to the paper by the supply of heat and pressure from the drum (*transfixing*). Following transfer of the printed image onto the paper, final fixing of the printed image is carried out using a non-contact xenon flash lamp through another brief fusing of the toner via the radiant heat on the paper (*flash fusing*).

The NIP technology of ionography is sometimes also known as *electron beam printing*. Around 1990, Delphax came on the market with digital printing systems for single-color printing. A printing unit of this type is shown in figure 5.3-2. This unit prints at a speed of 90 A4 pages/min. The imaging system is designed as an ion source array in sixteen rows with a resolution of 240 or 300 dpi.

The ImageFast 180 system from Delphax is shown in figure 4.5-12 in section 4.5. Figure 5.3-3 shows a similar

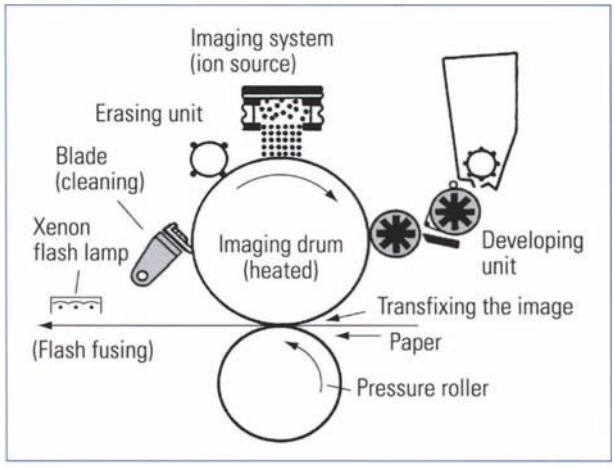


Fig. 5.3-1
Components of a printing unit based on ionography (Delphax)

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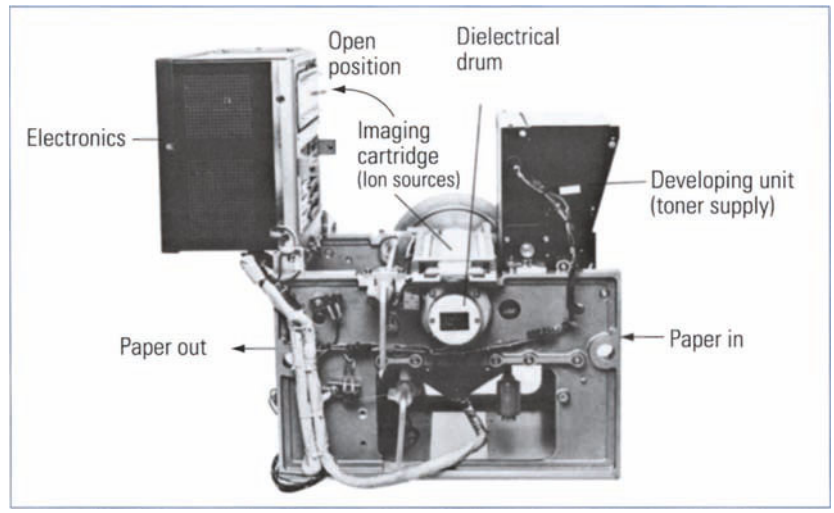


Fig. 5.3-2
Ionographic printing unit
(X-90 Image Output Module, Delphax)

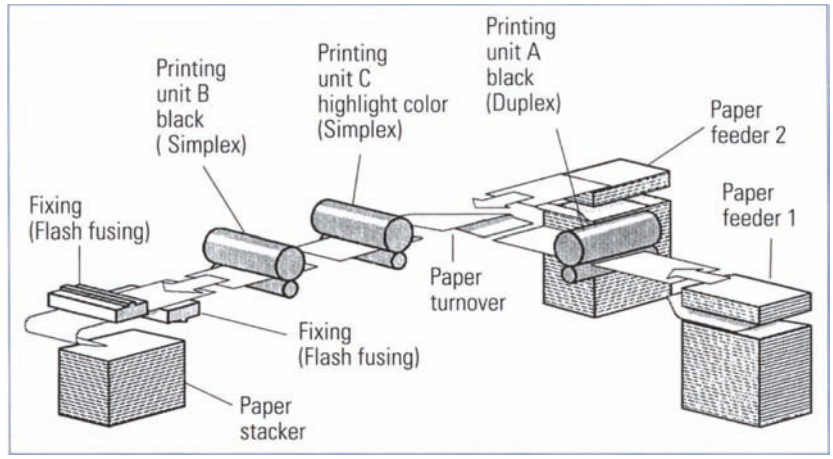


Fig. 5.3-3
Printing system configuration for duplex printing with the possibility of printing a second color on one sheet side (highlight color) with ionographic printing units (Delphax)

variant with the functional assemblies of the printer unit for ionography as explained in figure 5.3-1. This system configuration with a total of three printing units permits printing on both sides as well as highlight color or special color printing on one side of a sheet (see also fig. 5.2-16c).

5.3.2 Imaging System and the Principle of Ionography

The central module in ionography is the imaging unit acting as an *ion source*.

The ions, that is, positively or negatively charged atoms or molecules, are formed from the ambient atmosphere and through the material of the ion source by means of high voltage signals and are then transported to the imaging surface. Controlling the humidity in the vicinity of the ion source is of particular importance, since arc-over voltages can arise in cases of excess humidity, which can cause wear and the destruction of the ion source and surface. Heating of the imaging drum is therefore essential (there are designs where imaging takes place in an inert gas atmosphere, so as to reduce the wear (ablation) on the ion source).

The cross-section of an individual *ion source* is shown in figure 5.3-4, in a design such as that used in the first devices from Delphax. Imaging units that operate across the entire page-width are set up on this ba-

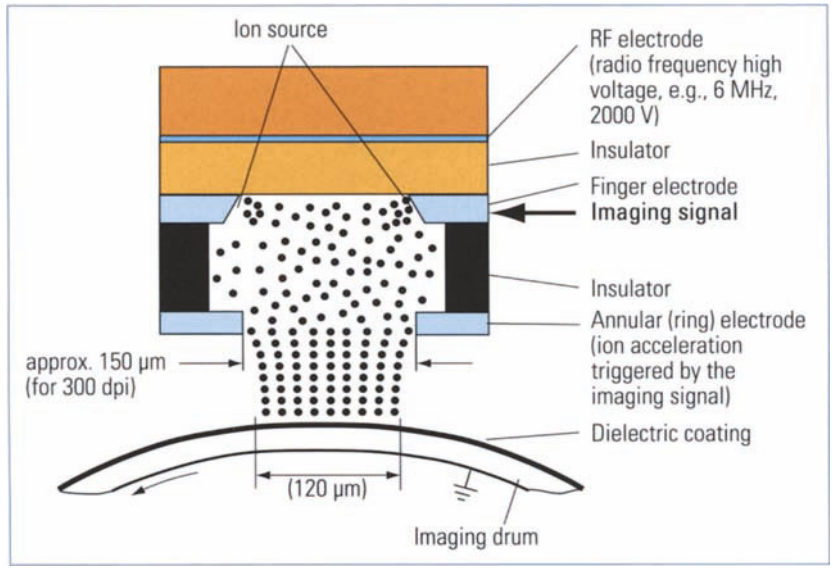


Fig. 5.3-4
Basic structure of an ion source for imaging a dielectric surface in ionography (Delphax)

sis as an *ion source array* with a resolution of 300 dpi in a multi-row design (e.g., 16). The distance from ion source to ion source is about 1.35 mm (line spacing approximately 300 µm, see also figure 5.5-20b). More recent ion sources based on thin-film technology together with photolithographic microstructuring technologies have enabled the development of imaging systems with a resolution of 600 dpi. Similarly, there are concepts for setting up ion source arrays using micromechanical structures. It is to be expected that a resolution of up to 1000 dpi with multi-row configurations will become possible.

The disadvantage of the initial designs of cartridges as imaging units was the wear-out rate of the ion source. This meant that the imaging system was a consumable, which made it very expensive. The current material and production technologies have permitted the implementation of ion source imaging systems with long service lives (several million prints).

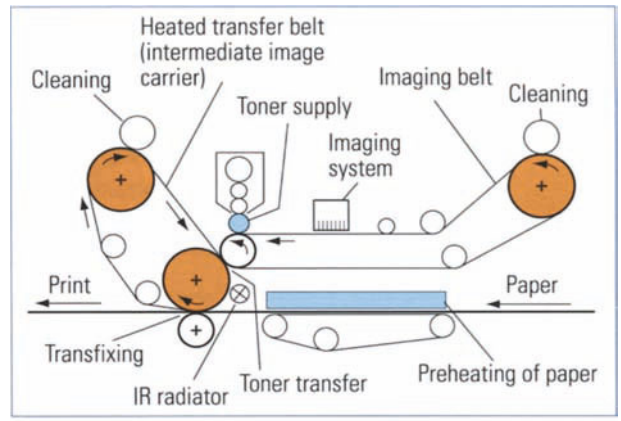


Fig. 5.3-5
Printing unit with dielectric belt and intermediate carrier belt for single-color printing based on an ionographic process; resolution 600 dpi, print speed 0.5 m/s (Gemini Engine, Delphax)

5.3.3 Printing Unit Concepts and Printing Systems based on Ionography

Image Carrier in a Belt Design

Figure 5.3-5 shows the diagram of a printing unit with ionographic imaging, in which the charge pattern is applied to a revolving, dielectrically coated belt. To protect this high-grade image carrier, the colored printed image is not transmitted directly onto the paper, but onto an *intermediate carrier system*, which also consists of a revolving belt. The ink transfer to the substrate takes place as shown in figure 5.3-5 after prior *preheating* of the paper as part of a multistage fixing process.

This type of printing unit was first used in a single-color printing system for the personalization of preprinted forms, checks, or other commercial docu-

ments (fig. 5.3-6). The system was presented around 1995 by Check Technology in cooperation with Delphax (now Xerox). The print speed is about 0.5 m/s, which, with a print width of around 420 mm, results in a productivity of around 200 A4 pages/min.

In 1999, a new model, the "Delphax 1300," was announced. The printing unit is equipped for imaging at 600 dpi and the print speed is quoted as being 1.5 m/s, with printing taking place on web material (since the end of 1999, Delphax has been a corporate entity of Xerox).

Color Printing on the Basis of Ionography

Since approximately 1993, concepts for multicolor printing that use the NIP technology of ionography have been under discussion, in particular when employing liquid toners. Two such printing press config-

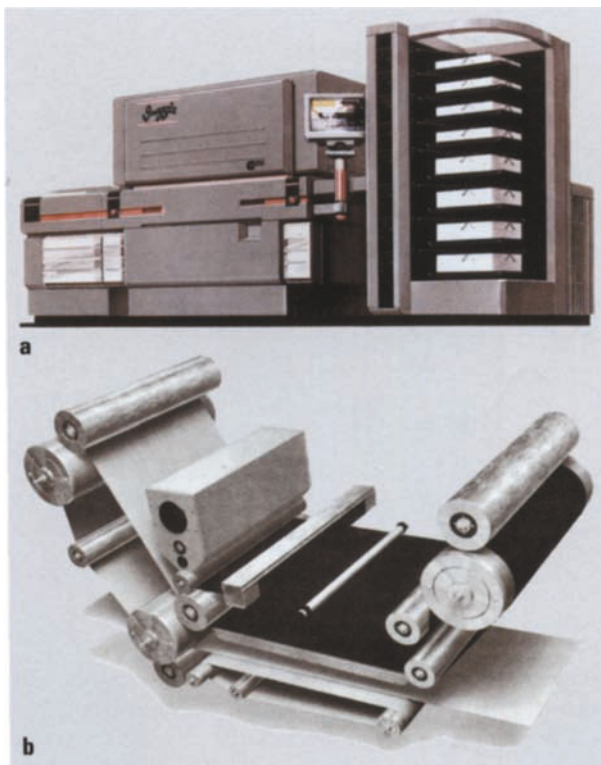


Fig. 5.3-6
Printing system for digital printing (**a**) based on ionography; printing unit (**b**) as in fig. 5.3-5; resolution 600 dpi, print speed 0.5 m/s (Imagia MG20, Check Technology/Delphax)

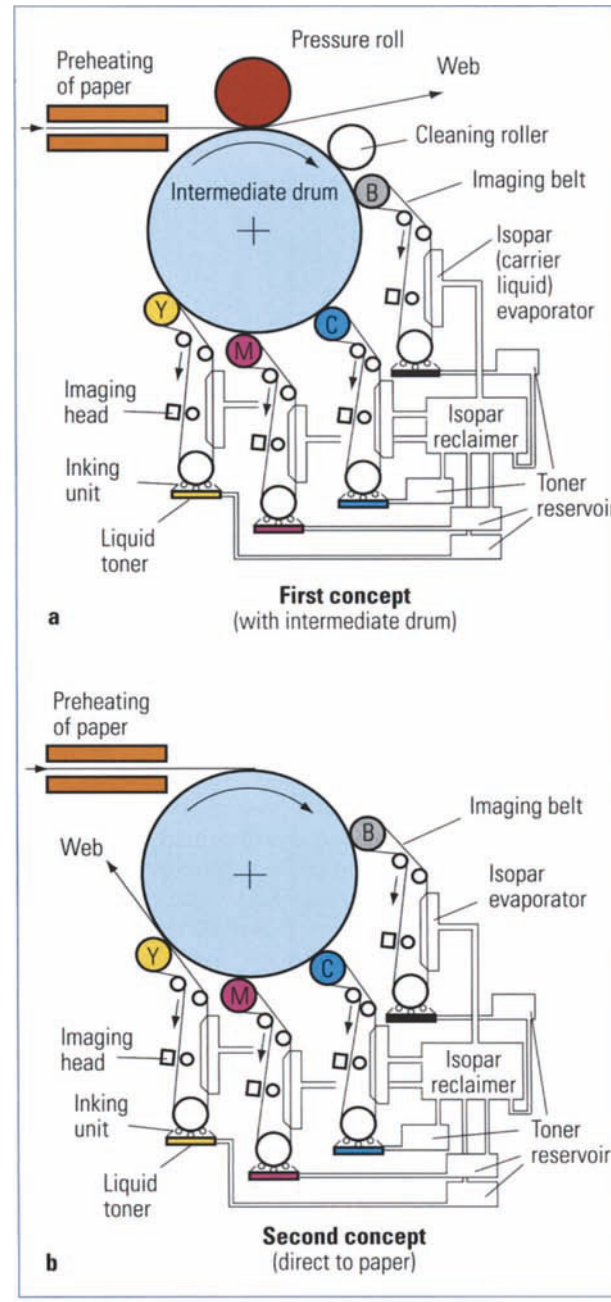


Fig. 5.3-7
Concepts for digital multicolor printing system based on ionography for printing with liquid toners (satellite design).
a Color separations collected on an intermediate carrier;
b Color printing directly on the substrate
(CIPRESS concept, Delphax; diagrams based on company information, not confirmed; status: 1995)

urations in a *satellite design* are shown in figure 5.3-7. Printing takes place in figure 5.3-7a on web material via an intermediate carrier system, on which the color separations are collected. In figure 5.3-7b printing takes place directly on the substrate without an intermediate carrier. The design concepts can quite easily be applied to printing on sheet materials. A special feature of both systems is the imaging on a dielectrically coated belt as well as the procedures for removing the carrier fluid when using liquid toners. The printing system described in figure 5.3-6 can be integrated as a component of the system concepts shown in figure 5.3-7.

Further Printing Systems that are based on Ionography

In the previously mentioned concepts, printing takes place on the substrate by means of image carriers. Printing is possible on most substrates/papers.

According to figure 5.3-8, ionography is also used together with *paper* which is provided with a *dielectric coating*. The image can be generated directly on the paper by charge transfer. In the schematic diagram shown in figure 5.3-8 the toner is transferred to the paper surface directly, after imaging via an ion source from the developing station. In the example shown, four-color printing is achieved by the separated colors being imaged in sequence by just one ion source on the paper and subsequently being colored with toner. After the paper web has returned, imaging takes place with the second separated color and by the subsequent coloring, and so on for the third and fourth color (multipass system). A highly precise register system for web transport is required. There is also the unit design variant (singlepass system), in which a separate ion source is installed in front of each developing station. The example shown in figure 5.3-8 was presented as a proof system in 1995 by NTT-AT in Japan.

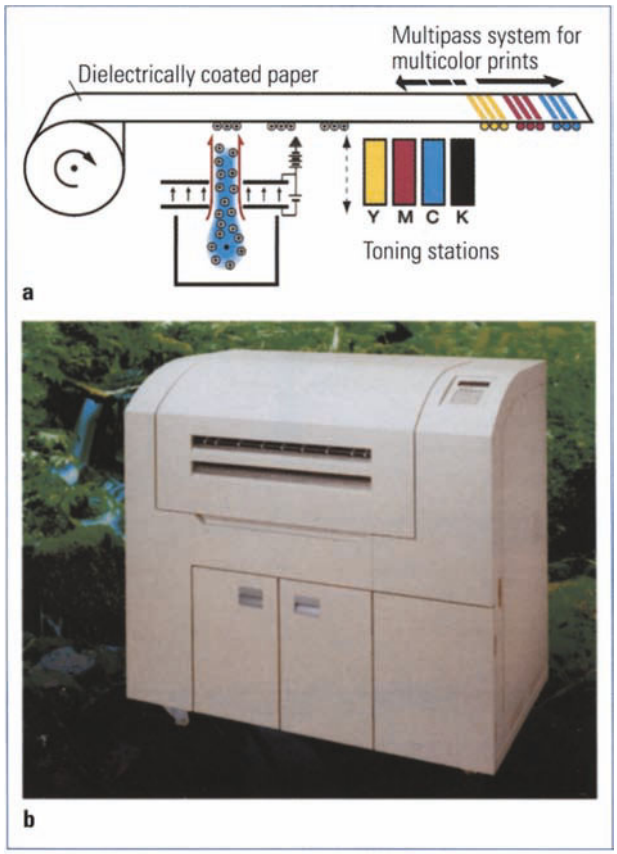


Fig. 5.3-8
Digital proofing system based on the NIP technology of ionography.
a Principle of "Ion Flow Full Color Printer";
b System for the production of digital proofs (D/IP-1000, NTT-AT)

5.4 Magnetography

An example of a magnetography-based non-impact printing system was already detailed in section 4.5 (fig. 4.5-13).

In section 4.4 magnetolithography was described as a method for setting up computer to press/direct imaging systems with re-imageable surfaces. This process is based on magnetography (see fig. 4.4-29).

The following deals with magnetography in greater detail.

5.4.1 Principle of Magnetography

Figure 5.4-1 shows the *printing unit* of a magnetography-based printing system.

A *magnetizable drum* serves as the image carrier; it consists of a non-magnetic core, coated with a *soft magnetic* FeNi layer (thickness around 50 µm). On top of this there is an additional *hard magnetic* Co-Ni-P layer (around 25 µm thick) and then finally a *protective layer* (around 1 µm thick) that gives the surface a high degree of wear-resistance.

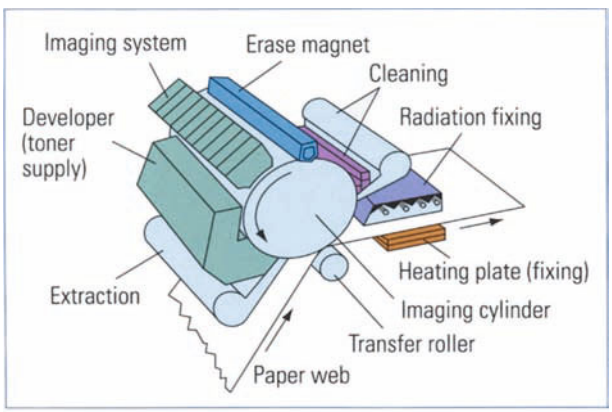


Fig. 5.4-1
Components of a printing unit based on the NIP technology of magnetography (Nipson)

The imaging takes place via *magnetic imaging heads*.

Imparting a *magnetic pattern* onto the image carrying surface is based on the orientation of the magnetic dipoles within the material. As shown in figure 5.4-2, the orientation of the magnetic field within the domains is reversed via an external magnetic field (H). This introduces a magnetization (M) in the imaging layer, which creates a magnetic field on the surface. The *hysteresis loop* between the magnetic field strength and the resulting magnetization as shown in figure 5.4-2 demonstrates that, despite an outer field strength of "zero", there is still residual magnetism present. This means that the *latent image is saved* after the magnetic pattern has been introduced to the drum surface and can, in principle, be used to print the same image content several times without the need for re-imaging (as mentioned in sec. 4.4, this effect has not really been exploited yet, probably due to system design and destabilizing effects within the material and the immediate environment that can lead to poor quality in the print).

Figure 5.4-2 also shows how it is possible to *erase* the magnetic pattern impressed. This is done by using a special erase magnet (see fig. 5.4-1), which causes a constant magnetic reversal of the domains during the hysteresis loop cycle with alternating field strength and decreasing amplitude, until a neutral non-magnetic surface is created (State: H = 0, M = 0).

Figure 5.4-3 shows a diagram of an *imaging head* for magnetography. The imaging head is in mechanical contact with the hard, wear-resistant surface of the drum (to introduce a well-defined, reproducible magnetic field pattern). The flux density is so great on the narrow recording pole that the orientation of the magnetic dipoles is changed, while on the broader pole for closing the magnetic flux, the flux density does not create any significant change to the polarization of the magnetic domains.

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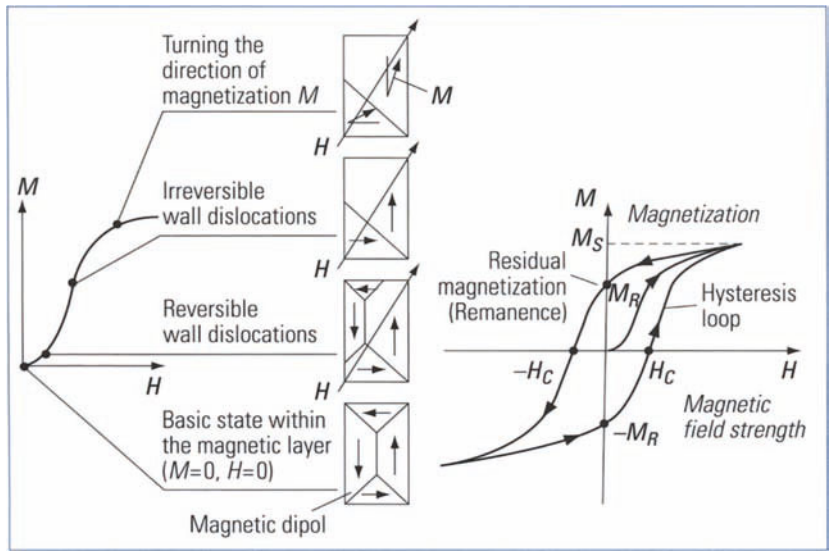


Fig. 5.4-2
Magnetization to create a latent magnetic field image in magnetography

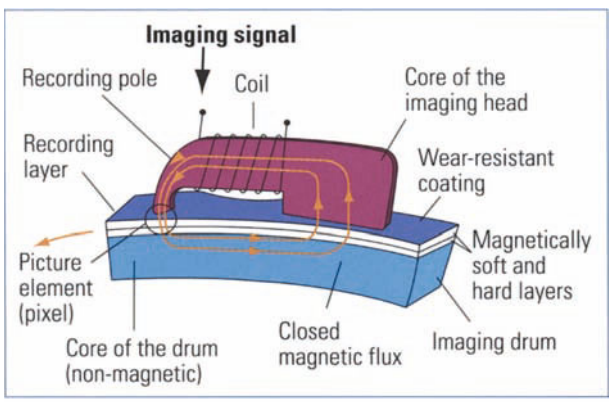


Fig. 5.4-3
Structure of an imaging head for magnetographic imaging (Nipson)

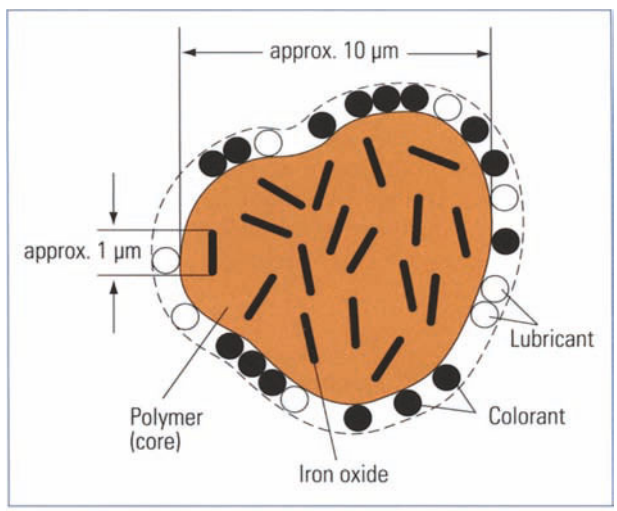


Fig. 5.4-4
Structure of a magnetic single-component toner (schematic diagram, colorant and lubricant surround the toner core)

Bull/Nipson has had single-color high performance printing systems based on the physical effect of magnetization on the market since around 1985. The major technical challenge lay in the development of imaging systems able to produce high resolution images that were both reliable and at the same time economical. Explanations of new developments are given in the following section.

Figure 5.4-1 displays the basic principle of magnetography and shows the position of the *developer*. A single-component magnetic powder toner is used. Figure 5.4-4 shows that the core of the *magnetic toner* contains iron oxide and is covered with colorant, which gives it color. The toner is magnetized at the end of its manufacturing process. The dipoles are oriented in the iron oxide through the magnetic field. The quantity (volume) ratio of color coating to core is around 40:60, meaning that the color of the single-component toner is influenced significantly by the *dark core* as a conse-

quence of the iron oxide contained in it (magnetic single-component toners for electrophotography have a low core content of around 10%, which is sufficient for transport via magnetic rollers). As shown in the partial picture in figure 5.4-5 the single-component toner particles are transferred to the magnetized surface of the imaging drum as a result of the iron core.

The high concentration of iron oxide in the toner particles means that it is not possible to create *pure colors*, particularly bright hues. It is therefore mainly used in black and white printing or when printing with several, relatively dark spot colors.

The *transfer procedure of the toner onto the imaging drum* is shown in greater detail in figure 5.4-5. The developer consists of a rotating magnetic roller that takes the toner from the container. The toner is transported into the direct vicinity of the imaging surface by a blade-like component. The toner particles adhere to the imaging drum in accordance with the magnetic field pattern. Since a surplus of toner is present in the feed gap, other toner particles are also attracted. This can lead to distortions and a lack of definition in the image. Figure 5.4-5 shows a unit for *magnetically enhancing image quality*. This consists of a rotating sleeve and a stationary permanent magnet in the core that picks up any non-adhering toner particles (e.g., for improving the sharpness) and feeds them back to the circuit. In addition there is an extraction unit that removes any excessive toner particles.

The *application of toner onto the paper web* takes place under high pressure. The majority of the toner is transferred here and the remainder must be removed via a cleaning device consisting of a doctor blade and extraction system (fig. 5.4-1).

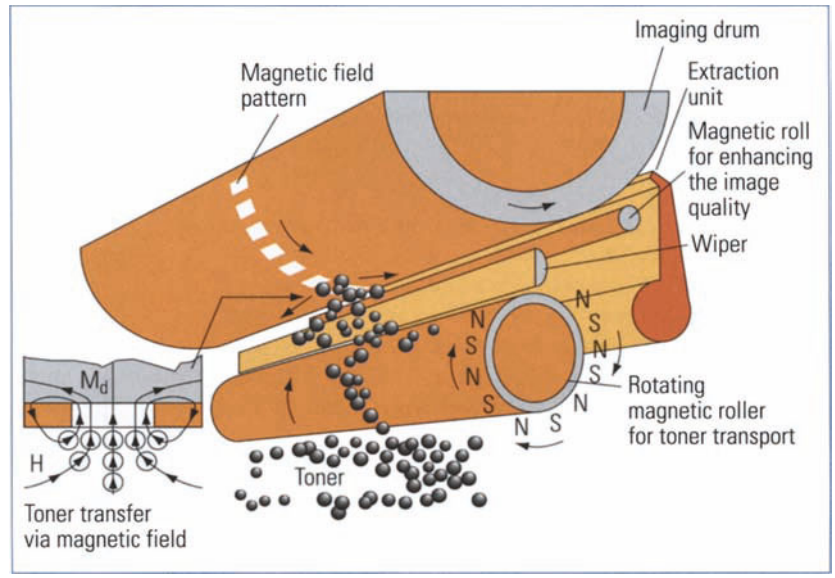
The print image is *fixed* by fusing the toner through heat radiation (fig. 5.4-1). The heat can be applied to the reverse side of the paper using heating elements. Additional radiant heat can be fed from the image side to fix the image. The dark hues, which are typically used in magnetography, ensure good heat absorption. So-called "*flash fusing* units" using impulse-commutated xenon lamps can be employed to fuse and fix the print image.

5.4.2 Imaging System for Magnetography

Page-wide imaging heads can be designed based on the imaging head principle shown in figure 5.4-3. Systems with a resolution of just 240 dpi were in use for a long time due to the discrete micromechanical elements and the necessary electrical feed systems. The *imaging head* in figure 5.4-1 has a *modular structure*. One module is around 36 mm wide and contains some 340 individual imaging elements (recording poles) for a resolution of 240 dpi. The imaging poles are arranged in two rows, whereby the imaging poles in a row are 0.21 mm apart.

More recent developments and procedures in *micromechanics* and microelectronics have made it possible

Fig. 5.4-5
Inking of the latent magnetic pattern of the imaging drum with magnetic toner including devices for image improvement (Nipson)



to reliably manufacture imaging heads with a resolution of 480 dpi. Figure 5.4-6 shows a section of the surface of this kind of magnetic imaging head. It is made up of six lines, where the distance between each individual magnet is 318 µm in each line. A resolution of 480 dpi is achieved by the staggered arrangement of the micro magnets in six lines, each having 80 dpi.

As shown in figure 5.4-6, the coil for magnetizing each iron core is manufactured micromechanically.

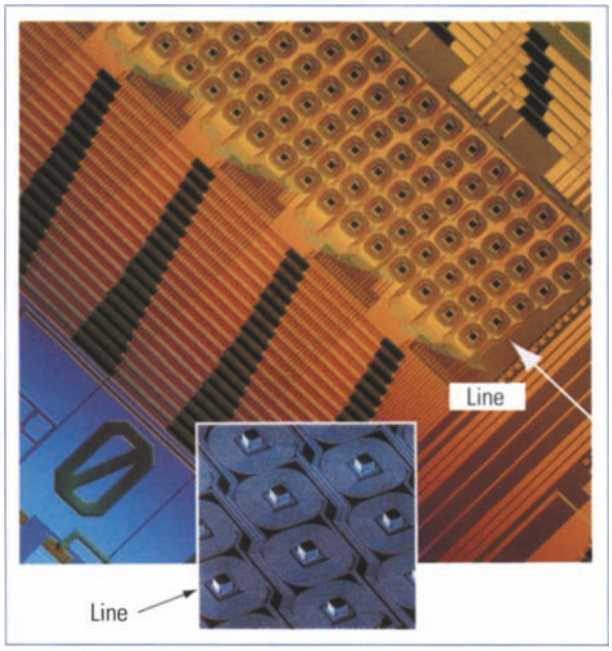


Fig. 5.4-6
Micromechanical imaging system for magnetography with a resolution of 480 dpi (with 6 lines, 80 dpi per imaging head line), (Nipson)

Connection to the electronic control system takes place via flexible live and energized components. The development of imaging systems with 1000 dpi is currently being discussed.

5.4.3 Examples of Applications/Printing Systems

In section 4.5.2 (fig. 4.5-13) the VaryPress T700 is shown together with the specifications in table 4.5-2. The printing speed is principally determined by the imaging and toner application processes which can be comparatively fast with magnetography.

On the model shown in figure 4.5-13 the printing speed is 1.75 m/s with a resolution of 240 dpi (480 dpi with a more recent model). The Nipson 7000, introduced in 1998, images with a resolution of 480 dpi and is currently offered for printing speeds of up to 1 m/s (fig. 5.4-7). There are announcements of a high-speed model series with a resolution of around 1000 dpi and a printing speed of 2 m/s.

Figure 5.4-7 shows a *special application for duplex printing* for a single printing unit. Here, just one half of the web width is printed and after printing the front side, the web is fed back to the same printing unit via turning bars to print the reverse side. Half of the printing unit width is used per side of the web (the color sections of the print pages shown in figure 5.4-7 were preprinted and fed to the system for personalization).

There are also variants for the feed of magnetic toner where the toner feed (developing unit) is split in the axial direction, which is similar to *rainbow printing* used in conventional printing technologies. This means that different colored toners can be transferred to the imaging drum and the paper simultaneously in several segments (in principle this is also possible with other non-impact printing technologies).



Fig. 5.4-7
Printing system for magnetography-based digital printing for printing paper webs. Resolution: 480 dpi, printing speed 1 m/s (Nipson 7000, Nipson; status: 1998)

Systems based on magnetography were the fastest systems available for a long time. The imaging technology using magnetic fields is comparatively simple. Printing systems based on NIP technologies are generally designed for a certain invariable printing speed; the systems (from Nipson) that are based on magnetography have variable speeds, for example, to adapt the speed to the substrate.

5.5 Ink Jet

Computer to Print based on Ink Jet Technologies

In additon to electrophotography, the most common non-impact technology used for digital printing systems is ink jet. The ink jet process is a computer to print technology in which ink is sprayed from nozzles, which means that no image carrier is needed (see fig. 5.1-5). As shown in figure 5.1-1 imaging is done directly onto the substrate. The data of the digital print job is transferred directly to control the imaging unit. In this case the imaging unit is the ink jet system itself, which transfers the ink to the paper via nozzles, mostly directly or in same applications indirectly depending on the technology used. Therefore, in the system illustrated in figure 5.1-5 the functional units, imaging system, image carrier, and inking unit are combined into a single module and they transfer the ink directly onto the paper. (However, there are also ink jet systems in which printing is done via an intermediate carrier.)

Because of its importance, explanations of ink jet technology have already been given in preceding chapters and sections of the book, together with examples for conversion and application as a printing system in sections 1.3.3.2, 4.1, and 4.5.2. In section 4.4.2.1 it was explained how the ink jet process can also be used as an option for setting up computer to press/direct imaging systems. In section 4.3.2.2 the platemaking process based on ink jet technology in a computer to plate system for offset printing was described.

This means that in the ink jet process the information to be printed can be transferred to the paper by the shortest route, with a minimum of functional elements (and in the case of page-wide nozzle arrays even without moving parts), and it is this fact that is the driving force behind further enhancements and new developments in ink jet systems and processes.

5.5.1 Overview of Ink Jet Technologies and Processes

A more detailed division of *ink jet processes* as in figure 5.1-4 is given in figure 5.5-1.

The basic variants of the process are *continuous ink jet* and *drop on demand ink jet*. A schematic diagram of the processes is given in figure 5.5-2.

Process Variants

Whereas in the *continuous ink jet* process, only part of the continuously generated flow of small ink drops is directed onto the paper during printing in accordance with the image, in *drop on demand ink jet* processes drops of ink are only generated if the information to be printed requires them.

Continuous ink jet can be subdivided into the process variants of binary deflection and multi-deflection. The *binary deflection* variant, in which the drop has one of two charge states (namely uncharged for conveyance to the paper and charged for deflection in an electrical field)

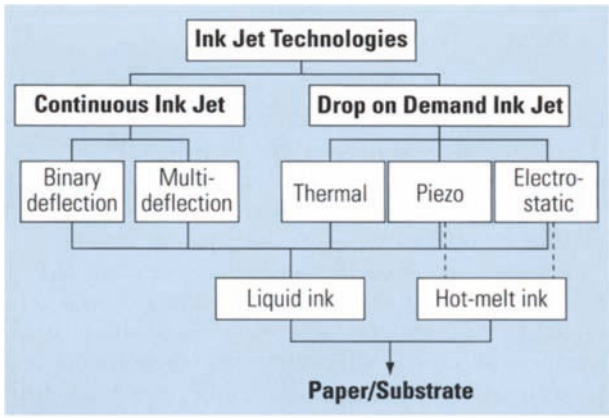
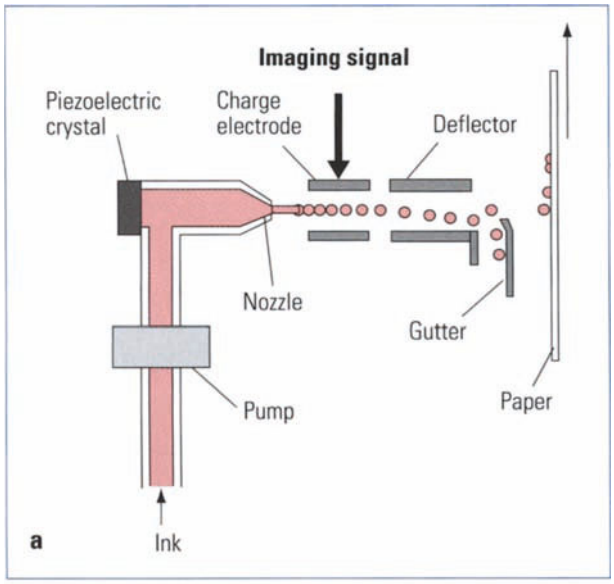


Fig. 5.5-1 Ink jet technologies: overview of processes

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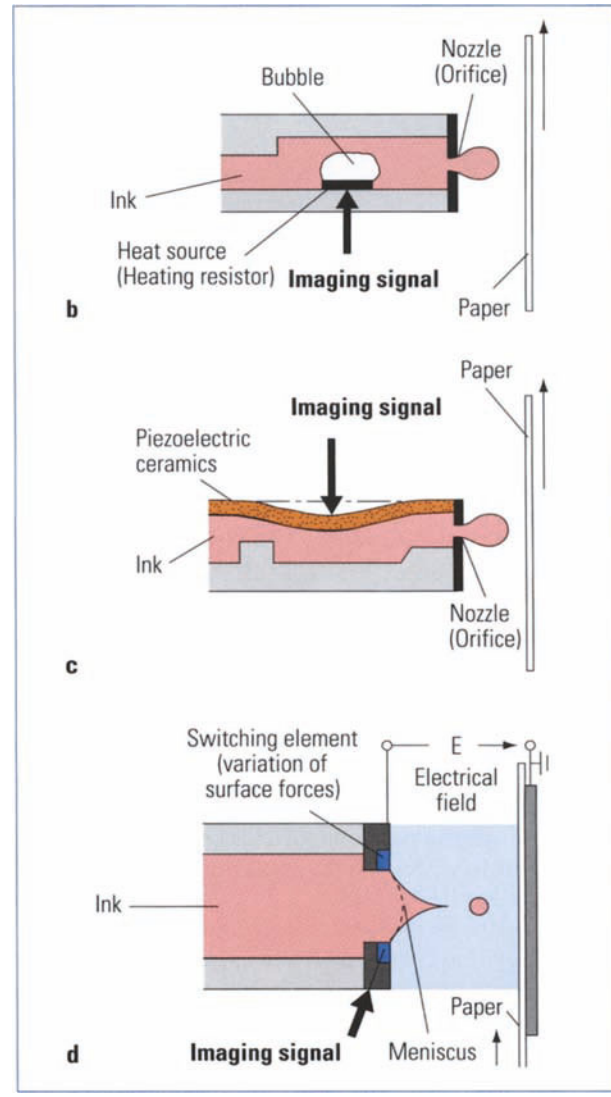


Fig. 5.5-2 Functioning principles for ink jet technologies.
a Continuous ink jet;
b Drop on demand ink jet/thermal ink jet;
c Drop on demand ink jet/piezo ink jet;
d Electrostatic ink jet

has been described in preceding sections (fig. 5.5-2a). In the *multi-deflection* process the drops receive different charges, so that as they pass through the electric field they are deflected in different directions and are transferred to different positions on the substrate (see fig. 5.5-9).

Drop on demand ink jet processes can be classified according to the way that the individual ink drop is generated. In the *thermal ink jet process* this is done by heating the liquid ink until it vaporizes, whereupon a certain quantity of ink is ejected from the nozzle as a result of the pressure exerted by the vapor bubble, hence the name "*bubble jet*" (fig. 5.5-2b).

In *piezo ink jet* systems, the drop is generated as a result of a change of volume within the ink chamber due to piezoelectric effects, which leads to the drop of ink being ejected from the nozzle system (fig. 5.5-2c).

Electrostatic ink jet is the third variant of the drop on demand ink jet process referred to in figures 5.5-1 and 5.5-2d. There are different process variants, but common to all of them is the fact that an electrical field exists between the ink jet system and the surface to be printed, and that by means of image-dependent alterations in the ink jet nozzle system, either the forces can be balanced or the surface tension ratios between ink

and outlet nozzle can be changed, so that a drop of ink is released as a result of the field forces. Withdrawal of ink from the nozzles is prepared via the electrical field, and a control pulse (e.g., electric signal or the supply of heat) then enables the release of a drop.

Inks

The states (liquid or solid) in which the ink for ink jet processes is used are summarized in figure 5.5-1. It is usually liquid inks that are used although some drop on demand ink jet systems are equipped to use *hot-melt inks*.

An *overview of the inks* for ink jet processes is given in figure 5.1-16, which also contains information on the composition of the inks and the drying processes associated with them. An explanation is also given as to what *ink film thicknesses* occur in single-color printing with ink jet systems according to the type of ink used. Particularly noteworthy here is the fact that if liquid inks are used, very thin ink films (low drop volumes) can be applied, which is the basis for very high quality prints especially in the case of color images.

Multicolor prints of extremely high quality can be created by using specially *coated papers* that help to prevent the ink from feathering, to control the spreading and penetration into the substrate), and also offer good setting characteristics and good drying results.

Further improvement in quality can primarily be achieved using ink jet systems with which several *gray values per pixel* (printed dot) can be created.

Creating Gray Values with Ink Jet Processes

As illustrated in figure 5.1-6c, if the density is modulated to create a pixel, a different ink film thickness is transferred to the paper surface. This is an idealized illustration since an increase in film thickness usually also entails a change in the diameter of the individual pixel (single dot).

In the ink jet process the size of the single dot depends on the volume of the individual drop ejected onto/transferred to the paper (and also, of course, on the absorption characteristics of the paper, although the latter is disregarded in the description that follows). *Different ink volumes* can be created in different ways, with drop on demand processes by selectively addressing the individual ink jet channel so that *different quantities* of ink are ejected from the nozzle. This may be done via the intensity of the control pulse and also via the type of controller used for the individual nozzle (e.g., the overlapping of a high frequency signal that generates several drops for one pixel).

However, larger drops for creating gray values can be generated whereby shortly before striking the substrate *several individual drops* combine in flight or strike the substrate in rapid succession, before the information for the next pixel is generated for printing.

Figure 5.5-3a shows in simplified form how several drops, which combine after release from the nozzle to form a single drop volume, can be generated in rapid succession by means of special controlling of the heating elements for the *bubble jet* process. The sequence of photographs taken of drops (fig. 5.5-3b) shows how a larger drop forms from three separate pulses of a piezo ink jet system.

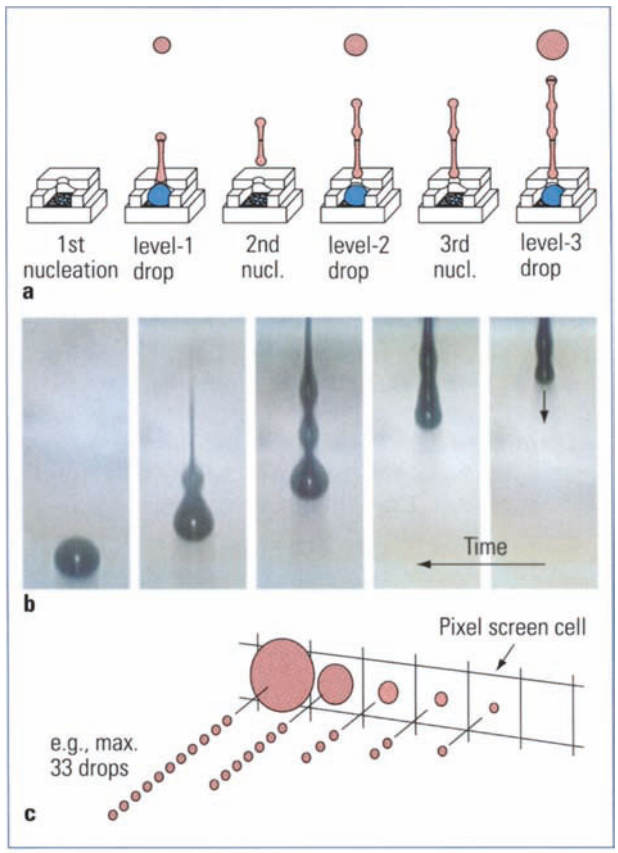


Fig. 5.5-3 Creating grey values with ink jet processes.
a Collecting drops by high-frequency generation (Thermal Ink Jet, HP);
b Forming one drop from individual drops (high-speed photography, XAAR);
c Dots of varying gray levels within a pixel screen cell, created by collecting several drops per pixel [5.5-1]

Figure 5.5-3c shows in simplified form how individual drops can be selectively collected on the pixel positions of the substrate for density modulation as a result of the very high frequency during generation of the drops in the *continuous ink jet* process. This process can produce up to around thirty gray values.

Drying Process

Figure 5.5-4 shows examples of how ink drops may react with the paper in the ink jet printing process. The surface properties of the paper determine the *spreading* and *penetration* into the substrate. The illustration shown refers to water-based or solvent-based standard inks with which the colorants (pigments or dyes) and binders produce a very thin layer of less than 1 µm ink application after *vaporization* and *absorption* of the base liquid.

More data on the drying of ink jet inks is to be found in figure 5.1-16.

5.5.2 Continuous Ink Jet

Binary Deflection Continuous Ink Jet

Figure 5.5-5 shows the underlying principle of a nozzle system based on *Hertz technology*, which enables a high frequency stream of drops (of 1 MHz or more) to be created. The pressurized liquid is pressed out of the nozzle. The high-frequency excitation via a piezo-oscillator results in the constriction of the stream due to fluid dynamics-related effects and the separation of individual drops from the stream.

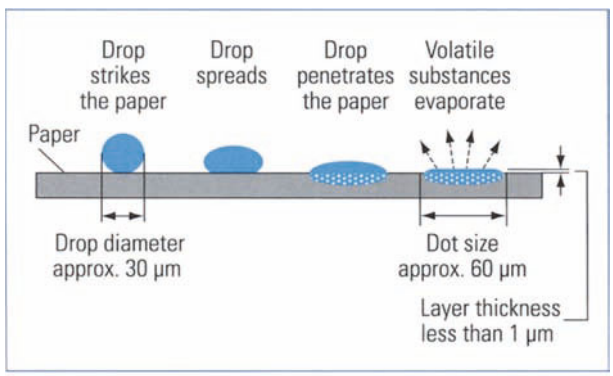


Fig. 5.5-4
Dot formation resulting from the reaction of ink drop with substrate in the ink jet process

Figure 5.5-6 shows how *drop formation* is calculated with a mathematical model and captured by means of a high-speed exposure. Drop size and interval basically depend on the nozzle diameter, and the viscosity and surface tension of the liquid, as well as the frequency of the excitation.

The individual drops are electrically *charged by an electrode* in accordance with the image just before separation from the jet (fig. 5.5-5). The charged drops are deflected in a subsequent electrical field (plate capacitor, *deflector*) and fed to a collecting device. The uncharged drops reach the paper.

As shown in figure 5.5-6b, so-called *satellite drops* are produced during the drop formation process, which should then merge with the main drop. The quality of the print depends on the quality and continuity of the drop stream generated.

Typical data (Hertz technology) on frequencies (around 1 MHz) and drop sizes (approximately 4 pl)

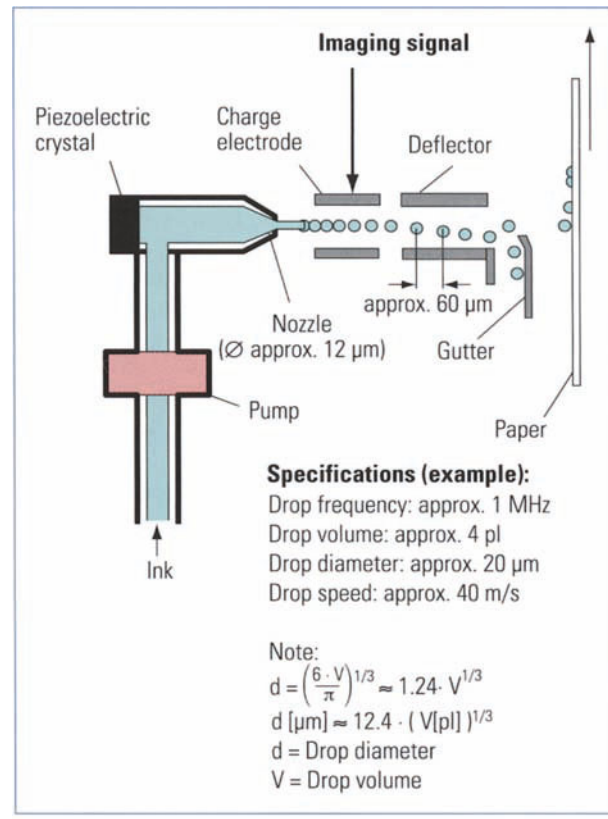


Fig. 5.5-5 Continuous ink jet: process specifications

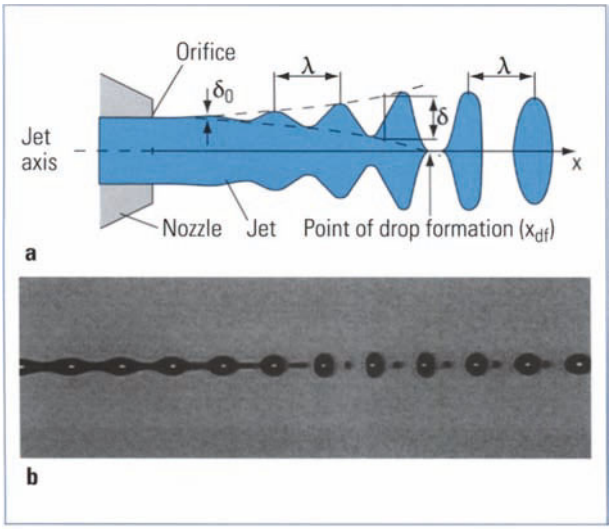


Fig. 5.5-6 Drop formation with continuous ink jet.
a Constriction of the ink jet to form a drop;
b High-speed exposure of a stream of drops with satellite drops combining with the subsequent main drop in flight [5.5-1]

are given in figure 5.5-5. (A drop volume of 4 picoliters, i.e., 4×10^{-12} dm³, is equivalent to a sphere diameter of 20 µm.)

A *practical example* of the industrial application of the continuous ink jet process as a *high-speed printing process* is given in figure 5.5-7.

The system illustrated in figure 5.5-7 consists of two groups of two ink jet modules for printing on web material (fig. 5.5-7b). The individual ink jet head is about 108 mm (4.25")wide. The nozzles are arranged to give a resolution of 240 dpi (1024 nozzles in one head/module).

Another example of industrial use with more sophisticated systems is given in figure 4.5-14 (300 dpi and an ink jet head width of approximately 229 mm (9"), equivalent to 2700 nozzles per head).

Figure 5.5-8 shows an application of continuous ink jet systems for multicolor printing (*digital proof system*). In this system, printing is done with four ink jet heads, one head per color for black, cyan, magenta, and yellow, with a resolution of 300 dpi. The sheet is fastened onto a drum. In this example, a color proof is being created with an axially moving ink jet system and a rapidly rotating drum. Approximately fifteen gray values per pixel can be reproduced (by the accumulation of drops in flight and/or by assembling them on the paper, see fig. 5.5-3c).

Multi-Deflection Continuous Ink Jet

In the continuous ink jet system shown in figure 5.5-5, the individual drops to be deflected are charged with the same voltage, consequently there are only two charging states, charged or not charged, that is, binary (therefore *binary deflection*, in accordance with fig. 5.5-1).

With the *multi-deflection ink jet*, the drops can be given different charges in the charging system and, as a result of this, they can be deflected more or less strongly between the deflector plates, depending on the intensity of the charge (fig. 5.5-9). Consequently, one nozzle system can be used to image a short line (e.g., 10 mm in height). The jet can be deflected in approximately sixteen reproducible positions. The height of a line written in this way depends on the distance between the ink jet head and the paper surface. The writing height increases as the spacing increases, although the resolution will be reduced. The resolution in the direction of printing is determined by the speed of the substrate and the drop frequency. The minimum resolution for the recognition of digitally represented characters (matrix structure) should be 7 × 6 dots (height × width).

In principle, systems with *two-dimensional jet deflection* are also feasible. In this case the deflectors act in two directions so that two-dimensional characters can be printed even if the substrate is static.

Examples of two *multi-deflection systems* are illustrated in figure 5.5-10. Figure 5.5-10a shows a system with four separate modules for four-line addressing used in newspaper mailing. In figure 5.5-10b, a multi-deflection system is being used to address printed products sent by mail. In this example six lines are written with a writing head fitted with separate systems and the installation is used for in-line addressing in the mailroom of the printshop in conjunction with the press.

5.5.3 Drop on Demand Ink Jet Technologies

With drop on demand technologies, a drop is only generated if the print image requires it.

The drop can be generated either by heat transfer (bubble jet) or by changing the chamber volume in a nozzle channel (piezo ink jet).

The two drop on demand technologies, thermal ink jet and piezo ink jet (including system specifications) are compared in figure 5.5-11.

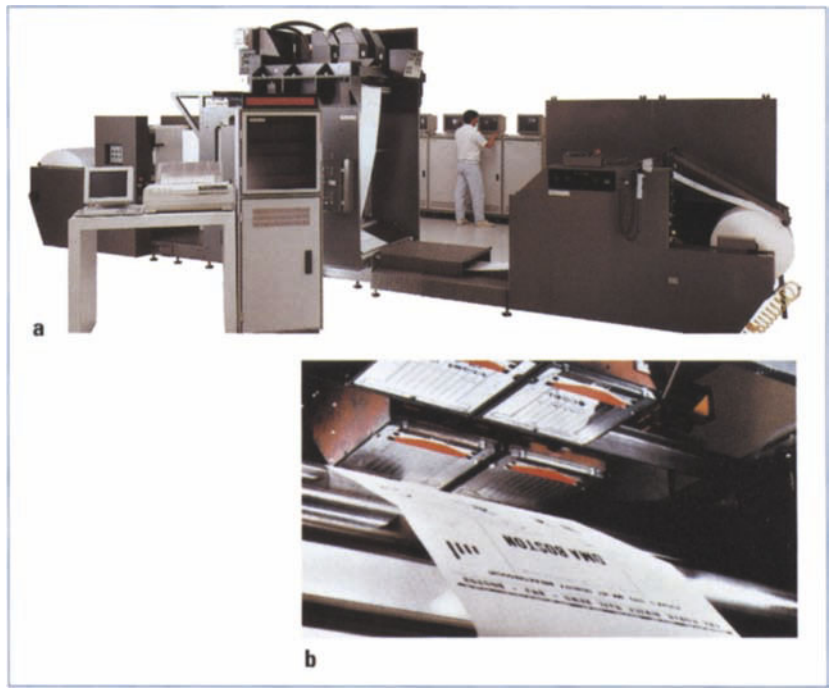


Fig. 5.5-7
High-speed ink jet system for web-fed printing.
a System with four print heads (240 dpi, head width of about 108 mm (4.25"), web speed of up to about 2 m/s);
b Ink jet heads with nozzle system (System 3600, Scitex Digital Printing)



Fig. 5.5-8 Digital proof system with continuous ink jet NIP technology.
a System example (300 dpi, 15 gray values per pixel);
b Mounting the paper on the drum and ink jet head with 4 systems for the process colors cyan, magenta, yellow, and black moved in axial direction (Digital Cromalin, DuPont/Stork Digital Imaging)

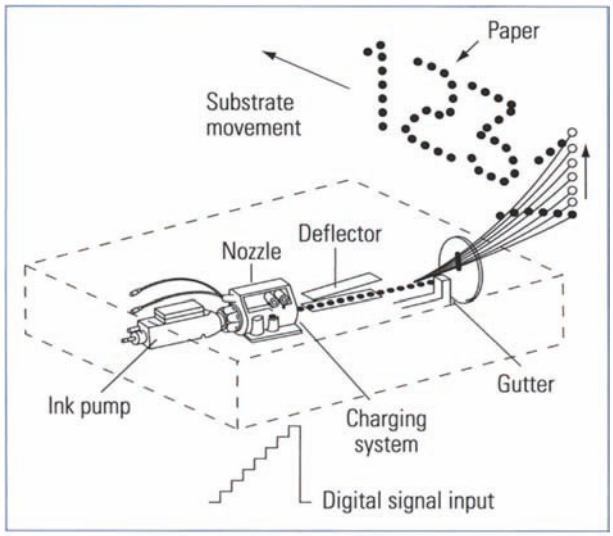


Fig. 5.5-9
Multi-deflection continuous ink jet system (e.g., seven drops within the height of a line)

Thermal Ink Jet

The sequences in figure 5.5-12 show in simplified form how an ink drop can be ejected as a result of *heating and bubble formation* and how the channel is then refilled with ink. Drop volumes of about 23 pl (equivalent to a representative drop diameter of about 35 µm) are possible on the basis of current thermal ink jet technologies (Hewlett Packard and Canon are the leading manufacturers in this case). Drop frequencies are in the range of 5 to 8 kHz. The resolution must correspond to the drop volume; 600 dpi is possible with 23 pl (dot diameter in the print around 60 µm, depending on the viscosity of the ink and the absorption characteristics of the paper, etc.). Depending on the design of the jet system with regard to the direction of the drop jet discharge and the position of the heating elements, a distinction is made between "*roof shooters*" (e.g., fig. 5.5-12b) and "*side shooters*" (e.g., fig. 5.5-12a).

The color printers used in desktop-publishing or in an office environment mostly use thermal ink jet systems. In a typical application a separate ink jet head is used for each color, although a separate head is often used for the most commonly printed color, black, and a second head for the chromatic colors, cyan, magenta, and yellow. Powerful systems are available with resolutions of 600 dpi, operating at a drop frequency of



a



Fig. 5.5-10 Multi-deflection ink jet system for addressing.
a Ink jet head for addressing newspapers consisting of four individual systems for writing four lines (Imaje);
b Ink jet system for addressing periodicals with six lines during in-line production in web offset printing (Jet Array, Domino)

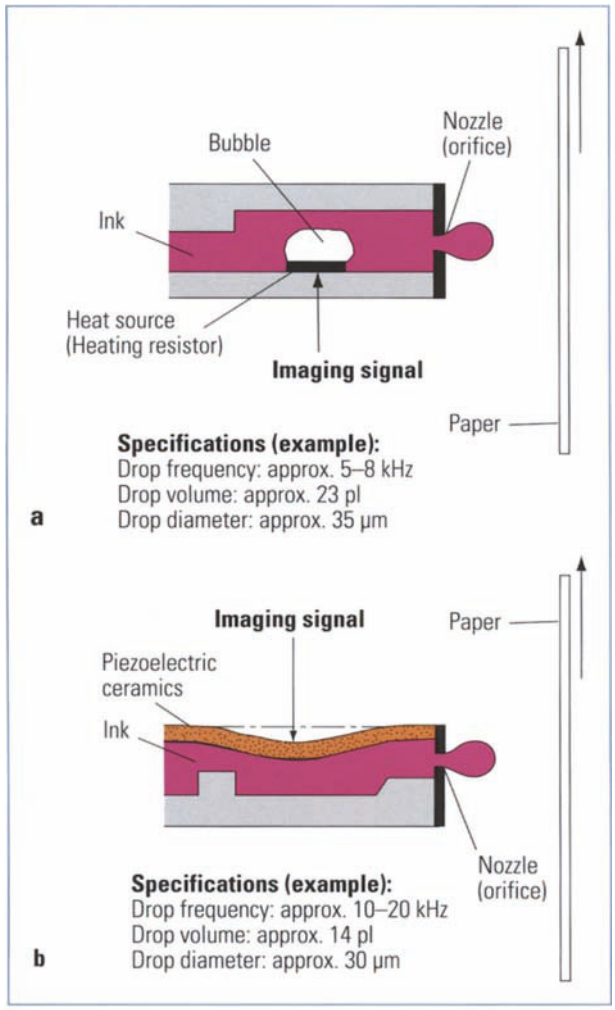


Fig. 5.5-11 Drop on demand ink jet: system specifications.
a Thermal ink jet (bubble jet);
b Piezo ink jet

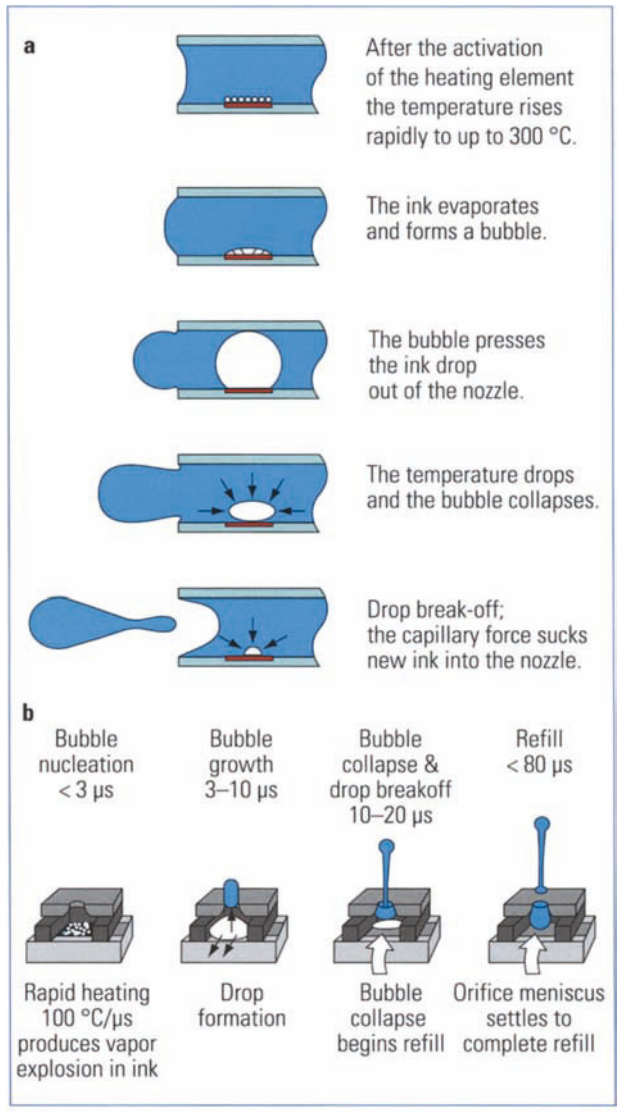


Fig. 5.5-12 Drop generation with thermal ink jet.
a Principle of bubble formation and of the drop outlet (Canon);
b Time sequence for drop formation (HP)

8 kHz, and with three hundred nozzles per printing head. The nozzles are arranged in several rows and staggered to ensure the desired resolution and the space required for installation of the individually addressable nozzles (see also figs. 5.5-20 and 5.5-21).

Piezo Ink Jet

With piezo ink jet, unlike thermal ink jet, ejection of an ink drop is generated by *mechanical displacement* in the ink channel, and not by heating and vaporization within the ink jet system (fig. 5.5-11b).

Piezo-ceramic materials are ideally suited for small, electrically addressable systems. As illustrated in figure 5.5-13a materials of this type change shape or volume in the electrical field. The so-called "*shear mode*," with the appropriate electrical controller, is usually used in piezo ink jet systems. In shear mode operation the material's volume remains unchanged and the geometry is deformed (fig. 5.5-13a).

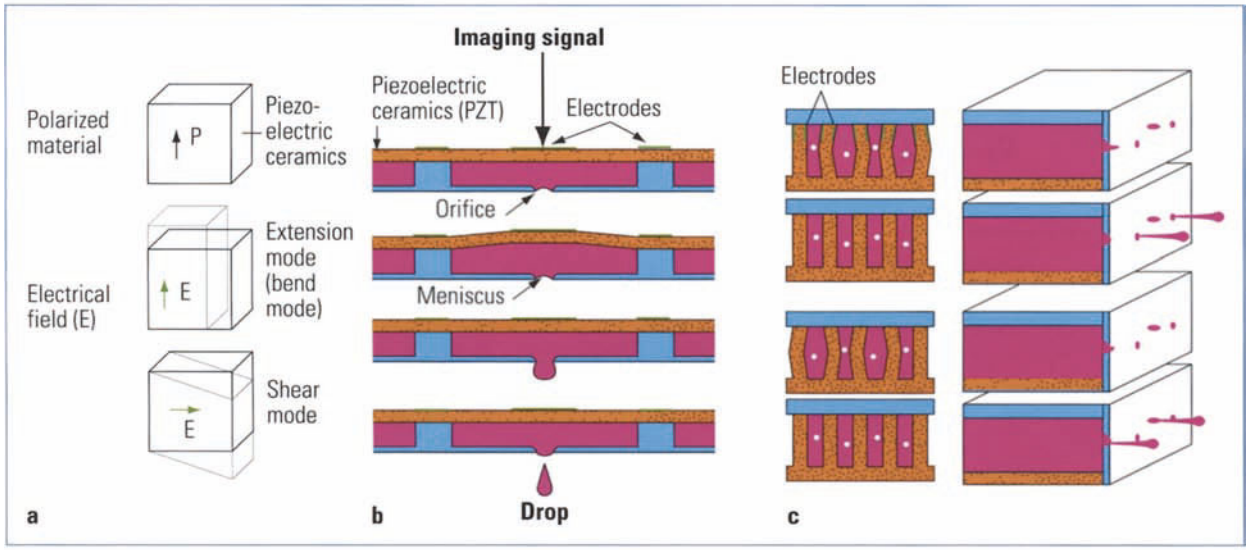


Fig. 5.5-13 Structure of drop on demand ink jet systems using piezoelectric ceramics.
a Deformation of the piezo-ceramics in the electrical field;
b Drop generation with piezo ink jet (shear mode) by deformation of the rear wall of the channel (Spectra);
c Piezo ink jet with drop formation by deformation (shear mode) of the channel walls (MicroJet, XAAR)

There are various options for different geometrical configurations to set up nozzles and nozzle systems based on these materials. An example of how a drop is generated for an individual ink channel via the *rear wall* of the chamber, similar to the way a diaphragm pump functions, is shown in figure 5.5-13b.

In the version illustrated in figure 5.5-13c the *channel walls* are deformed, which produces a pumping/suction action in one channel and an ejection action in the adjacent channel. This means that in this configuration there is always an effect on the adjacent channels (so-called *cross talking*). In the example shown, compensation is made for this effect by the fact that only every third nozzle chamber can be addressed simultaneously. Adjacent chambers cannot be used at the same time. Consequently there is alternate pumping and ejection and "cross talking" is put to positive effect.

Unlike thermal ink jet systems (normally, water-based inks are used), electro-mechanically based piezo ink jet systems can be addressed at *higher frequencies* and a broader *variety of ink formulations* can be used to great advantage.

The first applications using piezo ink jet technology with *nozzle arrays* came onto the market around 1990. *Hot melt inks* are used in the multicolor printer illustrated in figure 5.5-14. Four-color printing is generated via an ink jet head with 96 nozzles at a resolution of 300 dpi. (In spite of the considerably larger nozzle spacing of 500 µm, the low pixel spacing of 84 µm is achieved by inclining the nozzle row by about 10° when the line row is arranged vertically to the direction of paper transport. See fig. 5.5-14b and fig. 5.5-20c, but in this figure for a stationary writing head.) The solid hot-melt ink is heated and liquefied by heat transfer before being fed into the ink jet array. After transfer of the ink to the paper in accordance with the image, it cools down again and solidifies.

Figure 5.5-15 shows a more recent application of piezo ink jet technology, an *imprinting unit* which can be used to imprint additional information on preprinted web material. The preprint may have been produced with a system such as the digital high-speed single-color printing system illustrated in figure 4.5-9. Imprinting can, however, also take place in-line, as shown in figure 5.5-15c. In the configuration shown in figure 5.5-15a and b, eight ink jet heads are arranged behind one another in the direction of travel of the web. The axial position of each one can be changed independently of the others and each ink jet system can print an additional, different color, which means that informa-

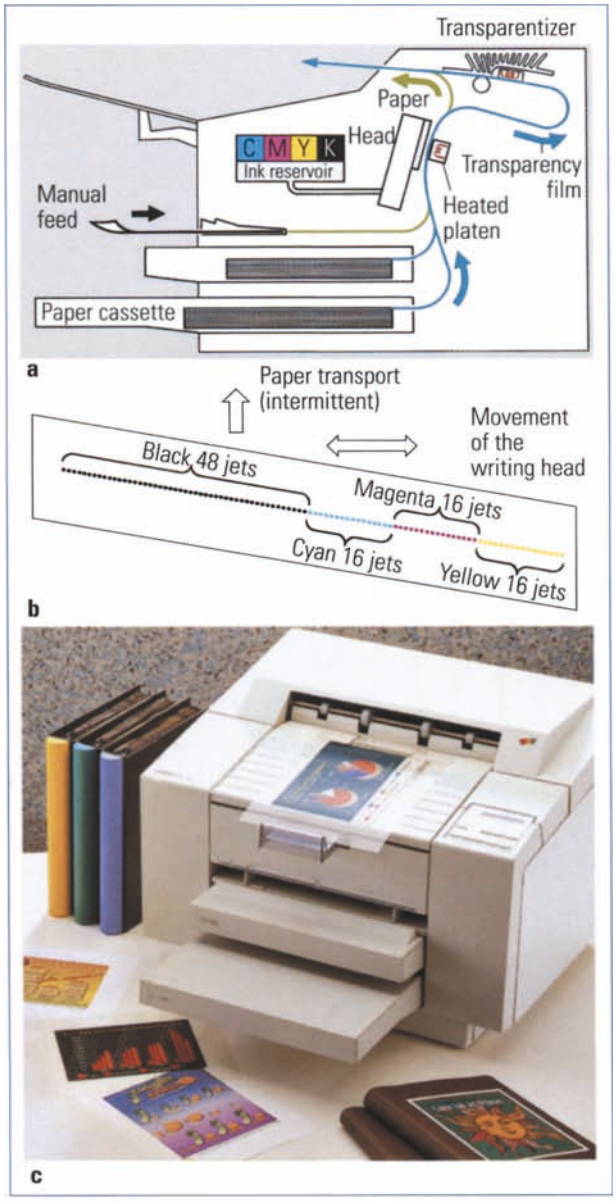


Fig. 5.5-14
Piezo ink jet system for multicolor printing with hot-melt inks.
a Printer design for A4 format;
b Nozzle arrangement and channel partition for multicolor printing (300 dpi, by tilting the array with a line resolution of 50 dpi; 96 nozzles: 48 for black, 16 each for C, M, Y);
c Example of an office printer (HS-IPS, Brother/Spectra; about 1993)

tion can be imprinted in color. The individual print heads can produce a resolution of 240 dpi with 256 nozzles per print head. The printing width per head is about 27 mm (see also fig. 5.5-20c).

Figure 5.5-16 shows a piezo ink jet system based on the technology illustrated in figure 5.5-13c. The individual print head is equipped for 180 dpi with 512 nozzle systems arranged in a row. Higher resolutions can be achieved by arranging these modules one behind the other, and larger print width can be obtained by combining modules across print direction. The system illustrated in figure 5.5-16b for creating large-format four-color ink jet prints is set up for a resolution of 720 dpi (moving writing head).

Electrostatic Ink Jet

In the drop on demand ink jet systems described above, the drop of ink is generated by the imaging system alone, in thermal ink jet systems by the pressure of a bubble of evaporated liquid, and in piezo ink jet systems by the electrically controlled mechanical deformation of the channel geometry (fig. 5.5-2b and c).

The basic principle of *electrostatic ink jet systems* (fig. 5.5-2d) is to generate an electrical field between the ink jet writing system and the substrate. Ink drops are generated by sending image-dependent control impulses to the nozzles. These impulses cause a drop to be released and routed through the electrical field onto the substrate.

Developments of systems based on these techniques are in progress and are discussed at conferences in the run-up to the technical realization of such systems. Information on this is also available in patent literature.

Electrostatic Ink Jet using the "Taylor Effect." Since about 1990 there has been discussion about an ink jet process based on the Taylor effect [5.5-2], whereby fine filaments of liquid from a nozzle are formed in an electrostatic field. The diametric ratio of filament to nozzle is about 1:20. Figure 5.5-17 shows in simplified form an ink jet nozzle design based on this idea [5.5-3].

With suitable shaping of the outlet nozzle, a jet of ink (fig. 5.5-17b) with a diameter considerably smaller than that of the outlet nozzle is formed from the so-called "*Taylor cone*." The advantage to be gained from this effect in ink jet printing is that *very small drops can be generated with relatively large nozzles* and that many gray values can be printed per pixel. Drops are generated in accordance with the image as a result of an electrical field being established between paper base and

5.5 Ink Jet

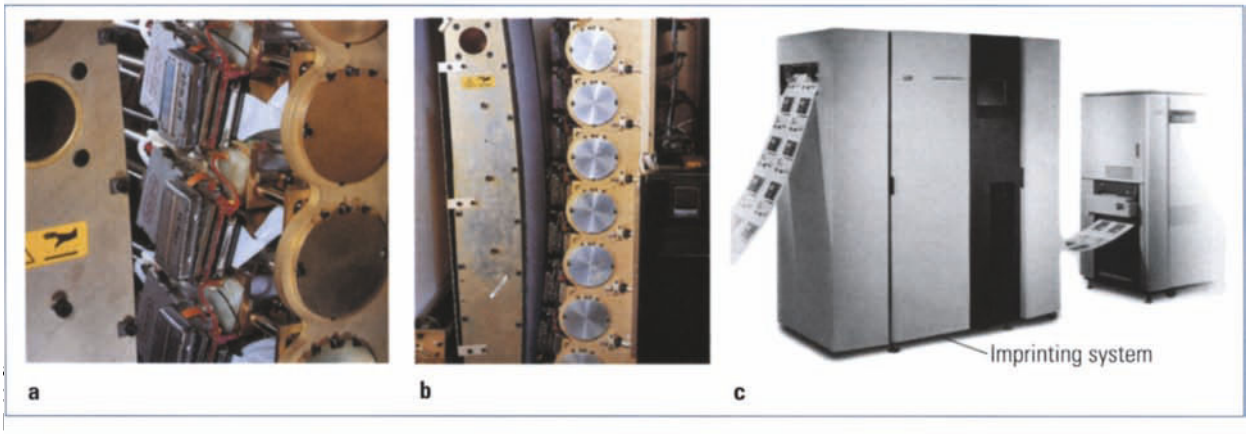


Fig. 5.5-15 Ink jet imprinting system.

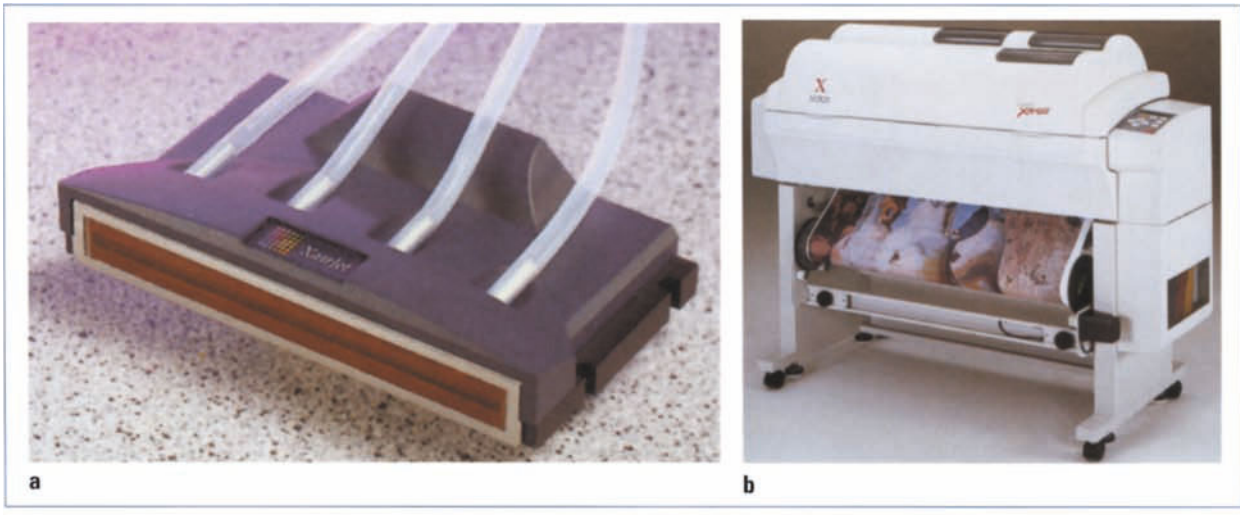


Fig. 5.5-16 Piezo ink jet system.
a Print head (nozzle line with 180 dpi and 512 nozzles), (XaarJet, XAAR);
b Large-format ink jet printer, 720 dpi (XPress, Xerox/XAAR, Seiko, Olympus)

nozzle outlet and the superimposing of voltage signals. The drop's volume is determined by the duration of the control pulses (see fig. 5.5-17a). Hot-melt inks are used in the design shown in figure 5.5-17c.

There are concepts relating to the above process for designing nozzle arrays on the basis of special micromechanical methods with optimal design of the nozzle shape. The nozzle diameters are about 400 µm and nozzle spacing of less than 1 mm is realistic. By arranging the nozzles in several rows behind one another where the nozzles are staggered within a row, arrays can be created which are able to attain resolutions of 600 dpi and higher, also for larger imaging widths (see fig. 5.5-20b).

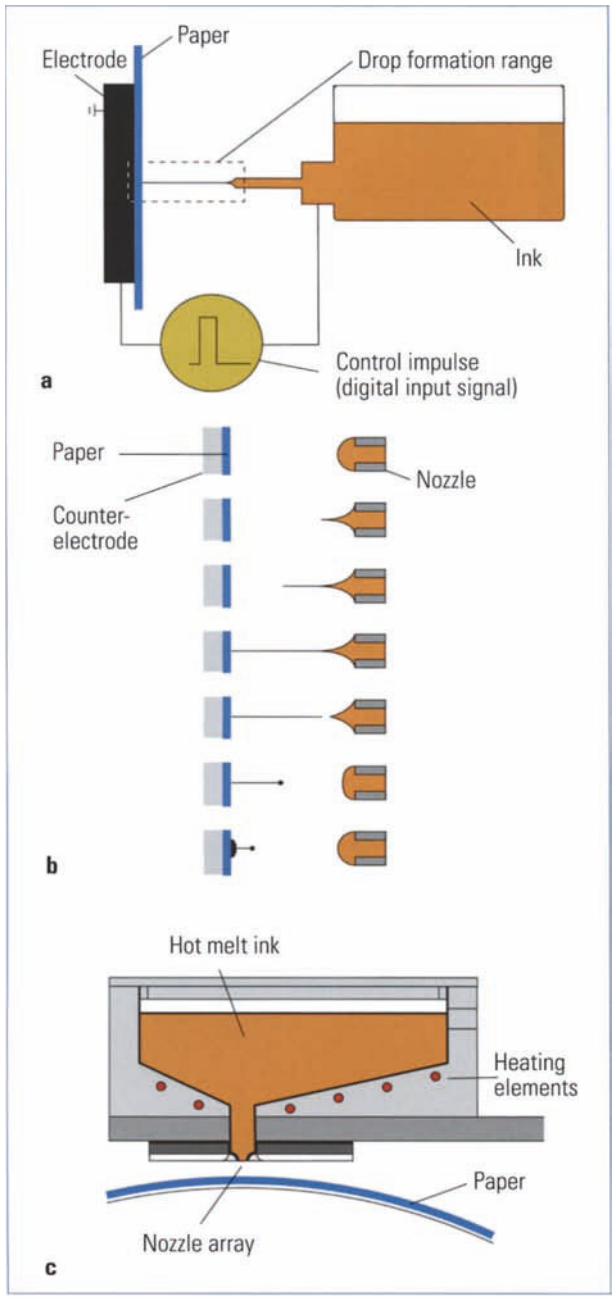


Fig. 5.5-17 Electrostatic ink jet based on the "Taylor effect."
a Underlying principle of drop generation;
b Drop formation in electrostatic field (sequence);
c Concept with specially shaped nozzle array and hot-melt inks (ESIJET, iTi: Imaging Technology International; [5.5-3])

Electrostatic Ink Jet with Control via Thermal Effect to Change Viscosity. The ideas of Silverbrook [5.5-4], which are based on a special nozzle control for ink jet printing, have been around since 1995.

As illustrated in figure 5.5-18, the liquid ink is under slight overpressure in a tank covered with a nozzle plate. The overpressure in the ink and an electric field between nozzle array and substrate surface are in equilibrium with the *surface tension* of the liquid in relation to the nozzle rim. All nozzles have *ring-shaped heating elements* and can be controlled separately. The rim of the nozzle can be heated by means of a current pulse, the surface tension changes and, as shown in figure 5.5-18a, an ink drop is formed for the imaging.

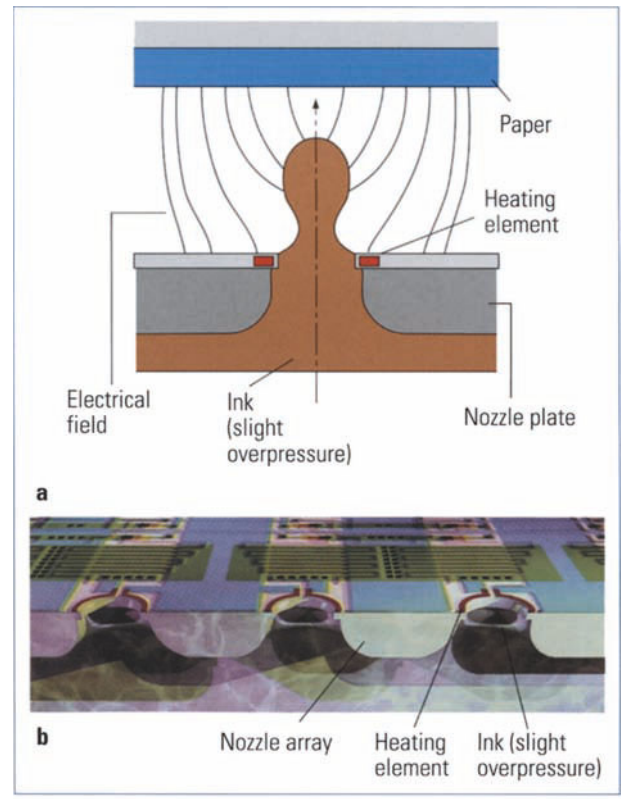


Fig. 5.5-18
Electrostatic drop on demand ink jet with control via heating elements.
a Section of a nozzle array with integrated heating elements and electric circuit;
b Drop generation via electric field after reduction of the interfacial tension by heating the nozzle rim (LIFT technology, Silverbrook Research, [5.5-4])

The inventor calls the printing technology based on this effect *LIFT Drop on Demand Printing* (LIFT signifying liquid ink fault tolerant). This name is based on the fact that economical, large-surfaced nozzle arrays with more nozzles than are needed for the required resolution can be set up using special techniques and silicon-based material (described in patent applications, some of which are not yet published). This can be used both to create several gray values per pixel and also to prevent quality being impaired during printing due to the failure of individual nozzles. The nozzle function is controlled via the electronics, with changeover to reserve nozzles, if necessary.

The distinctive feature of this process is the relatively simple structure of the nozzle system for ink jet printing with a high resolution (no channel system, merely a nozzle plate). Solutions for the design of nozzle arrays that will enable the mass production of nozzle menisci of between 10 and 20 µm at a distance from nozzle to nozzle of only about 60 µm are under discussion.

Electrostatic Ink Mist Jet. There have been reports in fairly recent publications [5.5-5] on the generation of very small droplets of ink (ink mist) using *ultrasonic effects*.

The structure of a nozzle for creating fine, very small drops is shown in figure 5.5-19 (average diameter about 2.5 µm). As illustrated in figure 5.5-19b, ultrasonic waves are focused on the nozzle outlet, as a result of which surface waves are produced at the nozzle outlet that result in the ejection of small drops, as shown in figure 5.5-19b. The transfer of ink onto the paper is triggered by the image signal and the number of mist droplets can be controlled in combination with superimposed high-frequency signals of different duration. Figure 5.5-19c shows examples of three gray levels formed from small droplets of mist. In experiments it was possible to reproduce about thirty-two gray levels with a resolution of 300 dpi. Care must be taken to ensure that the expansion of the image element is approximately of the same size. The gray values are created by the different number of small dots formed by the mist droplets.

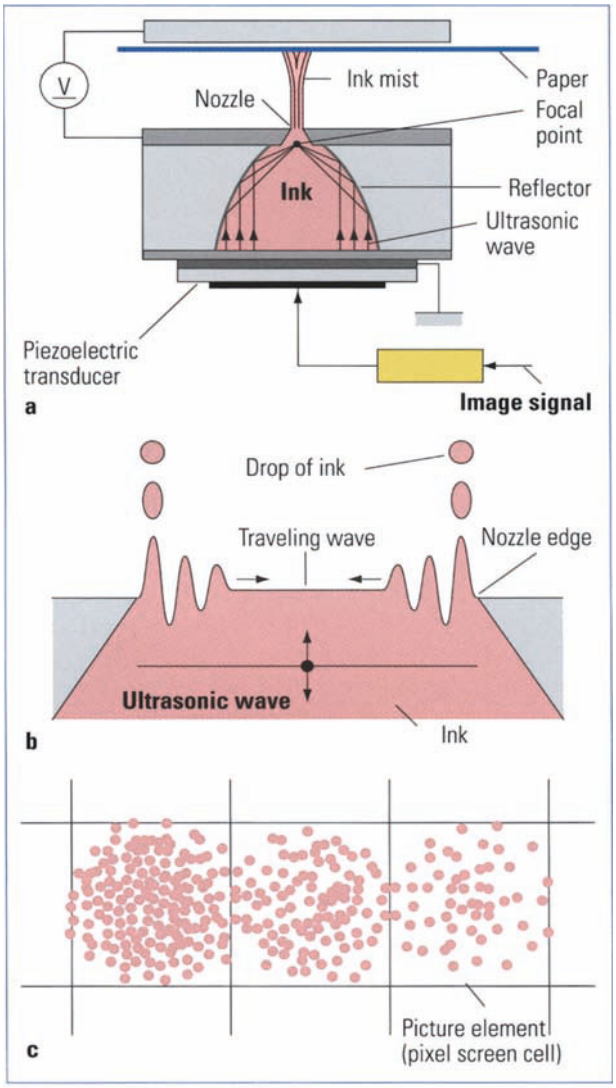


Fig. 5.5-19
Ink mist jet: electrostatic ink jet with ink mist, generated ultrasonically.
a Underlying principle on a nozzle for ink mist jet;
b Drop/mist formation by ultrasonic and surface waves; drop diameter about 2.5 µm, nozzle diameter about 50 µm (for 300 dpi pixels);
c Gray values generated by ink mist transfer, time-controlled; pixel size about 85 µm × 85 µm (equivalent to 300 dpi),
(Mitsubishi, [5.5-5])

5.5.4 Structure of Ink Jet Arrays

To create ink jet printing systems with higher productivity, imaging systems with nozzle arrays are required.

Ink jet print heads can either be designed as page-wide stationary arrays or assembled in imaging systems in which the print head moves at right angles to the direction of travel of the substrate (imaging/writing direction).

Figure 5.5-14b shows an example of how ninety-six channels can be assembled in one line. To produce a resolution of 300 dpi at a distance from nozzle to nozzle of 500 µm, the line was inclined by about 9.6° (the *nozzle row* is slightly inclined to the perpendicular, relative to the cyclic/intermittent paper feed direction; the writing head crosses the page width).

Figure 5.5-7 illustrates a system with a stationary ink jet head in page-wide configuration. The system comprises *several adjacent rows of nozzles*, and here the rows are arranged parallel to the web travel and slightly inclined in order to achieve a higher resolution.

Lines of nozzles, similarly slightly inclined to produce a high resolution, are shown in figure 5.5-15. The lines are also oriented in direction of the paper travel.

Figures 5.5-20 and 5.5-21 illustrate how, in principle, lines of nozzles can be suitably arranged with a greater spacing than the *desired resolution*. Options for *assembling page-wide arrays* are also shown.

Figure 5.5-20a shows how the resolution can be doubled quite simply by offsetting the nozzle outlet in one line of a two-line assembly. Arrays having the desired resolutions can be obtained by extending this alternative, that is, the desired resolutions can be achieved with each successive line having nozzles staggered in relation to the preceding line.

An example with 6 lines is shown in figure 5.5-20b. This results in a resolution of 600 dpi, with an individual line resolution of 100 dpi. (The corresponding arithmetic correlations are also given in the illustration.)

Figure 5.5-20c depicts how the resolution can be increased by a single row, if the line is arranged in the direction of printing. This necessitates a very long array for larger writing widths or synchronized axial movement of the individual head, as in the system shown in figure 5.5-8. (Figure 5.5-15 shows a system that can be firmly positioned in the axial direction for a writing width of about 27 mm.) Arranging several rows alongside each other in this way for larger writing widths results in a structure such as the one in figure 5.5-20b.

These design principles for imaging arrays producing high resolutions can, of course, be applied to other imaging systems, in spite of the large installation space required by the individual components. Figure 5.4-6 shows an array for magnetography that is designed to provide a resolution of 480 dpi from six lines (see fig. 5.5-20b). The magnet spacing in an individual line corresponds to a resolution of 80 dpi. The structure of an ion source array is explained in section 5.3. A resolution of 300 dpi from 16 ion source lines at right angles to the direction of print was achieved (consequently the spacing of the ion sources in an individual line corresponds to 18.75 dpi).

It can be seen from figure 5.5-20 that the spacing of successive lines can be selected relatively freely and focus can be placed on manufacturing and installation aspects. However, it must be taken into account that in imaging array installations with several lines for increased resolution, in contrast to single lines, the *pixel size must also be adapted*, that is, smaller pixels for increased resolution. Taking the example of ink jet technology, this means that the nozzles and orifices in the individual line has to be designed for a drop size in accordance with the desired high resolution.

The distances from nozzle to nozzle are determined by the nozzle design and the mechanical/electrical system. Moreover, the line length and the extension of an array are restricted for manufacturing reasons and by the requirements on the electrical circuits, ink feed, material properties, cost, the reliability requirements, and production engineering. This results in page-wide *arrays* usually being built up *from individual modules.*

Figure 5.5-21 shows an example of the possible structure of an *imaging system* (made up of thirty modules) for 600 dpi and a printing width of 325 mm in which the nozzle arrays of the individual modules are 65 mm wide. This configuration requires both extremely accurate mechanical alignment and the correct synchronization for controlling the individual channels. In particular errors in aligning the modules at right angles to the direction of printing for perfect positioning of the imaging line can lead to clearly visible defects in the quality of the printed image.

The ink jet system illustrated in figure 5.5-16 can be assembled as a page-wide ink jet imaging head (similar to fig. 5.5-21). At the DRUPA 2000 exhibition, an imprinting system based on the configuration shown in figure 5.5.-21 was presented within a hybrid printing system similar to the concept as explained in chapter 6 (see fig. 6.3-9).

The configurations for array systems discussed above refer to systems for one *color*. For multicolor printing, assignment within an array can be done according to colors (e. g., as shown in the system given in fig. 5.5-14).

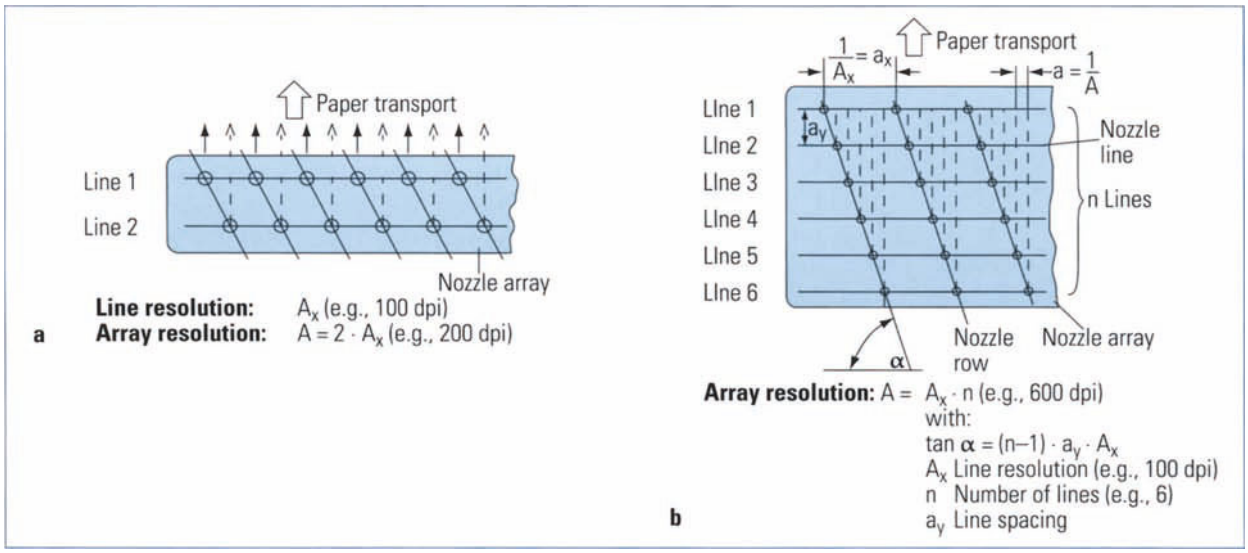
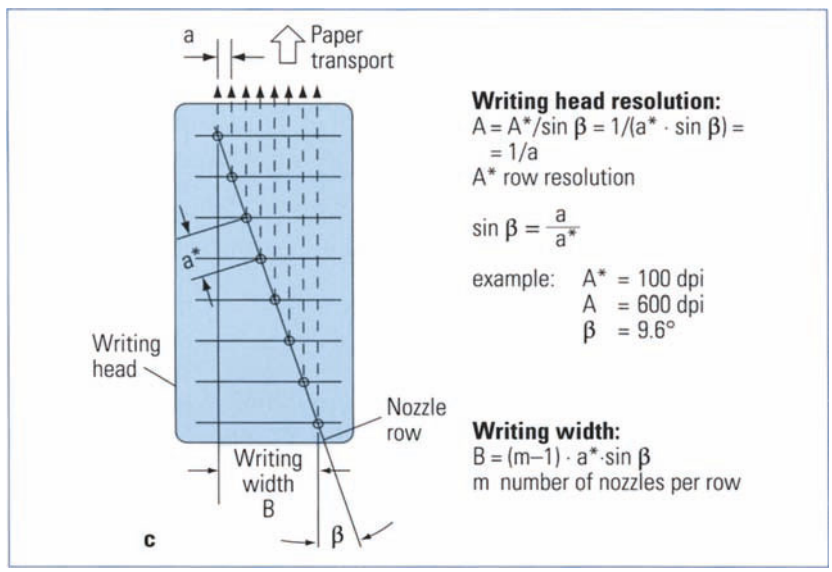


Fig. 5.5-20
Underlying principles of the design of ink jet arrays.
a Increasing the resolution by arrangement of two lines (line position perpendicular to direction of printing/paper transport);
b Multi-line array to increase resolution (line position perpendicular to direction of printing);
c Ink jet module with line alignment in direction of printing, inclined configuration



For multicolor printing with a page-wide ink jet array configuration (singlepass system), four separate arrays are needed.

5.5.5 Printing Systems based on Ink Jet Technology for Multicolor Printing (Selection)

As a supplement to the preceding examples and the examples dealt with in other chapters, systems using ink jet NIP technology for various, wide-spread applications, are explained below.

In principle, distinction can be made between *high-speed printing systems*, which print predominantly with one color or with an additional spot color, and systems for the high-quality printing that is required for *proof purposes*. Small-format (A4, A3) multicolor ink jet printers are most widely used in *office applications*, desk-top publishing, and for private use. Ink jet systems for *large-format printing*, such as posters and billboards, are

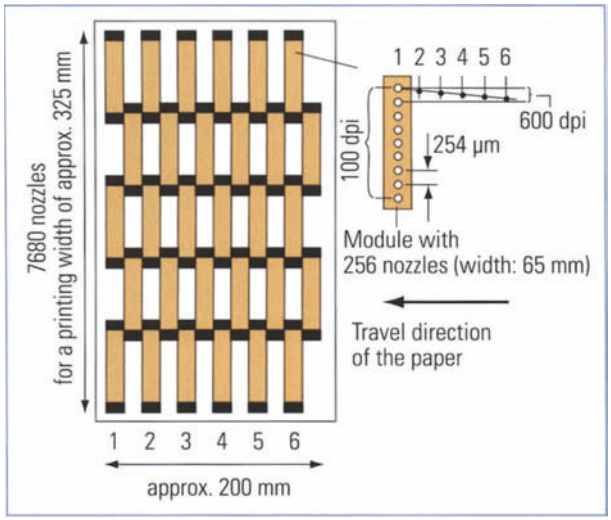


Fig. 5.5-21
Modular structure (in principle) of a page-wide ink jet array by means of adjacent modules at right angles to direction of printing and increased resolution by means of successively positioned modules (Heidelberg/Spectra)

becoming more widely used. Ink jet systems are also used in connection with *digital photography* for printing high quality, mostly small-format color images.

Ink Jet Systems for Digital Proofs. Figure 5.5-8 shows an example of proof production based on a continuous ink jet system. The example in figure 5.5-22 shows a proof system that operates with *piezo-technology* and uses *hot-melt ink*. This system is equipped with eight imaging heads for *eight different colors*, each one transferring color separations to the substrate by means of forty ink jet nozzles and printing being done with cyan, magenta, yellow, and black. To achieve a higher range of color gamut, printing is done with two different optical densities (different concentrations of colorants) for cyan and magenta, with three different optical densities for black, and with only one for yellow. The system prints with a resolution of 600 dpi. It takes about eleven minutes to print an A3 proof.

A proof system that works on the basis of drop on demand technology of *thermal ink jet* is shown in figure 5.5-23. The imaging is done by eight ink jet systems, configured in sets of four (one after the other in the direction of rotation of the drum holding the substrate). This system also images in *eight colors*, but this time with three different optical densities for cyan and magenta, and only one for yellow and black. The resolution is 300 dpi. An image quality equivalent to about 1000 dpi is achieved by using eight colors (but not for line art). This system is designed for the production of large-format proofs (A1), a proof being produced in about eight minutes. The system can be switched over to printing with only four colors, for color reproductions where a lower range of color will suffice.

Figure 5.5-24 depicts another example of a system for high-quality digital proofs. Imaging occurs with a resolution of up to 600 dpi based on the *continuous ink jet principle*. The drop volume is only about 3 picoliters (corresponding drop diameter around 18 µm). Several gray values per pixel can be created. The system is available for formats up to A2+.

Another system explained later in figure 5.5-29 is also widely used for proofing applications; the applied ink jet technology is drop on demand/thermal.

Large-Format Ink Jet Printing Systems. There are very many systems available for printing large format products such as posters and large-scale advertising displays. *Wide-format ink jet printers* are often used. Widths of about 135 cm are common, though there are also systems for printing widths of about 5 to 8 m. Printing can be done on various materials, textiles and plastic film for billboards by adapting the inks. The systems operate with imaging heads that scan at right angles to the direction of travel of the paper. It is not reasonable to use format-wide imaging heads for the large-format width. These imaging heads for the individual colors can be arranged behind each other, that is, in the direction of printing, or alongside each other, as well as in an array block for both directions.

Figure 5.5-25 shows an example of the large-format production of color prints in high quality. The system is based on *thermal ink jet* and images with a resolution of 600 dpi, the maximum printing width is 1340 mm and the production speed (printing speed) about 3 m²/h. The web material is available with various coatings, depending on whether the prints are to be used in or out of doors. There are also materials available that enable later mounting of the print on a different base material. Laminating equipment can be used to apply protective films to the front and reverse sides by means of pressure and heat.

Figure 5.5-26 shows examples of two systems for printing *extremely large formats*. The printing widths

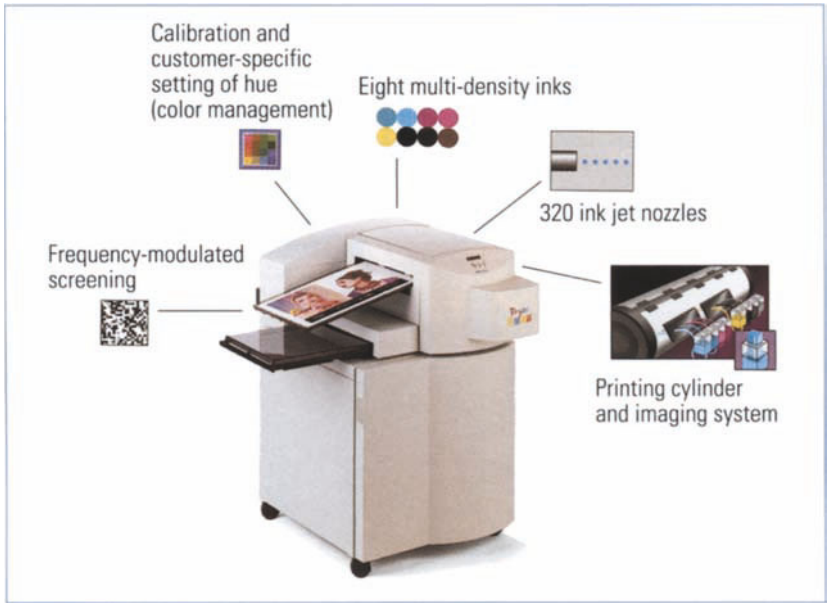


Fig. 5.5-22
Ink jet system (piezo drop on demand technology) for digital proofing; 600 dpi resolution, eight colors (2× cyan, 2× magenta, 3× black, 1× yellow, different ink density), A3 format
(DryJet, Polaroid Graphic Imaging)



Fig. 5.5-23
Ink jet proof system (thermal drop on demand technology); 300 dpi resolution, eight colors (3× cyan, 3× magenta, black, yellow), A1 format (AGFA Jet Atlas, AGFA)

for these examples are 5 m, the resolutions between 19 and 300 dpi. A resolution of 30 to 70 dpi is sufficient for many applications involving large-format prints (posters, advertisements), depending on the distance from which they are observed, that is to say, it is not detrimental to quality if the viewing distance is large.

The systems illustrated in figures 5.5-25 and 5.5-26 operate with web material and are therefore suitable for imaging a great variety of formats.

High-Productivity Ink Jet Printing Systems. The systems shown in figures 5.5-7, 4.5-14, and 1.3-32 use format-wide imaging systems for print production at speeds of up to 2 m/s (approx. 400 ft/min) in a single-color or with additional spot colors.

Ink jet systems for high-productivity and high-quality multicolor printing comparable to the electrophotography-based systems on the market are not yet available in working practice. Various announcements have been made and high-productivity digital printing systems based on ink jet can be expected to be available soon.

As illustrated in figure 5.5-27 a multicolor system based on the ink jet technology (continuous ink jet) and as used in a similar way in the system shown in figure 4.5-14 has been announced. The problem here lies in the drying process for multicolor halftone printing, the possibly restricted range of printable materials,



Fig. 5.5-24
Digital proof system based on continuous ink jet; resolution 600 dpi, A2+ format (Iris 4Print, Scitex/Iris)



Fig. 5.5-25
Ink jet system (drop on demand/thermal) for the multicolor printing of large formats; resolution 600 dpi, printing width 1340 mm (DesignJet 3000 CP, HP)

and not least in the technological feasibility and related cost of investment.

Another product announcement for multicolor printing is based on the *piezo drop on demand technology* such as is used in the equipment illustrated in figure 5.5-16. Figure 5.5-28a shows the laboratory test system of an installation in which the ink jet systems for the four process inks are arranged behind one another. As already explained, systems for large printing widths can be assembled from individual modules. A project study is shown in figure 5.5-28b.

Ink Jet Systems for Small-format Applications (Office Environment, DTP). There is a great variety of ink jet printers available for A4+ or A3+ formats, for desktop publishing applications and for office use.

Key features of present-day equipment are its high quality and acceptable productivity. The inks are adapted to the respective equipment and are mostly suitable for printing on paper and on transparencies.

There are also ink jet designs in which printing is not done directly onto the paper but via an *intermediate cylinder*. The advantage of a system of this type lies in the greater variability of the printable paper stock and lower ink film thicknesses, especially in the case of printing with hot-melt inks.

Numerous companies, such as Hewlett Packard, Epson, Canon, Lexmark, and many others supply powerful equipment with good potential for high printing quality.

Ink Jet for Small-format Proofing. In the small-format range, equipment that produces high-quality prints in more than four colors is finding favor, similar as has been illustrated in the examples in figures 5.5-22, 5.5-23, and 5.5-24. Figure 5.5-29 shows an ink jet printer (A3 format), with which color prints of a very high quality can be created. The resolution is 720 dpi and the resolution can be doubled to 1440 dpi in the direction of paper travel by addressing electrically (dot sizes not adjusted). This equipment is also used to make color proofs.

Digital Photography. As a result of the increasingly wide-spread use of digital photography there is a demand for small-format digital printers giving high image quality (photo quality, that is, color images in high resolutions and with continuous tonal gradations). Until now it is predominantly printers working on the NIP thermal sublimation principle that are being



Fig. 5.5-26
Ink jet printing systems for the multicolor printing of large formats.
a Model Blueboard 2; resolution 70 dpi, printing speed 60 m²/h, max. printing width 5 m, continuous ink jet (NUR Macroprinters/Salsa);
b Model UltraVu 5000; resolution 300 dpi (also addressable for 37.5 and 18.75 dpi), printing speed 110 m²/h with low resolution of 18.75 dpi, max. printing width 5 m, piezo drop on demand ink jet (VUTEk)

used, although ink jet-based systems adapted for papers with special coating for achieving "photographic quality" are being increasingly exploited. Developments by Canon, Epson, and HP also target this market segment.

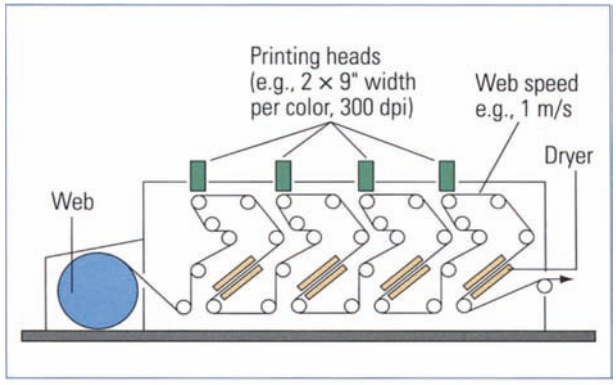


Fig. 5.5-27
System configuration for a multicolor continuous ink jet printing system (Scitex Digital Printing; diagram based on sundry company information, status: 1996, not confirmed; see also fig. 4.5-14)

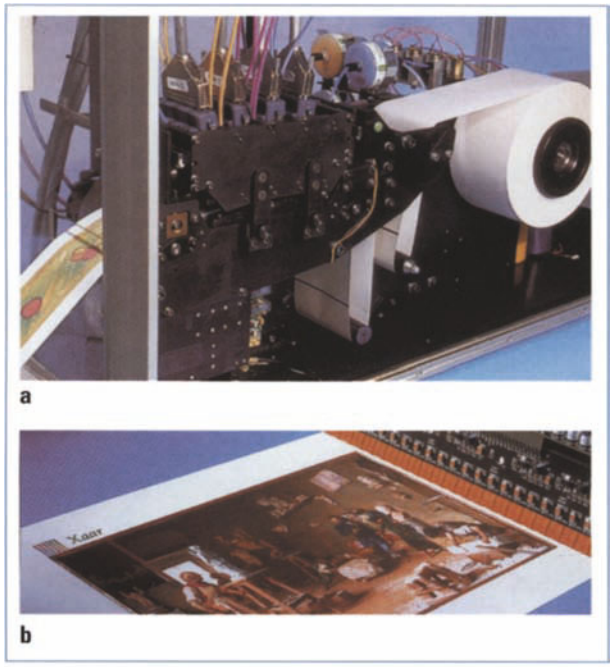


Fig. 5.5-28 Ink jet printing system for multicolor printing.
a Laboratory system with piezo drop on demand ink jet print heads; **b** Project study on multicolor printing with modular structure, page-wide printing system (XAAR Digital)



Fig. 5.5-29
Ink jet printing system for high quality multicolor printing/digital proof; resolution 720 dpi (1440 dpi possible in direction of printing), six colors (2× cyan, 2× magenta, black, yellow), piezo ink jet technology, A3+ format, around 5 min. printing time per A3 page (Stylus Pro 5000, Epson)

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Further Reading for 5.5

Le, H.: Progress and Trends in Ink Jet Printing Technology. Journal of Imaging Science and Technology, Vol. 42, No. 1, pp. 49–62, 1998.
Pond, S.F.: Inkjet Technology and Product Development Strategies. Torrey Pines Research, Carlsbad (CA) 2000.

5.6 Thermography

5.6.1 Overview of Thermography Technologies

As explained in figure 5.1-4, the NIP technology of thermography can be in the main divided into *thermal transfer* and *thermal sublimation*.

In both processes, the ink is applied to a donor (sheet or web) and then transferred to the substrate by the application of heat (or, depending on the system, first to an intermediate carrier which subsequently transfers it to the substrate).

Figure 5.6-1 adds to the illustration in figure 5.1-4 by sub-dividing thermography into *direct thermography* and *transfer thermography*. Transfer thermography is further sub-divided into thermal transfer and thermal sublimation.

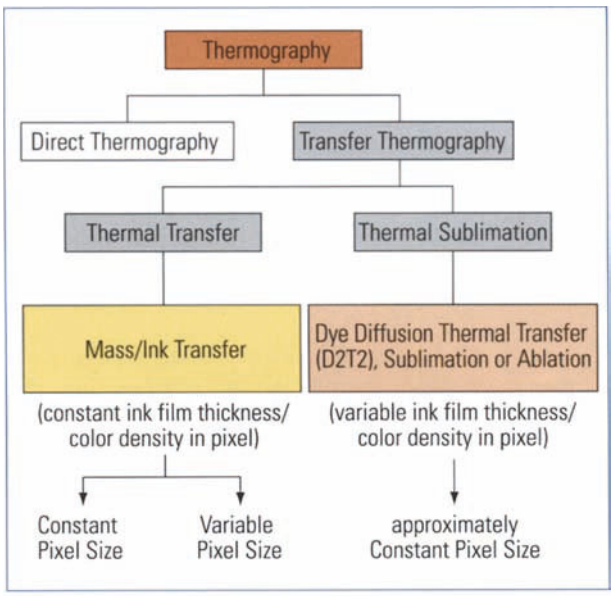


Fig. 5.6-1 Overview of thermographic processes in thermography

Direct Thermography. In direct thermography the substrate is treated with a special coating, which changes its color when subjected to heat. This kind of special paper is often used for applications in fax machines and for labeling and coding (e.g., bar codes). Machines using thermal printing systems (thermal printers) are label printers or receipt printers. Direct thermal printing will not be dealt with in detail here; those processes are described that are largely independent of the substrate and where the ink is supplied via the system.

Transfer Thermography. In *thermal transfer*, in contrast to direct thermography, the ink is stored on a donor and is transferred to the substrate by the application of heat.

Put simply, part of the ink layer is released from the donor and transferred to the substrate (a large quantity of ink is transferred). The ink on the donor may be wax or a special polymer (resin). For this reason thermal transfer is sometimes also called "*thermal mass transfer*."

In *thermal sublimation*, on the other hand, the ink is transferred from the donor to the substrate by diffusion. The heat melts the ink and initiates a diffusion process onto the paper. This requires a special coating on the substrate to take on the diffused colorants. The physically and chemically precise term for thermal sublimation is "*dye diffusion thermal transfer*," which is shortened to D2T2.

Ink Donor. Figure 5.6-2 shows the structure of the ink donors. It shows the importance of selecting a suitable combination of coating on the printing material and ink layer on the donor material, particularly in thermal sublimation (D2T2).

Whereas in thermal transfer the donor material is always in contact with the substrate during transfer, there may be a small gap between the receiving layer and the ink layer in thermal sublimation. This can be achieved by spacers, for instance, which are integrated into either

H. Kipphan (ed.), *Handbook of Print Media*
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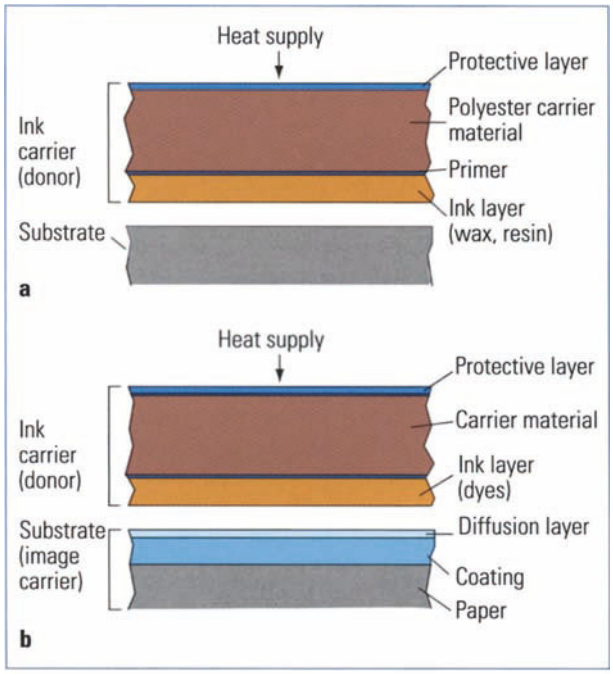


Fig. 5.6-2 Structure of ink donor material.
a Thermal transfer;
b Thermal sublimation: coating of paper with diffusion layer (ink receiving layer)

the receiving layer or the ink donor (e.g., spherical particles, forming a special surface structure).

Printing Unit. A simplified illustration of the fundamental principle of a thermography-based printing unit is given in figure 5.6-3. In multicolor printing, for example, the colors black, yellow, magenta, and cyan are applied to a donor. A thermal printing head is in contact with the donor material. By controlling the heating elements in this head in accordance with the image (systems with a resolution of 600 dpi are available) the ink is transferred from the donor to the paper. As mentioned previously, the donor is in direct contact with the paper (or other substrate).

Figure 5.6-3 shows how multicolor printing is carried out by the thermographic transfer of *color separations* onto the substrate. The different inks are positioned on the ink donor ribbon one after the other. In multipass principle the color separations are collected on the paper.

Figures 5.6-4 and 5.6-5 give a simplified illustration of the *principles* of thermal transfer and thermal sublimation.

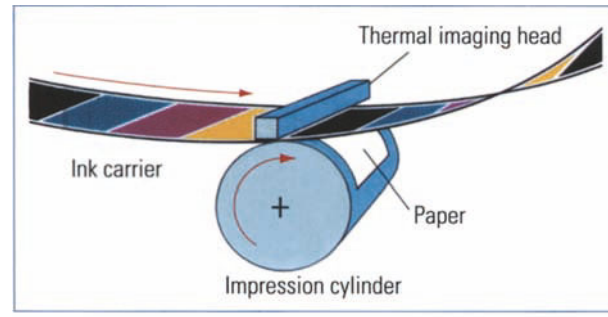


Fig. 5.6-3
Principle of ink transfer onto the substrate in thermal transfer (multipass system)

Thermal Transfer. As shown in figure 5.6-4, thermal transfer is based on the ink melting onto the carrier film when heated. The liquefied ink is transferred to the substrate under low pressure. In the simple binary process, the optical density of the print is set in advance by producing the donor with a specified thickness of layer, pigment concentration, and hue.

This is the original version of thermal transfer; a binary ink transfer process – illustrated in figure 5.6-4 – that consists of controlling the heating element of the printing head and transferring the entire ink layer per pixel onto the paper. When the heating element is switched off there is no ink transfer. The use of micromechanical and microelectronic techniques in the mechanical design of the thermal head facilitates finely controlled heating of the image area. This makes it possible to transfer different quantities of ink. Due to the composition of the ink layer, however, the ink concentration of the transfer remains constant, although the dot size may vary. This means that smaller or larger amounts of ink can be transferred by defined melting. This variant of thermal transfer is also called VDT (*variable dot thermal transfer* – see also the overview in fig. 5.6-1).

Thermal Sublimation. Figure 5.6-5 shows the principle of thermal sublimation. In thermal sublimation, the ink evaporates locally through the application of heat, which triggers sublimation. In physical terms, sublimation is the vaporization of a solid without the intermediate formation of a liquid. This is not necessarily the case with thermal sublimation – the better, or generally more accurate, term for the flowing process is defined by diffusion effects (*dye diffusion thermal transfer*, *D2T2*). Depending on the thermal energy supplied

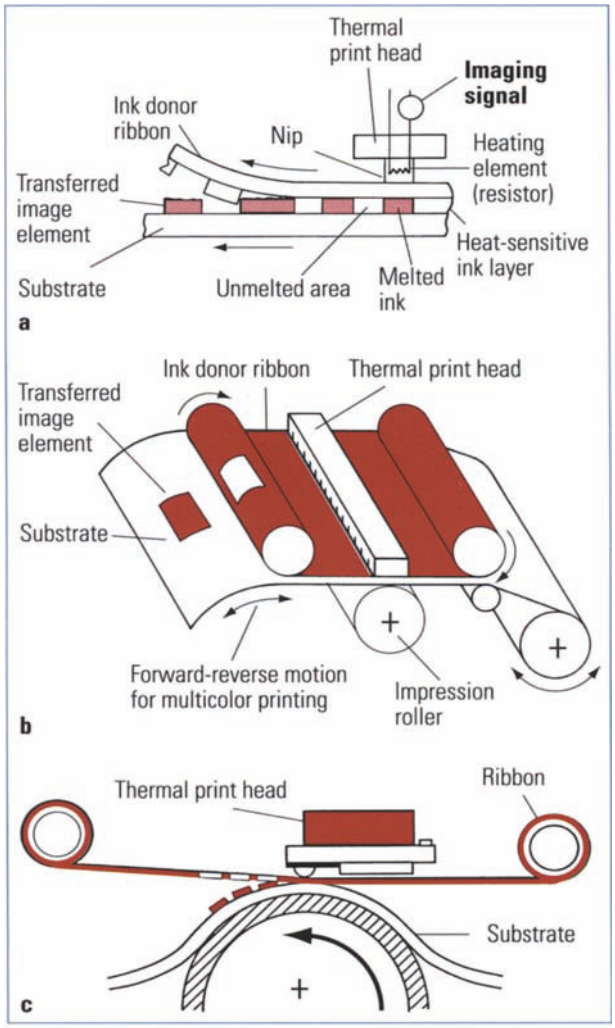


Fig. 5.6-4 Thermal transfer.
a Principle of ink transfer in thermal transfer printing;
b Thermal transfer for printing with page-wide imaging unit;
c Example of transfer system design configuration [5.6-1]

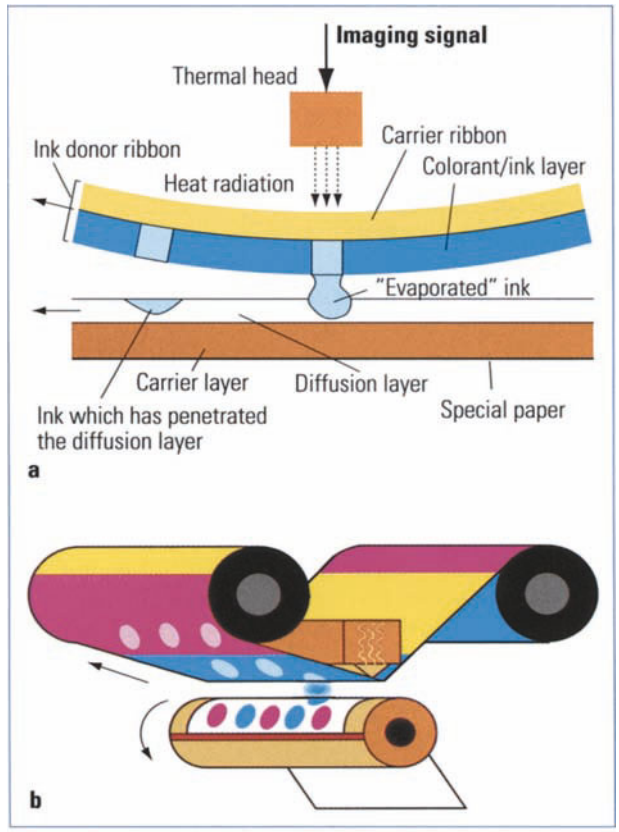


Fig. 5.6-5
Thermal sublimation (or D2T2: dye diffusion thermal transfer).
a Principle of dot formation (Note: The thermal system can be in direct contact with the ink donor, e.g., with thermal print heads or without contact by using thermal laser light sources);
b Principle of multicolor printing with cyan, magenta, and yellow (Tektronix)

to the pixel/dot, a different amount of ink (pigment/dyes in the ink layer) is transferred to the substrate. The printing material must be treated with a *special coating*, as already illustrated in figure 5.6-2, into which the ink penetrates by means of diffusion. With this method several gray values can be produced per dot depending on the quantity of ink diffused. The process is controlled by the temperature and/or the duration of the heating signal. In contrast to thermal transfer with variable pixel size as explained above, here the diameter of the dot remains roughly the same although the color density changes.

Ink Donor Transfer and Configuration. As illustrated in figures 5.6-4b and 5.6-5, a complete section of the donor material is used for each color in the format, which is designed specifically for the equipment. After the ink has been transferred, the remaining surface of the donor sheet can no longer be used for printing, which means a relatively poor utilization of donor sheets is achieved.

The *ink donors* (fig. 5.6-2), in the form of sheet or web material, typically have a thickness of around 10 µm;

the ink layer itself has a thickness of around 3 µm. In addition to this there is a protective layer of around 2 µm. The protective layer has the task of ensuring good heat transfer from the imaging system and simultaneously facilitating secure handling of the thin material. Further information on the structure of the material is given in figure 5.6-2.

As explained above, the *web material* is configured in such a way that the individual colors are arranged behind one another on a web. As shown in figure 5.6-3 the colors are transferred onto the printing substrate successively in a printing unit. Thermal transfer for multicolor printing is also done with only the three colors cyan, magenta, and yellow; black is produced subsequently by overprinting.

The ink donors are also available in the form of *sheet material* and are fed into the printing process using a special device (figs. 5.6-9 and 5.6-10).

The substrate must be fed into the printing unit several times (multipass system). As detailed later, there are also multicolor printing options that use the unit design principle in order to raise productivity (fig. 5.6-7).

Comparison of Thermography Processes. In figure 5.6-6 *sections of printed images* produced by *thermal transfer* and *thermal sublimation* are compared. It becomes apparent that in thermal transfer only two gray values can be produced while in thermal sublimation (fig. 5.6-6b) various gray values are possible per dot of the same size. (The possibility of transferring various dot sizes in thermal transfer is not shown; see fig. 5.6-9b.)

A survey of the current state of thermography is given by way of example in [5.6-1] and [5.6-2].

5.6.2 Thermal Transfer Printing Systems

The following contains some observations on the technical equipment based on the illustrations of the principle of thermal transfer given in figures 5.6-1 and 5.6-4.

In thermal transfer the printing takes place in a simple manner by transferring all the ink from the donor to the substrate. The ink donor is in contact with the thermal print head and the substrate.

For multicolor printing within a *multipass system* the colors are located behind one another on the ink donor (fig. 5.6-3). For a four-color printed image, four ink transfer processes are needed. To raise productivity,

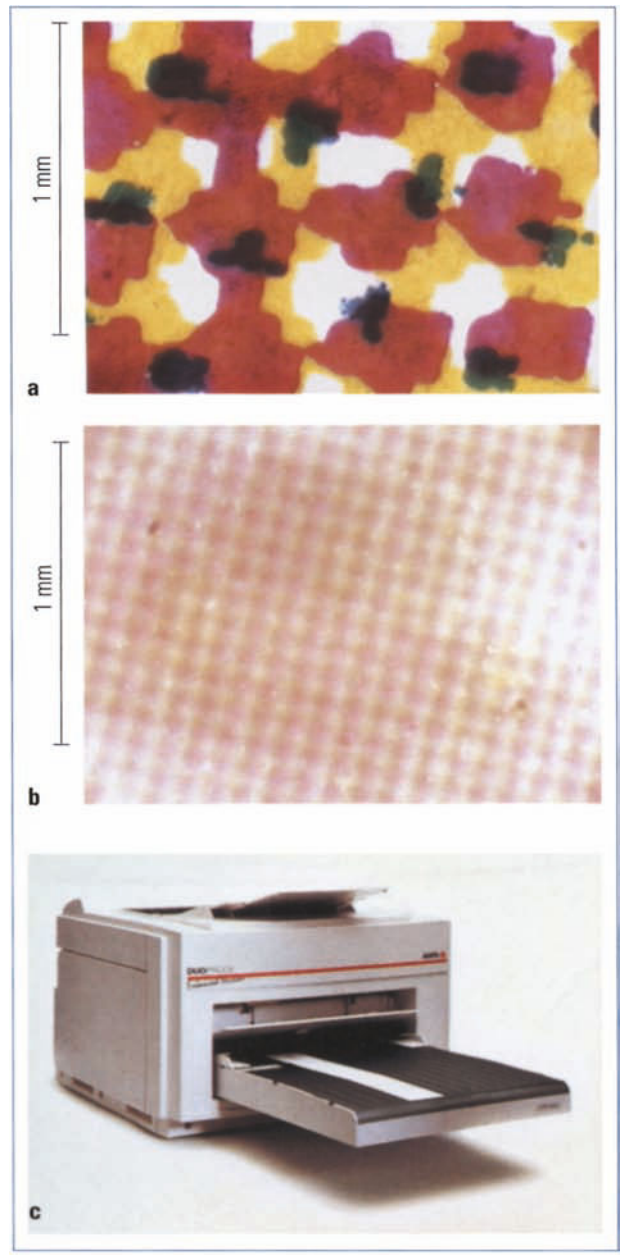


Fig 5.6-6 Printed dots produced by thermography.
a Image section for multicolor printing with thermal transfer (produced at 300 dpi and screen ruling of 24 lines per cm/approx. 60 lpi);
b Image section for magenta in multicolor printing using thermal sublimation (D2T2); resolution 300 dpi (screen ruling 120 lines per cm/approx. 300 lpi);
c Multifunction proofing machine (thermal transfer or thermal sublimation (D2T2) mode); 300 dpi, format A3+ (DuoProof, AGFA)

equipment designed in *unit design* is also available, as shown in figure 5.6-7.

In the digital printing systems illustrated in figure 5.6-7 four separate thermal transfer printing units (*singlepass system, unit design*) transfer each color separation onto the substrate (sheet material). The quality of the multicolor image is determined by the quality of the inks, the register precision of the overprinting, and the resolution. Page-wide imaging systems (around 320 mm) are available with resolutions of up to 600 dpi. The system shown in figure 5.6-7 is equipped for printing with 300 dpi and a printing speed of 20 A4 pages per minute. In figure 5.6-7b an early version of the printing system is shown to clarify the principle.

In figure 5.6-8 another thermal transfer printing system is shown. It is designed for printing larger formats. The printing is carried out using four printing stations with a resolution of 400 dpi on *web material* with an image width of up to 900 mm.

Figure 5.6-9 shows a digital *proofing system* for the A3+ format that produces a four-color image by thermal transfer (fig. 5.6-9c) with a variable pixel/dot size (fig. 5.6-9b). The color separations are successively



Fig. 5.6-8
Thermal transfer printing system for large-format multicolor printing; unit design, resolution 400 dpi, printing speed 1 m/min, image width 900mm (MSP 36, Matan)

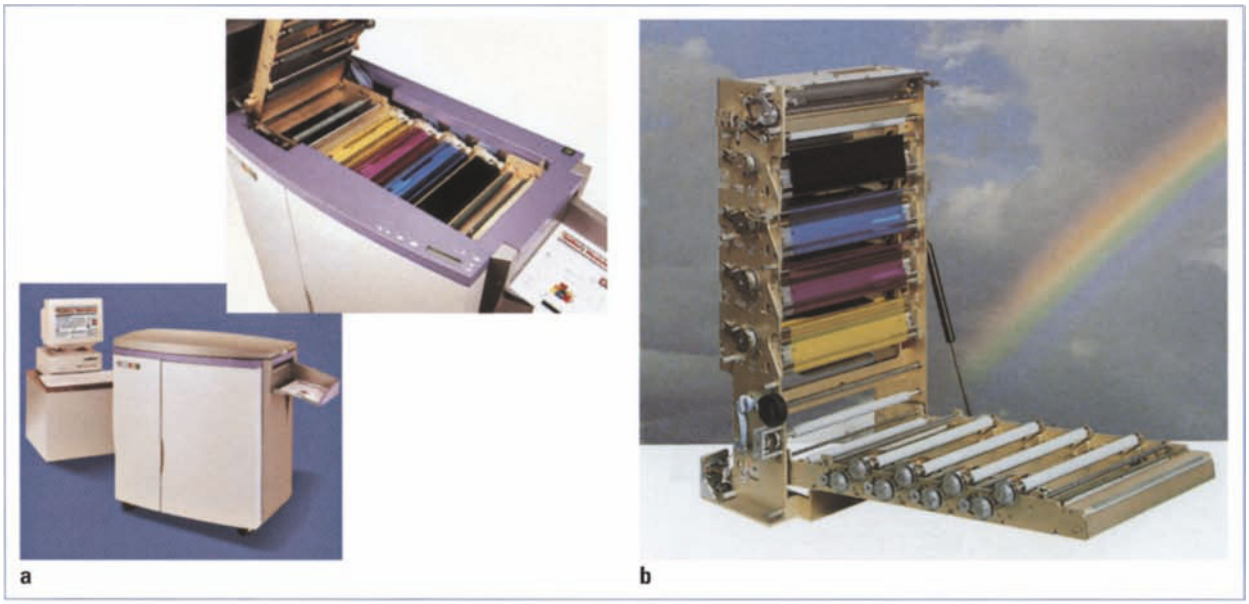


Fig. 5.6-7
Digital multicolor printing system in unit design based on the NIP technology of thermal transfer; resolution 300 dpi, printing speed 20 A4 pages per minute, A3 format.
a Model CYMax 3240 (A.B. Dick/Datametrics);
b Model LAURA (Datametrics)

transferred from a *color ribbon* onto an *intermediate carrier* at a resolution of 300 dpi. In a subsequent process the image is then transferred from the intermediate carrier to the paper through the application of pressure and heat. The system shown in figure 5.6-9 has a resolution of 300 dpi. Dots of varying size can be produced by special screening, which is carried out in steps in the paper transport direction that are smaller than the pixel distance related to the resolution (called VR, *variable resolution screening* by Fuji, fig. 5.6-9b). A higher quality of image reproduction is possible than with a two-dimensional resolution of 300 dpi. The technical implementation is also based on special donor material [5.6-3]. The quantity of ink transferred is fixed by controlling the duration of the heat impulses, in particular in conjunction with a thin ink layer of only 0.3 µm (thin-layer thermal transfer material, 3T, fig. 5.6-9c). This device is an example of the *thermal transfer* variant shown in figure 5.6-1 *with variable dot/pixel size.*

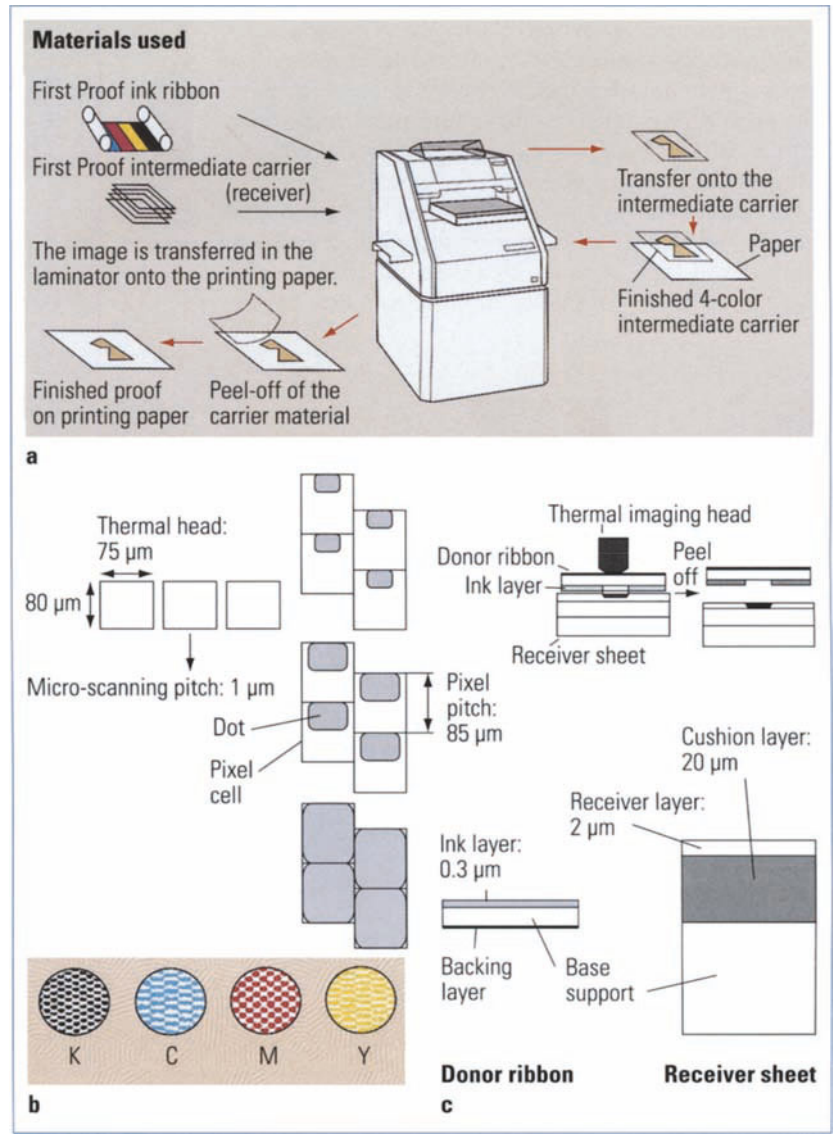


Fig. 5.6-12
Digital multicolor proofing system based on the NIP technology of thermal transfer with variable dot size; resolution 300 dpi, A3+ format.
a Process steps for producing proofs;
b Example of variable dot size;
c Structure layers of donor ribbon and intermediate carrier (receiver sheet), (First Proof, Fuji Film [5.6-3])

Figure 5.6-10 shows a system for *digital proofing* with the highest resolution. This system, as already shown in figure 3.2-76, images with a multibeam *thermal laser system* (around 830 nm, 220 beams) using thermal transfer *color sheets* on an intermediate carrier (fig. 5.6-10a).

This *intermediate carrier* (transfer base material) is fixed onto a drum in the form of a sheet. The system can transfer the individual color separations onto the intermediate carrier with a resolution of up to 3200 dpi. The process is based on thermal transfer, where the dots are transferred in a binary fashion. The halftone dot is built up from several individual pixels (similar to the illustration in fig. 5.6-6a, only with much higher resolution). In the system shown in figure 5.6-10 the heat is supplied without contact by laser light (thermal, about 830 nm). With this high resolution the screen structure of multicolor printing can be reproduced, as it is in the offset process for producing the print job with high run length. (The system shown in fig. 5.6-10c is a *multi-function system* and can also be used for imaging printing plates with the same data file.) To transfer the individual color separations to the image carrier, the operator inserts the corresponding donor sheets into the system one by one. The donor sheets are fixed to the drum by a separate vacuum system. The color image on the intermediate carrier is transferred onto paper in a separate machine (laminator) by the application of pressure and heat.

In the system shown in figure 5.6-10 the image is first transferred to an intermediate carrier and then onto paper. This substrate is specially conditioned to ensure

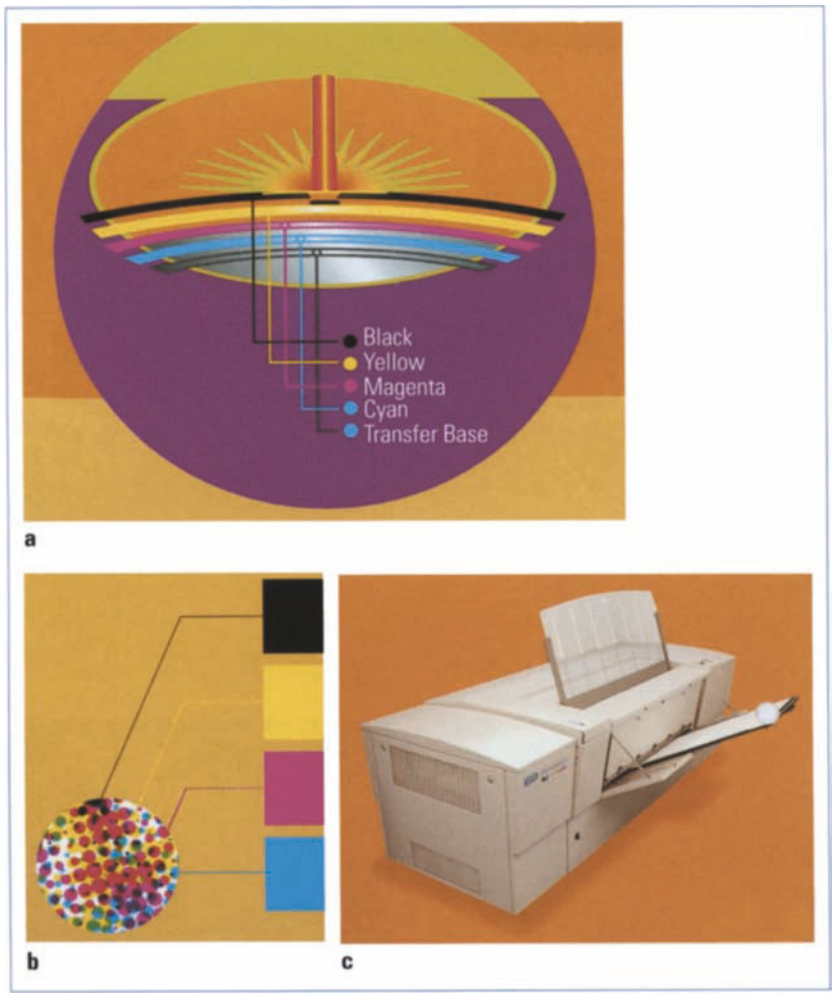


Fig. 5.6-10
Digital thermal transfer proofing system for multicolor halftone proofing; resolution up to 3200 dpi, format: A1+ (8 A4 pages), 20 minutes per A1 four-color print.
a Layer transfer by thermal transfer;
b Halftone structure with four color separations;
c Proofing system (TrendSetter Spectrum: multifunctional system for platemaking and proofing, Heidelberg/Creo/Imation)

stability and quality. It is not possible to directly use the conventional production paper as it is used in a wide range in offset printing. There are ink donor structures that do allow *transfer onto this paper* (as for example in the PolaProof process by Polaroid, see fig. 3.2-77). However, a special laminate is later imposed onto the printed image to stabilize the transferred ink.

Foils (colorless) with various surface structures are available to create or imitate different *gloss effects*.

5.6.3 Thermal Sublimation Printing Systems

The principle of thermal sublimation was given in figure 5.6-5.

In thermal sublimation a large number of different *gray values* can be produced through controlled diffusion per dot of the inking materials (see also fig. 5.6-6b). As in thermal transfer the imaging can be carried out using arrays of individually controllable heat elements, but also through heat transfer with thermal laser light sources.

Since both *thermal transfer* and *thermal sublimation* are based on ink transfer using thermal energy, the *systems* can, in principle, be used *multifunctionally* for both processes when using suitable inks. In the equipment example in figure 5.6-6 it is possible to work with a system following either the thermal transfer or the thermal sublimation process. Various donor materials are combined with the same imaging system (thermal print head) depending on the process. Ink donors coated with wax are used for thermal transfer. In thermal sublimation high quality, multi-layer treated ink donors are employed, enabling production of different gray values with the same dot size in the diffusion process.

Figure 5.6-11 shows one of the first large-format *thermal sublimation proofing systems*. In this highly automated system the color separations are transferred to an

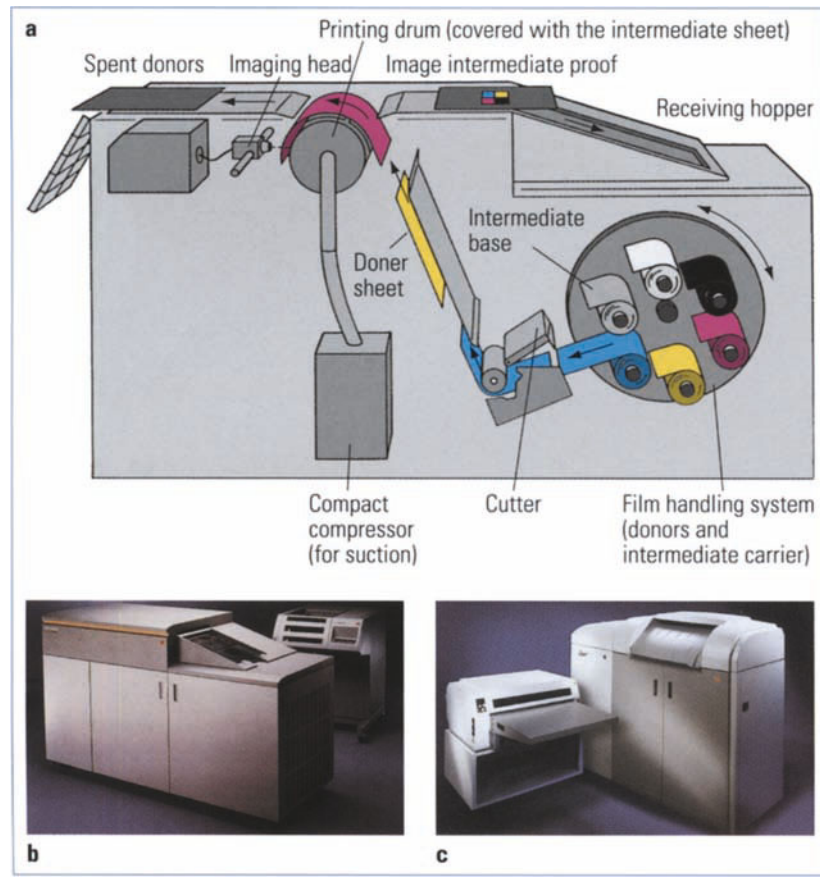


Fig. 5.6-11
Digital color proofing system based on thermal sublimation.
a Function principle of the Approval system; resolution 1800 dpi, A3+ format;
b Proofing system with laminator (Approval, Kodak);
c Proofing system for A2+ format; resolution 2400 dpi; color density for each color application can be set at 22 levels per color separation for various densities, 15 minutes per A2 Proof (Approval XP4, Kodak Polychrome Graphics)

intermediate carrier by thermal *laser exposure* via donor sheets cut from webs. The material for the intermediate carrier is also housed in the storage system for the donor reels of the process colors cyan, magenta, yellow, and black. One position is designated for a special color. The intermediate carrier sheet is fixed onto a drum by vacuum. The color separations are transferred onto the intermediate carrier one by one in precise register via the four donor sheets. These are held on the carrier drum by means of a separate suction system. The printed image is transferred from the intermediate carrier onto normal paper by a *laminator* (in fig. 5.6-11b, shown in the background next to the proofing system).

By controlling the energy supplied to the dots by laser, various quantities of ink can be diffused to produce dots of the same size with variable color density (optical density, chroma). To be able to use this system to produce *proofs for the offset process*, an imaging mode is of advantage that creates pixels with identical color densities (basically the same principle as with conventional offset printing processes) and the halftone dots made up of several pixels of the same density. The system can be operated as a "thermal transfer equipment" for this purpose. The system shown in figure 5.6-11a has a resolution of 1800 dpi, with which a good replication of the dot structure is possible.

Further developments have taken place on the principle of the system shown in figure 5.6-11. Systems with an addressability/resolution of 4000 dpi are available for the A2+ format. With the system shown in figure 5.6-11c a four-color proof in A2 format with a resolution of 2400 dpi is produced in about 15 minutes.

In principle, the system can also be operated as a thermal transfer or as a thermal sublimation system with the advantage of thermal sublimation to generate several gray values per pixel to reproduce continuous-tone color images. The appropriate ink donor sheets, intermediate carriers, and receiver paper sheets have to be used. The laser imaging system must also be controlled at the appropriate energy levels (256 levels/8 bits is possible).

Figure 5.6-12 shows the *layer structure* of the donor sheet for thermal sublimation and the transfer to the *intermediate carrier* and later to the *production paper*

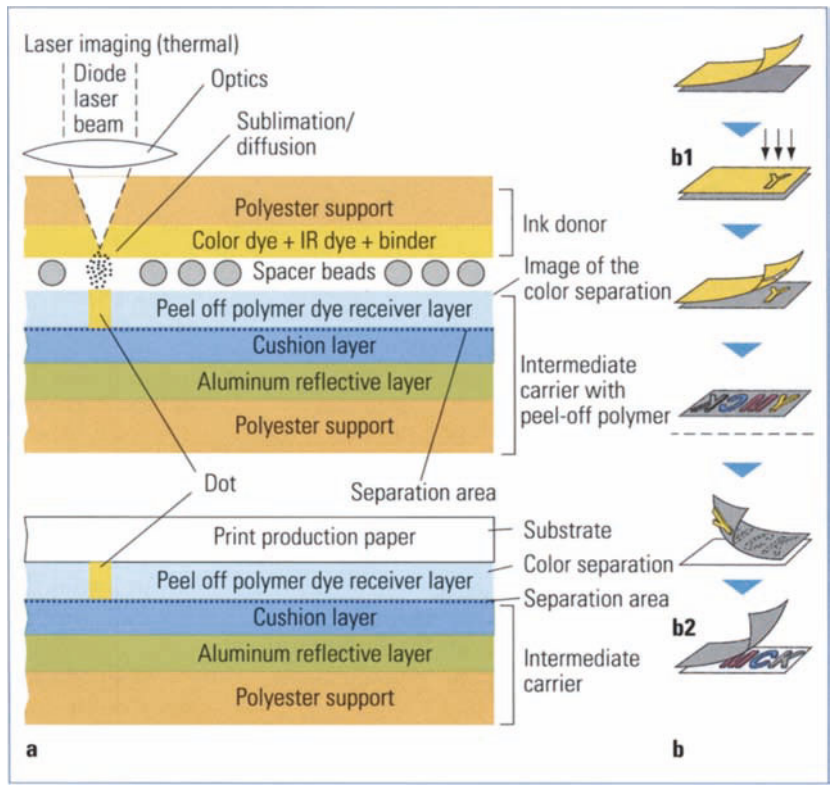


Fig. 5.6-12
Thermal sublimation with intermediate carrier.
a Layer structure of ink donors, intermediate carrier, transfer process onto production paper;
b Process steps for indirect thermal sublimation (printing via intermediate carrier onto substrate);
b1: onto intermediate carrier,
b2: laminating onto production paper
(Approval, Kodak [5.6-4])

[5.6-4]. In figure 5.6-12 small spacer beads are shown between the ink donor layer and the surface of the carrier (< 1 µm). A sublimation process takes place in this gap between the two layers and the ink subsequently diffuses into the receiving layer of the intermediate carrier. In the later transfer process onto the paper the receiving layer (thickness of approximately 2 µm) is also transferred onto the paper.

Small-format Applications. There are various types of high-performance *small-format thermal sublimation printers* available (A4 and A3 format). Even with relatively low resolution of 300 dpi a very good color reproduction can be achieved due to the ability to produce several gray values (in general with 8 bits, that means 256 specified gray values, which applies to electronic drives and potentially results in a fine gradation in the printed image). This corresponds in many cases to *photographic quality* (continuous tone).

A *thermography printer* is shown in figure 5.6-13. With a resolution of 300 dpi an A3 proof is produced in three minutes using three colors (donor sheets are also available for four colors, including black). This system is available as a thermal transfer printer or as a thermal sublimation printer.

In figure 5.6-14 a further example is shown. This proofing system was also shown in figure 3.2-71 in conjunction with a computer to press/direct imaging printing system.

Thermal sublimation printers are used particularly often with *digital photography*. High-performance equipment is available for small formats of, for example, approximately 10 cm × 15 cm. The equipment can produce high quality reproductions of images (corresponding to the so-called "photo quality"); a resolution of up to 600 dpi and for example 100 gray values per pixel can meet the highest photographic standards with thermal sublimation.

Thermal transfer and in particular thermal sublimation methods are already used for printing on *plastic cards,* such as credit cards, membership cards, and similar small-format documents with high quality image reproduction. The example in figure 5.6-15 shows clearly how membership cards are produced with ink donors on web material and a thermal imaging head. Resolutions of 300 dpi and more than one hundred gray values per pixel are standard.

Multifunctional Equipment. As mentioned above it is, in principle, possible to construct equipment that is suitable for both thermal sublimation (dye diffusion thermal transfer) and thermal transfer, using the appropriate ink donor material. Various quantities of ink can be transferred in variable dot size.

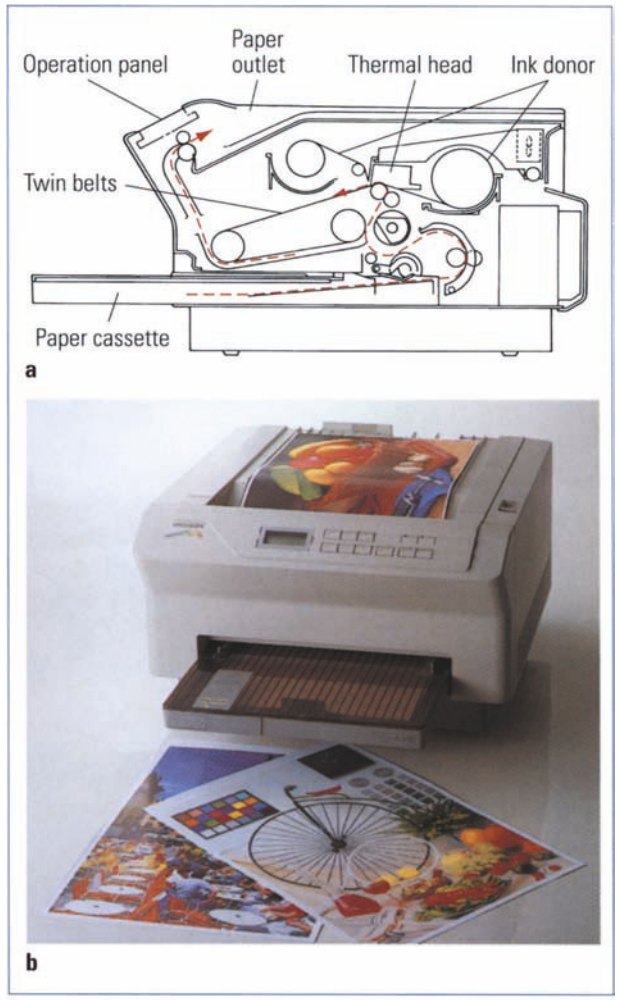


Fig. 5.6-13 Multicolor thermography printing systems.
a Equipment diagram for thermal transfer printing system (Mitsubishi Electronic); resolution 300 dpi, (256 addressable gray values), Format A3+, 3 minutes per A3 print;
b Thermal sublimation printer; 300 dpi, 256 addressable gray values (S6600-30, Mitsubishi Electric)

Comparison with Other NIP-Systems. Admittedly, the price of the donor material required for thermal sublimation and thermal transfer is a disadvantage compared to toners used in electrophotographic non-im-



Fig. 5.6-14
Digital proofing system based on thermal sublimation (D2T2 process); resolution 300 dpi, 256 gray values, A3+ format, approx. 5 minutes per A3 proof (DCP 9500 Proofer, Kodak Polychrome Graphics)

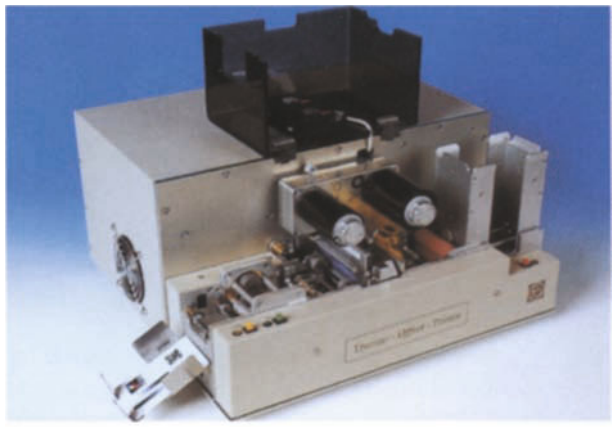


Fig. 5.6-15
Digital thermal sublimation printer for plastic cards (300 dpi, approx. two cards per minute) for printing with four colors and additional coating film; can also be adjusted for operation as thermal transfer printer (TOP, F&O Electronic Systems)

pact systems and to ink used in ink jet systems. However, the higher cost of ink is to some extent compensated by the fact that certain components, such as a developing unit for supplying toner in electrophotography, is no longer required and that the thermal printing heads are of a simpler design than is the case with ink jet systems. Printing systems based on thermal transfer have a relatively simple structure.

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5.7 Electrography

Unlike electrophotography, non-impact printing processes based on electrography use an electric field to transfer the image information onto the substrate [5.7-1, 5.7-2].

If the paper has a dielectric coating (as shown fig. 5.7-1a) it is possible to write the latent *charge image directly onto the paper*. A simple three-stage printing process of imaging, inking, and fixing becomes possible. Due to the *air gap* between paper and writing electrode high field intensities are required.

For an efficient, precise charge formation while imaging, the *writing electrode (stylus) may be in contact* with the coated paper surface (fig. 5.7-1b). Imaging head and paper surface must be resistant to wear and exhibit good sliding properties.

To transmit the charge over the entire width of the page, the imaging system is configured as an *electrode array*; resolutions of 400 dpi are possible by arranging the electrode pins in several rows.

Figure 5.7-2 shows how imaging and inking take place one after the other. The imaging electrode is brought into contact with the paper under light pressure. After imaging, the paper web comes into contact with the *liquid toner*, which is kept at a constant color concentration in a closed circuit. Paper surface and liquid toner act together in such a way that the toner is only attracted to the charged areas of the paper surface.

In a subsequent process, similar to other NIP technologies with liquid toner (e.g., with electrophotography or ionography) the toner image must be fixed on the paper in a fusing unit.

As per figure 5.7-1c, non-contact imaging could also take place via a *conductive contact fluid* [5.7-1].

In the case of *electrophotography* (see sec. 5.2) an electric charge image is generated on the image carrier (e.g., photoconductor drum) via photons. The toner is routed to the charge carrier via the electric field between the developing unit and the imaging surface; after that the toner is transferred onto the substrate. In

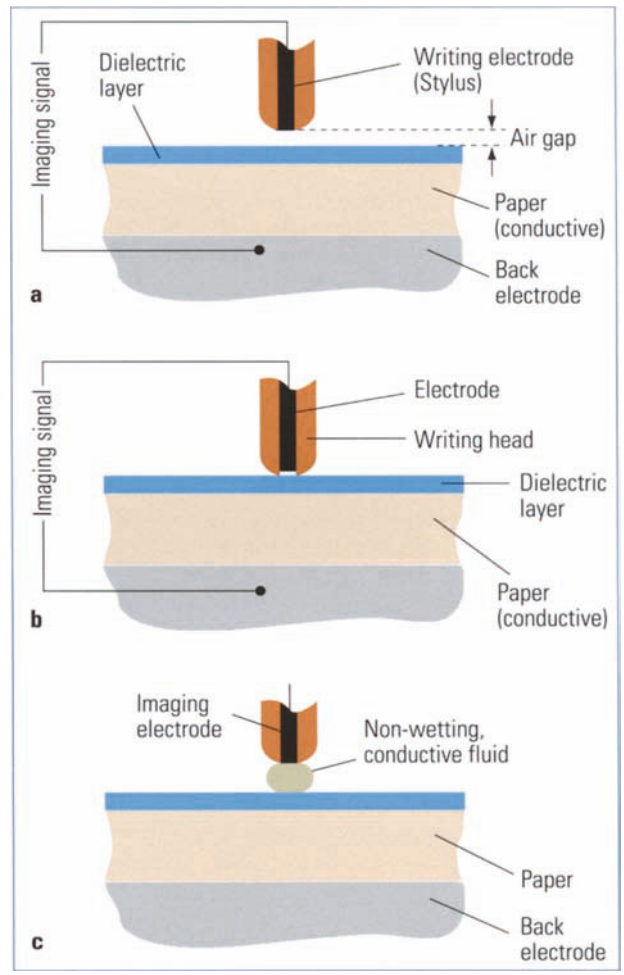


Fig. 5.7-1 Creating a latent image in electrography.
a Writing electrode (stylus) is not in contact with the substrate;
b Writing head is in contact with the substrate;
c Writing electrode is in contact with the dielectric layer of the substrate via a conductive fluid

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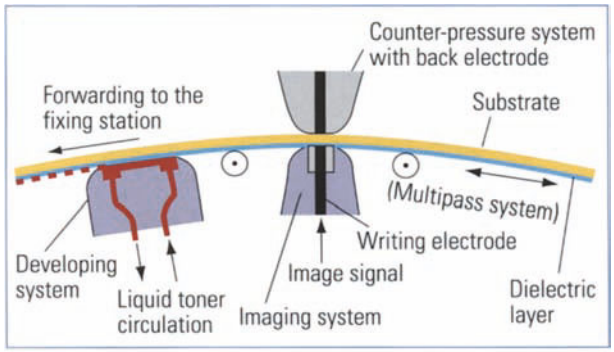


Fig. 5.7-2 Imaging and inking process in electrography

the case of *ionography* (see sec. 5.3) a charge pattern is generated on the dielectric surface via an ion source and developing, inking with toners takes place as in electrophotography. In both processes the charge image is generated on an intermediate carrier for printing on substrates that have no coatings with special dielectric properties. The intermediate carrier is then inked via electrostatic forces and the ink is transferred onto the substrate, in other words in an *indirect electrostatic process* via a latent charge image. If the charge image in the electric field is generated directly between ink and substrate and the ink transfer takes place without an intermediate carrier, this technology is referred to as a *direct electrostatic printing technology* [5.7-3].

A definite categorization of the term *electrography* is not possible. If electrography were a process in which the image would be generated as a charge pattern by electric fields and transfer of charge (and not by photons), then ionography would have to be included, especially in accordance with the diagram shown in figure 5.3-8. With the ionographic system in figure 5.3-8 electrically charged particles are generated via an ion source and a charge image is transferred onto dielectrically-coated paper to be subsequently inked up with liquid toners.

According to figure 5.7-3 and previous considerations, electrography is seen to some extent as an, independent NIP technology in which the charge image is transferred via electrodes directly onto specially coated paper, where inking-up via electrostatic forces takes place between paper surface and toner. (In the case of photography the image is generated via incident light radiation on specially coated photographic papers; see sec. 5.8.) The inking process (development) with liquid toners following the electrographic imaging process has proven to be useful for the technical realization of electrography in digital printing equipment.

Electrographic printing systems based on direct electrostatic imaging were first used for *large-format single-color printing*, such as for drawings (text and graphics) in connection with systems for computer-aided-design (CAD). Specially coated paper in combination with liquid toners was used here.

The development of liquid toners for multicolor printing was also beneficial for the enhancement of electrographic printing systems.

Figure 5.7-4 shows a *multicolor printing system* for printing a four-color image at a resolution of 400 dpi

Fig. 5.7-3
Electrography together with other non-impact printing technologies

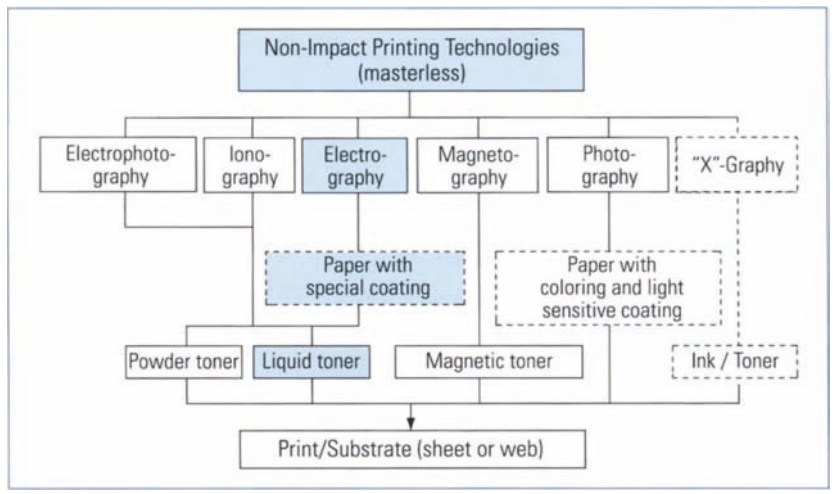




Fig. 5.7-4
Electrographic printing system for large-format multicolor prints (electrostatic plotter); resolution up to 400 dpi, up to six colors (liquid toner), printing speed about 0.08 m/s, multipass system, width of printed image about 1330 mm (Xerox 8954, Xerox Engineering Systems; previously Versatec)

and up to a printed image width of about 1330 mm. As many as six colors can be printed with liquid toners. The system consists of only one imaging unit; the multicolor print is created by means of repeated imaging and inking processes (multipass system). The imaging and inking process is similar to the process shown in figure 5.7-2. Keeping accurate register is of special importance when creating multicolor prints with multipass systems. Special control marks are printed on the sheet for register adjustment and control purposes.

The system depicted in figure 5.7-5 is based on a similar principle. Imaging can be performed with resolutions of up to 400 dpi, the printing speed is about 0.2 m/s. Printing can take place using the process colors cyan, magenta, yellow, and black and an extra color such as a metallic effect color, or a coating can be applied to the printed image. Generally the inks are pigment-based, which means that high qualities can be attained.

The electrographic process, that is, applying the charge image (electrostatic/latent image) to a dielectric layer of the substrate, can occur at relatively high speeds (about 1 m/s); a resolution of 600 dpi and higher is possible when the electrodes are suitably arranged.



Fig. 5.7-5
Digital multicolor printing system with electrostatic imaging technology (electrography); resolution up to 400 dpi, process colors C, M, Y, K (liquid toner), additional spot colors or coating, printing speed up to about 0.2 m/s (for each color separation, multipass system), width of the printed image up to about 1330 mm (Digital ColorStation 5442, Raster Graphics)

In electrography there are also concepts whereby the latent image is *first transferred as an intermediate image* to a hard, wear resistant dielectric layer on a drum via contacting imaging electrodes and then onto the paper, which is then inked with liquid toner. The advantage here is that electrical fields can be built up efficiently at relatively low voltages and the charge image can be transferred even with rough paper surfaces.

To *sum up* it should be emphasized that *electrography* is used with dielectrically *coated papers*; *liquid toners* have proven their worth here. The constraint on this technology lies in the coating of the paper. Imaging speeds are relatively high, the process itself is uncomplicated, which results in simple system designs. On the other hand, the use of liquid toners places special challenges on the system design. The applications are limited, electrography is used as shown in the examples for printing large-format single-color and multicolor prints.

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5.8 Photography

Electrography was explained in section 5.7; this is the process in which the image is produced on special coated material. A latent charge image is applied to the dielectric layer of the substrate. The visible image is then produced from this in a subsequent inking and fixing process. The multicolor print is produced by means of repeated imaging and inking.

Special coated paper is used in *conventional color photography*. A color change dependent on the wavelength of the light takes place in several layers and results in a *continuous-tone picture (photograph)*, in which the color transitions appear smoothly and the finest structures can be reproduced. It is only the chemical-physical composition of the layers [5.8-1] that determines the resolution for photographic papers and analog imaging. Continuous color tones are produced dependent on the light intensity and wavelength. The chemical components that give image and shape have dimensions in the micrometer range (0.1–2.0 μm) and below.

Photography (NIP). The non-impact printing technology of photography is the conversion of analog photography into the digital generation of the image. For this, *photographic papers* are used that are imaged via digitally addressed *laser systems*.

Specially coated paper is used for photography as in electrography; this is depicted in figure 5.7-3 in the previous section.

Image setup takes place by imaging with three wavelengths for the *colors red, green, and blue*. The required hue in the image is produced through the intensity control of the individual laser light sources. Gas lasers or semiconductor lasers can be used as light sources. Sophisticated systems work with *gas lasers* in the following configuration: for red a helium neon-laser (633 nm), for green a helium neon-laser (543 nm), and for blue an argon ion-laser (458 nm).

Figure 5.8-1 shows a *proofing system*, with which large-format color pictures can be produced. The resolution for this system is up to 4000 dpi. An external drum system provides the imaging using an imaging system with axial movement. The imaging process is followed by a development process that is compatible with the photographic paper used (fig. 5.8-1b). Due to the high imaging resolution it is possible to reproduce the *screen structures* of the color separations for offset printing. Photographic papers might have *surface structures* which can differ from the paper quality specifications in print production. In particular, adaptation of paper white has led to enhancements in photographic paper for use in proof printing.

In the case of large-format digital imaging systems for photography (photofinishing), the *structures* correspond to those of computer to film or computer to plate applications. For example, there are also internal drum systems (see fig. 3.2-85) and those that work on the capstan principle (see fig. 3.2-86); the latter enable the exposure of webs using roll material (up to 50 m in length).

LED-light sources are also used in digital imaging systems.

Figure 5.8-2 shows a *digital color printer* based on photography. This system can be seen as a *hybrid non-impact printing system*, in which the procedures of *thermography* and *photography* are combined. As shown in figure 5.8-2a, the exposure of light sensitive ink donor paper (fig. 5.8-2b) takes place via *three laser diodes*; this sets up the image information on the *ink donor* with the light sensitive layers for the colors blue, green, and red. The latent image is developed by means of *applying heat* at the same time as *transferring* the image *to the substrate* (special paper). A very high photographic image quality is achieved with this process. The number of gray values per pixel is given as 256. Fine structures are reproduced at a resolution of 400 dpi and a large gamut is achieved for color reproduction. It must be emphasized that in comparison with the system in figure 5.8-1, laser diodes are used rather than gas lasers. More recent

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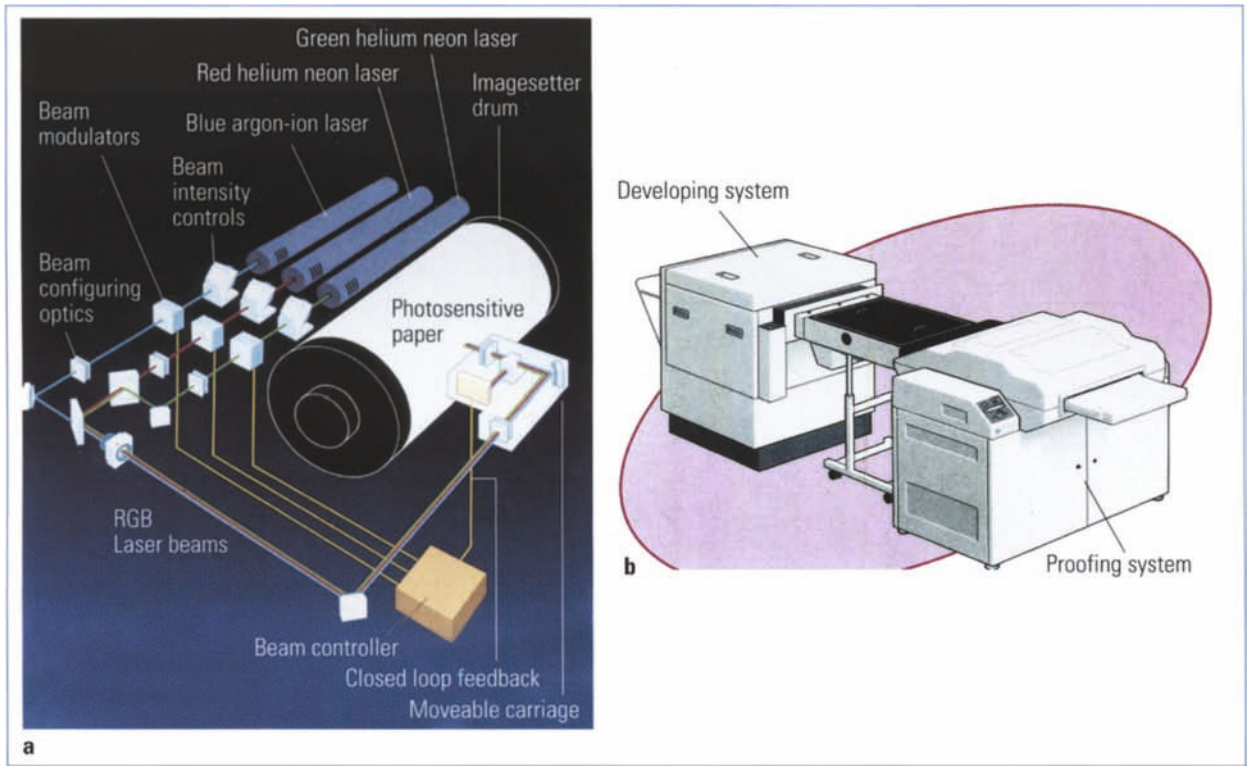
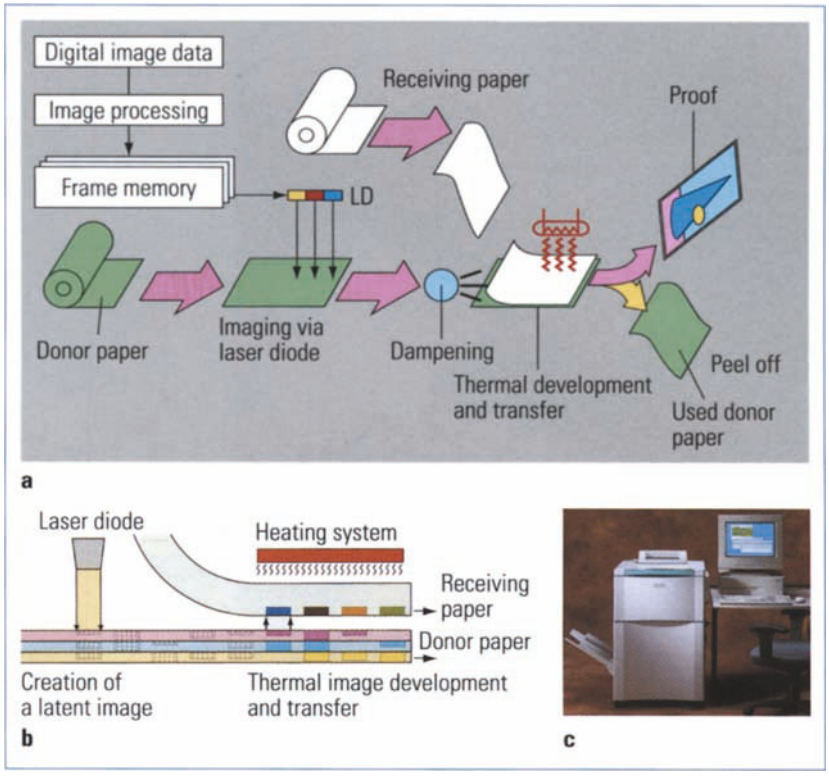


Fig. 5.8-1 Digital proofing system based on photography, using coated photographic papers (e.g., from Konica).
a Imaging via laser systems making use of the external drum principle; resolution 2000 or 4000 dpi (adjustable), A2+ format;
b Proofing system with developer (IntelliProof/Colorsetter 4400, Optronics/Intergraph; status: 1995)

technology means that today blue laser diodes are also available with the required specification.

Digital Photography. It may be expected that there will be developments in digital printers based on *digital photography* to produce small-sized prints on photographic papers (photofinishing). These printers will also be interesting for the private sector and will be competing with systems based on ink jet technology and thermal sublimation.

Fig. 5.8-2
Digital proofing system based on photography and thermography (hybrid technology).
a Process steps for image generation and transfer;
b Ink donor structure;
c Examples of installations: Pictroproof (resolution 400 dpi, 256 intensity levels for producing gray values, A3+ format, productivity: 1 A3 proof in 90 seconds) (Pictrography 3000/Pictroproof, Fuji Film)



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Further Reading for 5.8

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5.9 "X"-Graphy

As shown in figure 5.9-1, new types of non-impact printing technologies that cannot be attributed to known technologies are classified under *"X"-Graphy* NIP technology (see also [5.9-20]).

It was possible to attribute the non-impact printing technologies dealt with so far to certain physical effects. In the case of the non-impact technology of *electrography*, however, it has already been demonstrated that making a clear classification is difficult. If electrography is understood as imaging where a latent charged image is built up without photons (therefore not with electrophotography), ionography (using ions for imaging) would al-

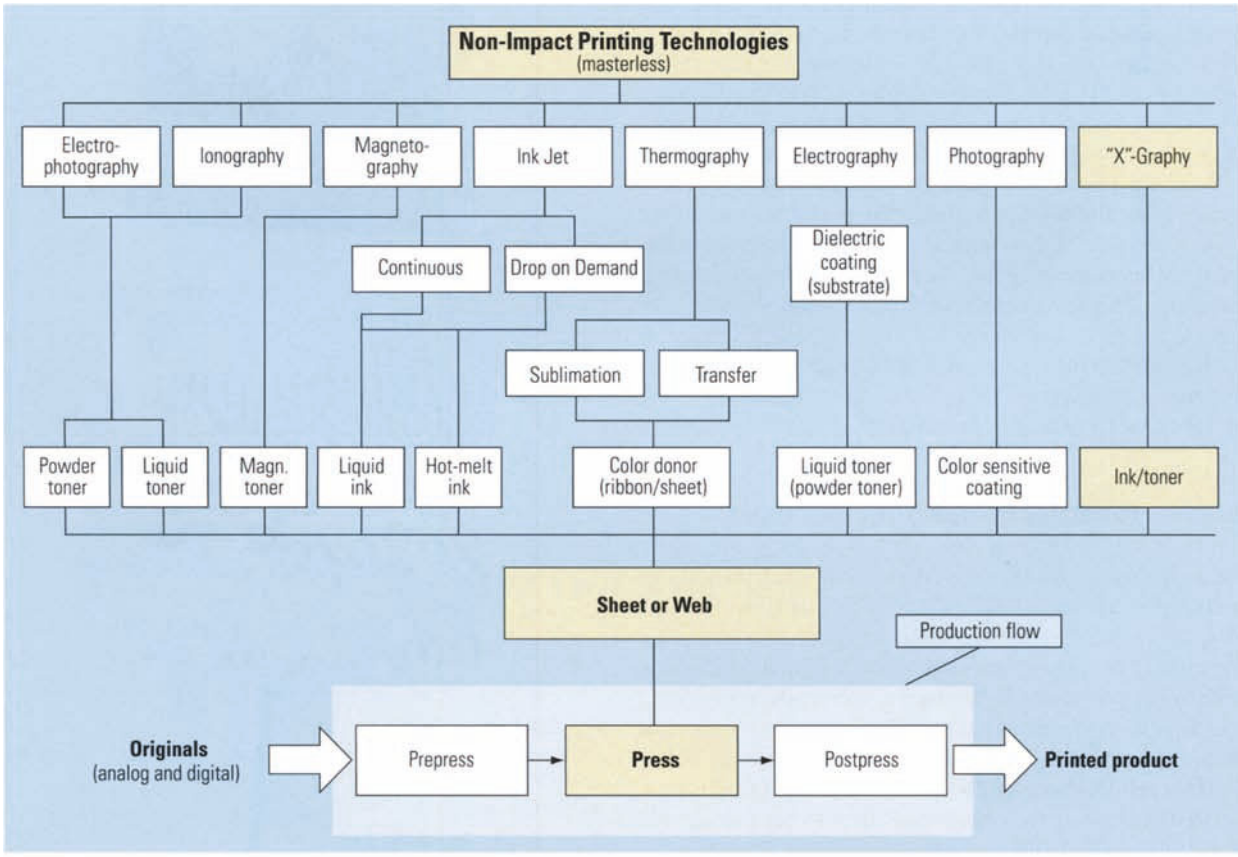


Fig. 5.9-1
"X"-Graphy as a new kind of technology for setting up non-impact printing systems shown together with well-known NIP technologies

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so have to be classified as an electrographic technology. As shown in figure 5.7-3, however, electrography is concentrated on technologies in which the imaging to build up a latent charged image is done on special paper (substrates to which a dielectric coating has been applied). It was mentioned in section 5.7 that a process category can be defined for NIP technologies in which an electric field is generated for the direct transfer of ink onto paper without the need for a special coating of the paper involved [5.9-1], although this category does not as yet include any technology that is in actual industrial use.

The technology of "*Pictrography*" (Fuji Film) was dealt with in section 5.8 (Photography), figure 5.8-2. It can be considered a combination process involving photography and thermal transfer and cannot thus be definitely assigned to one or the other NIP technology.

Patent literature, publications, presentations at conferences, and discussions in the relevant industry have illustrated that numerous approaches are being taken for new types of non-impact printing technologies, making use of special physical effects, material properties, and system designs. There are regular reports on non-impact printing technologies at NIP conferences [5.9-2] and on the topics of color hardcopy and graphic arts at IS&T/SPIE Conferences [5.9-3].

Selected new technologies, for which laboratory prototypes have already been presented in public and/or for which the date of their introduction onto the market has already been announced, are explained in the following sections. This involves the following technologies:

1. TonerJet Printing Technology (Array Printers);
2. Direct Imaging Printing Technology (Océ);
3. Elcography (Elcorsy Technology).

5.9.1 TonerJet Printing Technology

In 1993 [5.9-4] there were reports on a technology in which *powder toner* is transferred directly from the inking unit onto the paper via an *array of apertures* surrounded by *ring electrodes* as shown in figure 5.9-2. Here, a thin film of toner is fed to the electrode array (ring electrodes) via a magnetic roller, released by electric fields from the film of toner entrapped on the roller surface, and transferred to the paper. The apertures are switched from open to closed to allow toner passage via the control electrode voltage.

As with other toner-based NIP technologies, the toner image is fused onto the paper by heat transfer (usu-

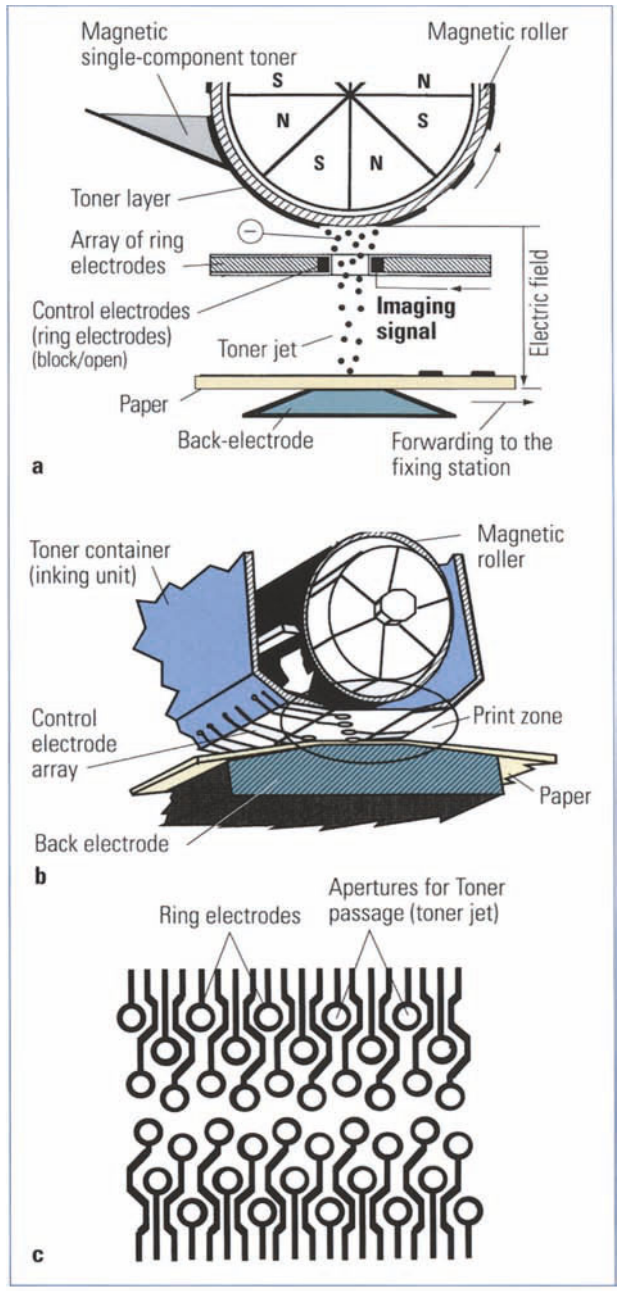


Fig. 5.9-2
TonerJet technology: toner transport in the electric field by means of controlled ring electrodes.
a Principle of the toner transfer;
b Printing unit design [5.9-4];
c Array of ring electrodes [5.9-5], (Array Printers)

ally under pressure) in a subsequent fusing process (see also fig. 5.1-5).

The name *TonerJet* was selected by analogy with ink jet because the toner is transferred to the substrate through nozzles affected by electric field forces. As with ink jet technologies, a relatively simple printing unit can be constructed for the TonerJet technology, with which the image is transferred directly to the paper *without any intermediate carrier.*

As illustrated in figure 5.9-3, digital *multicolor printers* can also be based on this printing technology.

The technology was originally designed for a resolution of 300 dpi [5.9-5]. The restriction is imposed by the need to be able to assemble *ring electrode arrays* of sufficient stability and with sufficient space to supply the lines for the control signals. The first solutions attempted were based on a multi-line configuration to achieve a resolution of 200 dpi.

As shown in figure 5.9-4 [5.9-6], by extending the process employing additional electrical deflection forces that act on the toner particles during passage through the ring electrodes, with a basic resolution of

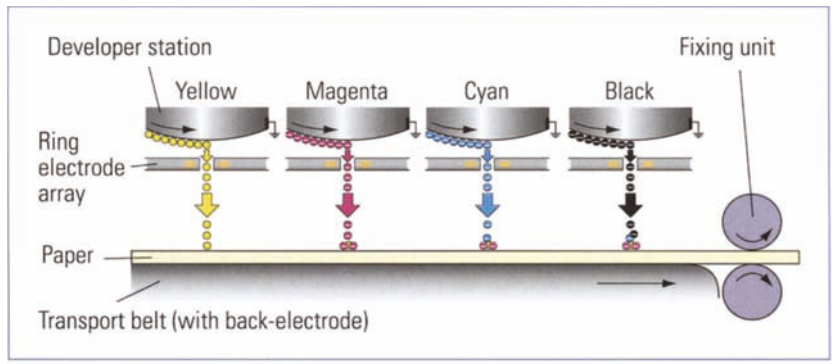


Fig. 5.9-3
Principle for setting up a multicolor printing system based in TonerJet technology (Array Printers)

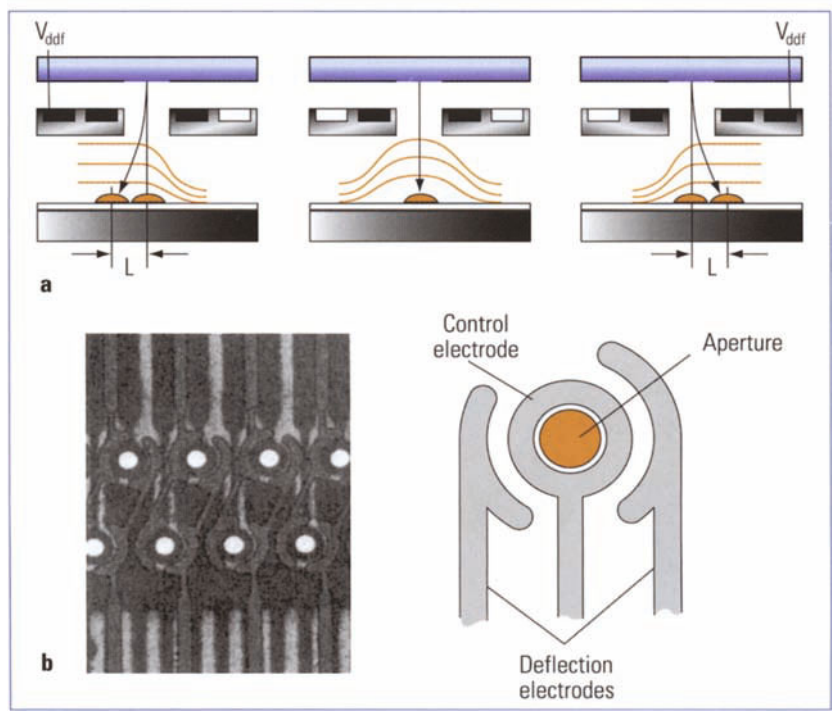


Fig. 5.9-4 Ring electrode array.
a For a resolution of 300 dpi (arrangement of ring electrodes corresponds to 100 dpi); **b** Ring electrode configuration with deflection fields (dot deflection control method) to triple the resolution within a ring electrode array (Array Printers, [5.9-6], [5.9-1])

100 dpi for the two-line array, an effective addressability of 300 dpi was achieved (*dot deflection control multiplexing method*, [5.9-6]). Extending the multi-line configurations in this way enables arrays for a resolution of 600 dpi to be designed.

The evenness of the toner feed to the array, keeping the apertures clear, preventing toner build-up, and the transfer onto the substrate all present challenges. Toners (with special coating) can, for example, also simultaneously act as *spacers* between electrode array and surface of the toner supply system to ensure even metering.

In more recent publications [5.9-7] there are reports on the special shaping given to the apertures in the ring electrodes, together with adapted signal control to optimize print quality with regard to evenness of toner transfer and to increasing edge definition. There are also designs where several gray levels per pixel can be achieved by varying the width of the signal pulse for the electrical control of the ring electrodes.

Figure 5.9-5 shows a *design study* for the assembly of a modular *multicolor printing system*. The system design should enable printing speeds of 10 to 20 A4 pages a minute to be achieved at relatively low costs (resolution up to 600 dpi, eight gray values per pixel). Unlike the original designs (fig. 5.9-2) non-magnetic single-component toners are used, especially for multicolor printing.



Fig. 5.9-5
Design concept for a multicolor printing system based on TonerJet technology (Array Printers)

As explained before TonerJet technology is therefore based on electrostatic forces between toner feed and paper [5.9-1]. The application of toner in accordance with the image is triggered by voltage pulses to the ring electrodes. The toner particles are transported to the paper by the adjacent high-voltage field. Therein lies the analogy with electrostatic ink jet (see sec. 5.5., figs. 5.5-1, 5.5-2d, and 5.5-17).

5.9.2 Elcography

In 1996 a technology based on *electrocoagulation* (merging very small particles of ink in a liquid to form larger particles) was presented [5.9-8].

This process requires a special ink consisting of an aqueous *carrier liquid* in which short-chain *polymers* with finely distributed *pigments* and other additives are mixed as a *colloidal solution*.

A *chemical process* is triggered via an *electrical field* in which metal ions (e.g., iron), formed from the surface of the imaging cylinder, are used. Depending on the duration of the current pulses the finely distributed ink constituents in the carrier liquid coagulate to form larger particles on the imaging drum.

The underlying principle of the *printing unit* design is illustrated in figure 5.9-6 in accordance with [5.9-9]. Conditioning equipment prepares the imaging cylinder's metal surface by applying a thin film of oil. An inking system feeds the liquid ink to the gap between imaging cylinder and imaging array. The *imaging array* is constructed from electrodes, via which an electrical field between the electrodes and the cylinder surface is controlled in accordance with the image to be printed. After *coagulation* and transport to the cylinder surface, the particles of ink lie on the surface matching the image, together with carrier liquid and uncoagulated ink constituents. This liquid is removed from the surface by a suitable system. The image is transferred to the paper via an impression cylinder.

The chemical-physical electrocoagulation process and the precipitation of the ink on the imaging drum take place very quickly due to the high mobility of the small particles. The technology therefore has potential for creating *high speed printing systems*.

The quantity of coagulated ink particles is determined by the current pulses during imaging, which

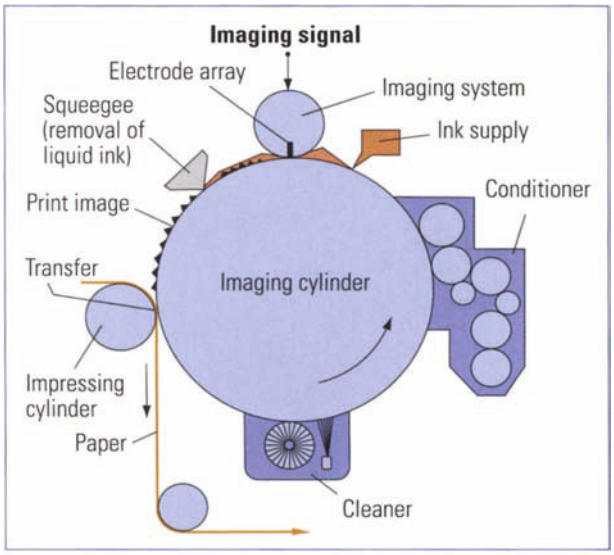


Fig. 5.9-6
Printing unit based on the NIP technology of Elcography (Elcorsy, [5.9-9])

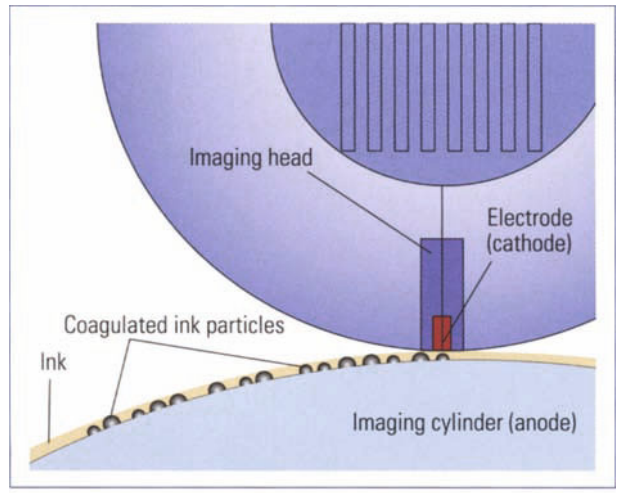


Fig. 5.9-7
The transfer of different quantities of ink per pixel using electrocoagulation (Elcorsy)

makes it possible to transfer a different quantity of ink per pixel. This in turn means that it is possible to image with numerous *gray values* per pixel. This principle is illustrated in figure 5.9-7.

Figures. 5.9-8 and 5.9-9 show the structure of a printing unit and a complete *printing system*, as it was first presented to the public in 1998 (addressability 200 dpi, printing speed 1 m/s).

As already detailed, "*Elcography*" is based on the electrocoagulation process, which requires a *new kind of ink*. Ink development has to be undertaken in close, intensive collaboration between printing system manufacturer and ink manufacturer (fig. 5.9-8, [5.9-10]).

The primary technological challenges in terms of implementation are ink formulation, removal of carrier liquid after imaging, and surface configuration of the image cylinder for a long service life. Printing systems in which the resolution has been doubled to 400 dpi and the speed increased to 2 m/s have already been announced (System Elco 400, a lab prototype was presented during DRUPA 2000).

Because of the extremely rapid reaction times (nanosecond range) for coagulation and the transfer of ink to the imaging cylinder, this new kind of non-impact printing technology has potential for further development, especially with regard to high production speeds, with speeds in excess of 10 m/s predicted.

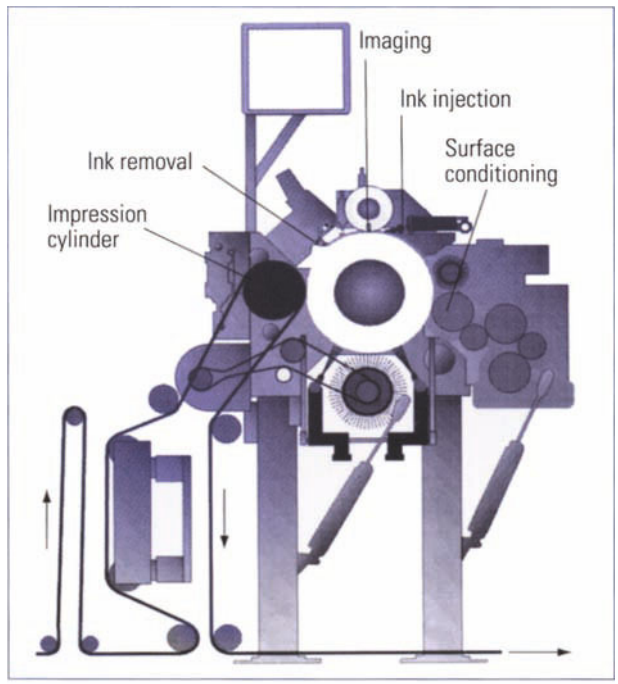


Fig. 5.9-8
The printing unit of a digital multicolor printing system based on Elcography (Elcorsy/Toyo Ink, [5.9-10])

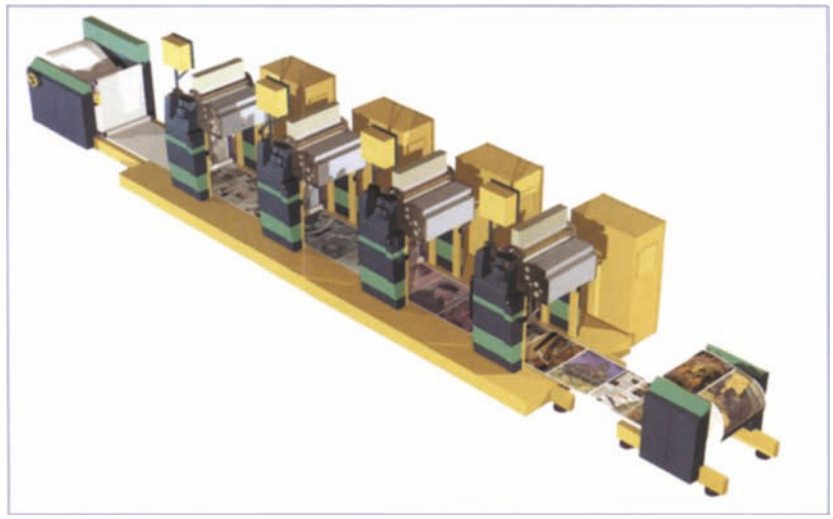


Fig. 5.9-9
The prototype of a digital multicolor printing system based on electrocoagulation; resolution 200 dpi, printing speed 1 m/s, imaging electrode controlled in 256 levels to create gray values (Elcorsy/Toyo Ink; status: Sept. 1998)

The basic patents for this technology are listed in [5.9-9], [5.9-10], and [5.9-11].

5.9.3 Direct Imaging Printing Technology

In 1996 Océ presented a digital multicolor printing system based on a new type of imaging technology.

The principle of the printing equipment on which it is based is shown in figure 5.9-10. Particular *innovations* that have been made in the process illustrated in figure 5.9-10 are the type of imaging via magnetic single-component toner, the controller for image build-up on the imaging drum from within the drum interior, and the inking process for the imaging surface with powder toner.

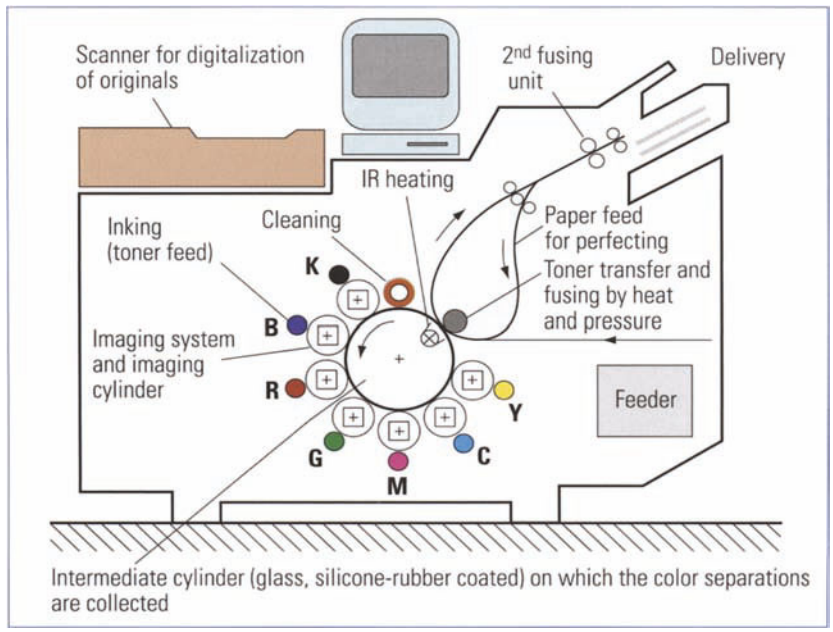


Fig. 5.9-10
Digital multicolor printing system based on Direct Imaging Printing NIP technology (EuroColor 3125 C, Océ; product announcement, presentation 1996)

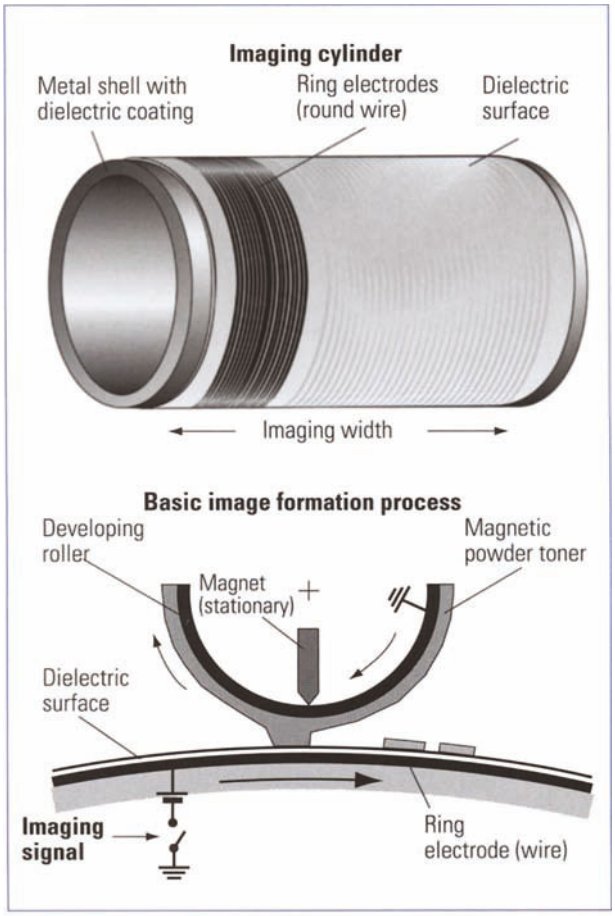


Fig. 5.9-11
Structure of the imaging cylinder and underlying principle of toner transfer by means of magnetic and electric fields (Océ; [5.9-15])

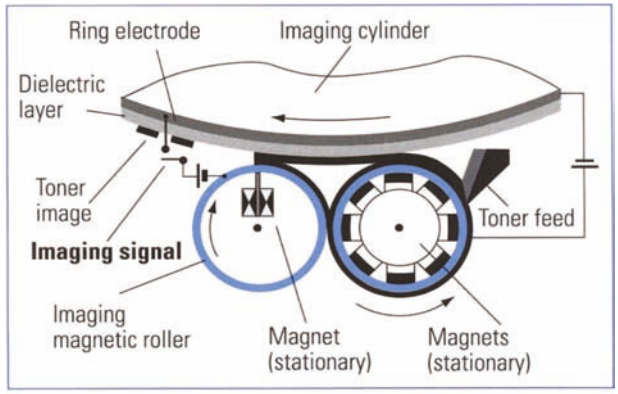


Fig. 5.9-12
Toner transfer with the Direct Imaging Printing NIP technology in a two-stage system (Océ; [5.9-12], [5.9-13], [5.9-14])

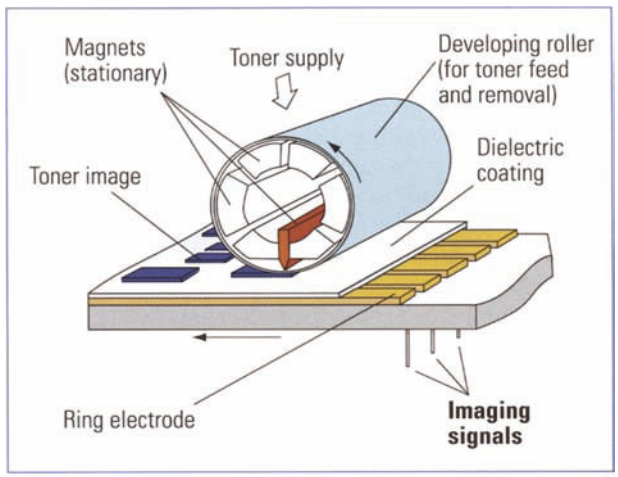


Fig. 5.9-13
Toner transfer for Direct Imaging Printing (simplified drawing) (Océ; [5.9-15], [5.9-16])

To carry out page-wide imaging, the *drum is fitted with individually controllable ring electrodes* made of wire, wound in a circumferential direction (fig. 5.9-11). The distance between these ring electrodes (63.5 µm) is equivalent to an addressability of 400 dpi at right angles to the direction of printing. The imaging cylinder's surface is protected by a dielectric coating.

The *magnetic single-component toner* is fed to the imaging surface via a *magnetic roller (developing roller)*. A defined, finely metered quantity of toner is removed from the developing roller of the toner feed system by the ring electrode's controller by means of an image-dependent voltage pulse and transferred to the imaging cylinder by the ring electrode. There are various developing unit designs (toner feed systems), as shown in figures 5.9-12 and 5.9-13.

As illustrated in figure 5.9-10, multicolor printing is carried out in *satellite configuration* around one cylinder, which acts as the intermediate carrier for assembling the color separations. For multicolor printing *seven imaging units* are used (each consisting of an imaging cylinder and a developing unit), with four units for the usual process colors of black, cyan, magenta,

and yellow and three others for the complementary chromatic colors red, green, and blue.

In the printing process illustrated, the multicolor print is not produced by overprinting the individual colors. Instead, the images of the individual color separations are positioned alongside each other (*mono-layer multicolor printing*). For this, the respective imaging units are controlled according to the color tone using a special color separation technique. In order to achieve the desired hue with as few inks as possible, only the required printing units (usually three to four) are used.

This type of *color image composition* is also necessitated by the magnetic toner. Due to the composition of the magnetic toner with iron oxides, it is expedient to position the individual color elements of the color separations alongside each other and not to print one above the other as is usually the case with non-magnetic toners. Moreover this technique results in a thin toner application (only one layer), producing smooth surface structures with multicolor prints.

Compared to magnetography, the proportion of iron oxide in this special magnetic single-component toner is very low (approximately 5% by volume instead around 60%), meaning that light colors, such as a pure yellow tone, can also be created.

Unlike magnetography, in the Océ imaging process it is not magnetic, but rather electric fields that are used for toner transfer.

Imaging *in the direction of printing* can be achieved with greater *addressability* using a control system operating via the ring electrodes with voltage pulses of different frequencies and/or different durations, together with a special magnetic roller design to generate a sharp-contoured magnetic field and image edges. As a result of this, it is also possible, in principle, to transfer pixels of differing size in the direction of printing in order to create gray values.

A detailed explanation of the *toner feed* is given in figure 5.9-12 (see also [5.9-12] and [5.9-13]). Another variant that is also familiar from patent literature ([5.9-14] and [5.9-15]) is illustrated in figure 5.9-13. As illustrated in figure 5.9-12 a homogenous, thin layer of toner is first fed to the surface via an inking unit. The layer of toner is then removed again from the imaging drum by a roller rotating in the opposite direction, via which the sharply defined magnetic field is developed, as long as the toner is not held on the imaging cylinder by the ring electrode as a result of a control signal. If the ring electrode is triggered by a control signal, the corresponding forces acting in the field hold the toner on the drum and only a proportion of it is fed back. The pulse width of the control signal is therefore the determining factor for the size of the pixel in a circumferential direction. Addressability is greater in a circumferential direction than in an axial direction (specified distance between ring electrodes), so that gray levels per pixel can be created by signal pulse widths of different lengths.

As shown in figure 5.9-10, the multicolor image is transferred to the paper in one contact. A sheet-reversal option in the form of a return/duplex loop can be used for *duplex printing*.

In contrast to the basic design of the non-impact printing systems illustrated in figure 5.1-5, in Océ's direct imaging technology the functional components imaging surface and imaging system are united. There is no latent image on the imaging surface and developing (inking) is done directly with the image signal. Océ refers to the technology as DIP, that is, Direct Imaging Printing technology, although depending on the process it is also sometimes referred to as Direct Inductive Printing technology.

The technical challenge is the design of the imaging drum with the ring electrodes for a resolution of 400 dpi and the feeding/transmission of the control signals via driver boards inside the drum. The combination of monolayer printing technology and seven-color printing means additional expenditure as against conventional multicolor printing systems based on four colors only, although this must be assessed as a whole, taking into account the relatively compact design of imaging and inking units.

Product announcements specify a resolution of 400 dpi, the creation of approximately five gray values per pixel, and a printing speed of approximately 25 color prints (A4) per minute, A3+ format (portrait). The patents on which the technology is based go back to around 1985 [5.9-15, 5.9-16].

5.9.4 Assessment of New Types of NIP Technologies

The three new types of non-impact printing technologies described above are examples of current and additional new activities and concepts for NIP technology. Without going into further detail here, one should mention processes based on so-called "*Traveling wave*" *technologies* [5.9-17, 5.9-18] as well as a NIP technology called "*Zurography*"; in "Zurography" a charge image pattern on the imaging cylinder is gen-

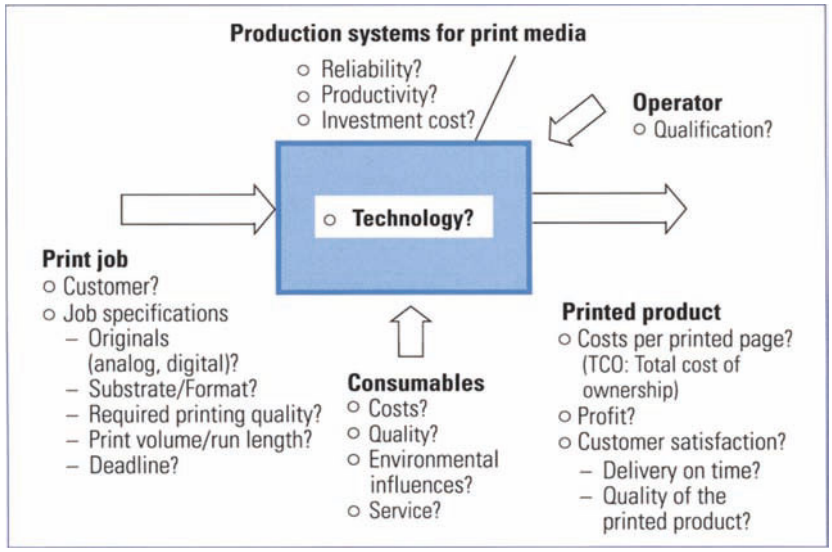


Fig. 5.9-14
Criteria/questions involved in the selection of a printing system

erated by means of an integral ion source and ring electrodes [5.9-19].

It will be common to all new technologies for *special physical effects* to be employed, often in conjunction with *new developments in the chemical structure of the inks* and the use of additives to implement computer to print technologies, that is, printing technologies that do not require a printing master/plate.

Which of the technologies and the printing systems based on them will *succeed on the market* depends in essence on the reliability of the process, the unit, the investment and the operating costs, that is to say, ultimately on the cost per printed page and the print quality achieved. The investor/buyer of the printing system is less likely to ask in detail about the technology employed in the production systems with which he serves his customers; the decisive factors will be the cost per printed page, the reliability and productivity of the system, and consistently reproducible quality. Figure 5.9-14 lists examples of the *requirements as well as the questions involved in the selection of printing systems* that have to be answered before any individual investment decision can be made.

From the great number of non-impact printing technologies now available and those which may become available, individual technologies will successfully penetrate the market depending on the specifics of production and product. The decisive factors are the *areas of application*, for example personalized high-speed single-color printing, short run color production, high-quality proof output in a digital workflow for print run production, or office and desktop publishing applications.

Non-impact printing technologies and *conventional printing technologies* (requiring a plate) have their own special areas of application and, for the most part, they complement each other. In principle, the areas of applications for conventional printing technologies requiring a master are comparatively long print runs of consistently high quality at low cost. For non-impact printing processes using no permanent master, the main areas are the production of small print runs with moderate quality demands and the necessity/option of personalizing the printed product in-line, or "print on demand", and "book on demand" applications for the production of one or only a few complete booklets in an enclosed workflow environment.

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6 Hybrid Printing Systems

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6.1 Overview of Printing Methods and Technologies

Figure 6.1-1 provides an *outline of the printing technologies* (see sec. 1.3.1 and [6.1-1]). The diagram shows conventional printing requiring a master, as well as non-impact technologies, which operate without a master, printing on sheet or web material using the relevant inks. The printing press, as a component within the production process taking in prepress, press, and postpress, is equipped with suitable technology, as already explained in the previous chapters and sections.

It is evident that every *technology* has its own *special applications*, which can be characterized by the size of

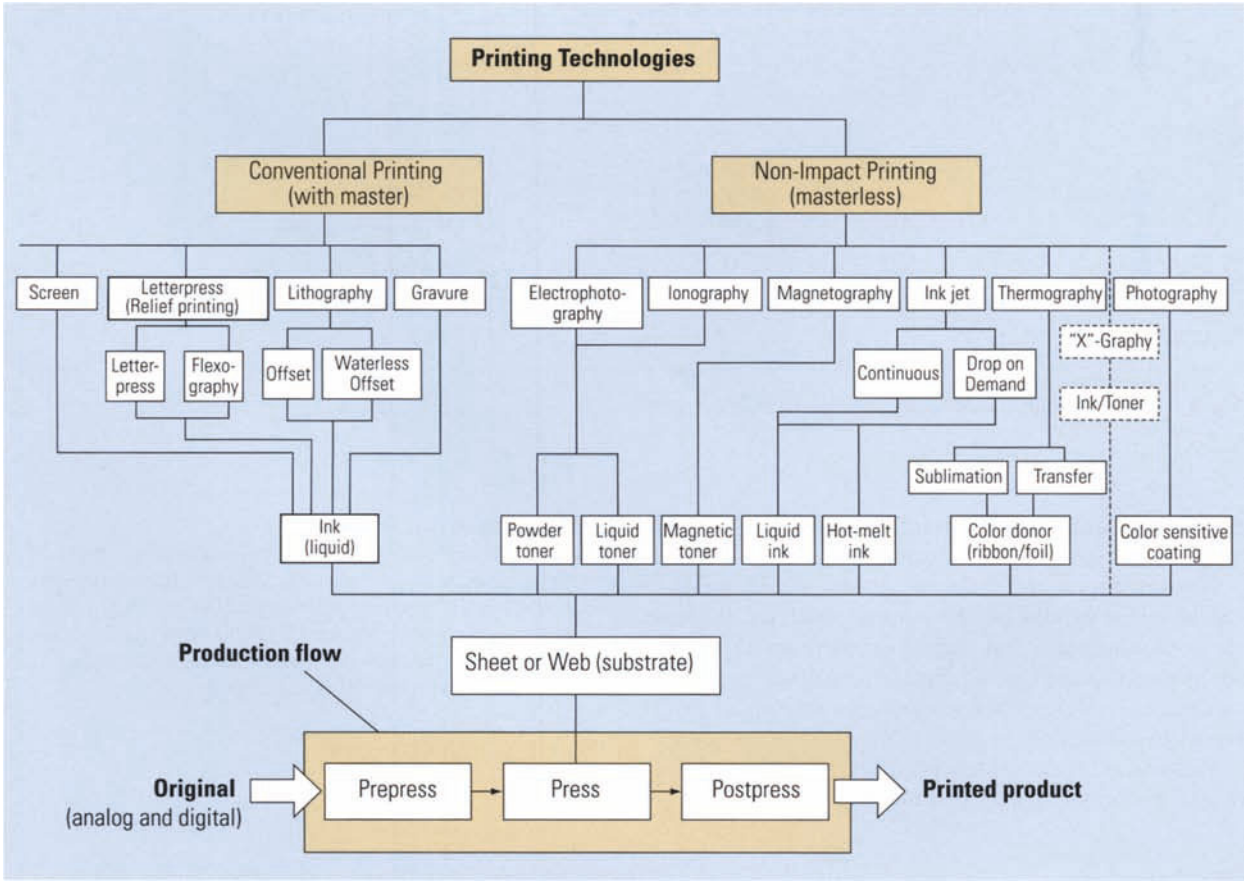


Fig. 6.1-1 Overview of printing technologies for the production of print media

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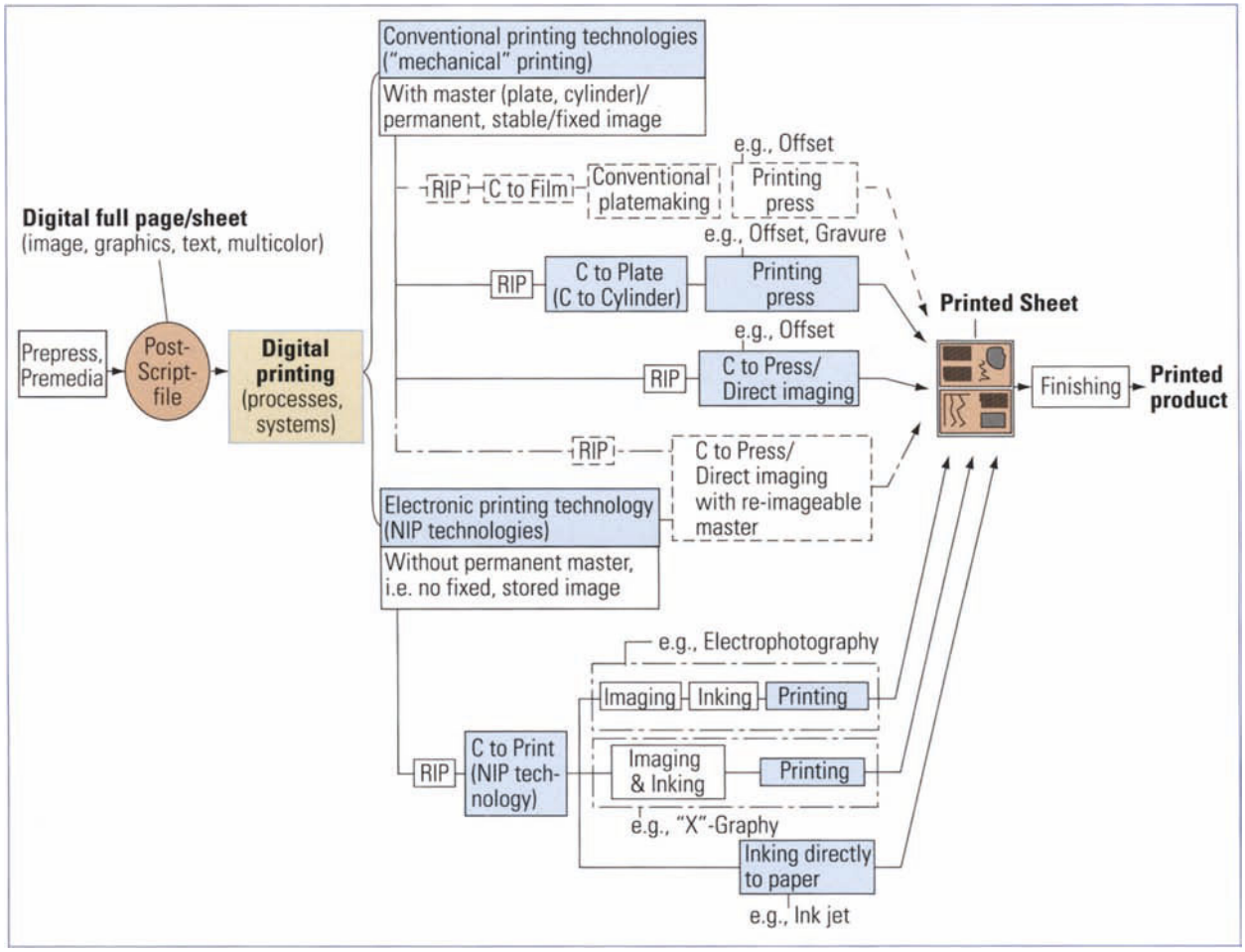


Fig. 6.1-2 Digital printing: technologies, components, and systems

the run, the quality of the print, further processing options, cost structure, and economy.

Also of importance is *incorporation in the complete workflow* for producing the printed matter. Computer to … technologies and digital printing are used both for conventional printing, that is, processes requiring a master, as well as, in particular, for non-impact printing technologies.

Figure 6.1-2 shows those versions that are capable of *digital printing* and are currently in use.

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6.2 Combination Variants of Hybrid Printing Systems

There are many methods and practical examples demonstrating that it is not always just a single printing technology that is used for the production of a printed product, but that a *combination of various printing technologies* can bring about very interesting production options, with both a high degree of economy for the printing company and benefit to the customer; see [6.2-1].

Hybrid Printing Systems. Figure 6.2-1 shows how so-called *hybrid printing systems* can be set up from a com-

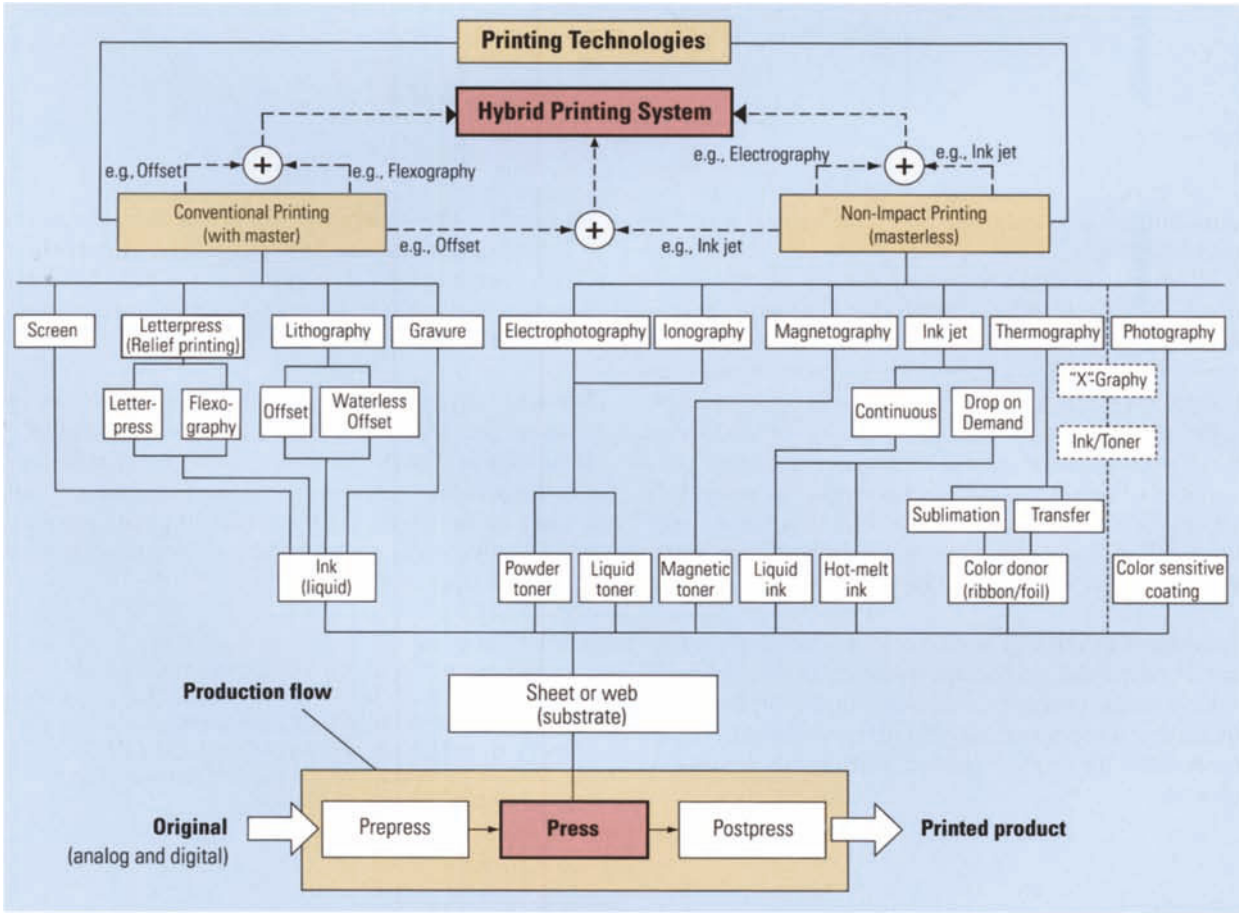


Fig. 6.2-1 Combination of various printing technologies to set up hybrid printing systems

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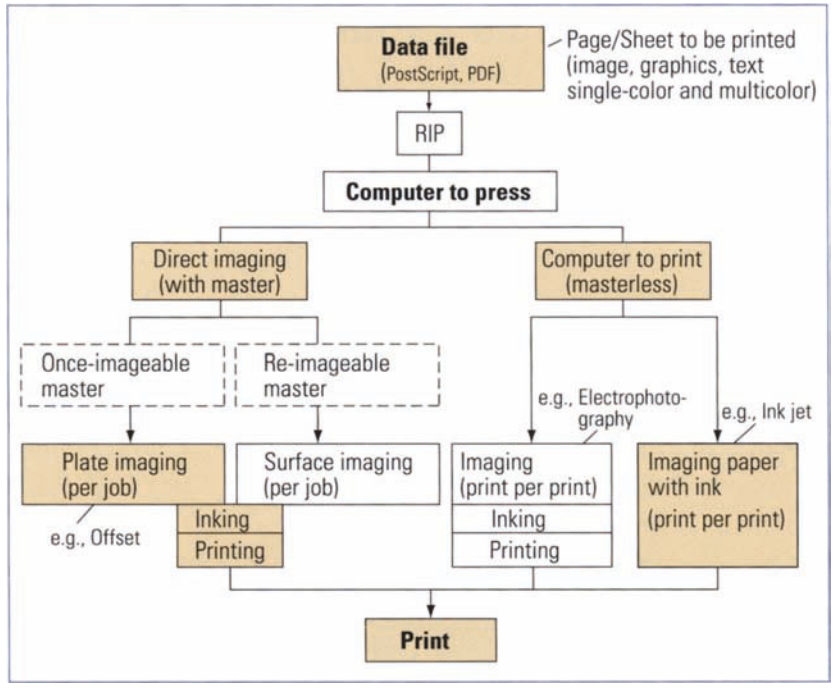


Fig. 6.2-2
Computer to press/direct imaging and computer to print technology as alternatives for setting up digital hybrid printing systems (e.g., combination of offset printing/direct imaging with ink jet/NIP technology)

bination of conventional and non-impact printing technologies.

Hybrid printing systems can also be set up from a combination of *various conventional* systems, that is, technologies using a master, or by combining various *non-impact printing technologies*. Such combined technologies are also shown in figure 6.2-1.

For computer to ... technologies (see sec. 4.1), figure 6.2-2 shows selected parts of the computer to press variants of *direct imaging and computer to print*. Efficient hybrid printing systems can also be set up by combining these computer to press variants, as is explained with examples in the following chapter.

Substrates and Inks. The characteristics of the *substrate* are of particular importance when printing with hybrid systems. Where printability, ink acceptance, print quality, and paper run in particular are concerned, they must fulfill the requirements of both technologies employed.

Regarding the different *types of ink* used, printing with hybrid systems can be problematic, in particular when overprinting is carried out with different processes, for instance when printing by ink jet on a multicolored offset printed picture.

Flexibility. *Hybrid printing systems* can be *modular* in design so that they are formed, for example, by separable linkage of a multicolor offset press to a single-color or multicolor NIP press. This has the advantage that in-line production is possible combining both printing technologies, while each of the two printing systems can also be operated separately.

References in 6.2

[6.2-1] Kipphan, H.: Digital Multicolor Printing and Printmedia Production – Status, Trends, Challenges and Innovations in Technology, Equipment and Market. 42nd FINAT World Congress (Proceedings). FINAT (The International Association for the Self Adhesive Label Industry), The Hague (NL) 1999.

6.3 System Concepts and Examples of Implementations

6.3.1 Hybrid Printing Systems combining Conventional Printing Technologies

Within conventional printing technologies, hybrid systems are already well-known that combine *offset and flexographic printing* such as sheet-fed offset presses; the latter have an attached coating unit for the whole surface or partial (spot coating) application of a coating onto a high-quality multicolor print produced in the same press (fig. 6.3-1, see also sec. 2.1.2.7). With these systems, it is also possible to produce colored imprints by means of a flexographic plate, for instance, with special effect coatings or special colors (spot color).

Where a multicolor offset press is prepared for waterless offset printing (temperature control of the inking unit), and the printing units are nevertheless equipped with the dampening units, this press can be operated as a hybrid printing system by combining conventional and waterless offset printing. With this kind of printing system it is possible to produce the job by applying the *waterless offset process* for the multicolor print and the *conventional offset technology* for the single-color printing of text and line art.

Other examples of hybrid printing systems based on technologies requiring a master are systems for label printing, such as those described in section 2.5.3. The combination of *flexographic printing, offset printing,* and *screen printing* is shown for label printing in figure 6.3-2.

Figure 6.3-3 shows the structure of another hybrid printing system that uses *flexographic printing* (for multicolor printing as well as for coating), *screen printing,* and embossing (with *letterpress plate*).

6.3.2 Hybrid Printing Systems combining NIP Technologies

Combined processes are also possible for non-impact printing systems. Figure 6.3-4 shows a system where *electrophotography*, for high-speed single-color printing, has been combined with an ink jet printer for imprinting additional information in color (see also fig. 5.5-15 in sec. 5.5.3).

Section 5.8 (fig. 5.8-2) describes a printing system with which high-quality multicolor prints can be produced through a combination of the NIP technologies of photography and thermography (with low productivity).

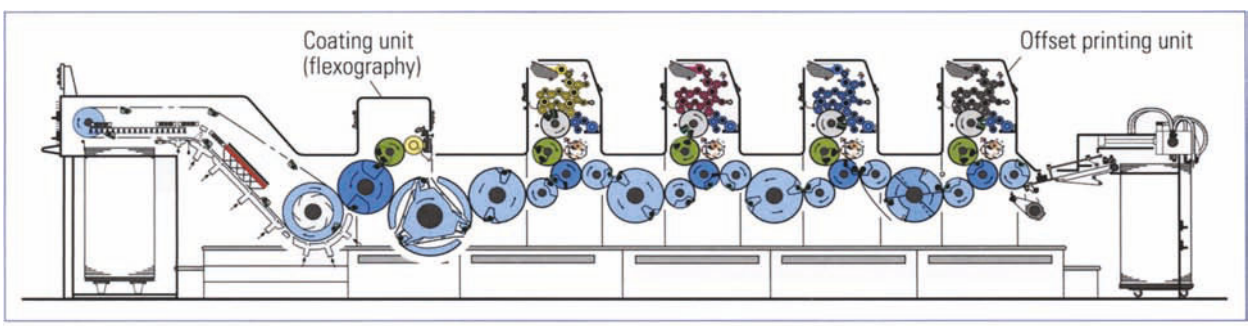


Fig. 6.3-1
Multicolor sheet-fed offset press with coating unit as a hybrid printing system combining offset and flexographic printing (Speedmaster SM 74, Heidelberg)

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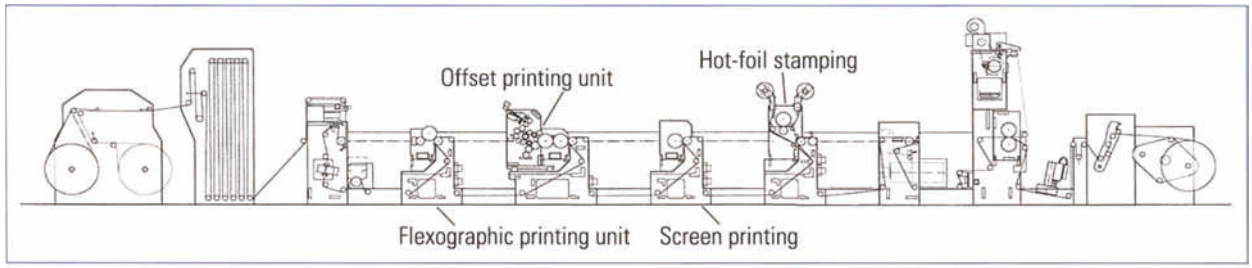


Fig. 6.3-2
Hybrid printing system for label printing; combining the printing technologies of flexography, offset, and screen, as well as letterpress (with heated plate) for hot-foil stamping/embosssing (CombiPrint, Goebel)

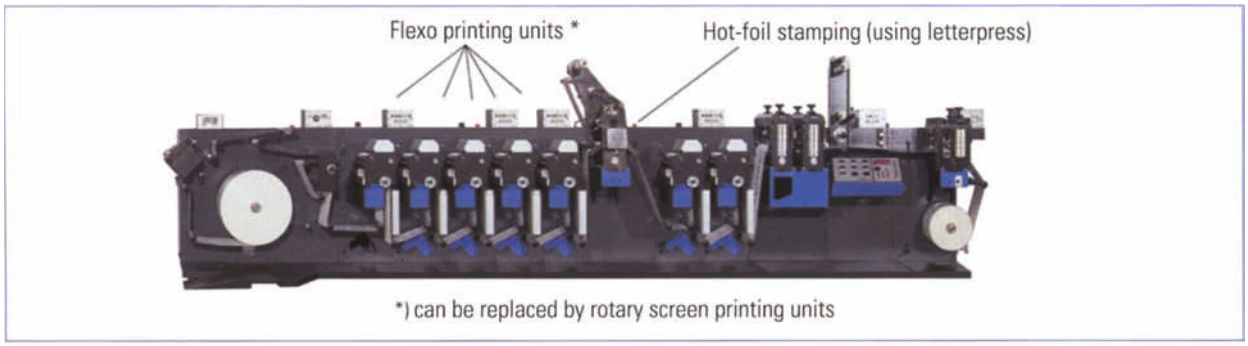


Fig. 6.3-3
Hybrid printing system for label printing; capable of combining flexography for multicolor printing or coating and letterpress for hot-foil stamping/embossing and numbering as well as rotary screen printing (Arsoma EM 280 KS, Gallus)

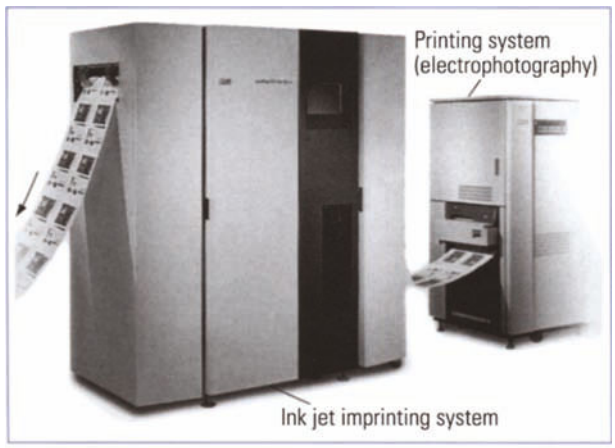


Fig. 6.3-4
Hybrid printing system combining the NIP technologies of electrophotography (single-color web-fed printing) with ink jet for multicolor (spot color) imprints (corresponding to figs. 5.5-15, 4.5-9), (InfoPrint 4000/Info Print Highlight Color, IBM)

6.3.3 Hybrid Printing Systems combining Conventional and NIP Technologies

Of particular interest when setting up hybrid systems is the combination of conventional with non-impact printing technologies. With these installations, the advantages of both technologies can be optimally combined.

By means of a hybrid system with printing units for color printing of the highest quality based on a printing technology using a master (in particular *offset printing*) and one or more printing units based on non-impact technology (e.g. ink jet), it becomes possible to add personalized information to the high-quality color print in-line. As shown in figure 6.3-5, these *printing systems* are able to print different information sheet by sheet, as well as to segment a complete job, for instance, by printing parts of the job with single-color information (in particular text) in different languages or with different recipient/company addresses.

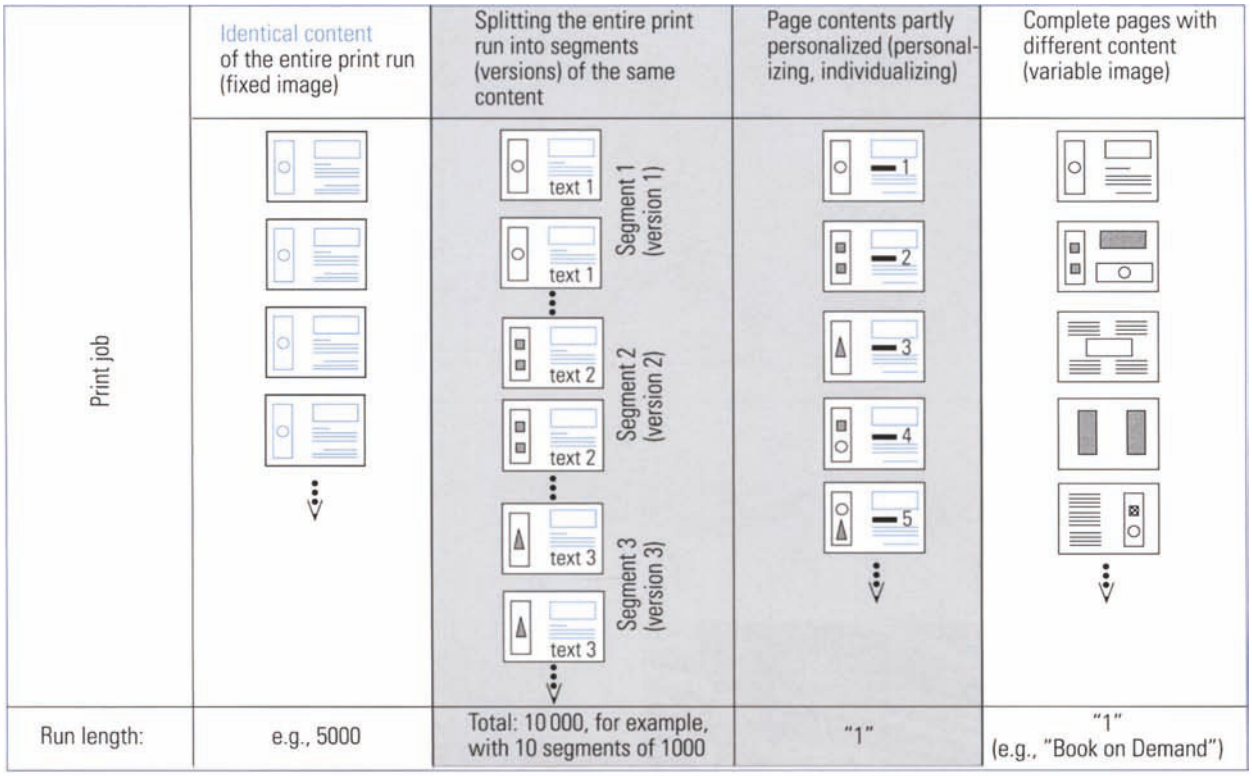


Fig. 6.3-5
Production options with hybrid printing systems by combining printing technologies requiring a plate and NIP technologies (the sheet content marked in blue is identical for the entire print run)

The illustration in figure 6.3-5 shows that hybrid printing systems provide *production capabilities* ranging from print jobs with a fixed content throughout the entire print run (0% variable page content) to jobs with a completely variable content from page to page (100% variable page content).

Figure 6.3-6 shows an example of a *hybrid printing system* where a four-color *sheet-fed offset* press is equipped with an additional printing unit for personalization. This printing unit can operate, for example, on the basis of the NIP technology *ink jet*. In the example shown in figure 6.3-6, the non-impact technology ink jet has the advantage that the imprinting unit does not come into contact with the not quite dry offset ink on the paper surface. Where drying is positioned downstream of the final offset unit, it is also possible to print the personalized information with an *electrophotographic printing unit*, where the imaging or the intermediate drum physically touches the surface of the substrate.

In section 5.5.2 (fig. 5.5-10) application examples of ink jet systems are described for off-line personalization/addressing, in particular in connection with finishing processes. An example of an *in-line installation of ink jet systems for sheet-fed offset* is shown in figure 6.3-7; the ink jet heads can, for example, be used – for individualization and/or segmentation purposes – to add variable information to the offset print over the complete sheet width on security paper or package printing.

The very different top *production speeds* when setting up hybrid printing systems employing different printing technologies are, however, problematic. The fastest NIP technology for *single-color printing* achieves print speeds between 0.3 and 5 meters/second (electrophotography, magnetography, ink jet). With NIP systems for *multicolor printing*, print speeds are between 0.1 and 0.5 m/s (electrophotography, ink jet). Further developments are in progress and some have already been

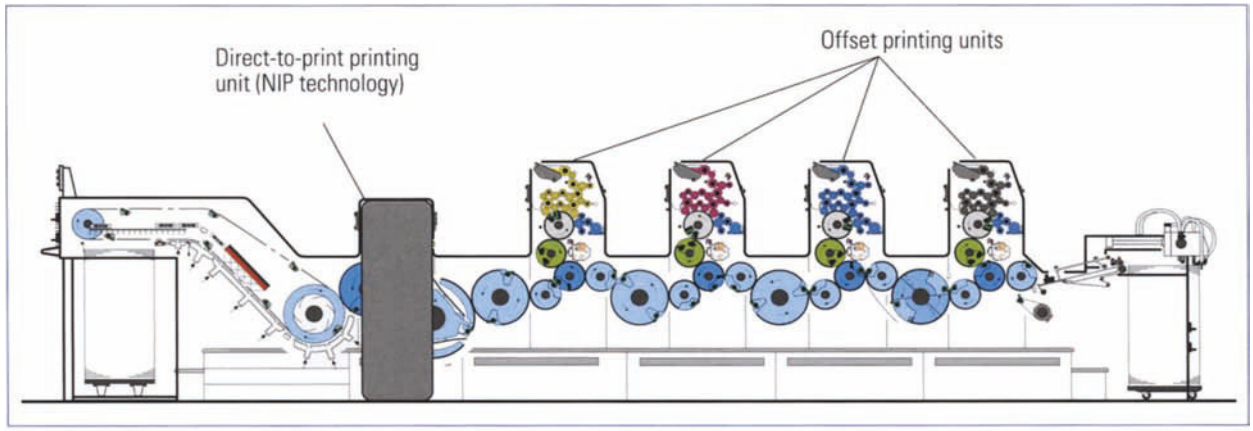


Fig. 6.3-6
Hybrid printing system combining offset printing for multicolor printing with NIP technology for the imprinting unit for printing partly variable contents from sheet to sheet (SM 74 + NIP/concept study, Heidelberg)

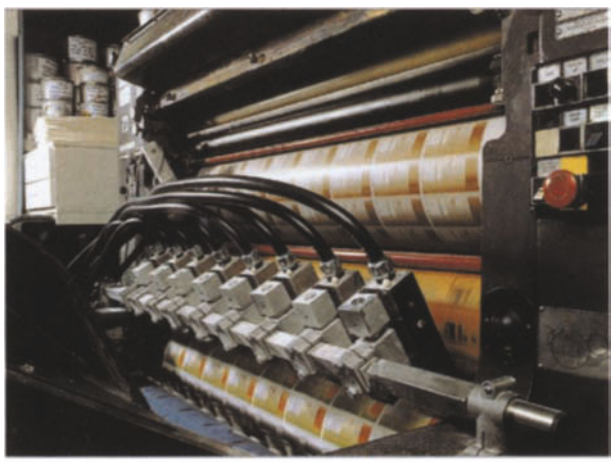


Fig. 6.3-7
Hybrid printing system: multicolor offset printing press with ink jet imprinting system for numbering, personalization, and segmentation of the job (Domino/Heidelberg)

announced (like from Elcorsy, see sec. 5.9.2, around 2 m/s). With offset printing presses, by comparison, the print speeds are in the upper range between 1.6 and 4.5 m/s for sheet-fed and between 8.5 and 15 m/s for web-fed printing. Due to process-based differences, in-line combination of printing technologies may prove to be unsuitable, or the productivity of the hybrid system must be adapted to the slower technology.

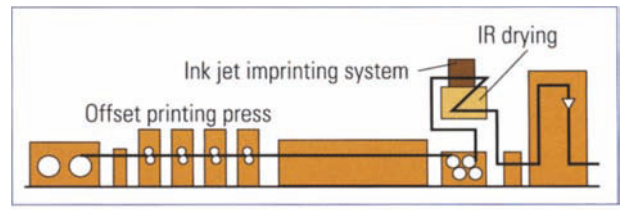


Fig. 6.3-8
Hybrid printing system for web printing for in-line personalization/addressing of print media (Mohndruck; [6.3-1])

Figure 6.3-8 shows one installation example where a *web offset press* is combined in-line with a high-speed *ink jet system* to personalize the print, that is, to provide additional information for specific customer groups. Finishing equipment incorporated in the web offset printing system is then used for in-line production of a print product such as a stitched brochure.

6.3.4 Hybrid Printing Systems combining Computer to Press/Direct Imaging with NIP Technologies

Figure 6.3-9 shows another combination for setting up a hybrid printing system: A computer to press/direct imaging press together with a computer to print system. High-grade printed matter of uniform high quality is produced with the direct imaging multicolor

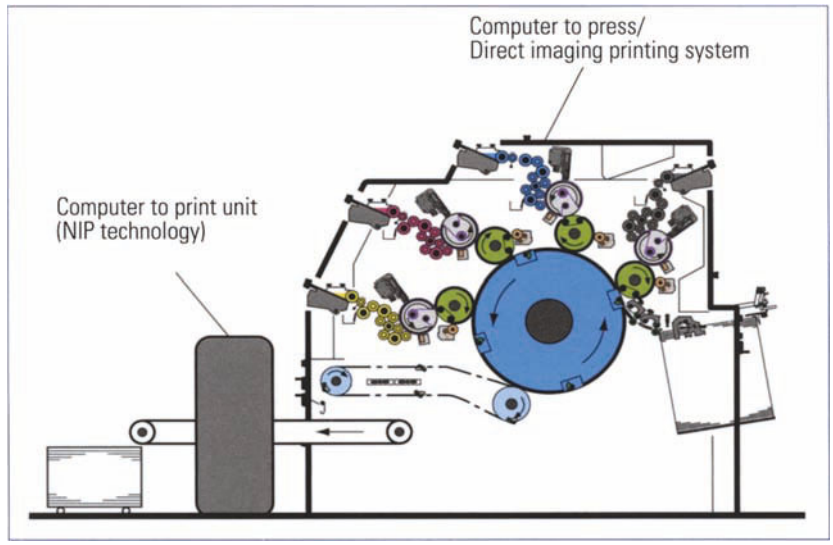


Fig. 6.3-9
Digital hybrid printing system using the combination of computer to press/direct imaging technology for multicolor printing (waterless offset) and computer to print imprinting system (NIP technology, e. g., ink jet) (Quickmaster DI + NIP/concept study, Heidelberg)

sheet-fed offset press, to which personalized information in one or more colors can be added by the modular imprinting unit connected.

For a system configuration as in figures 6.3-6 or 6.3-9, where printing is carried out by means of the *offset technology* and the NIP technology is used for personalization or segmentation of the print job, various NIP technologies can be used depending on the *drying process* and the degree of drying of the offset print. If the ink has not yet been dried, a non-contact printing process, such as *ink jet printing*, is advantageous. Where suitable ink and drying systems (e. g., UV inks and UV dryer) are used for offset printing, the printed image will already be dry after multicolor offset printing, and can therefore be imprinted using contact NIP techniques (the ink-carrying surface of the printing unit is in contact with the substrate) such as *electrophotography*.

Where the personalized imprint with *NIP technology* takes place *prior to offset printing*, the preprinted variable image portion will already have been dried thanks to the fixing process implicit in the procedure, and the printed image can in principle come into contact with the blanket cylinder of the offset printing press without loss of quality.

The hybrid printing system as in figure 6.3-9 is *modular* in design, that is, the imprinting unit is not rigidly incorporated in the computer to press offset printing system. This offers benefits with regard to the flexibility of the printing system and the modular structure of different model variants. A firmly incorporated NIP printing unit is also possible, as in figure 6.3-6.

The *hybrid printing system* as in figure 6.3-9 is a digital printing system in which computer to press/direct imaging and computer to print are combined. Accordingly, the complete print job can be processed with regard to its fixed and variable image content using *digital job definition*. Digital *in-line imaging* of the master prior to print start is used for the fixed image portions, and *real-time* imaging during printing is used for the variable page content.

NIP printing systems can be equipped for single-color printing as well as for multicolor printing.

6.3.5 Hybrid Printing Systems combining Conventional Printing Technologies with Computer to Press Technologies

Figure 6.3-10 shows the components of a *hybrid printing system* for the production of print media by *web offset*.

In addition to the system illustrated in figure 6.3-8, there is an *imprinting unit* that can be used to print single-colored text within the multicolored printed matter [6.3-1]. By exchanging the plates it is possible to print in a different language; the complete print run is thus segmented into partial runs according to language. With a sufficiently well-designed imprinting unit, the plate can be changed without any interruption to production. The imprinting unit can be equipped with two plate cylinders, with one always in

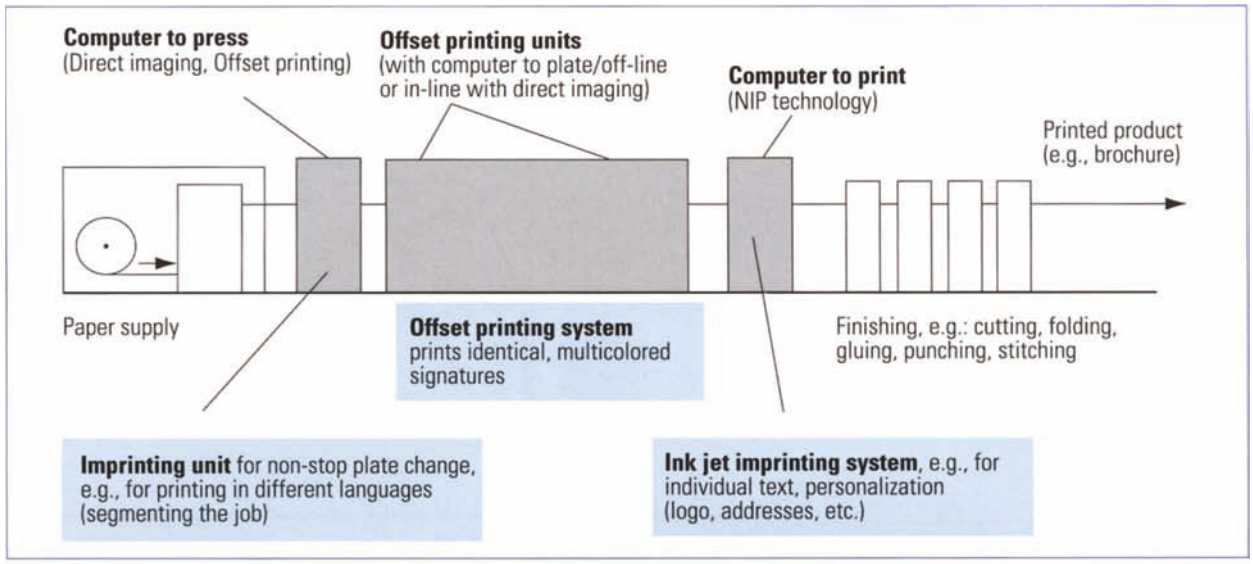


Fig. 6.3-10
System components of a hybrid printing system for web-fed printing for the production of segmented, personalized/individualized print media

production and the other at the same time being fitted with the new plate for the next job segment. This permits an "on-the-fly" exchange of the imprint with a minimum waste rate.

In principle, such an *imprinting unit* can be designed as a *computer to press/direct imaging unit*. This provides the means for production of segmented runs according to the target group on the basis of the digital job specification. A *hybrid printing system* is thus set up, in which *computer to press/direct imaging* (digitally imaged offset master in the imprinting unit), the *computer to print technology* (ink jet imprinting unit), and the *offset technology* are combined. The printing plates for multicolor offset printing can be produced off-line using computer to plate systems. A digital printing system is therefore set up as a hybrid system and functions with varying degrees of digitization (see also fig. 6.1-2).

As explained in section 4.4.2, research is being carried out on printing systems with *rewritable (re-imageable) surfaces* and a few laboratory prototypes have already been presented. Flexible hybrid printing systems can be designed with computer to press/direct imaging systems using rewritable masters (see fig. 6.2-2). In printing units using direct imaging technologies, a completely new master can be imaged, or *sections of the master can be erased* and re-imaged. Thanks to the memory capability of direct imaging systems with reusable masters, the same printing unit can be used for long runs with an identical printed image as well as for very short runs. In one operating mode the printing system, following imaging of the master, produces print-by-print the same printed image, while in the other operating mode the printed image can be changed for each print. Of particular interest is most certainly the application in which the run can be divided into sections with different imprints, so that there is no new imaging from print to print. As shown in fig. 6.1-2 this kind of printing system represents a hybrid technology for digital printing, a combination of conventional "mechanical" technologies using a fixed master and "electronic" printing processes based on NIP technology, the latter of which can be re-imaged from print to print (with NIP technologies, new imaging is normally always required, since the image carrier has no memory capacity).

References in 6.3

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6.4 Hybrid Techniques for In-line and Off-line Print Production

For the production of print media, various printing technologies may often be in competition with each other. Whether using masters/printing plates or the NIP technology, every technology has its advantages for specific applications, types of production, and production strategies.

Hybrid Printing Systems. As described in the previous section the combination of various printing technologies (*hybrid printing systems*) can create powerful means of production, making possible special production methods and strategies. This ultimately means that the processes can be adapted more flexibly and with greater customer focus to product and cost requirements. It is to be expected that an increasing number of combination systems will be employed for the *in-line production of printed products*. In any case, the *off-line use* of various printing technologies/systems will be employed for the production of a print job (e. g., printing the job using conventional printing technologies and subsequent personalization or segmentation with the aid of non-impact printing techniques). In the simplest case, this involves the numbering, addressing, or addition of recipient-specific information on preprinted forms with a general content.

Hybrid Production. Various printing technologies are used for the production of print media; these can be done in-line in the case of hybrid printing systems as well as off-line when using automatic print production systems. The *printing equipment* used for production in printing companies will become *increasingly diverse*, both for the *formats* or production on *sheet* or *web material*, and for the application of different *printing techniques*. Both conventional printing systems as well as those based on NIP technologies will be used. The systems will, for the most part, produce *independently* of one another although they can be *interconnected* for job-specific or system-specific reasons. In a printing company with *hybrid production*, print systems with various printing technologies will be used. One example is given in section 9.2, figure 9.2-13; the view of the press room shows sheet-fed offset presses and a non-impact printing system producing different print jobs alongside each other.

Digital Printing. The penetration of digital prepress is leading to an increasing integration of the workflow for producing print media, with the job being increasingly provided in digital form. With the help of different *digital printing technologies* (see fig. 6.1-2) it is possible to meet the most diverse, job-specific customer requirements. The use of production systems based on various printing technologies (see fig. 6.1-1) and hybrid printing systems (see fig. 6.2-1) is increasingly being taken for granted. It is also essential for successful economic production of print media of high quality and in short throughput times.

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7 Print Finishing Processes

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7.1 Classification of Print Finishing Processes

Finishing (postpress) is a segment of the print production flow in which the printed product is given its requested features of form and functions (fig. 7.1-1). The end products produced in the finishing process are therefore characterized by the design (shape) and the functions that are determined by the information content.

The product variety of the finishing industry is illustrated in the overview shown in figure 7.1-2.

The following *products are produced in the finishing* sector (the information content is not taken into account):

- Individual sheets — trimmed sheets, cuttings
- Folded sheets — sheets in various sizes that are folded according to a certain, sometimes complicated pattern
- Newspapers — gathered folded sheets
- Booklets — inserted folded sheets with a cover, stitched with wire or thread in the spine, secure binding
- Brochures — single or multi-layer blocks, stitching or perfect

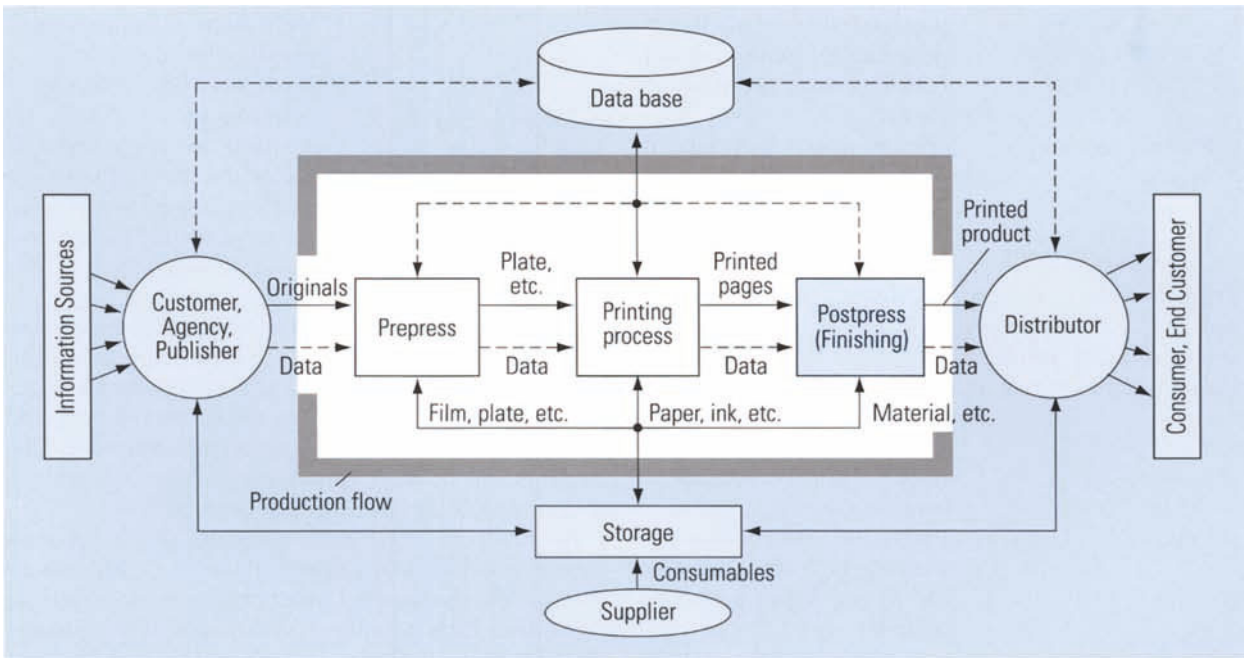


Fig. 7.1-1 Production flow of materials and data for the creation of printed products

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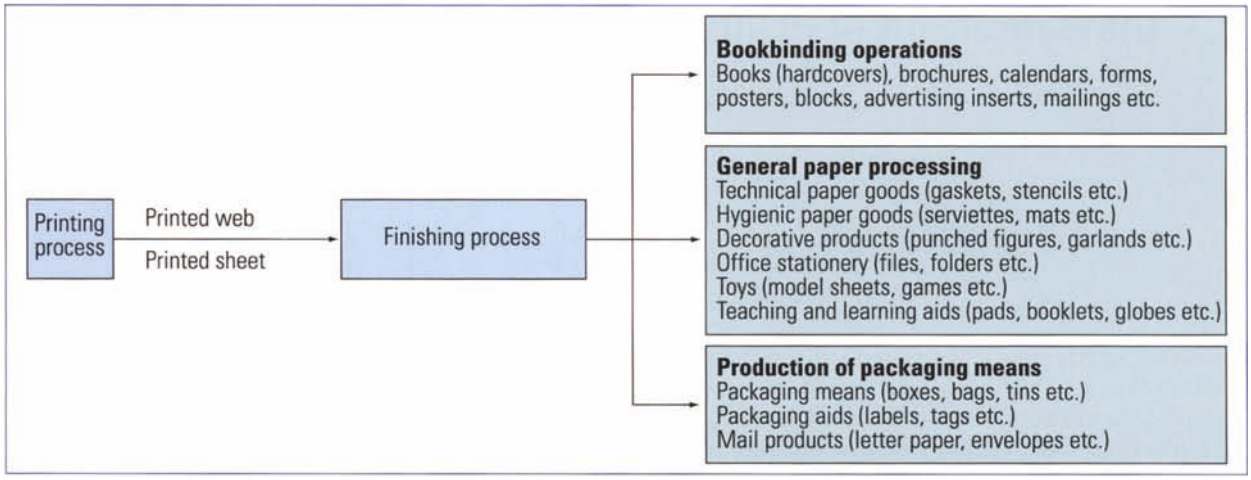


Fig. 7.1-2 Print finishing products

	binding, cover (mostly made of heavier stock)
• Hardcovers	multi-layer block, thread-stitching or perfect binding, cover consisting of several parts (usually referred to as a book)
• Assortment of sheets	binding technique: mechanical (very often detachable), comb or spiral bindings using metal or plastic
• Packing material/ means	open or closed material, cut to size and formed to hollow bodies during the packaging procedure.

Printed products, in particular book binding products are usually assembly products, that is, they consist of several partial products that have been produced independently of one another:

• Block	Carrier of the printed information (book block, content sheets)
• Cover	Protection unit connected with the body (case, cover, file, folder, lid) or packing material
• Finished parts	Structural parts made of metal, plastic, board, etc., which need to be attached to the product (e.g., binding mechanisms in files)
• Supplements	Information and advertising material that is added to the body or the finished product (inserted, glued). They differ considerably in their shape and comprise graphical products (e.g., cards, booklets), mailings, and samples
• Jacket	A jacket that is put around the actual cover of books and brochures. Today jackets serve mainly for advertising purposes.

To analyze the organization of the processing procedure it is useful to structure the finishing process into individual process sections. Each section characterizes the transformation of the material (partial product) with regard to the desired processing outcome. The designations of these processing sections use unique terminology that has historical origins.

Rausendorff [7.1-1] made a suggestion for a process classification in bookbinding (table 7.1-1). This structure can also be used for other print finishing processes. Section 7.2 is organized on the basis of this process classification and therefore deals mainly with the production of hardcovers and brochures.

Processes:	Sheet/web processing	Block production	Casemaking	Finishing
Process sections	Cutting Folding Forwarding Preparation of processing and functional points	Gathering to blocks Binding blocks Trimming blocks Rounding blocks Coloring edges Joining of extra items	Trimming the case material Jointing covers Surface finishing covers Rounding covers	Assembling the product Shaping the product Completing the product Packing the product

Table 7.1-1 Overview of the process classification in bookbinding

The following operations are carried out in the process sections:



Cutting of webs and sheets
Paper webs or sheets are cut to a format that is suitable for further processing (see sec. 7.2.1).



Folding
Sheets or webs (book binding sheets) are folded once or several times so that connected folded sheets or webs are produced at the folding edges (see sec. 7.2.2).



Forwarding
Forwarding comprises all operations on the folded sheet where a jointing procedure takes place (see sec. 7.2.3).



Preparing processing and functional points
Separating or forming operations are carried out on partial products to prepare processing or functional points:
- rule perforation as tear-off, gluing or bending edge,
- hole punching for positive jointing operations,
- scoring, grooving, creasing to fix a bending edge.



Gathering to blocks
Producing an unbound block of independently produced and folded sheets of a book or brochure in the correct sequence (see sec. 7.2.4).



Binding blocks
Creating a temporary or permanent connection of the collated folded signatures/ sheets to a block by a jointing operation (see sec. 7.2.5).



Cutting blocks
(Also referred to as trimming.) Blocks are trimmed to the end format on three sides (see sec. 7.2.6).



Rounding blocks
Forming book blocks so that the block spine has a convex and the front trim a concave shape in the block thickness direction (see sec. 7.2.7).



Coloring edges
One or more block edges are covered for coloring with an ink or metal foil (see sec. 7.2.7).

Jointing extra components
Book marks, headbands (ornamented bands), or similar materials are attached to the block (see sec. 7.2.7).



Trimming case material
Trimming cardboard covers, book cloths, and inserts for the case-making process or trimming of jackets (see sec. 7.2.8).



Jointing covers
Making a book case by jointing the cover cuttings (see sec. 7.2.8).



Surface finishing covers
Printing or embossing covers or jackets (see sec. 7.2.8).

Rounding covers
The cover spine is rounded in a forming operation to conform to the rounding of the block spine (see sec. 7.2.9).

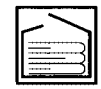


Casing in
Jointing procedure of book block and case (see sec. 7.2.9).



Forming the product
Comprising procedures for stabilizing the glued joint, forming an opening hinge (fold) and carrying out the book spine rounding (see sec. 7.2.9).

Completing the product
Including putting on a jacket, inserting supplements, and sticking labels onto the cover or the jacket (see sec. 7.2.9).



Packing the product
The products are packaged individually or in piles; packing of the transport unit (pallet packaging) (see sec. 7.2.10).

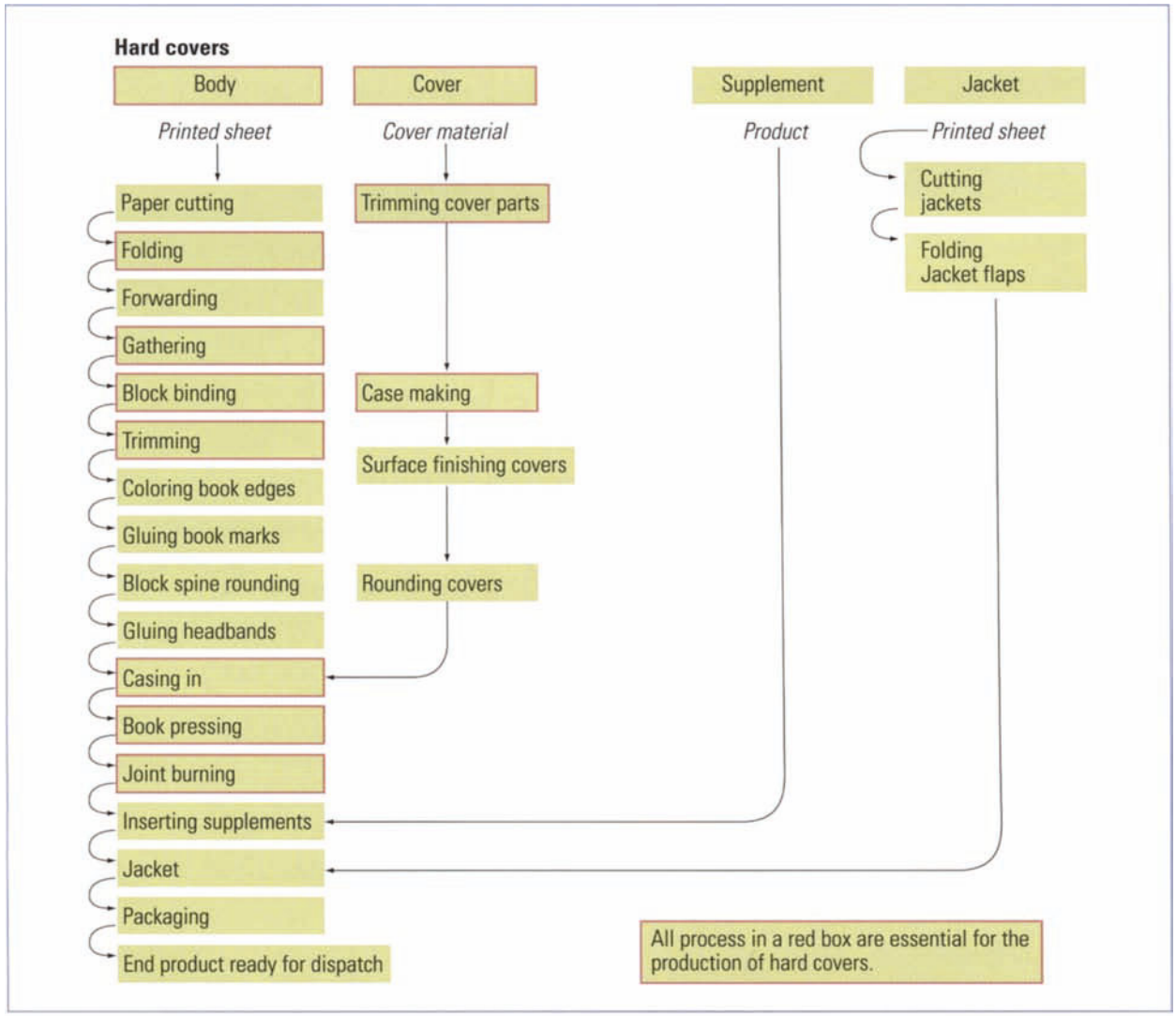


Fig. 7.1-3 Process steps for the production of fancy books

The process sections have been assigned with symbols (pictogram) that are used in the following to illustrate the process flows.

Figure 7.1-3 shows an example of a manufacturing process for hardcovers for fancy books. In practice we can distinguish between categories such as fancy books, simple edition bindings, school books, children's books, and so on, which reflect the degree of complexity of the book blocks and the extent of surface finishing of book covers. The diagram (fig. 7.1-3) describes the production process for fancy books from print sheets. All process sections inside a red box are essential for the production of hardcovers and represent simple edition bindings.

Figure 7.1-4 shows a possibility for processing brochures. It becomes obvious that the assembly of block and cover takes place during the block binding process. All process steps in a red box are essential for the production of brochures. Those process steps in a green box are typical operations for the production of magazines. In a description of the processing steps of newspapers, the operations for the production of the cover, block binding, and trimming would not take place.

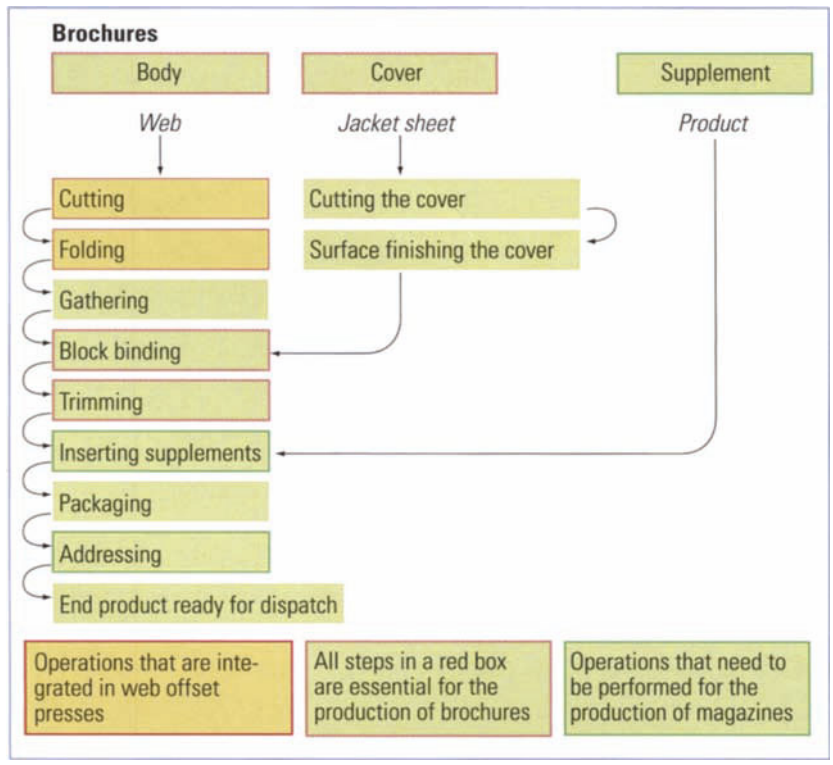
The collection of loose leaves in a binder is described in another example (fig. 7.1-5). For the most part the same operations are carried out as in the previous examples. The preparation of functional and processing points includes the producing of binding holes in the spine of binders and punching the block as a preparation for the positive joint/linkage between file and block by means of a mechanism.

To assess a process step it is necessary to investigate the technical means (tools) used for the transformation of the partial product. The way a material is changed by a tool is referred to as the working method. A selection of working methods applied in finishing is listed in table 7.1-2.

A process step can in principle be achieved by several working methods.

The "block binding" process step can be achieved by the working methods: stitching, gluing, or clamping, the "surface finishing" process step can be achieved by the working methods: printing or foil embossing.

Fig. 7.1-4
Operations for the production of brochures



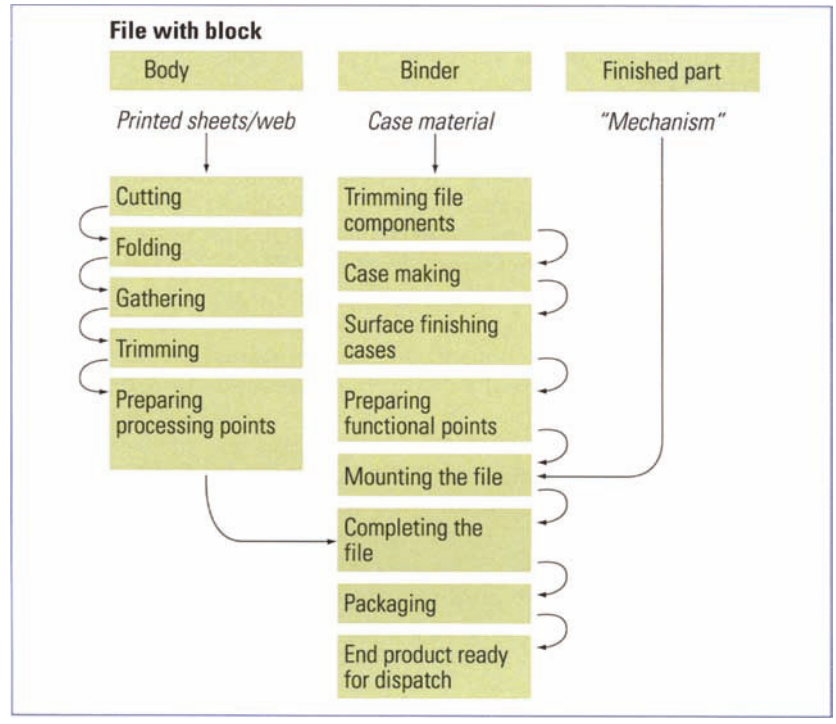


Fig. 7.1-5
Process steps for the production of files with an assortment of loose leaves

	Basic method			
	Forming	**Separating**	**Jointing**	**Coating**
Method groups/Working methods	*Forming the print* – Blind embossing – Pressing *Bend forming* – Folding – Creasing – Rounding – Pleating	*Dividing* – Cutting – Die-cutting – Scoring – Perforating *Metal cutting* – Milling – Sawing – Drilling – Grooving *Dismantling* – Separating *Changing the physical state* – Drying	*Positive linkage* – Stitching – Screwing – Inserting, bending – Crimping *Bond linkage* – Gluing – Welding – Sealing – Perfect binding *Non-positive linkage* – Suction – Clamping *Loose linkage* – Gathering – Collecting	*Coating from liquid, pasty or solid state* – Brushing – Spraying – Rolling on – Printing – Foil embossing

Table 7.1-2 Overview of method groups and working methods applied in finishing

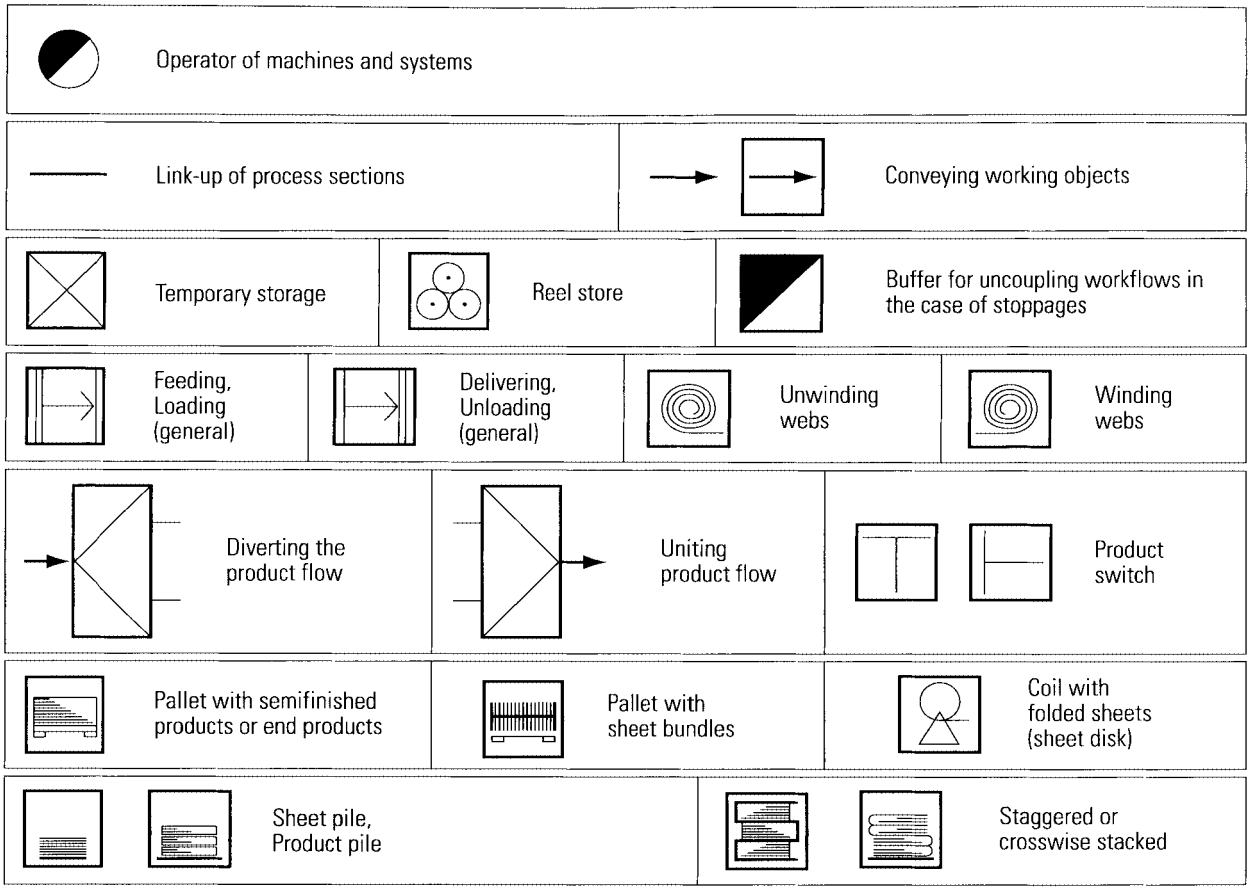


Fig. 7.1-6 Description of symbols for the structuring of processes

The description of methods makes finishing comparable with other engineering sciences since they apply the same working methods (e.g., scoring, die-cutting, milling, welding, spraying). But there are also working methods, such as folding, pleating, perfect binding, crimping, or gathering, that are exclusively used in the graphic arts industry. In these cases the process section and working method have an identical designation.

For the description of finishing processes (see sec. 7.3), logistics processes (loading, unloading of machines, transporting, temporary storing of semi-finished products and products) must be considered. For a better understanding of the process flows, frequently used logistics symbols are illustrated and described in figure 7.1-6.

References in 7.1

[7.1-1] Rausendorff, D.: Beiträge zur Systematik der Verarbeitungstechnik. Habilitation, TU-Chemnitz, 1981.

7.2 Process Steps and Procedures for Print Finishing

7.2.1 Cutting and Die-Cutting

7.2.1.1 Characterization of the Processes

The *cutting* procedure is carried out in several print finishing procedures. The main applications are:

- *Paper cutting.* This also involves cutting piles of print sheets to bookbinding sheets. Paper cutting is also referred to as cutting through.
- *Cutting webs.* Printed paper webs are cut in web presses or in separate reel slitters to part webs (ribbons) or sheets.
- *Trimming.* The three-page trim of books and brochure blocks after block binding is referred to as trimming.
- *Cutting case material to size.* Boards, cardboard sheets, endless cardboard, as well as sheets and webs for book case material are cut to size for book cover production or jackets.

Cutting materials to size also takes place within binding, joining additional parts, and packing processes.



In print finishing, cutting is the mechanical separation of a material by pressure where shearing strain is predominantly in force.

Figure 7.2.-1 shows an overview of the *Cutting* process in print finishing.

Sheets, webs, and boards are mainly separated by the shear cut using cylinder and circular knives. On the other hand, when cutting piles and blocks, a knife cut using flat knives is mainly deployed (fig. 7.2-2).

Characterizing the Cutting of Webs and Sheets



Printed webs and sheets are separated individually or in piles to a size required for further processing or to a final size.

Tables 7.2-1 and 7.2-2 show an overview of materials/partial products to be processed and products created by cutting.

7.2.1.2 Cutting with Guillotine Cutters

The fundamental design of guillotine cutters (knife-cutting principle, flat knife with linear motion) is illustrated in figure 7.2-3.

When cutting, the knife must overcome the cutting resistance of the material.

The main influences on the cutting resistance are:

- cutting material properties (type of paper, direction of grain, moisture),
- conditions specific to the pile (pile height, cutting length),
- structure and condition of the knife (cutting angle, degree of wear),
- knife travel during the cutting process.

The type of cut refers to the knife travel for cutting the material. There is the parallel perpendicular cut (for tough materials), parallel diagonal cut, swinging perpendicular cut, and swinging diagonal cut. In guillotine cutters for print finishing only the swinging diagonal cut is used, as very good cutting quality can be obtained with the lowest cutting resistance.

The forces shown in figure 7.2-4 become effective on the blade during the swinging diagonal cut.

Specifications for paper cutting are indicated in [7.2-1]. Forces effect and repel the knife, which is sharpened on one side (fig. 7.2-4), as is generally the case with guillotine cutters. This may result in cutting differences (see table 7.2-3).

Figure 7.2-5 shows the design of a guillotine cutter. The basic components of guillotine cutters are:

- enclosed frame with knife guide,
- cutting table to support the cutting piles,

H. Kipphan (ed.), *Handbook of Print Media*
© Springer-Verlag Berlin Heidelberg 2001

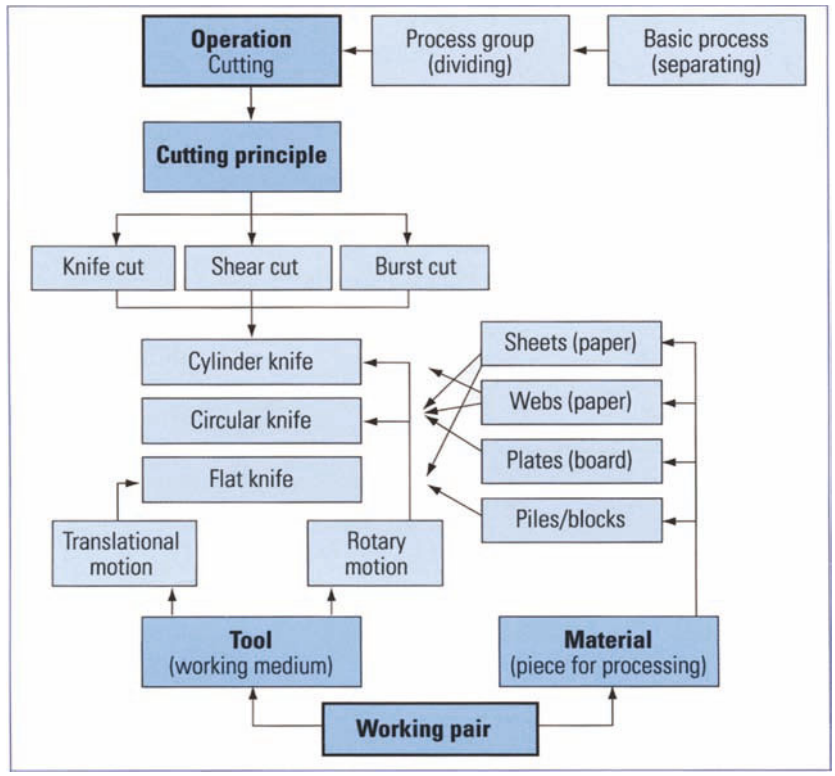


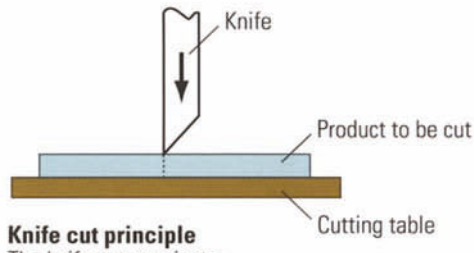
Fig. 7.2-1 Overview of the cutting process

- cutting device with knife holder and drive,
- pressing unit with pressing bar, kinematics, and drive,
- control panel,
- safety device (light barrier),
- stop for the cutting product with drive and guide, lateral stops.

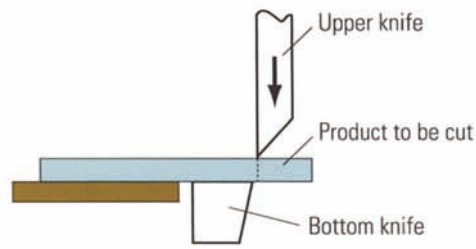
Cutting a pile requires the following actions:

- *Loading:*
  - taking up part of a pile (80 to 150 mm high) from the pallet,
  - stacking in a jogger;
- *Jogging:*
  - fanning the pile to reduce the friction between the sheets,
  - aligning (jogging) the sheets to one another at two edges,
  - removing any air from the cutting pile;
- *Transporting:*
  - transporting the cutting pile into the guillotine cutter;
- *Cutting:*
  - setting the cutting dimensions on the guillotine cutter,
  - aligning the cutting pile in the guillotine cutter,
  - cutting,
  - removing the cutting shavings from the cutting table,
  - manipulating the cutting material in the machine to prepare for the next cut;
- *Unloading:*
  - transporting the part of the cut pile into the delivery area,
  - depositing the trimmed piles onto a pallet,
  - handling the pallets in the delivery.

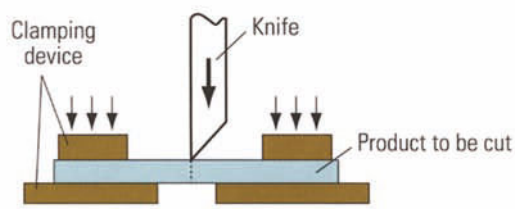
Cutting systems, also referred to as cutting lines (fig. 7.2-7), are made up of producing and logistics modules. The logistics processes (loading, unloading, pile manipulation in the guillotine cutter) are the important factors. The effective output of a guillotine cutter (as an economic parameter) is influenced by



Knife cut principle
The knife cuts against a surface plane, which supports the cutting force.



Shear cut principle
The upper knife works against a lower knife. In this way the cutting material is sheared off against the lower knife.



Burst cut
The knife works without a counter-acting tool. The cutting force is compensated by the tension force of the clamped cutting material.

Fig. 7.2-2 Cutting principles

- the feeding height of the cutting material (between 500 and 1500 sheets per pile),
- the number of cuts per pile (when cutting labels up to 100 cuts),
- the degree of automation of the cutting system.

Work Preparation for a Cutting Job

If paper cutting is used for dimensioning the print sheet to the bookbinding sheet, the number of cuts per sheet is relatively small.

For product groups such as labels, securities, posters, and postcards, paper cutting is a central process. The number of cuts per sheet is usually high and the arrangement is very often complicated.

The basis of the cutting program is the cutting sheet and the cutting sequence that is derived from it. (These considerations are essential, even with non-programmable cutting machines or for jobs for which it is not worth writing a special program.) The *cutting sheet* is initially the print sheet with the cutting marks already determined in the printing plate production. These should be checked for correctness and completeness. The cutting lines are drawn (and often labeled too; if the operator has good know-how, this contributes to minimizing errors). This determines where to cut.

The *cutting sequence plan* determines in which sequence cutting takes place and at what dimensions. There are some useful rules for this that should be adhered to in order to keep the risk of errors low and to work efficiently:

- The aligning edges of the printing press should also be the aligning positions in the guillotine cutter for the first two cuts.
- If all four sides are to be trimmed, the other mtwo cuts should be done immediately there after.
- You should cut from a big to a small size, that is, as many cuts as possible in a backgauge advance movement.
- You should make as few pile rotations as possible, and have minimum temporary storage.

When programming the cutting sequence, it is also necessary to

- determine a stacking size,
- mark the pile rotations,
- program the ejection of the cutting material (with the backgauge).

Table 7.2-1
Materials/partial products to be processed

	Materials/partial products to be processed	see also section
Webs	• Unprinted and printed paper reels	7.2.1.3
	• Unprinted cardboard reels	7.2.8
	• Unprinted fabric reels	7.2.8
Sheets/boards	• Unprocessed sheets	7.2.1.2
	• Printed sheets with uniform ups and with combined jobs	7.2.8
	• Unprinted and printed cardboard	7.2.8
	• Boards	7.2.8
	• Unprinted and printed covering paper sheets	7.2.8
	• Covering cloth cuttings	7.2.8

Table 7.2-2
Products produced by cutting (examples)

Partial products	Final products
Bookbinding sheets Printed sheets for finishing in folding machines	Unprinted *paper blanks* for office communication, schools and at home
Book cover material Unprinted or printed covering material cuttings for finishing in casemaking machines	Posters, placards Business paper and business cards
Die-cutting labels Labels for finishing in corner punching units or die-cutters	Postcards, picture postcards Trim labels
Board covers For finishing in casemaking machines and for producing files and folders	Securities, bank notes
Carton cuttings as a cover for single-layer or multi-layer brochures, for folding boxes	
Cuttings for general paper converting processes	

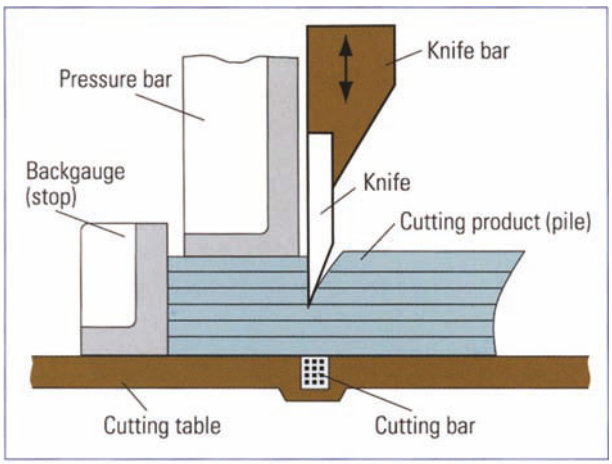


Fig. 7.2-3 Design of guillotine cutters (Polar Mohr)

Material	Vertical forces F_v in N/mm	Horizontal forces F_h in N/mm
Book paper	15 to 25	5 to 15
Art paper	20 to 40	5 to 25
Cardboard	25 to 50	5 to 30

Table 7.2-3
Specific cutting resistance (swinging diagonal cut, β=20°, blade is sharp, knife angle of attack/swinging shear cut angle 2–3°)

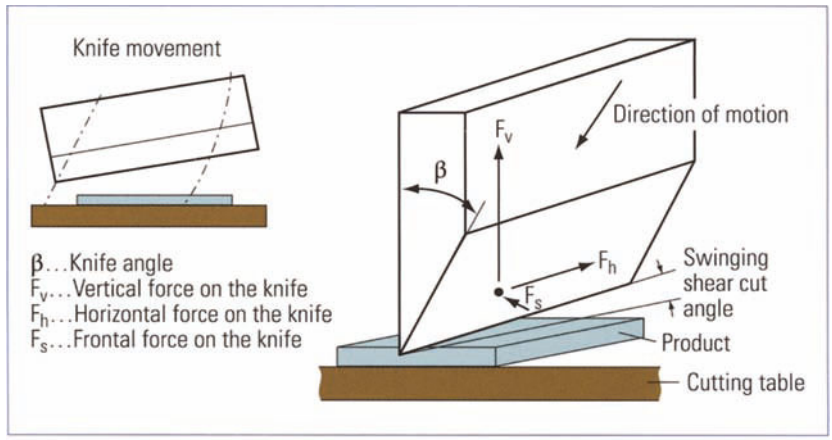


Fig. 7.2-4
Cutting forces on the blade with the swinging diagonal cut

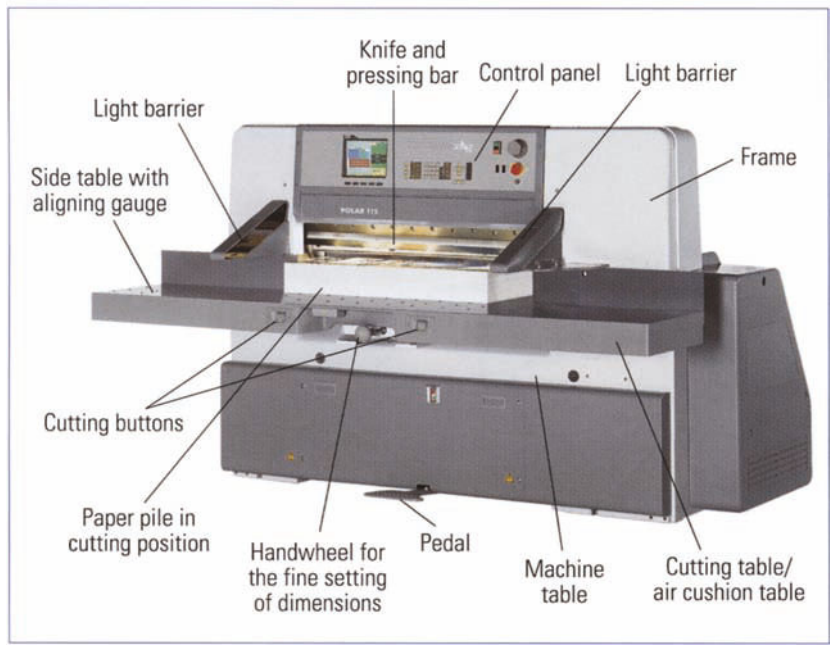


Fig. 7.2-5
High-speed guillotine cutter/main units (Polar 115, Polar Mohr)

The job planner creates the cutting sheet. It is the operator's task to determine the cutting sequence and to do the programming; the option of external programming is not generally the norm.

Knowledge of some terms and descriptions for cutting arrangements is an advantage for understanding the process (fig. 7.2-6).

The operator makes a further differentiation of the types of cut:

- *First cut:*
  first cut opposite the print sheet aligning or gripper edge,
- *Counter cut:*
  the print sheet aligning edge or the pull aligning edge is cut off,
- *Subsequent cuts:*
  separating cuts with one backgauge forward movement.

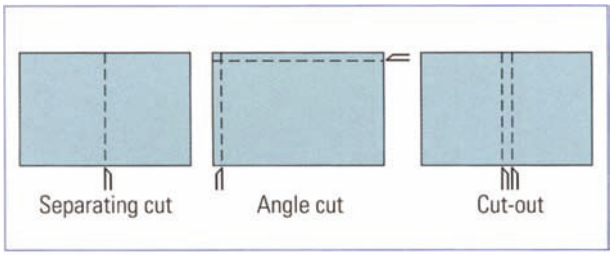


Fig. 7.2-6 Designations of cutting arrangements

Quality of Cutting Products

Trimming print sheets to bookbinding sheets takes place at the beginning of the book and brochure- production process. The dimensional variations arising here form the start of the error propagation chain (cutting, folding, binding). Minor deviations from the desired dimensions during paper cutting can lead to serious quality deficiencies in the final product. The formatting of labels and securities, among other things, requires cutting tolerances of several 1/10 mm so that label machines, cash machines, and money-counting machines can work fault-free. A high level of cutting accuracy has priority here over the attainable production output of the system. The cutting precision depends considerably on the material properties of the cutting product. To compensate for dimensional deviations of the cut (with the correct dimension setting), the cutting device offers various options such as:

- changing the knife angle (change of knife),
- changing the contact pressure,
- mounting additional pressing elements,
- altering the inclination of the backgauge.

The operator of the guillotine cutter must monitor the proper condition of the knife (sharpness, nicks) and cutting bar (plane surface). These parameters are to be taken into account for the changeover to a new job. If these measures should fail, the height of the cutting pile must be reduced. This is a procedure that is often applied.

The concept of cutting quality involves the following parameters:

- deviations from the specified cutting edge,
- format deviation in the direction of cutting,
- exactness of the cutting edge (deviation from the straight line),
- evenness of the cutting surface,
- separation of the sheets after cutting (sheet edges do not stick).

"Quality," which is defined as remaining within specified desired tolerances, is determined by the condition or property of tools and material. Some general rules:

- *Knife life:*
  The smaller the knife angle, the shorter the service life of the knife, that is, the sharpness of the knife quickly diminishes.
- *Knife angle*:
  A soft cutting product requires a smaller knife angle. Hard cutting material requires a larger knife angle.
- *Pressing force*:
  Great force is required for a soft cutting product. Low force is required for a hard cutting product.
- *Sharpness of knife:*
  Indicators for the bluntness of the knife are
  – cutting edges interlock and stick together,
  – scorching (singeing) of cutting edges,
  – a thud when cutting through the bottommost sheet.

Typical faults when paper cutting and suggestions for remedial measures are generally listed in the manufacturers' operating manuals. They also contain parameters for the knife angle and the pressing force for different types of materials.

The cutting of great volumes of paper piles is carried out on cutting lines. Figure 7.2-7 shows *a standard cutting line* for companies with a variable job structure and low to medium quantity of cutting work.

This configuration consists of the *pile lift,* which enables an optimum operating level when loading up the line, the *jogger* for aligning the sheet in the pile, *air conveyor tables* for transporting the pile, the *cutter* and the *unloading device* for exact delivery of the cut pile onto a pallet. This cutting line is mainly operated by *one* person. It is his job to:

- take sheet sections (approximately 100–200 sheets) from the pallet and ventilate and feed them into the jogger;
- remove the air from the pile, take the pile out of the jogger and load it into the cutting machine;
- carry out the cutting sequence operations and load and operate the cutting material delivery (outline in fig. 7.2-8).



Fig. 7.2-7 Cutting line for cutting printed sheets for medium-sized bookbinding companies (Polar Mohr)

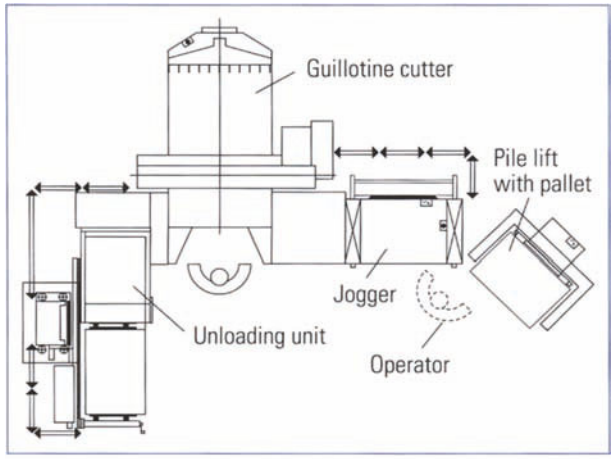


Fig. 7.2-8 Cutting line (corresponds to the installation in fig. 7.2-7)

Aligning the sheets generally takes place at the print alignment edge. The *jogger* consists of a tiltable table with two pile boards. The sheets have to be aired in order to enable a relative movement of the sheets to one another. This is done by the operator when loading up. With very large sheet sizes this process is supported by blowing air in from the sides. After the jogging operation, the jogging table is moved into a horizontal position and the air is pressed out of the pile with a roller. The compressed pile is transferred to the conveying system. A side delivery board can be swung down and thus becomes part of the transport table.

The pile is conveyed on *air conveyor tables* with pressurized ball valves embedded in the transport level. If there is a pile on the table, the balls are pressed into the table and this opens the valves, such that an air cushion is created between the table and the pile. This means the pile can be moved along with a small expenditure of energy.

Along with these modules, the *guillotine cutters* themselves have been further advanced by a series of functional units that increase the cutting quality as well as the productivity. They are offered as a modifications or extra accessories to the basic systems. Examples are:

- Devices for loading the cutting machine with piles at the lower cutting table. A *lowerable feed angle* and a mechanical pile transport system are used. Loading at the rear cutting table improves the product flow.
- A mechanical *pile manipulation device* on the cutting table to eliminate manual pile turning operations when doing angle cuts.
- Devices for automatic *elimination of cutting waste.* Before a faulty cut the front cutting table is moved a few inches forward, so that the offcuts fall into the disposal chute located under the table. Thus both sides of the cutting machine are free for feeding the uncut pile and moving out the cut piles.
- *Product retainers in front of the knife.* Narrow pile sections tend to tip over, which can considerably interfere with a subsequent cutting program. The retainer prevents the pile that is located in front of the knife from tipping over.

- *Sheet retainer in front of the backgauge.* This retainer prevents paper that tends to roll, or voluminous paper from rising up. This results in greater cutting precision.
- The *counter scale* integrated in the jogger determines the exact volume in sheets and quantity specifications of the pile. The determination of quantity is an important incoming goods check for print finishing companies and an aid for identifying finishing waste.
- Differentiated adjusting system for the *cutting backgauge* in order to compensate for quality deficiencies in earlier processes.
- Automatic *pressing force control,* so that with varying cutting widths constant predetermined pressing tension acts on the cutting product.

The trend in modern production concepts is to eliminate flow production between jogging and cutting, that is, to jog the cutting pile and then put it into temporary storage. The prerequisite for this is that the unloading of the jogger and the loading of the guillotine cutter takes place without any major additional effort and that there is no loss of quality through the temporary storage (see also sec. 7.3.2.1). For efficient temporary storage an air pallet buffer system is used. The piles are pushed onto intermediate boards and then put down on a pallet (on top of one another). The same component is used for unloading the pallets. By separating these two operations, jogging as well as cutting can be optimized independently of each other. Another variant is that the jogged piles are piled onto the pallet without air boards. A specially formed plastic plate (chip marker) is pushed between the piles, which can then be inserted into the cutting machine feeder. In this way one jogger system can be used for two cutting systems.

For each new cutting job a new cutting program needs to be created. As with every other makeready process this requires time and creates costs. Misprogramming would result in an extremely high waste quota. Therefore the cutting machine manufacturers (by using process computers which are already available) have created computer-based job processing systems, with which the setting data of the system can be ascertained, also making use of data interfaces, such as CIP3 (see also sec. 8.2.3). The data can either be transferred to the finishing system online via a network or by data carrier, e.g., floppy disk. Production data acquisition (data return) can also take place this way.

7.2.1.3 Cutting Webs

Cutting devices for paper webs (paper rolls) are required to cut webs (strips), sheets, or cuttings from blank or printed webs. This usually takes place in-line, that is within web presses (see also sec. 2.1.3). In addition there are special slitters for cross or longitudinal cutting of webs.

The cut takes place parallel to the web edge. The web is divided into two or more webs (ribbons).

The principle of longitudinal cutting is simple, as the running direction of the paper and the cut direction are identical. Driven circular knives are used (fig. 7.2-9),

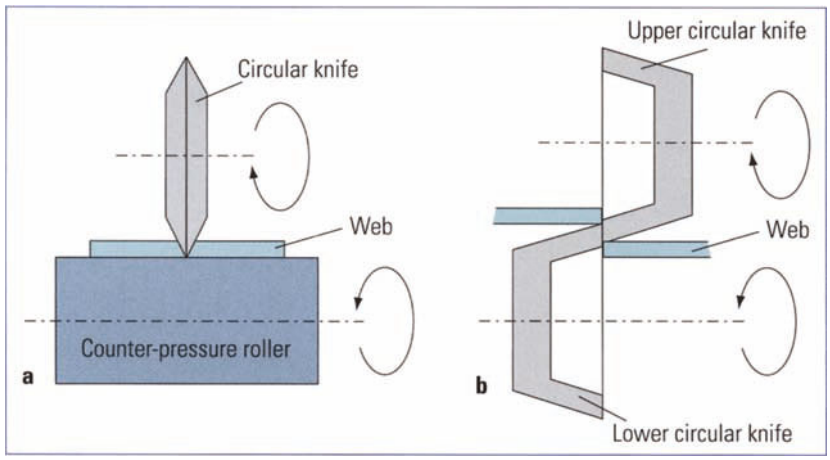


Fig. 7.2-9 Principle of knife cutting.
a Longitudinal knife cut;
b Axial shear cut

which work either according to the shear cut or the knife cut principle.

Knife Cut – longitudinal cutter. The knife cut is also referred to as the pressing or crease cut. To set the width of the cut, the circular knife is moved axially on the slitter shaft. The cutting principle is used in particular when cutting narrow webs in longitudinal cutting machines.

Shear Cut – longitudinal cutter. With the shear cut principle, the upper knife is pressed onto the lower knife, whereby the web is divided by shearing forces. To set the width of the cut, the circular knife is moved axially on the slitter shafts. The cutting principle is used to divide webs.

The circumference speed of the circular knife is approximately 10 to 15% greater than the web speed, and so a drawing cut is the result.

Burst Cut. In addition to the principles shown in figure 7.2-9, longitudinal cutting can also be carried out as a burst cut. With the burst cut there is no counter-pressure tool to the knife. The shearing strain is achieved by the web tension. The razor-blade cut is a special example of the burst cut.

Cross Cutting of Webs

The cut takes place crosswise to the web edge. The web is cut into sheets. The cutting movement takes place perpendicular to the web surface. To be able to carry out an exact cut, the web must be stationary during cutting, or the knife must move in the direction of web travel. Both methods are used for processing paper.

The shear cut is the cutting principle predominantly used. Frequently used cross-cutting variants are compared in figure 7.2-10.

Simple Cross Cutters. When the cut is taking place, the web must be stopped below the knife. This is achieved with the dancing roller which moves against the travel direction of the web. To avoid a rough cut over the whole web width, the knife is tilted towards the web surface. This results in a chronological cutting sequence. This principle is mainly used for separating slow running webs.

Rotary Cross Cutters. The cut takes place during the movement of the web. In the example, a rotating upper knife works against a stationary lower knife. A chronological cutting sequence is achieved by the upper and lower knife being on the web surface at an angle (0.5° to 2.0°) to one another. Rotation cross cutters are required to separate fast running webs.

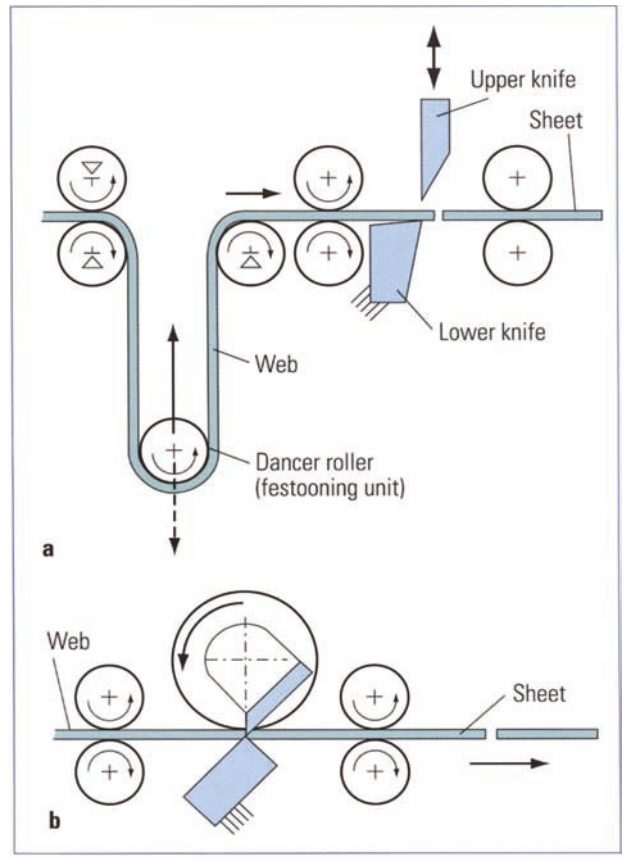


Fig. 7.2-10 Structure of cutters.
a Cross cutter;
b Rotary cross cutter

The designs of rotary cross cutters for carrying out a chronological cutting sequence are diverse. Distinguishing features are for example:

- *Cutting edge geometry*
  The upper knife is installed on the surface line of the rotation cylinder (perpendicular to the web edge)
  → The lower knife is of helical shape or is v-shaped, the upper knife is of helical shape
  → The lower knife is placed perpendicularly to the web edge

- *Knife movement*
  - Stationary lower knife and rotating upper knife
  - Rotating upper knife and lower knife
- *Knife speed*
  - The circumferential speed of the rotary cylinder(s) and the web speed are the same (synchronized cutter)
  - The circumferential speed of the rotary cylinder(s) is greater than the web speed (advance cutter).

By raising the circumferential speed of the cutting cylinder as against the web speed, the cut-off length can be reduced.

In the graphic arts industry, longitudinal and cross cutting units are usually integrated within printing or paper processing machines (see also secs. 2.1.2 and 2.1.3).

In addition separate web cutting machines are used where paper reels are commissioned in paper production, paper finishing, or packing material production:

- *Longitudinal cutters* (reel slitters) produce reels of narrow ribbons (5–50 mm). It is particularly difficult to roll up ribbons precisely and to achieve constant reel tightness with this. One way of separating the webs is managed by the fact that cutting-off wheels run between the webs, or that the ribbons running next to one another are wound on different shafts. The web speed of reel slitters is up to 10 m/sec.
- *Rotary cross cutters* are used to produce precisely dimensioned print sheets from paper webs. This requires longitudinal as well as cross cutter units. Several reels are processed simultaneously for ordinary quality requirements of the printing material. In the system configuration in figure 7.2-11 four webs are being cut simultaneously.

Sheets that have particular quality requirements (no stains, holes, creases, sticking patches), are dimensioned on sorting cross cutters. The individually unwound web is scanned optically, cut, and the sheets with quality flaws are automatically singled out.

7.2.1.4 Die-Cutting

With a number of products and semi-finished products, die-cutting is an important working method in finishing. Section 7.3.2.1 (Labels) contains additional information on die-cutting.

In contrast to cutting and trimming where the material is cut in a straight line, *die-cutting* is a process in which materials are cut in a specific pattern. Normally these products are produced in a closed cutting line. Sometimes, however, open cuts are produced, for instance, to round off corners on book blocks, playing cards, and so on, as well as register punching (index thumb, index sequential, etc.). Perforating, where material is removed, is also referred to as a die-cutting operation.

In figure 7.2-12 a differentiation regarding the goal of the die-cutting process is explained. In both cases, a closed cut is produced on a semi-finished product using a (round) die-cutting tool.

When cutting the substrate itself into a specific pattern, the outer form of the product is maintained. This operation is used to prepare processing and service areas on the product (process section), such as tear-off

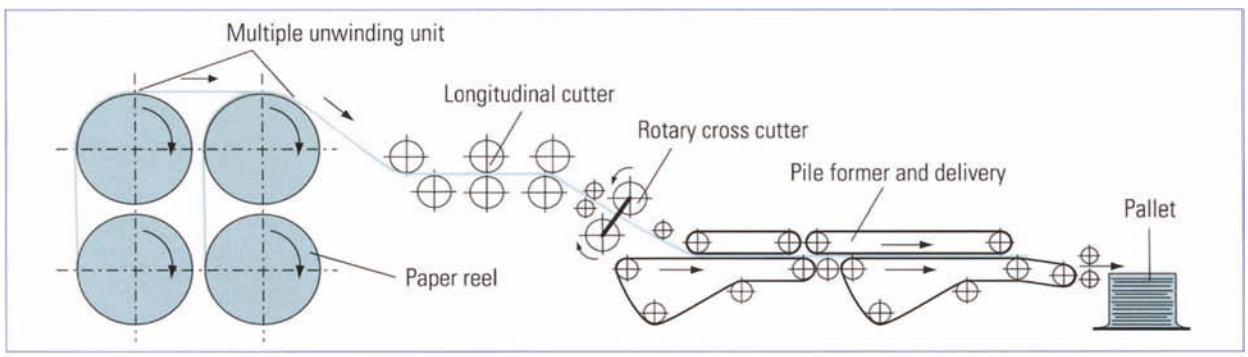


Fig. 7.2-11 Rotary cross cutter (cutting 4 webs)

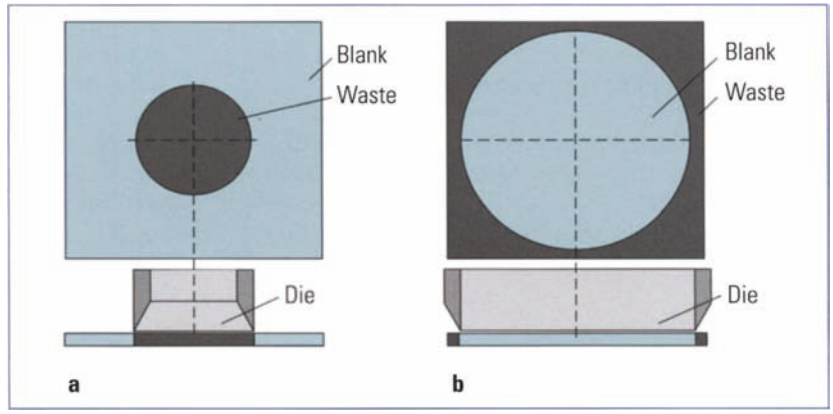


Fig. 7.2-12
Processing purposes of die-cutting operations.
a Cutting the substrate itself into a specific pattern;
b Cutting a specific pattern into a substrate

lines, finger holes, viewing windows, and so on; the cut-out material is then waste. Typical products are

- tear-off calendars with hole perforation,
- continuous forms with line hole punching,
- envelopes and folders with viewing windows,
- files with finger holes,
- brochures with wire comb and spiral binding, and so on (perforation to insert the binding elements).

When cutting a specific pattern into a substrate, the product is given a new geometrical shape. The waste is on the outside. Typical products not having straight edges:

- labels where the corners are rounded off, special shaped labels,
- beverage mats, coasters, stands,
- playing cards, figures, transfer pictures, jigsaw puzzles,
- garlands, joke articles,
- blanks for folding boxes and other packaging material,
- indexes.

The technical realization of die-cutting jobs varies considerably. The following diagram (fig. 7.2-13) contains those variants that are essential for industrial finishing operations.

For die-cutting of paper, card, and board, the knife cut method is mainly used, as the manufacture of knife cutting tools is simpler and therefore cheaper than for shear cutting tools. With shear cutting tools the shape,

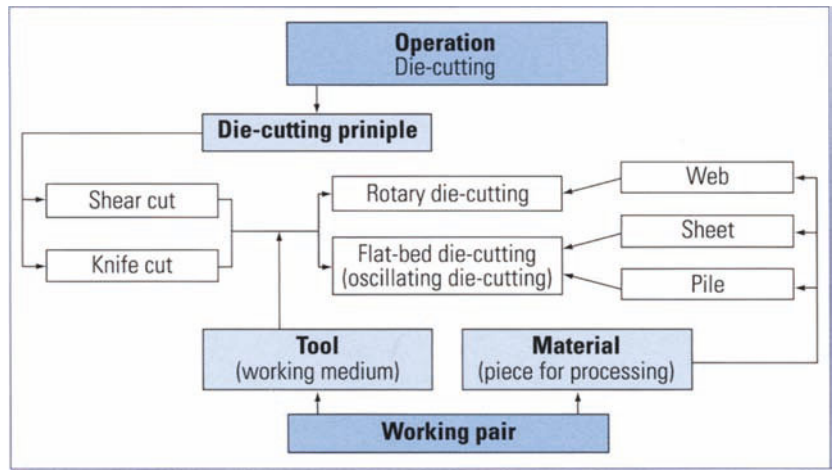


Fig. 7.2-13
Diagram of the die-cutting operation

the die, and the counter tool need to be adjusted to one another very accurately and the vertical movement of the die to the cutting plate lower tool requires a complicated guiding system.

Tools for punch perforation represent an exception as they need to be designed for long service life. The flatbed shear-cutting for tear-off perforations and for the insertion of binding elements into loose-leaf brochures is done with perforating combs. The moved punching elements (e.g., needles) are guided in a special way.

Line hole punching of continuous forms takes place in the printing press with shear cut rotary die-cutters, a sprocket hole punching machine. They have a die wheel onto which the punching die is fixed and a die wheel that carries the lower knives. During perforation the dies move cyclically into the holes of the "female" die wheel. Therefore the dies have only a little immersion depth (< 0.5 mm). The rotary movement of the die wheel (female) is achieved by the forward movement of the dies. This means that several dies move into each hole on the female die wheel.

For cutting a pattern into a substrate and for cutting the substrate itself into unevenly shaped patterns using the knife cut method the following *equipment* is mainly used:

- column and bridge die-cutters, mostly to cut product piles,
- automatic through die-cutters with a permanently fixed punching tool to cut product piles (see sec. 7.3.2.1),
- automatic vertical die-cutters and platen die-cutters to cut sheets,
- rotary die-cutting sub-assemblies as modules in web offset presses to cut webs.

Column and Bridge Die-Cutters

Column die-cutters are simple machines where the products are loaded and removed manually by the operator. In the most simple construction, a pile is placed on the cutting base (flat counter tool) and a cutting tool is put on top of the pile manually in accordance with the pattern or register mark. The die-cutting arm is then swiveled horizontally above the tool and the cutting process is started. Finally the die-cutting arm is swiveled back again, the waste removed, and the cut blank taken out of the tool. These operations can be automated, and an example of such an automatic column die-cutter is illustrated in figure 7.2-14.

Dies (fig. 7.2-12) are forged tools with an inner or outer ground edge. The knives are shaped in accordance

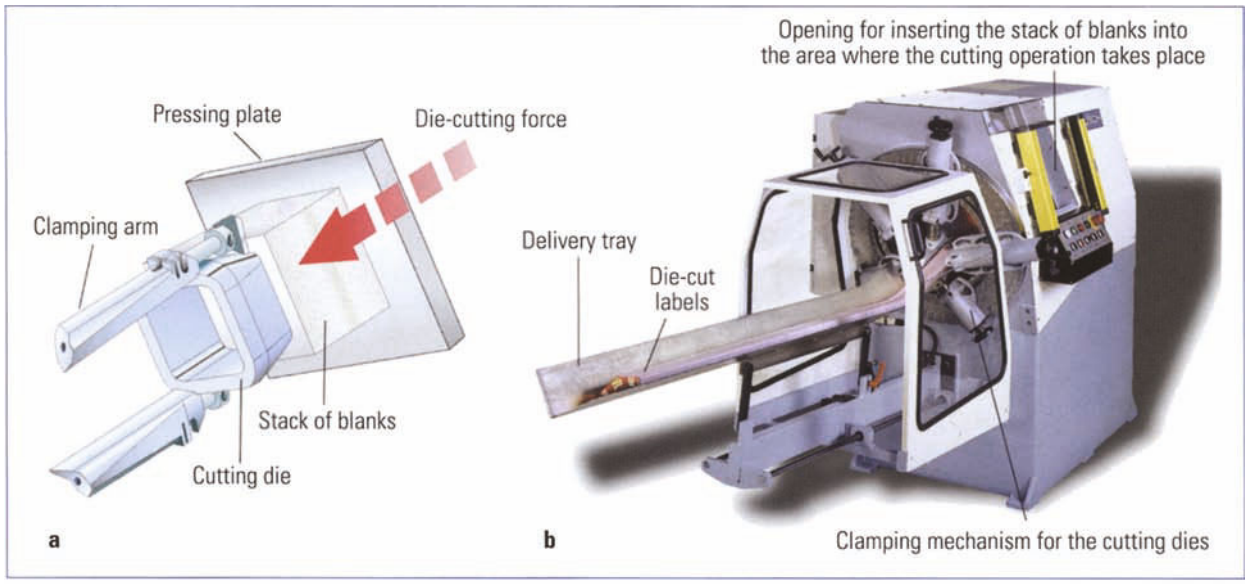


Fig. 7.2-14 Column die-cutter in horizontal construction.
a Schematic structure of the die-cutting tool;
b Die-cutter (Busch)



Fig. 7.2-15
Hydraulic flat-bed/bridge die-cutter with reversible bridge (Model 6100B, Schön & Sandt)

with the cutting pattern and the angle of bevel is between 15° and 18°. They are either made as through-cut tools or are equipped with a product ejector in the case of low cutting depths. The making of dies is very labor-intensive since it is difficult to mechanize operations.

Bridge die-cutters (fig. 7.2-15) have two or four columns. The products are placed on a cutting table underneath the cutting bar. During the die-cutting process the bar moves towards the cutting table. To load and unload the products, the table is moved to the side so that the die-block is accessible on the table. For this purpose it is carried on a stable slideway. In some configurations, the die (with ejector plate) is attached to the cutting bar. The products are then arranged on the cutting table at a three-point alignment.

Vertical Platen Die-Cutters

With these types of die-cutters, the products are cut out from printed paper, card, or board sheets. The sheets are separated in conventional vertical pile feeders and transported through the machine by means of a gripper chain. The sheets are cut one by one using vertical platen die-cutters; the waste is removed and the individual blank delivered. The working principle is shown in figure 7.2-16.

The platen die-cutter is based on the knife cut principle. The die is fixed to the chase of the cutting bar (also called "fundament"). The cutting table moves towards the fundament. The table is driven by a camshaft and toggle lever (see fig. 7.2-17). The sheet is stationary during the cutting operation. After the cut, blanks and waste are still sticking together. This facilitates the conveying of the products through the machine and the disposal of waste. In a waste-stripping station, tools push the waste into a container. The individual blanks are still connected by attachment points.

The final process section is the separation of the blanks in the delivery. In this process, the gripper edge (if there is one) needs to be removed from the blanks and the blanks themselves need to be separated. Simple vertical die-cutters are not equipped with a separating unit of this type. This operation must then take place manually outside the machine.

Figure 7.2-17 shows the characteristic structure of a vertical die-cutter. The platen die-cutter is either equipped with steel-rule dies or magnetic die plates. With both types of tools, productive makeready of the machine for a job is possible since all cutting knives are arranged in one tool in accordance with the pattern to be cut out on the sheet.

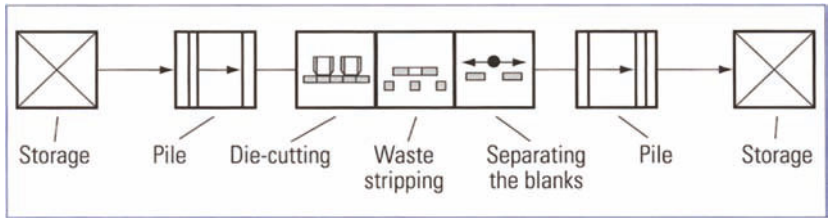
Steel-rule dies include a plywood base (multi-layer, 16 to 18 mm thick), in which the steel rules are inserted. Figure 7.2-18 illustrates the structure of these tools. Tracks are cut into the plywood base in accordance with the cutting pattern and the imposition pattern of the blanks on the substrate. The steel rules are inserted into these tracks (see fig. 7.2-18b). To stop the inner plywood sections from falling out, the track is interrupted by crosspieces. The steel rule has recesses at these places (fig. 7.2-19).

To cut the contours into the base, computer-controlled laser cutters are used. The data that is used to control the laser is the same as was produced for the development of the die-cutting products and for the sheet imposition.

Release material, made of rubber, presses the sheet down on the cutting table when the die is opened (see fig. 7.2-18a). In this way the sheet is transported smoothly into the stripping station.

With steel rule dies it is also possible to score and crease the products at the same time. For scoring, shorter steel rules are used than is the case with cutting. Steel rules for creasing are rounded off at the top. Two plastic rails serve as counter tools; the creasing tool sinks in between these two rails (fig. 7.2-18).

Fig. 7.2-16
Working principle of the vertical die-cutter



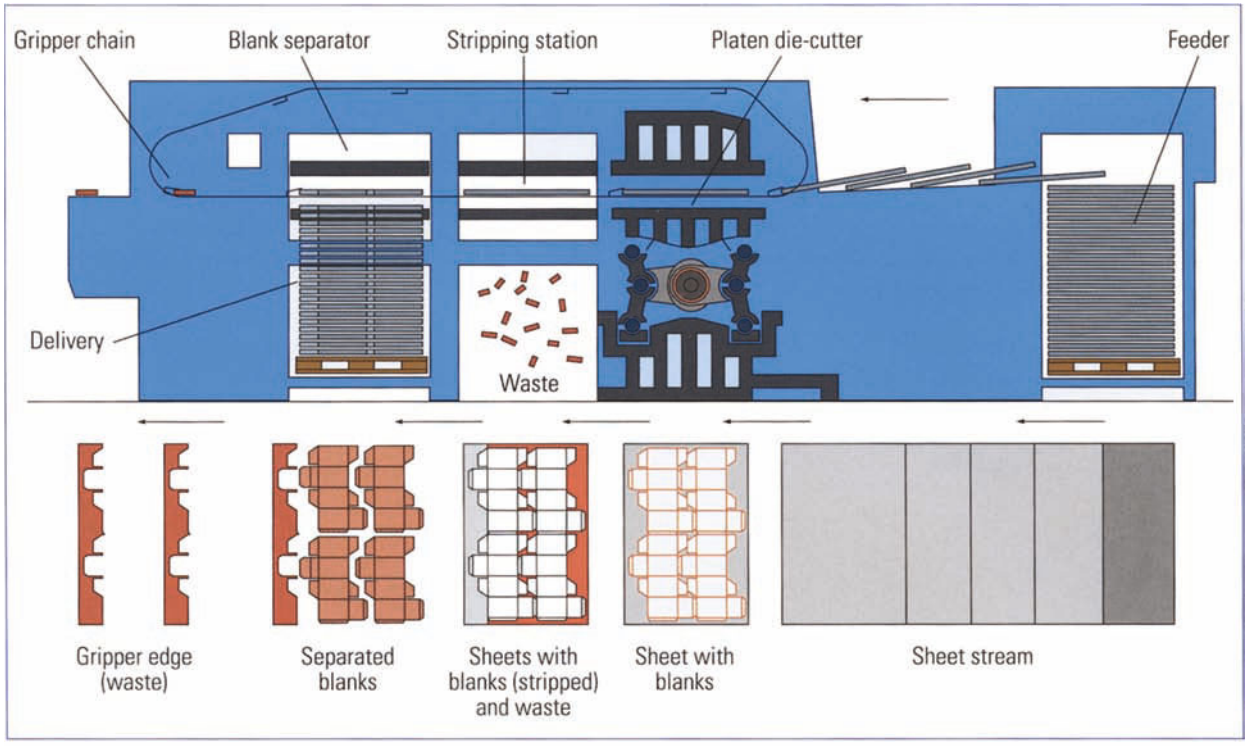
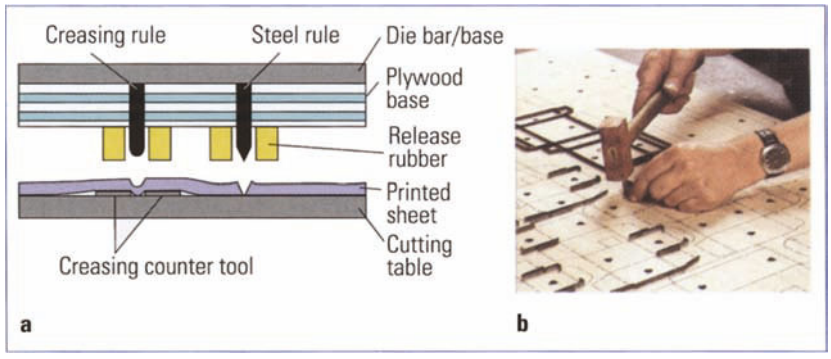


Fig. 7.2-17 High-speed die-cutter (Bobst)

Fig. 7.2-18 Structure of steel-rule dies.
a Diagram;
b Making a tool



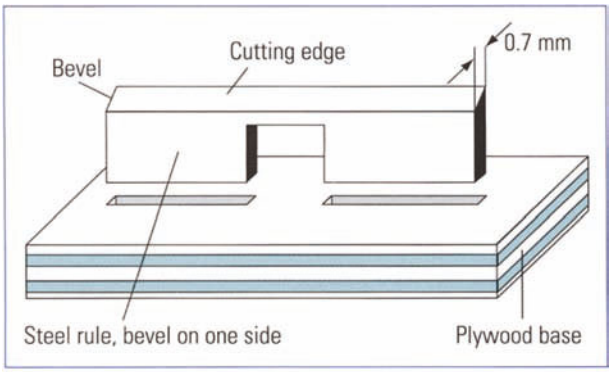


Fig. 7.2-19 Inserting the steel rule into the plywood base

Specially equipped vertical die-cutters are able to do embossing or relief embossing operations. For hot-foil stamping

- the base must be heatable (regulated heating up of the stamp), and
- the machine must have an unwinding and rewinding unit for the foils.

Magnetic cutting dies represent an alternative to the steel-rule tool, in particular for cutting card (thickness < 0.3 mm). The platen die-cutter must be equipped with a magnetic base. The magnetic dye-cutting plates have a normative thickness of 0.44 mm (thicker steel plates are used for special applications). To produce the cut, scoring, microperforation, and creasing contours the plate is first etched. Here, similar methods as for the production of gravure printing masters are applied. In the next step, the cutting rules (cone) are ground on computer-controlled milling machines so that an accurate cutting geometry is produced. To increase service life, the cutting edge and the knife flanks can be hardened by means of laser technology. The distinguishing features of magnetic dye cutting plates are absolute contour accuracy, long service life of tools and little makeready work.

Rotary Die-Cutters

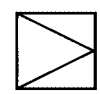
Continuous forms, adhesive labels, mailings, and similar products in long print runs are mainly printed on small-format web (narrow web) offset presses. To finish the webs these machines can be equipped with rotary die-cutters in addition to folders, and perforating and cutting units. The cutting-die assembly, which operates on the knife cut principle, consists of:

- A cutting cylinder that holds the die. As with impression cylinders, this cylinder can also be replaced when another format is being processed.
- The anvil cylinder; this is the smooth impression cylinder with an unchangeable circumference.
- The extraction unit, which removes the cutting waste.

Figure 7.2-20 shows the finishing system of a printing press, which can be used for processing continuous forms. The die-cutting unit (first station) can be replaced by a second file hole puncher. Magnetic die-cutting plates can be used as die-cutting tools. The die-cutting cylinder must then be configured as a magnetic cylinder. For very long runs, compact cylinders are also used.

7.2.2 Folding

7.2.2.1 Characterization of the Process



Folding is the sharp-edged bending of paper webs or sheets under pressure at a prepared or unprepared bending point along a straight line according to specified dimensions and folding layouts [7.2-2]. The folding line is referred to as the fold in bookbinding terminology. The materials/partial products to be processed are webs and bookbinding sheets. The term *bookbinding sheet* is chosen for a sheet lying flat that is to be folded (fig. 7.2-21).

The folding variants are listed in table 7.2-4. The new products created by folding are given in table 7.2-5.

7.2.2.2 Folding with Folding Machines

Folding machines are primarily designed according to two principles of function (fig. 7.2-22):

- the buckle fold principle,
- the knife fold principle, also known as the right-angle fold principle.

Buckle Fold Principle. The bookbinding sheet is transported through the upper and lower folding roller into the buckle plate. The sheet bumps against the buckle stop so that due to the movement of the folding roller a buckle is created. The buckle is now taken up by the

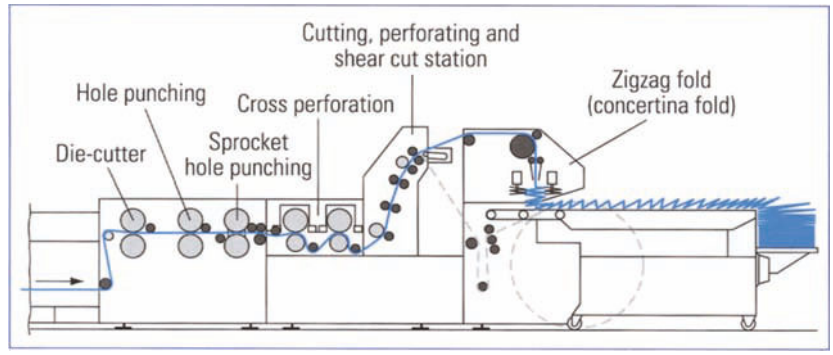


Fig. 7.2-20
Finishing system for continuous forms (Müller Martini)

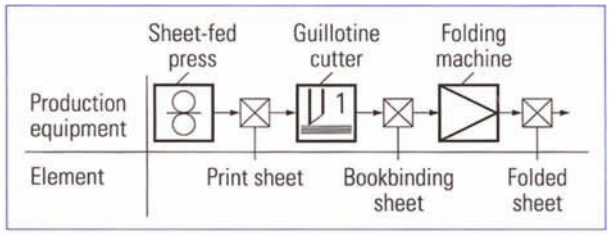


Fig. 7.2-21 Elements of sheet processing

Material	Direction of folding	Result of folding	Equipment (Examples)
Web	Lengthwise to the web Crosswise to the web Lengthwise and crosswise to the web	Web → Folded paper web (ribbon) Pile → Continuous paper pile (concertina fold) Folded sheet → Rotary folded sheet	Former fold, plow fold Form folding apparatus Jaw folder
Sheet	Lengthwise and crosswise	Folded sheet	Sheet folding machine

Table 7.2-4 Folding variants

Table 7.2-5 Examples of folded products

Intermediate products	End products
Folded sheets For production of book blocks, multi-layer brochures and back-stitched brochures	*Folded brochures* For industry, trade and culture *Mailings* with various designs. By using cutting and joining units within the folding machines, letters, envelopes, etc., are cut and folded from sheets, and envelopes are folded up. Fold-glued *single-layer brochures* usually up to 32 pages. Use of strip gluing units and cutting devices integrated in folding machines

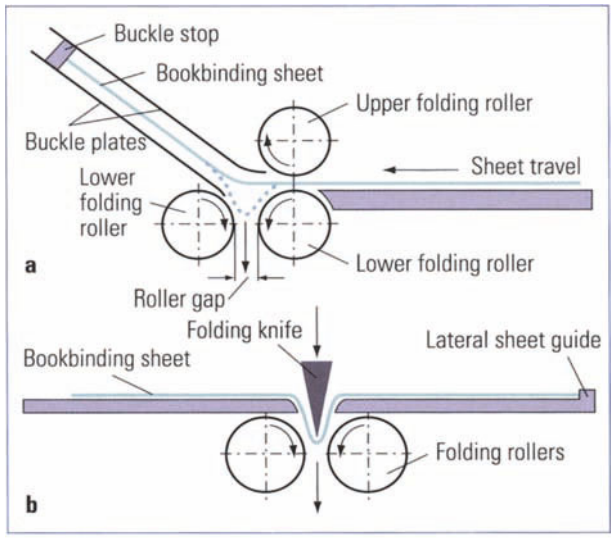


Fig. 7.2-22 Folding principles in sheet folding machines.
a Buckle fold principle;
b Knife fold principle

lower folding rollers. The fold is created between the folding rollers.

Knife Fold Principle. The bookbinding sheet is fed between the folding knife and the folding roller. The folding knife adjoins the sheet of the specified folding line between the folding rollers. Between the folding rollers, the fold is formed.

Buckle Folding Unit

Three folding rollers and a buckle plate limit the folding space in which the buckle fold in the paper is formed. The correct folding space geometry, namely the diameter and location of the folding rollers in relation to one another, the development of the upper and lower buckle plate in-feed, and the engagement of the buckle plate are prerequisites for reliable and accurate folding. The rotating folding rollers enable a continuous folding process. A setting device serves to aid rapid setting of the *folding roller gap* where a number of strips corresponding to the sheet thickness of the print job paper are pushed into a clamp (fig. 7.2-23).

The design of the folding rollers is of particular significance for ensuring good folding quality. They must convey the sheet in a slip-free, directionally accurate, mark-free manner. The availability of elastic and resistant polyurethane plastics with self-cleaning properties has resulted in the development of rollers with "composite surfaces," as the examples in figure 7.2-24 show.

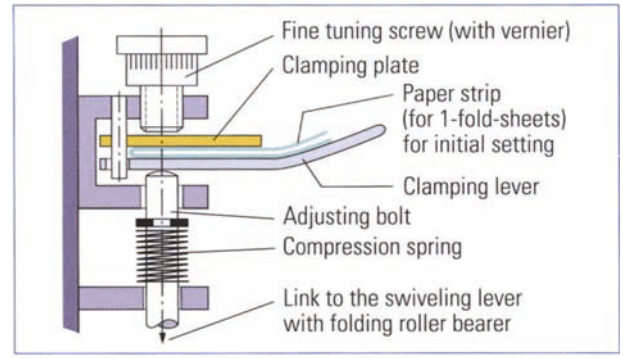


Fig. 7.2-23 The principle of adjusting folding rollers (roller gap)

In the roller couple having the roller surface as shown in variant 4 a steel and polyurethane ring run against each other. The plastic rings have low slippage properties while the steel body eliminates electrostatic charges in the paper.

The striking of the sheet edge onto the buckle plate stop creates typical noises. This effect cannot be fully prevented. Therefore, buckle fold units are equipped with noise hoods. The buckle plate is a bar-like construction with a small contact surface for the sheet. The buckle plate stop, which is primarily responsible for the location of the fold on the sheet surface, can be precisely adjusted on the buckle plates. The formation

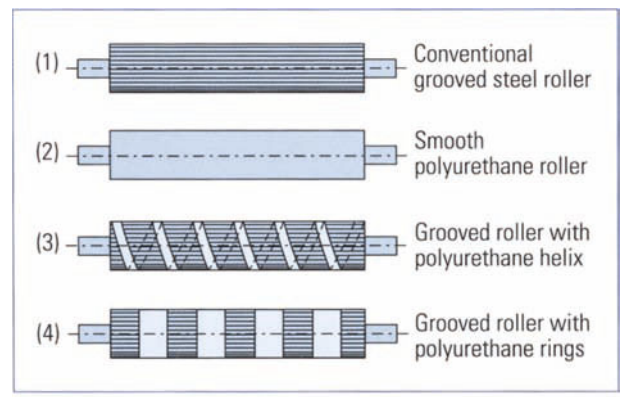


Fig. 7.2-24
Types of folding rollers with homogeneous and composite surfaces

of the buckle fold is, moreover, determined by the nature and feeding speed of the sheet. Therefore, folding machines must be adjusted in accordance with the type of material to be folded and the production speed.

The space-saving, compact design of a buckle folding unit allows the simple series connection of folding modules to folding machines, as shown in figure 7.2-25.

Usually, a folder has two to eight series-connected folding modules (four upwards and four downwards). For special machines, a considerable increase in modules is possible. Folding modules that are not needed are deactivated by sheet deflectors, which are either integrated in the buckle plates or installed in the folding unit in place of the buckle plates. Within buckle plate folders only parallel folding (the folds that follow one another run parallel) can be carried out.

In addition to continuous mode of operation and high variability of buckle folders, the following features should be particularly emphasized:

- high effective output,
- low folding tolerances,
- simple design.

However, buckle folders are sensitive to

- too light paper (< 40 g/m²) and too heavy paper (> 120 g/m²),
- extreme electrostatic charging (static electricity) of printing paper.

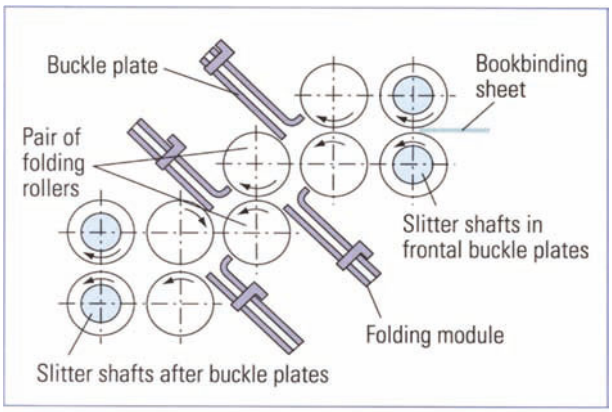


Fig. 7.2-25
Buckle folding unit with four folding modules and slitter shafts

Knife Folding Unit

The bookbinding sheet is aligned to the front edge and one side edge, and is transported between the folding knife and folding rollers (fig. 7.2-26). Triggered by the position of the sheet in the folding unit (opto-electronic sensor), the folding knife strikes the sheet on the specified folding line between a pair of folding rollers.

With an oscillating cyclical movement, the folding knife moves to a gap between the rollers where the fold can be carried out safely. Folding knives are very stable and at the same time lightweight in construction.

The design of knife folding units prevents such rational parallel switching of folding units as is possible with the buckle folding method. In order to increase variability of the knife folding units, they could be coupled to a buckle plate. If the additional buckle folding unit is not needed, it can be excluded by means of a sheet deflector. The buckle folding unit folds parallel to the knife folding unit.

For knife folding units, the following features are to be emphasized:

- not sensitive to extreme kinds of paper,
- low folding tolerances.

Compared to buckle folding units the principle has, however,

- a more complicated structure,
- less folding variability.

Additional Functions in Folding Units

Tool carrier shafts are installed immediately in front of and/or behind the folding units; they permit additional functions such as

- cutting,
- perforating,
- creasing, and
- joining (e.g., gluing, welding),

all in the direction of sheet travel. The location of the tool shafts (commonly known as "knife shafts") is shown in the example of a simple buckle folding unit in figure 7.2-27.

Circular knives are mounted onto the knife shafts. The circular knives are of varying shapes so that not only cutting but also perforating, punch perforating, or creasing is possible (more than one hundred different shapes and sizes are available). They are selected ac-

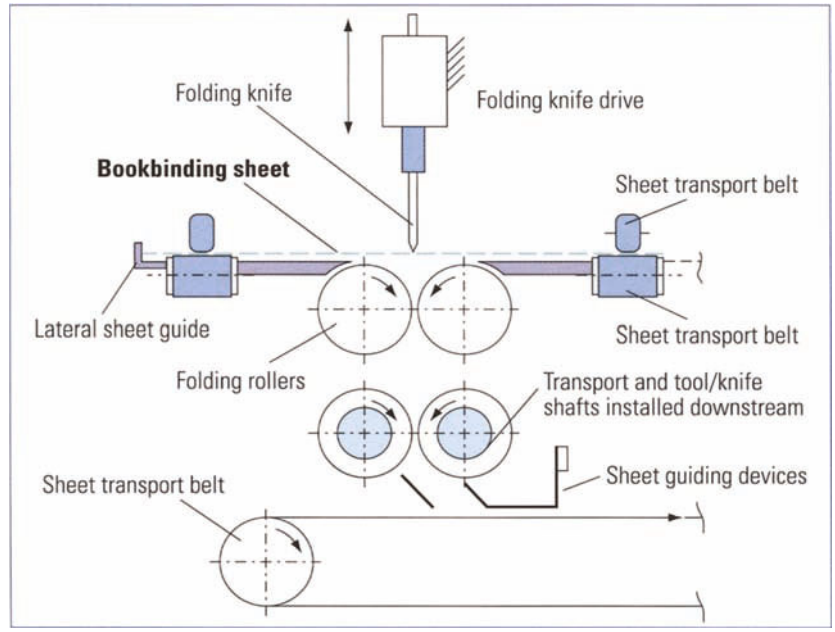


Fig. 7.2-26
Schematic representation of a knife folding unit

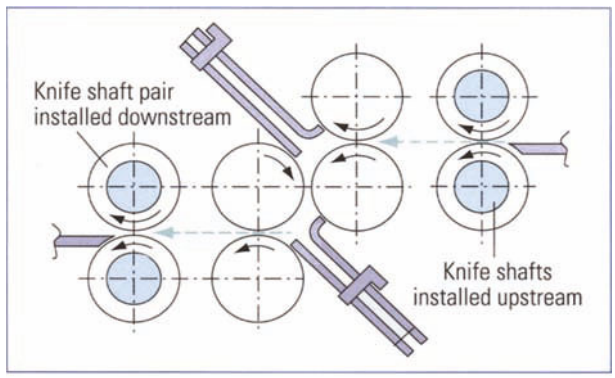


Fig. 7.2-27 Knife shafts in a buckle plate folding unit

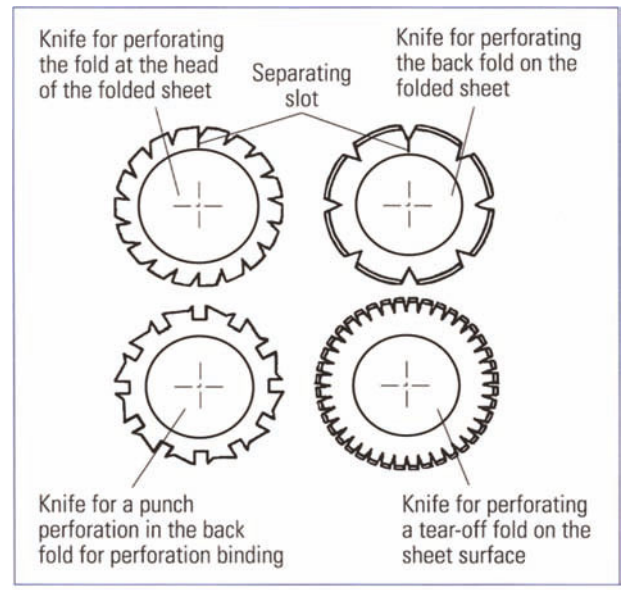


Fig. 7.2-28 Example of perforating tools for knife shafts

cording to the specific processing function. Four examples of perforation tools are shown in figure 7.2-28.

To install the tools, the knife shaft must either be removed from the folding unit, or the tool be bent so far apart at the separating slot that it can be pushed across the shaft.

Folding Machines

Folding machines consist of technological modules (folding units, feeder, delivery, etc.) that can be arranged by the manufacturer to perform a specific task or put together according to customer requirements. The *basic modules* are listed in table 7.2-6.

Moreover, further modules such as gluing units, thread-sealing units, gatefold units, or sheet presses can

	Feeder: Piles or sheet streams are fed into the press by operators. In the feeder, the folded sheets are separated, aligned, and transported into the first folding unit.
	Folding units: In the folding units, the process tasks are realized. They can be distinguished as: • Buckle folding units – in which only the buckle folding method is applied. Each buckle folding unit has a separate drive. • Knife folding units – usually additional modules in each of which one knife fold is carried out. • Combined folding units – are compact systems in which one buckle folding unit and at least two knife folding units are interlinked (arranged crosswise) with one another.
	Conveyance units: The conveyance units transport the sheet to be folded from the feeder into the first folding unit and between the folding units. At the same time they align the sheet to an edge parallel to the direction of travel by diagonally arranged transport rollers or tapes.
	Deliveries: Deliveries on folders are technological modules that are equipped with a separate drive, can be coupled to different exits of the folding machine, and deliver the folded sheet in a way that the operator can easily remove it.

Table 7.2-6 Basic modules of folding machines

be integrated. An electronic control module takes over the networking of the technological modules, some of which have a separate drive. Quality control, job management, or machine statistics are also carried out by this control module.

Primarily used folding units are

- buckle folding machines (fig. 7.2-29) and
- combined folding machines (fig. 7.2-30).

Buckle Folding Machines. In buckle folding machines, up to four independent buckle folding units can be interlinked. The relative position of the folding units to one another can be altered according to the job. To produce right-angle folds (the successive fold is carried out at an angle of 90° to the previous fold), the folding units are arranged at an angle of 90° to one another. The folding units are normally fitted with 2 to 8 buckle folding modules, whereby the first folding unit has the most buckle folding modules and the last folding unit has normally only two buckle modules.

Within a type of folding unit there are module variations whose size scale is determined by the sheet infeed width, such as 36 cm, 52 cm, 56 cm, 66 cm, 78 cm, 94 cm, 112 cm, 142 cm. The size scale follows frequent printing sheet sizes and bookbinding sheet sizes.

In contrast to printing presses where the sheet is usually fed sideways, that is, with the longer sheet edge in front, with a folding machine it is usually fed lengthways to the first folding unit, that is, with the shorter sheet edge in front.

In a four-unit buckle folding machine up to eighteen folding modules can be used. There is no single folding task for which all the folding modules are required.

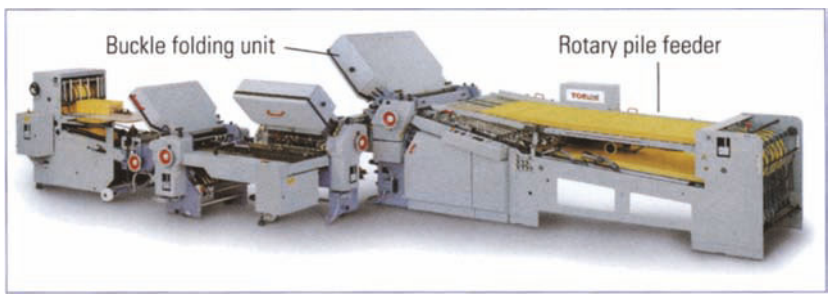


Fig. 7.2-29
Buckle folding machine with noise insulation hoods, max. format 78 cm × 116 cm and rotary pile feeder; folding unit layout shown in fig. 7.2-37
(Topline TD 78, Heidelberg)

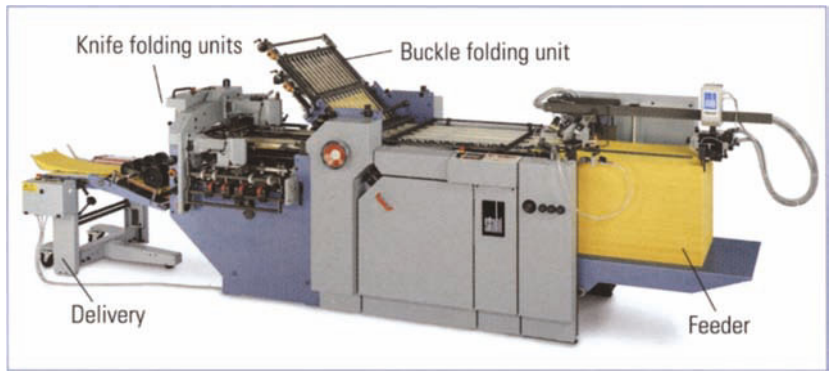


Fig. 7.2-30
Combined folding machine with buckle folding and knife folding systems and vertical pile feeder
(Proline KI 55, Heidelberg)

In general, the number of folds comes to one to six per bookbinding sheet. Because it is possible to rearrange folding units and also activate or deactivate individual folding modules, the number of possible fold variations is very large, on account of which various special folds can be planned and carried out alongside standard folding patterns. In this diversity lies the principal advantage of buckle folding machines.

Figure 7.2-29 shows a buckle folding machine equipped with a rotary pile feeder (fig. 7.2-31), three buckle plate units and a delivery. Two of the buckle plate units have four folding modules and the third has two. The machine produces right-angle folds. If eight concertina folds are required for a job, the second folding unit can be swiveled by 90° and positioned in a straight line behind the first one. The delivery is then located behind the second folding unit.

Combined Folding Machines. These folders are made up of a combination of buckle folding units and knife folding units. The folding machine shown in figure 7.2-30 is a buckle folding unit with four to eight folding modules and two to three knife folding units coupled rigidly to one another. The buckle fold unit is installed in front of the knife folding units. The first knife folding unit is positioned at an angle of 90° to the buckle fold; the second one, underneath the first one, is arranged for a right-angle fold. In front of the folding unit stands the feeder and behind it the delivery, which can be moved to two or three exits in accordance with the folding pattern. If necessary, this configuration can supplemented by a further buckle folding unit arranged at a right angle. For ordinary folding tasks in print finishing companies, this variability is sufficient. Moreover, combined folding machines are distinguished by a range of further features:

- They require less working space and are cheaper than comparable buckle folding machines.
- Paper with extreme characteristics (e.g., lightweight paper or bulky paper) can be folded more easily than with buckle folding machines.
- The machines can be converted for a different job in a few minutes.

This machine type is also offered for various processing widths (e.g., 56 cm, 66 cm, 78 cm, and 94 cm).

Fig. 7.2-30 shows a combined folding machine with an infeed width of 55 cm. The machine consists of a vertical pile feeder, a combined folding unit, and a stream delivery. The maximum sheet size to be processed is 55 cm × 90 cm. The folding machine is principally designed for the production of cross folds.

Feeder. The reliability factor of folding machines for bookbinding sheets is determined by the degree of development of the feeder's mechanical design since most production interruptions occur when the sheet is separated from the sheet pile and when it is transported to the folding unit. Five different feeder principles are used in sheet folding machines.

Rotary pile feeders (fig. 7.2-31) are the most frequently used feeders for high to medium runs. They are predominantly used for sheet sizes greater than 70 cm × 100 cm. The sheet piles are taken manually from the pallet, laid onto the feeder table, and spread into a sheet stream. The sheet stream is conveyed on transport belts and the reversing drum to the separating table. The sheet stream is arranged such that the sheet to be separated can be taken from above. The suction roller separates the upper sheet and transports it out of the feeder; usually it is supported in this process by blower nozzles. The rotary pile feeder is a nonstop feeder offering high relia-

bility since (manual) pre-separation takes place due to the shingling of the pile. The disadvantage is the high physical burden on the operator in placing the sheet pile onto the feeder table and shingling the pile.

Vertical pile feeders are frequently used for small to medium job runs and are predominantly used for sheet sizes smaller than 70 cm × 100 cm. The principles of the vertical pile feeder correspond to those of sheet offset presses (see 2.1.2.2); an example is shown in figure 7.2-30.

The *pallet feeder* is a type of feeder seldom used in finishing. It is predominantly installed for direct finishing of printed sheets in large sheet-size folding machines (similar to fig. 2.1-161).

The *stream feeder* (fig. 7.2-32) is suitable for folding machines processing small formats and small runs (approx. less than 10 000 sheets per job). Stream feeders are nonstop feeders. Separation is achieved with a front upper suction roller, that is, the top sheet is transported. Therefore, when reloading the feeder, the sheets must be pushed underneath the end of the *sheet stream* in the feeder. This simple and reliable separation method is especially intended for small-format folders (infeed width less than 40 cm). The sheet stream in the feeder is fanned out by air nozzles located in the side frames.

Box/suction feeders (fig. 7.2-33) are predominantly used in office folding machines for the smallest sheet-size range and folding the shortest runs. Box feeders have a lower, front suction roller separation. They are nonstop feeders. However, because of the pile weight, the maximum pile height is limited to approximately 8 cm. Box/suction feeders are not suitable for industrial folding.

Deliveries. Deliveries on folding machines show an even greater diversity than that of feeders. In the area of delivery extra tasks can be carried out by installing additional units:

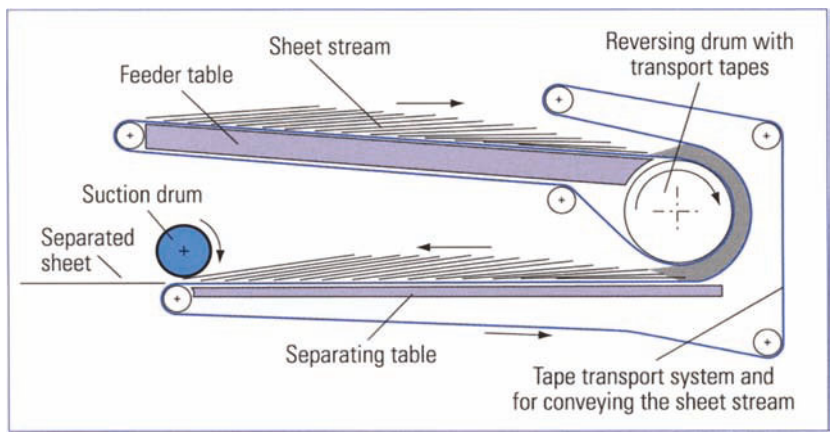
- Backfold pressing attachments improve the storing properties and workability of folded sheets.
- Stacking units are used to improve stacking coordination and to check the quantities.
- Strapping final folding products for dispatch in accurate quantities.

Deliveries can principally be categorized by type such as stream deliveries, upright sheet deliveries, vertical pile deliveries, and bundle deliveries.

With *stream deliveries* (fig. 7.2-34) the folded sheets arrive shingled in the delivery and can be removed by the operator in portions, jogged into packages, and set down on a pallet. In finishing this form of delivery is very popular if somewhat labor intensive. It is cost-effective and easy to handle. This type of delivery is offered in various modified versions. Stream deliveries have proven themselves to be especially effective for finishing short print runs and variable production structures.

In the case of an *upright sheet delivery* (fig. 7.2-35) the sheets are placed on their backs and form horizontal piles. Portioning into packages by shifting the pile is possible. Upright sheet deliveries simplify manual removal of the sheet packages and therefore lead to a better performance. Therefore, these deliveries are favored for use in high performance folding machines producing long run jobs.

Fig. 7.2-31
Rotary pile feeder in folding machines with sheet reversal (see also fig. 7.2-29)



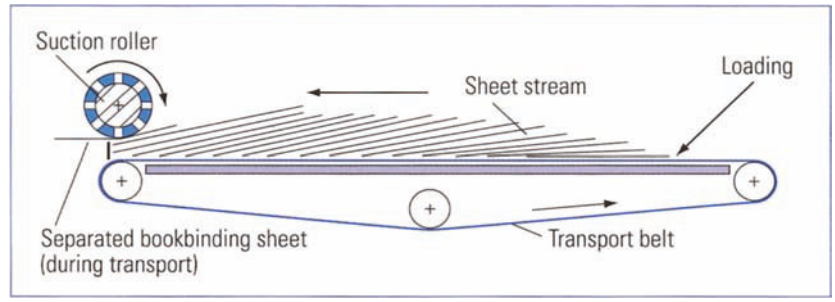


Fig. 7.2-32 Principle of the stream feeder

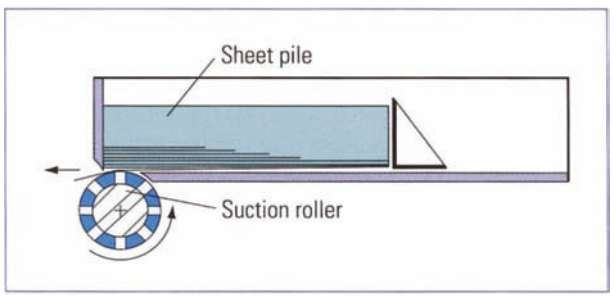


Fig. 7.2-33 Principle of the box/suction feeder

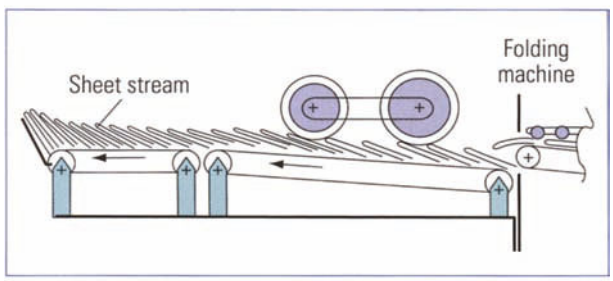


Fig. 7.2-34 Stream delivery on a folding machine

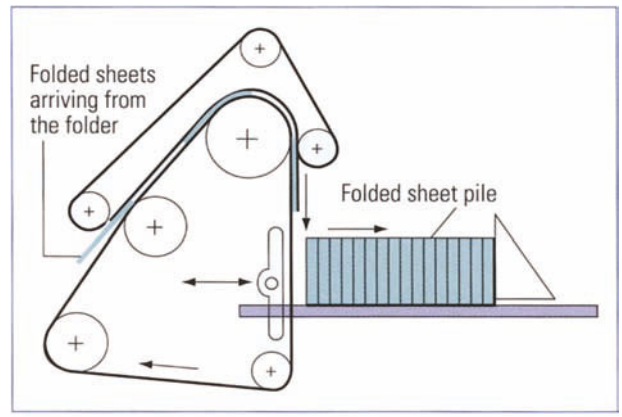


Fig. 7.2-35 Upright sheet delivery on a folding machine

In the *vertical pile delivery* an upright positioned pile with folded sheets is formed in the delivery. This delivery can be coupled with a strapping unit.

In *bundle deliveries* piles of some 50 cm in height are formed, these are then pressed between end boards and, while in a compressed state, bound with a polypropylene tape. The bundles must then be set down on pallets.

Deliveries have a separate drive and their height can be adjusted since they are positioned at various exits of the folding machine.

Folding Production Lines

Highly equipped products with low numbers of pages are being increasingly processed in folding production lines. The basic units of these lines are various folding units. These are interlinked with modules that can

- carry out complicated adhesive binding using various glues for different tasks (e.g., accurate partial strip gluing),
- carry out wire-stitching tasks,
- gather sheet sections and finish them together,
- glue cards, mailings, samples, and so on, onto a base sheet,
- cut, cut out, cut into, perforate, punch, and so on, according to complicated patterns,
- stick labels, seals, and so on, onto sheet surfaces,
- personalize products using ink jet or electrophotographic imprinting units,
- bundle units ready to be posted.

These units are supplemented by a range of logistic modules. Folding workflows are only at the beginning of their development. In businesses producing advertising material they are already a dominating economic factor.

Folding Unit Scheme

The variety of folding units and special equipment forced folding machine manufacturers into setting up symbol systems for technical characterization of their modules. Symbols are used to describe technical configurations. This form of representation helps the press operator since he also works with graphical symbols when setting the press. The symbols listed in table 7.2-7 are necessary for describing the layout of folding machines.

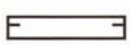
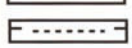
The technical structure of a folding unit is drawn up from these symbols and from this the whole folding machine. This results in the *folding unit layout*. (Not to be confused with the *fold layout*. A fold layout describes the type and sequence of folds necessary to carry out a certain finishing task.)

Figure 7.2-36 shows the configuration of a combined folding machine. The buckle fold unit has knife shafts installed upstream and downstream as well as two upward-facing and two downward-facing buckle plates (see also fig. 7.2-25). In no circumstances can the four-knife folding units all be used simultaneously: After the first fold, the sheet is either transported to the left or to the right.

The largest number of folds that can be carried out in this version is seven (four parallel folds in the buckle fold unit and three cross folds in the knife folding unit). Usually, a separate single-folding unit is installed in place of the two knife folding units for the third knife fold, which is adjusted according to the requirements of the fold layout. The delivery is also to be adapted to the fold layout and the desired direction of sheet exit.

The buckle folding machine in figure 7.2-37 represents a typical configuration in industrial bookbinderies. It consists of three buckle folding units, where the first two are each equipped with four buckle plates and two knife shafts and the third is equipped with two buckle plates and one knife shaft mounted downstream.

Table 7.2-7
Symbols used to describe the configuration of folding machines

Symbol	Description
	The arrow represents the *infeed direction* of the sheet into the first folding unit.
	The corner represents the lay edges in the feeder of the folding machine (*folding lay*).
	The thick line stands for a buckle fold module with *upper buckle plate*, i.e., the upper face of the sheet in the infeed goes to the inside of the folded signature.
	The thick broken line stands for a buckle fold module with *lower buckle plate*, i.e., the bottom side of the sheet in the infeed goes to the inside of the folded signature.
	The dotted line symbolizes a pair of tool-carrying shafts (*knife shaft*) for carrying rotating creasing, perforating, and cutting tools in front of or behind the folding units.
	*Knife folding module.*
	*Knife folding module with pair of knife shafts installed downstream.*
	Buckle folding module that is integrated into the knife folding unit and produces a parallel fold to the knife fold.
	Separate, *folding module in a variable position* (knife fold) for one fold. The folding unit can fold upwards and downwards.
	*Transport table*, which conveys the sheets betweenthe folding units. During transport, the sheet is also aligned to a lay edge (thickly marked).

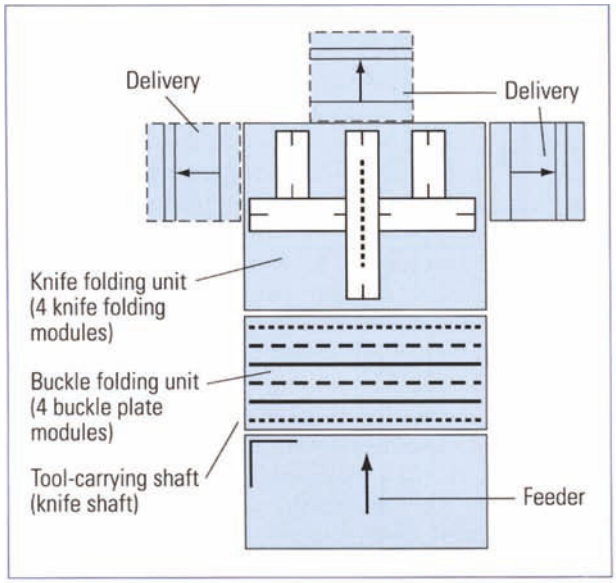


Fig. 7.2-36 Configuration of a combined folding machine

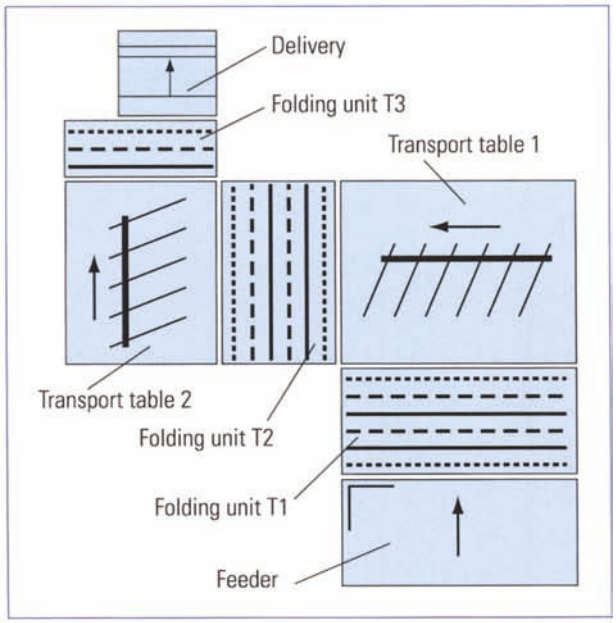


Fig. 7.2-37
Configuration of a buckle folding machine (according to fig. 7.2-29)

To produce right-angle folds, the folding units must be arranged at an angle of 90° to one another. The folding units' infeed width is graduated since smaller fold widths come about with cross folding. The machine is set up for ten folds, which, however, cannot all be used in one process due to technical limitations of the material. The variability of buckle folding machines is achieved by using different types of buckles and by rearranging the folding units to one another. Figure 7.2-29 shows a buckle folding machine that is set up according to the folding unit layout (fig. 7.2-37).

7.2.2.3 Folding Bookbinding Sheets

In the folding process, bookbinding sheets are transformed such that

- a gross format is produced that is capable of being processed further,
- the pages lie on top of one another in the "correct" order,
- finishing is ensured,
- the aesthetic demands (quality) of the user on the end product are satisfied.

The conditions for finishing are laid down during the printing plate production (position of the pages on the printed sheet, slitting allowance, routing allowance for perfect binding, etc.). Therefore, a page layout on the printed sheets must be arranged between printer (or printing plate producer) and bookbinder that corresponds to the premises listed above. The production planning of books and brochures should therefore logically start with the finished product, namely the book bindery/finishing.

When deciding upon the type of folded signature and the page layout on the bookbinding sheet, two procedures are commonly applied:

- On the basis of quality requirements and binding specifications, a (best possible) fold is recommended, and the printing format is determined from this, taking account of the available printing technology.
- The type of fold is selected based on the kind of press used and the maximum exploitation of the print format. The further processing of the folded sheet is of secondary importance.

Between printers and bookbinders explicit instructions are essential to eliminate any misinterpretations. The features of flat bookbinding sheets (fig. 7.2-38) are:

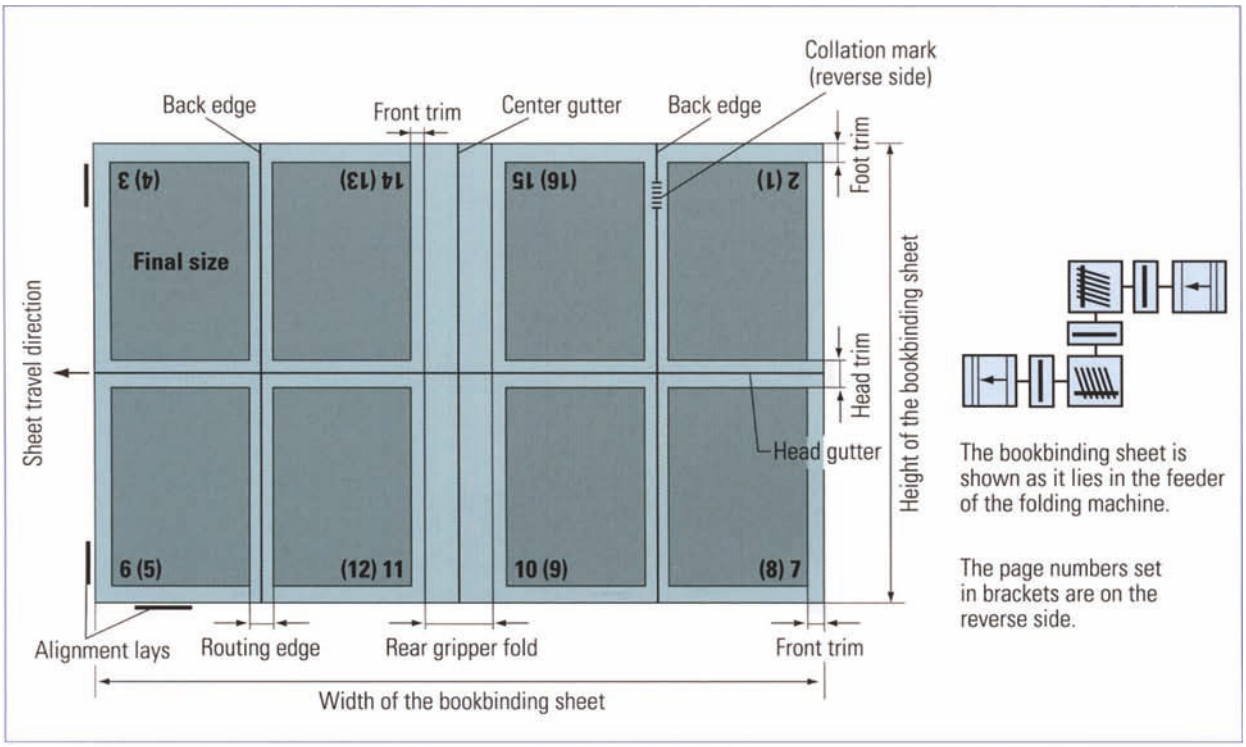


Fig. 7.2-38 Bookbinding sheet with physical dimensions and markings as well as the configuration of the folding unit

- Columns in the type area (text).
- Margins; taking note of trimmings and routing depth (with perfect binding, etc.).
- Sheet numbers with abbreviated title (outer edge), sheet numbers with asterisk (inner edge). The sheet number is referred to as the signature. It depicts the position of the folded sheet in the block. When allocating page numbers for a signature, preceding signatures must consequently be taken into account. (In a 16-page folded sheet of signature 2, pages 17 to 32 are arranged in the correct order if signature 1 also consists of 16 pages.)

The number of pages of the *folded sheet* semi-finished product usually requires a folding sequence that varies in terms of the number and position of the folds on the sheet. A classification of the different types of folded signatures is given in figure 7.2-39.

Practical limitations to folding variations arise through:

- quality demands on the folded signatures (limitation of the number of folds) and
- the variability of the folding machines.

Several important types of folded sheets are presented in figure 7.2-40.

For the traditional and still the most frequently used fold sequence – *symmetrical right-angle folds* – a technical colloquial language has come about (table 7.2-8).

Alongside the folded sheets, containing one page of each surface (one-up folded sheet), two-up folded sheets are produced and processed, especially in large companies in the graphics arts industry. With two-up jobs, two folded sheets are placed on top of one another and processed jointly. Figure 7.2-41 shows the variations of the two-up operation:

- Two-up, genuine: The same folded signatures stand above one another.

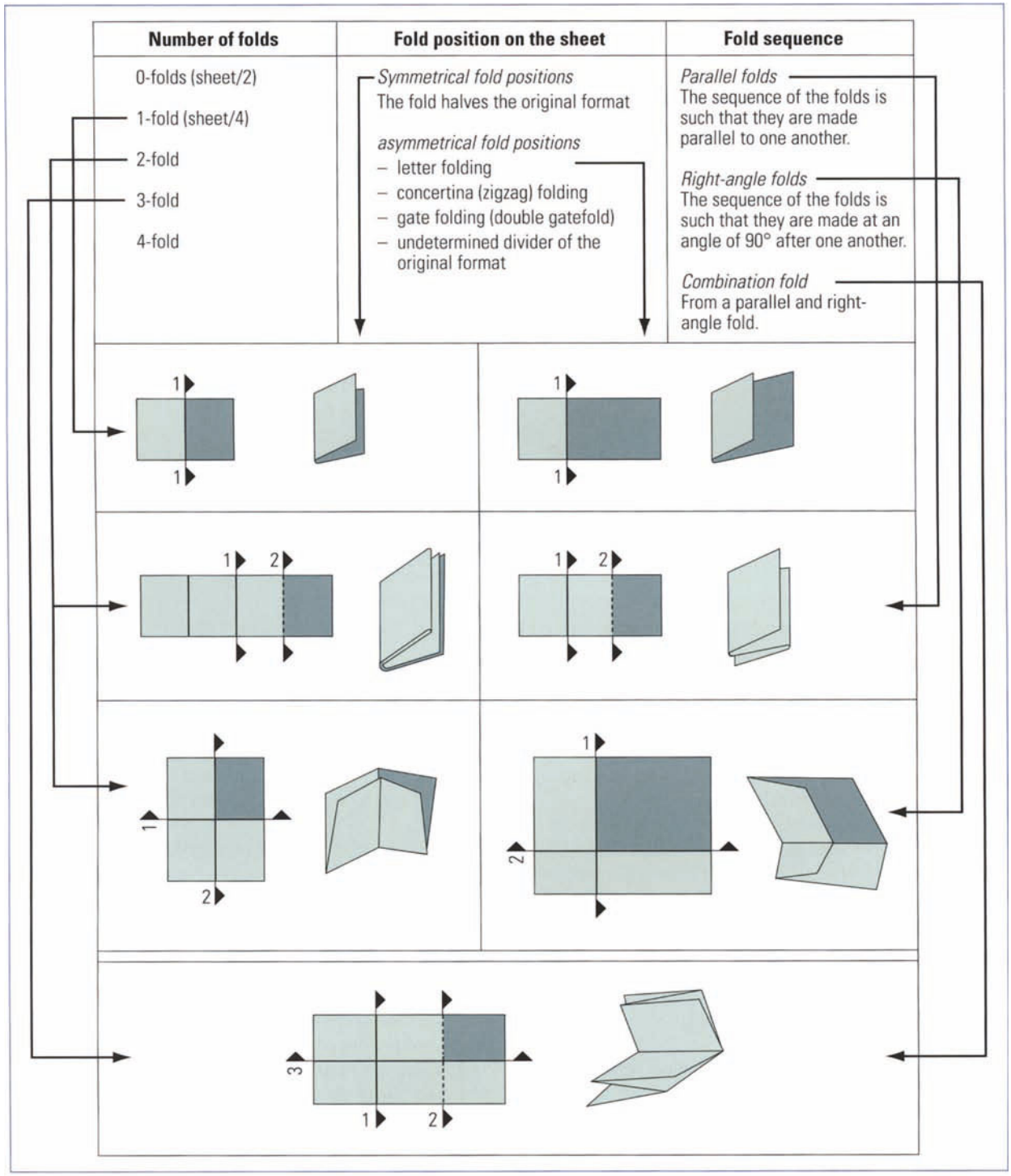


Fig. 7.2-39 Folded sheet classification [7.2-3]

Fig. 7.2-40 Types of folded sheets [7.2-3]

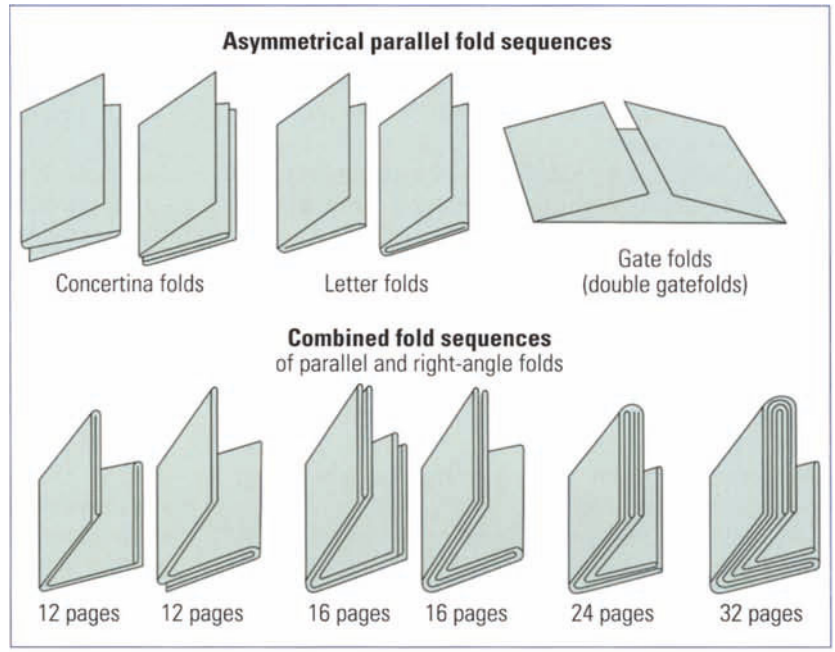
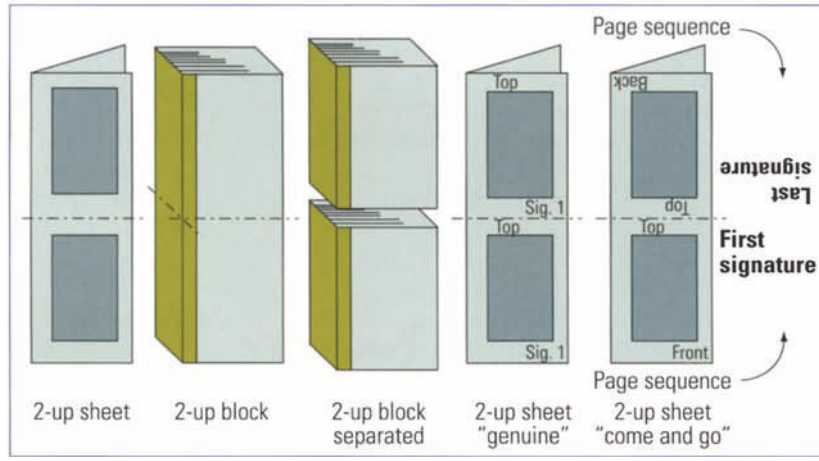


Table 7.2-8
Designations for symmetrical right-angle folds

Designation	Number of pages	Number of folds (symmetrical right-angle folds)	Alternative designation
Eighth sheet	2	0	Sheet/2 → sh/2
Quarter sheet	4	1	Sheet/4 → sh/4
Half sheet	8	2	Sheet/8 → sh/8
Full sheet	16	3	Sheet/16 → sh/16
Double sheet[a]	32	4	Sheet/32 → sh/32

[a] not to be confused with two-up work!

Fig. 7.2-41
Variations of two-up (two identical parts printed on one sheet) folded sheets



- Two-up, "come and go": The first sheet is folded and finished with the last sheet, the second sheet with the penultimate sheet, and so on. The "folded sheet from two folded sheets" has, for the most part a narrow format.
- When processing small book and brochure formats (mini books) it might be necessary to bind 4, 8 or 12 blocks simultaneously.

Furthermore, printers and bookbinders agree on the definition of *folded sheet families*. For the selected fold characteristics (e.g., symmetrical right-angle fold and/or asymmetrical right-angle fold), base sheets (e.g., 8-page right-angle fold; 6-page letter fold) are defined. There are usually variations to the base sheet that are produced with more (or as it may be, fewer) symmetrical right-angle folds.

By maintaining the sheet family when printing end sheets, the same sheet size can be used as for the base sheet (when printing several ups per sheet). In this way the job can be produced on the same press using just one paper size/sheet format.

For the *page layout* on the bookbinding sheet, information on the method of block formation (gathering or inserting), along with the folding layout and the number of ups (see also sec. 7.2.4.1) is required.

There are three typical methods used to layout the page:

- manual preparation of fold patterns,
- using existing catalogs with folding techniques,
- computer-aided page division using folding technique files or algorithmic preparation of virtual fold patterns.

The easiest method is the *manual folding of folding samples:*

- folding according to a specified pattern,
- entering the correct page sequence manually into the sheets,
- applying the page pattern to all signatures.

To simplify the work of job processors and folding machine operators and to avoid the communication of incorrect information, manufacturers of folding machines have developed *catalogs* in which frequently used folding layouts are systematically compiled. In this way, the following additional information is also available:

- clear designation of the folding machine system on which the folding layout can be produced,
- concept of folding units that can be arranged variably to one another and the nature of their assignment,
- instructions on the setting of folding machines, including feeder and delivery,
- data on the special features and/or limitations when selecting the intended folding layout.

In practice the work with the folding pattern catalogs is done in such a way that

- the creator of the graphic product or the job processor first selects a folding layout from the catalog,
- the printing plate producer uses the folding pattern in the catalog for the printing plate imposition; the folding pattern and the printing variant are prerequisites for the assembly of printing plates,
- the folding machine operator uses the information in the folding pattern catalog to set up the folding machine.

In this way the job can be completed perfectly. A systematic description of various folding sequences and the corresponding planning routines (independent of folding machine manufacturers) occurs through the fold type catalog of trade associations. This method is based on the bookbinding sheet travel through the press.

The *computerized page layout* serves to automate the planning and production processes in the printing industry. Computer programs for

- calculating and processing jobs (commercial software), and
- controlling machines and systems,

require modules that are able to execute the automatic page layout and the imposition of printing plates in the next production stage. Similarly to manual procedures, these programs are based on two principles (fig. 7.2-42).

Quality of Folded Sheets. Significant features of the quality of folded sheets are:

- folding accuracy, that is, deviations in image area locations,

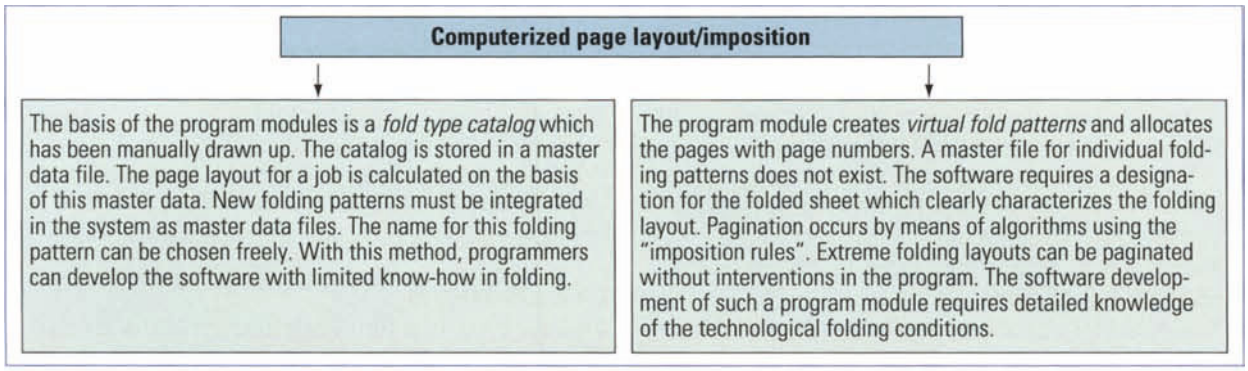


Fig. 7.2-42 Computerized page layout principles

- deformation of folded sheets in the area of the fold edges (wrinkling),
- sharply defined folds.

The folding accuracy is the most significant quality feature since deviations from the specified fold edge cause visible image-area location errors in the end product.

The deviation of the fold line from a specified position can be set right by means of controls. The settings require experience since the origin of the deviation is sometimes difficult to identify. Incidental errors are deviations that occur during production after the machine has been set up in accordance with the desired values. They can be influenced by

- the type of fold and number of folds in the sheet,
- fluctuation in the quality of the printing paper,
- the design of the folding machine,
- momentary technical problems,
- the operating speed of the folding machine,
- environmental changes in the operating room.

The operator has little influence (apart from changing the operating speed) over incidental errors.

A further cause of image-area location faults in the folded sheet is the shifting of inner sheet sections into the fold curvature (fig. 7.2-43). In thick single-layer brochures (e.g., magazines), the shifting of the inner folded sheet sections is evened out in the printing plate production by increasing the gutter dimensions of the outer folded sheet sections.

Creases occur on the bending edges and corners due to material displacement and stretching. The thicker the paper and the higher the number of right-angle

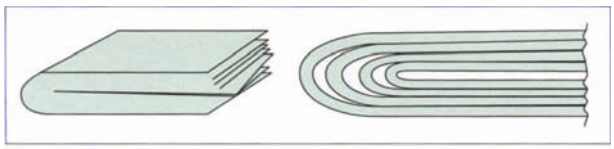


Fig. 7.2-43
Twisting and shifting sheet sections caused by fold curvature [7.2-4]

folds per sheet, the greater the tendency to wrinkling. Creasing is counteracted by the slot perforation of the fold edges (fig. 7.2-28). If the sheets are bound to blocks using the stitching method, the back edge (fold on which the binding occurs) must not be perforated.

Sharply defined folds in the back edge can primarily be improved

- through an additional pressing station in front of the delivery of the folding machine (very high pressing force) and
- by pressing the folded sheet when it is temporarily stored (e.g., folded signature bundles).

7.2.3 Forwarding

7.2.3.1 Characterization of the Process

Forwarding:
Folded signatures, sheets, or inserts are jointed by bonding means (e.g., glued) or loosely inserted in the folded sheet.
Also: equipping procedures on folded signatures prior

to collation into multi-layer blocks or insertion into single-layer blocks.

The forwarding process is generally followed by gathering into blocks partial products such as:

- folded sheets, base folded sheet of the process section,
- folded sheets of the same paper quality and size as the base folded sheet,
- folded sheets in another quality and/or size than the base folded sheet,
- leaves in another quality and size than the base folded sheet,
- mailings, cards,
- product samples.

With bonding forwarding processes, dispersion glues (e. g., polyvinyl acetate dispersions) are primarily used. For gluing on mailings and samples, hot-melt adhesives and contact adhesives are also common. The forwarding variants are listed in table 7.2-9. A list of products created with forwarding operations is given in table 7.2-10.

7.2.3.2 Forwarding Process in Industrial Finishing

The forwarding process is avoided as much as possible in industrial bookbinding companies, since individual signatures of a job need to be separated and further processed after the folding operation. This requires logistics and special coordination in job planning. An appropriate product design is beneficial. Printed products are designed such that forwarding operations are no longer required. This is achieved by

- avoiding end-folded signatures of two or four pages, by means of composition measures, and
- planning in of picture sheets into the block instead of gluing pictures on and in folded sheets.

Despite this, the process needs to be carried out for special jobs.

One possibility to minimize the forwarding process is the integration into earlier (folding) or later (e.g., gathering) processes. This is often the case

- when pasting cards to magazine sheets and
- when gluing on end papers for book blocks.

Forwarding in a separate operation is done with *tipping machines* (fig. 7.2-44). The machine is capable of:

- tipping single sheets or folded sheets to base sheets,
- inserting or gluing single sheets or folded sheets into the middle of base sheets,
- attaching single sheets or folded sheets onto base sheets (with two or more adhesive strips),
- hanging or attaching pictures of smaller size than the base sheet onto or into the middle of base sheets.

Gluing Endpapers

Endpapers are vital construction elements for hard covers since the pasting of the book block to the book cover takes place through the endpapers on the first and last signature. Endpapers are folded sheets (in industrial bookbinderies usually quarter sheet) made from particularly bend-resistant papers that are glued with an adhesive strip to the back edge in front of the first text sheet and behind the last text sheet. When connecting block and cover, in each case the outer endpaper is glued across the whole surface onto the case of the book cover (fig. 7.2-45; see also table 7.2-9).

The connection between book block and cover can break easily when no endpapers are used and when the first and last sheet of the book block are glued to the cover.

In craftsman's bookbinding special endpaper constructions are used in order to make the opening hinge point particularly robust (e.g., for leather or parchment covers).

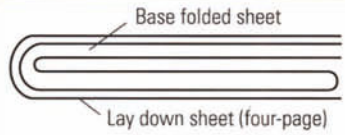
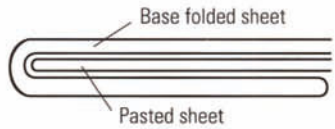
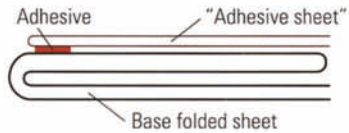
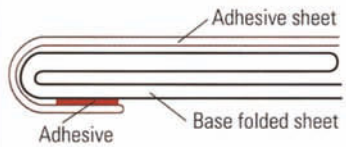
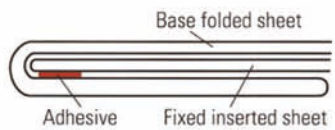
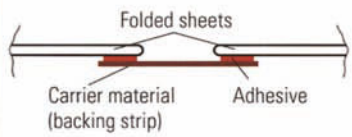
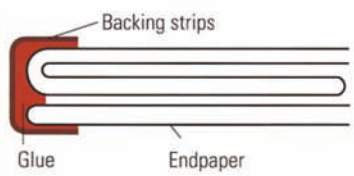
The integration of endpaper gluing into the subprocess of *block production* has been achieved in three variations:

- as a module in perfect binding lines (fig. 7.2-46),
- as a module in finishing lines for thread-stitched (or sewn) books,
- as a "replacement cover" in perfect binders (fig. 7.2-47).

Endpaper gluing stations are positioned between the gathering machine and the perfect binder in perfect binding lines (fig. 7.2-46).

In a usual arrangement, subsequent to the separating operation, the endpapers are routed on rails, which carry endpapers 3 to 5 mm higher than the spine height of the blocks. While they are conveyed, they are glued by the strip gluing unit and pasted to an aligned outer sheet of the block. The back edge of the block is removed in the perfect binder, though the endpaper folds stay in place. The spine gluing is carried out and back

Table 7.2-9 Forwarding variants
(continued on next page)

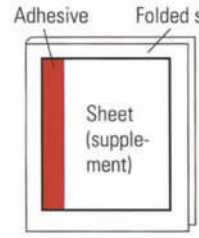
	*Laying down* a (usually four-page) folded sheet around a base folding sheet.
	*Inserting* a (usually four-page) folded sheet into a base folding sheet.
	Sticking and pasting a leaf or a (usually four-page) folded sheet onto a base folded signature (end papers, plates, etc.)
	*Sticking* a sheet or (usually four-page) folded sheet around a "core sheet" as protective sheet or as end paper (out-of-date form).
	*Tipping* in a loose leaf or (usually four-page) folded sheet into a "core sheet" as an advertising insert or similar.
	*Flat gluing* sheets (endpapers) onto a substrate (backing strip). This sheet construction is used as a "pseudo cover" in adhesive binders. In this way book blocks can also be produced on a binder for multi-layer brochures.
	*Backing* is the connection of two folded sheets (e.g., first signature and endpaper) by means of backing strips (paper or fabric strips) on the back edge of the sheets. In this way the product is strengthened at the bending points.

stripping is applied to the block spine. The backing strip ensures an additional stabilization of the endpaper hinge point.

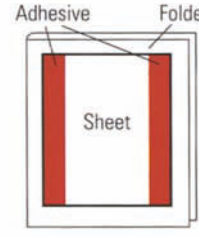
A rational variant is endpaper gluing with the help of brochure cover feeders in adhesive binding machines. Here, the endpapers are glued flat to the backing strips. This product is fed through the cover feeder to the glued block spine (fig. 7.2-47).

Tipping in cards in magazines (back-stitched brochures) is carried out in gatherer-stitchers. To do so

Table 7.2-9 *(continued)*
Forwarding variants



Attaching supplements, usually pictures on or in a folded sheet by means of one strip gluing. The picture is smaller than the folded sheet. Even mailings or samples are attached. In card gluers, sheets are also attached with glue spots.

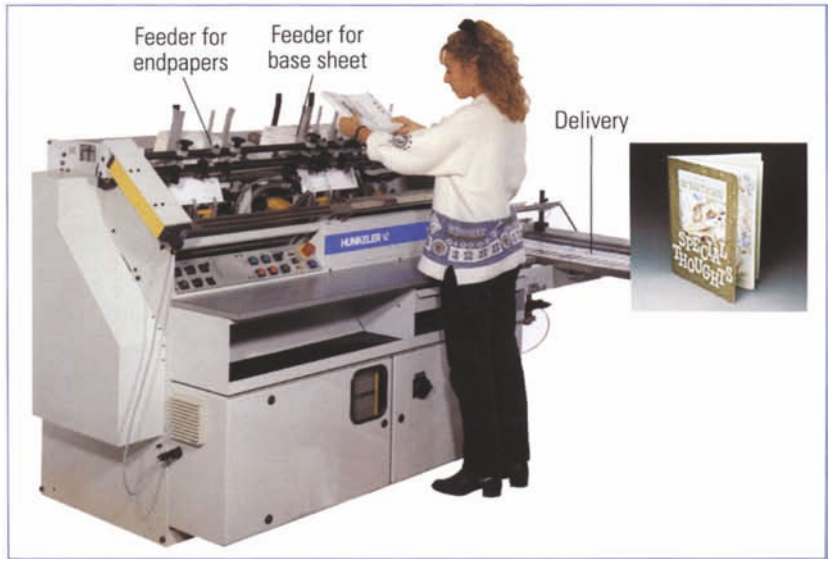


Fastening sheets, usually pictures on or in a folded sheet by means of two adhesive strips opposite each other. The picture is smaller than the folded sheet.

Table 7.2-10 Products in forwarding

Intermediate products	End products
Forwarded sheets For the production of book blocks, multi-layer brochures, and back-stitched brochures	*Folded brochures with cards, mailings or samples* for industry, trade and culture
Folded sheets with front and back endpaper For the production of book blocks for fixed bindings	

Fig. 7.2-44
Combined sheet gluing and tipping machine (Tipping machine VEA 520, Hunkeler)



card gluers are installed in the inserters in place of folded sheet feeders (Müller Martini) or positioned between the feeders (Ferag, cf. sec. 7.3.2.4).

Problems of Quality with Endpaper Gluing

In conjunction with endpaper gluing, three areas are evident where quality is lacking:

- The adhesive strip that connects the text sheet and endpaper is too wide and/or uneven. The error comes about either through the adhesive layer being too thick or the processed papers lacking absorption capability (e.g., art printing) so that the glue is squeezed out when pressing the joint.
- The gluing bursts during the subsequent processing step of the blocks or when the end product is used. The cause of this shortcoming is the use of an unsuitable endpaper adhesive. Particularly when processing text sheets that are printed extensively right up into the back edge, there is no sufficient wetting with glue. The problem can be reduced by using glues that spread better. It is preferable, however, not to print on the surfaces to be pasted.
- The endpaper is placed too far into the inside of the sheet. This causes tension on the end product, which, when the book is used, can lead to the book falling apart prematurely. The problem is pointed out in figure 7.2-48. If the endpaper is set off too far from the back edge of the text sheet, as shown in the middle drawing, the position of the endpaper opening hinge and the cover fold no longer line up. When opening the cover (bottom drawing), the

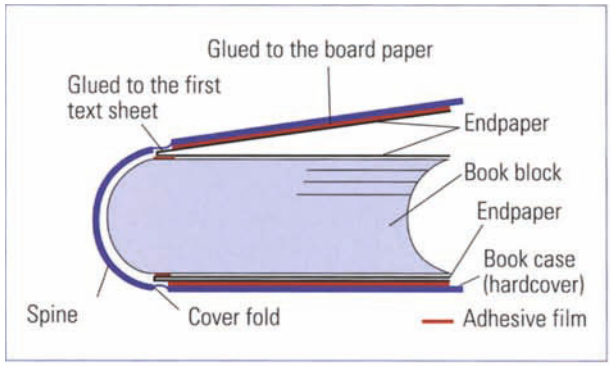


Fig. 7.2-45 Endpapers in mass-produced hardcovers

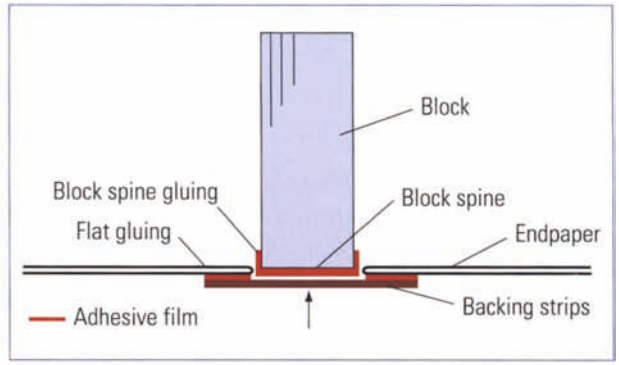


Fig. 7.2-47 Flat glued endpaper

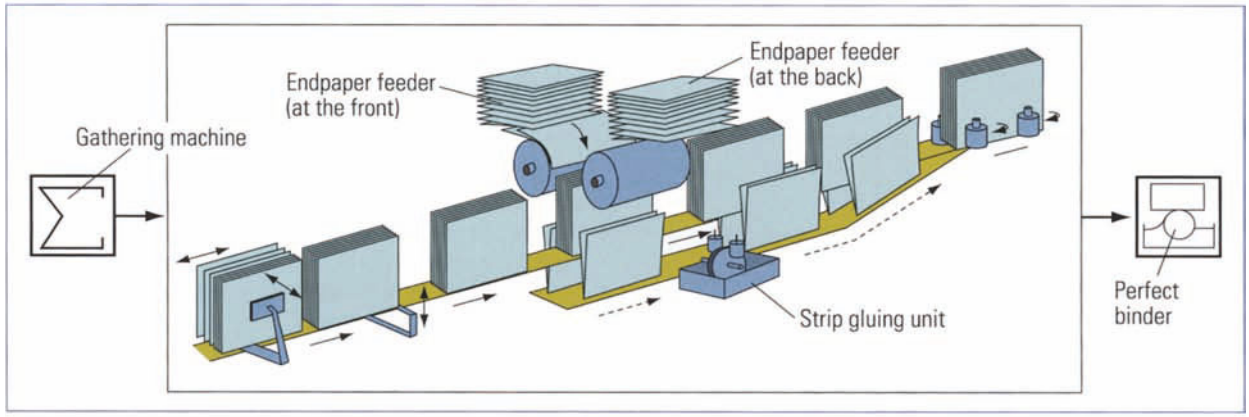


Fig. 7.2-46 Endpaper gluing machine in binding lines

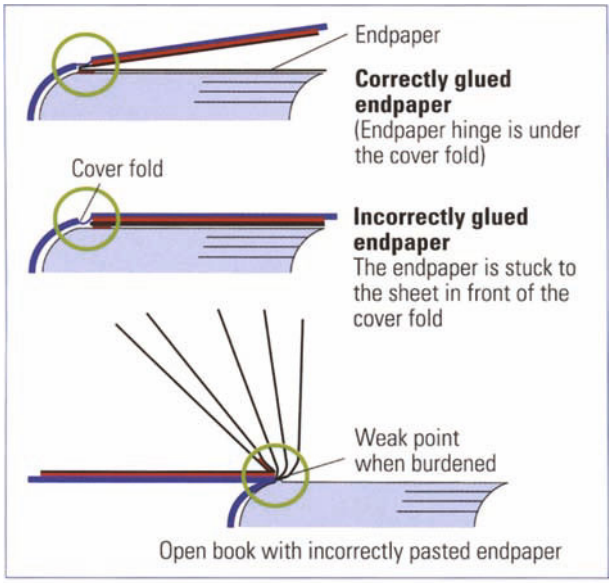


Fig. 7.2-48 Tension due to incorrect endpaper gluing

first few pages of the block are pulled around the pivoting point – the fold between the cover and the spine inlay –, which creates excessive tensions in the binding. This overly high burden destroys, in particular, the adhesive bindings, which would otherwise be sufficiently robust.

7.2.4 Assembling into Blocks

7.2.4.1 Characterization of the Process

Assembling is the production of a specific sequence of folded sheets, leafs, or webs into a loosely jointed block.

The sorting of product items also occurs

- when assembling printing forms,
- when assigning interrelated printing units that produce newspapers from several webs, and
- in digital printing systems.

Materials and partial products to be processed are

- non-folded and folded substrate webs,
- printed sheets or bookbinding sheets,
- unprepared and prepared folded signatures,
- sheets.

In conventional finishing, it is usual to process folded sheets or leafs (individual sheets) in the untrimmed format of the end product. Principally, it is also possible to assemble non-folded printed sheets or bookbinding sheets and to fold after that in the sequence of the signatures. Two basic principles are to be applied for the assembling of sheets and leafs into blocks (table 7.2-11). Table 7.2-12 lists the types of products created by assembling

Prior to assembling, all signatures of an end product produced independently of one another must be available at the same time. Each signature is temporarily stored on its own "storage unit." This leads to the following elementary processes:

- Separation from the same quantity of signatures from feeders to a stacker (table 7.2-13),
- Production of a block in the assembler (several bins/trays), (table 7.2-13),
- Conveyance of separated signatures, feeder supplies and assembler collects (see also fig. 7.2-49).

"Gathering/inserting into blocks" is an *assembly process* with the transition into a different processing dimension (n folded sheets into one book block). This results in organizational, planning, and intermediate storage problems with a varying number of signatures in consecutive jobs.

7.2.4.2 Gathering

Gathering Machines in Bookbinding Shops

When gathering books and multi-layer brochures the following elementary processes must be carried out:

- transporting the folded sheets (stored on pallets, for example), which are sorted according to signatures to the corresponding sheet feeder for the signature,
- loading the folded sheets into the correct feeder,
- separating the folded sheets,
- transferring the separated folded sheets to the assembler, collecting into a block,
- transporting the blocks into the delivery,
- unloading the blocks onto a pallet or transferring them to a finishing module,
- checking the correct sheet sequence (collating).

Table 7.2-11
Basic principles for assembling signatures and leaves (individual sheets)

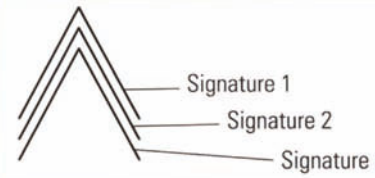
Assembling/Gathering into blocks	
Collating/Gathering into multi-layer blocks	Inserting/Gathering into single-layer blocks
	
Assembling by **collating** of signatures → unbound multi-layer blocks arise. Collation of sheets → unbound sheet blocks arise.	Assembling by **inserting** signatures into one another → unbound single-layer blocks arise.

Table 7.2-12
Products created by assembling

	Inermediate products	End products
Multi-layer block	*Collated blocks* are bound into book blocks for hardcovers and multi-layer brochures. *Sheet collations* are used in binding as an adhesive binding product or for various individual sheet binding systems	*Loose leaf assemblies* *Loose sheet assemblies* *Inlays for files*
Single-layer block	*Magazines* *School books* *Booklets*	*Newspapers*

Figure 7.2-49 shows the structure of a conventional gathering machine (for collating signatures).

The folded sheet pallets are transported from the folded sheet temporary storage into the machine prestorage. A feeder is required for each signature. The folded sheets are stacked in the corresponding feeder magazine. A separating module with front underedge separation puts each sheet into the raceway, so that the sheets can be conveyed by pushers towards the delivery. The speed of the assembler and pushers is synchronized such that the separated sheet from one magazine drops onto that of the previous magazine. In this way a block is produced with each feeder cycle. The blocks are in the delivery, staggered if necessary, ready for the operator to remove and place on pallets. Since the number of sheets per block can exceed the number of feeder stations with some jobs, a partial block feeder is installed at the beginning of the assembler. The assembling then takes place in two steps. First of all, a part block is gathered. In the second step the part block is manually put into the part block feeder. The additional sheets are gathered on the part block.

Figure 7.2-50 shows a gathering machine; loading the feeder from the pallets is done manually. The number of feeders in a gathering machine depends on the job structure of the print finishing company. The machines are made up of sections of three or four feeders. It should be possible to produce at least 90% of the jobs without pre-gathering (i.e., without a part block feeder). Gathering machines can be equipped with more than forty feeders.

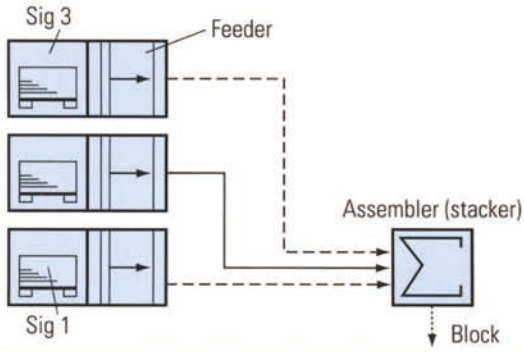
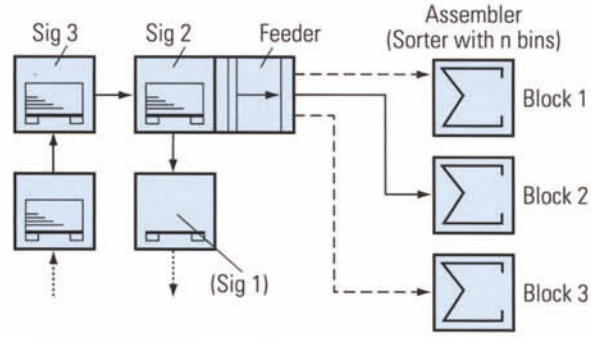
The principle of gathering (stacker principle)	The sorter principle
	
For each signature batch there is a feeder (sheet separator). The separated signatures are put into the stacker one after the other so that a block with consecutive signatures results. The block is ready for the next finishing process. Conventional bookbinderies make use of the principle of gathering. The number of active feeders corresponds to the number of signatures per block.	A signature 1 batch is separated in the feeder. Each individual signature is laid into a separate bin/tray. After that, the same procedure occurs with the signature 2 batch, etc. When all signature quantities have been separated, each bin contains a block with consecutive signatures. In conventional bookbinderies, the sorter principle is not expedient, since the number of the bins would have to correspond to that of the print volume.

Table 7.2-13 Basic principles of the assembling techniques using stacker (gathering; inserting or collating) or sorter (collating)

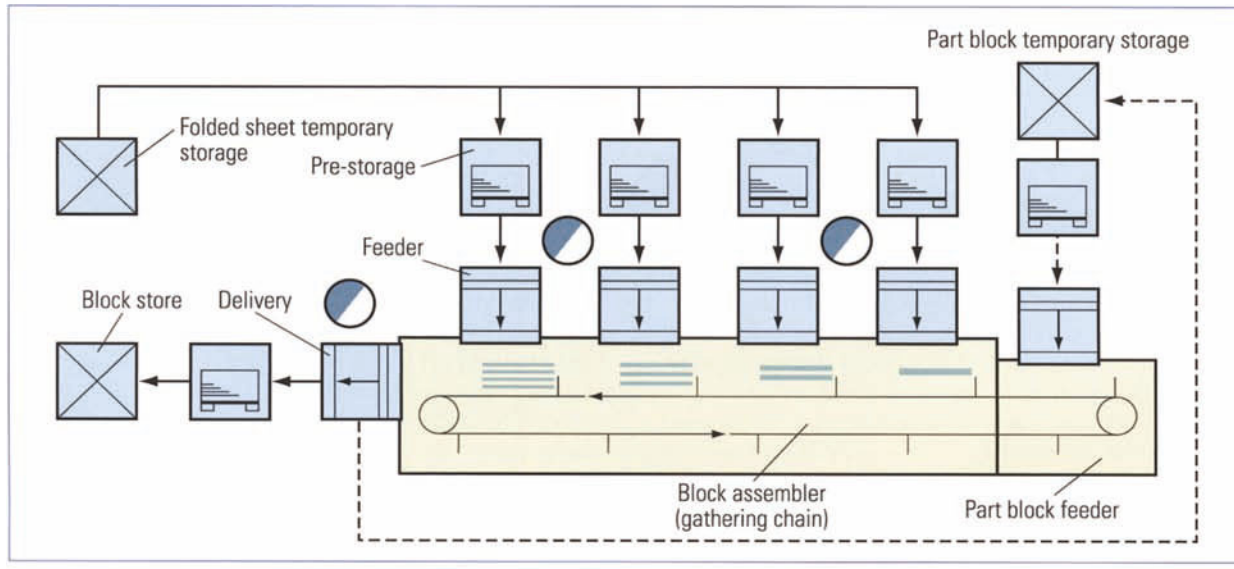
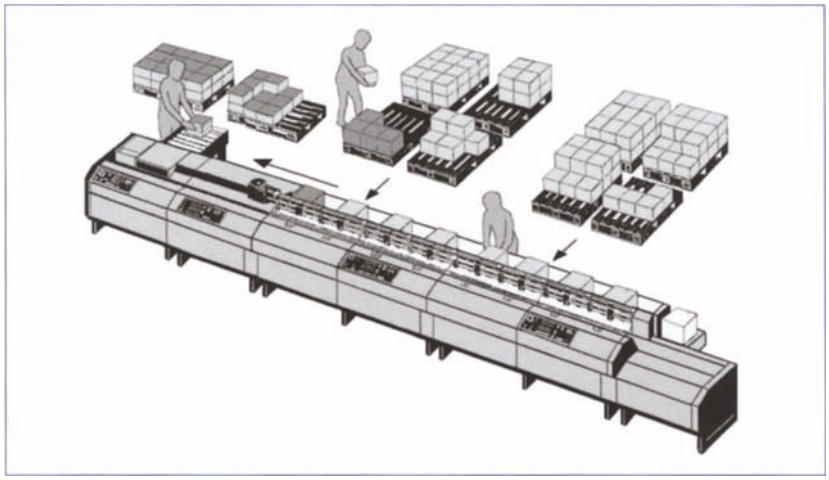


Fig. 7.2-49 Structure of a gathering machine (collating individual sheets or signatures)

Fig. 7.2-50 Gathering machine



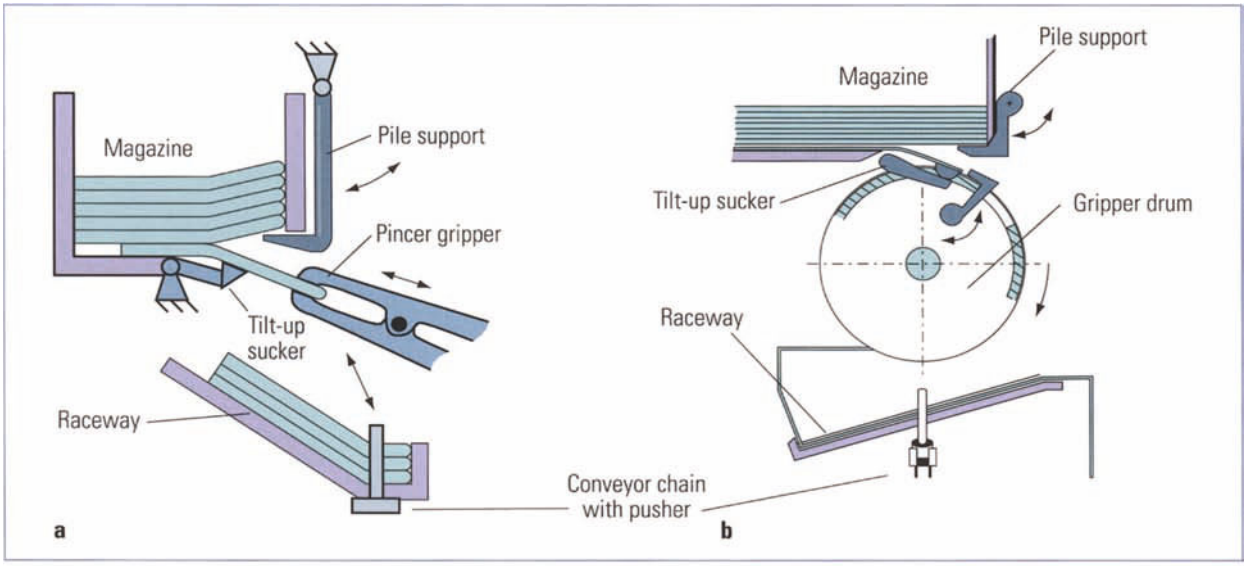


Fig. 7.2-51 Feeder variants in gathering machines.
a Feeder with pincer grippers;
b Feeder with gripper drum

Figure 7.2-51 shows two typical feeder principles in gathering machines. The same design elements are found in both versions:

- Folded sheet pile magazine for continual insertion of signatures by the operator or by loading systems with a front underedge separation of sheets to be separated.
- Separating the separation edge of the sheet using suction air (tilt-up sucker).
- Pile support for the sheets remaining in the magazine; the support is swung out of the way when the tilt-up sucker pulls off the back edge of the bottom sheet in the pile.
- Removal using pincers or drum grippers and simultaneous transportation to the raceway.

- Conveyor chain with pushers. The continual pusher movement runs at an angle of 90° to the separation motion.

A serious disadvantage in this design is that the acceleration of the sheets during a working cycle of the machine changes continually. When removing the sheet from the magazine there is an acceleration that is then stopped during feeding in the raceway. Finally the pusher of the conveyor chain accelerates the sheet to the transport speed in the raceway. The intermittent acceleration of the sheets in the raceway can result in damage to the sheet and unstable machine operation. Therefore high-speed machines (more than 10000 products/h) are equipped with a sheet accelerator between each magazine and raceway, which "gently" brings the sheet to the effective chain speed. Solutions applied for rectifying the separating and gathering movement are rotating the magazine and gripper drum by 90° or modifying the separating principle.

In addition to the nominal output, the effectiveness of machines is determined mainly by the degree of automation of the loading unit and the delivery (operating effort). The following are alternatives for loading:

- Manual insertion of sheet piles into feeder magazines. One operator can manually load between three and eight magazines depending on the operating speed and sheet volume.
- Loading the gathering machines with bundles (fig. 7.3.-6). One operator can load approximately 15 bundle feeders (see sec. 7.3.1.3).
- Loading folded sheet reels (fig. 7.3.-7). One operator can load all the reel feeders of a gathering machine during operation (see sec. 7.3.1.3).

The following processing errors can occur with gathering machines:

- missing sheets in the block,
- double sheets in the block,
- mixed up sheets in the block.

Each deficiency results in rejection of the product. To avoid missing or double sheets, grippers are equipped with sheet thickness detectors. To avoid mixed up sheets, the correct position of each folded sheet must be checked in each block. Common collation checking processes are:

- *Manual check of collating marks* (fig. 7.2.-52). Each signature gets a collating mark printed in the back edge, which moves by a mark length each time in ascending signature sequence. Thus the correct sheet sequence is recognizable at a glance. The process does not work, however, when the gathering machine is rigidly interlinked with the binding machine in workflows.
- *Electronic detection of collating marks.* To determine whether there are collating marks in the scan field or not, optical scanning heads located in each magazine are used. The marks are conveniently positioned in the trim.
- *Barcode scanning.* Each signature receives a barcode (area: 5 mm × 5 mm) at the same place, which is put into the trim. Electronic barcode scanning takes place in each magazine.
- *Electronic determination of the ink density on the print surface.* In a simple case a density value of a defined sheet surface area is determined. Fault clearing takes place if the density deviation tolerances are not met.

To increase reliability (particularly of integrated gathering machines in binding lines) the defective product is channeled out of the system in the case of individual errors, without the system stopping.

Collators for Individual Sheets

Collators are mainly used in companies or departments that

- produce products for office communication in small and very small volumes,
- produce sets of forms,

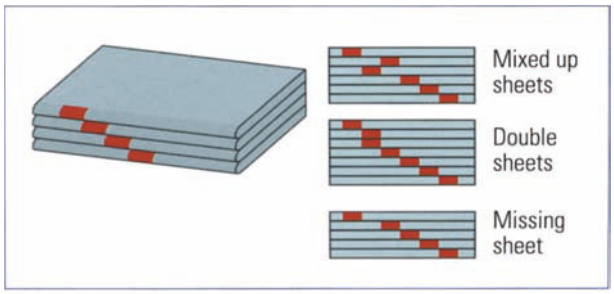


Fig. 7.2-52
Collating marks used for checking the correct sequence of signatures

- produce wall calendars or calendar types of products.

The machines mainly differ in the arrangement of the magazine, as especial attention is directed at space-saving constructions in the business field concerned.

Distinguishing features of collators are listed in table 7.2-14.

Tower collators dominate in finishing businesses (these are postpress companies that mainly produce simple products). These machines are very variable since

- they can also collate folded sheets (not as efficient),
- if required, several towers can be interconnected in tandem,
- they can be interlinked with binding units (e.g., wire stitching machine and front cutter) to one integrated workflow.

Figure 7.2-53 shows a *tower collator*. The number of gathering towers connected in series is determined by the scope of pages that are normally to be processed. Two collating towers have been linked to a binding line with a saddle stitching unit and a front trimmer (only the front edge is trimmed).

For large format sheets (≥ A3) there is a range of special collators that are frequently the base module of binding lines. The characteristic structure of such a workflow can be seen in figure 7.2-54. The machine is arranged in a *horizontal line* and equipped with special pallet feeders. Sheets can be placed here up to a height of 65 cm. The sheets are separated from above using suction rods. The assembler moves cyclically in front of the pallet feeders. The collating machine can be linked up with various units for different binding methods, such as wire stitching or wire comb binding.

7.2.4.3 Gathering into Single-layer Blocks

Collating folded sheets to produce single-layer blocks generally takes place in gathering machines that are integrated with wire saddle-stitching units and trimmers for the three-side trim. The production lines are referred to in practice as gatherer-stitchers. The gathering unit is the basis module of such lines. Gathering machines have the same function groups as collators:

- folded sheet feeder corresponding to the number of folded sheets per block,
- block gatherer,
- delivery.

To be able to place the sheets within one another, they must be open in the middle. They are then put on a saddle bar one after the other. The saddle bar has an assembling chain with pushers. The chain transports the sheets from feeder to feeder, so that an inserted block is produced. The principles are sketched in figures 7.2-55 and 7.2-56.

For separating and opening the folded signatures, two methods are mainly used:

- sheet separation and opening according to the rotating transfer technique,
- sheet separation and opening according to the roll-off principle.

An example of the *rotating transfer technique* is shown in figure 7.2-56. The folded signatures are piled into the feeder by the operator. The "bottom" sheet is separated. To do this the back edge is pulled off the pile by a tilt-up sucker, such that the gripper of the transfer drum can separate the sheet.

At the rear stop the pick-up drum gripper opens, and the sheet is taken at the front edge by the gripper of the

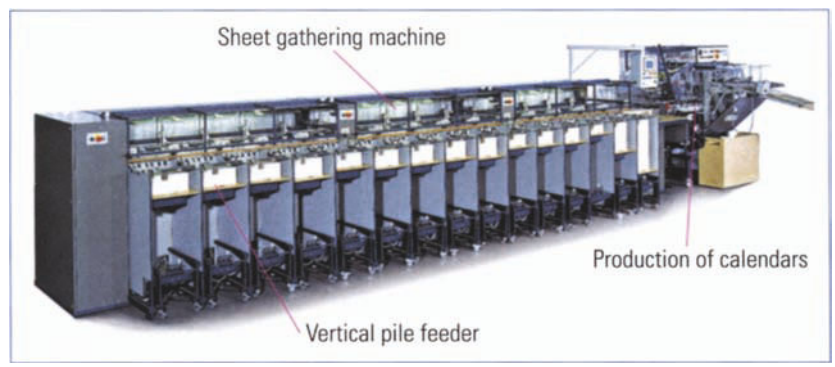
Feeder arrangement	Assembler collects the separated sheets from each feeder	Feeders transport the separated sheets to the assembler
Horizontal arrangement of the feeders in one line	*Case 1:* Assembler completes a circulatory movement	
Horizontal arrangement of the feeders on a circular disc	*Case 2:* Several assemblers rotate above a feeder carousel	*Case 3:* Feeders rotate underneath the assembler and deliver the separated folded sheets
Vertical arrangement (tower) of the feeders in one line	*Case 4:* Assemblers move past the feeders and pick up the separated sheets	

Table 7.2-14 Distinguishing features of collators



Fig. 7.2-53 Tower collator (vertical feeder arrangement) with further sheet processing (Horizon)

Fig. 7.2-54
Calendar collating machine with horizontal line feeder arrangement (Theisen und Bonitz)



counter-rotating transfer drum. The folded signature has a gripper fold, which is the designation for a paper surface protruding on the front edge of the folded signature in front of or after the center of the sheet. The transfer drum gripper seizes the gripper fold, such that it only holds the sheet half that is lying on the drum. With the transport movement running in the opposite direction the opener drum gripper takes over the free front edge, whereby the sheet can be opened and put down on the saddle bar. The gripper fold is the most reliable design element for opening sheets at the centerfold.

An alternative to the gripper fold is to open folded signatures using rotating suckers. To do so, the folded signatures on the head edge must be closed. This requires that the penultimate and the last fold of the folded signatures are executed as a center cross fold.

For separating and opening folded signatures using *roll-off feeders* (fig. 7.2-57), a gripper fold is also advantageous. The well-known "Hepp feeder" is presented as an example. The rolling drum rotates against the back edge under the folded sheet pile of the magazine. Roll-off rollers support the pile. The roll-off drum is equipped with three suction rollers. Their suckers car-

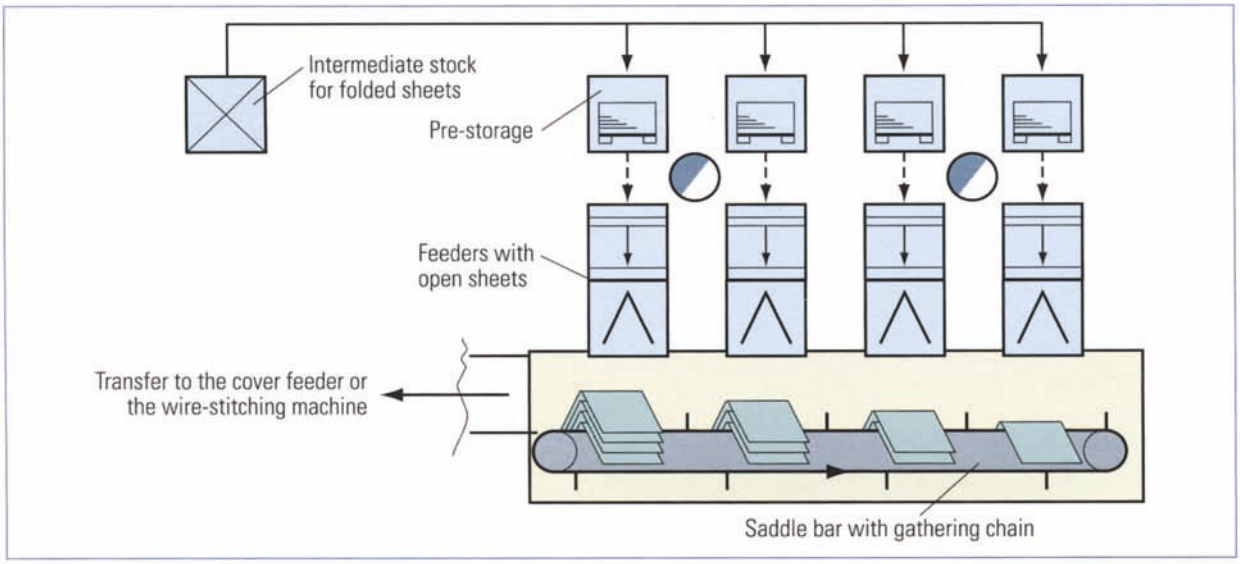


Fig. 7.2-55 Structure of a gatherer for single-layer blocks

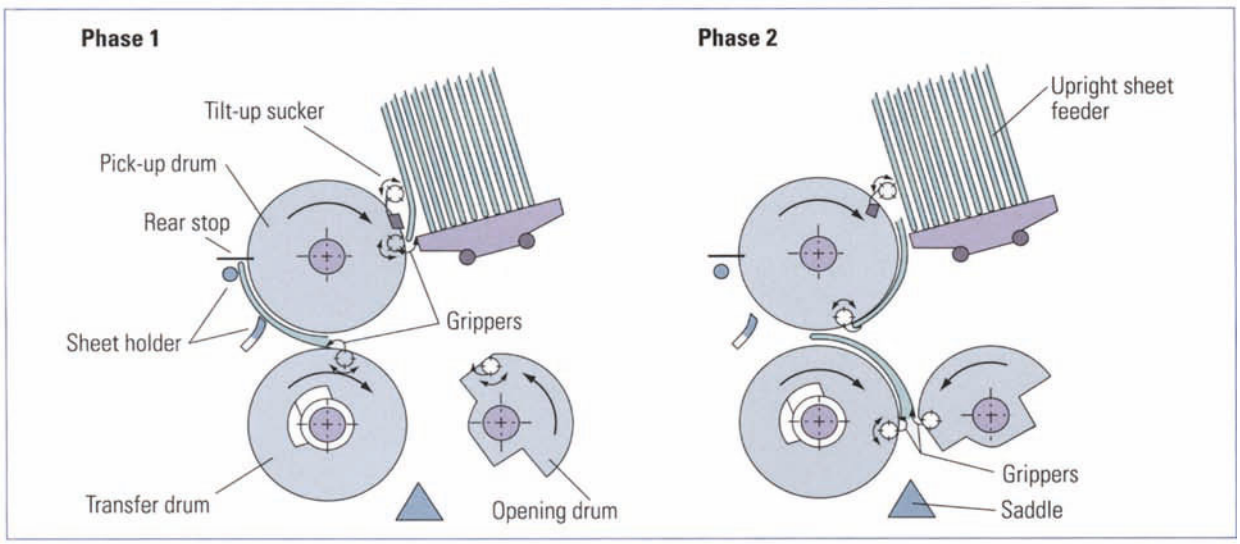


Fig. 7.2-56 Feeder for gatherers based on the transfer technique (Heidelberg)

ry out a cycloidal movement against the direction of run of the roll-off drum.

The roll-off process is designed such that the sucker seizes the bottom-most folded sheet at the back edge and takes it along into the inside of the roll-off drum (upper red sheet). After one suction roller revolution, the back edge of the sheet arrives at the clamping lever and is fixed there. The second suction roller revolution places the sheet in the sheet holder (lower red sheet). The sheet jogger in the roll-off drum pushes the sheet out of the sheet

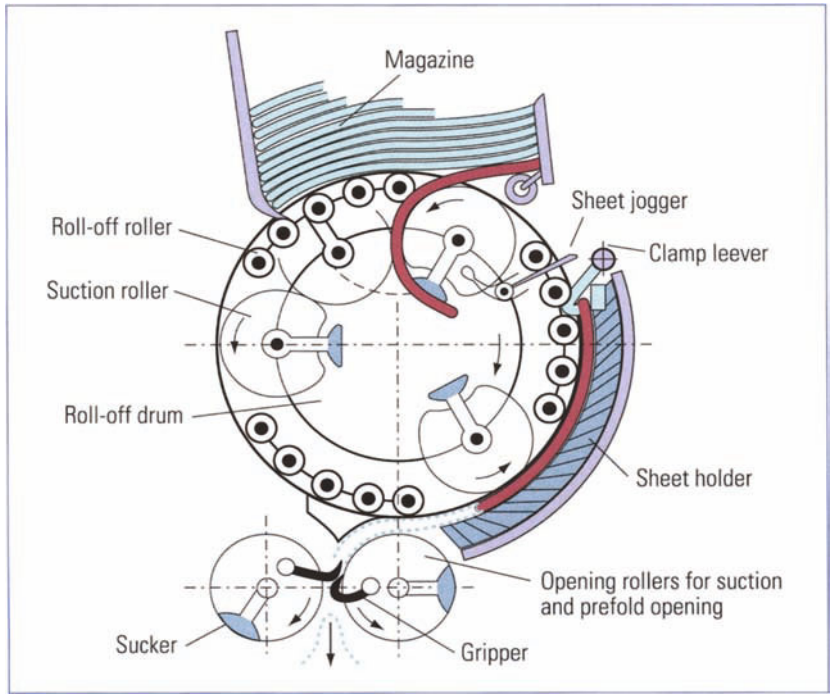


Fig. 7.2-57
Roll-off feeder (Hepp feeder) [7.2-2]

holder onto the opener roller pair, where it is opened by the grippers (gripper fold sheet) or suckers (cross fold sheet) and deposited on the saddle bar.

The feeders of conventional gatherer stitchers are connected in series (fig. 7.2-58). The open sheets deposited on the saddle bar are transported by the pushers on the saddle chain to the next feeder. An output of up to 20 000 cycles/h can be reached with the feeder magazines arranged in a line.

The demands of magazine producers for systems with a considerably higher nominal output has resulted in the development of so-called *drum processing systems*. Here the sheets are transported to the next station in a three-dimensional curve. Figure 7.2-59 shows the operating principle of a *conveyor drum*.

The "drum" is a folded signature transport cylinder. Up to forty saddle bars are mounted on the cylinder circumference. The processing stations are located above the cylinder alongside the surface line. After the sheets have been put onto the respective bar by a chain conveyor, they are rotated around the cylinder shaft with simultaneous continuous shift in the surface line

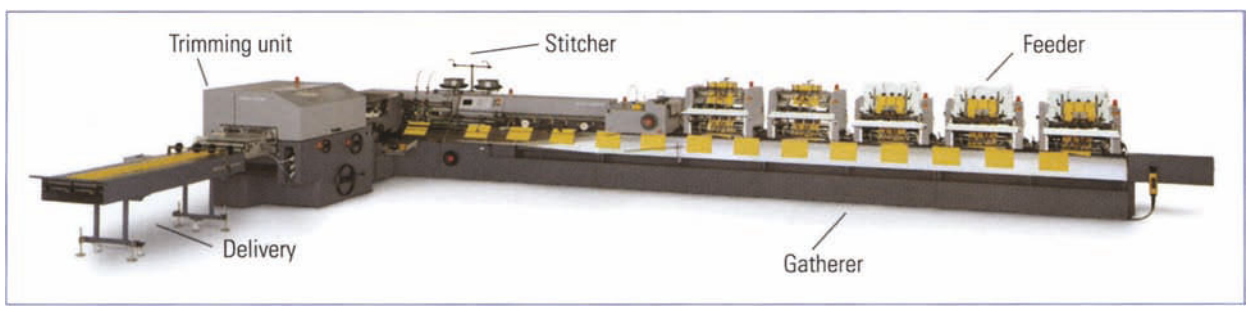


Fig. 7.2-58 Wire-stitching production line/gatherer-stitcher (Stitchmaster ST 250, Heidelberg)

direction. Applying this method of conveyance enables an increase in output of brochure assemblers of up to 40 000 *products per hour*.

This output cannot be reached with manual loading. Therefore drum processing machines are mostly equipped with folded signature reel feeders (fig. 7.3-7) or, as a less effective alternative, with bundle feeders. Figure 7.2-60 shows a saddle-stitcher conveyor drum system from Ferag for the production of magazines.

7.2.5 Binding Blocks

7.2.5.1 Characterization of the Process

Binding blocks is the production of a temporary or permanent connection of the collated book block by positive, non-positive, or bond jointing processes (i.e., held together by force, fixing elements or adhesives).

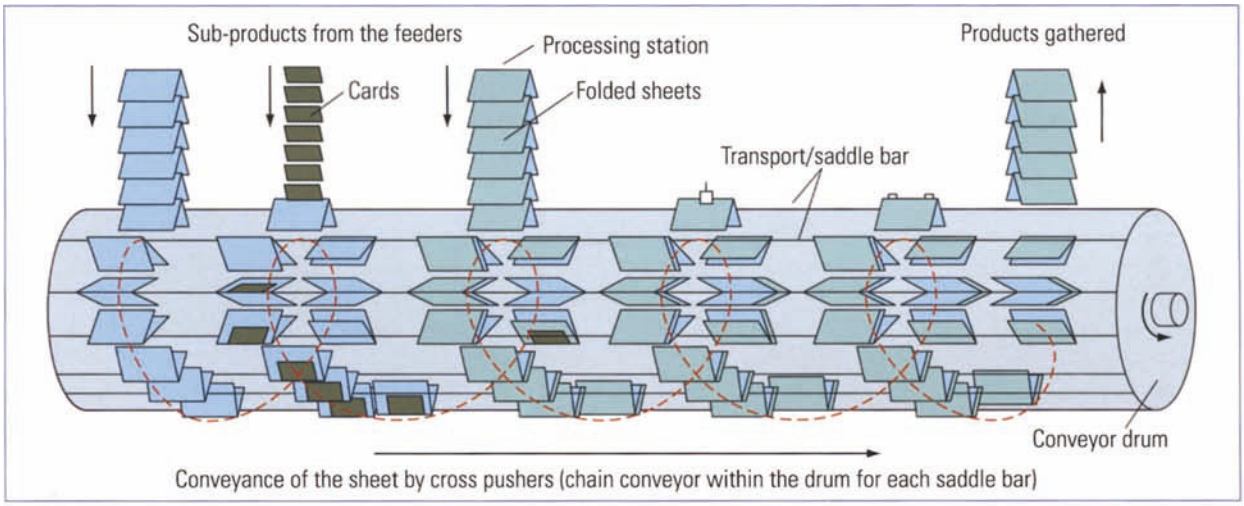


Fig. 7.2-59 Operating principle of a conveyor drum processing system (Ferag)



Fig. 7.2-60 Saddle-stitcher drum for the production of magazines (Ferag)

Materials and partial products to be processed are:

- collated multi-layer blocks and loose-leaf blocks,
- inserted single-layer blocks,
- folded sheets.

Very often binding occurs in several elementary processes. Both the link-up of elementary processes in workflows (e.g., perfect binding) as well as a non-interlinked process flow (e.g., thread sewing) is usual here.

Auxiliary materials:

- Fabric threads or wire are deployed as jointing media for positive binding methods.
- Adhesives are used for bonding processes. Thread-binding methods for multi-layer blocks usually receive additional glue application.
- To cover the adhesive binding and for better binding strength, paper lining (backing) strips, muslin (fabric), or compounds are used. *Lining* is also taken for stiffening and strengthening the binding.
- Single sheet binding systems use different jointing elements such as wire or plastic spirals, wire or plastic combs, rings, cords, and also screws.
- Non-positive (or pressure-based) jointing processes are based on the use of rail-shaped metal or plastic staples.

Other aspects for structuring the means of binding are:

- *The jointing medium location*
  In the back fold of the folded signature or on the rear edge of sheets (e.g., for thread-sewing books, adhesive binding, back margin wire stitching); before the back edge through the leaf surfaces (stitching on the side). Side-wire stitching is an example.
- *Differentiation of folded signature binding and block binding*
  Uniform and simultaneous binding of the block parts and the block is usual (e.g., when thread-sewing books, the folded signature is stitched to itself as well as to others);
  when binding folded signatures, the sheets can be bound independently of the block using a different process (e.g., with thread-sealing).

In book binderies, the positive jointing process with threads or wire is colloquially referred to as stitching, bond-jointing is called perfect binding or block gluing.

The examples in table 7.2-15 will give an idea of the many different ways block binding is practiced and some final products produced with this process are listed in table 7.2-16.

7.2.5.2 Thread-Stitching Books

The thread-stitching of books is a block binding process where the connection of the inner sheet sections and the sheets to one another is primarily achieved by fabric threads. This connection is improved by gluing, gauzing and/or backlining or back-stripping, as well as subsequent backlining of the block. Thread-stitching of a book block comprises the following elementary processes (see table 7.2-17):

- *Thread-stitching:*
  form-fit connections of sheet sections and sheets.
- *Gluing block spines:*
  glued connections of stitched sheets in a block.
- *Gauzing blocks:*
  additional reinforcing of the binding by sticking a gauze strip on the block spine which overlaps the front and back side of the block spine by 1 to 2 cm.
- *Back-stripping blocks:*
  gluing a paper or paper gauze laminate to the block which overlaps at the sides.

As an alternative to gluing and gauzing: the sheets are simultaneously stitched onto a gauze strip in the thread-stitching machine; then it is only a case of gluing.

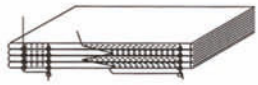
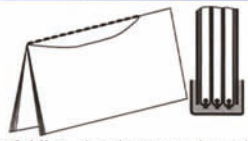
Thread-stitching by machine is modeled on the traditional work done by hand. The following operations are to be carried out in the book thread-stitching machine:

- loading the gathered blocks into the stitcher,
- separating and opening the folded sheets,
- stitching the separated folded sheet to itself and to the previous sheet,
- cutting off the binding threads between the blocks,
- delivery of the threaded blocks.

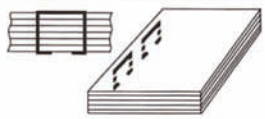
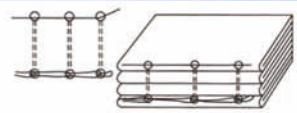
The typical function groups of thread-stitching machines are represented in figure 7.2-61.

The feeders of thread-stitching machines must separate the sheets, open them in the center, and lay them on the saddle, since book thread-stitching is done through the back edge. Therefore the folded signatures

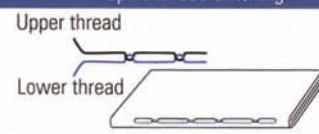
Multi-layer blocks with binding in the back spine

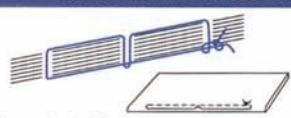
Thread-stitching	Thread-sealing	Perfect binding
		
Each sheet is stitched individually to the previous one.	During folding, the sheets are bound with thread staples; the block is then glued together after completion of the collating process.	The back edge of all the folded signatures is cut off and the sheets are bound with adhesive.

Multi-layer blocks with lateral binding

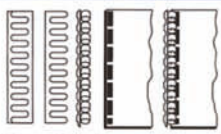
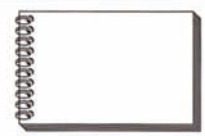
Side wire stitching	Side thread-stitching
	
Wire staples are pushed into the block surfaces.	Stitching for thin blocks.

Binding single-layer blocks

Wire saddle-stitching	Spine thread-stitching
	
Wire staples are inserted from the inside to the outside or from the outside to the inside into the spine (for magazines).	A stitch seam is placed in the binding margin (for identity cards, passports).

Saddle stitch knot thread sewing	Cord binding
	
A thread is put through the binding margin and knotted (for school exercise books).	A cord is tied in the binding margin around the cover and sheet and then knotted (for documents).

Loose leaf binding systems

Plastic comb binding	Wire comb binding
	
A cylindrical rolled plastic comb is inserted into prepunched holes in the block.	A cylindrical rolled wire comb is inserted into prepunched holes of the block (also called wire-o-binding).

Spiral binding	Binding mechanism
	The sheets contain a two, four or six-fold lateral hole, into which the clips of the binding mechanism are inserted (file).
A plastic or wire spiral is inserted into the prepunched or predrilled openings of the block.	

Table 7.2-15 Block binding variants

to be stitched have a central fold as the final one. The feeders perform the same functions as the feeder in the gatherer stitchers (see sec. 7.2.4.3), so that the same technical principles are applied:

- Folded sheets have gripper margins; opening operation is done with gripper drums.
- Opening right-angle folded sheets using suction drums.

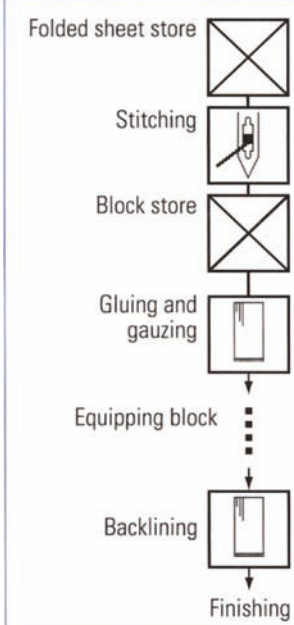
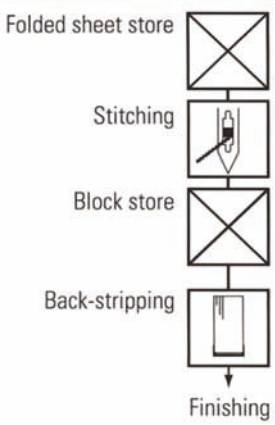
In addition a series of further feeder principles has become established for opening the folded sheets up to the center of the sheet by machine leafing. On the feeder in figure 7.2-61 several rotating suction levers successively lift the sheets to the center of the sheet. These methods have been developed so that a great variety of folded sheets can be processed (open at the head, prepared).

The stitching takes place with tools that are installed in the swinging saddle as well as in a stationary position above the swinging saddle. Figure 7.2-62 shows a stitching process in four phases. At first the piercing needles punch holes into the back binding margin. The sewing needles, which carry the thread, and the hook-shaped needle are pushed from above into the holes. The thread remover "hooks" the threads during the crosswise movement into the hook-shaped needles. The process is completed when the needles have returned to their original position. When the saddle swings backwards, the sheet remains under the stitching unit on the block delivery. Alongside the back edge there are three to five parallel stitching units depending on the sheet height. In this way one sheet is stitched per operating cycle. When all sheets of a block are connected, an empty stitch is executed to knot the threads (if there is no empty stitch, the threads are sealed). Then the threads are cut off.

Intermediate products	End products
Blocks for: • *Hardcovers* • *Multi-layer brochures* • *Single-layer brochures*	Finished by: • *Spiral binding* • *Comb binding* • *Perfect binding* • *Binding mechanism*

Table 7.2-16 Book binding products

Table 7.2-17
Technological variants of thread-stitching

Conventional thread-stitching technique	Thread-stitching and back-stripping
	

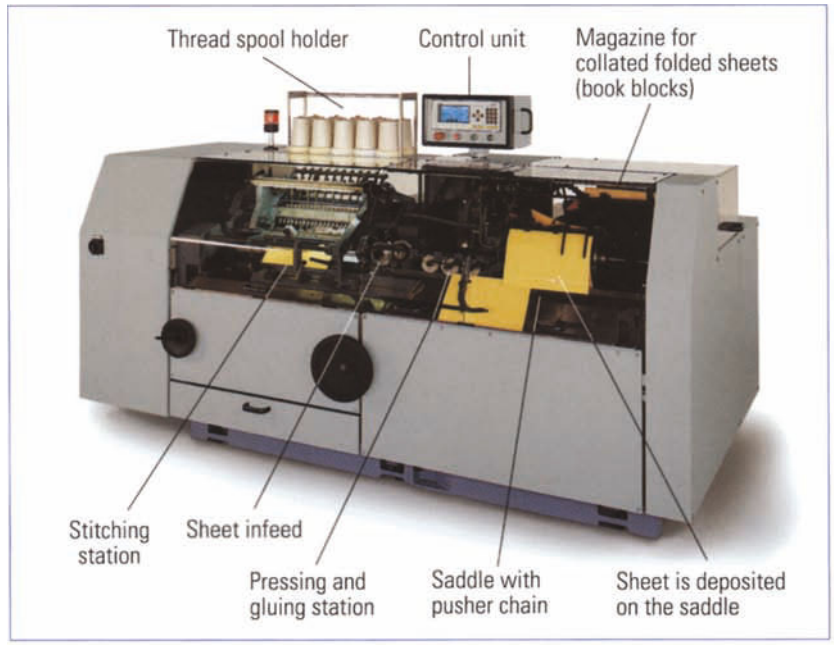


Fig. 7.2-61
Components of thread-stitching machines (Bookthread-stitching machine F 140, Heidelberg)

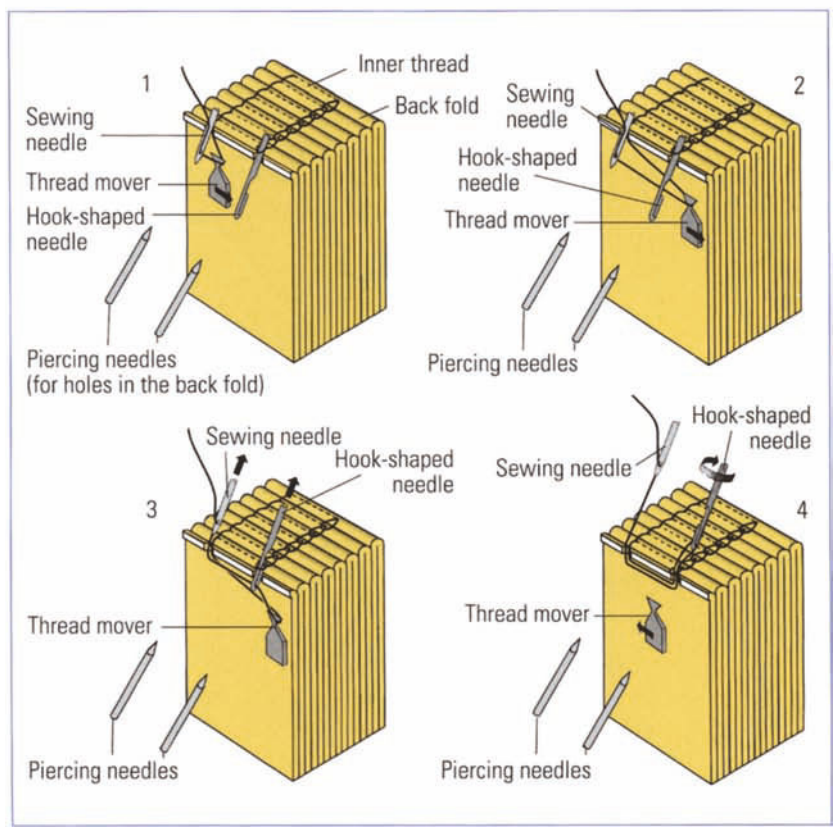


Fig. 7.2-62
Simplified illustration of the thread-stitching principle brochure stitch

With older stitching machines it is possible to place a gauze strip over the binding surface and to integrate it in the sewing process. This results in a better binding stability. The wide-meshed gauze is penetrated by the adhesive during gluing, so that the gluing of the spines of the block is ensured. In addition to the brochure stitch shown in figure 7.2-62, other types of brochure stitches are practiced (kettle stitching, staggered stitching). The staggered stitch line is used to reduce the raising of the block spine (thread build-up).

It proves disadvantageous for the process organization in industrial binderies that each folded sheet requires one work cycle for stitching, after a whole book block has been produced in the gathering process per work cycle. This change in the output rate complicates the coordination of workflows. However, due to the high binding quality of thread-stitched books, thread-stitch workflows have been developed despite the difficulties referred to. Figure 7.2-63 shows the structure of such production lines. It is possible to include back-stripping or gluing as well as the following equipping processes in the workflow.

Quality of the Binding with Thread-Stitching. Thread-stitching is a reliable binding process that in addition permits good qualities of wear and tear. The following stand out:

- *Binding stability:* Removing individual block sections from the stitched block is only possible by damaging the paper.
- *Ease of opening*: Thread-stitched blocks can be opened up easily up to the spine.

There may be flaws:

- If the stitching is too loose: *A sheet overlap* may result, where the inner sheet sections push forwards after the three-page trim.
- Due to *glue lines* in the center of the folded signature: Glue lines are particularly disturbing to the eye with art paper printed up to the back edge. The cause is mainly too thin adhesive, which runs into the thread holes when back gluing/back-stripping.

7.2.5.3 Perfect Binding

Perfect binding is the dominant binding process in industrial book and brochure production today. The main reason for this is the high efficiency of the process. This is achieved because perfect binding has the same productivity rate (block/work cycle) as gathering and trimming. This enables efficient workflows to be set up. Endeavoring to make perfect binding more hard-wearing, a series of variants were developed, which are illustrated in tables 7.2-18 and 7.2.-19.

At present the *spine routing method* is used in all perfect binding machines. To achieve reliable binding, careful spine machining and the correct choice of adhesive are particularly important.

With perfect binding block production processes can be automated.

Figure 7.2-64 shows a perfect binder as installed in many industrial finishing enterprises. Such systems are characterized by:

- interlinking with gathering and trimming machine (very common),

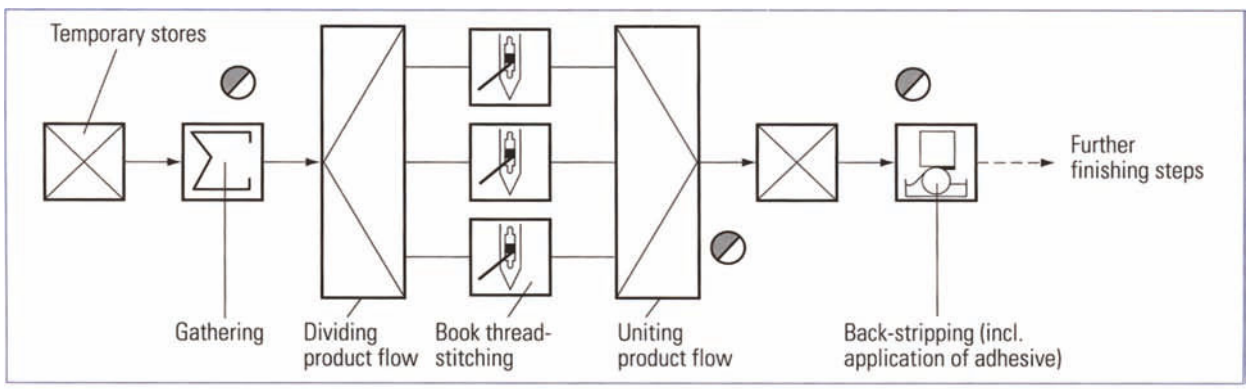


Fig. 7.2-63 Basic principle of thread-stitching lines

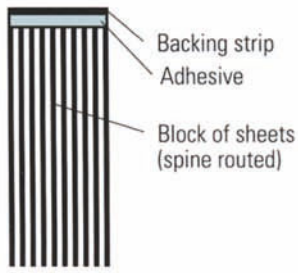
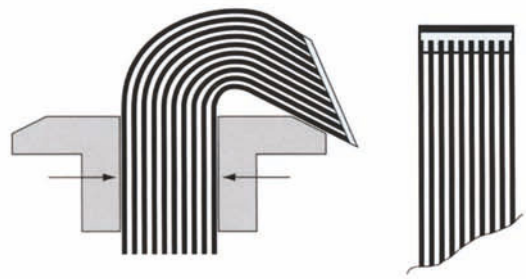
Perfect binding/Spine routing principle	Perfect binding/Fan principle
	
With the spine routing principle, the back edges of the block's folded sheets are removed with the help of knives or cutters. The result is a sheet block. Adhesive is applied to the sheet edges. The adhesive is covered with a backing strip.	Fan binding, also called padding is the original method of perfect binding. By fanning out the block spine while applying adhesive, a narrow strip of glue reaches between the sheet edges. The glue surrounds the sheets in the joining area, which increases the stability of the binding.

Table 7.2-18 Principles of perfect binding

- the large number of variable processes for binding various product types with varying demands on binding quality,
- the module concept by which the appropriate set-up can be made available to the user.

The diagram (fig. 7.2-65) of the inner structure of the perfect binder (as shown in fig. 7.2-64) shows a possible arrangement of processing stations.

The following are characteristic *elements of perfect binding systems*:

- *Endpaper feeder stations.* Here the endpapers are fed to be then bound together with the block (for adhesive binding of hardcovers).
- *Jogging station.* Here the folded sheets of the book block are aligned on the block spine and block head.
- *Transport system.* The block to be processed must be able to run through the necessary elementary processes while securely clamped.
- *Spine processing station.* The back edges of the folded sheets are cut off. Undercutting devices, brushes and suckers for paper dust removal are used to improve adhesion in the potential jointing areas.
- *Gluing unit.* The gluing unit is used for applying glue. Different adhesive systems are in use for binding; they are selected according to the paper to be processed. Each adhesive system requires its own gluing unit construction and influences the structure of the subsequent stations.
- *Lining station.* This is used for binding book blocks for hardcovers. The backing strip paper covers the adhesive surface and reinforces the hinge. The station is switched off for brochure production.
- *Cover scoring and feed station.* This is used for processing multi-layer brochures. The cover is pressed onto the open adhesive surface. It must previously have been separated from a pile and scored. There are various feeder variants.
- *Cover aligning and pressing station.* The cover is formed around the block using pressing tools.
- *Dryer.* Gluing is stabilized in the dryer with aqueous dispersions. High frequency drying (example) is integrated in the adhesive/perfect binder. No dryer is required when processing hot-melt materials. Hot-melt materials must be cooled down.
- *Delivery.* The delivery of the bound blocks must be designed such that there is no block deformation and optimum further processing is achieved. Depending on the degree of coupling (the next processing step follows directly after or the products are put into temporary storage) various design variants are used.

Two gluing units are installed in the system shown in figure 7.2-65, so two adhesive layers are applied to the blocks, separated by infrared intermediate drying. The first very thin and low viscous adhesive layer is to ensure optimum adhesion, while the second highly viscous layer generates a flexible "clamp," so that the block does not break in two at the jointing point.

Table 7.2-19 Perfect binding variants

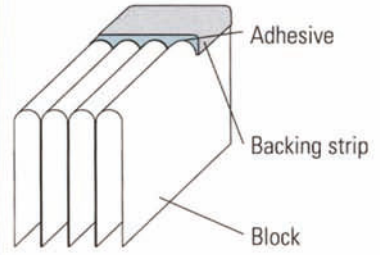
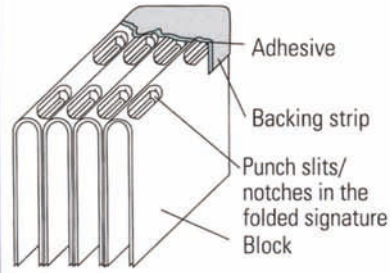
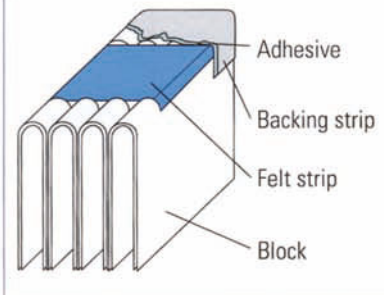
Drawing	Processing principle
	*Quarter sheet binding* By doubling the adhesive surface in the binding, the binding strength increases compared with the individual sheet binding. However, the process is unsuitable for the industrial bindery, as there are no folding layouts which can be efficiently implemented and which consist of more than four pages, folded such that the spine consists of 1-fold edges.
	*Notch binding* This process (also referred to as perforating binding) occurs in two stages. Firstly the back edge is perforated in the folder using a special punch knife, so that the grooves can be filled with adhesive. Gluing the spine and back-stripping of the block takes place in the perfect binder. The spine routing station is put out of action.
	*Flexo-stable binding* Flexo-stable binding describes the aim of obtaining maximum perfect binding strength. Here the back edges in the area of the head and foot trim are not routed off. This requires an additional control of the routing unit in the perfect binder. To reinforce the opening hinge and to counter-balance the spine, a felt strip is glued in the area routed off. The join is covered with a backing strip.



Fig. 7.2-64
Perfect binding machine (Ratiobinder, Kolbus; see also fig. 7.2-65)

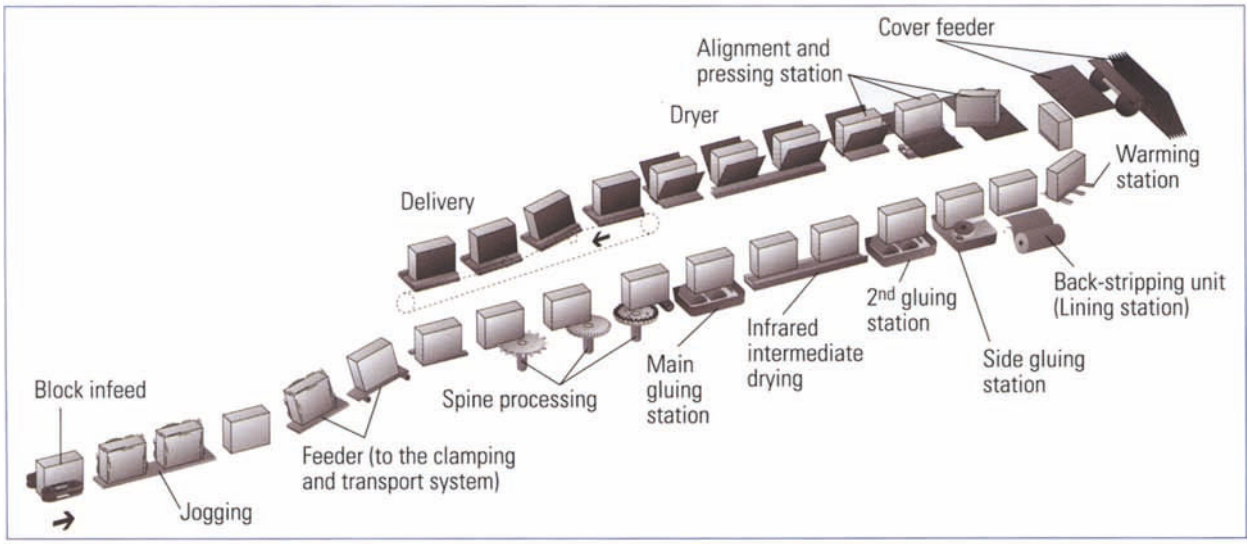


Fig. 7.2-65 Diagram of a perfect binding machine (Ratiobinder, Kolbus)

In all well-known perfect binding machines the same effective processes are carried out using various means. Differences between the machine types, which influence both the output as well as the product quality, result mainly from the

- clamping and transport systems for the blocks,
- block spine processing,
- glue and adhesive application systems.

Clamping and Transport Systems

The most important configuration variants are:

- *Plate chain perfect binders.* Assisted by block feeding the gathered blocks are pushed between two transport chains aligned in parallel and equipped with pressure plates. The distance between the blocks is approximately 2 to 4 cm. The maximum length of the transport system is 10 m, since the clamping forces necessary for processing increase proportionately to the length of the chain carrier. Plate chain binders are mainly used for perfect binding of hardcovers and for back-stripping of stitched blocks. Plate chains are open transport systems (fig. 7.2-69).
- *Carousel perfect binders.* The machine clamps are located at the circumference of a rotating table. The processing stations are positioned under the table. Carousel perfect binders are a special form of the clamp carriage machines.
- *Clamp carriage perfect binder.* Clamp carriage perfect binders are conceived for complex binding lines on which different product types can be produced. The number of work stations of this modular concept is matched to the user's requirements. Depending on the equipment level, up to sixty-five clamp carriages are possible. Clamp carriage chains represent a closed transport system.

The machine diagram shown in figure 7.2-66 corresponds to the system illustrated in figure 7.2-65. The system illustrated is equipped with thirty-two clamps. The clamp length is approximately 50 cm. Each clamp has a separate block clamping unit, which must be

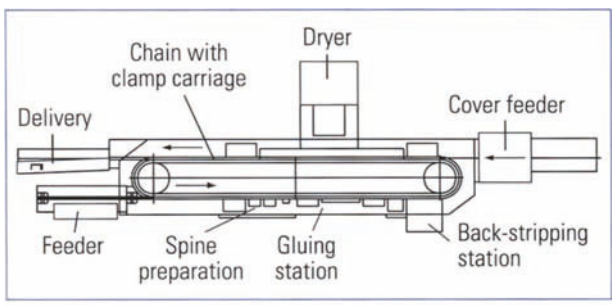


Fig. 7.2-66
Diagram (overhead view) of the clamp carriage perfect binder (Kolbus)

opened for inserting the block aligned at the head and spine via a stationary mechanism.

Block Spine Processing

The back edges are cut off from the folded sheets using circular knives or circular rotary grinders. The interface must not become too hot so that the structure of the sheets is not damaged (burning or melting). To increase the application surface of the spine, notch cutters or routing discs are used. Finally, the adhesive area must be cleared of paper dust and torn cellulose fibers by brushing and suction.

It has been proven that, above all, the processes of routing (levelling) have a strong influence on the strength of the binding. With special routing tools the sheet tear resistance can be increased by 10 to 20%. This knowledge led to the development of special routing systems among the leading perfect binding machine manufacturers, where not only groove lines, but a network of grooves is generated.

Block Spine Gluing

The type of adhesive used and the gluing station must be matched for the application of adhesive onto the block spine. The adhesive properties determine usage. For perfect binding three basic types are used with many modifications:

- *Polyvinyl acetate dispersions* (dispersion cold glue with approximately 50% solids content). PVAC is a polymer of vinyl acetate that is kept in aqueous dispersions. Polyvinyl alcohol is used as a protective colloid (avoiding precipitation). The dispersion contains between 10 and 15% softener, as well as additional substances that influence the physical properties. The particle size is 0.5–5 µm.
- *Hot-melt adhesives.* Ethyl vinyl acetate copolymerides are used as basic polymers for hot-melts in the graphic arts industry. Hot-melt adhesives are three-substance systems. They are composed of approximately 50% basic polymer, approximately 30% sticky resins to improve adhesion (including colophonium), and approximately 20% softeners (in hot-melts paraffin). In addition there are heat stabilizing antioxidant agents (up to 1%). The specific mix results in the desired adhesive properties.
- *Polyurethane adhesives (PUR).* PUR hot-melts are prepolymers with NCO end groups. Prepolymers are prepolymerized molecule chains capable of further polymerization. In addition to the basic adhesive substance, fillers and diluting agents are added. The setting occurs in two phases:
  - a fast, physical setting process by solidification (3 to 5 min),
  - a slow running chemical setting process during which the interlacing of prepolymers takes place under the influence of air humidity and/or own moisture (adhesive that hardens with moisture). The final strength is reached after approximately three days.

Applying Adhesive in Perfect Binders

The application of adhesive is generally carried out with roller gluing units (fig. 7.2-67). In general two gluing form rollers with blade metering are used. A counter-rotating *spin roller* at the exit of the gluing unit smooths the adhesive layer on the block spine (mainly) when processing hot-melt material and prevents the glue strips from soiling the machine. In addition, hot-melt gluing units require heating and exact temperature regulation, since the application temperature (150–190 °C) has a great influence on the binding quality. Hot-melt adhesives are preheated in a premelter to the approximate gluing temperature.

In some gluing units the gluing rollers are engaged at an angle to the block direction of travel, or conical form rollers are used (as with padding, see table 7.2-18), so that a fan effect results. In carousel perfect binders the adhesive is applied between the sheet edges (fan principle) during the circular block movement.

For PUR adhesives, the glue troughs are particularly small and protected by covers. This is necessary, since

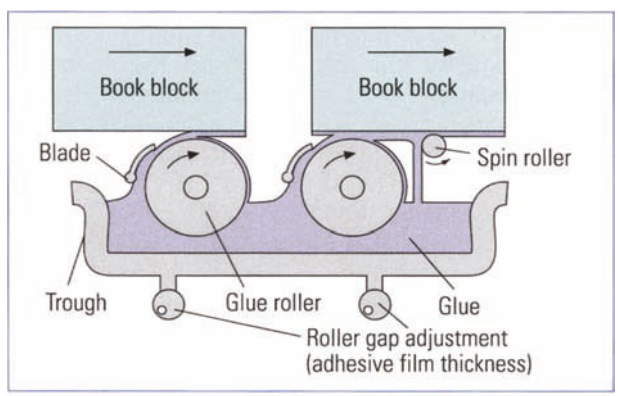


Fig. 7.2-67 Two-roller gluing unit [7.2-4]

the adhesive sets insolubly due to the air humidity. Therefore the volume of adhesive in the gluing unit must be removed once the work is completed.

A further improvement in the intensity of adhesive application can be made by installing several gluing units in one clamp carriage perfect binder. Those gluing units apply adhesives of differing viscosity and harmonized adhesive properties (see fig. 7.2-65). The first application of glue with a low viscosity adhesive provides a close connection between the sheet edges and the adhesive substances. To increase the thickness of the layer (clamp effect on the block spine) a higher viscosity adhesive is applied before the adhesive layer is covered. Variants are:

- two layer dispersion application,
- two layer hot-melt adhesive application (two-shot method),
- three layer hot-melt adhesive application (triple-shot method),
- combined dispersion/hot-melt adhesive application (primer-two-shot process).

The first dispersion adhesive application requires short shock drying, so that the second adhesive layer can safely be applied and a sufficient adhesion is achieved between the adhesive layers. Occasionally an insert of fibrous material is placed between the adhesive layers.

Side Gluing Unit

Side gluing units are required to smear a 1 to 2 cm wide adhesive strip on the front and rear block surface of the book block. This is necessary in order to

- put on an overlapping backing strip or
- to glue brochure covers on the sides.

Dispersion or hot-melt materials are used for side gluing. The tools are disks that transport the adhesive from one of the glue pots located under the clamp carriage and apply it. Nozzle gluing units can also be used.

Lining/Back-Stripping Station

After the application of glue, book blocks are back-stripped according to a lengthways or crossways lining principle.

- *Crossways lining principle* (fig. 7.2-68). From a lining material roll, whose width corresponds to the block length, a web is transported crossways to the direction of block movement and pressed onto the adhesive surface while it is cut off simultaneously. Before, the block was coated laterally with adhesive up to the overlapping height of the back-stripping material. Very firm crimped paper is normally used as back-stripping material. To increase the block strength, large perfect binding systems can be equipped with two crossways lining stations connected in series, where gauze is first pressed onto the adhesive surface by means of compressed air. The crossways lining principle is used in clamp carriage machines.
- *Lengthways lining principle* (fig. 7.2-69). Lengthways lining is integrated in plate chain machines. In the lengthways lining process a glued lining web sized to strip width is put around the book blocks in the direction of run and pressed down. The web is separated in the machine after being inserted. Lengthways lining produces a very close link between adhesive and lining strip.

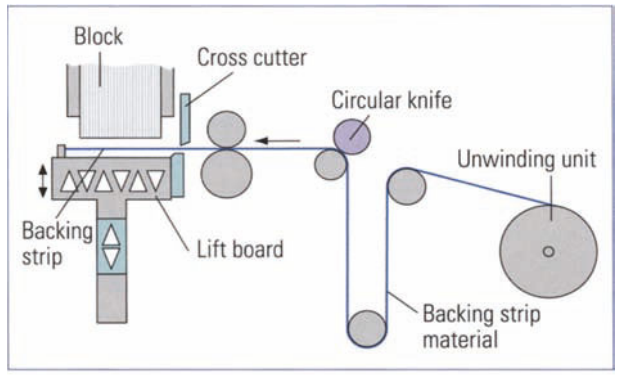


Fig. 7.2-68
Crossways lining station (back-stripping machine) [7.2-4]

Cover Feeder

With clamp carriage perfect binders, the cover feeder station is positioned on the turning circle (see fig. 7.2-66). This leaves space for manual feeding. Three principles are used:

- upright sheet/flat pile feeder (e.g., fig. 7.2-56),
- vertical pile feeder (e.g., fig. 7.2-54),
- stream feeder (e.g., fig. 7.2-32),

whereby the stream feeder is used most frequently, since the simple design principle guarantees good reli-

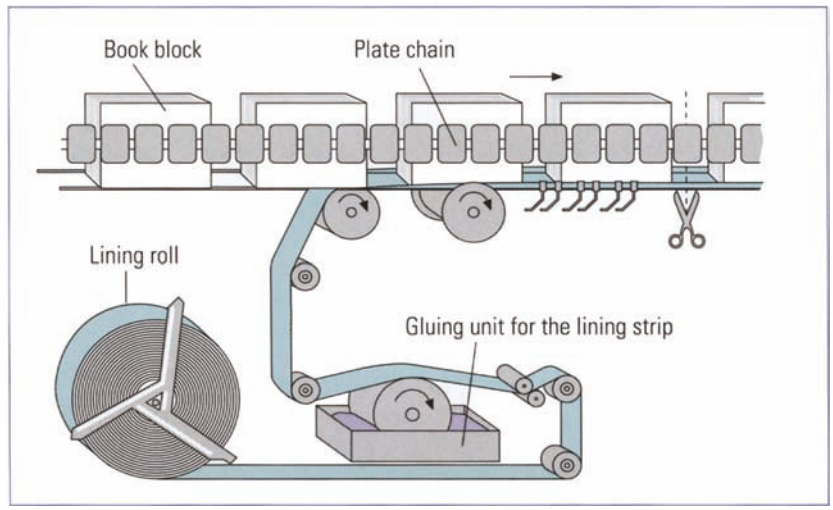


Fig. 7.2-69
Lengthways lining (back-stripping) principle in a plate chain perfect binder (Sigloch)

ability. The covers are separated and transported in the direction of block movement. In plate chain machines the feeder is placed below the level of the plate chain.

Block Stabilizing

To dry dispersion adhesives, the dispersing agent (water) must firstly be vaporized by energy input. In modern perfect binding systems this is done with high frequency dryers. To trim the blocks in the workflow, cooling from approximately 180 °C to about 60 to 80 °C is necessary. External transport belts are used as cooling lines. The necessary cooling time of 2 to 5 minutes requires a cooling line of 50 to 100 m. The cooling lines are used simultaneously as a transport device to the next processing step. Hot-melt adhesives are cooled down in the same way.

Alternatives to high frequency drying (heating up the water by microwaves, whose frequency corresponds to the main resonance frequency of the water) are the convection drying (heated gas is routed around the block) and the infrared drying processes (where the high-energy electromagnetic radiation supplied is converted into heat energy in the product being dried).

Perfect Binding Quality – Prognosis and Checking Problems

The quality characteristics of the binding are:

- binding strength,
- ease of opening the book/brochure,
- compactness of the book block,
- invisible glue strips,
- form stability of the book during use.

Both the binding process as well as the properties of the material to be processed (paper, adhesive) and the outer product characteristics (format, block thickness) have an influence on the adhesive quality.

The quality analyses in perfect binding relate in practice mainly to the block strength, as the customer usually requires a certain binding process when placing an order, and is aware (or should be) of the "normal" framework of additional characteristics for use.

The method used most frequently to assess block strength is the *pull test*. If there is an appropriate test device this test does not require much time and allows a good assessment of the durability of the books and brochures in usage.

The pull test (fig. 7.2-70) is a static testing method, where an individual sheet is stressed using force over the whole sheet length vertically to the block spine. The force F is uniformly increased until the sheet tears. The tearing strength of the sheet F_z is the quotient of load at tearing F and block height h in N/cm,

$$F_z = F/h.$$

The standard values summarized in table 7.2-20 show the rating of perfect binding strength.

Prognosis of Sheet Tearing Strength. The prognosis of the binding strength has a special significance with perfect binding, since the possibility of insufficient block

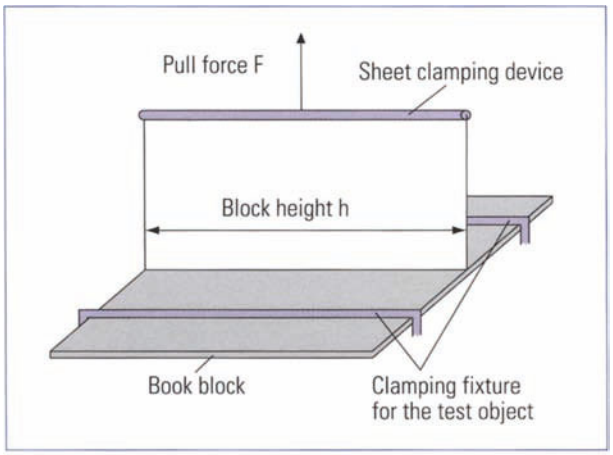


Fig. 7.2-70 Pull test

Rating	General scale	FOGRA standard in N/cm
Bad binding strength	less than 4.5	less than 5.5
Sufficient binding strength	4.5 ... 6.2	5.6 ... 6.5
Good binding strength	6.3 ... 7.2	6.6 ... 7.7
Very good binding strength	more than 7.2	more than 7.5

Table 7.2-20 Pull data (sheet tearing strength F_Z in N/cm)

strength of whole jobs cannot be ruled out. However, the test can only be carried out on fully stabilized blocks, that is, after binding the job. Moreover, the bound products are destroyed in the test.

The sheet tearing strength is mainly influenced by the following parameters:

- *Machine*: construction principle (transport system, routing and roughening module, gluing unit arrangement, type of drying/cooling), machine setting (sharpness of the cutting tools, adhesive temperature, adhesive application thickness, blade and spinner setting).
- *Adhesive*: adhesive type (dispersion, hot-melt, PUR glue), adhesive viscosity, open time of adhesives.
- *Paper properties*: paper thickness, paper grain direction, paper kind (differentiation between uncoated paper and art paper/illustration printing paper is advisable), "inherent" paper properties (e.g., degree of gluing, paper thickness, paper grammage, paper smoothness).

Due to the many influences it is not possible to make an overall applicable prognosis. Specific tests must be carried out for each machine configuration, and standards can be specified as a result. When properly set (the setting instructions should be precisely adhered to) the main influencing variable for a machine is the paper grade used. Because of the significance of the perfect binding strength for industrial binderies the following table contains some useful information on the suitability of frequently used printing papers (table 7.2-21).

In the development of printing paper the trend is towards filled and coated varieties, which leads to an improvement in the printing gloss while using less primary fiber and generating fewer production costs. The interests of finishing are viewed as a subordinate problem here, if at all. That does not mean that the perfect binding capability is generally deteriorating. In the past, very good perfect binding results were achieved with modern paper constructions. On the other hand, the ability to predict the binding strength has seriously decreased.

A solution to the problem is pre-production of test blocks with the job paper. This is often not possible due to deadlines. The development of a simple, fast, and cheap test process would be advisable, which would allow the bookbinder to immediately be able to estimate the paper binding strength prior to perfect binding with adequate certainty.

7.2.5.4 Thread-Sealing

Perfect binding is an economic yet qualitatively unstable process. Thread-stitching leads to excellent binding quality but is too expensive for most products. As a compromise, thread-sealing was developed; a process that is more economic than thread-stitching and also more reliable and more user friendly than perfect binding. This process has two stages:

- the binding process of folded sheets to one another with textile threads during folding and
- the binding process of folded sheets to the block through block linings after gathering.

The principle is shown in figure 7.2-71.

During folding, a textile mixed fiber thread of cotton and polypropylene is pushed into the fold of the back edge and sealed on the spine of the sheet with help of a heated sealing tool. The staple length is approximately 12 mm, the spacing between the staples is 38 mm.

Designation	Suitability for perfect binding
Newsprint paper	Newsprint paper is good for perfect binding, since it is an uncoated paper with little rigidity. The adhesive strength which can be attained is generally close to or above the load at rupture of the paper, which means the paper tears frequently during the pull test. There is no objection to the use of hot-melt adhesives.
Book paper	Book paper is very good for perfect binding, since the uncoated paper has little smoothness, a high load at rupture, and limited rigidity. The ease of opening of an adhesive bound block is worse than that of a stitched one, thus thread-stitching is often used for fancy books despite the good perfect binding strength.
Bulky printing paper	In general, bulky printing paper has a high rigidity, so that the use of adhesive bound blocks overcomes the staple effect in the binding area, which results in a big decrease of the tolerable load tension. Frequently the reader breaks the staple tension by force. Therefore perfect binding is only of limited suitability for bulky printing paper. Despite this, such paper is frequently bound adhesively, because the pull test produces good to very good test results.
Thin printing paper, Bible paper	Thin printing paper is especially good for perfect binding since it • permits opening of the product in front of the joining edge due to its low rigidity, • has a high load at rupture compared to its thickness, • is machine finished. There is usually a cohesion rupture of the paper during the pull test. (The maximum relative sheet tearing strength is reached.)
Magazine paper, Rotogravure paper	With hot-melt adhesives good binding strength is generally achieved with magazine and rotogravure paper since the binding is less strained during use because of the low material rigidity. The risk of smearing the joining edge with coating because of the minimal coating strength is low. Problems occur when printed images extend over the binding margin up to the adhesive edge (bad moistening). Additionally there is a risk in this case of softener migration (change in the print image, disintegration of the perfect binding).
Art paper	Art paper is not good for perfect binding as generally it has too high a rigidity, the coating covers the cellulose fibers, and the coats (recently often multiple coats) have often been bonded with plastics. Perfect binding of art paper always represents a risk. Using PUR adhesives reduces the risk of sheets coming off. When processing unknown types of art paper a pre-run should be carried out before the perfect binding takes place.
Offset printing paper	Offset paper (uncoated paper) is good, but not as good as book paper for perfect binding, as it is usually smoother and more heavily glued (reducing the moistening if necessary).
Matte coated paper	Matte coated paper should be good for perfect binding because of its physical properties (limited rigidity, sufficient load at rupture). However, the coating is less concentrated and tends to smear the sheet edges when working on the spine. Furthermore, paper manufacturers are experimenting for cost-cutting reasons with the furnish (coating composition, binding agent) without taking account of adhesive properties. Overall this leads to a lot of uncertainty in prognosis for the adhesive strength. With perfect binding of products, which demand a good binding strength, pre-runs are therefore advisable. The most reliable binding results can be expected with PUR glues.
Recycled paper	The high proportion of secondary fibers in printing paper, combined with the finishing of the fiber material by coatings (mat and glossy coated), results increasingly in serious (unforeseen) loss of quality during perfect binding. When processing waste paper (de-inking) not all the binding agents or other dispersed plastic constituents or coating from the fiber material are removed. This binding agent residue is deposited in the hydrophilic pores of the cell pulp and reduces the wettability of the recycled paper (compared to that of the primary fibers). The reduction in adhesive properties is very difficult to forecast, so that tests prior to binding are advisable.

Table 7.2-21 Suitability of printing paper for perfect binding

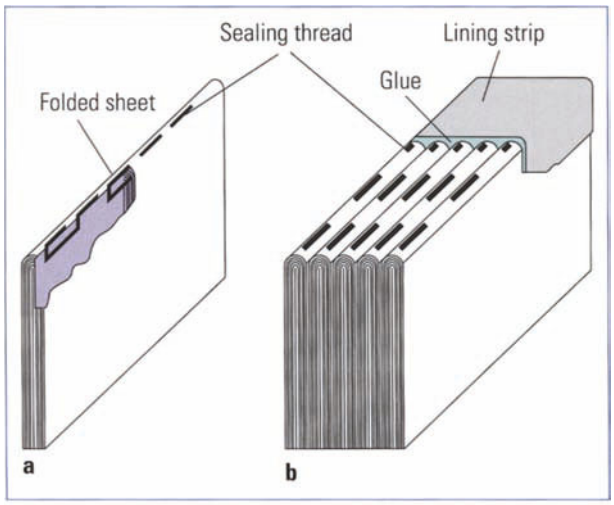


Fig. 7.2-71 Thread-sealed product.
a Thread-sealed folded sheet;
b Book block made up of thread-sealed folded sheets

Since the sealing device is integrated into the folding machine, the production of thread-sealed sheets is achieved without additional manual operations.

The gathered sealed sheets are bound to a block in perfect binders. The spine processing unit is deactivated. When lining blocks, the sealing staples are covered by the adhesive that gives the "inner" sheet binding its final strength. The binding strength in the block is guaranteed since the glue covers the entire spine of the sheets.

The folding and sealing of bookbinding sheets takes place in folding/sealing units. The configuration of a folding/sealing device is shown in figure 7.2-72.

First, the bookbinding sheets are folded in the first and second folding units. Here, the folding layout is optional. In figure 7.2-72, the possibility of a right-angle fold arises due to the position of the folding units to one another.

In the sealing unit, located in front of the final fold, the sealing threads are stuck into and sealed in the final fold. For the final fold, a separate knife folding unit or a special folding funnel is employed. A final pressing of the spine fold is advisable.

Figure 7.2-73 shows the currently used principle of thread-sealing.

The sealing thread is grasped by a sealing chain, clamped, cut, and guided over the sealing line. Stapling takes place there by means of circulating fork needle pairs, which push the ends of the thread through the back edge. The sealing of the free standing staple arms takes place with a stationary, heated sealing tool/rail at a temperature of between 250 and 350 °C. In this process up to 32-page fold sealing sheets can be produced.

Figure 7.2-74 shows a typical module arrangement of folding and thread-sealing machines.

7.2.5.5 Wire-Stitching

Wire-stitching is a form-fit jointing method. With wire-stitching binding, wire staples are pushed through the sheets of a block and closed on the underside (fig. 7.2-75).

Due to the shortcomings in quality for readers of wire-stitched printed products, such as:

- danger of oxidation of the stitching,
- danger of damage to the staple arms, and
- poor aesthetic effect of the binding,

the process is avoided in conventional bookbinding. It is due to the advantages of

- the simple and safe working principle,
- the possibility of direct finishing in workflows,
- a secure block binding, and
- high economic efficiency,

that the process takes absolute priority in the production of magazines, multi-page advertising brochures, and similar products. The dominating process is that of the wire-stitching of single-layer brochures, for which two or more staples are inserted into the back fold. The staple closure usually takes place in the product interior.

These products are colloquially called *back-stitched brochures.*

The principal areas of use for wire-stitching are

- *Production of mass edition magazines.* Gatherer-stitchers are used for the production of mass edition magazines. They are production lines which principally consist of a gathering module, a wire-stitching device and a module for three-side page trimming. For magazines with a few pages, wire-stitching modules are also integrated into web presses (see fig. 2.1-89).
- *Finishing simple printed products.* Finishing is a special area of bookbinding in which only simple products,

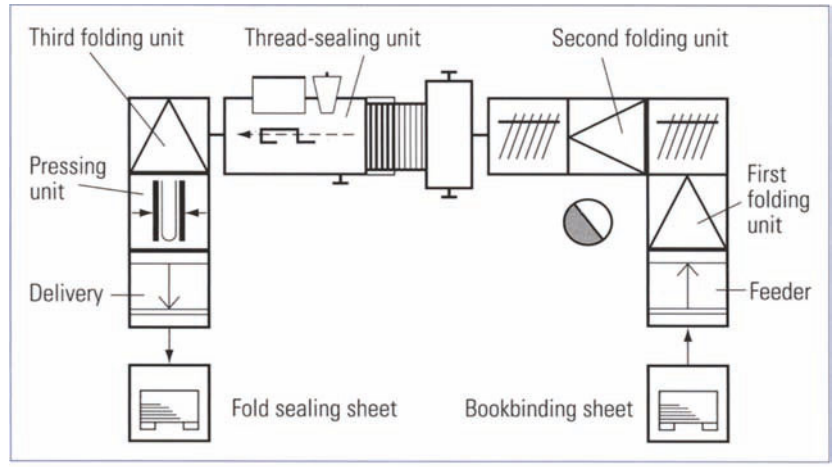


Fig. 7.2-72
Diagram of a folding and thread-sealing production line

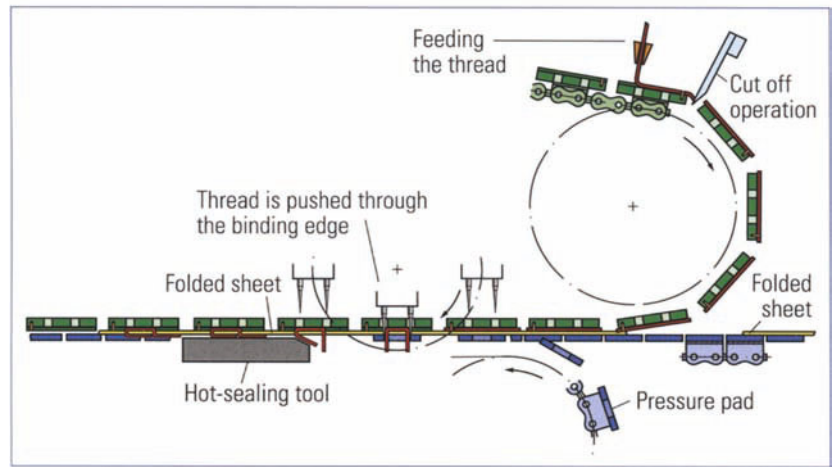


Fig. 7.2-73
The working principle of thread-sealing

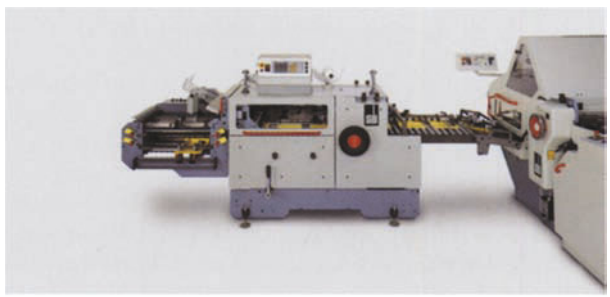
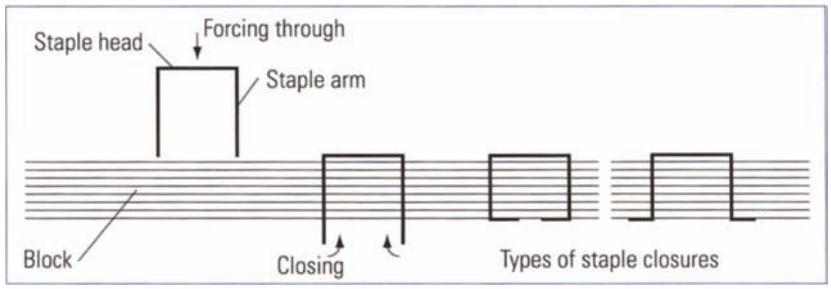


Fig. 7.2-74
Thread-sealing/folding machine with upstream folding unit (Heidelberg)

such as leaflets, back-stitched brochures, loose leaf brochures and similar are produced. The latest field of business is the processing of sheets which have been printed on digital printing systems using NIP technology. Production lines consisting of such a digital printing system or a vertical gatherer, a wire-stitching unit and a front cutter are predominantly used.

Wire-Stitching Devices in Gatherer-Stitchers. The tool for stapling in gatherer-stitchers is called a stitching head. For each staple in a back-stitched booklet, one stitching head is installed. The stitching head has the task to cut the stitching wire coming from a spool to staple size, form it into staples, and push it through the binding margin. Underneath the stitching head, a staple plate is located

Fig. 7.2-75
The principle of wire-stitching and types of staple closures

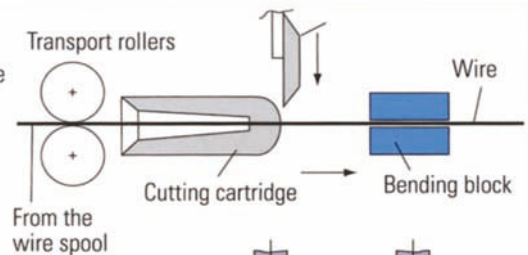
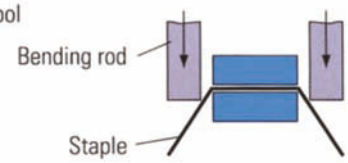
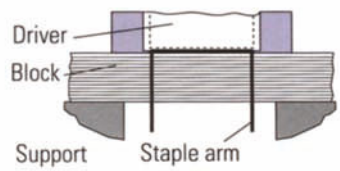
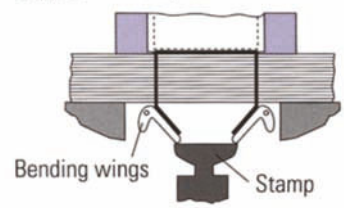


that is responsible for closing the protruding staple arms. Alongside conventional stitching heads that are installed in the gatherer-stitchers of various manufacturers, special designs exist, in particular for high performance gatherer-stitchers. In all stitching heads the same actions are carried out for shaping the staples (table 7.2-22).

Buckling stresses arise when the wire arms are pressed through the block. The buckling stresses increase, the harder the paper to be processed and the thicker the block. If the buckling tolerance of the staple (which is also dependent on the arm length) is lower than the book resistance, the staple snaps prior to the staple closure. This shortcoming is counteracted by use of a thicker and/or stiffer wire. Stitching wires are distinguished by shape (round, square) and by cross sectional dimension. An additional feature of stitching tools is the shaping of eyelets in the staple head in the stitching tool as a means of collating the product.

There must be no relative motion between stitching head and block during stitching. For this purpose,

Table 7.2-22
The function of stitching heads/tools in gatherer-stitchers

A transport roller couple transports the wire from the cutting cartridge into a groove of the bending block that opens to the front. A disk knife cuts and separates the wire so that a staple section is produced.	
While the bending block holds the staple section, the staple is shaped between the bending rods.	
The driver presses the staple into the block after it has first pushed the bending block away from the staple.	
In the lower position of the driver, the two bending wings produce the staple closure under the block.	

- the inserted block is stationary under the stitching station or
- with high performance machines, flying stitching heads are used (see also sec. 2.1.3.4).

Stitchers in Forwarding Shops. For forwarding processes the following distinction must be made:

- *Devices and units for individual construction.* Stitchers and wire-stitchers are used for short runs and single-piece production. They are equipped with one or two stitching heads and a stitching table for wire-stitching on the side which can be converted into a stitching saddle. Stitchers process pre-shaped staples with differing arm lengths and, if necessary, different staple head shapes (eyelets), which are inserted into the stitching head as staple packages. Stitchers are offered with various grades of automation.
- *Book modules for gatherer-stitcher lines.* The finishing of four-page print sheets into back-stitched booklets of up to 100 pages per block is produced in workflows in forwarding shops.
  Here, different from usual production, the non-folded sheets are collated. In a stitching and folding unit, the two wire staples are pushed into the binding margin and the block is folded. After fold pressing, the front of the block is trimmed. Stitching heads that work from wire spools are used.

7.2.6 Trimming

7.2.6.1 Characterization of the Process



Trimming
Blocks for hardcovers and brochures are cut on one, three (or four) sides to the final format, whereby the closed fold edges on the head, foot, and front side of the block are eliminated, if this is intended for the product.

Materials and partial products to be processed are (see also table 7.2-23):

- bound book blocks,
- multi-layer brochures,
- back-stitched brochures,
- leaf assemblies.

Bound blocks can be provided in one-up or two-up form (see fig. 7.2-41). In the case of small-format products more than two copies can be bound as multiple-ups (arranged on top of one another). Folded products or mailings are already trimmed to their final size during folding. In job bookbinderies, the trimming of individual products or small editions takes place mainly on guillotine cutters.

7.2.6.2 Trimming Book Blocks and Brochures

Blocks produced in two-up production must be separated into one-up products prior to trimming.

Trimming machines are differentiated according to the cutting principle:

Knife cutting principle: Machines using the knife cut are designated as

- *three-knife cutters/trimmers.*

With this principle flat knives work against a cutting bar. The block does not move. On three-knife cutters, multi-layer blocks for hardcovers and multi-layer brochures are trimmed.

Shear cut principle: Shear cut machines are classified under:

- *Trimmers*, which work with a flat upper and lower knife whereby the block does not move during cutting.
- *Cutting drum machines*, which work with a flat upper and lower knife whereby the block is moved against the upper knife during cutting.
- *Rotary cutters*, which cut a shingle product stream with a pair of center slitters at each cutting edge.

Shear cut machines are designed for the trimming of back-stitched brochures.

Separating Two-Up Blocks into One-Up Blocks. Industrial bookbinderies use nonstop saws to separate two-up blocks (fig. 7.2-76). The two-up blocks (usually coming directly from the binding line) are separated in the feeder magazine, aligned, and conveyed through the machine on transport belts. The 1.5 to 3.0 mm wide circular saw has carbide-tipped teeth and runs at a rotational speed of greater than 3000 revolutions per minute. Since most of the two-up productions are imposed based on "come and go," one of the

separated blocks must be turned around the head or foot edge so that all the blocks are in the same position for the subsequent finishing processes.

Three-Knife Trimmer. Three-knife trimmers produce an even cut with high precision. The effective block height ranges from 70 mm to 150 mm depending on the type of machine. Several blocks can be trimmed simultaneously (above one another).

The machine consists of the following function groups:

- *Feeder.* Die blocks aligned in the feeder magazine are separated into piles (usually 1 to 5 blocks) and passed on to the transport device.
- *Transport system.* The blocks are transported into the trimming station by means of grippers and pushers. From there, they are conveyed by pushers on transport belts.
- *Cutting station* (fig. 7.2-77). The cutting station consists of a pile pressing unit and the cutting system that produces the front cut followed by the head and foot trim. When changing the format, the

Table 7.2-23 Products created by trimming

Intermediate products	End products
Book blocks for hardcovers and brochures with protruding flaps	*Multi-layer brochures*
Leaf assemblies, which are bound after trimming (four sides)	*Single-layer brochures*
Multi-layer and single-layer brochures, which receive a further feature after trimming, such as a colored edge, attachments, or a jacket	

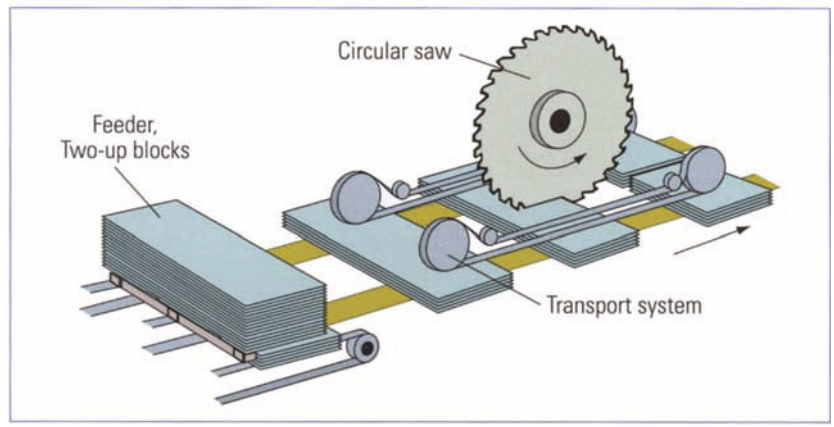


Fig. 7.2-76
Saw for the separation of two-up blocks (Kolbus)

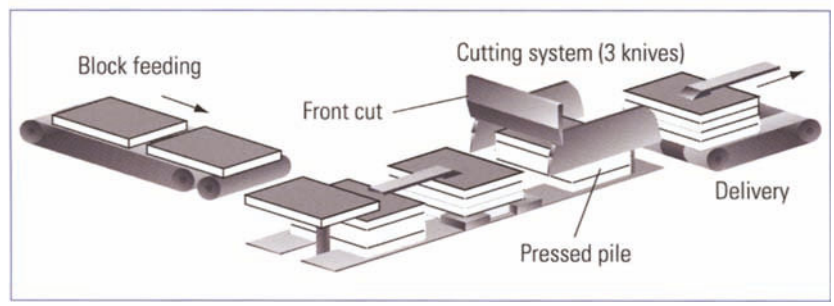


Fig. 7.2-77
Characteristic structure of cutting stations using three-knife trimmers (Kolbus)

pressing unit (imposing surface with board matrix to even out the pressure) must be changed in the same way as the cutting table that holds the cutting. The trim requires two operating cycles per cut. To produce a smooth cut, the knife motion takes place according to an optimized movement function (oscillating diagonal cut) towards the block spine or the front cut. If the knife motion goes towards the front cut, the installation of a scoring device is necessary to trim multi-layer brochures in good quality. The scoring device opens the brochure covers along the cutting edge, otherwise the cover material might tear at the brochure spine.
The cutting knives are either made of high alloy steel, or the cutting edges are carbide-tipped.
- *Removal of shavings.*

In order to achieve the required precision of the cut and an even cutting surface, the knives must be regularly replaced and sharpened. Usually this takes place when starting a new job. Even when using sharp knives, cutting errors cannot be eliminated, in particular when processing overly high block spines with cutting tolerances of greater than 1 mm. A further lack of quality is the skewed nature of the cuts to the block spine. The principal causes for this are imprecisely bound blocks (skewed block spines, uneven block spines).

The nominal output of three-knife trimmers lies between 30 and 120 piles/min. Three-knife trimmers are predominantly integrated into binding lines. If, in one area of production, only hardcovers are produced, it is advantageous to locate the three-knife trimmer at the beginning of the book finishing line.

Trimmers. Since trimmers are generally interlinked, the machine parameters have to be compatible with those of the gatherer-stitcher. These are:

- cutting capacity
  up to 20 000 products per hour, pile trimming,
- input height
  up to 15 mm,
- long knife life
  from shear cut against fixed lower stationary knife.

The required cutting capacity is achieved through the low product input height, the cutting principle, and the separation of the front and head/foot trim in two stations. The upper knives are fixed on a vertically oscillating knife holder which is guided through four or six columns. The cut is a parallel cut with obliquely engaged knives. For processing two-up blocks, splitting knives can additionally be installed in the head and foot-cutting station.

The blocks are transported with their backs facing forwards to the transport system of the trimmer, aligned in the front trim station and cut. The transport cycle corresponds to the oscillation time of the knife holder. In the second cutting cycle, the head and foot trim is executed. The cuts can be carried out in one clamping position of the transport system.

Drum Cutters. Drum cutters were developed for the interlink with drum gatherer-stitchers. The back-stitched books are fed individually into radial take-up cassettes of a rotating drum cutter for the head and foot trims and are pressed there. The pressing plate in each cassette is designed as a lower knife. For cutting, the products run past two stationary "upper knives." They are then removed from this drum and routed into the front trim drum. In a further variation, drum cutters are offered as one-drum trimmers. The use of the drum conveyance principle (shortest transportation paths) and the kinematic reversal of the cutting movement the output could be doubled compared to conventional trimmers. Back-stitched brochures with a thickness of up to 12 mm can be trimmed.

Continuous Trimmers. Continuous trimmers serve to trim rotary folded products with a thickness of up to 4 mm. A product stream is transported into a cutting station with rotating, carbide-tipped circular knives and trimmed at the head and foot during the transport movement. The front trim is carried out in a second rotary trimming module that is arranged at an angle of 90° to the first one. For the front trim, the product stream must be rearranged so that the front product edges make up one of the shingle edges. The unit is capable of trimming up to 100 000 products per hour and can therefore be coupled with web offset printing presses.

7.2.7 Edge Treatments on Books and Brochures

7.2.7.1 Characterization of the Process

The term "edge treatment" summarizes operations carried out on trimmed book blocks or brochures that improve the functionality of the product. However, in

the first place they serve to improve the aesthetic appearance of the overall product.



Edge staining/coloring
The application of a colorant or a metal foil on one or three cutting surfaces of the book block to improve the aesthetic appearance and/or to protect the block.



Attaching a bookmark
One or more fabric ribbons are glued to the block spine and inserted between the leaves of the blocks.



Rounding spine
Bringing the bound sheets or leaves in a position so that the block spine becomes a part of a cylindrical shape.



Adding headbands
Adding a thin strip of cotton or silk to top and bottom of the block spine is referred to as headbanding.

Furthermore, the

- die-cutting of registers on the open cutting edges,
- creation (die-cutting, cutting) of openings in the binding or parts of the binding, and
- drilling of holes in the block

are also assigned to the edge treatment processes.

Materials and partial products to be processed are:

- book blocks,
- multi-layer brochures,
- back-stitched brochures,
- bound or non-bound leaf assemblies, and

Additional materials for
- Edge staining:
  dyes, metal foils,
- Attaching a bookmark:
  textile bookmark, glue,
- Headbanding:
  Headbanding with a single or multiple-colored boarder, glue.

After the edge treatment operations, book blocks are converted into hardcovers and multi-layer brochures.

7.2.7.2 Process Sections of Block Edge Treatments

Providing a Colored Edge (Edge Staining)

Originally all book block edges were covered with gold foil for aesthetic effect and to protect them from climatic influences. Nowadays the colored edge is solely a design feature in industrial binderies. For the most part only a head staining is carried out. Common types are:

- metallic coating,
- closed colored edges.

Gold, silver, or aluminum (together with colored coating) are used for metal-like edges. Machines for producing metallic edges work with cylindrical rolls of multi-layer foils. The carrier, a heat-activated separating layer, the coating and metal layer, and a thermoplastic adhesive layer are constituents of the foil. The foil is pulled over the cut surface and sealed onto it applying heat and pressure. The wax separating layer makes it possible to remove the carrier from the metal layer. After the sealing process the coating layer must be broken up, this means that the cohesion of the metal between the book sheet edges is neutralized.

The closed colored edge is used with approximately 10% to 15% of hardcovers and less than 1% of multi-layer brochures. Mineral inks (finely ground minerals) bound with glue are used. These inks form sediment if they are not constantly kept in motion. Therefore mixer-settlers are installed in the ink application units. Figure 7.2-78 shows a frequently used edge coloring machine. The machine can be integrated in production lines.

It is important that the ink layer is applied thinly, otherwise the ink could peel off when the book is opened. Paper with bad absorbency must be primed prior to application of ink, since otherwise the cutting edge becomes blotchy (with glue water or alum water). For this

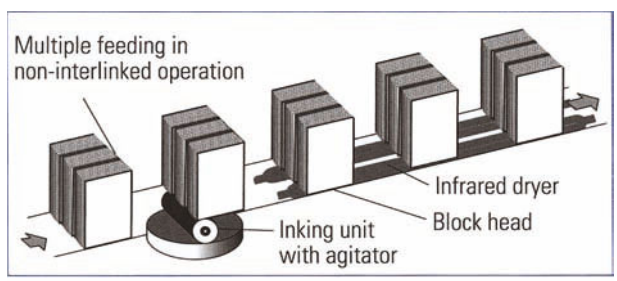


Fig. 7.2-78 Edge coloring machine, head trim (Kolbus)

purpose the machine can be equipped with a second inking unit.

Inserting a Bookmark

Edition covers are seldom fitted with bookmarks (mainly used in reference books, specialized books). The bookmark should be of such a length that it can comfortably reach diagonally across the page to be marked (fig. 7.2-79).

Figure 7.2-80 shows the structure of a bookmark inserting machine. It can be integrated in production workflows.

The bookmarks are transported in the block divider (maximum of four ribbons). During transportation the ribbons are inserted into the block. After that the following elementary processes are carried out:

- cutting the book marks to size,
- inserting the loose bookmark section into the block foot trim; the end of the mark blown to the side is pushed into the foot trim by a slide,
- sticking the upper bookmark section onto the block spines with hot-melt adhesive.

Rounding and Backing the Block Spine

Most hardcovers with a block thickness greater than 15 mm are rounded and backed as shown in figure 7.2-81 (see also fig. 7.2-88).

Rounding and backing

- make the build-up of the block spine when binding beneficial for the assembly process,
- improve the block stability (the tensions caused by reshaping bring the block spine back to its specified shape after usage of the book),
- increase the binding strength,
- improve the opening properties of books.

The backing edges are put into the linings of the book cover, whereby the binding obtains additional stability. The height of the backing edge should correspond to the thickness of the book cover. The optimum

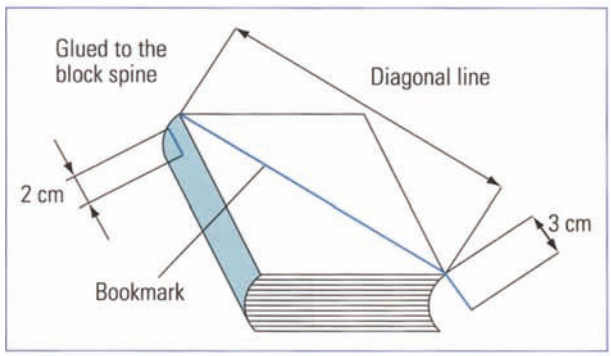


Fig. 7.2-79 Bookmark in book block

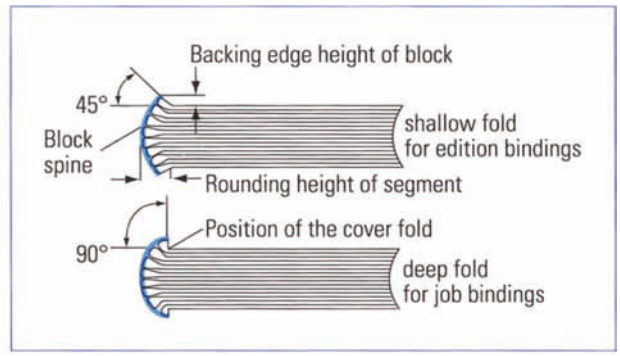
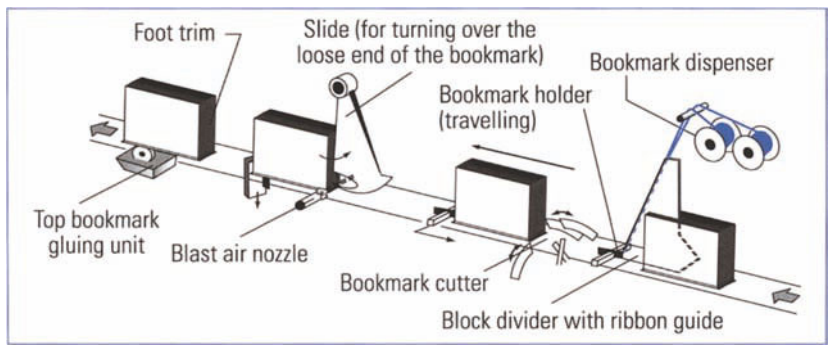


Fig. 7.2-81 Rounded and backed book block

Fig. 7.2-80
Principle of a bookmark inserting machine with the example of inserting two bookmarks (Kolbus)



height of the rounding segment is (0.15–0.2) × block thickness.

The *roller rounding principle* is generally accepted for machine rounding processes (fig. 7.2-82). In the rounding operation, two rotating rollers press the block together and transport it simultaneously upwards. The rounding results from the different movement of the individual sheets. A swinging form tool "bends up" the back edges in the backing station while the block is held by pressing jaws. The two stations are connected in sequence in the machine (fig. 7.2-83).

Rounding of a perfect binding block is troublesome, since the adhesive reacts elastically to the straining strength. Therefore the adhesive must be made plastic by heating up (40 to 60 °C) and if necessary, by adding water (adhesive sources).

Attaching the Headband

Headbands are decorative bands on the upper and lower edge of the book block spine. The woven bands colored on one edge are approximately 1 cm wide. It is difficult in machine processing to place the narrow bands precisely on the block spine. Because of this, headbanding in machines is combined with the backlining of the block (fig. 7.2-84). The backlining process stabilizes the block spine additionally.

The headband is stuck to a backlining paper web, which is the height of a block. The web is fed crossways to the block, cut into strips the width of the spine, and these are positioned on the block spine. Headbanding units are usually elements of book production finishing lines.

Edge Treatment Operations in Production Lines

In traditional bookbinding the process sequence is such that optimum product quality is ensured when the operations are performed correctly (fig. 7.2-85).

For the setting up of production lines for edge treatment processes those operations relevant for the majority of jobs must in particular be taken into account. These are rounding and backing, headbanding and backlining, casing in, and book forming. The operations seldom required are arranged non-interlinked in

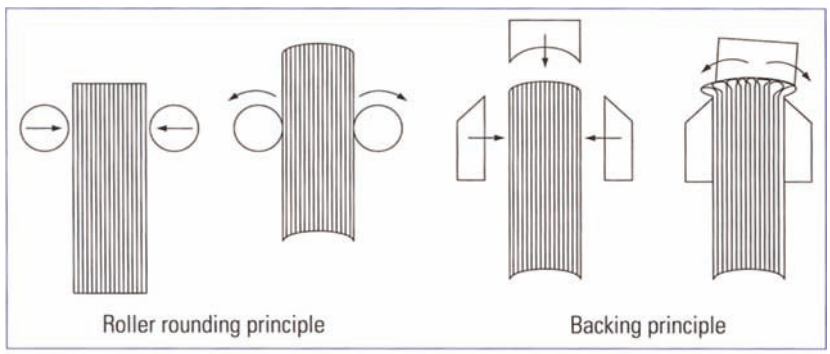


Fig. 7.2-82
Operations and tools for rounding and backing (example)

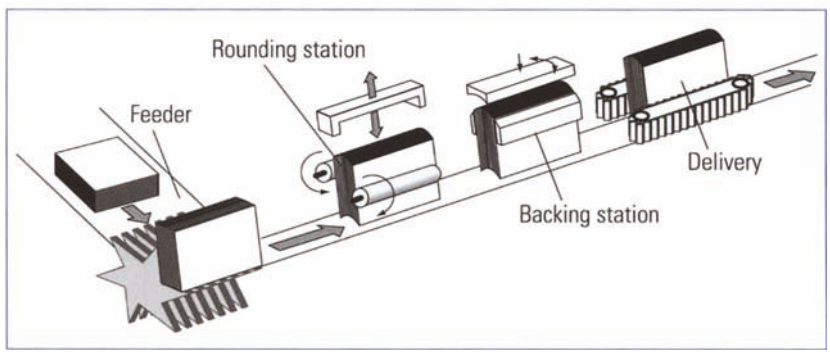


Fig. 7.2-83
Configuration of a rounding and backing machine (Kolbus)

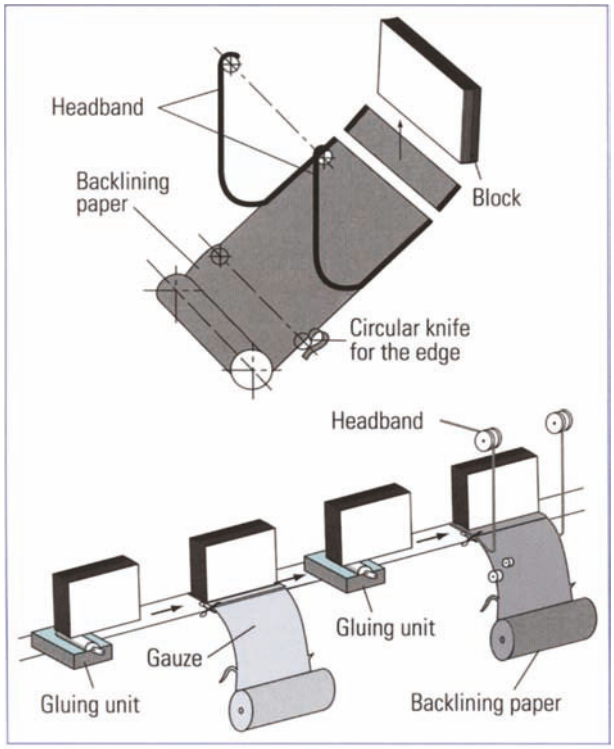


Fig. 7.2-84 Principle of headbanding by machine (Kolbus)

front of the workflow. Edge staining must take place (even if this might mean a loss of quality) prior to rounding (fig. 7.2-86).

In complex binding lines edge staining and inserting the bookmark are integrated within the flow production. Since these operations are only required for some jobs and do not always have to take place at the same time, they are connected parallel to the main product flow (fig. 7.2-87).

7.2.8 Case Making

7.2.8.1 Characterization of the Process

Importance of Covering

The term "covering" (or cover) stands for a design element that is a durable integral part of graphic products. They are connected inseparably or separably with a "block." In contrast to the cover, packaging is solely conceived as protection for the product during dispatch. The purpose of covers is:

- protection of the block without fundamentally affecting the usability of the printed contents,
- to describe the contents (e.g., title, author, abstract),

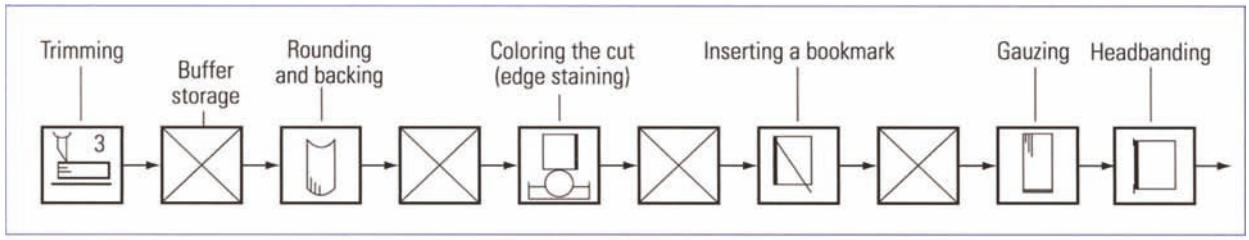


Fig. 7.2-85 Sequence of process sections for optimal product quality in block edge treatment

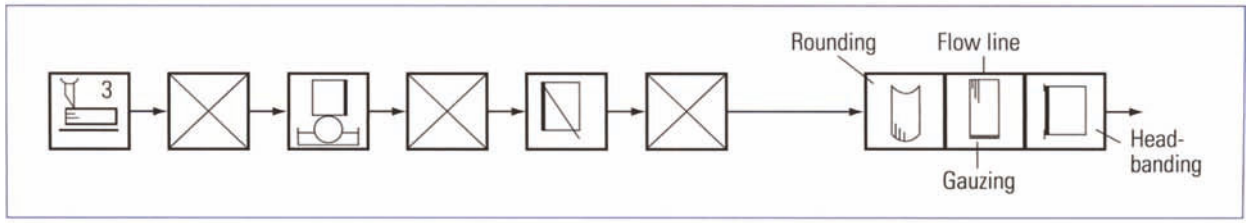


Fig. 7.2-86 Rarely needed (unlinked) process sections for block edge treatment arranged in front of the flow line

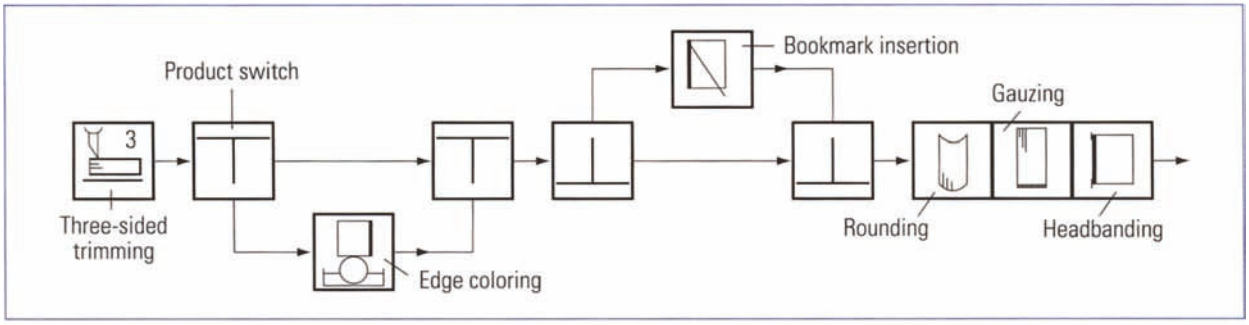


Fig. 7.2-87 Parallel arrangement of rarely needed process sections for block edge treatment

- as an advertising medium for the book or other products,
- as an object of art which represents an aesthetic image in harmony with the internal and external design of a product.

The cover designs listed in table 7.2-24 are used in print finishing.

The book cover is the most costly covering for graphic products. Normally it is made up of (fig. 7.2-88)

- two stiff covers for protecting the block pages,
- a flexible spine insert to protect the block spine,
- the book covering material, which at the same time forms the opening hinge.

The differences in covers due to the design, advertising, and economic aspects are mainly achieved through variation of type and color as well as different decoration of the book cloth.

Figure 7.2-88 shows the cross-section of a hardcover, which demonstrates the connection of book block and book cover. The endpaper is used as a joining element in the case of edition binding.

Book Covers

Several operations must be carried out to produce the book cover, which is made up of various materials.



Trimming cases to size
Cases are cut to size from plates, sheets, or reels.

Cover design	Type of product	Structure
Book cover	Hardcovers	Consists mainly of several parts made of stabilizing and surface material, inseparable connection between block and cover
Cover	Brochures	Consists mainly of one part made of surface finished cover stock, inseparable connection between block and cover
Protective jacket, advertising jacket	Hardcovers, brochures	Jacket around an end product of printed, surface finished paper
Slip carton, cases	Hardcovers, brochures, sheet assemblies	Consists of several parts with stabilizing and surface material or one-piece folding construction, loose leaves. Sturdy protective boxes for bound or unbound graphic products
Files	Sheet assemblies	Consists mainly of several parts made of stabilizing and surface material, carrier of a binding mechanism, separable connection between block and file
Folders	Sheet assemblies	Consists mainly of one part made of surface finished cardboard, carrier of a binding mechanism, separable connection between block and folder

Table 7.2-24 Cover designs

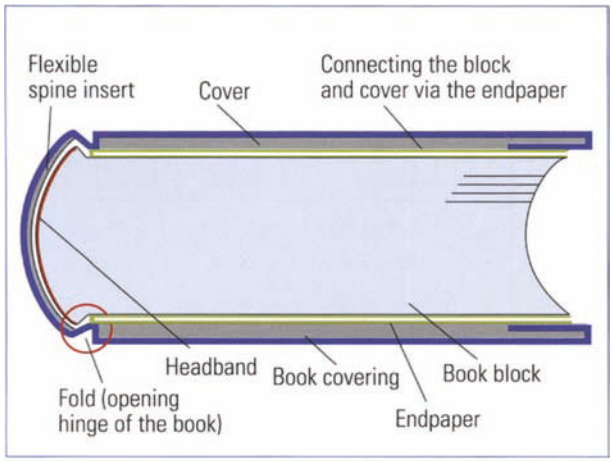


Fig. 7.2-88 Book cover construction

Casing in
Assembling the book cover by joining the cover parts.

Case decoration
The cover is embossed and/or printed. The decoration is used for information and/or for aesthetic design of the binding.

Producing openings
Openings in the covers are produced by die-cutting, which results in an improvement of the product usability (e.g., handle holes or windows).

Materials/sub products to be processed:

- board in the form of plates,
- board inserts in reel form,
- book cloth in sheet or reel form,
- closing mechanisms for holding sheets.

Additional materials:

- adhesives for joining the case,
- embossing color, blocking foils for decoration,
- rivet for joining the closing mechanism in the cover.

Products produced in casing-in processes are book covers for hardcovers and files.

Brochure Covers
Brochure covers mainly consist of cover stock of various quality. When decorating, the cover stock is printed and finished prior to finishing the product. The product can be embellished in the following operations:

- single-layer or multi-layer, full-surface and/or partial coating,
- laminating with foils,
- foil stamping/embossing.

Further design variants can be achieved by

- folding flaps, gluing with a protective cover,
- different connection variants with the block.

Possible design variants for multi-layer brochures are illustrated in table 7.2-25. Comparable constructions can be applied for back-stitched brochures.

In the recent past a large number of cover designs as well as variations for jointing the cover to the block have been developed along with more traditional forms. These developments aim to offer impressive products with good handling, which come close to the binding in appearance and functionality and in production close to the brochure.

The following process steps are necessary to manufacture covers:

Trimming covers
Covers are cut from printed and finished cardboard plates on guillotine cutters. Usually one plate contains multiple ups.

Producing openings
Openings are produced in the covers by die-cutting, which results in an improvement in the product's usability (e.g., window).

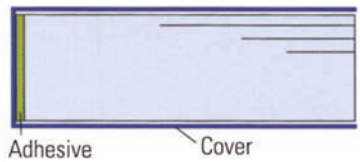
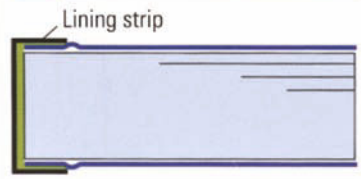
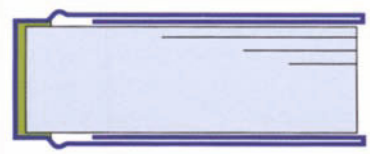
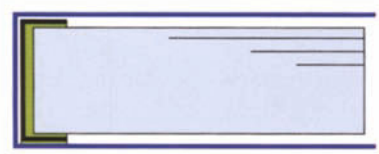
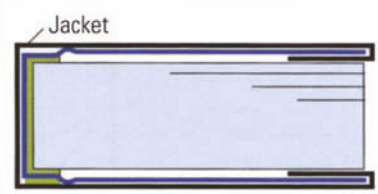
Materials/partial products to be processed are printed and finished cardboard plates.

Products produced in cover production processes are brochure covers, folders, and jackets.

7.2.8.2 Producing Book Covers

The case consists of flexible design elements (in the spine and fold area) and two rigid, robust covers. Therefore, it is possible to cover the spine area and the covers

Table 7.2-25
Brochure cover constructions (block generally produced in perfect binding; similar design for back-stitched brochures)

Illustration of brochure forms	Explanation
	*Simple brochure form, creased twice* A heavier stock cover cut to size is wrapped around the block during perfect binding.
	*Brochure with a cover creased four times* A cardboard cover cut to size is creased in the perfect binder and glued to the spine and to the side of the block. Remark: Creasing is generally performed outwards, as shown. It can, however, also be done inwards.
	*Lining strip brochure* Two creased cover sheets are put onto the block as cover and rear leaf. The block is backed with a textile book lining strip.
	*Flap brochure* Before the perfect binding process, the side parts of the cover are scored and folded to double "cover parts". Two passes in the perfect binder are necessary.
	*Swiss brochure* A cardboard cover (protruding, if necessary) is tucked around a lining strip brochure. Strip gluing is only done on the block spine.
	*(Protective) cover brochure* A protective cover is put around a cardboard brochure and glued to the rear side of the cover. The flaps can be also glued.

with two different kinds of material (flexible and robust on the spine, covering and smooth on the covers).

Materials for Book Covering

Conventionally produced covers with one covering material are designated as *full binding*, covers with two covering materials as *half binding*. The traditional classification of book covering is done according to the number and type of covering materials and designation of the spine covering (table 7.2-26).

The use of soft PVC (polyvinyl chloride) as a covering material led to a different type of design since the material's properties do not allow it to be easily glued and turned. The plastic sealing cover was developed with which the stabilizing material (board) is enclosed between the PVC trims. This takes place by means of high frequency sealing machines (commonplace today in *folder production*). The simplest variation of the PVC cover is the flexible one-part cover. The pretreated soft PVC blanks (usually finished in

Full binding covers	Half binding covers
Leather full covers Fabric full covers Full paper covers (paperback)	Leather half binding Fabric half binding
The cover is a 4-part construction (fig. 7.2-89)	The cover is a 6-part construction (fig. 7.2-90)

Table 7.2-26 Classification of book covers (examples)

screen printing beforehand) are glued to the block endpaper.

Conventional covering materials can be classified into:

- *animal skins* (leather, vellum),
- *fabrics* (book cloth).
  Cotton and rayon fabrics serve as a base material that is produced in various kinds of weaves (linen binding, map binding, etc.):
  - natural fabrics (usually laminated with paper in order to stop the cover glue from "seeping through");
  - finished fabrics, that is, the fibrous fabric is dipped into a finishing agent;
  - layered fabrics: as layering material, PVC is mainly used.
- *Paper* in the specifications:
  - natural paper from various fibrous base materials. Paper is currently used most often for the production of covers;
  - coated paper: PVC or polypropylene is a commonly used material.
- *Fiber felts*: felts can be refined like fabrics.

Board (various thicknesses) is used for the spine insert and the cover (spine insert = *center strip* or *lining strip*). The grammage of center strip varies from 200 to 500 g/m², whereby the "heavy" center strip is used for books with straight spines and the "light" for rounded books. The cover board thickness depends on the book dimension.

Cover Productions

For the production of covers dimensional constraints exist that are based on the dimensions of the book block. Technological requirements are:

- three operations for the production of full binding covers (fig. 7.2-89),
- five operations for producing a half binding cover (fig. 7.2-90).

The case making process includes the following operations:

- *Trimming the cover material*
  Cover, center strip, covering cutting;
- *Case making*
  Assembly of the cover parts into a case for full and half binding covers;
- *Cover decoration*
  Embossing and/or printing of the case;
- *Shaping covers*
  Bending covers and rounding spines takes place during book finishing.

Trimming Covers. Boards are delivered as plates (sheets) that must be trimmed to the cover size. Here, attention must be paid that the grain direction of the cover is parallel to the block height (quality!). Board plates are usually cut on circular saws. Modern case-cutting machine units are equipped with an automatic feeder, two angularly aligned circular knife subassemblies, and an automatic delivery. Recently, board cutters have come onto the market on which the cross cut is designed as a chop cut.

Cutting Covering Material. Fabrics and felts are delivered in rolls. Paper is generally delivered in sheets. The correct grain direction is desirable on covering materials, too. Due to the high cost of material, however, this requirement is often ignored and the covers are cut out of the material in such a way that a maximum exploitation of webs/ sheets comes about. Usually both long grain and short grain covers are processed in one print run. Guillotine cutters are used to cut the lining paper. Roll material is processed into book cloth cuttings by means of special fabric cutters in which the lengthways cuts are carried out by circular knives and the crosswise cuts as chop cuts.

Cutting Spine Boards. Spine boards are delivered on rolls. The rolls are divided into narrow webs. Final formatting takes place in the case making machines.

Case Making

Case making is a complex process with the following elementary operations:

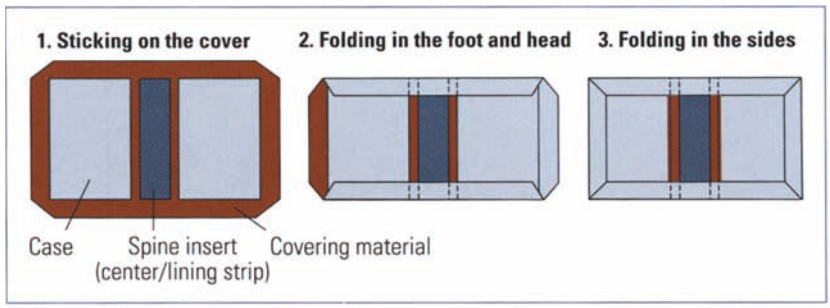


Fig. 7.2-89
Operations for producing a full binding cover

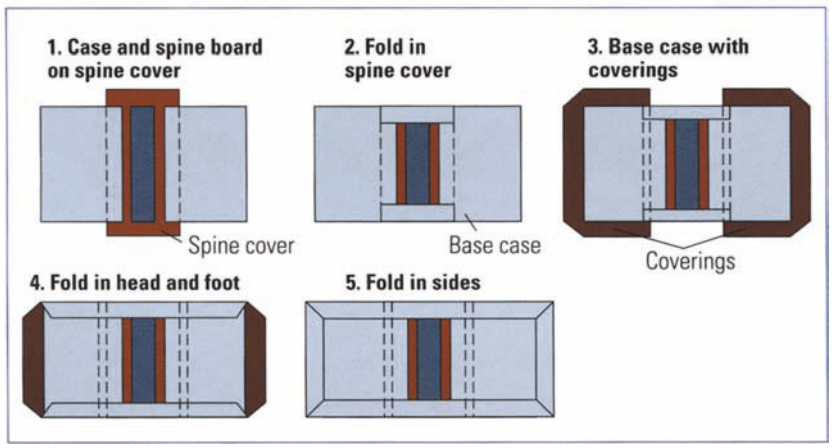


Fig. 7.2-90
Operations for producing a half binding cover

- separating and pasting the covering material with glue; as glue, "quick setting" colloidal pastes (dextrines and/or skin glues) are used,
- separating the covers and the precise positioning of the covers on the pasted covering material,
- cutting center strip and positioning on the covering material,
- tucking in the flaps at the top and bottom and pressing down the flaps,
- pulling in the corners,
- tucking in the side flaps,
- pressing and delivery of the joint covers.

Case making machines produce between 30 and 120 covers/min. Figure 7.2-91 shows a technological principle of a case making machine

Refining (Ornamenting) Book Covers

For refining covers, the covering materials are either printed before case making (e.g., screen printing, offset printing) or ornamented after case making. The most common form of ornamenting is *cover embossing*. Typical embossing processes are illustrated in figure 7.2-92.

During embossing, a plastic shape alteration of the cover material is achieved by means of a die (normally brass engraving). The effect is supported by heat energy. The most commonly used process is foil embossing. The principle of foil embossing can be seen in figure 7.2-93.

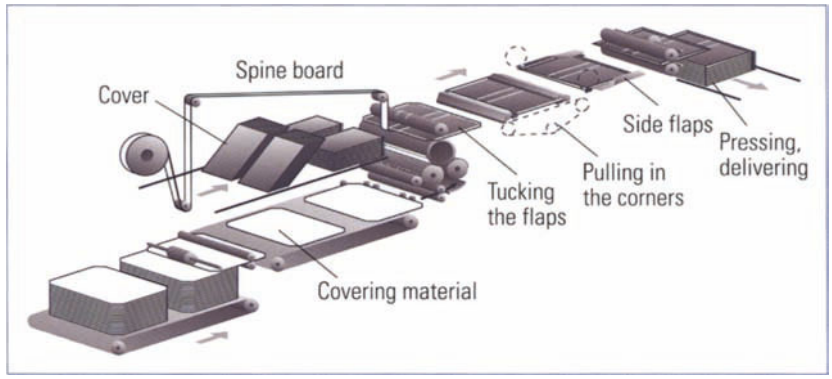
Embossing machines in edition bookbinding are equipped for ink and foil embossing. Embossing presses can be arranged modularly one after the other; corresponding to the number of modules, several embossing operations can be carried out in one machine pass.

7.2.9 Book Finishing

7.2.9.1 Characterization of the Process

The book finishing process contains the assembly of partial products (book and brochure blocks, book covers,

Fig. 7.2-91
The working principle of the case making machine (Case making machine DA85, Kolbus)



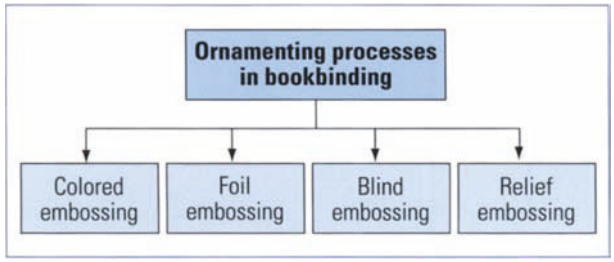


Fig. 7.2-92 Decorative operations in a bookbindery

inserts, jackets), which have been produced separately from one another, into the end product. The process steps are:

- joining of book block and cover to a fixed binding,
- joining of finished supplement products into cases, blocks, or books,
- inserting enclosures,
- attaching book jackets.

The packing operation, which is also part of the book finishing process, is described in more detail in section 7.2.10.

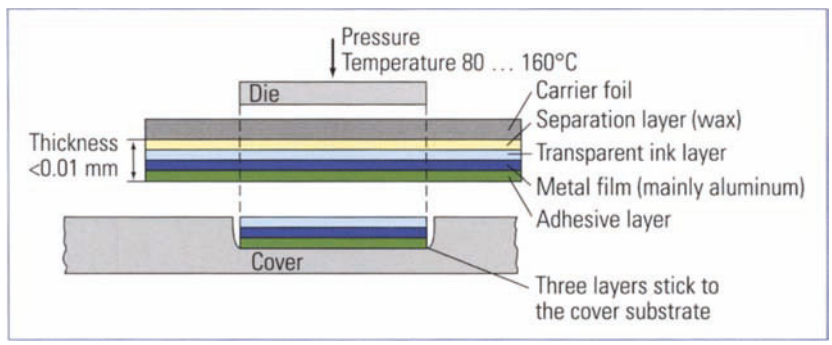


Casing-in
Casing-in is the colloquial description for the adhesive binding of book blocks and book covers.
Traditional description: *Inserting.* Inserting is the joining of block and cover by adhesive binding of the outermost endpaper and the covers.
The casing-in of books is defined as the adhesive binding of a hardcover to the book block. The outermost endpapers must be glued to the covers (gluing). The adhesive binding of the bound multi-layer brochure block to the cover is described as the casing-in of brochures.



Smashing
Smashing (pressing) describes the stabilization of the adhesive binding through surface pressing after the casing-in operation.

Fig. 7.2-93
The use of embossing foils for book cover ornamenting





Forming a hinge fold
Through a heated shaping tool, the opening hinge of the book block on the cased-in book cover is shaped such that the book cover can be opened exactly and with minimal actual service conditions.

The following operations are carried out with hardcovers and brochures:



Inserting inserts
In the inserting inserts operation, pre-finished information or advertising materials are inserted into the bound book. The inserts are positioned between the endpapers or placed in defined or undefined points in the book block. Inserting inserts is of particular importance in newspapers and magazines.



Jacketing
Attaching the cut and folded or creased jacket around hardcovers or brochures.

For casing-in, PVAC dispersions, paste, and paste mixtures are used.

Products produced in the book finishing process are completed hardcovers and brochures

7.2.9.2 The Process Sections of Book Finishing

Casing-In
When casing in, the following processes take place:

- the gluing of the cover on the block,
- the shaping of the opening hinge (fold),
- the stabilizing of the joining surfaces by pressure.

Figure 7.2-94 shows the continuous flow principle of a casing-in machine, which is most often used in edition bookbinding today.

When the book block is fed into the machine it runs over a separating knife and is pushed onto the wing of the paternoster transport system. During the vertical movement of the block in the paternoster, the endpapers are aligned and pasted by means of two gluing units. The separated cover from the feeder is bent (shaping of the case) and the cover spine rounded (when casing-in rounded blocks) and positioned over the glued block. The paternoster movement leads to the joining of the cover with the block and to the pressing of the join.

After assembly, the book is reshaped, the join pressed a second time, and the opening hinge of the book formed. This is done by a book press (usually directly coupled). The hinge formation is called a fold burn because the tools are heated.

The majority of industrially finished hardcovers are rounded, backed, and equipped with a headband. Therefore, the manufacturers of bookbinding machines have developed workflows (described as "book finishing lines") in which the

- rounding and backing,
- backlining and headbanding,
- casing-in, and
- shaping a hinge and pressing

operations are interlinked rigidly with one another (fig. 7.2-95).

Trimming machines, edge staining machines, and/or bookmark inserting machines can be loosely coupled

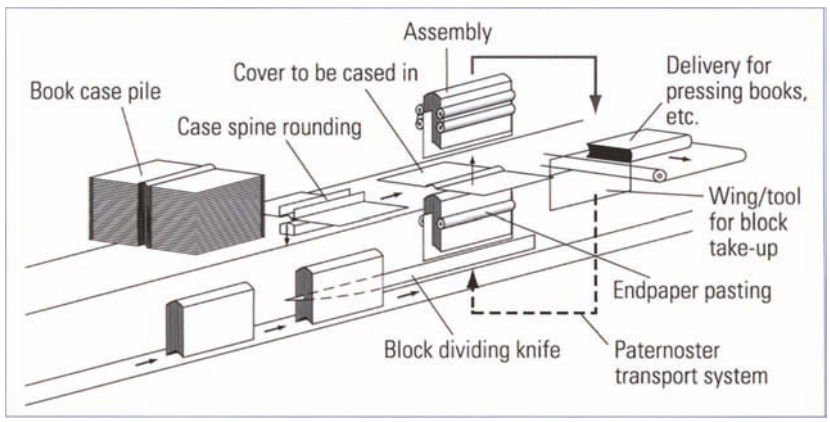


Fig. 7.2.-94 Casing-in machine (Kolbus)

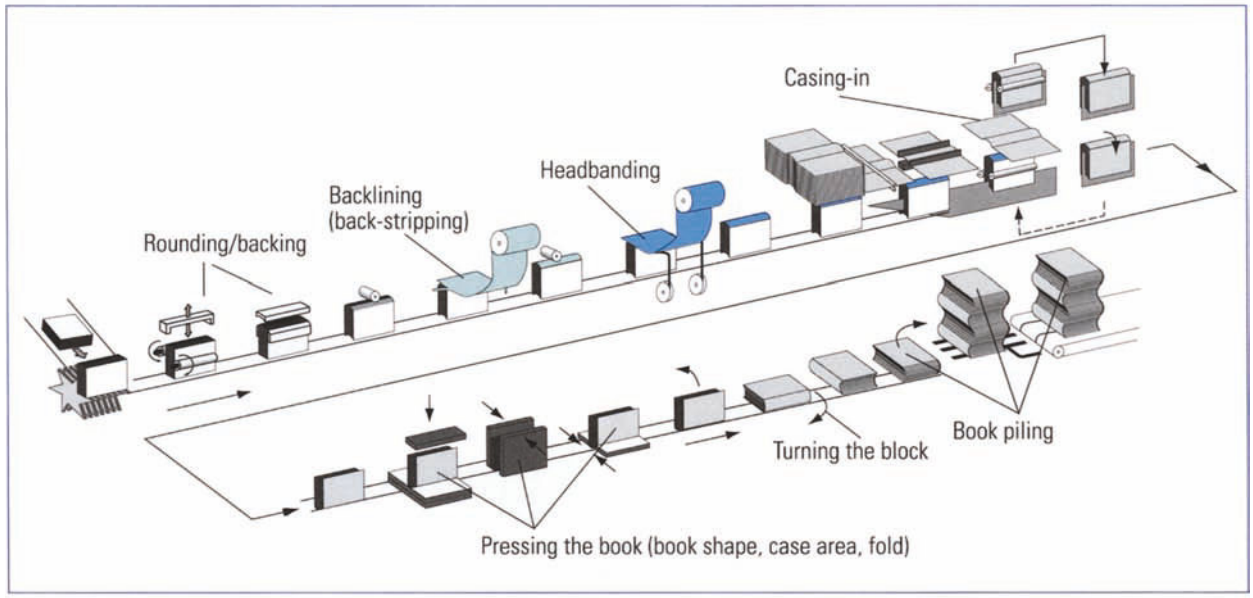


Fig. 7.2-95 Book finishing for the production of hardcover books (Kolbus)

to the book finishing lines (by means of transport belts). In bookbinderies that mainly produce hardcovers, workflows are installed that start with gathering and finish with the packaged book.

Inserting Inserts

"Inserting" involves pre-finished graphic products (sheets, booklets, tabular objects, etc.) inserted loosely into a hardcover or a brochure (advertising inserts). This is especially common with magazines. Inserting machines must

- usually insert several inserts and
- achieve the performance in the mail room of 20 000 to 80 000 products per hour.

Normally, the inserts are placed at an unspecific point in the core product. If the inserts are to be placed at a predetermined position in the block, they must be inserted manually.

Inserting machines in mail rooms apply various principles:

- *Drum-inserting machine*
  The operating principle corresponds to the gatherer-stitcher drum described in section 7.2.4.3.
- *Line inserting machine*
  Here, the inserts are assembled in a "gathering machine" and laid in the opened block.

These principles are not applicable for books since the rigid cover prevents bending for transport manipulation. The achievable working speed is not necessary since inserting machines are integrated into workflows and these, in general, only have a nominal rated capacity of 2000 to 4000 products per hour. The need for inserting inserts in books exists. To date, however, the number of inserts in books is limited to a maximum of three items.

Applying a Jacket

Jackets have become a main part of books. They are used

- to protect the book cover (this function has become of secondary importance),
- as an advertising medium for the content,
- as covering for the often low-grade covering materials and simple design of the book cover.

The width of the jacket is twice the width of the cover, the width of the spine, and twice the flap width. The flap width is usually 0.2 to 0.3 × cover width.

For mechanically placing the jacket around hardcovers,

- both book covers must be opened,
- the jackets must be grooved/creased on the potential bending fold,
- the cover flaps must be put around the opened book case,
- the cover must be closed to ensure snug fitting of the jacket.

Figure 7.2-96 shows the working principle of a jacketing machine where the blocks are supplied to the machine on their spine and the jackets are fed from underneath.

7.2.10 Packaging

7.2.10.1 Characterization of the Process

Packages have three basic functions to fulfill:

- *Protective function.* The finished printed product should be especially protected from mechanical strain (impacts, pressure), climatic influences (dampness, temperature variations, light), and soiling (dust, grease).
- *Logistics function.* Packages are working means for transportation, trans-shipment, and storing. The shape of the package and the packaging of the transport units have an important influence on the efficiency of shipping.
- *Information function.* Packages must contain information (pictures, text, machine readable data) that serves the purposes of identification, assignment, advertising, and so on.

Accordingly, at least the following procedures must be accomplished when packaging books and brochures:



Product packaging (production of packages)
Books and brochures are packaged individually or as multi-unit packaging.



Marking of packages
The product packages are provided with dispatch information and, if necessary, advertising stickers that are placed inside (transparent packaging material) or on the packaging.



Producing of dispatch units
The packages are piled on dispatch units in a stacking pattern (usually a pallet).



Packaging of dispatch units
Dispatch units are provided with packaging to protect the products on the pile and to maintain the pile order. The dispatch unit can be additionally marked.

Materials/partial products to be processed are

- books and brochures,
- means of packaging, such as packing foil, packing paper, collapsible cartons/folding boxes.

Additional material such as labels, marking material, glues, and adhesive foils are used. A description of different packing terms is given in DIN 55405; figure 7.2-97 shows a diagram of the different terms.

Products produced through packaging are, for example, transport units of printing products.

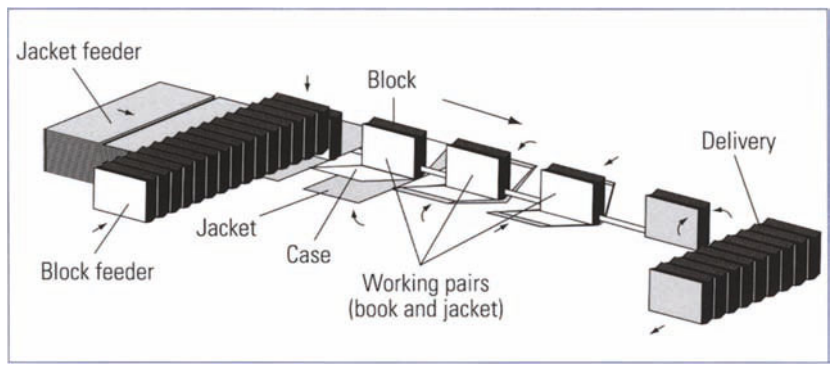


Fig. 7.2-96 Jacketing machine (Kolbus)

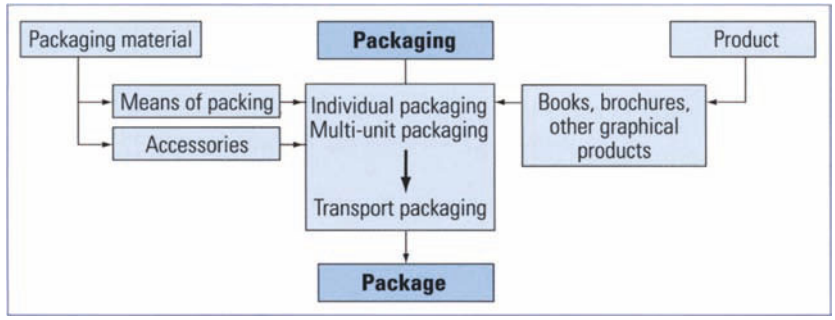


Fig. 7.2-97
Diagram on the basic terms used for packaging

7.2.10.2 Packaging of Books and Brochures

Types of packaging material used are:

- plastic films for individual products, product piles, and pallets,
- strapping paper for individual products and leaf piles,
- collapsible/folding cartons made of corrugated board for product piles.

In industrial bookbinding, *transparent plastic film* is predominantly used as the means of packaging. The film is wrapped around the product and sealed to form a casing. When using shrink film, the casing is brought to the correct size in a thermal shrinking process. The *advantages* of film packaging are:

- Plastic packaging protects well against detrimental climatic influences.
- The product remains visible after packing and the jacket design may be used for the product advertising.
- The packaging technique is, in contrast to paper or collapsible carton packaging, simple and can be easily integrated into production lines.
- The packaging has a snug fitting around the product so that no undesired deformation occurs.
- The film is inexpensive.
- The environmental burden from book packaging films is lower than that of other materials (e.g., paper).

Disadvantages can be said to be:

- The books/brochures cannot be checked for defects by the purchaser without destroying the packaging.
- The protection against impacts is minimal.

Packaging of Hardcovers and Multi-layer Brochures in Bookbinderies

Bookbinderies do not generally act as end distributors of books and brochures. Therefore, the number of products per package within an order is not changed:

- for hardcovers
  usually one book per package,
- for brochures
  usually multi-unit packages between five and ten brochures per package.

A typical routine is shown in figure 7.2-98.

The products are collated according to a predefined number of products per package. A packaging label is placed on each pile before it runs into the packaging machine (if necessary, the individual product is provided with a label prior to piling).

Palletizing machines are available to deposit the packaged products. Transport packaging is usually carried out in separate distribution sectors. Individual packaging is done on the same unit but without collation or attachment of a packaging label. For reasons of identification (price, barcode) the packaging is provided with labels.

Packaging

For film packaging, two basic principles are applied in print finishing companies:

- *Banding with cladding film.* Figure 7.2-99 shows a tubular sleeve wrapping with two seams. The packed good is placed into a film cladding that is formed by two film rolls. When sealing the film to the band, the new formation of the cladding takes place simultaneously. In the heat shrinking tunnel, the film is fit-

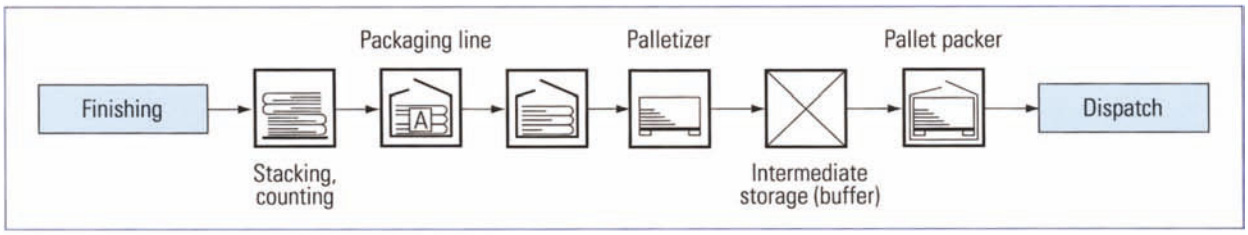


Fig. 7.2-98 Multi-unit packaging of books and brochures in bookbinderies

ted tightly around the packed product. The head and foot parts remain open.The process is modified by lateral sealing rails producing a full-wrapping. Perforated films are used for full-wrapping.

- *Tubular film bag wrapping.* When wrapping the books according to the tubular film bag method with perforated film (fig. 7.2-100), only one film roll is required. The books are pushed onto a film web that is formed to a tube at the front. During transportation, the book serves to shape the tube. A sealing and separating rail separates the tube into packages which then run into the shrinking tunnel. The tube seam stays open. The machines are primarily used for individual packaging.

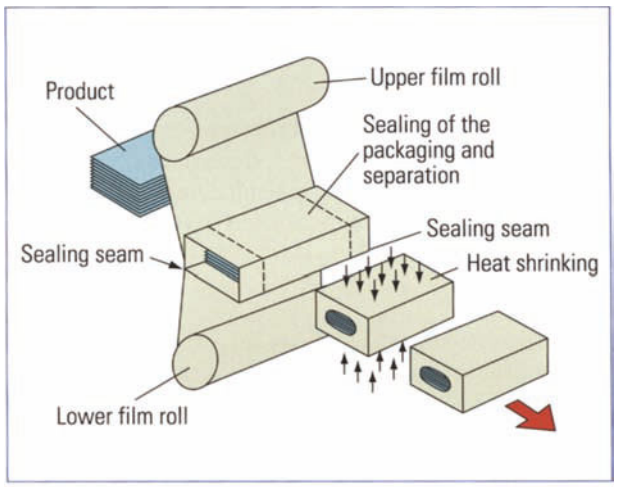


Fig. 7.2-99 Tubular sleeve wrapping with two seams

Palletizing for Transport. Palletizing of packed and unpacked books and brochures takes place either manually or with palletizing machines. The following actions take place:

- Positioning of the empty pallets.
- Producing piles.
- Setting down the pile according to a predetermined stacking layout to form a pile layer; the stacking layout can be turned by 180° with every new layer.
- Securing the pile layers by means of separating paper layers. The sheets put on top of each layer prevent the loaded pallets from falling apart.
- Removing of the loaded pallet from the loading room.

The palletizers consist of the pallet magazine for empty pallets, the separating layer charger, the roller conveyor for pallet delivery, and the palletizing unit. On the layer maker of the palletizing device, the product piles are arranged according to the pile layout plan. The complete layer is pushed onto the pallet. The palletizing process is computer controlled.

Production of Transport Packages. The primary task of transport packaging is the safeguarding of the freight so that no individual products slip or fall down during transport. For this, several variations exist:

- Strapping the loaded pallets with belts or strap iron when using a cover board.
- Providing the freight with film or fabric hoods. In this way, the top of the load is safeguarded. Textile hoods are equipped with buckles and can be reused.
- Stretching, that is, wrapping a film web around the freight.
- Shrinking, that is, the entire pallet is sealed with a shrink film. In the heat shrinking tunnel, a compact packaging is produced.

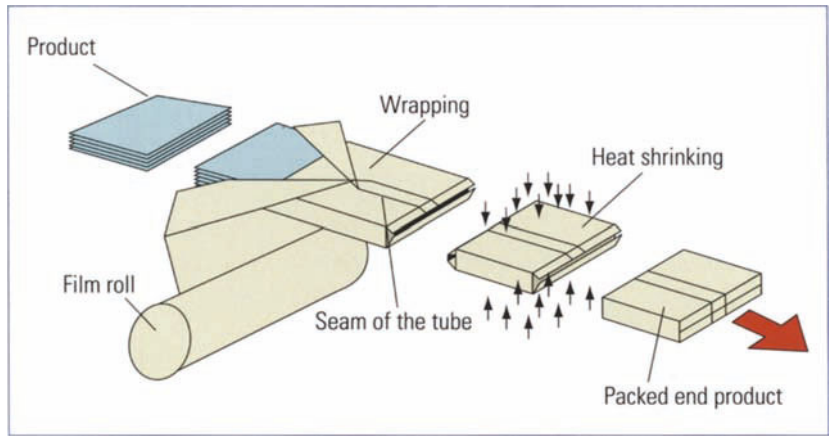


Fig. 7.2-100
Tubular film bag wrapping for books and brochures

Packaging Periodicals in Mailrooms

The necessity for personalized distribution within the shortest time places special demands on commissioning and packaging of newspapers and magazines. The following aspects must be taken into account:

- Within one edition there are several sub-editions that differ in terms of editor's and/or advertising inserts. Therefore, the allocation of dispatch packaging and packaging identification in accurate copies must be guaranteed.
- An edition is distributed via several channels (post, truck, airplane), some of which place different demands on the packaging. Therefore, it must be possible that one *issue* can be packed in various ways at the same time.
- One part of the copies contains client addresses. The addressing must be coordinated with distribution logistics.
- The packaging size is determined by the delivery circumstances of the periodicals. Standard packages and packages with only one copy must be packed in turn.
- From delivery to delivery, each package must be allocated a variable packaging label that contains special distribution information.
- Packages are re-opened as early as within a few hours (in the case of newspapers) or days (in the case of magazines) generating plastic waste.

The usual routine for packaging periodicals is shown in figure 7.2-101.

When packaging for delivery packages, a film wrapping (not shrink wrapping) and a simple or crosswise strapping with polypropylene belts/straps is usual. Strapping serves to provide a better grip of the package for manual distribution of the packages. To reduce over-proportionate packaging expense, especially in the case of newspaper distribution, alternative concepts have been developed (see also sec. 7.3.2.3):

- *Newsbox* (Müller Martini). Newsbox is a dispatch system based on circulating plastic containers for regional distribution. The newspapers are automatically laid into stackable boxes, piled on pallets, and directed to the corresponding dispatch channels. The recipient of the newspapers pre-

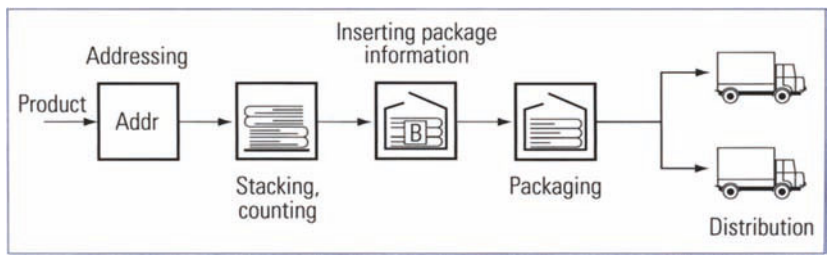


Fig. 7.2-101 Packaging of periodicals

pares the empty boxes (from the previous day) for return transport in the route distribution vehicle. The system uses no additional packaging material and offers maximum product protection. However, the circulation of the boxes causes a change-over of the traditional distribution system.

- *RollPack* (Ferag). RollPack is a cylindrical unit. A newspaper stack with packaging label and a film that stabilizes the roll is wound over a core. The "cylinders" can be set on pallets face down. The separation of the products during delivery occurs in an inwards-outwards direction. Due to RollPack the technical work in packaging is reduced.

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7.3 Process Structuring in Print Finishing

7.3.1 Basic Principles of Process Structuring

7.3.1.1 Production Flow in Print Finishing

Print finishing is a process in which a large number of sub-processes must be implemented to manufacture a product. For this reason the effectiveness of the process depends not only on the efficiency of the machines implementing the process sections (subsequently referred to as "operating modules"), but also on the way in which the operating modules are linked together by logistics modules. These links can be sub-divided according to the principles applied for *connection* and *interlinking*, as shown in the table 7.3-1.

The print finishing process can be interpreted as a *series/parallel connection*, because the operating modules must be passed through in a specific sequence in order to manufacture the product. With fixed performance parameters in a processing sector, *parallel connections* of weak operating modules are required within the line structure. The process between two buffer storages is technologically oriented, that is, all products of a job (in the technological segment) are processed and stored, before further processing resumes after any period of time. Production by the operating modules occurs in a process-oriented manner, that is, the partial product is transferred to the following operating module. A series of both loosely and rigidly interlinked operating modules is described as a "production line".

Print finishing is characterized by operating modules and production lines, which are separated by temporary storage. Table 7.3-1 shows normal coupling variants in print finishing (see also table 7.3-2).

The following workflows are used in the *bindery*:

- *Cutting lines* to produce book binding sheets from printed sheets.
- *Binding lines* to bind the signatures of a product, which have been produced independently of each other, other into blocks. Binding lines end with block trimming.
- *Book lines* to produce hardcovers from blocks. Book lines end with the forming of the cased-in hardcover.
- *Final finishing lines* to complete and package books and brochures up to dispatch packaging.

In the *mailroom* (print finishing of newspapers and magazines) the following production systems are used:

- *Gatherer-stitchers* to produce magazines, which are designed as saddle-stitched brochures (booklets). They are compiled from signatures that have been printed independently of each other. Gatherer-stitchers end with the trimming of the booklets.
- *Binding lines* for magazines, which are designed as multi-layer brochures.
- Production lines for the *completion, packing, and distribution* of periodicals.

For individual product groups, such as labels, passports, forms, and so forth, production lines that are geared to the respective special features of the product are installed. To produce mailings, printed advertising materials, or supplements, variable modules are grouped together in a production line according to the task, and can be dispersed again after the order has been completed. It is possible to interlink the workflows referred to above into complex finishing systems. The efficiency of the workflow depends on the degree of interlinking. This efficiency, for its part, is determined by the technological reliability of each module and the variability demanded of the system. The following aspects must be taken into account when deciding on the structure of the technological process:

- Production lines are the optimal form of process structure, since costly loading and unloading

H. Kipphan (ed.), *Handbook of Print Media*
© Springer-Verlag Berlin Heidelberg 2001

Module connection	Module interlinking
Series connection All partial products pass successively through the modules, which are configured in series with capacity-coordinated operating times.	*Unlinked operating modules* The structuring of the logistics modules (temporary storage) allows independent production by the corresponding operating modules.
Parallel connection The partial products are processed within a process section simultaneously in several homogenous (independent) modules.	*Loosely interlinked operating modules* The structuring of the logistics modules enables direct transfer of partial products between operating modules. Stoppages result in the links being disconnected.
Series-parallel connection The partial products are delivered for processing in a generated continuous process both in series and in parallel configuration.	*Rigidly linked operating modules* Direct product transfer takes places between rigidly linked operating modules.

Table 7.3-1 Principles for the connection and interlinking of modules

processes and temporary storage are no longer necessary.
- The construction of complex workflows should only be undertaken on the basis of a detailed review of efficiency, since the efficient operation of such systems is only possible if the technological modules are extremely reliable. The installation of buffers, which partially disconnect the process, is expensive. Moreover, there are no standard technical solutions in print finishing for the short-term storage of partial products.
- Temporary storage is (as before) expedient
  - after printing,
  - after sheet processing,
  - after book block production.

When finishing areas are being designed, the mechanization level of the temporary storage units must be adapted to that of the technological process:

- When structuring temporary storage units, care must be taken to balance out the product flow of incoming and outgoing products and to ensure that the temporary storage areas are correctly dimensioned (approach, failure characteristics).
- In workflows with many automated modules, loose interlinking is prevalent and expedient. The prevailing features of loose interlinking are the short-term storage units (buffers), which are mostly manually operated at present.
- Lower output is achieved with loose interlinking than with unlinked modular cycles, if the performance of the feeders and the delivery units of the unlinked modules are adapted to those of the corresponding operating units. On the other hand, their use requires fewer technological resources and manpower than unlinked modules. Losses in capacity occur with loosely interlinked systems compared to unlinked modular sequences because
  - breakdowns affect the entire workflow,
  - the line *set-up* time is greater than for unlinked technological modules,
  - the technology servicing times of individual modules affect the entire line,
  - the module with the lowest efficiency performance determines the performance of the entire line.

7.3.1.2 Interlinking Modules in Print Finishing

Logistics modules with different functions are needed to link machines and systems in print finishing:

- *Loading.* Machines (operating modules) are loaded by means of feeders. In this process the products to be processed are brought from an unspecified location (e.g., from a pallet) to a specified location in the operating module, so that the product can be collected by the operating module's internal transport system.
- *Unloading.* In the unloading process the product is transferred from the machine's internal conveyor system to a means of transport. In this case, the products are mostly conveyed to "compact packing."
- *Temporary storing.* Materials and semi-finished and end products are stored in temporary storage areas

until further processing occurs. The length of time they are stored is determined by production organization criteria.

- *Buffering.* Buffers are (short-term) storage units for the partial disconnection of interlinked machines while orders are being finished. The aim is to increase workflow performance.
- *Transporting.* The conveying system changes the location of products. It is characterized by a starting location (source) and a target location (sink). The path taken is known as the raceway.

The most important items determining the process's efficiency are

- printed sheets/book binding sheets,
- folded sheets,
- blocks/products in various states of finishing.

The technical structure of the logistics modules depends on the interlinking variant selected (table 7.3-2).

The logistics process sections shown in figure 7.3-1 need to be arranged between two operating modules in an unlinked process.

Unloading involves the machine's delivery unit and a transloading machine (LU). In the configuration shown in figure 7.3-1, the delivery unit has the task of picking up the products from the machine's internal conveyor system and converting them into stack units (provided that, as in the guillotine cutter, no stacks are being processed). Delivery units for blocks are referred to as *stackers*.

Transloading, that is, the depositing of stacks on a pallet, is mostly carried out manually. While depositing stacks, the operator also takes over a visual inspection of finishing quality. Palletizing machines are often placed after high-performance modules. The predomi-

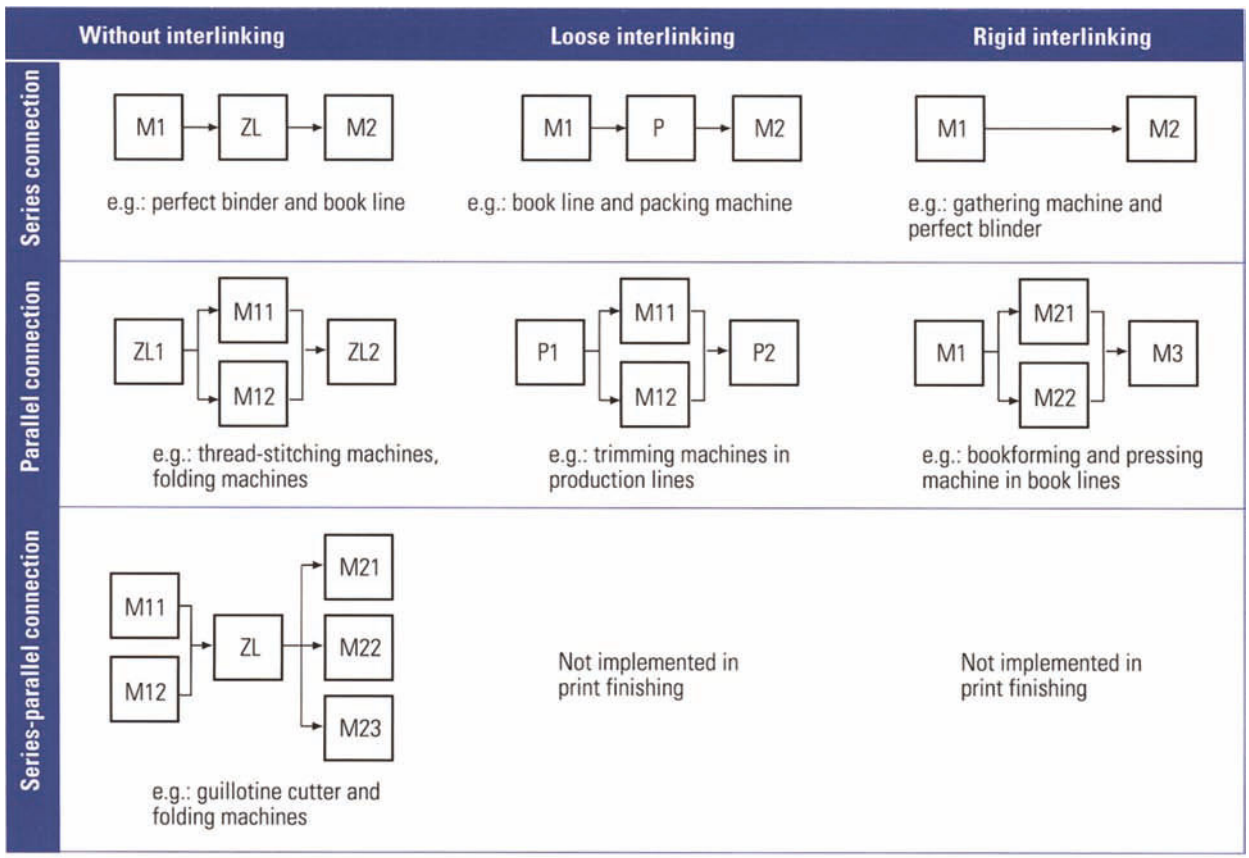


Table 7.3-2 Coupling variants in print finishing, M Machine (operating module), ZL Temporary storage unit, P Buffer (short-term storage)

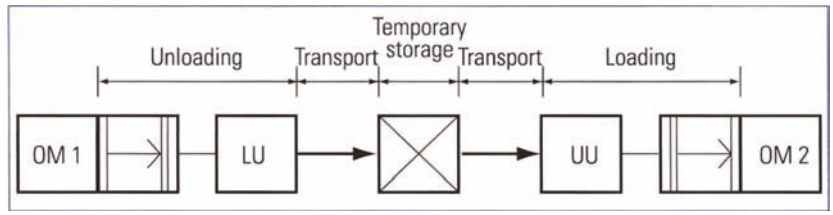


Fig. 7.3-1
Logistics in the unlinked process;
OM Operating module,
LU Loading an intermediate storage unit,
UU Unloading an intermediate storage unit

nating transportation and temporary storage unit for unlinked processes is the loaded pallet. Using *pallets* has the following advantages:

- They are standard logistics elements, which can be manipulated optimally using standard transportation and storage techniques.
- Pallets generate compact packing of the loaded goods.
- The high capacity loading with print finishing products enables rational process mechanization.

The pallets are transported either by manually controlled, independent, or operator-less, electronically controlled *floor conveyors*.

The organizational disconnection of the flow process occurs in *temporary storage units*. During storage a number of operations are necessary, such as

- marking and positioning of the storage unit for storage,
- retrieving, selecting, and preparing the storage unit for removal from storage.

Preferred storage forms in print finishing are

- stacked and unstacked surface block storage units with manual storage control,
- high rack stores with computer-aided storage control.

For the loading of operating modules, the transloading (UU) of the semi-finished products into the sheet feeder and transfer of the products into the machine's internal conveyor system by the feeder is once again necessary. Mechanical dispersal of the compact storage packaging of semi-finished products stored on pallets is difficult to implement. For this reason unloading is mainly done by operators, who load stacks into the feeder manually. The stack is separated in the feeder and transferred to the machine's conveying system in an accurate cycle. The devices for the manual transfer of product stacks into the sheet feeder are known as "feeder magazines".

The sequence of the logistics modules illustrated in figure 7.3-1 is not obligatory. Figure 7.3-2 shows a variant that may be used in the temporary storage of folded signatures for periodicals.

The semi-finished products are transferred to a transport system individually, as a stream, stack, or bundle and conveyed to the storage area. The storage area takes over all transfer and storage functions. Depending on the requirements, single products or product streams will be removed from storage, transported to the next machine in the sequence, and stacked in the feeder magazine. A feeder cannot, normally, be dispensed with, because it takes over the "cycling in" into the machine's internal conveyor system.

For *rigid interlinking* between two operating modules, a transport system is connected between delivery unit and feeder of the corresponding modules (fig. 7.3-3).

The standard conveyed products/units are

- single products (blocks),
- stacks of sheets, folded signatures, or blocks,
- streams of folded signatures and thin blocks (< 10 mm).

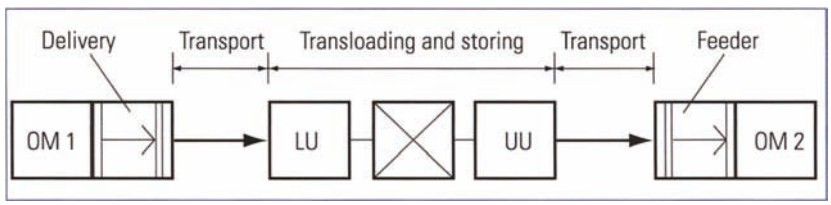


Fig. 7.3-2
Alternative to conventional temporary storage technology;
OM Operating module,
LU Loading an intermediate storage unit,
UU Unloading an intermediate storage unit

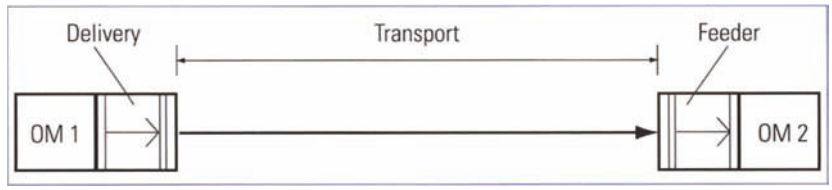


Fig. 7.3-3
Logistics modules in rigid interlinking;
OM Operating module

The transport system is also assigned with *other functions*, in addition to its main task of transporting products:

- *Streaming* Splitting a product flow into two or more channels (for the parallel connection of technological modules).
- *Combining* Bringing two or more product flows together into one product flow of the same type of product.
- *Synchronization* A product or stack is transferred under a set location and time regime.
- *Deceleration* Temporary reduction of the speed of a product flow. The density of the product flow is increased by deceleration (lower interval, steeper product stream).
- *Acceleration* Temporary increase in the speed of a product flow. The density of the product flow is reduced by accelerators (greater interval, flatter stream).
- *Change of raceway* A product flow is conveyed to a selectable end point.
- *Turning* The position of the individual product in the product flow is changed by turning. (Product lying→Product upright, Spine right→Spine left, Head facing forwards→Head facing backwards, etc.)

Devices for changing direction (to the right, to the left, upwards, downwards) will be required within the conveying system.

In print finishing two conveying systems have become generally accepted in addition to the transportation on pallets (table 7.3-3).

As regards the connection of buffers in *loosely linked workflows* distinction can be made between main storage and secondary storage.

The buffers that are connected in series to the operating modules are referred to as *main storage units*. Each product must run through the buffer. If a stoppage occurs in the downstream module, the continued operation of the upstream module is guaranteed by the packing density on the transport modules increasing. If there is a stoppage in the upstream module, the transport modules will run empty. Feeder magazines, for example, are series-connected buffers between operator and operating module.

Secondary storage units are connected in parallel to the product flow. For this reason they only operate if one of the corresponding operating modules malfunctions. Thus the buffer is at rest during trouble-free operation of the corresponding modules. In the case of secondary storage units, a higher degree of technical resources for diverters, buffer feeder, and buffer delivery units is necessary. Typical secondary storage units are stackers that are designed as emergency delivery systems. The effectiveness of the buffer, even when manually operated emergency delivery units are used, can only be guaranteed if it is backed up by corresponding speed control of the operating modules.

Not all technological modules in production lines are of equal importance from the economic point of view. There is usually a basic module, which incorporates the highest value as an investment item (e.g., perfect binders for book finishing or the gatherer-stitcher in the magazine mailroom). The modules completing the production line are connected to it. It makes good economic sense for the basic module to be in as constant production as possible, therefore the connected modules should not cause downtime in the basic module. For this reason basic modules are placed between buffers, which are intended to compensate for the malfunctions of the upstream and downstream modules. It is ensured that the connected modules have a higher operating speed compared to the basic module (this

Conveying systems for product streams	Conveying systems for blocks and stacks
The basis of the system is the so-called *chain conveyor*, a chain that is equipped with grippers for picking up a stream or for picking up single products from a stream. The closed chain is able to convey the stream flow over great distances to a target location. Because the chain is not tied to one conveying level and direction, the spread products can be distributed in a very effective and space-saving way to different target locations.	Blocks or stacks (sheet streams too) are transported on *conveyor belts*. In this case a closed belt is driven by friction over a rotating cylinder. The position of the products on the belt is not pre-determined. One conveying channel usually consists of several conveyor belts. To change the horizontal conveying direction, additional curved conveyors (e.g., curved belts) or angled conveyors must be built in. A conveying channel is built up using elements from modular conveyor systems.
Chain conveyors are mainly installed in mailrooms.	Conveyor belts are mainly installed in conventional book binderies and forwarding companies.
The chain conveyor system is supplemented by the following modules: • *Transfer points:* they are used for transferring products to another chain conveyor. • *Transfer units* from the processing machines to the chain and from the chain to the processing machine. • *Emergency delivery units* for system overloads.	Between the conveyor belts • *turning devices,* • *low dividers,* • *flow uniters,* • *compensating diverters,* etc., can be connected which create the optimal position of the conveyed items for the next machine in the sequence.

Table 7.3-3 Conveying systems in the print finishing process

can be achieved connecting several of the same kind of modules in parallel).

The buffer placed upstream of the basic module is called a *full storage unit*. It is fully occupied by products during normal operation, so that in the event of a stoppage on the upstream modules production in the basic module is guaranteed. The *empty storage unit* downstream of the basic module does not contain any products under the line's normal operating conditions. In the event of a stoppage of the downstream modules the basic module can still deliver products to the buffer. *Balance storage units* (ideally half-full) are located between operating modules of equal importance.

7.3.1.3 Temporary Storage of Folded Sheets

In most cases the folded sheets are deposited in *temporary storage*, which is used

- to store the sheets belonging to a print run until all successively printed and folded sheets are available for gathering (assembly process);
- to break off the production process so as to be able to optimize process organization by increasing flexibility;
- to achieve better utilization of printing technology capacity for the production of periodicals (advertising sections, non-topical editorial contributions, etc., can be produced prior to the editorial deadline).

The initial section of block processing, that is, *unloading* the sheets, *transporting* the storage units, and *loading* the gathering machine involve high manual outlay in the case of conventional folded sheets logistics (fig. 7.3-4). This applies to both web-fed and sheet-fed printing.

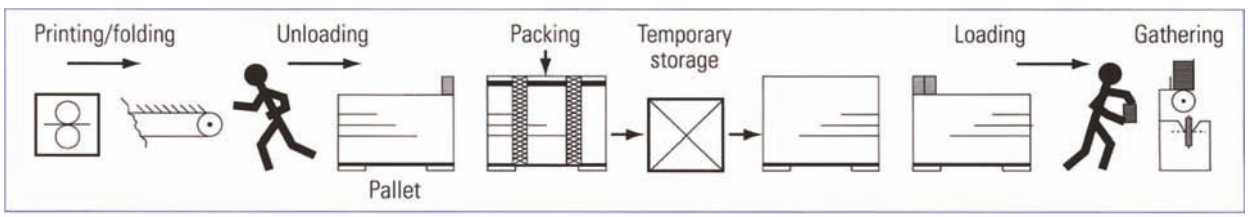


Fig. 7.3-4 Conventional folded sheets logistics process after web-offset presses

Traditionally, web-fed presses are unloaded manually. The delivered sheet stream is converted into stacks suitable for handling (about 50 to 100 folded sheets). The operator at the delivery takes the stack, "jogs" it, and places it on a pallet according to a loading plan. The loaded pallet is provided with a "protective packaging," which protects the sheets from damage during transportation.

When the gathering machine is loaded, the stacks have to be lifted from the pallet, fanned, and inserted in the (correct!) feeder magazine.

The characteristics of conventional (manually managed) temporary storage are:

- high packing density of the pallets for transportation and storage,
- low technical outlay, consequently low fixed production costs,
- intense operator action (about 10 min operator time per 1000 folded sheets),
- danger of displacement of the folded sheets on the pallet (spoil sheets),
- leading to diminished efficiency within the gathering machine (stoppages).

As a rationalization measure, *automatic batch technology* (bundle feeder) has been developed for the processing of books and multi-layer brochures. *A sheet bundle delivery unit*, which creates sheet bundles, is connected downstream of the printing press and/or folding machine. Sheet bundles (fig. 7.3-5) are 50 to 120 cm long stacks, which are pressed between boards (in the folded sheet format). The contents of the pressing boards are secured by a strap (usually polypropylene).

Hoists deposit the bundles on pallets where they are stored temporarily. Special bundle feeders, in which the bundle is converted into a sheet stream again, then conveyed to a conventional feeder magazine, have been developed for feeding folded sheets. The gatherer-stitcher operator has the task of placing the bundles from the pallet in the bundle feeders with a hoist and removing the pressing straps and end plates. The characteristics of *bundle temporary storage* are:

- low operator outlay (about 2 min operator time per 1000 folded sheets),
- accurate folded sheets pressing during storage,
- high packing density of the pallet during transportation and storage,
- danger of long bundles bulging out because of the uneven distribution of pressing tension over the sheet area (folded edge build-up),
- high demand on technical resources to form and separate the sheet bundles,
- end plates of various sizes as circulating medium;
- polypropylene pressing straps "lost" after the stack has been dispersed,
- danger of the "fresh" sheets blocking (sticking together).

A sheet bundle logistics system is shown in figure 7.3-6.

The *folded sheets reel system* is another rationalization of folded sheets logistics, especially for finishing newspapers and magazines. The folded sheets reel (fig. 7.3-7) is a temporary storage unit, in which the sheets are wound round a rotating core in the press delivery. The staggered sheets are held by a strap attached to the core. The reel is a folded sheets cylinder; its height corresponds to the height of the folded sheets. It has a diameter of 120 to 220 cm. The folded sheets reel is unwound again to load the next machine, though the front edges of the folded sheets face the front in the unwound sheet stream and have to be turned round again in the folded sheet feeder. There are various procedures for turning the sheets prior to further processing. The sheet reel can be wound into special transportation units, placed on pallets, or suspended on holding pins in a storage with several tiers. Special loading equipment is required for this. The empty reel cores (which at the same time hold the sheet straps) have a diameter of about 50 cm and can be stored compactly in temporary storage. Figure 7.3-7 shows folded sheets reel units.

The illustration on the left shows the stream being wound onto the reel. The illustration on the right shows filled reel storage units. A reel with a full diameter

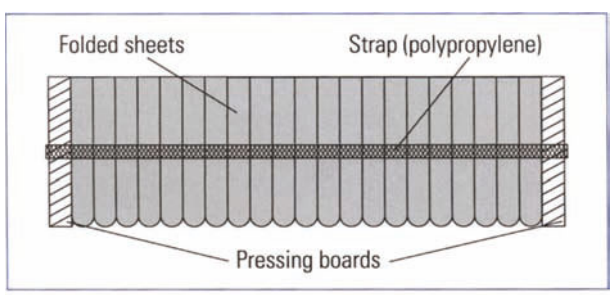


Fig. 7.3-5 Sheet bundle

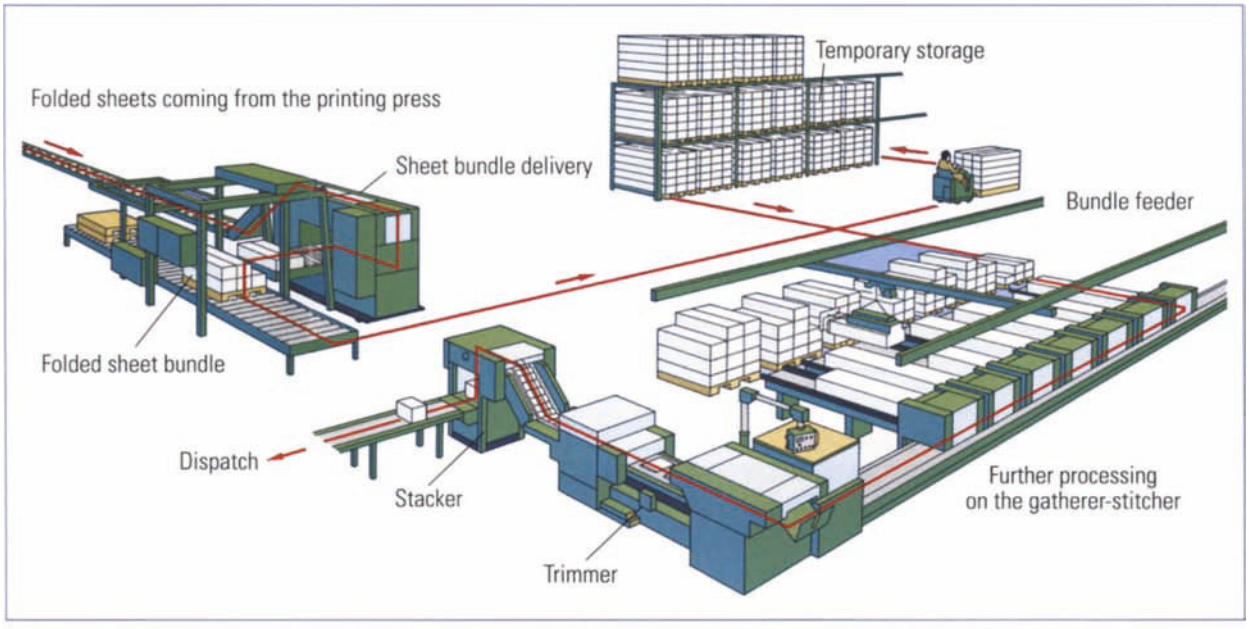


Fig. 7.3-6 Logistics system for folded sheet bundles for producing magazines (Müller Martini)

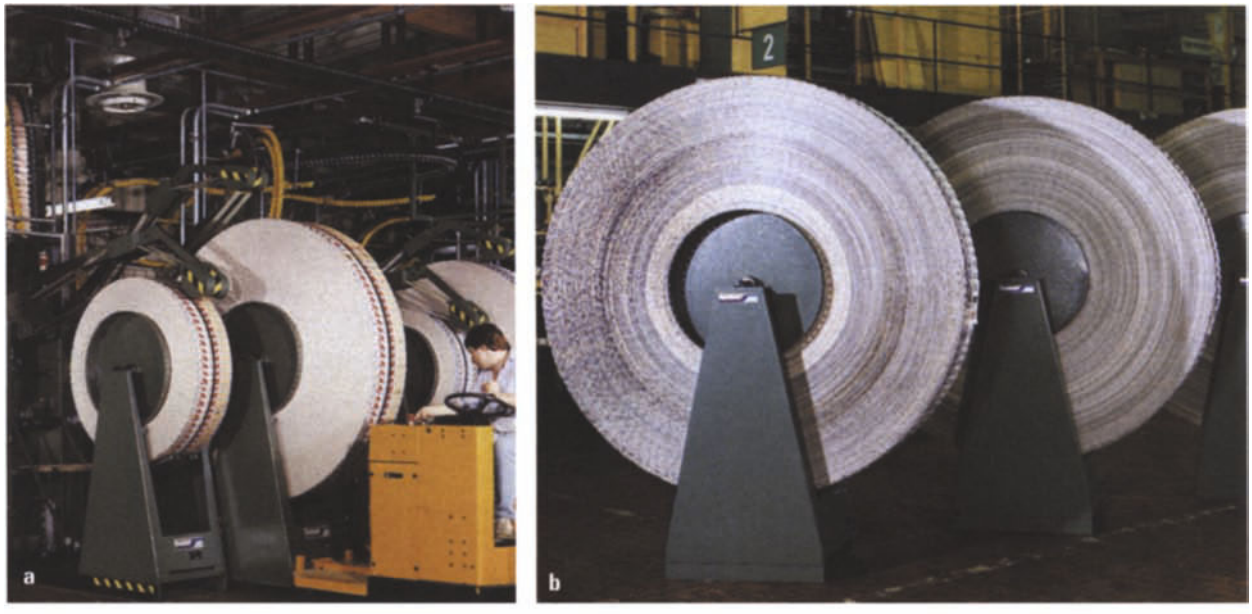


Fig. 7.3-7 Temporary storage for folded sheets on reel storage units (disk).
a Double rewinding station;
b Full reel storage units (PrintRoll, Müller Martini)

of approximately 200 cm and a core diameter of 50 cm can hold between 8000 and 10000 folded sheets. Characteristics of the folded sheets reel system are:

- very low operator outlay (< 1 min operator time per 1000 folded sheets),
- temporary storage maintains the sheet stream in the storage unit, as a result of which extremely high processing output can be achieved,
- pressing of the folded sheets during temporary storage,
- compact temporary storage,
- the working principle enables the creation of simple, reliable logistics systems,
- winding systems can be designed for short-term storage (as buffers in loosely linked-up sequences).

The introduction of such a system affects all areas of finishing (system installation necessary), with high investment costs accruing.

It can be seen from figure 7.3-8 that the introduction of a folded sheets reel system affects both printing and finishing.

Correct dimensioning is of particular importance in the automation of folded sheets temporary storage to enable accurate estimation of both the spatial and the storage accessory requirements. The dimensioning of folded sheets temporary storage is problematic in so far as it is concerned with a *pre-assembly store*, in which a constant number of sheets is usually deposited, but from which a variable number of sheets is removed (depending on the sheet volume of the print media to be bound). The customary storage dimensioning methods are inappropriate in this case.

7.3.2 Production Lines in Print Finishing (Examples)

7.3.2.1 Cutting Lines for Labels

Wet-adhesive labels (unlike self-adhesive labels) are stuck onto the packaging material with animal and/or

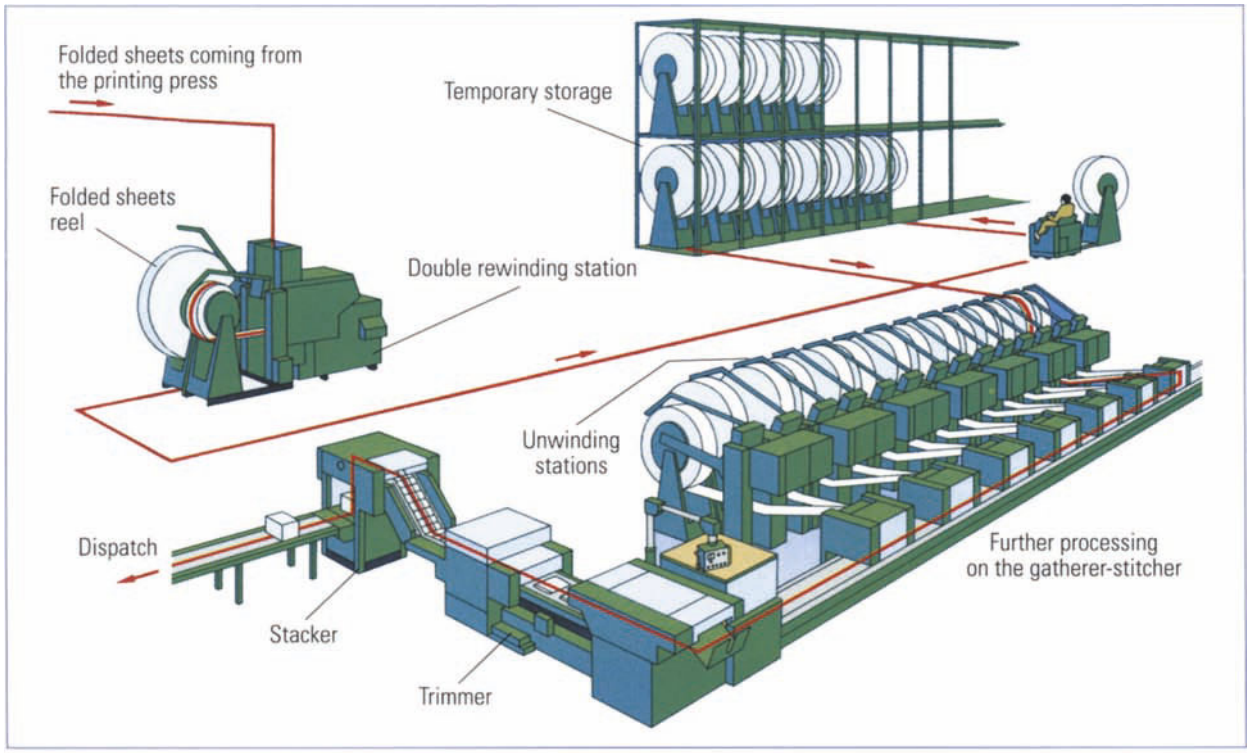


Fig. 7.3-8 Folded sheets reel temporary storage system used in finishing systems for the production of magazines (Müller Martini)

vegetable glue during the goods packing process. Wet-adhesive labels (henceforth referred to as labels) are typical representatives of a product group during the production of which paper cutting is the central processing task. Other examples of this type of product are bank notes, security papers, or transfers. The characteristics of these products are, among other things:

- A high *degree of technical print finishing* (multicolor sheet printing, special colors, bronzing, relief embossing, coating).
- *Limited size* (predominantly < 10 cm × 10 cm), a large number of copies have to be printed on one sheet. One option to enable the rational production of short runs (< 100 000 products), is to plan combined print runs, that is to place the labels of several clients on one printed sheet. This means that labels with different formats can be printed on one sheet.
- *The lowest cutting tolerances* are demanded of the label processor (< 0.5 mm).
- *The cutting* of multiple-ups that deviate from the usual rectangular shape.
- *The packing* of the stacks of blanks, with straps, then into folding boxes.
- *Work-intensive converting* of the processing technology for a new cutting job.

Special *cutting lines* have been developed by the manufacturers of paper cutting systems for the rational finishing of this product group (see also sec. 7.2.1). The lines are usually built up from standard modules, which are precisely adapted to the special finishing conditions in collaboration with the machine manufacturer and the user. The plan of a cutting line to produce rectangular labels of the same size is shown in figure 7.3-9.

The modules are not inter-connected because the performance parameters of the jogging device are much higher than those of the cutting machine. One jogger may serve several cutting machines. The jogger may be fitted with a counter, by means of which the number of sheets per stack can be determined. The jolted stacks must be deposited in such a way that they can be fed into the cutting line automatically. The stacks can, for example, be separated by a plastic board ("chip-marker"), which enables the stack to be separated from the pallet in the cutting line feeder.

In a cutting line, the stacks coming from the feeder are conveyed onto the rear *cutting table* by a gripper system, cut into strips in several cutting cycles (backgauge and knife movement), and placed in the strip buffer. The piles of strips are conveyed from the buffer to the rear cutting table of a cutting machine configured at an angle of 90°. Cutting waste is removed from the cutting area automatically.

Packing begins with the automatic feeding of the stacks into an automatic banding machine, in which a paper strap is put around each stack. Connection to an automatic packing machine, which packs several stacks in shrink film or puts them in trays (open folding boxes) is possible.

Figure 7.3-10 shows a cutting line, by means of which about 2.5 million labels an hour can be cut with an area of 10 cm × 10 cm.

The minimization of *set-up* times by the use of integrated process computers is particularly important. Job-specific cutting programs are drawn up outside the

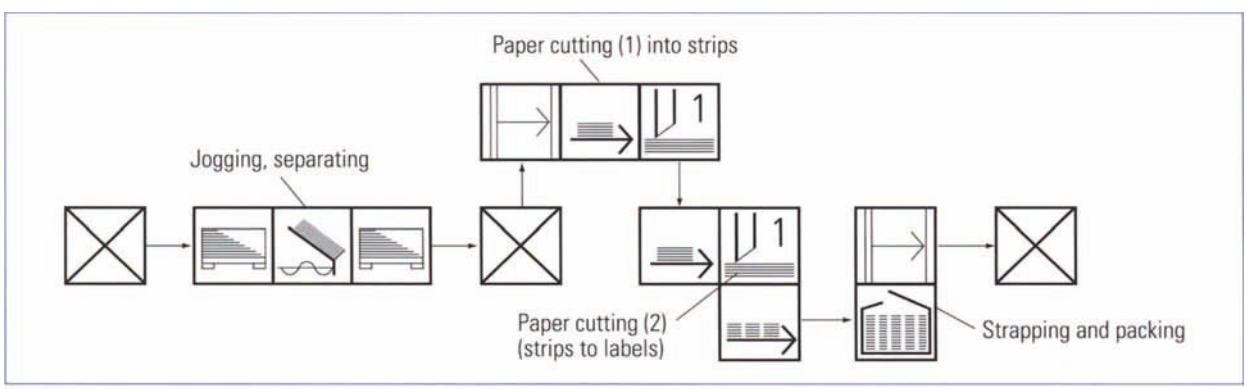


Fig. 7.3-9 Diagram of a label cutting line for rectangular labels

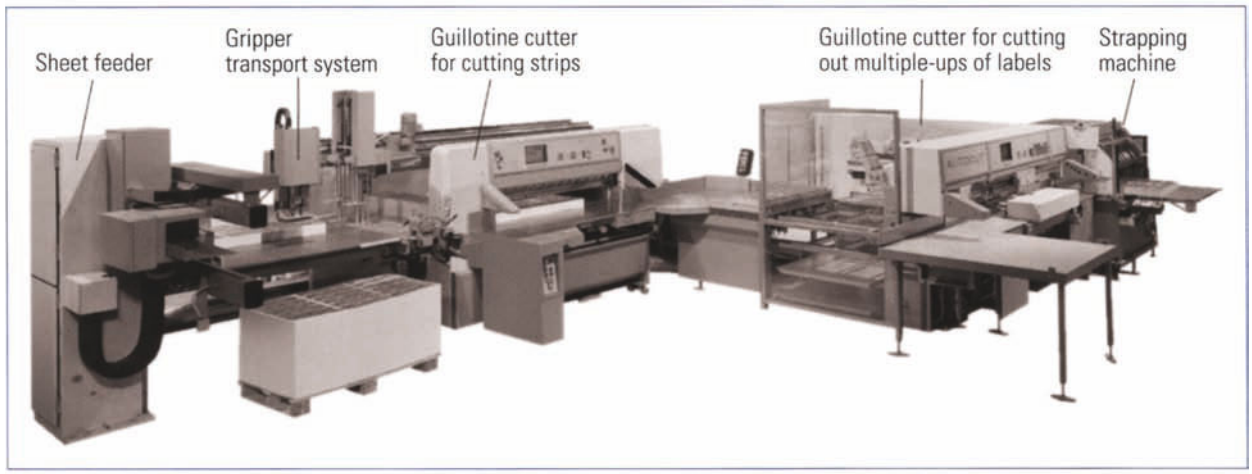


Fig. 7.3-10 Label cutting line (Polar Mohr)

installation and transferred to the machine control system via an external data carrier or via the computer network. The data produced in prepress and during the print can be used to rationalize the cutting programming in the preparation of the job. The necessary information is made available to the *user in the interface module CIP 3* (see also sec. 8.2.3).

A large proportion of labels has a shape deviating from the rectangular (rounded corners, oval labels, neck labels, etc.) They have to be die-cut after cutting. Automatic stack die-cutting machines are used for this, which may be connected to the cutting line.

Figure 7.3-12 shows a special die-cutter for label finishing. With this device the stacked "label blanks," which are cut at right angles, are pressed through a forged die and removed from behind the die. Packing modules are arranged after the die. The diagram of a module configuration for die-cut labels can be seen in figure 7.3-11.

The stacks of strips leaving the cutting machine are conveyed to a buffer and aligned there. The final finishing includes the

- cross-cutting of the stacks into stacks of unfinished labels by means of a special cutter,
- die-cutting the pile using a special stack die-cutting tool,
- separation of the bundle of labels into batched units,
- bundling/strapping and delivery of the packaging units.

An automatic carton packing machine may be connected after of this equipment, in which a pre-deter-

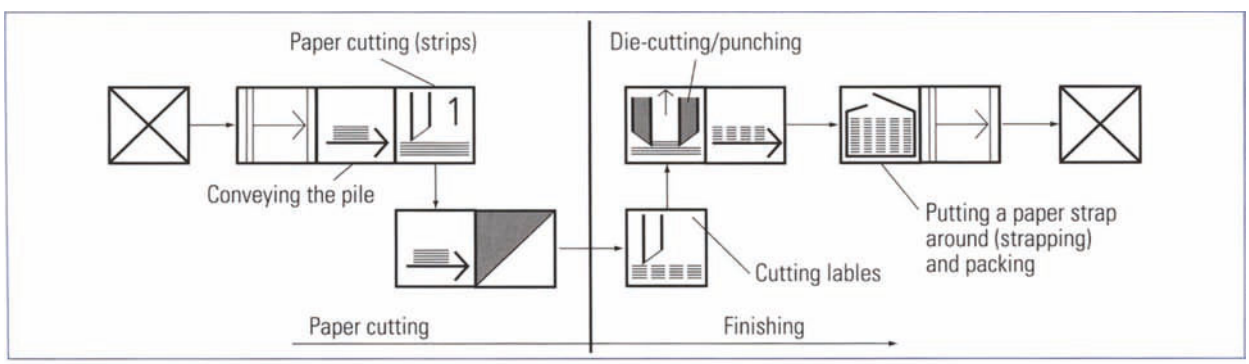


Fig. 7.3-11 Diagram of a module configuration for die-cut labels

mined number of batches can be packed in trays. The trays are made from blanks within the machine.

Figure 7.3-12 shows an automatic label die-cutter with strapping and packaging station.

7.3.2.2 Production Lines for Mailings and Folded Products

Printed products play an important role in presentations and/or advertising for trade and industry. It is to the multi-functionality that can be achieved, in particular, that the graphics product owes its special status. The printing industry operates as a service provider here. The important product groups are mailings, presentation/promotional printwork, and working papers.

Mailings are personalized letters to groups of potential purchasers, in which one or more goods and/or services are usually presented. The success of mailing actions depends on the extent to which the supplier succeeds in creating a positive association through its appeal to the reader. Consequently, the presentation of mailings must be varied and variable in form.

Promotional material is a synonym for a company's printed matter, such as brochures, catalogues, and image prints, which is used by the supplier to inform the customer and to advertise. Therefore, it should also be varied and luxurious in form and perform several functions (inform, advertise, ease purchase, establish trust, etc.). Presentation printwork is mainly produced in short runs, with a low page volume.

Working papers are used for functional purposes in administration and service (check books, operating instructions, service manuals, etc.). They are often numbered or personalized.

Printed products should, among other things:

- effectively present the item described,
- appeal to the addressee in person (address, personalized letter),
- provide means of action (invitations, smart cards, stickers),
- offer "trimmed-down" opportunities to reply (response cards, envelopes),
- guarantee protection of data from third parties (sealing of envelopes),
- be able to be integrated in a superordinate printed product,
- be sent directly by post.

To produce these products, the printed sheets or webs must be cut, sections cut out, perforated, creased, folded, gathered, glued, stitched, and so on – that is, all those working procedures that are customary in print finishing must be performed. Distinguishing features regarding the product design are given in figure 7.3-13.

The need to finish large print runs cost-effectively necessitates the use of production lines. Unlike conventional print finishing, these production lines are not of a set structure, but can be rearranged after each print job and/or supplemented by special modules. The producers of these products must have a wealth of the most varied, interconnecting working and logistics modules at their disposal. In exceptional cases, the modules will

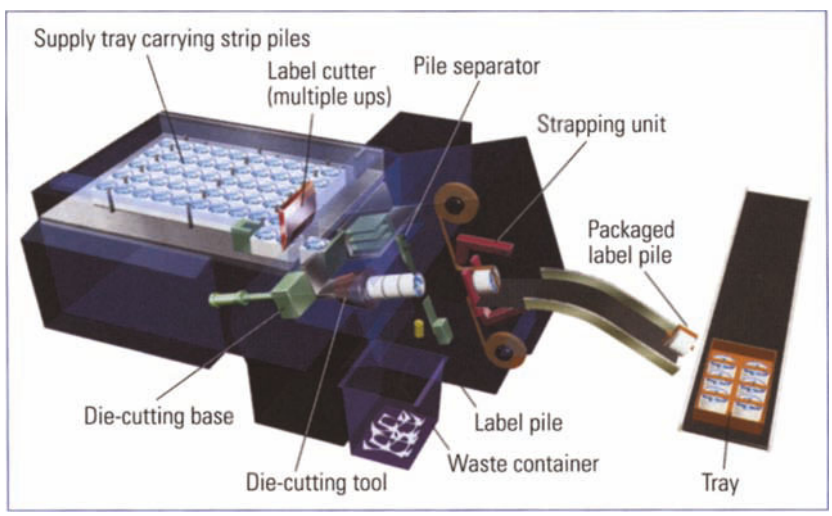


Fig. 7.3-12
Automatic label die-cutting machine (Blumer)

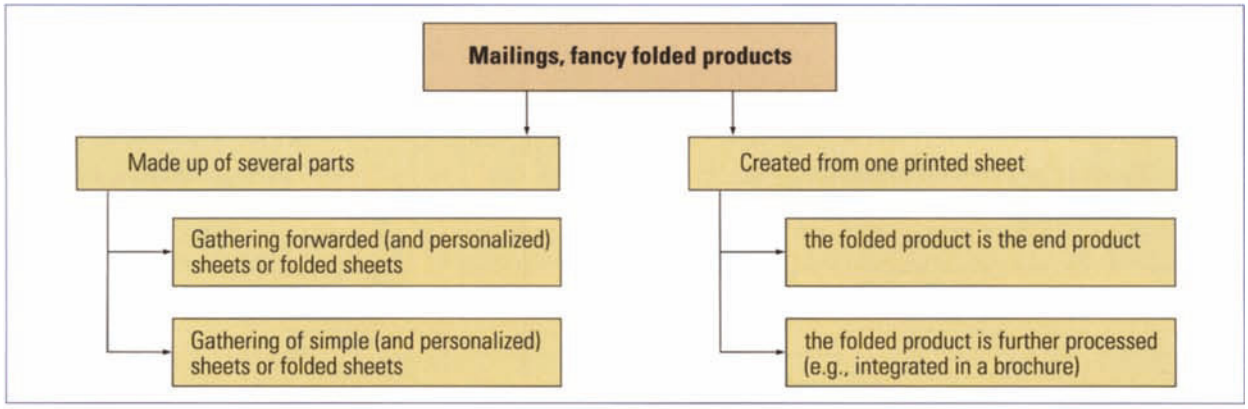


Fig. 7.3-13 Various product designs

be designed and constructed by the finishing firm itself (e.g., letter shops). The modules for the sticking of objects (keys, coins, or similar) onto papers or sheets at a specific position are an example of this.

A production line for mailings consisting of several simple folded signatures is shown in figure 7.3-14. In this example printed webs of 20 to 30 cm in width are being processed. The background (mostly colored) was printed on a web-fed offset press. The (single-color) personalization, which is controlled by an address file, takes place in a digital printing press (based on a non-impact printing process) as does the marking of the successive sections with a bar code. It is also possible to dispense labels at the same time. After imprinting, the webs are wound onto reels and put in temporary storage. In the mailings lines there is an unwind unit for each part product. The first step of the process is the cross-cutting of the imprinted webs. The machine-readable cutting line has been fixed by control marks. It must also be ensured that the correct (personalized) web sections of the reels are gathered. The bar codes of each section of each feeder must therefore be compared.

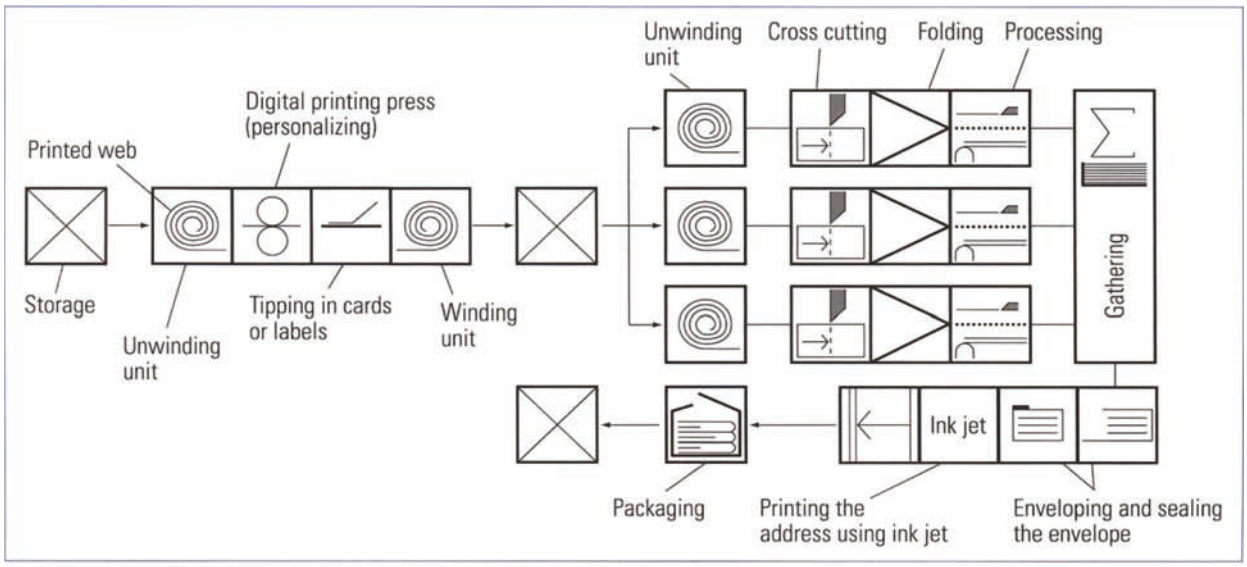


Fig. 7.3-14 Production line for mailings consisting of simple folded signatures

The sections are folded (mostly parallel), creased if necessary, perforated and/or cut, and conveyed to the raceway of an assembler. The length of the section and the type of fold may vary from unwind unit to unwind unit. The "block" is pushed into open envelopes and the envelopes are sealed. Then, unless window envelopes are being processed, the address is printed on them. The completed letters, deposited in transport containers, are passed on for dispatch directly to the mailing department in the lettershop firm.

A *different production line/process* than described before is the gathering and envelope insertion of *already completed partial products.* This is particularly necessary if

- bought-in components, such as diskettes, bagged lots, samples, reply cards, and envelopes for replies,
- complicated printed products, such as sheets with right-angle folds and special folds, back-stitched books, and
- prepared papers or sheets with glued-on objects, cards, labels

have to be inserted in the letters. An example of the finishing of such products is shown in figure 7.3-15.

The part products for a mailing are produced independently of each other on different production lines. The lines can be put together with selected modules in line with the current requirements. The manually-operated enveloping line is used to complete and envelope the letters. It must be ensured that the personalized products of an order are placed in the collator magazines in the correct sequence. Collating is done via the bar codes printed on during personalization.

Another possibility for the efficient production of mailings and of special folded products is to install *special folding workflows* that are able to produce a bound (and/or enveloped) product from a trimmed sheet. For this purpose, modules are integrated in the folding machine that perform various processes (see also sec. 7.2.2).

In contrast to this, figure 7.3-16 shows a *solution tailored* to these product groups with which simple folded signatures can be produced. In addition to the traditional processing units such as feeders, folding units, sheet presses, or delivery units, the following modules are available:

- A range of separate *adhesive application* stations for dispersions, hot-melt, and special pressure-sensi-

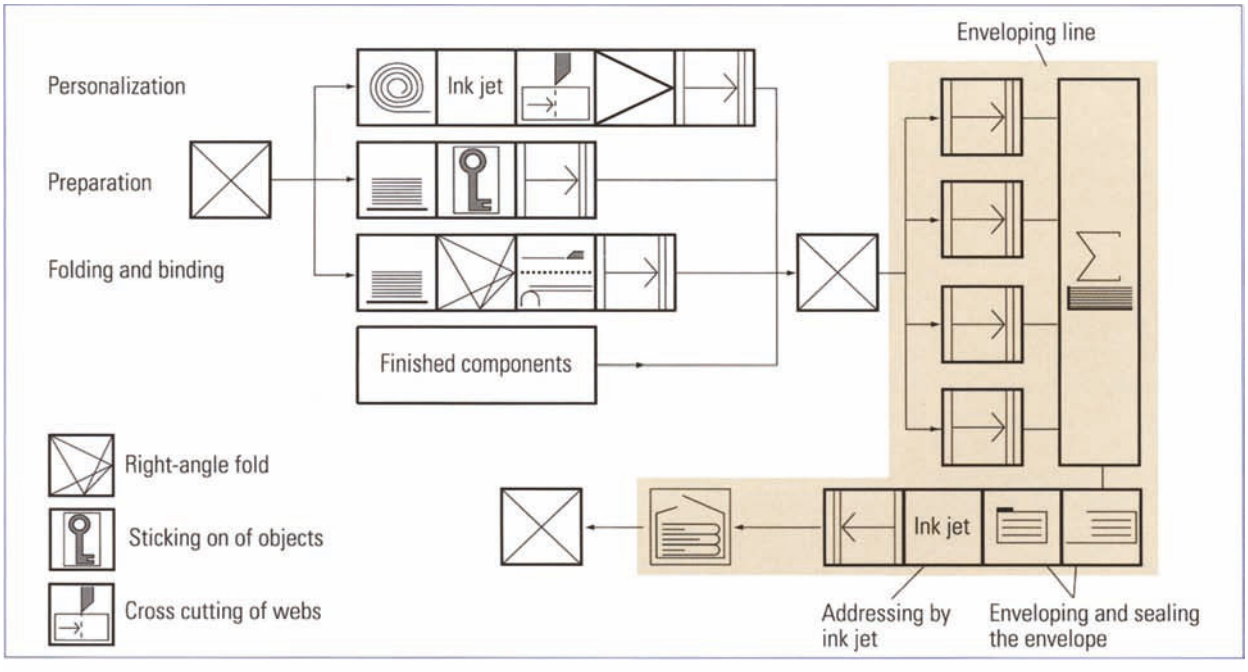


Fig. 7.3-15 Mailing production line for product sections with a high presentation requirement

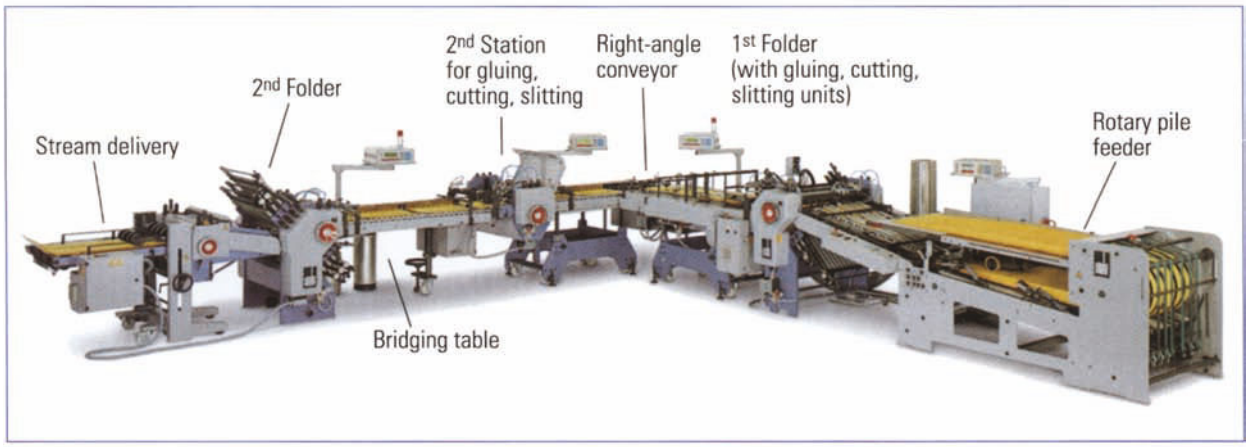


Fig. 7.3-16 Finishing line (Flexomailer; Heidelberg)

tive adhesives with an applicator nozzle control unit for precise positioning and dimensioning of the adhesive at each point of the product.
- Separate *cutting* and *perforating* modules for edge trimming, fold perforations, hole perforations (as "stop" perforations), or *creases*. In addition to this, the tool shafts installed upstream and downstream on the folding units can also be used for finishing jobs.
- Folding equipment, as well as opening, gluing, and sealing equipment, even a gluing/sealing module, by means of which *pockets can be formed* from the sheet and glued, or pre-coated adhesive strips can be reactivated.
- Modules for *dispensing labels* and for ink jet printing.

The working modules are supplemented by transporting and positioning modules, which help to ensure that the product flow is continuous (*bridging tables, right-angle conveyors*, product flow dividers, special delivery units). Extras such as a card gluer or a window cutting unit are useful additions. Figure 7.3-16 shows one of the "Flexomailer" processing variants.

The effective use of modular systems of this type requires exceptional expense for handling the order and for equipping the assembly which has to be paid for the customer. The finishing companies become the product designer, who, among other things, draws up the specifications for the printer to impose the print sheet.

7.3.2.3 Newspaper Mailroom

Newspapers have maintained their importance as information media in spite of the ever increasing presence of electronic media, however, external appearance on content concept have changed. The following can be mentioned as examples of newspaper design characteristics:

- fancy design as regards coloring and layout,
- the size of a newspaper (number of pages) varies according to the publication date,
- inserts are incorporated, which are externally supplied as product sections.

The following aspects deserve mention with respect to content:

- the regionalization of daily newspapers, that is, each edition is produced in several sub-editions, which deal with the events occurring in a residential area;
- advertising platform both for regional and national providers of services and goods;
- entertainment and education media (feature supplements).

The requirements are fulfilled in the production by separating the newspaper into:

- The *central product* (also referred to as the basic product), (frequently) consisting of a national and

a regional section. Central products are finished in a direct link between printing press and print-finishing lines.
- *Preprinted products,* which were printed and folded prior to the publication's editorial deadline (for the most part in a preceding shift), then placed in temporary storage and channeled into finishing machines at the required point in time. (The preproduct is also called the "editorial supplement".)
- *External inserts,* preprinted products of varying format, which are for the most part provided as externally supplied sections by cooperating firms (e.g., web offset, sheet-fed offset, and gravure-printed products).

The problem facing the central mailroom is the accurate "gathering" (inserting) of the edition, consisting of the central product, the preprint, and the inserts, with the preprints and a proportion of the inserts being changed for each sub-task, in a minimum of time. There is an increasing tendency to segment the print run. The task is to provide the correct quantity of the correct partial run of a newspaper edition for dispatch (e.g., truck at the loading platform). It must be taken into account that different distribution channels (mainly retail sales and subscription by mail or via supporting organizations) necessitate different processing and packing methods.

Print finishing tasks are performed by *mailroom cells,* several of which will be parallel-connected downstream of the newspaper press. A much simplified outline plan of a mailroom cell is shown in figure 7.3-17.

It is possible to arrange the mailroom to meet the individual requirements of each newspaper manufacturer (modular design). The mailrooms for newspapers are pure single-purpose operations that are only used a couple of hours per day (and normally in the middle of the night).

The mechanical equipment and spatial expansion of newspaper mailrooms has been greatly developed in the last years. The reason lies in the growth of preprinted products (greater number of pages) and the introduction of external inserts. Very often considerations go in the direction of a demographic distribution of external inserts and occasionally (especially in the USA and in northern European countries) it is put into practice, which means that special precautionary measures must be taken and mailrooms require special mechanical equipment.

The material flow and the respective facilities are dealt with in more detail in the following. Newspapers and sections leave the folder in a stream that should be maintained for the following operations in the mailroom, since it favors the flow production ideally. Therefore, "*stream conveyors*" (chain conveyor systems) are used for the transportation. Distinction is made between:

- non-cyclical stream conveyors with
  - wires (spiral-coiled springs),
  - belts (plastic ribbons),
  - grippers on one side of the product stream,
  - grippers on both sides of the product stream,
- cyclical stream conveyors with grippers in the center of the product stream, each gripper can hold one or two copies.

The advantage of the *cyclical stream conveyor* (fig. 7.3-18) compared to the non-cyclical conveyor is that each copy is as it were identified when it enters the process section and can be removed from the stream simply by opening the spring-tensioned gripper.

In the pick-up station located after the folder the unit stream lying on the delivery belt is spread by radial deflection. In this way the circulating stream grippers can grasp the folded spines one by one. The grippers arranged in a row transport the products into the processing modules by following the route of the rail.

Before reaching the first processing station the printer can remove a sample copy. This is done with the help of an "ejector". It might be necessary to integrate turnouts so that the stream can be diverted to various processing stations should one segment be overloaded or dropped out. It is a matter of a transfer station to a second chain loop that handles the transportation.

If the page volume of the end product newspaper is to be increased and will therefore be divided into one or more preprinted products and reunited with the current central product at a later date, the product stream is routed first into a product stream temporary storage unit. This temporary storage also serves as a buffer to uncouple the link between printroom and mailroom.

The following systems are used as temporary storage and buffer:

- tower stacking systems,
- reel systems,
- batch stacking systems.

Tower stacking systems (e.g., "Rotapal" from Ferag) are only found sporadically. *Reel systems* (fig. 7.3-19)

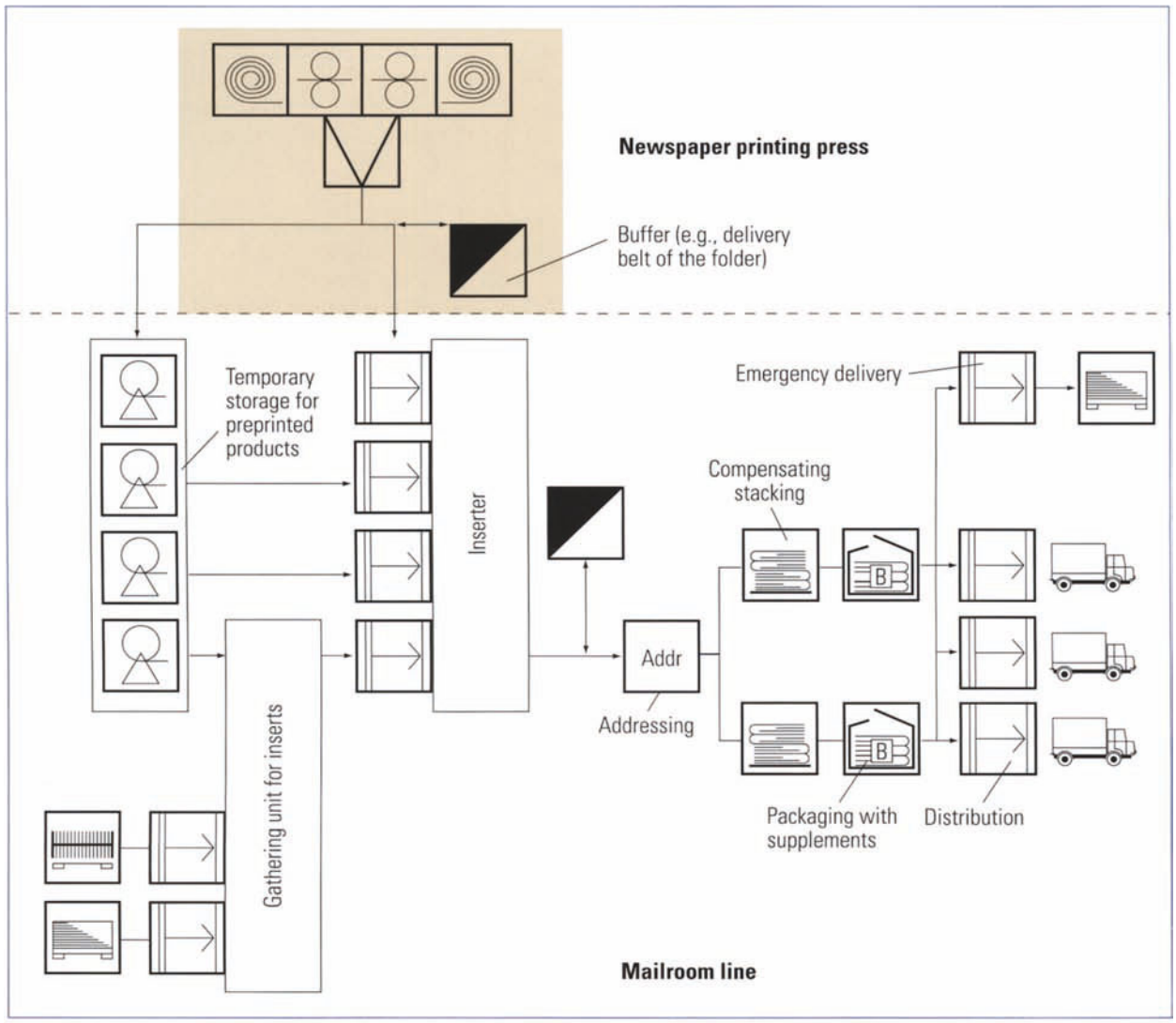


Fig. 7.3-17 Diagram of a mailroom line for newspapers

are preferred and offered in ever new variants not only from manufacturer to manufacturer, but also within the product range of individual manufacturers. They all use the same principle – the stream is wound radially and held by revolving plastic belt. On the reels that emerge consequently, the folding spine points inwards. When unwinding the reel, the open side of the newspapers would run in front, therefore measures for a turn in direction must be taken; and this is where the systems differ considerably. Another distinctive mark is the stationary or mobile operation where from time to time automatically operated shuttles are used.

A problem with reel systems is the offsetting of ink between the individual newspaper copies if the plastic belt is tensioned too strongly. To prevent this, the batch piling system (fig. 7.3-20) was invented. The stream is divided into individual batch layers and stored in a cabinet with many vertically arranged compartments. The cabinet is 4–5 m high. Hundreds of thousands of copies can be stored in several cabinets arranged in line or in parallel.



Fig. 7.3-18
Cyclical stream conveyor (Ferag)

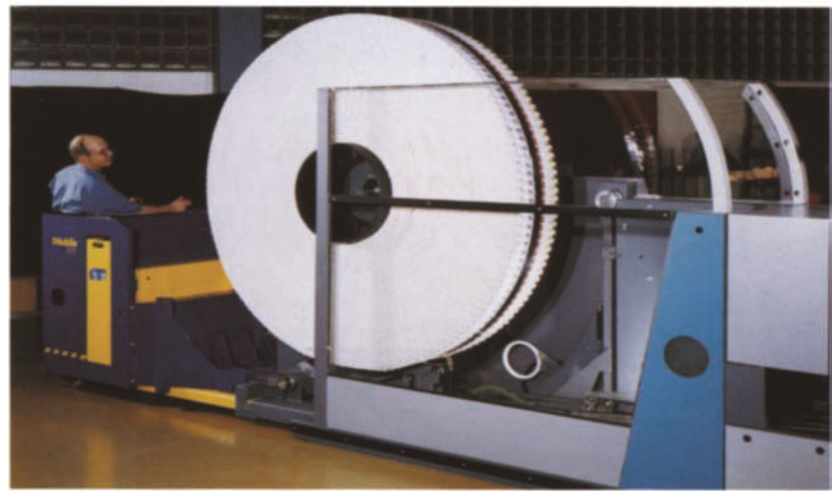


Fig. 7.3-19 Reel system (Ferag)

Since the cabinets have an inlet and outlet side there is no problem with the unloading direction because the FIFO principle (first in, first out) is ensured. Another essential advantage of this storing method is that the product stream is not pressed together when the layers are put on top of one another.

Apart from the product stream storing system, pallet or so-called "cart systems" are used. The disadvantage of these systems is that the product stream is interrupted and thus the next processing station needs to be loaded manually.

The central element in current newspaper mailrooms is the *inserting machine*. Here, too, various designs (fig. 7.3-21) are offered by manufacturers:

- drum system,
- wheel system,
- line system,
- carousel system.

The *drum system* is based on a revolving drum with fan-shaped segment buckle plates in which the central product (jacket/cover) of the newspaper is inserted by the stream conveyor. While the drum is revolving the jacket segment of the newspaper is moved sideways and opened in the center so that when the first inserting position is reached the stored preprinted product or the external supplement can be inserted. The procedure is repeated with the next revolution of the drum,

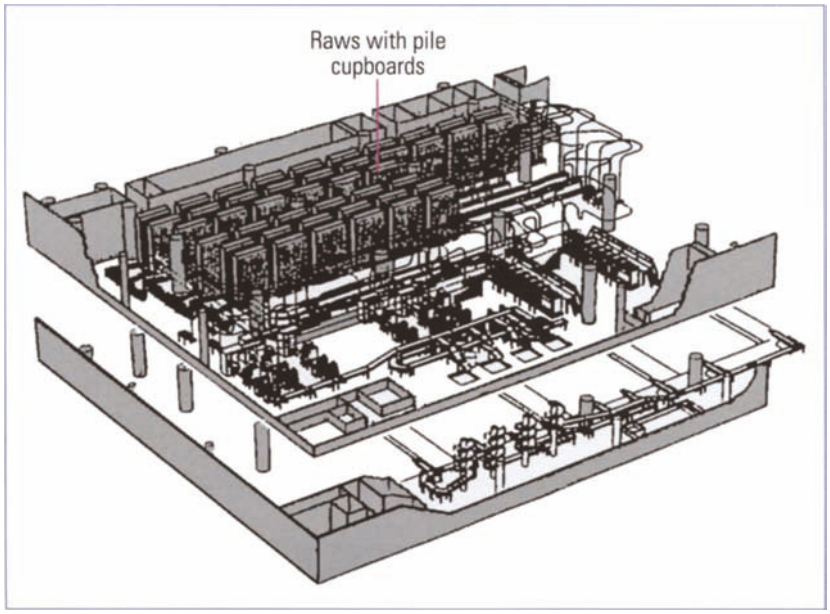


Fig. 7.3-20
Batch piling system (IDAP-WAMAC)

this process goes on until the output station is reached where the jacket segment is closed again. To make it possible to insert more printed products and external supplements than there are drum positions, pre-gathering stations are used as shown in figure 7.3-21.

On the *wheel system* there is no sideways motion – the whole process must be completed in one revolution of the insertion wheel. This makes the system considerably slower than the drum system.

In the case of the *line* and *carousel system*, the newspaper's jacket is moved along on straight or circular sliding rails to reach the individual inserting positions. The number of inserting positions is merely limited by the length of the line or the diameter of the carrousel. To increase the throughput on line systems, tandem versions are available, where two lines are arranged on top of one another.

Line systems have been enhanced in the last years to the extent that the jacket segment of the newspaper remains permanently in one gripper bite and is opened upwards in a V-shape by two buckle plate elements so that the inserts can be inserted from above. Depending on the demographic structure of the inserts up to thirty inserting positions might become necessary.

For postal dispatch and demographic composition of the newspaper it is necessary to *address the newspaper*. Nowadays this is mainly done with ink jet printers, but adhesive labels are also still in use.

After the newspapers have been addressed the individual copies are bound into bundles in the *stacker*. So that the bundles are square, layers that are turned by 180° are put on top of one another; this is referred to as compensating stacking. The bundles can also be made up of a varying number of newspaper copies. One refers to standard packages (always the same number of copies) and variable packages (varying number of copies). Single copies are possible too.

Packaging slips must be attached to the bundles; these are printed locally and placed on top of the bundle in a manual or automatic operation. They contain information of the route, the delivery address, and a barcode for the internal distribution at the loading platform. It might also be necessary to include so-called "displays" such as are used in newsstands for advertising purposes. After that the bundle is routed to the packaging machine via transport belts, angle conveyors, and deflectors, where it is sealed in plastic film.

As opposed to square bundles one manufacturer offers packaging in the form of a roll ("RollPack" by Ferag). The product stream is maintained even in the packaging, that is, mini reels are formed, which are wrapped tightly in a film with draw-in ends. Easy to handle and very sturdy packages are the outcome. The very compact construction that unites the functions of stacker, cover sheet feeder, packaging, and strapping in one single device is beneficial from an economic point of view.

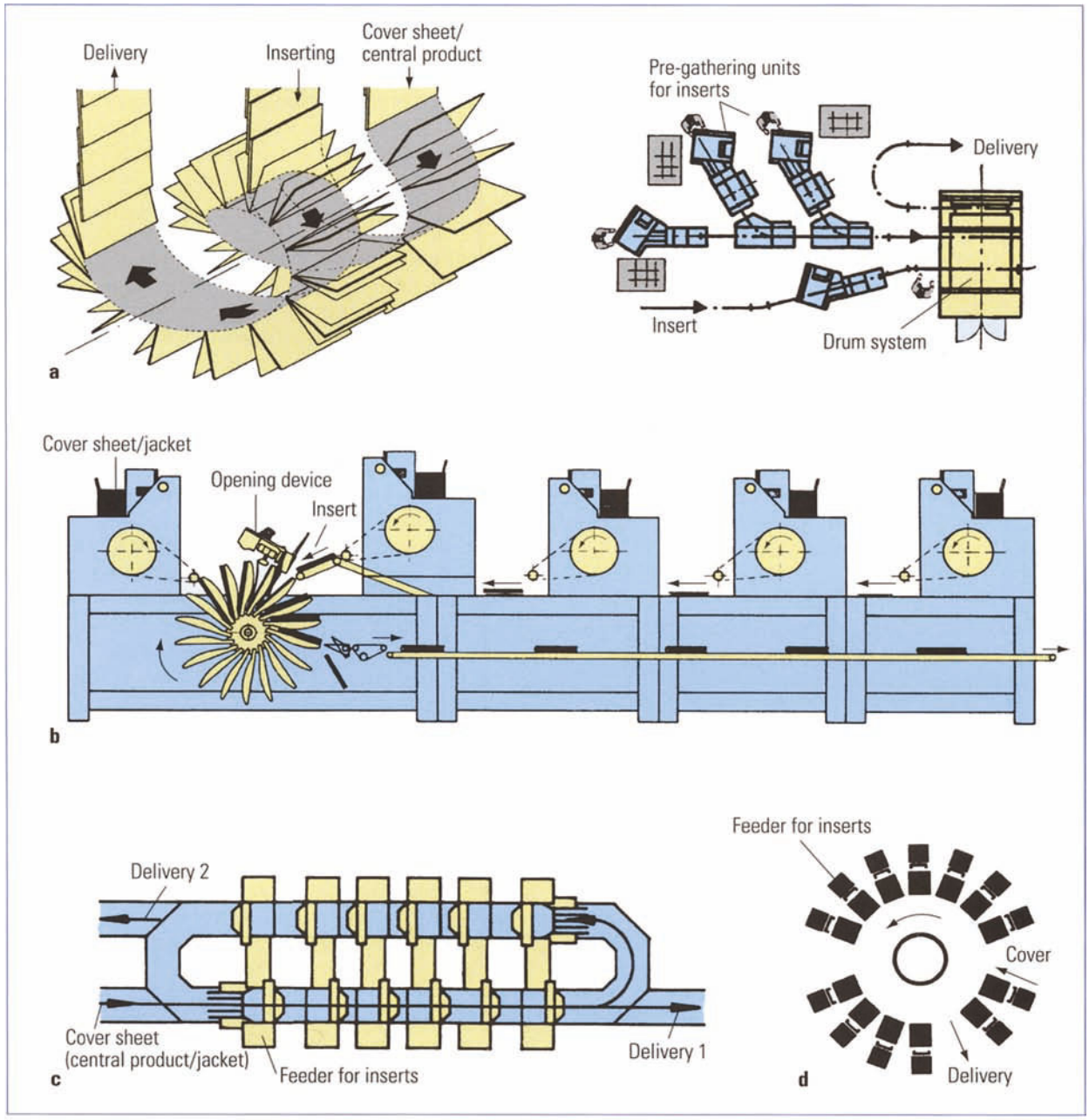


Fig. 7.3-21 Inserting (gathering) machines.
a Drum system and pre-gathering unit;
b Wheel system combined with a pre-gathering system;
c Line system;
d Carrousel system

Strapping takes place in the last processing station. The bundles are automatically strapped crosswise. Narrow, high tensile-strength reinforced plastic belts that are welded together at the ends are used as strapping material. Normally the bundles stop in the strapping machine while the strapping operation takes place, however, there are machines where the strapping unit moves along with the moving bundle and straps the bundle in motion.

To compensate for possible delays on the loading platform, the bundles are put into waiting loops on circulating plate conveyors that are equipped with an ejector. Bundles can be identified through bar codes so that they can be routed automatically to the correct loading platform. On the loading platform the bundles are transported on telescope tapes to the loading area of the truck.

Modern newspaper distribution uses sophisticated software for the optimum planning of the route since modern mailrooms are strongly influenced by control software in any case.

7.3.2.4 Mailroom for Magazines

The magazine product group is characterized by the periodic publication of editions in bound form. It is helpful to sub-divide the product group:

- *Mass-circulation magazines* are usually gravure-printed, saddle-stitched booklets (see sec. 7.2.5.5) for fashion, leisure, and TV programs, which may have up to 400 pages. With a predominantly weekly publication cycle, the print run is over 0.5 million products per edition. Mass-circulation magazines are supplied with an assortment of special advertising media. These media are often made of different material and have their own format (mailings, inserts, samples or specially-shaped, bound-in folded sheets).
- *Technical magazines, journals, hobby publications* are offset-printed multi-layer brochures (saddle-stitched brochures too) for various fields of expertise, which may have up to 200 pages. With a predominantly monthly publication cycle, print runs lie between 5000 and 100 000 products per edition. The extra items are comparable to those of mass-circulation magazines.
- *Company in-house magazines* are offset-printed brochures, of varying bindings and volume. These non-periodically published periodicals with print runs of up to 10 000 products are published by industrial companies and local authorities. The extra items included are limited.
- *Regional magazines/newspapers* are products for industrial/commercial use that are duplicated by offset printing, copying or, in the case of very small circulations, also by non-impact printing processes. They often have no fixed publication cycle and no extra items.

Mass-Circulation Magazines

Mass-circulation magazines are predominantly produced in multistage *gravure printing* operations. Consequently there is no question of printing and finishing operations being performed at great distances from each other because very large quantities of paper have to be conveyed during processing. Printing and finishing are separated by automated temporary storage (basis: folded sheet reel). The prevailing binding technique for mass-circulation magazines is *wire saddle-stitching* because this can be used in workflows with the minimum technical resources, even at high output cycles. Moreover, this type of binding remains stable even with robust handling.

The tipping or *gluing-on of mailings* and/or samples is performed by card gluers that must be directly integrated in the gatherer-stitcher. Mailings and samples are provided by external suppliers. The three-side trimming for the central product is done by *trimmers*. This procedure operates with upper and lower knives and offers a high knife life and relevant performance parameters with satisfactory cutting quality. When *inserting inserts*, the pre-gathered sections are inset in the open magazine (see sec. 7.2.9.2).

Production control, which includes the production sequence for partial print runs (regional specification), subscriber labeling, assembling in batches (of varying size), and packing the pallets is implemented according to distribution premises. The necessary control routines and labeling documents (address labels, packaging leaflets) are worked out in the production preparation. The delivery batches are prepared in *compensating stackers*. Shrink film is used to *package* the bundles for suppliers and distributors. The process is completed by the *palletizing* of the batches (the load quantity varies and depends on distribution requirements) and the allocation of the pallets to various delivery channels (distributor vehicles).

The finishing of magazines in the minimum of time is carried out efficiently in the magazine mailroom on high-performance production lines from units suit-

ably coordinated with each other. The structure of such a production line is outlined in figure 7.3-22. In most cases, several units have to be connected in parallel to ensure the required processing capacity.

The *basic module* of these production lines is the gatherer-stitcher, to which the necessary units are connected, some in parallel connection. These principally consist of:

- gluing-on units for mailings,
- trimmer for three-side trim,
- inserting machine for inserts,
- addressing/labeling machines for individual products,
- counter-stacker,
- packaging label inserter,
- route packaging/distribution packaging,
- palletizing machine,
- route allocation system.

Conventional gatherer-stitchers (e.g., those made by Müller Martini) and in particular drum gatherer-stitchers with drum trimmers (Ferag) are used (see secs. 7.2.4.3 and 7.2.6.2). The drum processing principle cur-

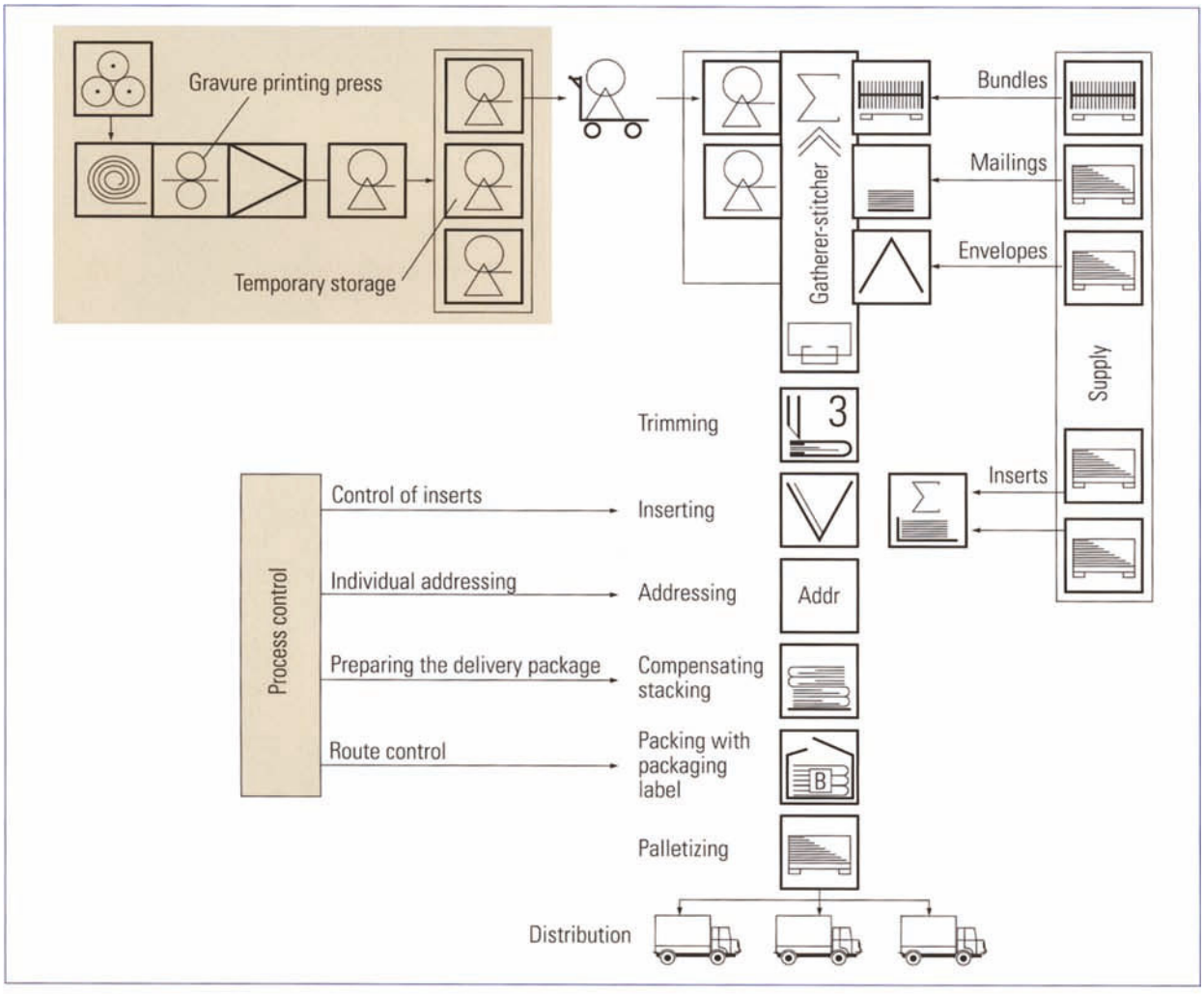


Fig. 7.3-22 System for processing mass-circulation magazines

rently achieves a nominal output of 40 000 cycles per hour. The gatherer-stitcher is first and foremost equipped with folded sheet reel feeders, as well as manual feeders (for cards and inserts) and bundle feeders (for externally-supplied inserts). The complexity of such systems can be seen from figure 7.3-23. Chain conveyor systems are used to connect the operating modules.

To minimize the manual loading operations from mini-disk units, there are automatic loading systems for drum gatherer-stitchers. The disks, stored on pallets, are moved from temporary storage to a "transfer channel." There they are identified and placed in a prespecified buffer zone. If a disk is run empty in the feeder, the core is removed automatically and the buffered disk is lifted into the feeder.

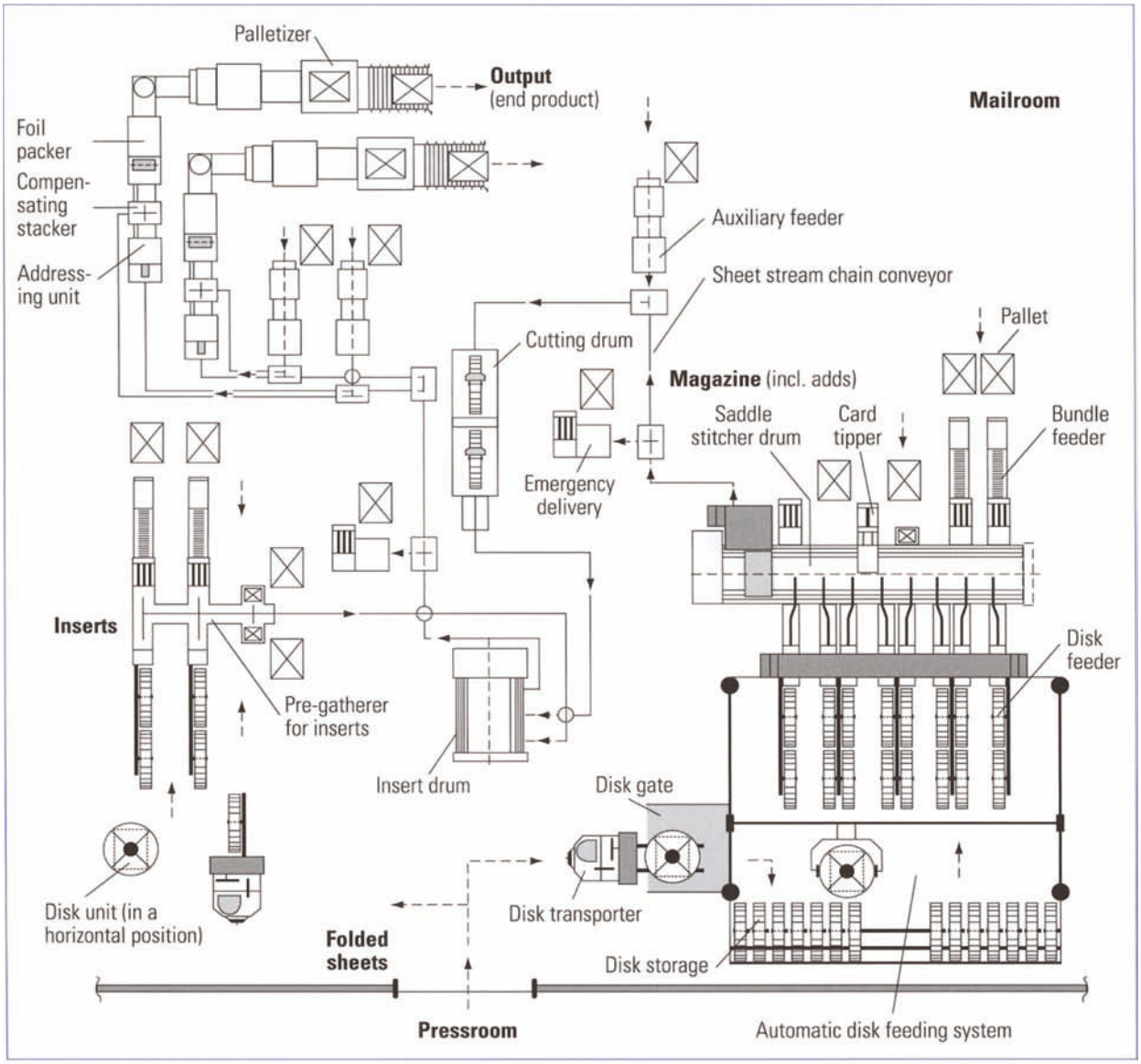


Fig. 7.3-23 Outline plan of an installation for finishing mass-circulation magazines (schematic diagram based on Ferag illustration)

Trade/Hobby Magazines

Trade and hobby magazines are usually intended for specialists who wish to keep themselves continuously informed about a limited field of special interest. The *special interest product* (*SIP*) concept has been developed for subscribers by publishers, to enable them to satisfy the special interests of small reader groups at cost-effective publication levels. The product is designed for an overall target group, within which characteristics such as sex, educational level, trade, and media behavior are representative premises. The basic product is sub-divided into partial editions, representing special fields of expertise. The special content can be selected by the reader. Each customer is offered a special magazine.

The SIP can be sub-divided into the following sales-relevant elements:

- Information, such as news, leading articles appealing to all readers, and so on, is placed in the *core product,* accompanied by the general advertisements.
- *Bound-in items,* mainly consisting of regional, expertise-specific, and age group-relevant editorial contributions together with special advertising are only incorporated in the magazine, if they have been selected by the customer.
- *Adhesive labels/mailings* are for the most part placed on the core product
- *Inserts* are of both a general and a particular nature.

Since magazines are finished according to distribution requirements, SIP that are to be bound in immediate succession to each other have to be provided with different bound-in items. This requires a process control system determined by the mail room.

For "genuine SIP concepts" finishing is based (expediently) on *perfect binding,* because it is easier to implement the cycled changing of signatures (of different content) for multi-layer brochures than for saddle-stitched brochures. The diagram of a perfect binding system for technical magazines is shown in figure 7.3-24. Printing and finishing are separated by temporary storage units. The perfect binding system illustrated is designed for a nominal output of 18 000 products per hour. The gathering machine can be fed both manually and by bundle feeders or disk feeders. The feeding units can be converted for a job change in a short time. A card gluer can be installed in place of any gathering station. An SIP (special interest product) magazine with an average of ten sheets may require more than thirty gathering stations. A stabilizing line must be series-connected downstream of binding, so

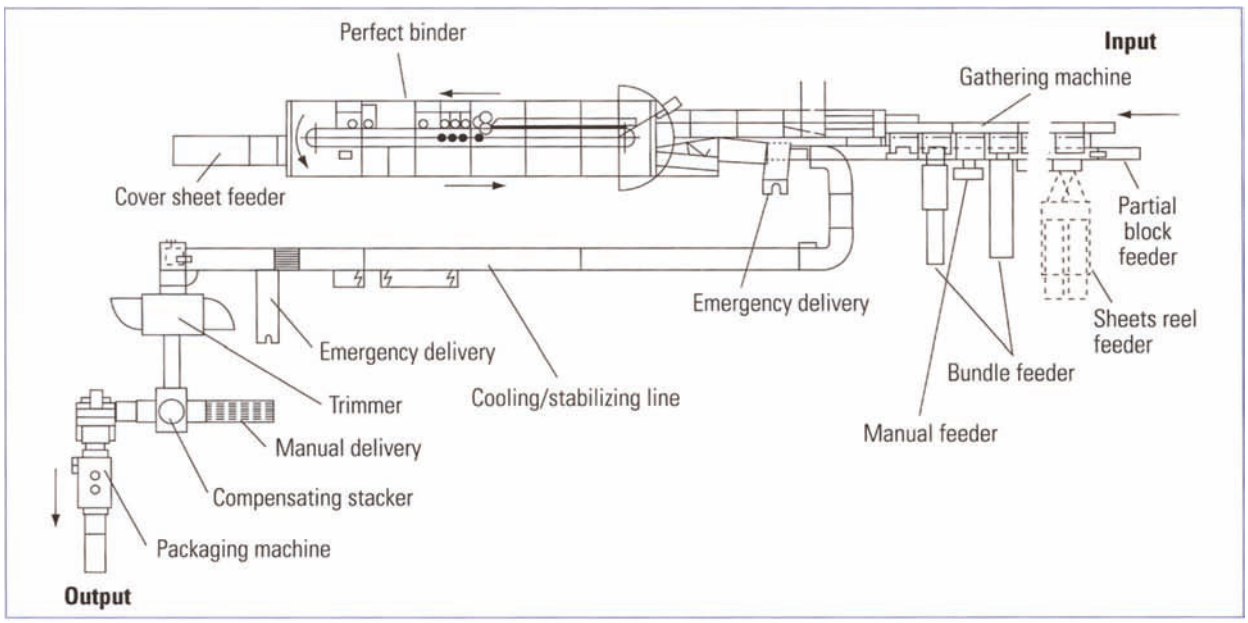


Fig. 7.3-24 Outline plan of equipment for finishing magazines (e.g., trade/hobby magazines)

that the brochures produced using hot-melt adhesive can be trimmed directly.

Other technological modules appropriate to the output, such as inserting machines, addressing units, stackers, or compensating stackers are series-connected (see fig. 7.3-22). Added to this is the need for the "correct" sorting of the enclosed documents. For all its advanced technical development, the technological reliability of graphical machines is limited. Any stoppages that occur bring the customer-specific control into a state of confusion in the production of SIPs. It has to be ascertained with respect to which customer an error has occurred. It is also expedient to make good the spoiled product. There are two possible methods:

- The spoiled product is transferred from the unit and a substitute product is supplied from a buffer installed in parallel.
- Post-processing of the products singled out takes place immediately after production of the job on the processing unit. This causes additional work in the dispatch sector.

A large proportion of technical magazines are published in relatively short runs, totally similar in form. They are produced to a large extent on conventional gatherer-stitcher systems in small- and medium-sized firms. Gatherer-stitcher and wire-stitching units constitute the basic equipment. They are supplemented by cover feeders, trimmers, and stackers. Packaging modules appropriate to the output are connected in series as required. The actual output of these saddle-stitching production lines lies between 8000 and 15 000 products per hour.

Figure 7.3-25 shows the configuration of such a production line.

7.3.2.5 Binding Lines for Multi-layer Brochures

The range of print finishing products that are finished as multi-layer brochures is very extensive. Magazines (see 7.3.2.4) are typical of this type. However, multi-layer brochures are also produced in extremely short print runs as craft. Two groups, which are of great significance in industrial bookbinderies, will be described in more detail:

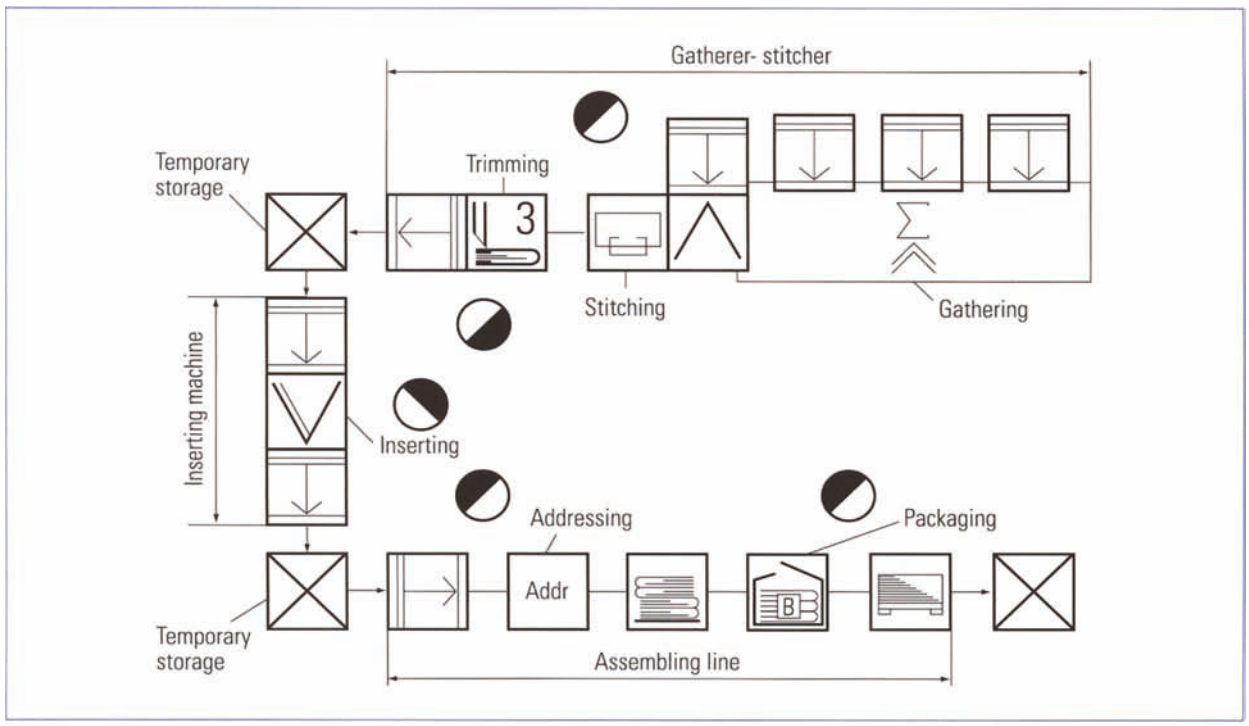


Fig. 7.3-25 Magazine production with technically separate (unlinked) modules

- *Goods catalogs.* Catalogs are offset or gravure-printed products produced in extremely large print runs (≫ 100 000 products per job). The main binding process is perfect binding with hot-melt adhesives. They are produced in one-up. The principal distinctive features are their large format inserts, and a high sheet volume.
- *Paperbacks.* Paperbacks are book products in small- or medium-sized print runs (< 20 000 products). The principal binding process is perfect binding with plastic dispersion, hot-melt, or PUR (polyurethane) adhesive. The preferred sheet layout is the two-up. Special features include lean production methods and stack packing.

Multi-layer brochures are produced on perfect binding lines. When investing in these production lines, the person undertaking the project can choose from an assorted range produced by various manufacturers, so that the respective system is very precisely tailor-made to the parameters of the product structure. During this process aspects relating to product quality and the positioning of the system in the workroom (including the temporary storage of the folded sheets) must be considered in addition to efficiency.

Catalogs

Catalogs are similar to magazines. The high volume of sheets entails high stock throughput on the binding line. Therefore the folded sheet logistics are particularly important. If the printshop and the bindery are accommodated on the same production site, it is expedient to install a disk-type temporary storage system. In most cases the folded sheets are wound onto reel cores at the gravure printing press. The unwinding of the folded sheets is done for each signature at the gathering machine. The technology enables a press delivery structure with a low operator requirement and the efficient feeding of the binding line. The perfect binder, as the basic unit, should have a high effective output. Special equipping of the perfect binder is not necessary. The adhesive must be suited to the type of paper used. Failure to take the grain of the paper into account may lead to production problems and impair quality.

Trimming is a weak point of the line. Individual trimming is necessary for thick catalogs. In this case, the use of a second, parallel connected three-knife trimmer is essential. It is customary for inserts to be inserted into the bound brochure, and there is a growing tendency for catalogs to be personalized and addressed. The catalogs are packed individually in shrink film.

High-capacity automatic palletizers or industrial robots are provided for delivery. The installed buffers, which isolate the process in the event of production stoppages, are particularly important for the efficient operation of the line.

Paperbacks

A binding line for paperbacks is shown in figure 7.3-26. Paperbacks are produced as "come and go" two-ups (see fig. 7.2-41). Two-up folded sheets are usually printed on "book webs". Virtually double the binding output is achieved with this procedure in comparison to one-ups, with the number of impressions remaining unchanged. Paperback bookbinding is simple in its outfit. Consequently paperback lines can be designed with lean technology.

The sheet stack (bundle) is the usual medium for the temporary storage of folded sheets.

There are often additional functional groups installed in the perfect binder, which enable the production of lay-flat brochures. Lay-flat brochures are given an additional spine lining. The block to cover connection is made by strip gluing on the backing strip overlaps.

Since the circulation volume of each print job is limited, the installation of a medium-range perfect binder will suffice (8000–10 000 products per hour). A particular consideration is the short set-up time, because the line usually has to be changed several times a day. After binding, the two-up product has to be separated. This is done in a separating saw. Squaring of the brochures is done at the same time. In the example a bundle packing with shrink film is intended.

7.3.2.6 Production Lines for Hardcovers

Hardcovers are the traditional print finishing products that have been subjected to most changes in their history and the development of which is still not been completed. Their aesthetic form is a cultural asset, which gains in importance in spite of the progressing virtualization of communication technology. The following should be mentioned as typical representatives of industrially manufactured hardcovers:

- *Technical Books.* Technical books are often produced in the form of hardcovers with medium to high page volume (>50 sheets/block) and short print run levels (<5000 products). The binding processes involved are mainly sewing and thread-sealing. The sheets are processed as one-ups. Special characteris-

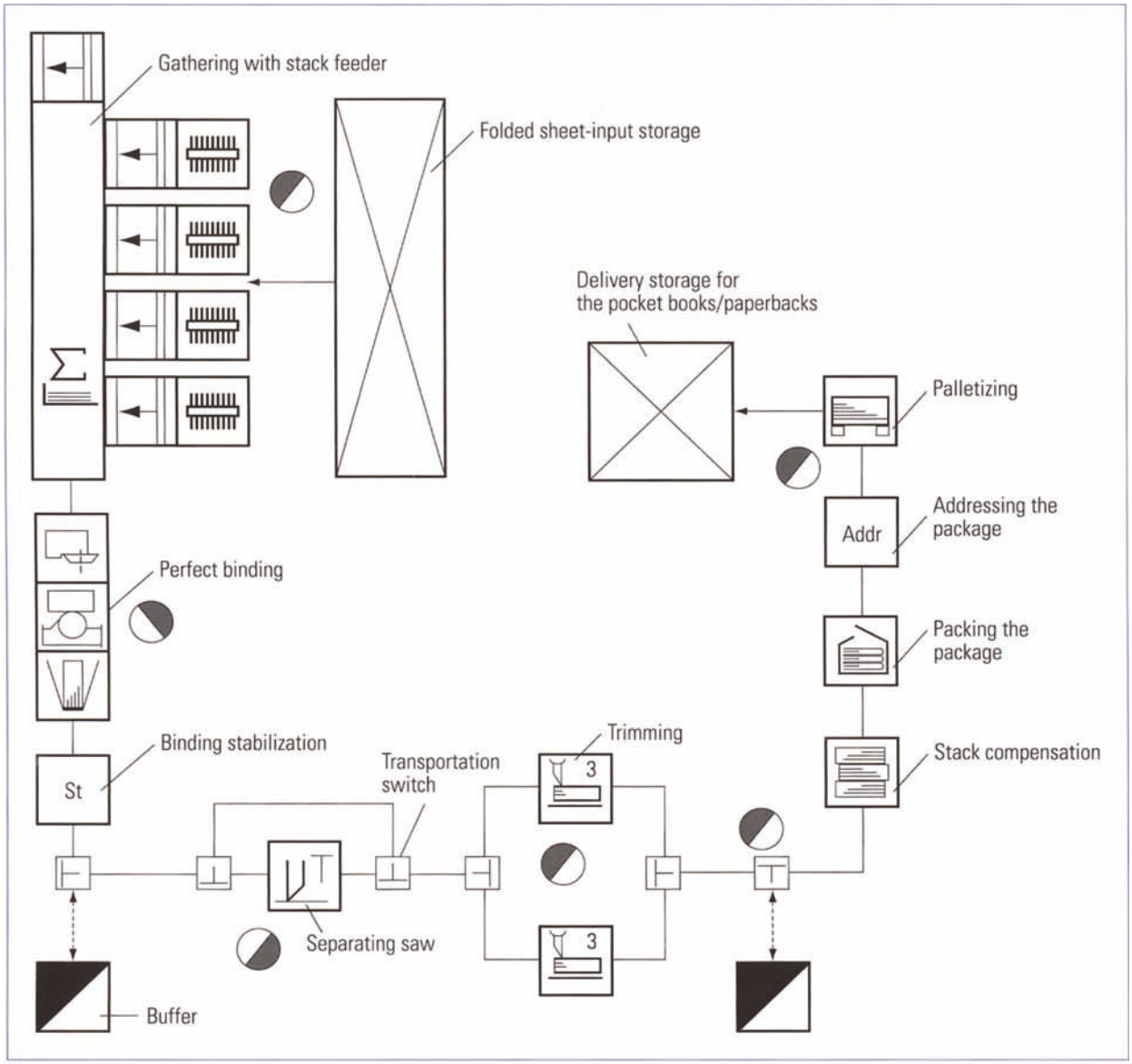


Fig. 7.3-26 Brochure binding line for paperbacks

tics are the demand for high durability of the block, robust book case and variable block presentation.

- *Coffee-Table Books.* Coffee-table books are large format books with hardcovers predominantly produced using coated paper and high-quality color printing in short print runs ($\ll$ 5000 products) and with low sheet volume ($<$ 50 sheets/block). The binding technique used is sewing. The sheets are processed as one-ups. Special characteristics are the high level of presentation of the books, decorative covers, and individual packaging.
- *Fictional Books.* Fictional books are book printing products that are mainly produced in short print runs ($<$ 10 000 products). The sheet volume varies very considerably. The main binding process is perfect binding with dispersion glue or PUR adhesive.

Two-ups are the preferred sheet form. Special characteristics may be the high degree of book binding quality, jackets, and individual packaging.

Hardcovers are products requiring complicated production technology and they are consequently expensive. The large number of necessary processing sections is performed by machinery (manufacturers are Kolbus, VBF, Sigloch, among others) that can both manufacture as technically separate units and be used as technological modules in production lines. This requires a modular system of production modules (delivering, conveying, distributing, buffering, positioning, feeding, etc.), which take care of the connection of the working modules.

Two variants have been selected as examples of the structure of flow production in industrial bookbinderies:

- production system for manufacturing fancy books (extremely high degree of surface finish),
- production system for simple edition binding.

Fancy Books

The reader expects a highly aesthetic effect and optimal utilization properties in fancy books. They are mainly bound by traditional book sewing/thread-stitching, which ensures very good serviceability. The main features involved are book spine rounding, colored book edges, bookmarks, headbands, and jackets. The system shown in figure 7.3-27, which is designed solely to finish sewn fancy books, consists of two workflows separated by book block temporary storage.

In a book-thread-stitching line a gathering machine is connected to two to four automatic book-thread-stitching machines. This type of connection can be found in many book binderies. It comprises a large number of modules, which are loosely connected to each other in sections. In the first section of the book line, which ends with trimming, block-forming and jointing processes are performed. This section of the line is not used if the company has a perfect binder in which back stripping of the book block can be performed. The edge-coloring and bookmark insertion machines are usually connected in a by-pass to the book block's main direction of flow. Each of the two process sections can be run individually in production with conveying arranged accordingly.

Book spine rounding takes place in the next process step as does the gauzing of the book spine, headbanding, backlining, and casing-in. Book production ends with the book forming and pressing machine, in which both stabilization of the adhesive binding of block and book case and post-forming take place.

The final finishing stage, namely putting on the jacket, packaging, palletizing, and applying the pallet dispatch packaging is separated from the preceding sections of the process by a buffer. These processes may also occasionally be separated by temporary storage. This is the case if, to give one example, both hardcovers and brochures are produced in the bookbindery, so that the entire final finishing takes place in one sector. The operating speed of such lines is about 50 cycles/min.

Edition Bindings

There are systems for processing simple edition bindings, as illustrated in figure 7.3-28, installed in many bookbinderies. These consist of a perfect binding line and a book line separated by temporary storage.

Occasionally the binding and book lines are connected. However, this is not particularly effective in practice, as the performance parameters of the two production lines are different, which reduces the production planning options. The medium-capacity perfect binder can operate at 80–100 cycles/min, while the book line has a nominal speed of 50 cycles/min. Since it is usual for both multi-layer brochures and book blocks to be bound on the perfect binder, a 50 cycles/min line is more often than not adequate for most bookbinderies, especially as these lines (compact lines) are more advanced than the faster variant. Perfect binding is very suitable for simple bindings because it produces an adequate binding quality for most of these products. Thread-sealing is to be preferred as a variant for higher binding quality.

Nevertheless, to be able to produce books with a higher presentation level in exceptional cases, medium-sized companies have turned to installing an edge-coloring or bookmark machine as an independent individual module. The trimmed blocks are then removed from the back-stripping block temporary storage to the units, processed there, and then fed into the binding line. This design is also suitable for finishing two-up folded sheets, though a separating saw must then be installed upstream of the three knife trimmer.

The following may be mentioned as *particular features* of a finishing system for simple edition bindings:

- The systems are lean in structure, which means that a high proportion of book production jobs can be efficiently produced.

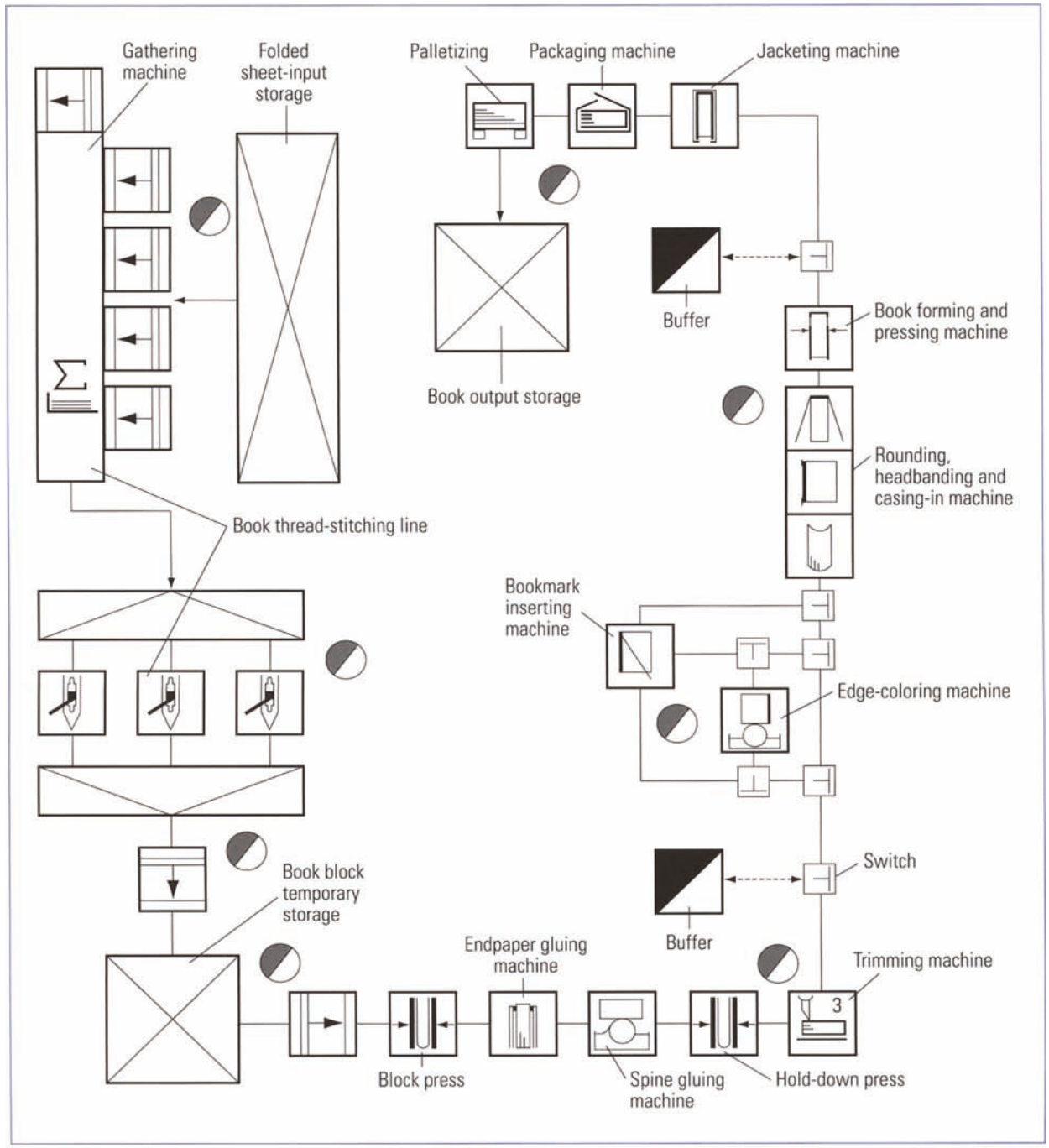


Fig. 7.3-27 Flow production of thread-stitched fancy books

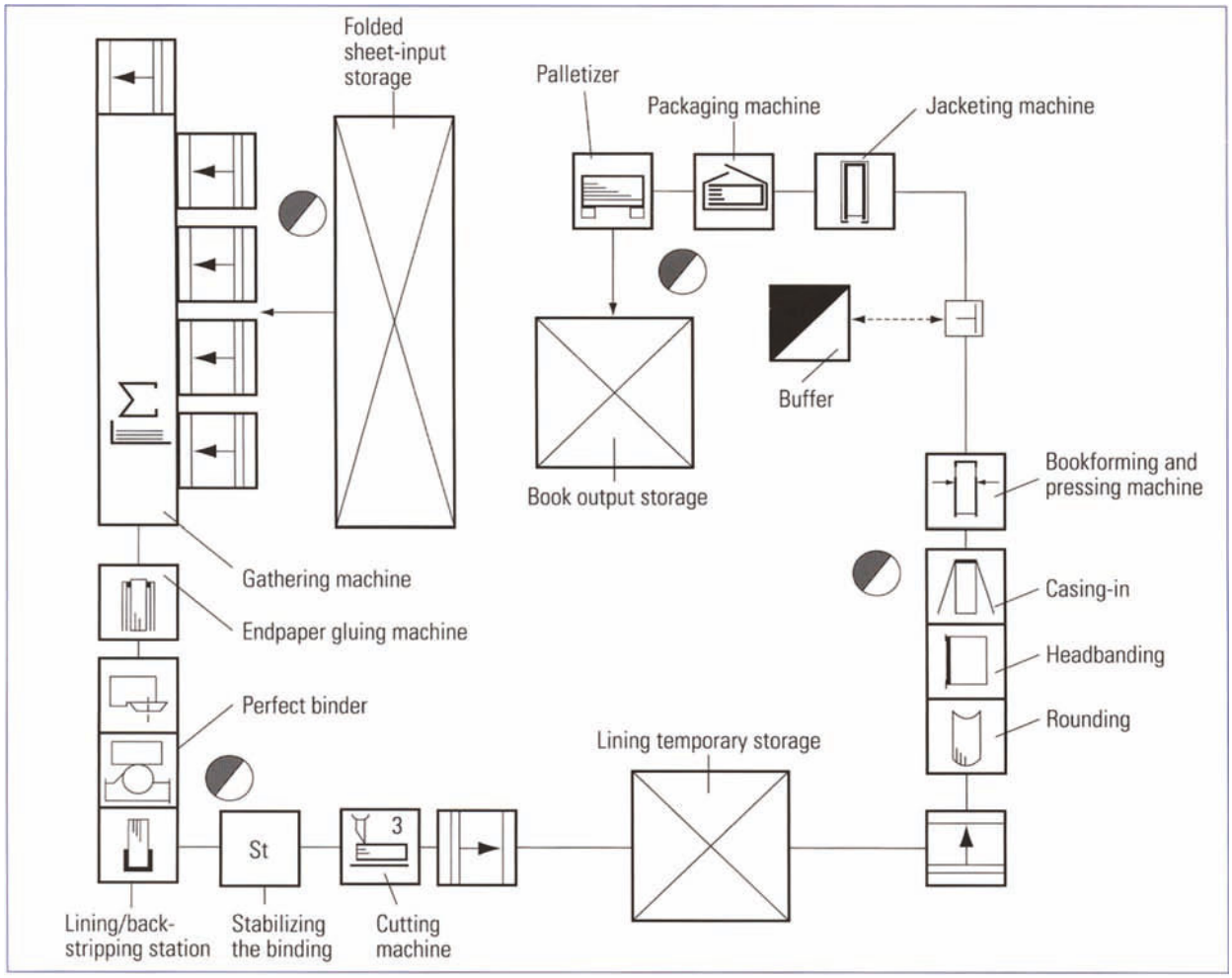


Fig. 7.3-28 Production system for manufacturing simple edition bindings

- System output is low compared to brochure workflows (nominal rated capacity: 50 cycles/min). The priority here is the short line set-up time.
- The choice of folded sheet temporary storage system depends on the type of folded sheet to be processed (one-up or two-up) and the company's mechanization level. It is mainly manual folded sheet manipulation that is practiced. The alternative, the sheet stack, is particularly advantageous for two-up processing.
- Expansion by adding-on technically independent outfitting modules, on the one hand, increases the firm's product variability at acceptable extra cost, and on the other hand does not affect system reliability.

7.3.2.7 Finishing Short Print Runs

The finishing of very short print runs is traditionally the task of manual bookbinderies, in so far as this is a matter of very fancy books and brochures, or that of forwarding companies in the case of simple printed products. The development of digital printing presses (based on a non-impact printing process), by means of which print run lengths from one product/job can be printed economically will enable the industrial processing of very short runs. The following should be

named as business areas for the finishing of very small print runs from digitally printed sheets:

- *operating instructions and media* for the commercial and private use of goods and for company organization, with no requirements for the printing and bookbinding design;
- *advertising media,* such as catalogs, brochures, sheets as single-color or multicolor printwork with economical finishing in the marketing sector of companies or in agencies;
- *publisher's editions* of special technical books, coffee-table books as hardcovers or in the form of multi-layer brochures in individual copies or very small print runs;
- *off-prints* of special literary editions as reprints or facsimiles;
- *checking/proof copies* for print run production;
- *mailings.*

It is the task of the operator carrying out the finishing operations to rationally convert small-size print sheets into a finished product. Depending on the kind of printing press used (conventional or non-impact printing) the print sheets are either arranged in stacks of sheets with the same printed image, or are already sorted in the correct sequence for the end product.

The process sections listed in table 7.3-4 are the minimum necessary for converting printed sheets into blocks.

There are two conceptions that are preferable for finishing very short print runs:

- printing systems that produce the completely finished product,
- technically separate print finishing. (Printing/gathering lines for blocks. Binding and finishing is done downstream of block temporary storage.)

Digital print/finishing lines have been developed for a number of special applications, which mainly produce saddle-stitched booklets. Possible principles are shown in figure 7.3-29.

The web, printed on a digital printing system, is cut into four-page sheets to produce saddle-stitched booklets, which are gathered and bound. The wire-stitching is done upstream of the layer folding. (There are also sheet-fed printing variants.) For perfect binding, the printed web has to be cut into sheets. The sheets have to be gathered. It must be taken into account during imposition that the back edge is placed in the direction of travel of the web.

An equivalent to the variant shown in figure 7.3-29 is to use tower gathering machines for print production systems downstream of a buffer storage for printed sheets, as illustrated in figure 7.3-30 (technically separate finishing).

The figure shows a printing system that prints consecutive four-page signatures. Binding takes place in a wire-stitching line downstream of printing. A process structure of this type is advantageous, if no finishing operations occur upstream of binding (folding, preparing, or similar).

Even when using a digital printing system the link between printing and finishing needs to be eliminated if various binding methods are employed after printing (fig. 7.3-31).

Blocks are delivered from the printing press. To deposit the blocks, it is expedient to fix the sheets according

Table 7.3-4
Process sections for the conversion of printed sheets into blocks for books

Section of the process	Limitations/Applications
Folding into folded sheets	If sheets with more than two pages per signature are delivered in the printing press.
Collating/ inserting in blocks	Gathering/sorting is necessary if the delivered sheets have been printed with more than four pages in accordance with an imposition layout.
Binding the blocks	Production consists predominantly of brochures with simple binding procedures (wire-stitching, binding of leaves). Thread-stitched binding also has to be done for the production of technical books.
Trimming the blocks	As 3-side trimming or front trimming.
Equipping for the final product	Binding into hardcovers is carried out independently of block production.

Fig. 7.3-29
Binding variants with digital printing systems (computer to print)

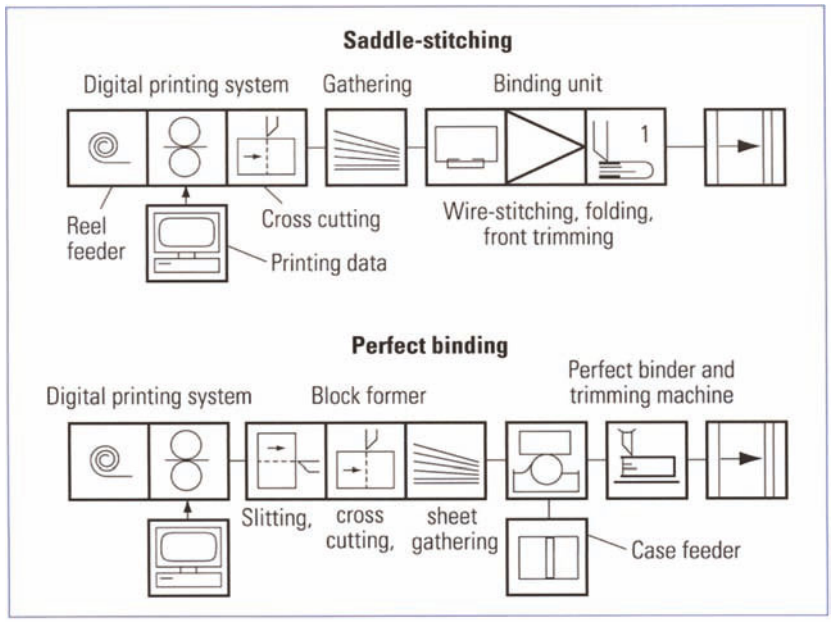
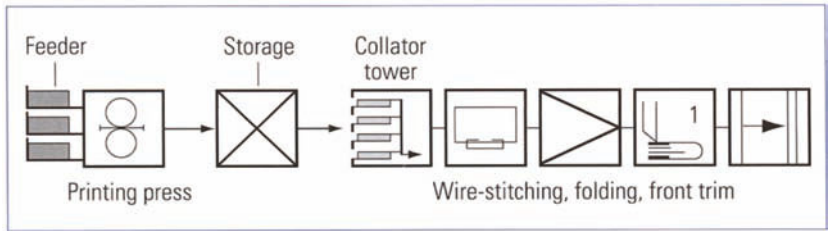


Fig. 7.3-30
Simple binding (wire-stitching) with temporary storage and collator



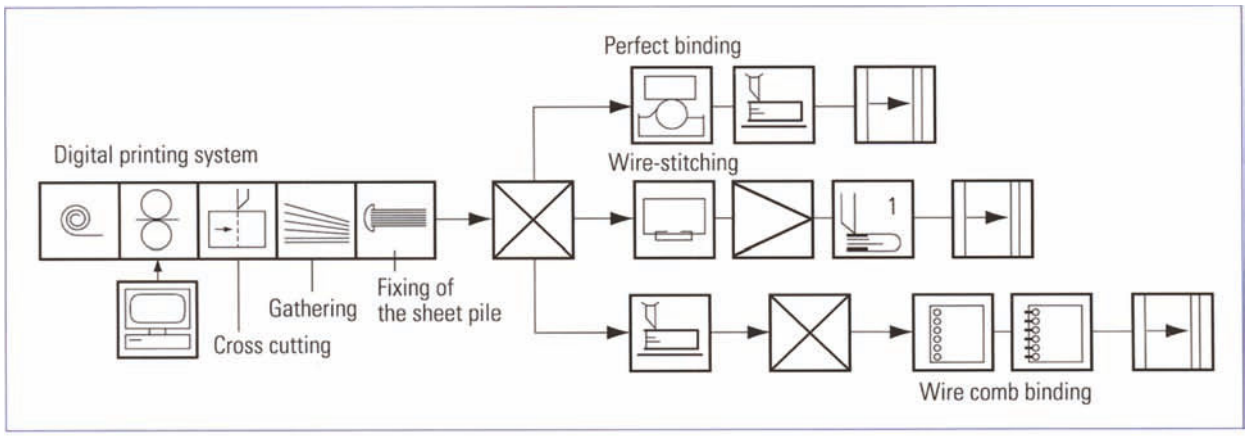


Fig. 7.3-31 Print finishing/binding variants

to the blocks. This will improve finishing unit manipulation (depositing, temporary storage, feeder). Finishing is carried out predominantly with small-scale mechanization operating resources.

The processes described are not very suitable for the production of books with a high level of hardcover binding, because these products necessitate thread-sewn binding. A *print-gathering production line*, in which the digitally printed small-format sheets are finished into a block comprising thread-sealed folded signatures (fig. 7.3-32) commends itself here. Jointing, forwarding, and the casing-in of the block are implemented in a separate production process. A production line structure of this type is sensible because the inevitable defective products from folding and thread-sealing can be "reprinted" immediately. In technically separate sheet finishing, a press stoppage would always entail the loss of a block.

The modules required for sheet finishing should be designed as a modular system so that jobs using different block designs can be produced by changing the modules.

For block binding and book production, complete blocks are compiled in gang runs of fifty to one hundred blocks and stacked in a conveying container. The conveying container passes through the necessary technological modules until the finished book has been formed. Machine conversions and the assignment of the book sections for jointing processes are taken over by a control computer, the input data of which is the order data and bar-code information on the book sections (fig. 7.3-33). This production method also enables integration of infrequently performed manual process sections, such as edge-coloring.

The development of technologies of this type is still in its initial stages. If there is a corresponding demand, it is to be expected that a further increase in finishing efficiency can be achieved by using new materials and production methods.

7.3.2.8 Bag Production Systems

Bags are packaging media that are mostly produced in a processing sequence that is independent of the packing. They are filled with the goods to be packed in packaging machines or manually, if the purpose is the short-term storage of goods. The predominant material is paper, but plastic film or compound material made from paper and plastic is also used. The bags are usually printed on the outside, for product identification and/or advertising purposes.

The following product groups can be gathered together under the term "bag":

- *Pouches* are packaging media that form a triangle in their flat state and are closed by means of a glued seam.
- *Bags* are in the flat state rectangular packaging media with or without space-enhancing floor structure, predominantly formed from tubing made from one or multiple layers of material.
- *Carrier bags* are different-sized bag designs that are given handles for carrying. Possible types of handles are punched handle holes, strings pulled through eyes (cords), strips of paper or cardboard shaped into handles and glued to the bag, and handle hole panels glued to the bag.
- *Sacks* are space-forming (mostly multi-layer) packaging media, the flat bodies of which form an area of more than 2700 cm^2. The design of sacks corresponds to that of bags. Moreover, a distinction can be made between

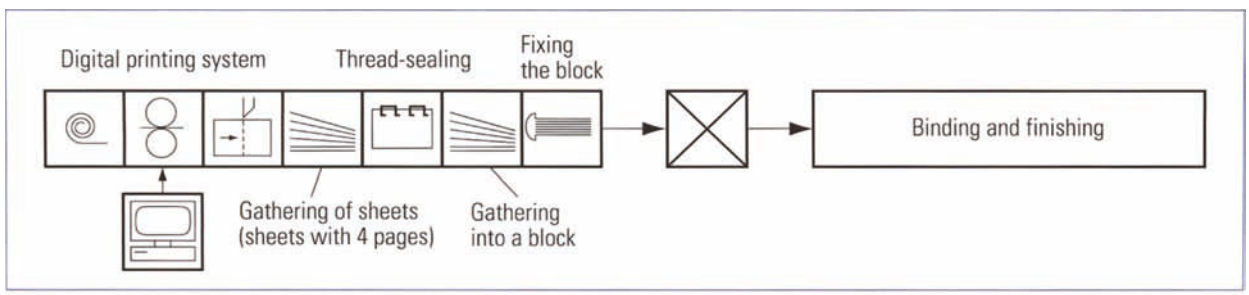


Fig. 7.3-32 Finishing operations for thread-sealed blocks

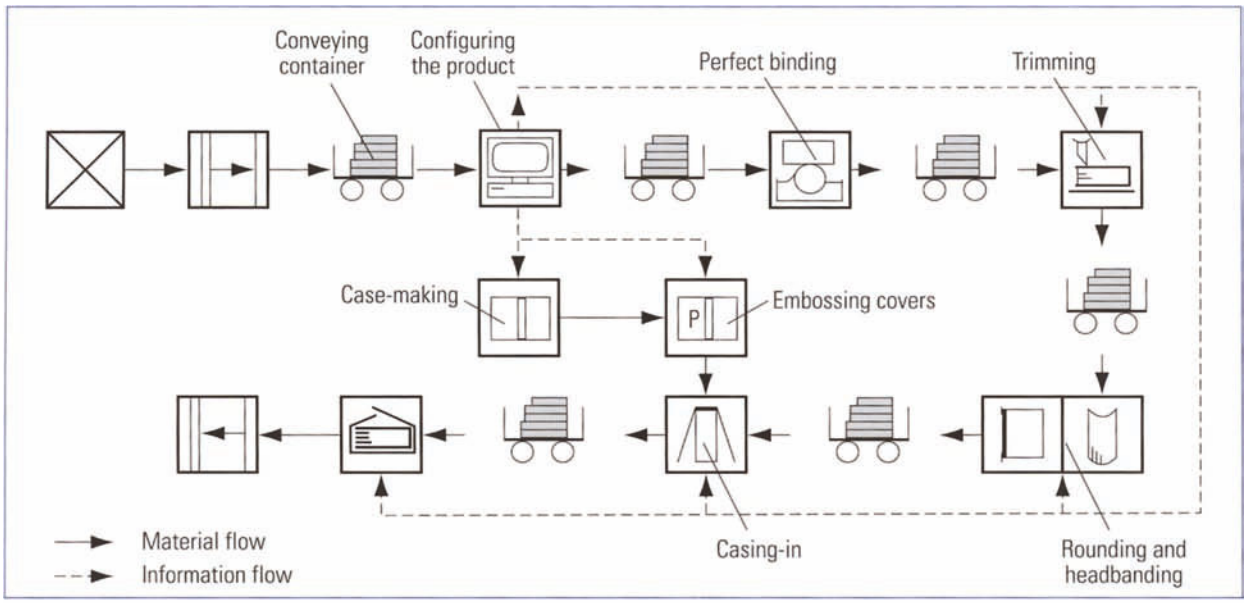


Fig. 7.3-33 Block binding and book production in very small editions/run length

- open sacks, the entire top side of which is used as the filling aperture and
- closed sacks, provided with special filling apertures on the top side of the sack (sacks with ventilated bottoms).

Bags are packaging media that only reach their full spatial extent when they are filled. Therefore before filling they are folded compactly and can consequently be transported and stored efficiently.

The design and production of bags is described in greater detail below.

The different bag designs are described in table 7.3-5.

Production systems have been developed for manufacturing bags, in which all sections of the process have been integrated, from the unwinding of the web to the packing of the bags (fig. 7.3-34).

The first unit in the system is the *tube-folding* unit (fig. 7.3-35). The paper web is pulled over a format plate. To create a wrinkle-free tube, the distance between format plate and unwinding unit, and the web angle in relation to the format plate must be arranged depending on the bag size. A double format plate between which two fold rails are placed is used to form the side fold. The section A-A in figure 7.3-35 shows the formation of a side fold in diagrammatic form.

The tube is converted into bags with the help of the *cross-cutting* device. Special slitting methods are utilized in addition to the familiar rotary cross cutters:

- Perforation slitting device; the tube is given a crosswise perforation here. Slitting is done by tearing off with increased web tension between pairs of conveying rollers.
- Rapier tube separator, in which a serrated blade (rapier) performs a chopping cut against a likewise serrated bottom blade.

The *bag bottom* is produced in several steps during motion of the bag by reshaping the front section of the bag, as shown for the cross bottom bag in figure 7.3-36.

After the tube has been opened, the bottom edges are folded, producing a square floor, the diagonals of which correspond to the width of the tube. To seal the bottom the pre-glued points of the square are folded into the floor area and pressed to stabilize the glue joint. A rectangular sealing fold can be formed, instead of the sealing points, by inserting two slits parallel to the center of the tube.

To prepare the bending points, to shape and glue together the floor, differently structured working principles are used depending on the machine manufacturer. When producing bag bottoms, it is a matter of form-

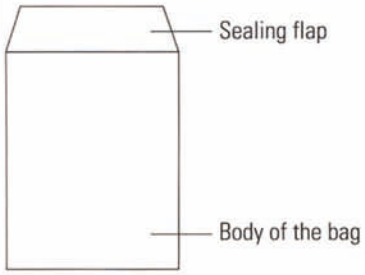
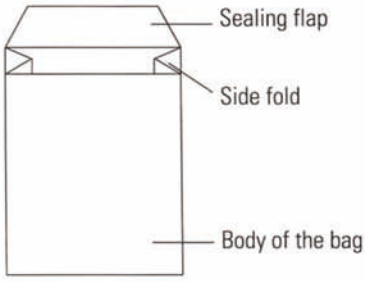
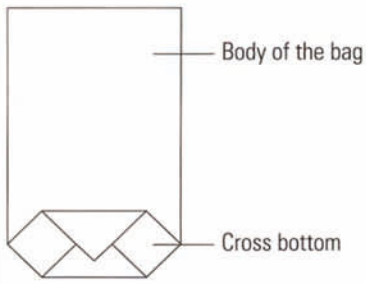
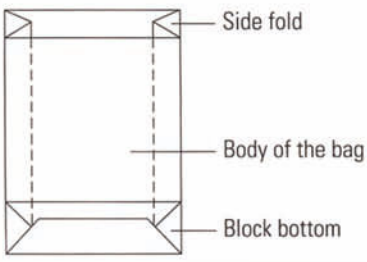
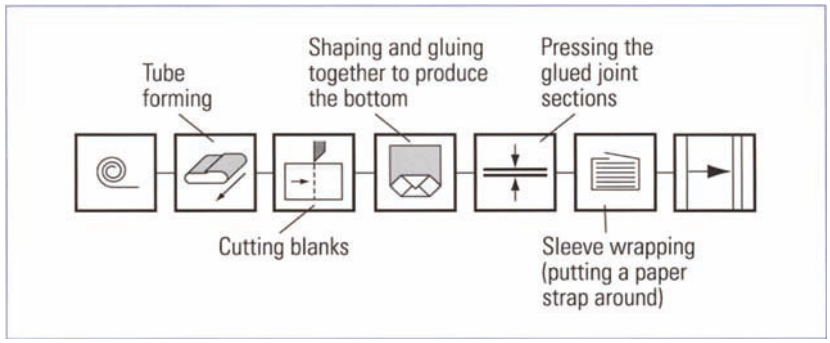
Diagram	Description
	*Flat bag* • Formed from a tube of paper (glued seam on the center of the bag's surface). The tube is separated at right angles to the direction of travel of the web, in such a way that an adhesive tab is produced for closure of the bag bottom. The tab is smeared with glue in a folding unit and sealed at right angles to the bag's direction of travel. • Formed from a paper web with two glued seams. Gluing tabs are punched on both edges of the web. The web is cut at right angles to form the blank for a bag. The gluing tabs are folded and glued before the bag is sealed off by a central flap fold in the floor line (at right angles to the direction of travel of the web).
	*Flat bag with the side fold* Side folds enable better opening of the bag for filling. The side folds are formed while the tube is being shaped, by means of a "double" format plate, around which the web of paper is pulled. The bottom is sealed either by means of a gluing tab or by rolling up the bottom adhesive-coated tube section (at right angles to the surface line of the bag).
	*Cross bottom bag* Cross bottom bags are flat bags without side folds. The bottom is formed from the bottom tube section and glued together. When the bag is opened, the floor stands at right angles to the surface line of the bag, a hollow body being produced that is easy to fill.
	*Block-bottomed bag* Block-bottomed bags are flat bags with side folds. The bottom is formed from the bottom tube section and glued together. When the bag is opened, the bottom lies at right angles to the surface line of the bag, a hollow body being produced which is easy to fill.

Table 7.3-5 Bag design

Fig. 7.3-34
Outline plan of a bag machine



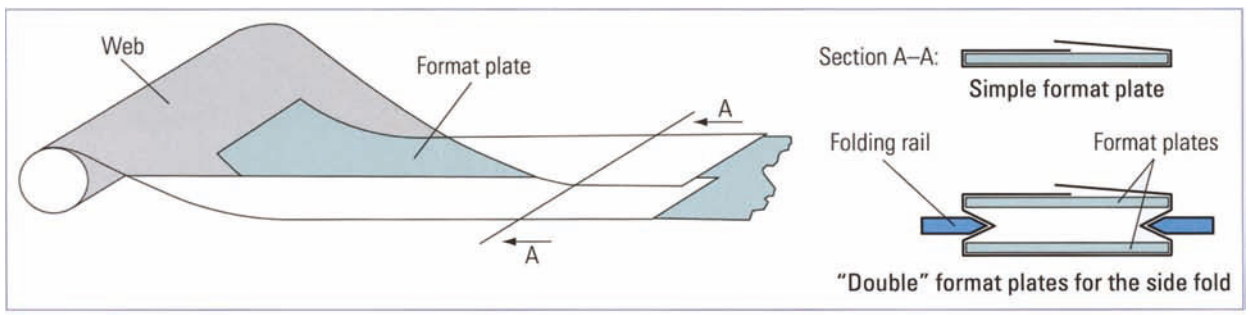


Fig. 7.3-35 Tube forming in bag machines for producing blanks for bags

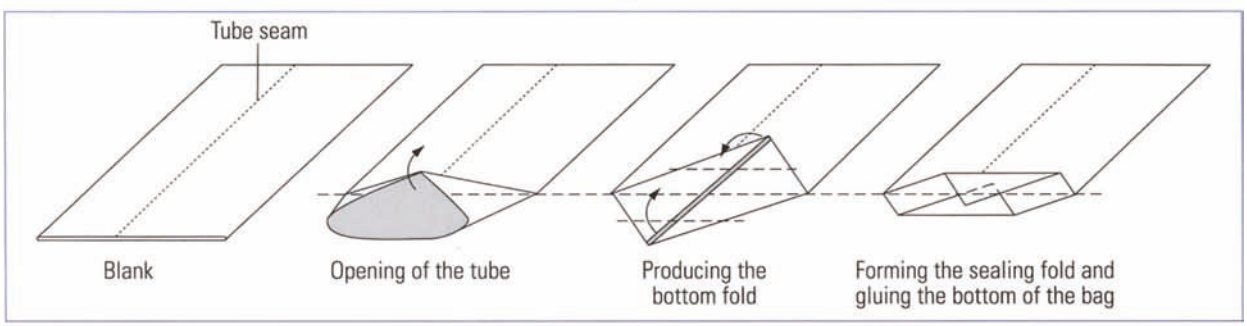


Fig. 7.3-36 Forming a cross bottom from a paper tube

ing a leak-proof hollow body from a tube both without cutting waste and without the use of additional materials. In modern plants for packing bulk materials (e.g., sugar, flour) the bag tube and bottom are formed directly before filling and sealing is performed directly after the filling process. Figure 7.3-37 shows a general view of a block-bottomed bag machine made by Windmöller & Hölscher.

7.3.2.9 Folding Boxes

Boxes are space-providing packaging media, formed from one or more flat cuttings. Because they are very easy to manipulate, stack, store, and transport in their prevailing standard shape, the square, they represent the most widely distributed packaging medium for trade and industry and for personal use. Accordingly, boxes appear in a particularly wide variety of forms.



Fig. 7.3-37
Block-bottomed bag machine (Triumph, W&H)

Possible attributes for product classification are listed in table 7.3-6.

The basic types (fig. 7.3-38) are subjected to a multitude of modifications (mixed designs). The endeavors of designers to develop attractive packaging that can also be produced efficiently has led to these products being designed to a great extent using CAD (computer aided design) programs. The following premises apply for sales packaging:

- The boxes should meet the high standards set for the aesthetic surface quality of the printing substrate and the print and surface finish.
- The shape of the hollow body should only be formed when the box is in the packing machine (erection of the box). This means that a spatial unit should consist of one cutting and that jointing and sealing elements must have a complicated surface that as a minimum, deviates from the rectangular.
- It should be possible to erect boxes of different designs in the same packing machine without fundamental technical alterations.
- The cuttings should be arranged closely together on the substrate surface (materials economy aspect).

The above-mentioned requirements determine the processing technology to be used. Figure 7.3-39 shows the diagram of the current standard technology for the production of folded and upright boxes. The process can be sub-divided into three partial processes, printing, forming the cutting, and forming the box. The partial processes are usually separated from each other by temporary storage.

Sales packaging is predominantly printed in a multicolor sheet-fed offset process and coated to increase brilliance, handling resistance, and cardboard imperviousness. This is mainly done with dispersion coating in the printing press. The alternative to coating, acetate lamination, is work-intensive because an additional operation becomes necessary, which must also be commissioned as an outside contract.

Forming the cuttings includes three aspects:

- Additional surface finishing of the outside surfaces of the boxes by relief stamping and/or by embossing with metal foils.
- Die-cutting the outside shape of cuttings. Since adhesive tabs, cover elements, and so on, usually diverge from the rectangular, the cuttings must be die-cut from printed substrate plates.
- Preparation of the processing locations, namely the folding edges of the boxes, which are creased, openings or slits for positive joints, and perforations for openings, which will simplify removal of the packed goods.

Lastly, a *waste stripping* process occurs, which means that the waste areas in the substrate are removed. The

Attribute	Characteristics
Material	Cardboard, paperboard Corrugated board Material combinations Plastics, metal, wood Note: Only boxes made from finished and unfinished composite fiber material are dealt with below.
Use	*Dispatch packaging:* cardboard cartons are known as "boxes". *Sales packaging:* additional functions are identification and advertising for the packed product. *Gift packaging:* boxes with special external and possibly interior decoration, which is mostly achieved by printing and print finishing processes (also referred to as fancy or de luxe packaging).
Box design (choice) see fig. 7.3-38	*Folding boxes* are produced from a cutting. The cutting must be joined along at least one edge. They are closed by folding up several folds arranged on the body. *Boxes with fold-up lids* are made from a cutting. The cutting must be joined along at least one edge. They are closed by snapping shut a fold-up lid, one side of which is joined onto the body. *Turning boxes* are produced from two cuttings (body and lid). Both cuttings must be joined along at least one edge. They are closed by putting the separately produced lid over the body. *Sliding boxes* consist of slide and sleeve. Both cuttings must be joined on at least one edge. They are closed by pushing the slide into the sleeve. *Sheath boxes* consist of an outer and inner section. They are closed by inserting the outer section into the inner section.
Supplied form	*Fixed form boxes:* Boxes are glued together and supplied upright for filling. This supplied form is avoided to a very great extent because of the large amount of space required, though it is required for gift packaging that is highly decorated on the inside and has a special design. *Joined folding or collapsible folding boxes:* The box cuttings are joined on one edge and folded. They are set upright in suitable packing systems (converted into hollow bodies), filled, and sealed. *Box cuttings,* which are set upright and joined up in the packing system immediately prior to the filling process and sealed afterwards.
Box wall connection	Wire-stapling Tab gluing Strip gluing Push-in connection Fold and clamp connection

Table 7.3-6 Possible attributes for product classification of boxes

forming of cuttings usually occurs by means of automatic vertical die-cutting machines during the finishing operation, in which the die-cutting, creasing, and waste stripping of the cuttings takes place. Most automatic die-cutting machines are also fitted with relief stamping devices (cold embossing). The working method applied is flat-bed die-cutting, in which both the cutting die and its counterpart tool (blade cutting method) are flat in form. Steel-rule dies are used in die-cutting. In this case, ground steel strips are inserted into grooves cut into plywood panels (see fig. 7.2-18). The grooves are cut in the panels by means of computer-controlled equipment, which takes over the data obtained during production of the printing plate. For the production of cuttings requiring little surface finishing work, finishing lines are used into which printing, die-cutting, and waste stripping operations are integrated.

The multicolor web-fed printing of the cardboard takes place first in *automatic printing and die-cutting machines.* The web is then cut on a flat-bed die-cutting machine. A cross cutter is configured upstream of delivery, so that cut and waste-stripped sheets can be delivered. The web has to be stopped during die-cutting (intermittent web travel). If there is a job-determined change to the length of the printing section, the

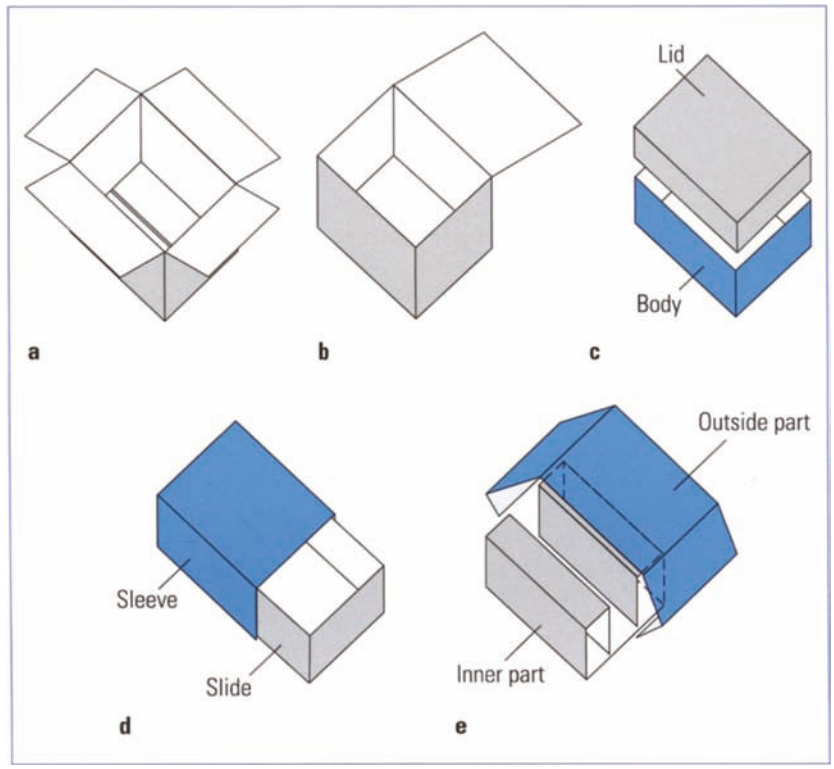


Fig. 7.3-38
Basic types of boxes made from cardboard, paperboard, and corrugated board.
a Folding box;
b Boxes with fold-up lids;
c Turning box;
d Sliding box;
e Sheath box

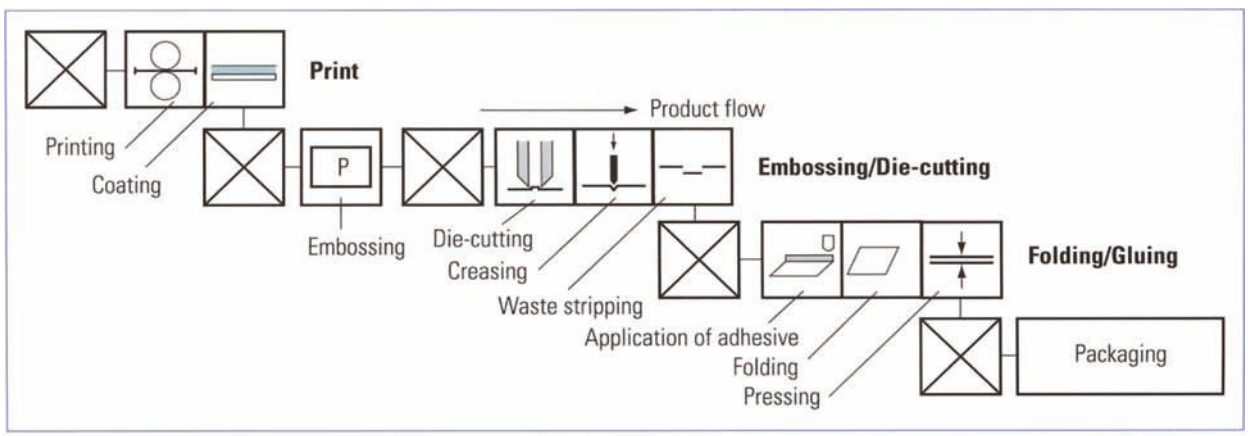


Fig. 7.3-39 Technology for the production of folding boxes

impression cylinders and the distance between the print units have to be changed.

In automatic die-cutting and printing machines the cardboard web is die-cut first (with margins to hold the blanks and waste together) and then cut at right angles to the sheet. Multicolor printing takes place in rigidly interconnected sheet-fed printing units. Blank stripping takes place in front of the delivery.

If it is not possible to process blanks in the packing machine, they must be jointed so that when they are

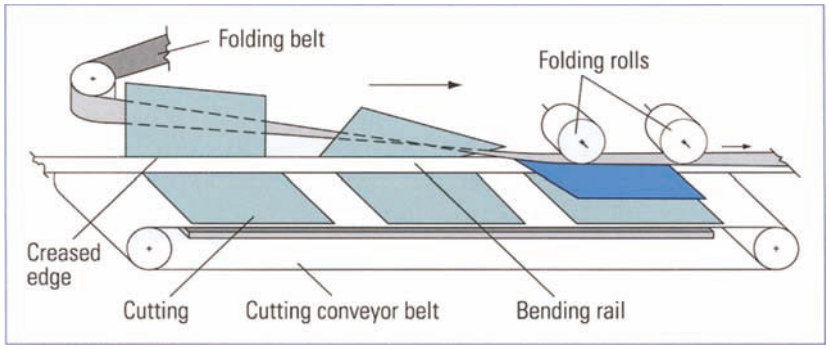


Fig. 7.3-40
Belt folding unit for folding creased box cuttings

erected a hollow body is produced in the surface line, and in the case of collapsible folding boxes also on the box floor. For sales packaging this is done in a *folding box gluing machine.* The cuttings are folded and glued here. The machines consists of

- The box feeder.
- One or more pre-breaking stations, in which the box edges are folded along the crease lines, so that the boxes are easily set upright in the packing machine. It is predominantly the strip folding method that is applied for the pre-breaking of edges running parallel to the direction of travel (fig. 7.3-40). Traveling folding fingers take over the shaping of the flaps in the case of edges running at right angles to the direction of travel (these machines are referred to as "straight gluing machines"). In gluers working at right angles, all edges can be folded with tape folders by changing the direction of travel of the cuttings.
- One or more adhesive application stations, in which glue is applied to the gluing tabs and edges. Dispersion or hot-melt adhesives are applied by gluing wheels or nozzle gluing units.
- One or more folding stations, which operate in the same way as the pre-breaking stations and take over the jointing of the glued edges and any box sections.
- The pressing station, in which the jointed areas are stabilized.
- The delivery for the folded and glued folding boxes. A packing module that collects the boxes and places them in dispatch boxes according to a stacking pattern is integrated in the delivery section of high-performance systems.

The operating principle of the folding box machine being used must be taken into account when boxes are being designed. Such systems have an output of up to 100 000 boxes an hour. Systems that process dispatch boxes made from corrugated board work on similar principles.

Further Reading for 7.3

Liebau, D.; Weschke, H.: Polygraph-Fachlexikon der Druckindustrie und Kommunikationstechnik. Polygraph-Verlag, Frankfurt/Main 1995.

8 Material and Data Flow in Print Media Production

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8.1 Material Logistics

Figure 8.1-1 shows, in a simplified form, how the different areas of the production workflow of print media are linked together by the flow of materials and data.

The logistics for supplying and conveying materials are a fundamental component of efficient production. The sequences that take place in the press area, in the printing plant, and in the publishing house are dealt with below.

8.1.1 Logistics around the Press

When working with printing presses it is essential to have paper, ink, printing plates, dampening solution, and other process materials on hand, as well as blast and compressed air. Such materials may also need to be discarded at some point, while half-finished or finished products should move on to the subsequent stages of production. To illustrate the material-flow, *an example of a newspaper printing plant* with web offset presses follows. To a large extent, however, this information may also be relevant when considering other machinery used for the production of printed products and *sheet-fed printing*, in particular. Section 8.1.1.5 deals with the special characteristics of sheet-fed offset printing.

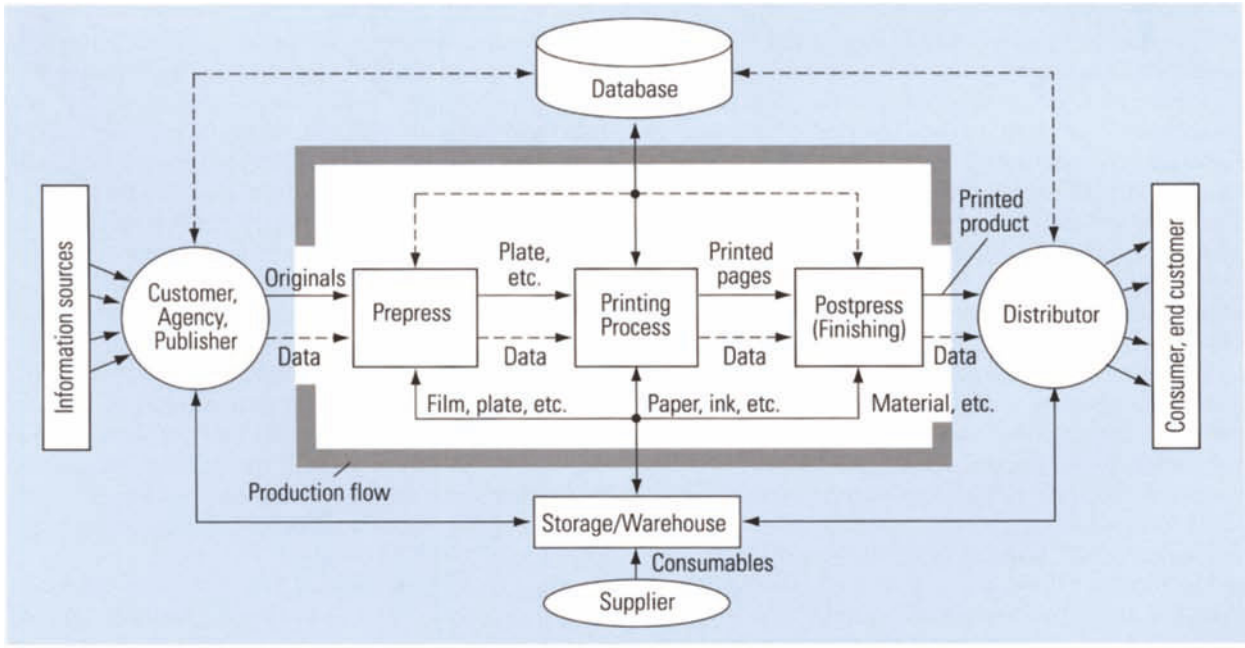


Fig. 8.1-1 Production flow and stream of material and data for print media production

H. Kipphan (ed.), *Handbook of Print Media*
© Springer-Verlag Berlin Heidelberg 2001

8.1.1.1 Supply of Printing Plates

Before printing can start, the press must be fitted with printing plates and supplied, naturally, with paper and ink. *Newspaper printing* will be used as an example because it requires a relatively large number of offset printing plates per print job. For this reason, one can find the most advanced level of automation in the newspaper printing sector. In newspaper printing it is normal for prepress and printing to be done in separate areas; the actual activity of printing begins with the production of the printing plates or the receipt of the full-page film data file using remote data transmission.

The *platemaking* process has already reached such a level of automation in the newspaper sector that the act of placing the full-page films onto the copying frame remains the only manually performed task (computer to film (CtF), fig. 8.1-2). Even this step is unnecessary in the computer to plate technology (CtP) that is becoming more and more prevalent (see sec. 4.3.2.3). Of course, piles of blank plates and developing fluids have to be fed to the platemaking line from time to time. This, however, should be seen in terms of equipment maintenance.

To increase printing plate throughput and ensure that it is not impaired by the manual feeding of the full-page films, there are usually two copying frames available at the start of the platemaking line, which can be alternately operated.

The complete process is to a large degree fully automatic. Process steps include the separation of the unprocessed plates from the plate pile, the removal of the intermediate layer of paper (inserted to protect the light-sensitive coating from scratches), the exposure of the plate, and the developing of the light-sensitive coating in the subsequent developer. Before punching the plates (in order to mount them in accurate register) and bending their edges (to fasten the plate tightly and securely in the clamping jaws of the plate cylinder), the coverage of the printing plate is measured using a plate image reader (e.g., line camera; see also sec. 2.1.5.4). This takes place in order to assess the printing plate's zonal ink requirement and to calculate the presetting values for the inking units' ink zones. (If the printing units are equipped with keyless inking systems, none of this is necessary.)

There are two different types of *register holes*, those of the film and those of the printing plate (fig. 8.1-3). Whereas the former are usually round, slit-shaped cutouts are preferred for the latter. Coordinate tables or revolving tables controlled by means of two video cameras that scan the register marks of the print image on the plate (fig. 8.1-3b), have recently been introduced to ensure the accurate alignment of the printing plates prior to punching and edge-bending. The inductive monitoring of three-point plate alignments – both during exposure and prior to plate punching and bending – provides yet another means of positioning the plate in accurate register.

At the end of the platemaking line, the finished printing plates are deposited in a shaft from which they can be removed manually. Western printing plants often continue to remove the printing plates for visual inspection; then the plate may be allocated to the individual sets of cylinders and/or full-color sets. Japanese newspaper printing plants, on the other hand, sometimes employ a fully-automatic conveying system that may be accompanied by robotic plating-up. In this case, classification according to color sets and cylinder alignment corresponding to the imposition layout follow automatically.

Marking the printing plates poses a particular problem if they are to be reused at different positions in the press for varying editions of the newspaper. Often, therefore, they do not carry a page number on the print image. This problem may be countered by affixing a bar-code in the plate's bevel, in which case an electronic sorting system will attend to the varying assignments.

In most situations, the operator at the end of the platemaking line sorts the printing plates into trays. When a cylinder set becomes available, the operator puts it in a conveyor box or hangs it in a conveying-rack that then transports this parcel to the printing unit by means of a rail-mounted conveying system (monorail, telelift). In this fashion, a cylinder set can be supplied to certain positions in the rotary press, where it is removed by the printer and its individual plates successively fixed onto the corresponding plate cylinder.

In the case of robotic *plate-mounting*, there are two possibilities in particular: First, plates may be initially *placed in shafts* that are located above the plate cylinders and then released at the time of plate change: In this situation the plates "place themselves" on the cylinder as a result of gravity and the pulling force of the front-clamping bar. Second, a programmed, *multi-articulated robot* imitates all the manual movement sequences.

After printing has finished, the *printing plates are removed* in reverse order as during the feeding. The old plates are then bundled and returned to a recycling firm.

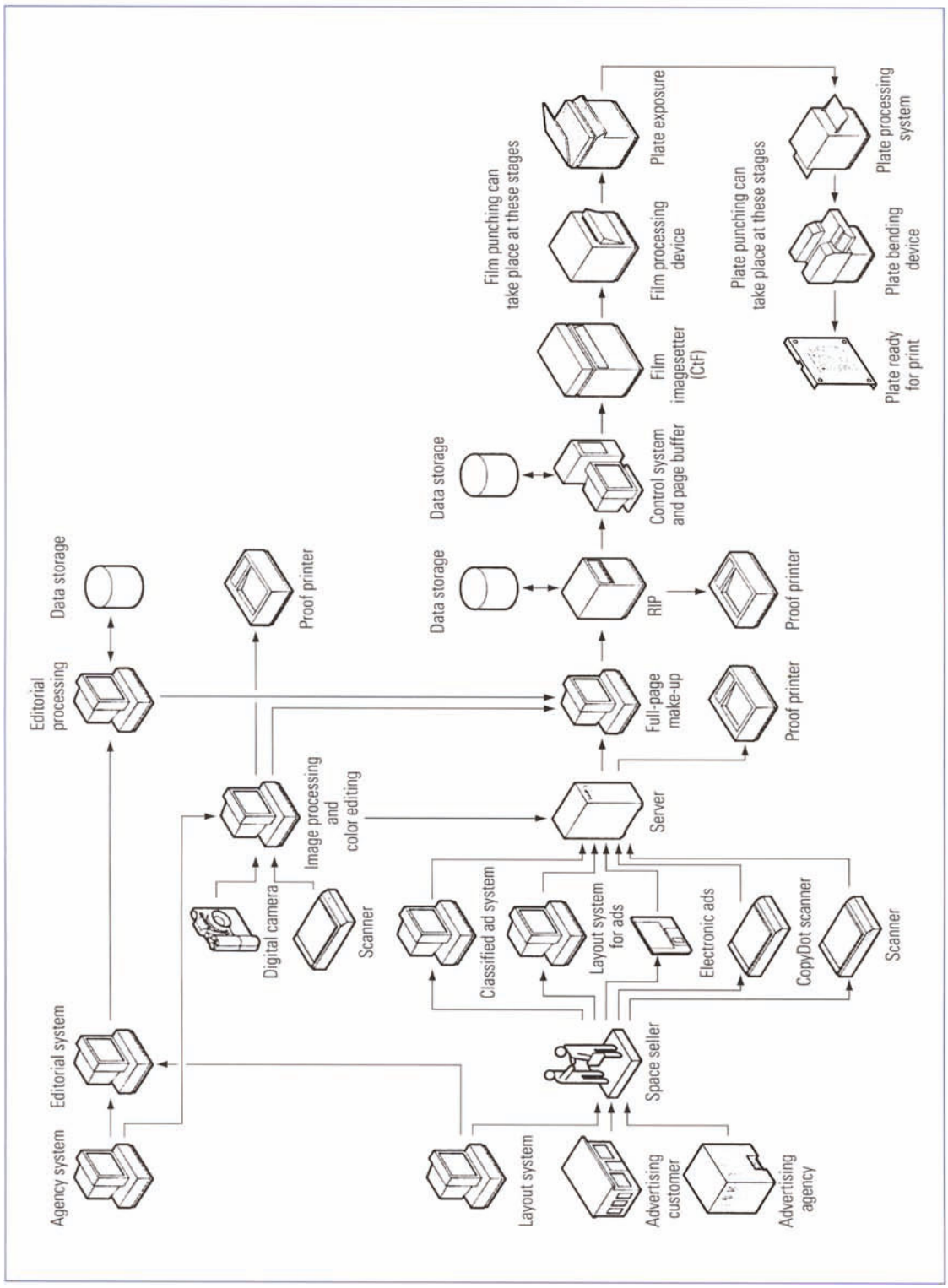


Fig. 8.1-2 Workflow: From data preparation up to supply of the printing plate for newspaper production using computer to film (CtF) technology (IFRA)

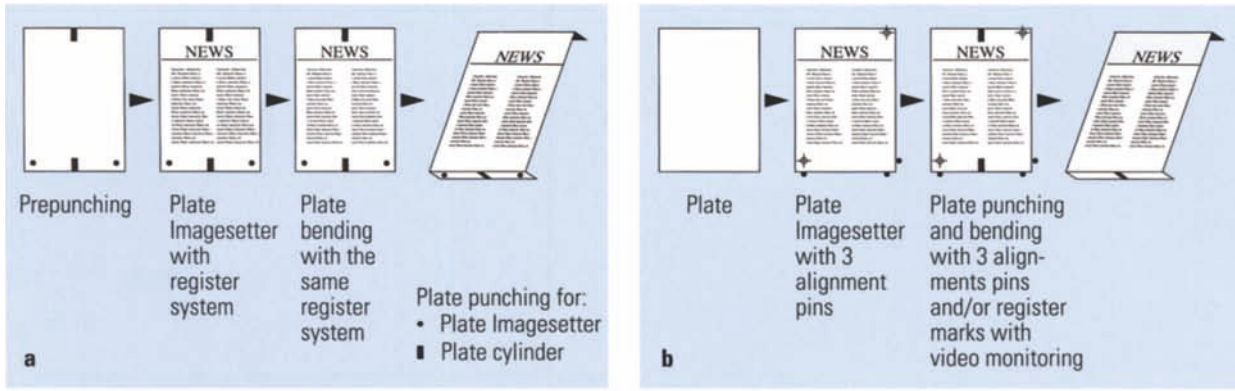


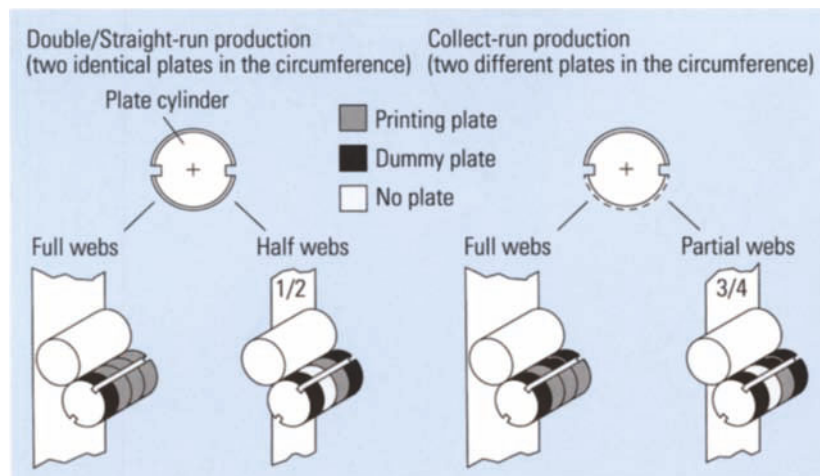
Fig. 8.1-3 Exposure with computer to plate technology and plate bending.
a Pre-punched plate;
b Without pre-punching; alignment pins are used for aligning and punching the plate. For plate-bending register marks are measured in the print image or a camera system is used for the alignment (IFRA)

It is important to remember that, in addition to the active printing plates, passive "*dummy plates*" must be supplied to the press. These plates are used where no printing occurs across the web of paper. Dummy plates are printing plates without a light-sensitive coating (fig. 8.1-4). Because of the high four-color capacity of modern presses, the number of dummy plates has considerably increased in relation to active printing plates. It is perfectly understandable that considerable research went into finding more cost-effective solutions. By reducing the thickness of the dummy plates, for example, it would be possible to cut down on the aluminum costs and increase the service life of these plates. Suppliers have, however, refrained from pursuing this option in order to continue the uniform production of printing plates and dummy plates.

8.1.1.2 Paper Reel Logistics

The paper to be processed on web-fed presses is supplied in web form. Due to the large size and weight of these reels well-organized logistics are required. The paper reel is usually unloaded from railroad freight cars or from the flatbeds on trucks by a *fork lift vehicle with a hoist,* which picks up the reel around its circumfer-

Fig. 8.1-4
Use of dummy plates (passive plates) in newspaper printing (IFRA)



ence and transports it to the storeroom, such as a bay with upright storage or high-rack storage. *Trucks with endless floors* are specifically designed for this task and automate the entire unloading process. *Gantry cranes* with special suction hoist gears present another option and can pick up a maximum of eight reels of paper at a time. (*The Chicago Tribune* makes use of such machinery, for example.)

Even during the unloading process it must be possible to *identify the individual reels* of paper so that any damage sustained in transit can be noted and claimed for. For this purpose, each *reel label receives a bar-code* that can be recorded, processed, and identified by a laser scanner or camera (fig. 8.1-5; see also fig. 2.1-79). Along with comments on the reels' condition, the scanned-in and recorded paper reel identification numbers are passed on to the purchasing department. Here, these ID numbers are compared with the dispatch data sent directly from the distributor or the paper mill. The use of a standardized electronic format is increasing: *EDIFACT* (Electronic Data Interchange for Administration, Commerce and Transport) is being promoted and developed in the paper sector by the EDIPAP work group of CEPI (Confederation of European Paper Industries), the umbrella organization of European paper manufacturers. Although EDIFACT is, in fact, an international standard, both the USA and Canada still make use of other standards. At present, however, there are attempts to bring these differences into accord.

Stacking the reels on top of each other (see fig. 2.1-78), that is, "*chimney storage*", has a disadvantage: Only the most recently delivered reels can be removed from each stack first. In contrast, removal according to the FIFO principle (first in, first out) is possible with high-rack storage, which also permits all types of storage, that is, "chaotic" storage, for a variety of materials. A computer-controlled manipulator enables access to every shelf and compartment. In the range of 1500 to 3000 paper reels can be stored in this space-saving way, regardless of whether standing or lying. If the reels are standing upright, they are usually stored on pallets, if horizontal, on prisms (so-called "*prism storage*", i.e., the stored product holder has a prism-shaped base to prevent rolling). Pallet storage makes it easy to accommodate other materials in the high-rack storage, whereas prism storage saves on vertical space.

Today, in large printing plants, the reels often travel on *automated guided vehicle systems* (AGVS, see sec. 2.1.3.1; fig. 2.1-78) from the storeroom into daily storage. Here, during the day, reels of paper are prepared for nightly printing. The reels of paper have to be *unpacked* beforehand and prepared for automatic reel change, for which both semi- or fully automatic equipment is now available. If no interruption in the sequence of unloading, storage in the storeroom, and day-to-day storage occurs, identification of the individual reels of paper by the remote, computer-controlled AGV remains certain. If this is not the case, before a reel label is removed with the packaging, its bar-code must be passed on. To accomplish this, the label has special self-adhesive strips (peel-off labels) with the bar-code printed on that can be firmly affixed to the

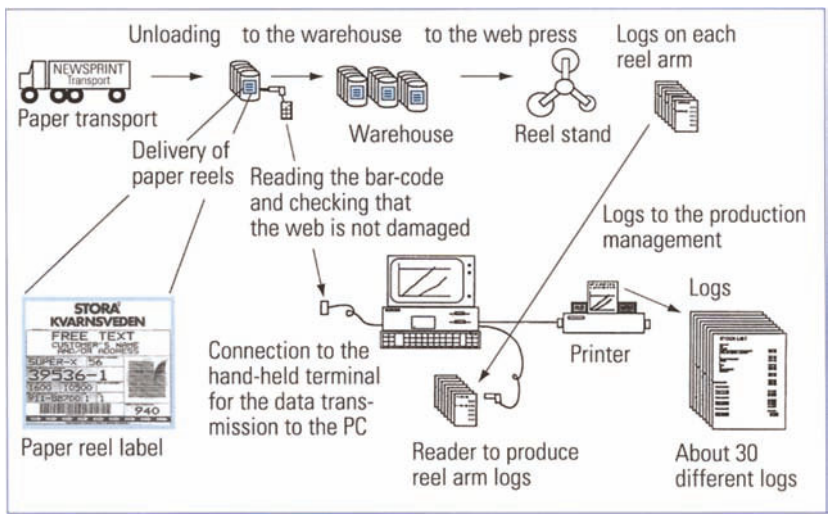


Fig. 8.1-5
Paper reel logistics and identification in a newspaper printing plant. Bottom left: paper reel label with bar-codes on self-adhesive peel-offs (Denex/IFRA)

end of the reel until it reaches the reel stand in the printing press.

The individual reels are again removed from *day-to-day storage* and taken to the respective *reel stand* by means of AGVS or computer-controlled overhead cranes. There the reel of paper is identified either by its bar-code in the automatic chain sequence or the *reel-handler*, that is, the operator at the reel stand who removes the peel-off label with the bar-code from the end of the reel and places it onto a form that indicates onto which of the reel arms the reel has been clamped. By inspecting this form, the printshop's administration can determine which reel of paper caused a particular web break or increase in paper waste. Nowadays, of course, far more data is recorded for production statistics, such as the web length that each reel has produced and how the area-related mass – the grammage of the paper – varies.

8.1.1.3 Ink, Dampening Solution, and Air Supply

Ink Supply

A distinction must be made in newspaper rotary printing between black ink and the considerably more expensive chromatic inks and special inks ("spot colors"). The first (black) is delivered by *tankers* and pumped into large storage tanks. In contrast, 1000 kg *piggy-back containers* are generally used for chromatic and special inks, which can again be emptied into stationary tanks (fig. 8.1-6). Pumps convey the inks from the tanks to the printing press's ink fountains (see sec. 2.1.3.1). The purchasing formalities take place in the usual way, that is, by means of tender, purchase order, and order confirmation, not by bar-code marking and EDIFACT.

Because of the increased use of *spot color* (special inks) some printers tend to *mix* these hues according to colorimetric data, commonly using up to twelve inks that are connected to a special color mixing station via a weighing device. The fact that one can change the ink's mixture after analysis of its composition is important when considering resource conservation. It is, therefore, possible to recycle the *residual ink* that, along with its colorimetric specification, was included in the mixing calculation. The spot colors, made up of twelve basic colors, have a considerably greater color gamut than is achievable with the four process colors.

Both web and sheet-fed printing employ *automatic ink feed systems*; filling-level sensors monitor the printing units' ink fountains, to which the filling level control constantly supplies an adequate quantity of ink (see also sec. 2.1.5.5).

Dampening Solution Supply

In offset printing, the dampening solution comprises about 95% water, which in most cases, however, has to be prepared beforehand in order to convert *untreated (tap) water into process water*. In many regions where it rises or is pumped from the ground, untreated water is actually too hard, that is, it contains too many mineral salts. Therefore, this water must be softened before mixing it with the dampening solution additives. Devices that work on the principles of reverse osmosis, for example, are capable of this and may be used to convert tap water to a hardness of approximately 8 °dH (German Hardness; 8° dH = 142.88 mg $CaCO_3$ per liter) – the optimal condition for attaining the highest print quality. Furthermore, it is especially important that the process water be adjusted to a special pH value and enriched with additives in order to achieve the desired surface tension (see also sec. 2.1.1.2).

The *dampening solution* obtained in this way is stored in large tanks from which it is pumped to the dampening solution containers on the printing press. Filling level regulators control the refilling process automatically. The press's internal dampening solution circuit between the dampening solution container and the dampening unit has already been described in section 2.1.3.1.

In the case of dampening solutions, it is often necessary to add controlled amounts of pesticides to prevent algae growth. Because of their slimy consistency, algae can block pipes in the supply tank, and so forth.

Compressed Air and Blast Air Supply

Printing presses usually require two types of compressed air. Highly pressurized air is used when operating the pneumatic control, and blast air under relatively low pressure circulates the air around the turner bars and the superstructure's formers. In sheet-fed offset printing, low pressure air may also be used for the sheet guiding elements. Compressors with the usual fittings and a pressure tank are used for compressed air under high pressure. These compressors should be fitted in a separate room in the printing plant. Radial and centrifugal blowers can be used for low pressures needed at the turner bars and former. They are installed as closely as possible to the points of consumption in order to reduce losses. Since the prints heat up around the turner bars and formers (because air heats up during

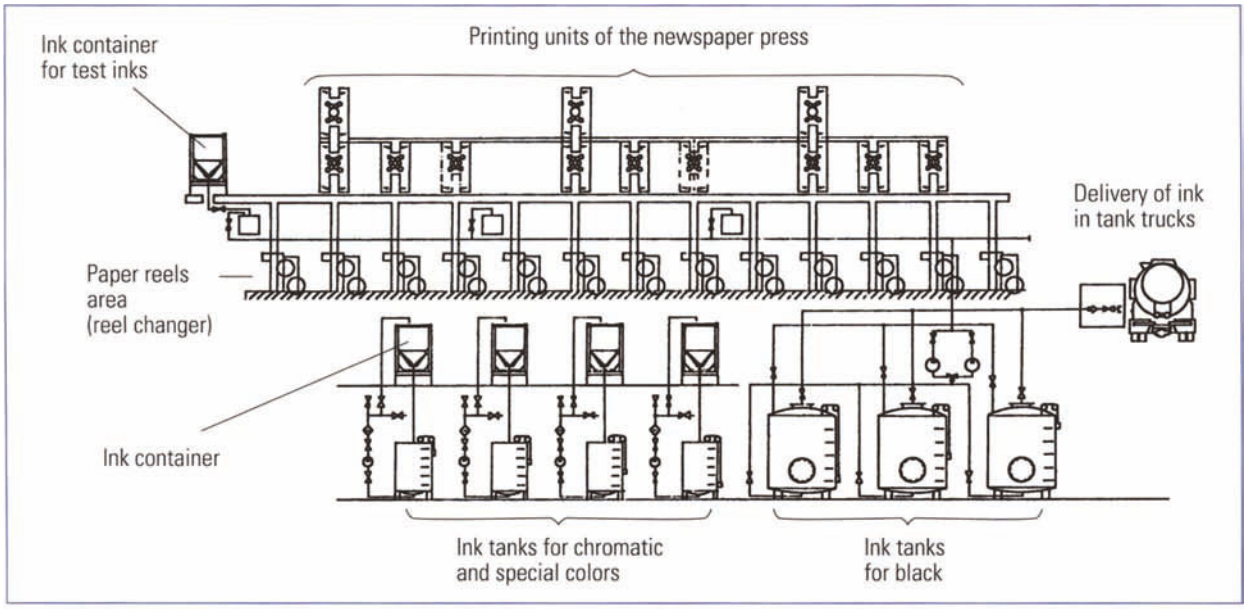


Fig. 8.1-6 The ink supply of a newspaper press (IFRA)

compression), a downstream cooler may be needed to avoid ink offsetting. The design engineer and installer need great skill when putting the blast air pipes in the press so that access to the press's individual elements is not obstructed and the aesthetic design preserved.

8.1.1.4 Waste Disposal

Not all products are printed in a saleable quality; a printshop also produces waste sheets that require disposal. *Paper waste* is classified into the following categories according to its point of origin (see sec. 8.1.2.3):

- damaged reels of paper marked for return,
- reel cores and packaging material,
- waste (white waste) produced during preparation of the reel,
- waste produced while setting up, starting up, and restarting the printing press,
- reel remnants,
- waste from misprints, including waste occurring during a reel change,
- waste from surplus impressions and returns.

The waste referred to above is usually collected in skeleton containers in the printing works and transferred to a disposal ramp (manually or with the help of an AGVS). At this point there is a baling press that has a large-scale container connected to it. After compaction, the waste is transported to a waste paper merchant or paper mill directly.

Discarding residual ink and washing liquids is more difficult. To some extent, these are considered hazardous wastes. These leftover materials, sealed in drums, must be sent to specialist companies which dispose of the waste in a proper manner, in line with the national regulations in force.

8.1.1.5 Paper Pile Logistics for Sheet-fed Offset Presses

Paper supply logistics for the sheet-fed offset printing industry is a field that must constantly be adapted to facilitate the ever-growing productivity of printing presses. Logistics become particularly important in sheet-fed printing when the substrate is heavy (cardboard, e.g., for folding boxes) and sheet thickness requires frequent stack changes.

The overview in figure 8.1-7 outlines the most important functions and *stations of the paper logistics* in sheet-fed presses. The areas in immediate proximity to the press, that is, the sheet feeder (paper pile feed) and the sheet delivery (paper pile removal), are shown once again in figure 8.1-8.

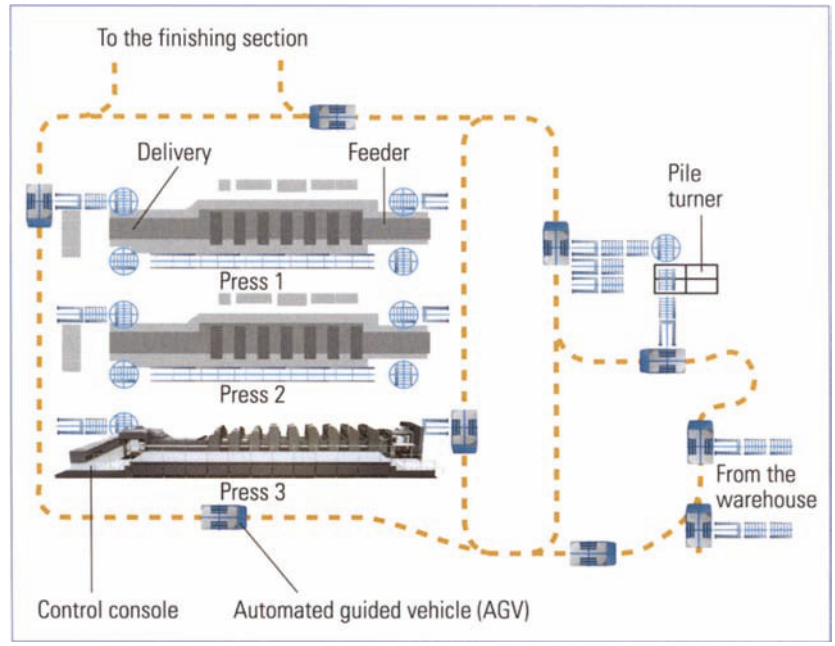


Fig. 8.1-7
Diagram of paper pile conveyance in the press area for supplying several sheet-fed presses (Heidelberg)

The paper is piled onto *system pallets* and taken to the press by manually operated fork-lift trucks. There may be a *buffer zone* in the feed area of the press, as illustrated in figures 8.1-8 and 8.1-9. In this buffer zone, these piles of paper are made ready on a *roller conveyor*.

This type of material buffering is especially important for presses with a *non-stop feeder* (fig. 8.1-9; see also sec. 2.1.2.8). To ensure that the pile is fed to the press in correct alignment, the paper piles are rotated by 90° on a turntable and fed to the press from the side. For pile changes, a fully automatic rake is pushed into the grooves of the system pallet. Main and secondary piles are merged to preserve straight edges.

As shown in figure 8.1-8, the conveyor system can transport empty pallets from the feed area of the press to the delivery area where they can take over the printed paper piles.

A buffer zone in the *delivery area* enables short-term intermediate storage of the loaded pallets until they are taken away for finishing. Within and outside the printshop, the standardization of pallet size and shape of the pick-up/transfer equipment is a preliminary requirement for the automation of pile conveyance. Only when the pallet geometry in the transfer areas is not dependent on particular manufacturers can the feeding of the pile for printing and delivery for finishing and/or storage and dispatch be done efficiently.

The delivery of a sheet-fed offset press with semi-automatic pile change can be seen in figure 8.1-10. When the pile is changed in delivery, a rake is inserted into the flow of sheets. The sheets collect there until an empty pallet is fed to the rake from below. The pallet is designed so that, during this operation, the rake slots into the grooves on the upper side of the pallet, with the first sheets of the new pile being transferred from the rake to the pallet. The rake can be withdrawn (manually). Automated solutions are also available in this instance: An intermediate carrier is activated in the delivery, onto which the sheets are delivered while the full pallet is moved out of the delivery and the empty pallet is moved in. The accurately stacked intermediate pile is then transferred onto the empty pallet (see also fig. 2.1-71).

Dual-stream deliveries, as illustrated in figure 8.1-11, for example, are a highly automated variant of a non-stop delivery. The paper pile can be conveyed away from the second delivery while the first delivery is taking over the sheets. Dual-stream deliveries can also be used for the express purpose of separating misprints, that is, waste (such deliveries may also be referred to as "waste diverters"; see also sec. 2.1.2.8). This can be activated manually, but it is more expedient for an in-line quality control system or an operator-activated control

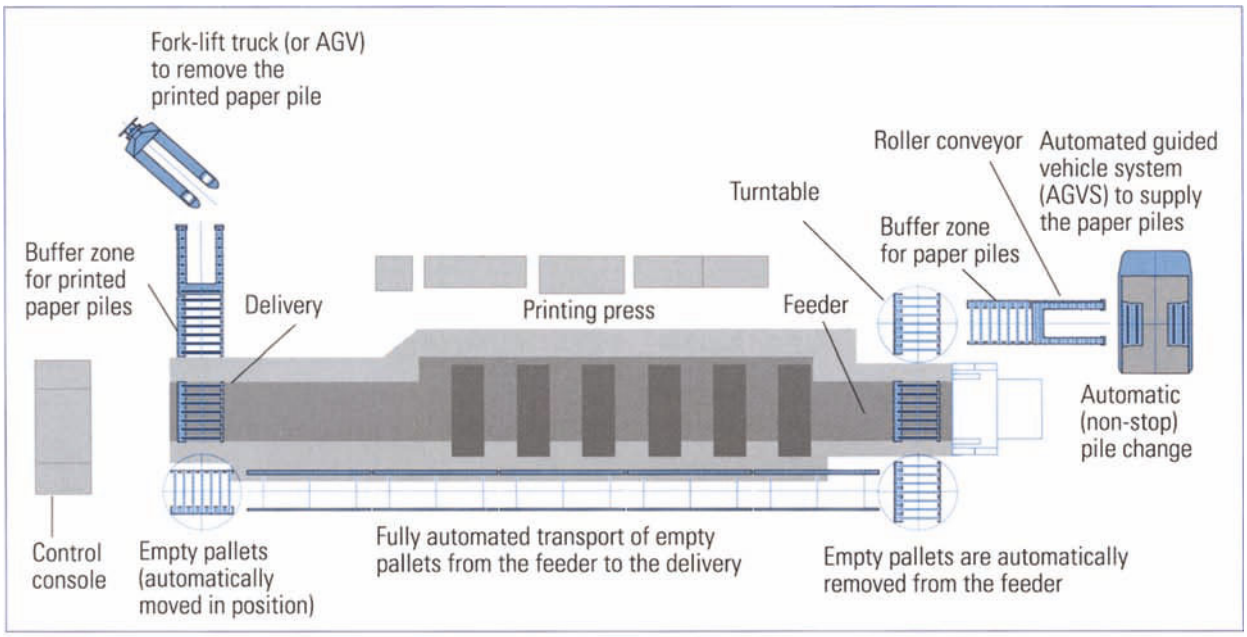


Fig. 8.1-8
Pile conveyance with functional components for pile loading and removal on the sheet-fed press and for the transfer of pallets between feeder and delivery (Heidelberg)

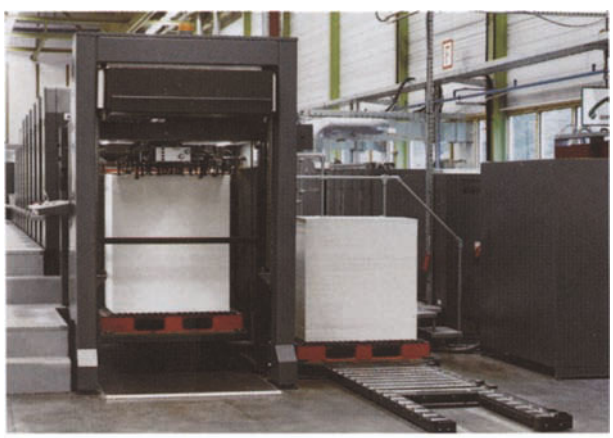


Fig. 8.1-9
Feeder with equipment for fully-automatic pile change (non-stop feeder) with buffer area (Heidelberg)

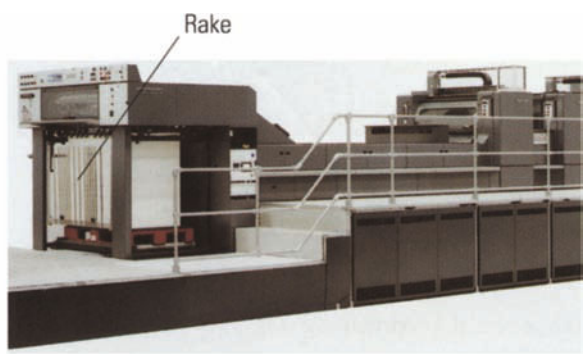


Fig. 8.1-10
Delivery with equipment (rake, etc.) for semi-automatic pile change in non-stop operation (Heidelberg)

command to do this. This equipment can naturally be used for the removal of specimen sheets, much like the manually or automatically activated intermediate storage described above.

AGVS (*automatically guided vehicles systems*), which enable automatic conveyance of palletized paper piles (fig. 8.1-12), represent an even higher level of paper logistics automation in sheet-fed printing. These AGVS



Fig. 8.1-11
Dual-stream delivery for automatic pile change or as "waste diverter" in connection with an in-line print quality inspection system (Komori)

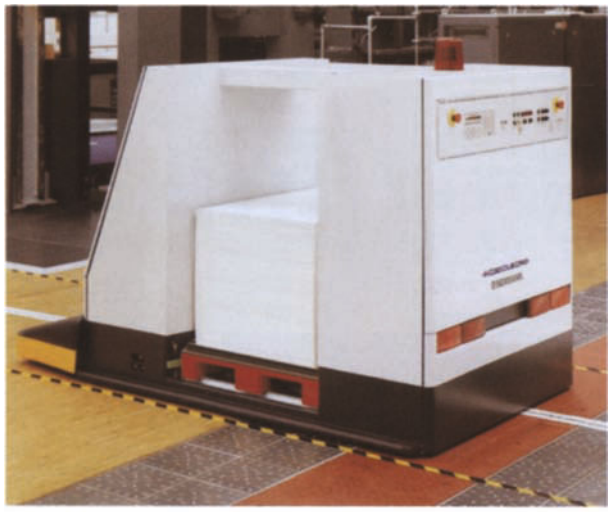


Fig. 8.1-12
Automated guided vehicle (AGV) for paper pile conveyance (Heidelberg/Eisenmann)





Fig. 8.1-13
Pile turning device for pallet transfer or reverse side printing (Busch)

take over the conveying tasks between the warehouse/storage, the press, intermediate storage, pile turners, and finishing.

Figure 8.1-13 shows a manual pile turning device. This *pile turner* is used to jog a paper pile before printing, to align and/or remove dust from the sheets, to remove possible waste (conveying/storage often results in damaged sheets in the first sections), and move piles onto system pallets. The pile turner can rotate a sheet pile printed on one side (straight printing) by 180° for reverse side printing.

The system outlines in figures 8.1-14 and 8.1-7 illustrate how the previously described logistics functions collaborate on the print floor of a sheet-fed offset printshop.

Despite the fact that it is technologically possible to implement the concepts illustrated above (especially those in figs. 8.1-14 and 8.1-7), the use of such logistics systems is not widespread.

8.1.2 Logistics in Printing Companies

As in many other branches of industry, in printing companies logistics rarely obtain the attention their importance merits. In many cases logistics are seen only as secondary consequences of the actual production processes, and, with regard to logistical organization and the available investment resources, the decisions made are often small-scale and non-committal. Yet logistics represent a complex and often very important administrative function in terms of overall productivity. Because printing companies must produce an

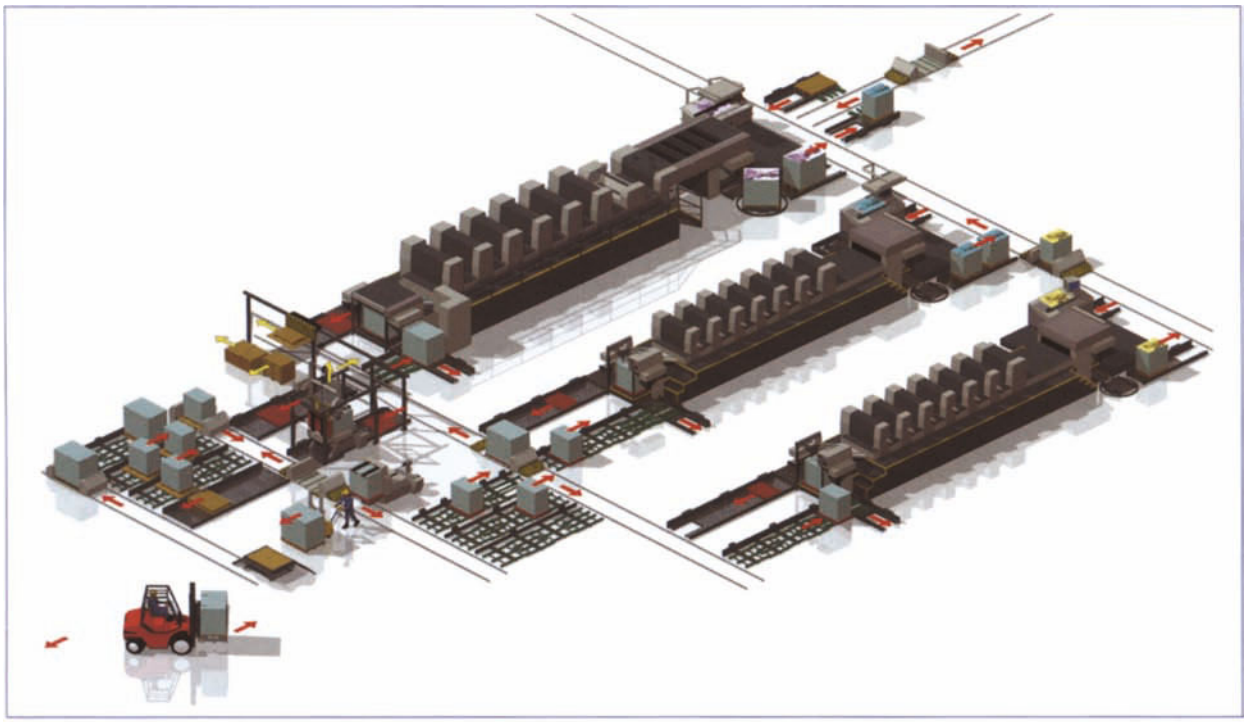


Fig. 8.1-14 Overview of a paper pile logistics system for feeding and removing paper piles for several sheet-fed presses (MAN Roland)

extremely wide range of different products, deal with dynamic timing sequences, and manage "difficult materials" such as paper, there are a number of great challenges for the organization of logistics.

In spite of these particular features, the logistics functions of many printing companies do not fundamentally differ from those of other industries. For this reason, only the specifics of logistics in printing companies are made available here. Otherwise references to literature covering the basic aspects of this topic are given.

In general, in the administrative organization of a printing company, the purchasing or production department is responsible for coordinating *logistics functions* (see fig. 8.1-15). There are, however, also printing companies in which the logistics functions are split into *procurement logistics* and *production logistics*. There is only a small number of printing companies that have their own large-scale and independent *distribution logistics*. Many newspaper printing houses, which maintain their own delivery service because they distribute their products to the end consumer on the subscription business level, are the exception here. After printing, there exists an independent distribution system of wholesalers and retailers for most other print media. This is the case, for example, for the book or periodical business (see sec. 8.1.3). Printed material distributed to final customers by mail occupies a special position. In all these cases, however, the finished products have to be delivered from the printing companies to only one or a limited number of locations.

The logistics department usually provides for *procurement, warehousing, materials flow*, and *dispatch* and *disposal*. To do this with cost-effective results, one must carefully consider favorable conditions, proper quality, and correct time of delivery.

8.1.2.1 Procurement Logistics in Printing Companies

In printing companies, the following *categories of materials* have to be procured for the production process:

- raw materials, especially paper, ink, and printing and finishing resources,

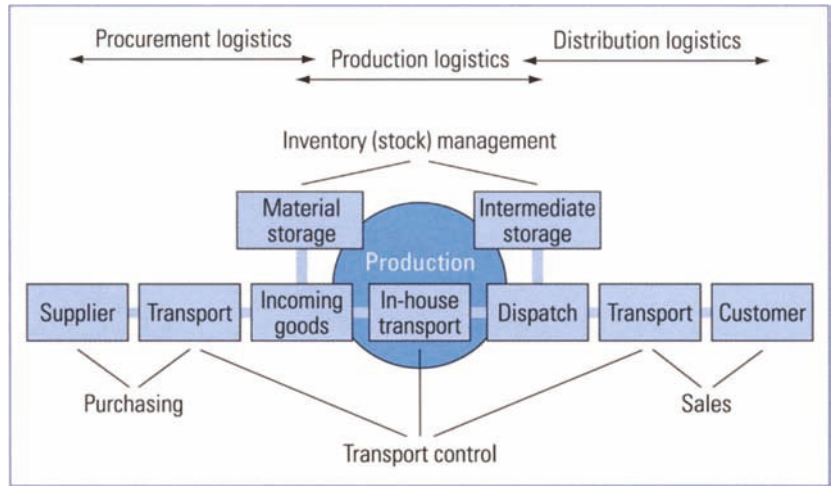


Fig. 8.1-15
Material flow and logistics tasks in printing companies

- semi-finished products, preproducts,
- services, equipment goods.

Although the last two categories hardly impose on the logistics of a printing company, the first category – providing the printing companies with raw materials – is a major logistics task. The range of raw materials processed in a printing company can be very large according to the products produced. With respect to bookbinding, for instance, customers often have diverse requirements for a product's design – a fact that calls for a diversity of materials.

However, only in exceptional cases do printing companies stock a great range of *inks*. Because process inks are standardized, printing companies frequently have only one set of inks that has been optimized with the ink supplier and produces the best print results under normal printing conditions. If needed, a few alternative types of ink suitable for different substrates may be kept in stock. Normally it is possible to agree upon a medium-term supply plan with an ink supplier and set up a closed container recycling program adapted to the print production. Depending on the size of the printing company, ink can be delivered in small pots, drums, tankers, or railway wagons.

However, procurement logistics become most important with regard to the *substrate*, that is, mainly paper. Paper is usually responsible for the largest proportion of turnover in a printing company, and because of its quantity, it involves, by far, the greatest scope of supply. Unlike ink, it is not possible for most printing companies to maintain a variety of paper types on a comprehensive scale. For one reason, the stock type often constitutes an important property of the printed product due to its haptic characteristics (e.g., feeling the paper surface, when turning pages), which clients place great importance on, using it to distinguish themselves from competitors. On the other hand, depending on the type, paper prices vary tremendously so that with the sheer mass of paper used in the printing process and the sweeping fluctuations in the cost of paper, the final costs of a printed product can skyrocket. Consequently, for larger print jobs, the client may decide to purchase the paper himself and supply it – along with the print order – to the printing company.

Paper production plants are very large and have remarkably complex requirements on workload, productivity, makeready times, and so on. In the case of larger quantities, the paper market behaves much like a daily market. This means that relatively large fluctuations in price and delivery times are the norm. Consequently, a well-devised paper purchasing strategy, which often necessitates greater stock storage, can bring about benefits for the company. On the other hand there is the risk of supply shortages. Therefore, printing companies accept large jobs only if the paper supply has already been guaranteed. There is yet another problem for paper logistics: many printing companies have dynamic scheduling of the production sequence, and printing deadlines often have to be postponed due to client requirements, problems with suppliers, or technical problems in the printing work.

The materials procurement department of a printing company repeatedly finds itself in conflict with pro-

duction. Because differences in the quality of materials have a very noticeable effect on the productivity of the production processes (e.g., the number of web breaks, soiling of the press by paper dust, etc.), production departments mostly require high paper quality. Purchasing departments, on the other hand, prefer to make decisions according to purchasing conditions. Another problem is the fact that larger amounts of paper are bought by weight. (In the web printing sector this is almost exclusively the case. In the sheet-fed offset sector, however, purchasing may take place according to the number of sheets.) Because in printing it is the surface area (number of impressions) that counts, shortages can occur if there are variations in paper density (content of water) or thickness in the paper supply.

As a result, numerous points will be repeatedly discussed between the paper supplier and the printing company, and because of the high value paper contributes to the product, these points are of considerable financial importance for both parties. Hence, purchasing departments must constantly deal with complaints pertaining to paper. In order to clarify problems and avoid disputes, each reel of paper is marked individually (see sec. 8.1.1.2). Therefore, a well organized procurement logistics department in a printing company will have established a continuous documentation system for paper handling: incoming goods are inspected, samples are analyzed in the quality assurance laboratory, and uninterrupted management of the paper reels carried out from storage to the press.

8.1.2.2 Inventory Management in Printing Companies

The demands on *stock control/inventory management* in printing companies are essentially the same as those in other branches of industry. All printing companies have *materials storerooms*, whereas the need for *intermediate storage* may vary considerably depending on the product range. *Newspaper printing houses* have very little need for intermediate storage; printing is usually done in one pass and delivery follows immediately. Some expenditures on storage first become necessary when a job requires preproduction processes or calls for inserts printed elsewhere to be put into the print run at a later time. Short-term intermediate storage is generally necessary in *catalog and magazine production*: The individual product sections are printed in succession, and for finishing, all product sections must be available at the same time.

For *calendar and book production*, on the other hand, structured intermediate storage is usually required because overall production may drag on for a fairly long time. This is sometimes due to scheduling optimization in the printing company itself.

Actual end-product storage facilities are rarely needed in printing companies because their production tends to be geared for one job that will be delivered immediately. For this reason, buffer areas (most often in intermediate storage) are needed to cover availability gaps.

In the printing sector, only webs of paper require special *storage techniques*; all other stored goods can be conveyed and stored on pallets. Accordingly, the general materials storage and intermediate storage are seldom physically separate. Common practice calls for reels of paper (in the form and packaging received on delivery) to be stacked on top of each other, lateral surface to lateral surface (*stacked storage*, see sec. 8.1.1.2).

The storage system for general materials and intermediate storage is usually based on *standardized pallets*. Depending on the storage space, the rate of turnover, and other relevant parameters, storage facilities may make use of standard industrial *steel shelving systems*, forklift trucks, and so on. Two-stage *storage systems* are found in many printing companies. In such a system, one area, with no storage system, is set aside for short-term storage. Pallets are kept there for, generally speaking, less than 24 hours. The second storage area may often contain rack storage facilities for more long-term use. *High-rack storage* with automatic loading systems is used by only a few, fairly large book manufactures and publishers (fig. 8.1-16).

In a printing company, the *stock control* is of considerably greater importance than the actual storage system. The general objectives of stock control to

- avoid high stocks and minimize tied-up capital,
- turn over stock quickly,
- avoid residual stock,
- avoid ullage, and
- provide economically sound inventory maintenance

are considerably more difficult to achieve. This is true because there are no recurring production jobs; each production run is created from new sections. The complexity that results from the great variety of stored goods and their constantly changing storage needs is further increased by the fact that the production is not planned very far ahead in printing companies. Hence, it may frequently be the case that production materials



Fig. 8.1-16
View of high-rack storage for books (Bertelsmann Arvato)

have to be removed from storage and made available for a machine at short notice or that materials removed from storage have to be returned because scheduling arrangements have changed. For these kinds of situations, storage systems must be equipped for easy accessibility and EDP (electronic data proscessing)-assisted inventory management.

8.1.2.3 Production Logistics in Printing Companies

Production logistics are concentrated on the following key concepts: the provision of materials for production, the internal conveyance of intermediate products between production stages to and from intermediate storage, the removal of the finished products from production machinery, as well as the disposal of waste and used printing plates.

Figure 8.1-17 shows an example of a *printing company* with the various functions of prepress, printing, finishing (in this case the production of *folding boxes* with die-cutting and gluing), and their connections to the materials flow going to and from storage.

The paper supply to presses is explained in sections 8.1.1 and 2.1 for both web-fed presses and sheet-fed presses (see figs. 2.1-78 and 2.1-82, in particular), the technologies for feeding printing sheets to finishing equipment are described in section 7.3.1. In a printing company, production logistics are often confronted with these questions: In what form should the loose, folded sheets be conveyed and stored, and what system should be used to solve the problem of internal conveyance?

Material flows analysis between the various stages of production and storage (fig. 8.1-18) constitutes the fundamental basis for designing production logistics. Minimum/maximum levels and systematic variants (e.g., for certain types of production at specific times of the year) must be taken into account.

When *conveying loose, printed sheets*, care must be taken to ensure that no damage occurs. Additionally, signature changes of the sheets in relation to each other must also be avoided. One sheet must not be turned or tumbled in relation to another sheet's position. Such an action, in particular, could cause sheets to be bound the wrong way around during finishing.

Although these requirements actually favor conveyance in closed containers, this type of transport has proved to be financially viable only in a few exceptional cases. The following four procedures are widely used at present:

- The sheets are deposited in *packages directly onto pallets*. The packages are stacked in criss-cross formation in optimal sequence in relation to each other in order to attain the greatest possible stability of the pallet contents as well as compensating for the fact that the folding spines are bulky. Pallets such as these can be conveyed as usual within the printing company. If they are to be transported over longer distances additional hoops must be fastened around the pallet or the pallet must be shrink-wrapped.
- The printed sheets are pressed together with special *stacker-bundlers* in a standing row and hooped together firmly. These bundles are deposited on pallets and are very stable for conveying. Bundles such as these can be formed automatically from an in-

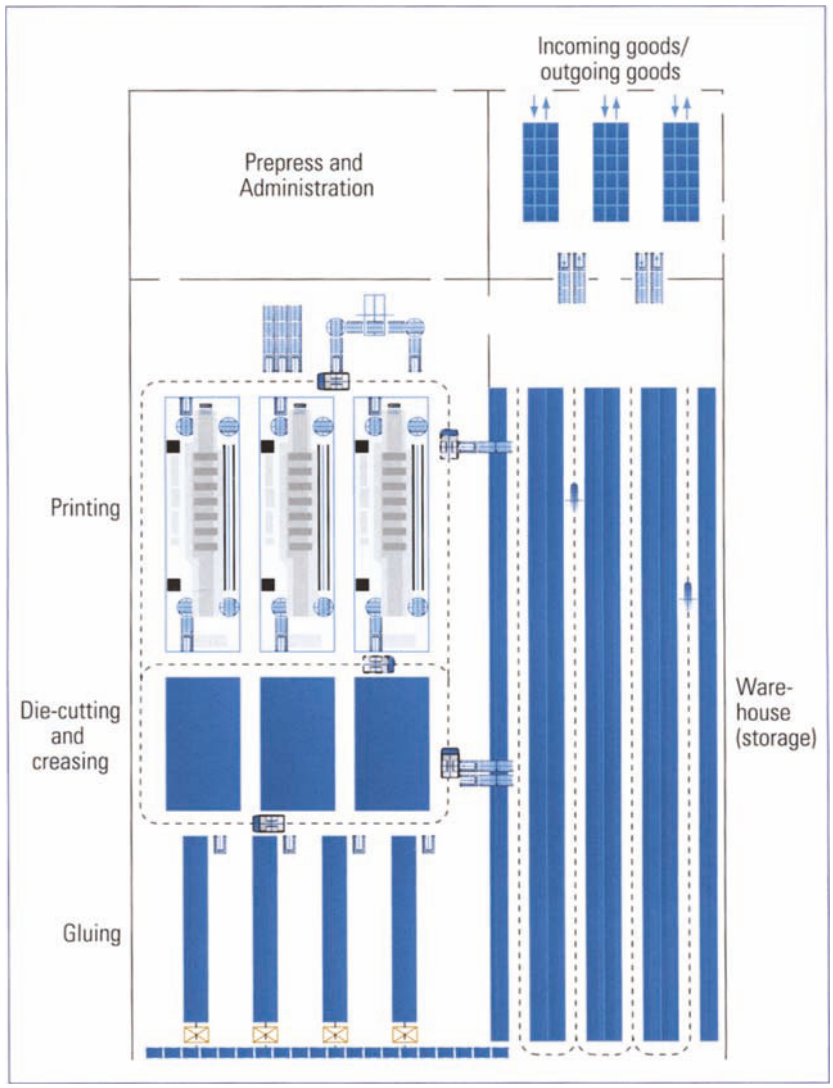


Fig. 8.1-17
Printing company (specialized for the production of folding boxes) with various production logistics functions (Heidelberg)

feeding stream, and the hooped bundles can also be automatically deposited on pallets (see fig. 7.3-6).

- The infeeding stream can be rolled *onto a core* with the help of a tape guide mechanism. These *reels* of rolled-up printed sheets can then be conveyed in either a vertical or a horizontal position and, upon reaching their destination, be unwound again (see fig. 7.3-7).
- The printed sheets running out of a unit can be transferred directly to the next unit by means of a *conveyor system*. One kind of conveyor system is a *chain conveyor*, onto which each separate sheet is fastened by a clamping mechanism. Another system, the *belt system*, conveys the sheet stream on a rotating belt (see also figs. 7.2-60 and 7.3-18).

Production logistics must also provide for the *disposal of waste materials*, the greatest proportion of which – in terms of quantity – is paper waste. The major sources of paper waste in the production flow are shown in figure 8.1-19. In conventional printing companies, the proportion of paper waste produced in web printing (necessitated by the technical design of production systems) may be up to 25%. In sheet-fed printing this per-

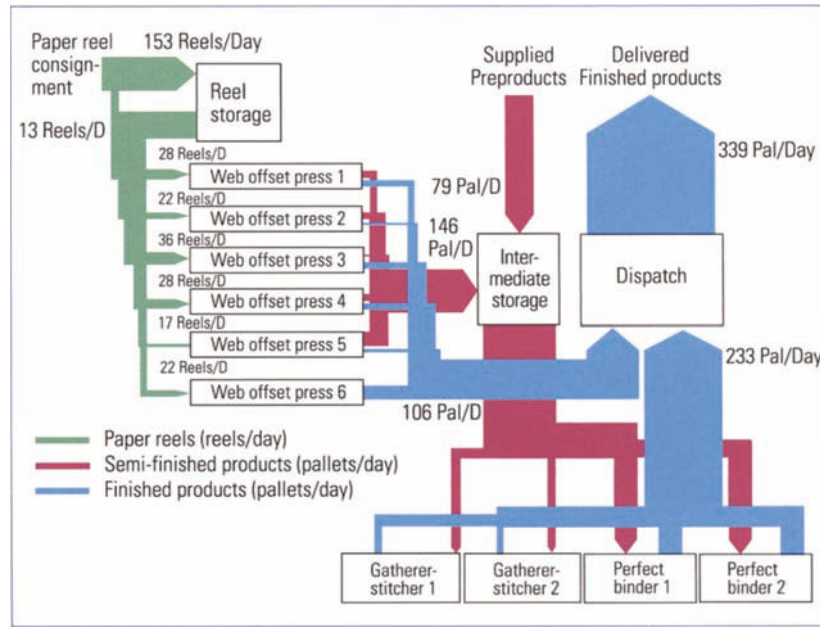


Fig. 8.1-18
Example of material-flow analysis between production stages; the average quantities conveyed in a large web offset printing company are shown

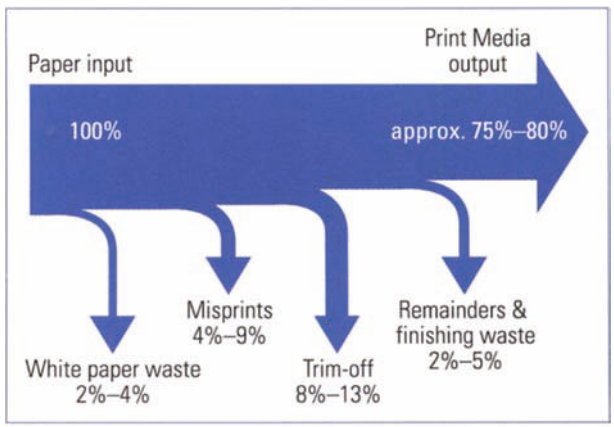


Fig. 8.1-19 Waste rate in printing companies

centage is considerably lower. In larger printing companies, waste paper is collected separately as white paper waste and print waste and then passed on to recycling companies. This may produce some revenue, depending on the market situation.

Used *printing plates* also accumulate in considerable quantities and are sold as scrap metal.

Because of the explicit *environmental regulations*, printing companies are now obliged to dispose of most waste materials. This means that internal waste disposal logistics must determine environmentally friendly ways of collecting, separating, and discarding ink and solvent residue, cleaning cloths, and so forth. (see also sec. 13.2.1).

8.1.3 Logistics in Publishing Houses

Publishing houses are at the head of the print media production *value-added chain*; they process predominantly organizational and content-related production tasks in the actual product planning stage (see also figs. 1.9-4 and 8.1-1). Consequently, this sector rarely deals with logistics beyond office organization and communication technology.

At the end of the value-added chain, however, the publishing house is responsible for taking over the sales, marketing, and distribution of the documents produced. Newspapers, periodicals, and books are three large product groups involving different requirements.

In the case of regional *newspapers*, the publishing house itself, for reasons of topicality, usually takes care of the distribution of its product. Here, one should distinguish between three different *distribution concepts*:

- subscription sales,
- street sales,
- delivery of free newspapers.

These three forms of marketing occur in quite different proportions according to national habits; in Germany, for example, subscriptions to newspapers are the most common form, whereas in the USA subscriptions constitute only a small proportion of the market. In the case of *subscription sales*, the publishing house runs its own organization: It looks after the final customer and, following production, directly distributes to households via its own delivery service. In the case of *street sales*, the newspapers are delivered directly to the sales outlets (kiosks, shops, etc.), which then receive invoices for the copies they sell. *Free newspaper deliveries* are usually arranged by independent companies that are able to make deliveries to every household in a particular district.

In the case of national newspapers, the mail delivery service is often used as the distributing organization for *subscription sales*. In other instances, however, a national newspaper may employ local newspaper publishing houses to distribute its product.

Since *newspaper* delivery seldom involves the use of storerooms, organizing fast and efficient distribution is of utmost importance. To accomplish this, distribution systems (generally in cascaded form) make use of intermediate distribution centers and, simultaneously, strive to optimize distribution routes. The issue of topicality calls for the direct coordination of the production sequence with the distribution schedule, and, as a result, the copies that take longest to deliver are printed first.

Subscription copies of *periodicals* are usually delivered by mail. Often, it is not the publishing house itself, but independent service companies that attend to the addresses and "preparation for posting." After receiving the quantity of periodicals required for subscribers from the printshop, these companies separate and package the material according to requirements. The mailing process itself is important and demands constant optimization: Special programs that sequentially organize the address data guarantee better mail distribution. Some mail distributing technologies may make use of a distinct lettering or font style and supplement the address with a bar-code. When delivering packages that have been optimized for mailing in this way, mailing companies can give very good discounts.

Wholesalers who market a wide range of periodicals have also established themselves as the main sources for the *street distribution* of such printed materials. Additionally, the wholesalers supply the shops at the end of the chain with a broad range of titles and also attend to invoicing. As is the case for newspapers, the actual distribution process has a similar, stream-lined connection with the production because topicality constraints require editorial deadlines to be set as late as possible. The first finished and bundled copies of the periodicals generally go straight to subscription distributors. As with newspapers, there are virtually no in-house storage logistics for periodicals apart from short-term intermediate storage. After production, in almost every case (scientific magazines sometimes provide exceptions), the complete print run will be distributed directly to and stored at the final sales outlets. Unsold copies later go back to the wholesaler as returns and become paper waste.

Selling *books* is different from selling newspapers and periodicals in that the sales period is usually very long. Because book buyers are accustomed to finding books available over several years time, there are many titles that generally have low, but constant, sales. This demand necessitates storage space for books.

Only very large or very small publishing houses do their own book storage. Most publishing houses, on the other hand, give their titles to special distribution services that organize individual, book-trade deliveries and may also attend to invoicing. These book wholesalers use organization and technology that hardly differ from those employed by other wholesaling companies. The publishing house gives its instructions to the printing works, which, in turn, delivers the printed books to the wholesaler's book warehouse. Here, books are kept in high-rack storage systems. Purchase orders from the book trade are generally consolidated daily; the individual orders are then picked out from stock and delivered to the retailers. As is common practice nowadays, delivery generally takes place within 24 hours.

In addition to the traditional book market, mixed outlets (supermarkets, gas stations, etc.) represent an ever-increasing source of book sales. In this case, respective marketing organizations receive the planned quantity of books directly. The *sales of books on the Internet*, however, is also a rapidly growing trend: The end customer electronically submits a purchase order right to the book wholesaler, thus circumventing the bookseller. A conventional delivery from the wholesaler's in-house stock ensues (see sec. 12.4, fig. 12.4-4).

Because book publications typically experience slow sales and a title's actual sales figures can be difficult to

determine, the publisher must contend with high prefinancing costs as well as storage fees. With these financial concerns in mind, publishing houses are always asking themselves how many copies of certain titles they should print and how long they should actually keep a title stocked and available for delivery. Clearly, a publishing house aims to lower the rate of unsellable returns and avoid the expensive reprinting of out-of-print products.

There are now high expectations for print on demand technologies, by means of which book production occurs only according to the purchase order and required quantity, that is, a "print run of one" is possible ("book on demand"; see also sec. 9.1.3 and fig. 9.1-6). Along with this technology, the electronic distribution of documents becomes possible, making physical book storage unnecessary. However, the current production costs and print quality are only acceptable for a very small range of products.

Further Reading for 8.1.2 and 8.1.3

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8.2 Networking and Data Flow

As shown in section 1.2, figure 8.2-1 describes the complete *production flow* once more, from the idea – the concept of a printed product – to the finished product, including its distribution to the user. At first, the different stages of production were linked together simply by the flow of material. Nowadays, this flow is increasingly complemented by means of digital information, that is, data.

The spreading of computers and networks increasingly affects the production of printed products. After networking prepress, networks are now being installed in the printshop and partly in finishing for a multitude of purposes. This is mostly due to the *digitization of the job data*, which is possible by implementing new technologies.

For instance, *computer to plate* technology requires a networked data flow down to the printing plate output, which can be considered the last stage of prepress. When using a computer to plate system, the conventional data carrier, film, is replaced by the digital data flow.

When implementing *computer to press technologies*, the digital data flow must extend to the press room/printing system, since only there will the digital job data be transferred to another medium in order to produce the print media. Depending on the technology used, the medium can be an intermediate carrier (printing plate) or the printing material (paper, cardboard, foil, etc.) itself (cf. sec. 4.1.4).

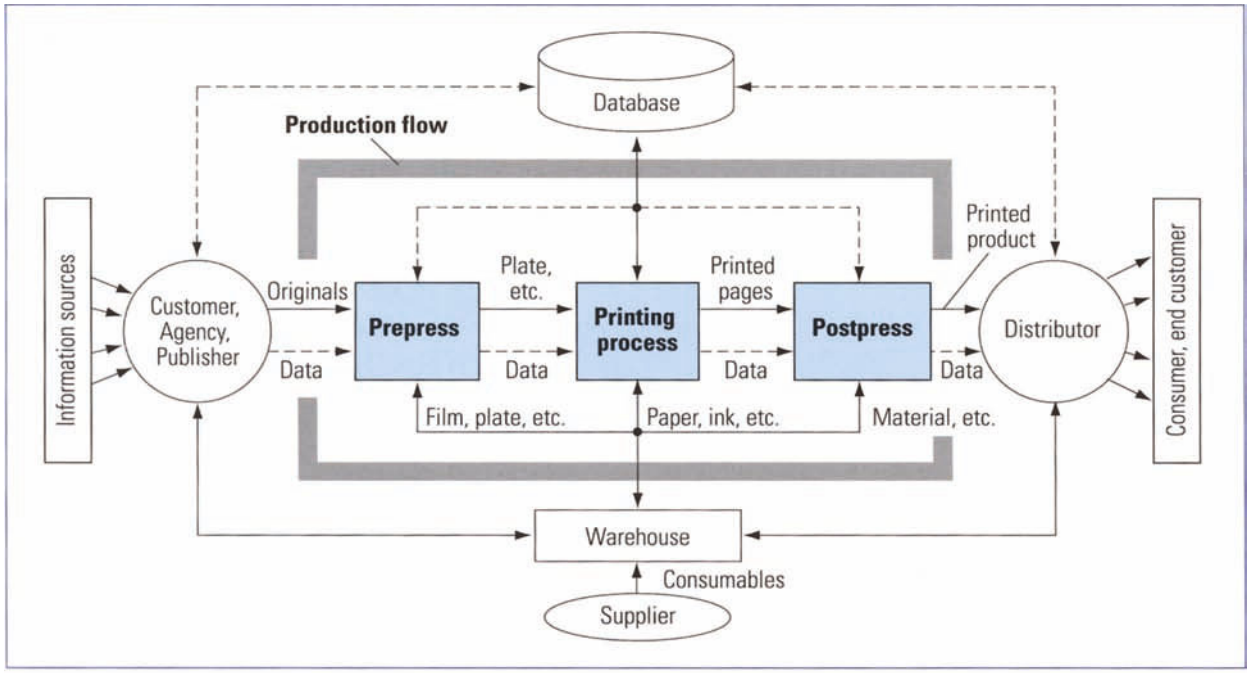


Fig. 8.2-1 Production flow (prepress, press, postpress) with material and data flow for the production of printed products

H. Kipphan (ed.), *Handbook of Print Media*
© Springer-Verlag Berlin Heidelberg 2001

Implementing a *digital workflow* reduces the number of steps in the process, and therefore the production costs. Another advantage of the digital data flow is the possible improvement in quality. As long as the job data exists in digital form, it can be transferred from one workplace to another without any loss of quality. Daily practice shows that faulty job data can also occur in a digital workflow. The advantages and the risks associated with a digital workflow are described in more detail in section 8.2.2.

The digital data flow does not necessarily end with the transfer of data to the printing system for the printing of the information on the substrate. To further reduce makeready times and the rate of waste sheets – that is, to cut the costs and to increase productivity – more and more production equipment (film or plate imagesetter, printing, finishing and packaging systems) is controlled electronically. With the *electronic control system*, *machine presettings* and production parameters can be defined. Today, electronic control mostly takes place by means of a control console directly linked to the machine (see also sec. 2.1.4). Yet, it is also possible to connect production equipment and to transfer the control data for the machine presettings and the production via a *network*, in order to increase productivity and cut costs. The electronic control data can be saved, for instance in the Print Production Format (PPF), a vendor-independent format, and transferred between the different production stages (more details in sec. 8.2.3, fig. 8.2-13, see also sec. 4.1.4).

In the coming years, the use of digital data and networks will not be limited solely to handling job data and production parameters. Today, both the organization and the management of a printing company can access a *printshop database*, to enable electronic job-processing and control. Figure 8.2-2 illustrates the connection of the different production stages via *data networks*; data relevant for controlling and supporting production can be exchanged via these networks (see sec. 3.2.8).

Section 8.2.3 describes the individual components of the digital data flow within the production. Since *network systems* are set to play a crucial role in the printing company of the future, network concepts and interfaces will be dealt with in more detail before the digital workflow is analyzed.

8.2.1 Network Concepts and Interfaces

After years of the most various, and partly incompatible networks and interfaces, a group of *network protocols* has become a standard. It is the family of Internet protocols, better known under the name TCP/IP (Transmission Control Protocol/Internet Protocol). Meanwhile, these protocols are used as a standard both in the Internet, and in Intranets and Extranets, both in Local Area Networks (LANs) and in Wide Area Networks (WANs) (see sec. 3.2.8).

A major advantage of TCP/IP protocols is that they are not affected by the type of *physical connection* used

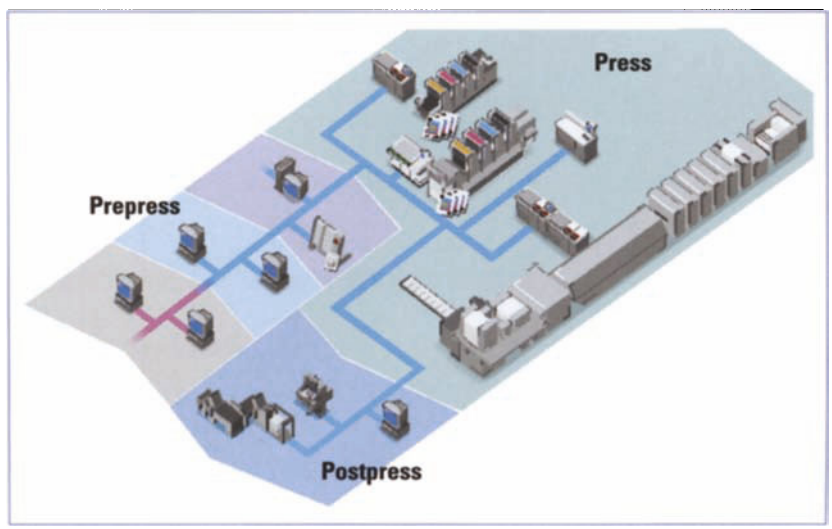


Fig. 8.2-2
The networked production sections (prepress, press, postpress) for producing print media (Heidelberg)

for the data transfer; it is therefore irrelevant whether the connection is established via a twisted pair, a coaxial cable, optical fiber, normal analog telephone, or ISDN; the *application protocols* remain the same. For instance, there is a protocol for the network services designed for the transfer of data, the so-called File Transfer Protocol (FTP). There is also a basic protocol used for accessing remote computers (telnet). Mail protocols, protocols for accessing databases, and protocols for the World Wide Web (e.g., http Hypertext Transfer Protocol) are also a part of the TCP/IP.

Another significant advantage is that Internet protocols are *available* on virtually all computer platforms. This is all the more important since the world of printing generally uses very heterogeneous systems, from Macintosh to PCs, generally under Windows or Windows NT, and Unix stations, which is typically available for servers.

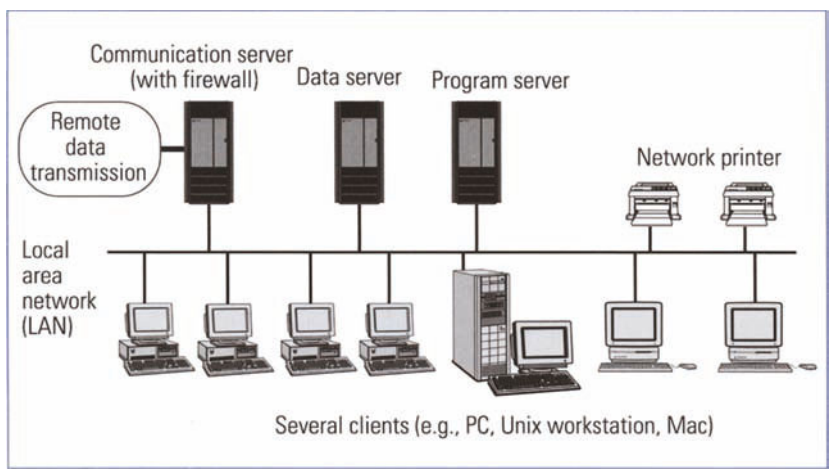
Moreover, using TCP/IP protocols makes it possible to harmonize *user interfaces* by running standard browsers; *browsers* are software utilities designed for the downloading and displaying of information from the World Wide Web, which can be used with a uniform user interface for the different services of the Internet. This is well illustrated by Netscape Communicator and Microsoft Internet Explorer. Under such circumstances, the browser itself is irrelevant, unless the information is optimized for a specific browser; this, however, makes the user dependent on one particular browser vendor.

The consistent use of TCP/IP [8.2-1, 8.2-2] also allows the implementation of the *Client/Server concept* [8.2-3, 8.2-4]. Client/Server systems offer the possibility of centralizing (on the server) specific services and making them accessible locally on each client system (fig. 8.2-3). The operations required are executed on the server, and the parts that can be executed locally are transferred to the client. Today, this can take place by using technologies that ensure platform independence. Achieving this requires using *Java Applets* [8.2-5 through 8.2-7] computer-independent parts of programs, which can be run locally on the client by means of an interpreter, the Java Virtual Machine.

When analyzing the use of networks in the printing industry, we can observe a continuous "spreading of network," which started in prepress. Today, *three typical forms* of network connectivity can be distinguished in the world of printing:

- *Stand-alone networks.* Some networks are limited to specific departments or fields (accounting, time recording, prepress, etc.). The interaction with other departments/fields or companies is not carried out via the network.
- *Internal networking.* The networking of departments/areas involved in the manufacturing process provides the means for a digital data transmission within a corporation. This can contribute to a more effective cooperation within the corporation and speed up the entire manufacturing process.
- *External networking.* The third level of networking includes a digital data flow for the entire workflow.

Fig. 8.2-3
Example of a Client/Server concept



It involves not only all the departments/areas participating in the production, but also includes all the workstations from customer enquiry to delivery to the customer. Therefore, this type of network connectivity not only covers the departments involved in the production, but also the customers themselves and all the administrative departments in the external companies and partners involved. Customer, agency, quotation costing, order acceptance, work scheduling/materials management, prepress, printshop, finishing/packaging, shipping, final costing, billing, and so on, are networked to ensure economical and fast communication, and production and distribution of printed products in high quality.

There are many facets and combinations of these three networking solutions. The following section will describe the data/contents, as well as the possible system configurations required to set up networked printing production.

8.2.2 Digital Workflow

8.2.2.1 Digital Workflow in Prepress

As already mentioned in section 1.2, the *printing workflow* was based exclusively on *analog* data until the 1970s (fig. 8.2-4). This meant that order-processing took place without recourse to any digital data, information, originals, or intermediate products. Not until the introduction of the scanner for the capture and digitization of originals, and digital phototypesetting, did the printing industry also start introducing digital processing into its production chain.

The *digitization of the workflow* is illustrated in the following example of offset printing. So far, its workflow has consisted of *five stages*. A similar development has been observed in the other conventional printing technologies (see also secs. 3.1 and 3.2).

First Stage: Digital Image and Text Capturing

At first, *color scanners* and *phototypesetting systems* (see also sec. 1.2.2 and fig. 13.1-35) were used to digitize the first steps of the process chain. Drum scanners read the originals electronically, carry out the color corrections and color separations in the processing unit, and record the result on film (fig. 8.2-5, see also sec. 3.1.4). By using phototypesetting systems, the composition, the exposure of text films, and partly the creation of vector graphics were digitized and output mostly on individual films (sec. 3.1.2). The text, image, and graphics were thus available in a digital form. All further steps in the process were based on the films generated and were analog, such as the assembling of the full-page film as the basis for the following steps of sheet assembly and platemaking.

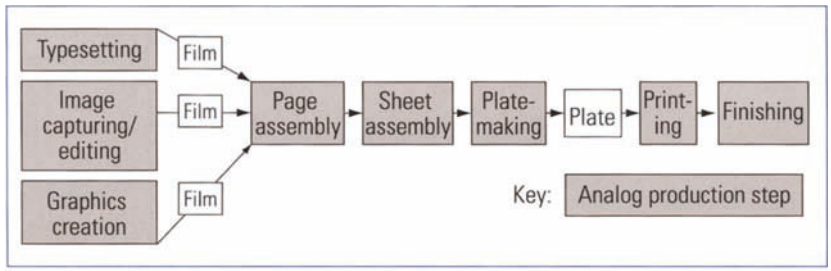


Fig. 8.2-4
Conventional (analog) workflow for the production of print media

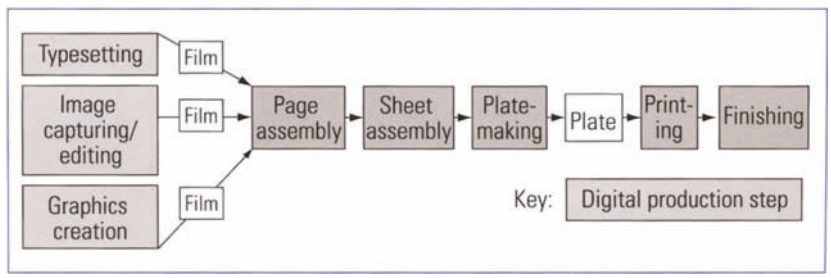


Fig. 8.2-5
Workflow with digital scanner and phototypesetting system

Second Stage: Desktop Publishing (DTP)

Another stage in the digitization of data began in the '80s, with the introduction of *Desktop Publishing* (DTP). This technology is based on powerful computing hardware and software, which could be economically introduced into the graphics industry, and has gained general acceptance in the entire printing industry. DTP not only allows texts, images, and graphics to be captured and edited on the same workstation (computer); it also permits the compiling of text, image, and graphics elements *digitally into complete pages* using layout programs and the outputting of these by *laser imaging units on film*. Thus, the manual process of page assembly is eliminated – but not the sheet assembly (fig. 8.2-6; see also sec. 3.1.5.2).

While the second stage is already fully established in the printing industry, an increasing number of companies are presently introducing stages three to five, described in the following paragraphs.

Third Stage: Digital Sheet Assembly and Computer to Film (CtF)

Already shortly after the introduction of DTP, *large-format laser imagesetters* (> DIN A3), which could expose films in the format of the corresponding printing presses, were becoming available on the market. At the same time, software utilities for the *digital sheet assembly* were being developed. These software utilities permitted the imposition of pages, the assembly of print sheets and their exposition on print format-size films. These films serve as originals for the plate exposure, which is the last analog operation in this stage of prepress (fig. 8.2-7); for further details, see sections 3.2.5 and 4.2.

Fourth Stage: Digital Platemaking with Computer to Plate (CtP)

The information is directly transferred to the printing plate from the digital sheet assembly without generating any film – and is called *computer to plate* (see also sec. 4.3, with details and examples of equipment). This generally takes place by means of a laser imaging unit directly on the printing plate in a special plate imagesetter. Thus, the conventional plate exposure is no longer required (fig. 8.2-8). The digitization of prepress ends with computer to plate.

Another use of CtP is that platemaking is directly integrated in the printing press (computer to press/direct imaging). This technology will be described in detail in section 8.2.2.2; details and examples of equipment can be found in section 4.4.

Fifth Stage: Computer-Integrated Manufacturing (CIM)

The transfer of production-relevant data from prepress, and the work preparation for the *makeready and*

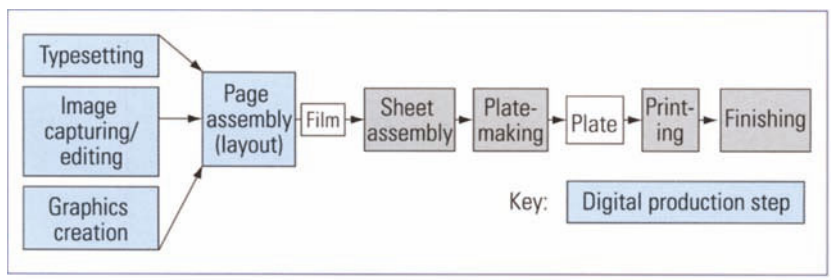


Fig. 8.2-6
Workflow with Desktop Publishing (DTP) for the page assembly

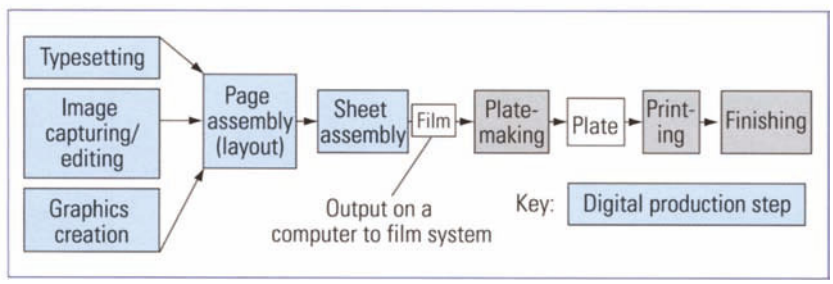
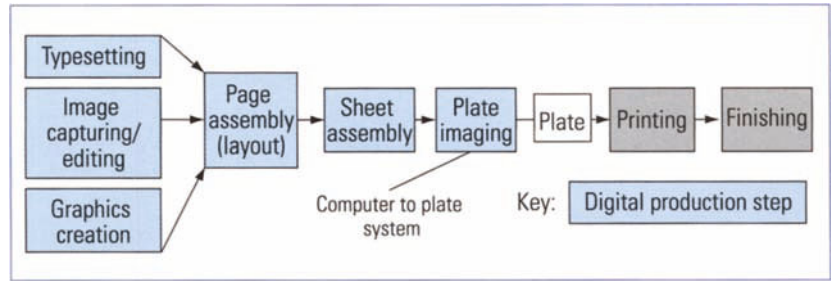


Fig. 8.2-7
Workflow with digital sheet assembly and computer to film system

Fig. 8.2-8
Workflow with computer to plate system



control of printing and finishing systems and the shipping processing (fig. 8.2-9) play a vital role in introducing CIM in the printing industry. The purpose of this development is to achieve a "networked printhouse," which will be discussed in detail in the next sections.

8.2.2.2 Digital Workflow and Digital Printing (Computer to Press)

In section 8.2.2.1 (see fig. 8.2-8) within the fourth stage computer to press/direct imaging has already been mentioned. In this particular case the image carrier is entirely generated in the press on the basis of digital data.

In *digital printing, non-impact printing technologies* (i.e., printing technologies not requiring any image carrier) enable the highest level of digital workflow including printing (see sec. 4.5 and chap. 5). The image carrier is imaged digitally for each new print copy; non-impact printing presses are directly fed with data from prepress, which means that the entire platemaking is no longer required (fig. 8.2-10).

Digital printing also includes the use of computer to press/direct imaging technology (sec. 4.4) on the basis of *conventional printing technologies*, in which the image carrier is automatically imaged within the press.

If the digitized workflow is not completely in place, *digital printing* is realized by means of the *computer to plate* technology, as well as computer to film in its extended sense, since these technologies are based on entirely digitized originals.

Figure 8.2-11 gives an overview of the *possibilities of digital printing*; the digitization of the production steps

Fig. 8.2-9
Workflow with Computer-Integrated Manufacturing (CIM)

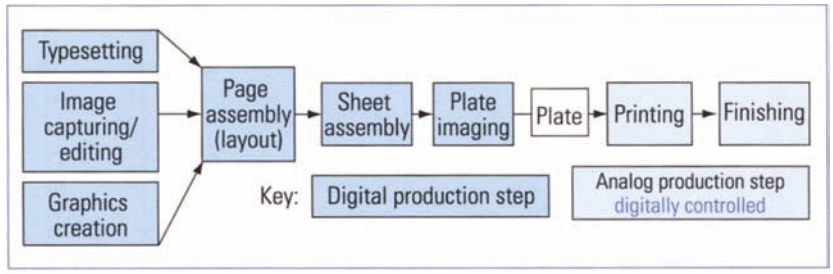
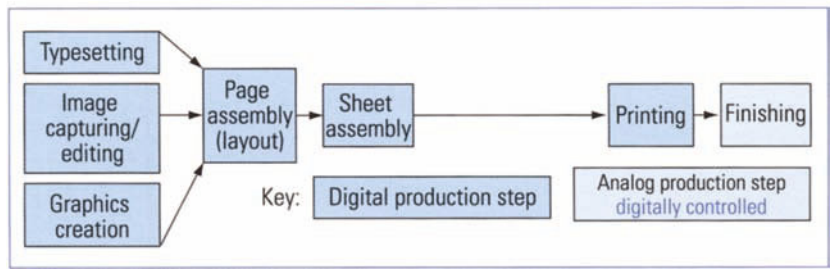


Fig. 8.2-10
Digital workflow with computer to press (NIP or direct imaging technology)



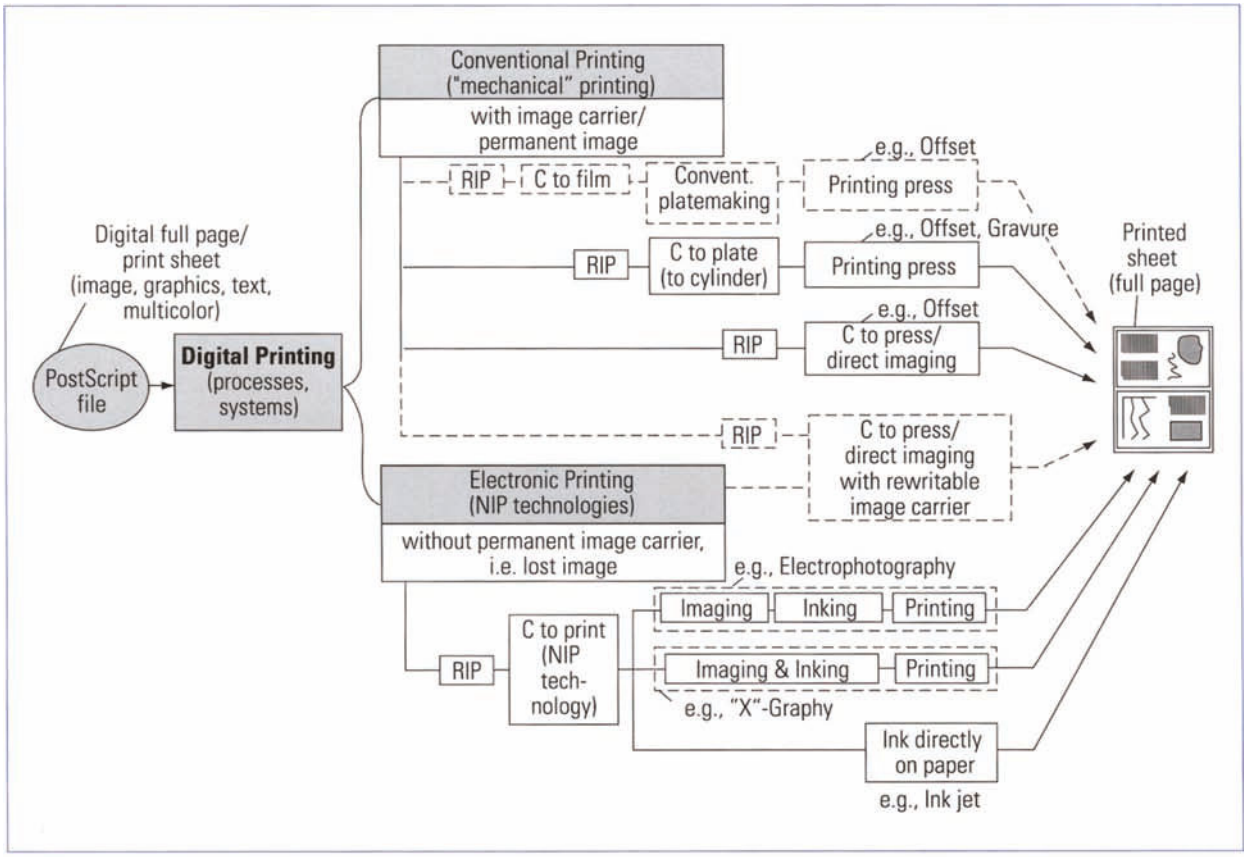


Fig. 8.2-11 Digital printing: processes, components, and systems

and production means is increasingly ensured by computer to plate technology through to computer to print systems, using electronic printing processes. All the possibilities presented share the fact that printing the entire sheet is based on a set of data that uniquely describes the complete multicolor sheet content (text, graphics, image).

8.2.2.3 Digital Workflow: Advantages, Challenges, and Possibilities

- *Saving time:* The generation of originals (films, printing plates) is significantly accelerated. Implementing CIM in printing and finishing has permitted the shortening of makeready times.
- *Saving material:* When changing over to computer to plate technology, savings in material becomes particularly obvious, since the use of film and film processing chemicals are no longer required. Further, using CIM reduces the number of waste sheets in printing and finishing, due to the simplified makeready procedure.
- *Quality improvements:* An improvement of quality can be observed through digitization in all stages. This is mainly due to the accuracy of data and the reproducible accuracy of the tonal range transfer. Digitization and automation also simplify the standardization of the entire printing workflow. A continuous color management can only be achieved by implementing full digitization throughout prepress.
- *Quality management:* The problem for computer to plate is that file errors can cause major losses of high-grade printing plate material. When exposing films for individual pages, a file error causes an exposure error for just this set of films, while when exposing a plate the error affects the complete set of printing plates. Thus, implementing digitization

and automation in ever more stages sets higher standards for quality management. A significant workstep in digital workflow is the input and output control of data (preflight check), which can be carried out by experts using special software utilities.

- *Digital proofing*: In an analog or partly digital system, it is helpful to prepare proofs before the sheet assembly. These are designed to simulate the printed result as accurately as possible. Color separation films are used for analog proofs. The procedure must be changed over to digital proofing systems (e.g., ink jet printers, thermal sublimation printers) at the latest with the introduction of computer to plate technology, since film is no longer used in the workflow. As yet, most digital proofing systems are still not able to simulate the printed result as accurately as the analog, film-based proof. Moreover, many customers are still reluctant to accept these systems, especially since most digital proofing systems cannot deliver a screen structure identical to the final printed copy. Another reason is that digital proofing systems often cannot be used on all substrates (see sec. 3.2.11).
- *Last minute changes*: Changes can generally be managed easily and without any loss of material, as long as work is carried out in the digital data file. For this reason, growing digitization makes changes at relatively advanced stages of production possible (e.g., sheet assembly, platemaking).
- *Archiving/re-use of data*: Archiving of digital data saves on space and is easier to organize than films and mounting films. In this way, previously generated data can be re-used at any time for other jobs, with or without any change. When using CIM, this advantage can also be seen in the makeready and the control of the printing and finishing systems. Archive systems must be well designed and structured to meet the operational requirement of ensuring that the required version of the files can be always found quickly.
- *Backup*: In a digital workflow, loss of data can have major consequences in time and cost if no specific form of backup is implemented. The installation of backup systems, overvoltage protection equipment, and stand-by units for servers, as well as the setting up of access rights, are important measures in order to prevent any loss of data.
- *Rationalization*: Due to increasing digitization and automation, workflow has been rationalized and made reliable and the staffing structure has been changed; manual and auxiliary work is no longer required, and operations that were previously separate and labor-intensive were combined.
- *Skilled personnel:* On the one hand, digital workflow has saved labor, on the other, requirements for the personnel have become more demanding, and new qualifications, such as for preflight tasks, are needed. This becomes particularly obvious in prepress, where the tasks of three former professions, compositor, reproduction technician, and platemaker are now combined into one and can be carried out at the same workstation. Moreover, this situation has created an increased need for system administrators to guarantee the operational safety of increasingly complex networked systems.
- *Decentralized publishing:* By integrating digitization, the processes of typesetting, image capturing, exposure, proofing, printing, and so on, can take place at different sites, while the data transfer and communication between the companies involved in these processes is ensured by means of networks (e.g., Internet) (see sec. 9.1.2).

8.2.3 CIP3 for the Computer-Integrated Manufacturing (CIM) of Printed Products

As already described in section 8.2.2.1 (fig. 8.2-9) the fifth stage of a digital workflow, the transfer of production-relevant data from prepress, is vital in order to introduce *Computer-Integrated Manufacturing* (CIM).

An important initiative for the support of digital workflow in the manufacturing of printed products is the *CIP3 consortium*. CIP3 stands for "International *Cooperation for Integration of Prepress, Press, and Postpress*"; it is an association of around forty international companies, mostly manufacturers of prepress, press, and postpress, as well as suppliers and users [8.2-8]. (In 2000 the CIP3 consortium was renamed CIP4: International Cooperation for the Integration of Processes in Prepress, Press and Postpress.)

The objective of CIP3 is to improve and automate the production of printed products by setting a standard throughout the industry, the *Print Production Format* (PPF). PPF defines a uniform data structure and associated coding for the data that is necessary for the whole technical production. This PPF is supported by the

products (software and hardware) of CIP3's members and other companies [8.2-8].

Print Production Format (PPF)

In the past few years, the printing industry has witnessed a trend that has become ever more defined: due to the advent of digital technologies, the *production of short print runs* has continued to gain in importance. In terms of production process, this means that the equipment must be ready for the next job more quickly.

In the long chain of operations necessary for manufacturing printed products many presses can already be controlled and preset electronically. Until now, the required *setting values* are often still input manually, although much of the information required is already available in previous operations.

The possibilities of electronic data exchange have hardly been exploited, especially in heterogeneous environments using equipment from different manufacturers, as is often the case in practice. This can be explained by the absence of a *uniform, manufacturer-independent format*, with which data could be sent from one processing step to the next.

In 1994, upon the initiative and order of Heidelberger Druckmaschinen AG, the Fraunhofer Institute for Computer Graphics published a study on the requirements of a *Print Production Format* (CIP3/PPF). This format would serve as data container for the exchange of information between prepress, press, and postpress. The objective of the research for CIP3's Print Production Format was to apply the concepts of computer-integrated manufacturing (CIM) to the *manufacturing of printed products*.

Initially, the study identified three areas of print production that would benefit from data saved in PPF: printing, cutting, and folding. These areas require information that is already available in prepress. Meanwhile, the range of application has been greatly enlarged, and now includes further operations in finishing, which are involved in the manufacturing of an entirely specific printed product, such as a brochure.

Integrating Prepress, Press, and Postpress

Whereas the current systems designed to support print production workflow are mostly limited to prepress, CIP3/PPF ensures a coherent model from prepress to finishing. The data format does not prescribe any specific workflow, but can be practically adapted to very heterogeneous environments (e.g., for highly automated computer to plate systems, as well as to conventional systems with film exposure).

The use of CIP3/PPF is currently limited to *technical production data*. Due to the diversity of (commercial) job management systems on the market, the adoption of a uniform format would have been welcome, but was not a priority since the development of systems performing these tasks was already more advanced than for the management of the technical production data. Numerous systems are already in use today. Consequently, CIP3/PPF does not contain any commercial data, but rather creates the interface with job management, job tracking and workflow systems. Finally, CIP3 Print Production Format is an *open-system standard*. The specification is freely accessible [8.2-8].

Content of CIP3/PPF Files

A CIP3/PPF file can contain descriptions of sheets, a related directory (*PPF Directory*), and product annotations and comments. PPF contents can be saved or edited successively or simultaneously in a PPF file. Based on the various sub-processes during the production of a printed product, the contents, which are saved, exchanged, or read in the PPF file (e.g., using *CIP3 Parser* or Editing Library), are described in the following.

Since all product information and sheet elements have been defined by the time of *imposition*, modern imposition systems offer the possibility of generating PPF files.

When *printing*, the ink zone presetting, paper travel, register adjustment, and the colorimetric and color density measurement can be set using the data from prepress (see fig. 8.2-13). During imposition, or in the RIP, a low-resolution preview image of the entire sheet can be stored in the PPF file. Appropriate compression processes for the sheet images compatible with CIP3/PPF (e.g., 20 MB) were selected since the image data can be up to 640 MB in size for a perfecting job of eight A4 pages per sheet side and 4 color separations per side.

Feeder and delivery of a sheet-fed press can be preset according to the sheet format. The PPF file contains the type and position of the register marks for the register control. Finally, the PPF file may also contain the positions and the setpoint values of color and density measurement fields for in-line and off-line color measurement and quality control. Other attributes are used, for instance, for the specialized support of web

presses, such as built-in cross cutters or the presetting of folders.

Cutting and folding are usually the two major stages in the process of *finishing*. *Cutting* involves dimensioning the cutting blocks and positioning the cutting marks. Nowadays the coordinates of all blocks to be cut must generally be recorded anew using a digitization tablet; the recording of the coordinates in prepress enables the automatic prepositioning of the corresponding sensors.

At the stage of *folding* all folding procedures and their individual parameters need to be set. Since the selection of the imposition layout already provides the folding layout, this information can be saved in the PPF file and transferred to the folding process. It can then be translated into a folding instruction (or in a folding program) adapted for the respective folder. (Fig. 8.2-13 gives a simplified description of the diversity of use of CIP3/PPF data via a *prepress interface*.)

In the subsequent *finishing*, CIP3/PPF describes how sections that were generated in the previous steps are processed *into a final product*. The setup data required for these operations is available in Print Production Format. Thus, a PPF file can contain a complete product description. It contains descriptions of operations such as collating or gathering, binding by various methods (perfect binding, thread-stitching, etc.), three-sided trimming, or information about accompanying products (e.g., CD-ROM) or pull-out postcards. In addition, the Print Production Format includes administrative data, such as an unambiguous job identification or information about the length of the run.

Within the CIP3 Print Production Format, production-specific data, called "*private data*", can be stored. By this means it is possible to save the actual setup values of a machine used for the production and the data originating from prepress in one CIP3/PPF file. If there is a repeat job on the same or a similar press, the old production settings can then be used directly. With the "private data" mechanism, the CIP3 Print Production Format can also be utilized to save parameters that are neither known in prepress, nor can be derived from the information already available (e.g., because they depend directly on the presses used for production).

Another benefit of the re-usability of this data are the significantly shortened makeready times for repeat jobs. If necessary, the private data can simply be deleted before data is sent to external production sites.

All data is stored in a structured form in the CIP/PPF file. For instance, there are separate sections for each side of a sheet. This logical structure is programmed with a data attribute *inheritance mechanism*. Thus, an element can inherit attributes from elements on a higher level of its hierarchy. In this way, the attributes valid for several elements can be copied in a higher-level structure. They can then be saved once for all the subordinate structures. This also facilitates access to the data required for a process (e.g., cutting).

Contrary to other solutions, which are either vendor-specific island solutions or solutions for a specific area (e.g., prepress), the CIP3 Print Production Format was designed to be a *vendor-, press-, and platform-independent* (processor type-independent) *data format*. This has greatly facilitated – if not enabled for the first time – the exchange of data in heterogeneous environments, that is, between systems from various vendors with diversified hardware and software components (as found in practice today).

Use of CIP3/PPF in the Workflow

The first application, which integrated CIP3/PPF in its workflow, was the *ink zone presetting* (fig. 8.2-12; see also fig. 2.1-163). The advantages of implementing CIP3 can be clearly recognized.

If the content of the entire print sheet exists as a CIP3/PPF file, it is possible to accurately calculate the ink quantity required for each color separation, that is, for each printing unit, thus achieving very precise ink zone presetting. Some software packages can be used as a digital equivalent to the plate image readers, which have been used since 1982 for the ink zone presetting (see also sec. 2.1.5.4). These not only guarantee a higher resolution compared to the conventional plate image readers, but are also cheaper and faster. The time saved in presetting the printing press and the reduced number of waste sheets represent further advantages of the digital equivalent to the plate image reader.

There are further applications using CIP3/PPF, which, for instance, automatically generate programs for the use of cutters, and which position the sensors, or transfer setpoint values for the control of the printing quality; these also contribute greatly to saving time and waste sheets. Figure 8.2-13 illustrates how CIP3/PPF can be integrated into *prepress* to create an *interface* between the various finishing sectors by using the existing information/data extensively.

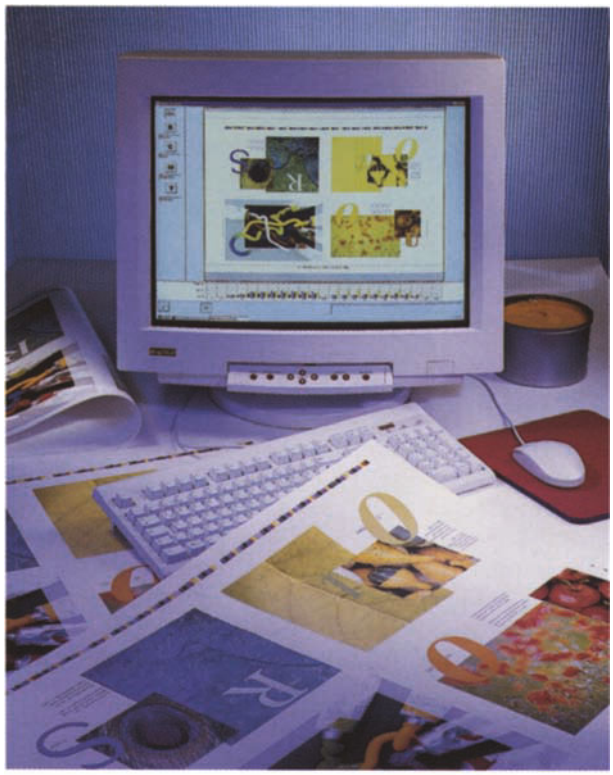


Fig. 8.2-12
Ink zone presetting for a multicolor sheet-fed offset printing press calculated with prepress data by using CIP3/PPF in the workflow (Heidelberg)

The companies using CIP3/PPF have experienced very satisfying results. Shortened press makereadies, which are all the more obvious in short print runs, constitute a major advantage.

Coding of CIP3/PPF

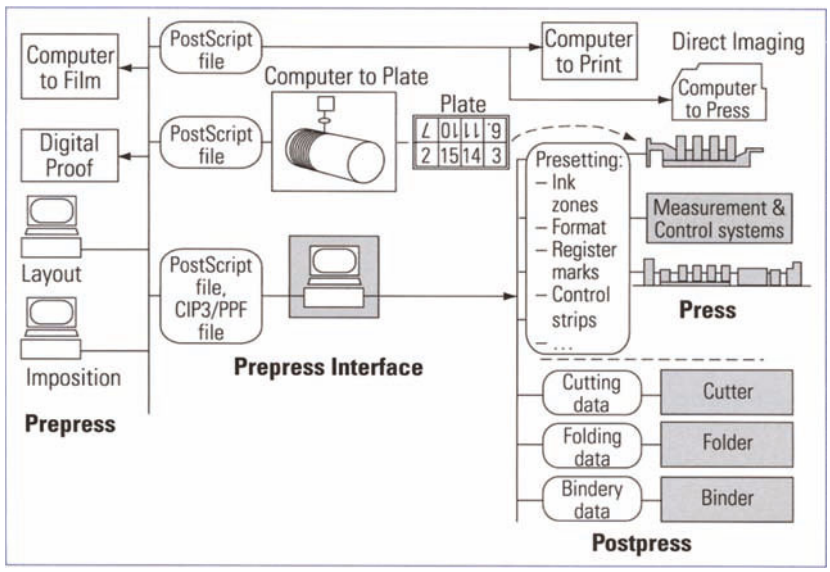
In its initial form, CIP3/PPF was coded in *PostScript*, a page description and programming language [8.2-9]. PostScript was used for the definition of data types and of the data itself. CIP3/PPF files are not to be confused with PostScript files, which are generally used today for film and platemaking. The CIP3/PPF file does not contain any data that is exposed, but only the *product information* described previously, which is coded in PostScript.

Other coding standards are also being developed. For instance, Adobe is working on designing a PDF-compliant coding, as a part of the Portable Job Ticket Format (PJTF) [8.2-10 and 8.2-11].

A standardization of other interfaces, and the implementation of file coding standards, would be welcome. The content of a CIP3/PPF file could then be coded in a *database*. In this case, a uniform database layout would be useful. A standardized programming interface, such as an *Application Programming Interface* (API), could also be used to access the data.

All these alternatives have in common that the underlying data structure and the semantics of the data would be harmonized. We might then imagine that

Fig. 8.2-13
CIP3/PPF-based prepress interface for the connection of printing and postpress/finishing (Heidelberg)



several companies that cooperate in generating specific products would use a file format for communication between companies, but a central database within each corporation. Upon receiving an order with a CIP3/PPF file, the content of this file would be converted into the database. As long as this order remained in this company, all applications would directly access the database, if the network architecture allows it. Alternatively, all applications could access the data via a uniformed API – regardless of the fact that this data still existed in the CIP3/PPF file or was stored in the database. It would even be possible to imagine using this API for remote access to the data via a network protocol.

A direct database interface can facilitate the exchange of CIP3/PPF data. Moreover, information regarding the production status of each job or page can be retrieved at any time.

Figure 8.2-13 illustrates how a *prepress interface* transfers the prepress information for the subsequent production steps to the print production. Prepress interfaces can process CIP3/PPF and PostScript files. The market is mostly dominated by CIP3/PPF. The Prepress Interface generally processes CIP3/PPF data that is prepared by the prepress system. It is of no importance whether the job is digitized in PostScript or PDF format.

Job Definiton Format (JDF)

Another new initiative by the core group of Heidelberg, Adobe, MAN Roland, and Agfa is the development of a "*Job Definition Format*" (JDF). This Job Ticket Format is compatible with Adobe's Portable Job Ticket Format (PJTF) and with the Print Production Format (PPF) developed by the CIP3 group, thereby contributing to a fully integrated workflow in the graphic arts industry. JDF also includes new commercial processes. Internet-based solutions for production at various locations are made possible by implementing XML (Extensible Markup Language) standards.

8.2.4 Production Management/Monitoring Systems

8.2.4.1 Purpose, Applications

In printing companies with large printing volumes, *production management* and *monitoring the jobs* play a vital role in ensuring punctual delivery and cost-effective production. Most printing companies do not have a detailed overview of the jobs in production, and in particular have no real-time update of their status. The company's management is generally not able to evaluate whether a job in production is being produced according to the hours calculated, or whether its printing will be delayed. The only way to find out is usually to "walk around the production" or to "phone around in all the departments," in order to form an opinion about the progress of the job.

For example, many companies organize daily 30-minute production meetings, during which the staff discusses and defines the outstanding jobs, what jobs are in production, and where. Even when planning the production of a job on short notice, there are still several changes during the daily production. Jobs that have been overlooked and urgent jobs often have to be slipped in between. This often causes additional, unproductive press makereadies, which could be avoided by means of reliable production planning.

In companies where absolute punctuality and transparency in the production status are required, certain specific procedures have been progressively established, together with the use of electronic planning and monitoring systems. The next section (8.2.4.2) will describe these systems in detail.

The newspaper printing industry, where up-to-date information is a must, requires an absolutely reliable production system on a daily basis. Besides the necessity to deliver the newspaper, speed – and therefore absolutely reliable scheduling – is a prerequisite for the production of a daily newspaper. There are similar marginal conditions in the printing of catalogs and magazines, for example, in rotogravure. In this case, the press utilization schedules have the highest priority because the equipment is so cost-intensive that idle time must be kept to a minimum. Further, any delay in delivering the product will not be accepted by the customer.

If the release of a weekly magazine is delayed, the majority of that issue would not be sold, the advertising customers would not pay their bills because of the delay, and might look for alternative media where they could place their advertising in the future.

This scenario serves to illustrate why the newspaper and magazine printing industries were the first to implement solutions that would reduce such risks. However, printing companies with a large printing output must also integrate a rational solution for the planning and monitoring of their production. On the basis of these prerequisites, and taking into account the different fields of application, systems were developed so

that production could be planned, monitored, costed, and commercialized efficiently.

8.2.4.2 Production Monitoring Systems

Although this topic was described in detail in section 1.9.2, the following will highlight a few specific systems.

To have an *up-to-date overview* of the production of a newspaper at any time, for instance, certain *tracking and visualization tools* are a must. Checking must be possible for each individual element, for example, an advertisement or an article that is to appear on the page of the newspaper. After checking, the system sends status messages such as "in production," "stopped," or "ready." This task is vast and complex since the entire production process can involve several systems from different manufacturers. When producing newspapers, diversified, independent systems are in use in the following areas: administration, editorial department, production of advertising, image editing, layout, printing, shipping, and so on.

Therefore, the task of *a tracking system* is to gather information from each partial system and to give an overview of the entire production. In order for this system to work properly, all partial systems must transfer the status information of each element in a standardized form to a central tracking system (see also sec. 1.9.2).

Upon the initiative of IFRA, the *association for newspaper and media technologies*, a workgroup was formed in 1994, in order to specify a vendor-independent tracking system. In 1997, a second version of IFRAtrack was released [8.2-12]. For the coding of the tracking information, XML (Extensible Markup Language) was preferred to IMF (IFRA Message Format). In addition, the connection protocol now used is TCP/IP (Transmission Control Protocol/Internet Protocol), which is based on existing standards.

Commercial printing has also introduced solutions for production monitoring similar to those in the newspaper printing industry. Table 8.2-1 enumerates some companies, who have developed systems specifically optimized for interfacing their own printing system components (see also fig. 2.1-169).

Several systems are used to support other diversified steps in production and organization. For example, modules of SAP/R3 software are utilized for monitoring costs and materials. Finally, each existing system and module must be integrated in order to provide a comprehensive solution for all areas of the company's administration and production.

Product	Manufacturer
DataControl/Prinect	Heidelberg
PECOM	MAN Roland
OPERA	KBA
K-LAN II/KMS	Komori
DiamondLink System	Mitsubishi

Table 8.2-1 Production and information systems (management information systems) for the graphic arts industry (selection)

Figure 8.2-14 shows the terminal for production monitoring on the control station of a production system. Figure 8.2-15 provides an overview of network connectivity and the use of software components and systems, installed in a typical company of the graphic arts industry.

Systems designed for remote data transfer, remote monitoring, and control of the production systems also play a vital role. They can assist the production carried out at different sites and ensure early detection and diagnosis of errors. They can therefore perform a quick service regarding maintenance work or malfunctions.



Fig. 8.2-14
Press terminal on the control station of a production system with connection to a production and information system (DataControl/Prinect, Heidelberg)

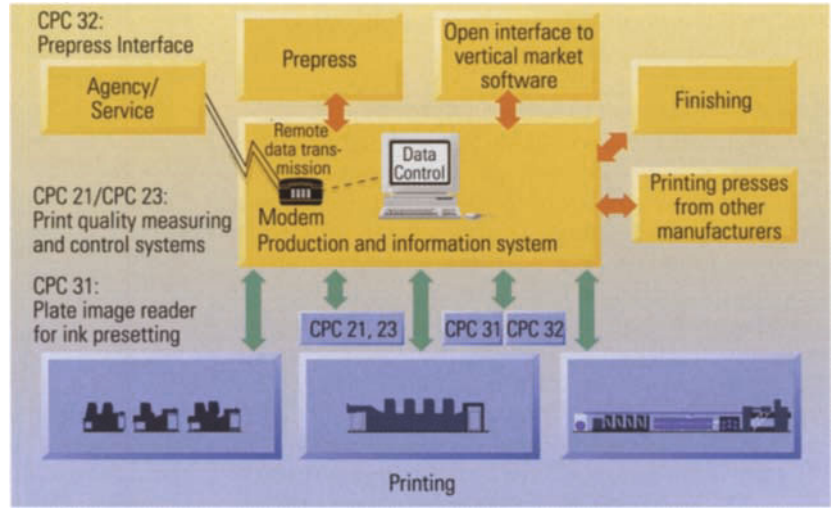


Fig. 8.2-15
Production and information system for the networking of a printing company and for the planning, execution, and monitoring of production (see also figs. 2.1-150 and 2.1-169), (DataControl, Heidelberg)

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9 Production Strategies for Print Media

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Production Strategies for Print Media

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9.1 Production Concepts

Sections 1.8 and 1.9 dealt with the great variety of printed products, applied business models, and the different aspects of management and costs. In this section the main technological possibilities and manufacturing concepts for the production of print media are described.

9.1.1 Strategic Orientation of Printing Companies

The multitude of printed products and the delivery times demanded in the market today means the spectrum of production strategies and therefore also the organization of manufacturing enterprises can be extremely diverse.

The basic differentiation to make is between non-commercial and commercial printshops. *Non-commercial operations* are directly affiliated with a company that requires printed products for marketing or support, or a publisher of printed products, on an economical and organizational basis. They have the task of producing the company's or publisher's product range and adapting to the requirements of the company or publisher, in particular with regard to capacity and availability. External jobs are only produced when there are gaps in capacity utilization to be filled. Non-commercial printing companies are mainly used if the production of certain product groups requires specific conditions. This is the case, for example, with newspapers where the shortest production times are of vital importance, or with wallpaper or foil printing where the material-specific demands outweigh the design of the content.

Commercial operations, on the other hand, offer their services freely on the market. They can usually manufacture at a lower cost than comparable non-commercial operations since they are not restricted in their activities by a controlling publishing house but can rather adapt to fit market demands optimally. In product areas with no stringent reasons for using non-commercial operations (e.g., book printing) most publishers have gotten rid of their non-commercial printshops. The publishers can make use of the competitive situation of the commercial printshops to reduce their production costs and deal with technical changes of their products much more flexibly by simply changing the printshop.

Commercial printshops, on the other hand, try to expand their chain of added value (see also fig. 1.9-4) with publisher-like activities or additional services (such as prepress) to ensure full capacity utilization. However, these activities can quickly develop into a competition for the regular clientele of a printshop, so that it is mainly only niche applications that are introduced in the context of plant expansions.

While in non-commercial operations the *strategic orientation* is defined by the holding publisher, commercial operations need to constantly analyze production strategies and adapt to the developments of the market. *Investment behavior*, in particular, is a key factor for the success of a business. Investments in printing presses represent a high capital tie-up for printshops and insufficient or uneconomical utilization of the press can quickly lead to serious burdens on the operational result of the printing company. Thus large capital investment requires a lengthy *service life* of the capital good; typically eight but often ten or more years according to the type of printshop and specific regional conditions. This means that the production parameters such as the formats and substrates that can be processed, the number of printable colors, possible folding variations, and so on, are inflexible. Therefore, future changes in the market need to be considered when making the investment.

Strategic decisions regarding the orientation of a printshop can be based on different approaches (fig. 9.1-1). One option is to define a *product group as a strategic production target* and to invest in the technology required for this production. The scope of demand cannot, however, normally be covered with an individual technology. Varying run lengths and formats often require different types of printing presses and/or print-

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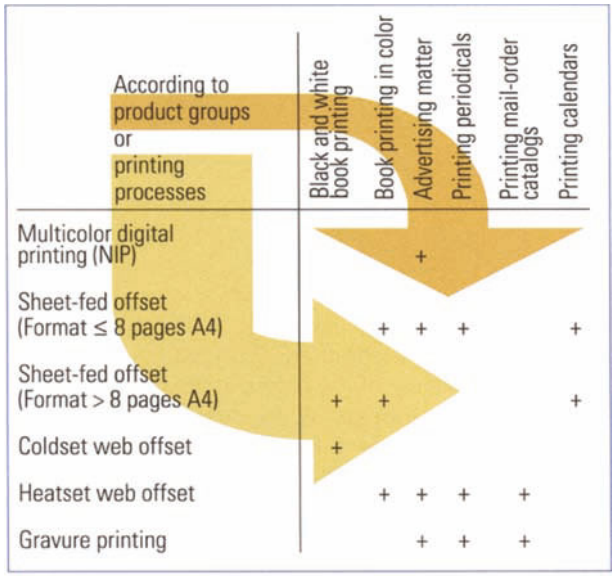


Fig. 9.1-1
Typical applications of printing technologies for selected product groups

ing processes, which are optimally adapted to certain areas of production. Even though press manufacturers are increasingly developing more variable or at least modularly expandable printing systems, a strategic orientation according to product groups places high demands on production since different printing processes that may become necessary create system incompatibilities, such as in paper logistics (webs and sheets), prepress (platemaking), and operation and maintenance of the press, as well as the internal organization of a printing company. Production is, therefore, more complex and consequently often burdened with higher costs than in a printing company that is organized based on printing processes.

Depending on the concept in place, *strategic orientation depending on the printing process* may not merely be limited to one process but may rather standardize further production-relevant parameters internally, such as the types of material that can be used or the range of formats that can be printed. These specialized printshops then have greater potential for gaining a *more competitive edge* in their particular segment. On the other hand, the distribution costs of such printshops are greater due to a much more heterogeneous clientele.

Seasonal variation in orders placed is another typical problem of the printing industry that is easier to overcome for a business with a mixed product group portfolio. Many product groups have a marked demand profile that follows a typical pattern over the course of a year and can, for example, be influenced by external factors such as Christmas for consumer-driven products, the New Year for the calendar business, large trade fairs, such as book fairs, or customary practices for a line of business, such as the telephone book business. A printing company that focuses mainly on one product group is obviously significantly more susceptible to these influences and must find practical solutions to compensate for the fluctuations in the utilization of its capacity.

Taking the example of the calendar business with its extremely marked seasonal fluctuations, in the first half of the year certain calendar sections are preprinted and in the second half the final product is produced in accordance with customer specifications. This ensures a constant degree of utilization throughout the whole year. On the other hand this makes the costs for circulating capital for the semi-finished product economically significant since the semi-finished products produced in spring must be stored until the fall. Printing companies usually try to make up for these seasonal fluctuations by having flexible working times so as at least to avoid extra personnel costs.

Alongside the types of orientation described according to product groups or printing processes there are also *further criteria* that can be called upon for a strategic orientation. Classification according to *type of customer* (customers in industry, end users, etc.) or *channels of distribution* (dispatch by mail, retail trading, etc.) can be useful. There are also *further parameters* to be considered for strategic orientation. These are in particular

- available manpower (qualification, cost level),
- physical location (proximity to customers and market, logistics costs),
- competitive position,
- company background (existing equipment, image).

The general criteria of marketing and strategic product planning also apply to printed products (e.g., [9.1-1]) where, at least in the industrialized nations, the conditions of a mature, established, and nearly saturated market apply for virtually all product groups. Quite the opposite applies to the development of internet media. The print market is basically growing (see

sec. 1.1.5) although the dynamics in each of the product groups are quite different (see fig. 1.9-3).

According to [9.1-1] a clear strategic orientation is a decisive factor for success under these market conditions. Either *cost leadership* or *product differentiation* can be targeted here. Companies neither focusing on cost-optimized production nor having set up a product or service offer with clear unique selling propositions have minimal chances of success in this kind of market. Product differentiation is ever more difficult to achieve in the printing sector, meaning that competition is based more or less solely on price. Since new technologies enable significant higher productivity for printing presses and production systems, meaning that cost advantages can be achieved with an offensive investment strategy, the print markets in the industrialized nations are being increasingly marked by excess capacity.

While large operations have a number of systematic cost advantages and small operations can increasingly concentrate on locally dominated services, it is above all medium-sized operations, often having limited investment power, that face key decisions.

The fundamental strategic decision regarding the product portfolio and the markets *necessitate a number of additional decisions* (fig. 9.1-2). Questions regarding location and degree of technical automation, which are discussed in the following section on centralized and distributed production, are particularly important. Based on these parameters many operative questions can be answered, from the concept of financing right up to the selection of suppliers.

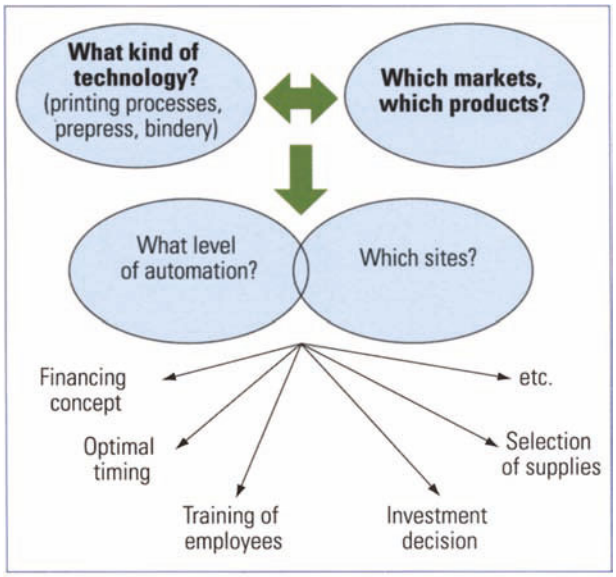


Fig. 9.1-2
Criteria for making strategic decisions for establishing a printing business

9.1.2 Centralized and Distributed Production

The decision for a centralized or distributed production is of vital importance as it determines the entire technical concept. Centralized or distributed production can be based on a single production location or several sites. In both cases the technological consequences are similar, although the decisive reasons in the first case normally lie in the market, while optimization of internal production is often sought in the second.

9.1.2.1 Centralized Production at One Site

To characterize the basic manufacturing structure of a company, distinctions are made between central and distributed production concepts. With central manufacturing of printed products all the technical functions required for production are centralized at one location (site) and semi-finished products are only transported within the production plant.

For the definition of production concepts within one location the term "*centralized production*" as opposed to "distributed production" is also often used. This means the extent to which a production process is carried out in a *central "large" unit* or *distributed to several analogous units* (fig. 9.1-3). Particularly with printing presses and finishing equipment there is almost always the alternative of either acquiring a central production unit that is able to cover the required capacity or distribute the same load to several production units with lower output ratios. The high productivity that can be achieved normally speaks in favor of large units.

Figure 9.1-4 shows the ratios for heatset web offset presses. Various configurations are currently available on the market ranging from small units that print eight pages per section right up to large machines with forty-eight pages per section. Smaller presses have a significantly lower printing capacity compared to large presses (approximately 20%), so that about five eight-page presses would be required to match the capacity of one forty-eight-page press (line 1). However, since the investment required for an eight-page press is approximately 35% of the level required for a forty-eight-page press, the option with five eight-page machines re-

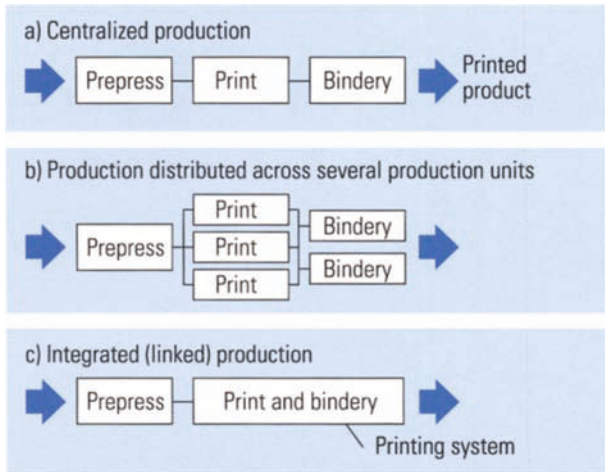


Fig. 9.1-3
Equipment concepts for central production of printed products at one production site

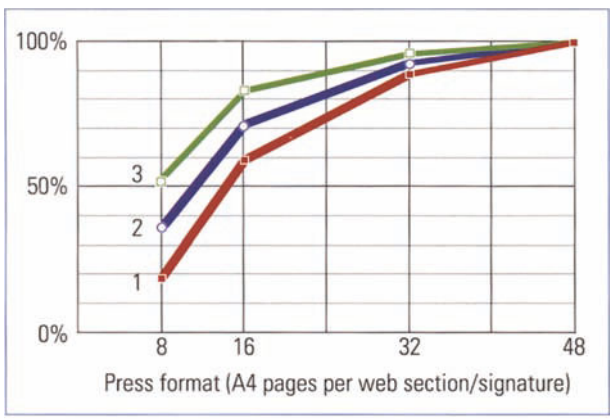


Fig. 9.1-4
Ratio between printing performance and investment costs based on the example of a heatset web offset printing in various press configurations (presses from various manufacturers, comparable equipment levels, four printing units); press with 48 pages per section corresponds to 100 %

Plotted line 1: printing performance, printed paper area per unit of time
Plotted line 2: average investment costs
Plotted line 3: printing performance/investment (derived from lines 1 and 2)

quires 175% the investment (line 2). The printing capacity/investment ratio is therefore around 50% worse. Larger units also offer comparable advantages in terms of running costs, such as manpower requirements.

In practice, however, there is often a whole range of reasons that reduce or completely eliminate the economic advantage of central production with a large unit:

- *Flexibility.* If the range of products is not uniform, the large unit must be set up for the maximum demand. In heatset offset printing, for example, the cylinder circumference of the press must be set up for a maximum format. With smaller format products additional costs arise because the unprinted paper must be trimmed. With distributed production the individual units can be adapted to meet various demands and together with an appropriate job control, a more economic production can be attained.
- *System reliability.* Failure of a central unit is a big risk when producing with tight deadlines since failure to deliver can lead to high claims for damages. With distributed production where several presses print in parallel, the failure of one press has a significantly less critical effect.
- *Continuous investment strategy.* Continuous investment becomes possible with distributed production. Replacement investments can be controlled so that an old press is replaced by a new one at regular intervals. For the financial planning of a printing company this offers an advantage over central production, where replacement investments affect the entire technology. This kind of one-off investment into central production also carries a significantly greater risk in the event of misinvestment.

There is no definite answer to the question of whether to go into production with one large central production system (production unit) or to opt for distributed production on several analogous systems. The pros and cons should be weighed in each individual case. Generally, specialized production systems with a clearly defined product and market spectrum are more suited to a single, central production system optimally set up for this purpose, while production with market and product conditions that are subject to frequent change can often be more successful with a distributed organization where production is assigned to several units with a lower productivity.

9.1.2.2 Distributed Production at Several Sites

As in other sectors, the basic pattern for the production of printed products is a central manufacturing plant in which all the production processes take place. Deviating from this principle and distributing production to several sites can take on two different forms: As shown in figure 9.1-5 production distributed to several sites can have a *parallel* (a) or at least *partially parallel* structure (b). This means that all the necessary functions can be carried out at each site and, as such, each site is capable of independently producing the end product. However, with *serially* distributed production (c) there are individual processes at different sites that must be interlinked for the print production.

Setting up distributed production across several sites is made easier by modern *digital technologies*. If the print job is produced fully digitally by prepress, then this data can easily be transferred to production facilities at various sites without it being necessary to transport production materials, such as films or printing plates. The local printshops must, however, be equipped with the appropriate technology to print the job with the data received, for example, computer to film/computer to plate systems or non-impact printing systems.

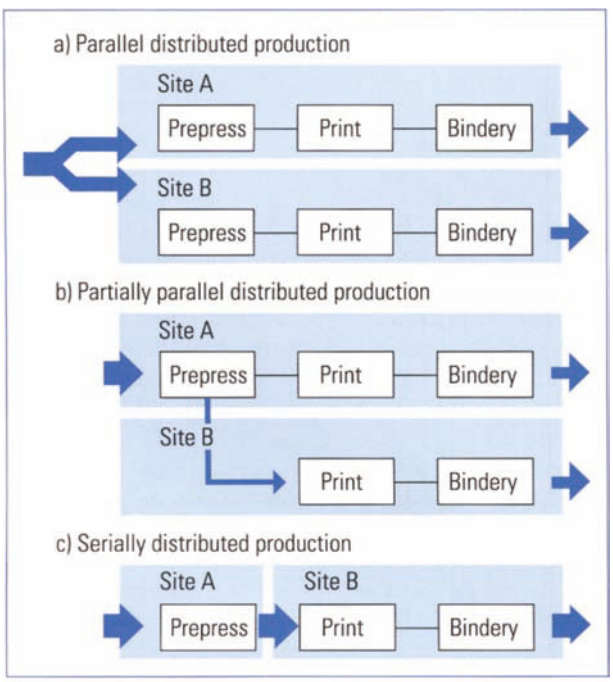


Fig. 9.1-5 Concepts for distributed production across several sites

Unlike present printing companies from which printed products are delivered to the *local* distribution organizations it is now possible to distribute immaterial data and produce the printed product *decentrally* near to the customer. This is shown in figure 9.1-6.

Many factors can be decisive in setting up different forms of distributed production:

- *Market proximity.* The individual sites are adapted to meet regional demands of the market. This means that important customers can be served quickly or logistics expenses can be reduced. This can relate either to international markets or nationally to various regions or industries whose supplier is the respective printshop. Both the relocation of complete service providers (parallel) or individual manufacturing stages (serial) to different sites can be sensible: a product, like a magazine or catalog, can require intensive and direct exchange with the customer so that prepress sections are set up near to the editorial offices of the customers. Large operations for book manufacture sometimes have a part of their prepress production located at the sites of their publisher customers while their printshop and bindery work centrally. For newspapers and magazines, where topicality is a priority, the system can work the opposite way around, with prepress production taking place centrally while platemaking and the actual printing is distributed and takes place regionally to keep delivery times (and also transport costs) down for the end user. Publishers often set up entire networks for decentralized production of printed products and production plants have to adapt to these demands.
- *Site costs.* As is the case in other industries the cost structures of production sites can be very different with regard to salaries, space, and buildings, necessary additional services, government regulated taxes/duties and subsidies, and so forth. The decision for a second site may therefore be very sensible for labor intensive productions. However, site advantages might not be present forever and should be analyzed in detail prior to making long-term site investments. Relocating sites just for the purpose of side-stepping environmental regulations is not acceptable.
- *Employees.* Alongside the salary level at a specific site, other criteria regarding the employees available may also be important, such as qualification of the employees, loyal employees, and the flexibility

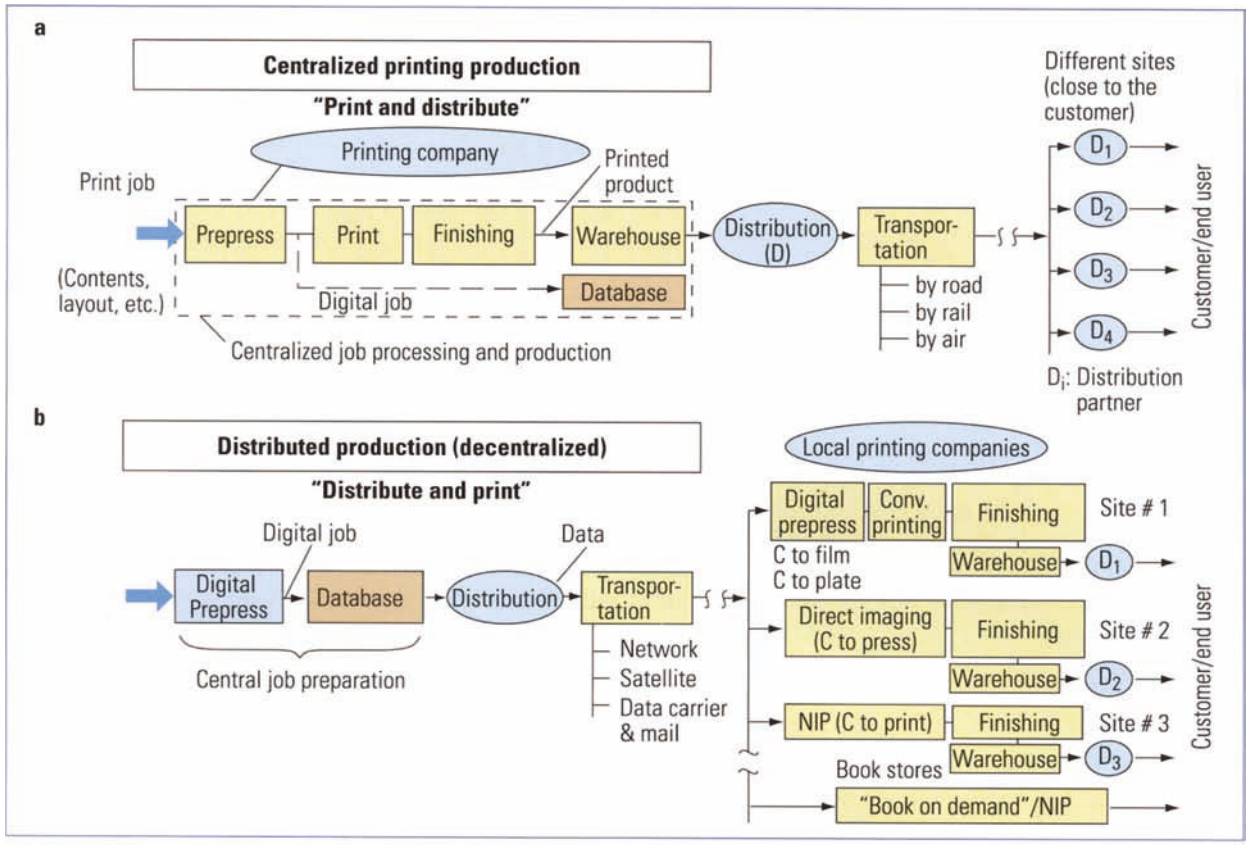


Fig. 9.1-6 Print production methods and distribution channels ([9.1-2])

of the local employment market to cope with short-term surges in demand.

- *Specialization.* Particularly with large central production and a complex product structure it may be sensible to manufacture individual product groups at separate sites and specialize the technical equipment at these sites.

Distribution of production stages to different sites, however, only becomes economically viable from a certain size of operation since it leads to a great *loss of rationalization* for small printshops on account of the low volume of orders. Distribution to several sites does make sense, however, for extremely large operations since this reduces the complexity of operations, ensuring a *smoother workflow* at each individual site. There are no known printshops worldwide that have significantly more than 2500 employees and a daily paper throughput higher than 700 tons.

9.1.2.3 Integrated Production, Interlinking of Systems

Another important factor involved in the organization of production is to what extent individual processes can be integrated into a linked production process. Integrated production normally offers great advantages with regard to personnel required and logistics costs since intermediate storage is no longer necessary and the total manufacture time for a product can therefore be reduced.

Linking manufacturing processes does, however, lead to increased complexity of the system and this ultimately results in a reduced *utilization ratio N°* (proportion of time within the working hours in which a system can be used for the intended purpose – also called "*availability*"). In the printing industry a utilization ratio of N° ≈ 90% is accepted (i.e., for 10% of the working hours the equipment cannot be used for the intended purpose), since an increase of this value re-

sults in disproportionate technical expense which would not be economical.

Without falling back on indepth scientific models, the *multiplication of the utilization ratios* can be applied as a basic method of approximation for interlinking individual units. Figure 9.1-7 shows the gradation of total utilization ratios for two or three linked units (e.g., when $N°_1 = 90\%$ then $N°_2 = 81\%$ and $N°_3 = 73\%$). For a normal printing operation these values are no longer acceptable. The improvements in productivity by linking units only make up for the reduction in the total utilization ratio to a certain extent. To achieve a total utilization ratio of $N° = 90\%$ with linked systems the individual utilization ratios must be as high as 94–96%.

Depending on the technical possibilities and the potential to reduce costs, the progress toward integrated manufacturing processes developed differently in the individual production areas of the graphic arts industry. In practice, it is the larger printing companies in particular that have invested in integrated manufacturing processes. In virtually all areas of production examples of this kind of production method can be found (table 9.1-1). The printing of direct mail represents a special case (see sec. 9.1.4). Because of the personalization of mailing, a fully interlinked manufacturing system is required here to maintain the sequence of the addressed products and eliminate loss of individual products. A relatively low total utilization ratio must sometimes be accepted for this.

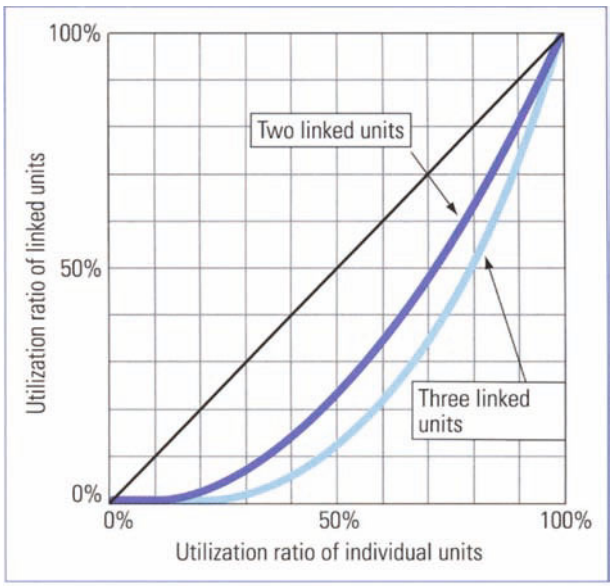


Fig. 9.1-7
Utilization ratio of linked technical units (where the individual units have the same utilization ratios; approximate calculation)

Linked systems are not found very often in sheet-fed printing since direct finishing, for example in a folder, is not possible with normal inks that dry by oxidation.

For the linking up of units the adaptation of the *production performance* as well as the utilization ratio of the individual units is a key issue. Since it is always the slowest unit in *linked* (serial) production that determines the overall speed, units with a higher speed would be operated uneconomically. An ideal balance in the capacities of linked components becomes difficult if the components depend on different parameters. The speed of a gatherer, for example, is scarcely influenced by the book thickness (see e.g., fig. 7.2-50 in sec. 7.2.4.2). The number of stations operated scarcely influences the overall speed. The book throughput of a sewing/thread-stitching machine, which processes every individual sheet of the book folded into book pages is, however, dependent on the number of the sheets to be processed. Linking both systems leads to a situation in which the production is limited by the speed of the sewing machine in the case of thick books and by the gatherer in the case of thin books. In this way the entire system can be operated optimally if the page count of the books to be produced does not vary too much. However, if the page count varies considerably, a linked production flow is almost always operated sub-optimally.

Through the *parallel operation* of individual units the productivity of the linked system can be increased. If the linked units are arranged in such a way that the flow of semi-finished products can, if necessary, also be fed to just one of the connectable units, the whole unit is flexible and can be optimally adjusted for each different job and in addition provide for redundancy with regard to a faster individual unit. Such an interlinked production is shown in figure 9.1-8 in the form of a diagram.

9.1.3 Print on Demand

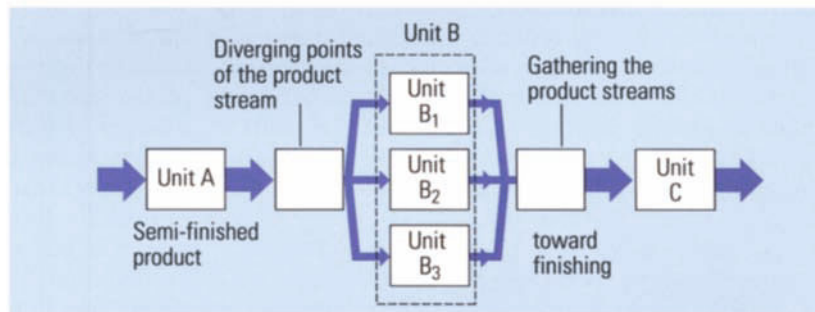
The term "print on demand" (PoD) may initially sound somewhat confusing since printed products are more or less only produced when a customer has placed the respective order. Unlike other branches of industry products are not made for stock. With PoD, however, the "demand" refers to the sale of the product by the

Table 9.1-1
Examples of typical utilization ratios (reliability, availability) for linked production in individual sectors of the printing industry

	Typical utilization ratio N°
Newspaper production system (Unwinding, printing, folding, mailing room logistics)	90%...95%
Heatset web offset system (Printing, folding, gluing and punching/die-cutting units)	90%
In-line production of mailings (Unwinding, personalization, gluing, die-cutting, decorative operations, folding, cross-cutting)	70%...85%
Book production lines (Cutting, rounding, headbands, casing in, jacketing books etc.)	85%...90%
Calendar production lines (Gathering, die-cutting, binding)	90%
Perfect binding systems (Collating, perfect binding/cover feeding, cutting, inserter)	90%

Utilization ratio: proportion of the working hours during which the unit can be used for production.

Fig. 9.1-8
Linking of individual units and increasing the production speed by operating individual units in parallel (with flexible diverging points and gathering unit)



customer placing the order. The publisher normally commissions a large quantity of identical printed products (run length). The option whereby the customer requests the *total run length* to be printed in several *part run lengths* (sometimes called "Quotas"), the delivery of which then becomes dependent on the resale, has been in place for a long time. While these jobs are sometimes printed in total by the printshop and put into temporary storage, they can also be produced in corresponding part runs. If the number of printed part run lengths gets close to the actual total run length (fig. 9.1-9) so that the customer can request delivery of the printed products in small batch sizes (in extreme cases the batch size may just be "one"), the term "print on demand" is used. PoD is, therefore, one form of the *just-in-time* production method.

Extremely flexible equipment and short makeready times are needed to technically realize PoD printing. With digital printing processes, in particular those that enable the print image to be changed for each printing process without a makeready procedure (without a physical printing plate with a fixed image, cf. chap. 5 and fig. 9.2-3), it is possible to economically print a run length as small as "one". PoD systems are normally not understood to be small printers for the office, but rather high-performance printers for industrial use. With regard to the print quality, PoD-capable printing systems based on non-impact technology have not yet been able to achieve the high level of quality typically associated with the conventional printing processes. For certain product areas, such as black-and-white printing without continuous-tone images, hardly any qualitative limitations can be recognized nowadays. Even in color printing the shortcomings in quality are becoming fewer and fewer and for many applications a slightly lower quality is accepted.

The demand for PoD production comes primarily from the market. Although the overall quantity of information is constantly and rapidly rising, the number of

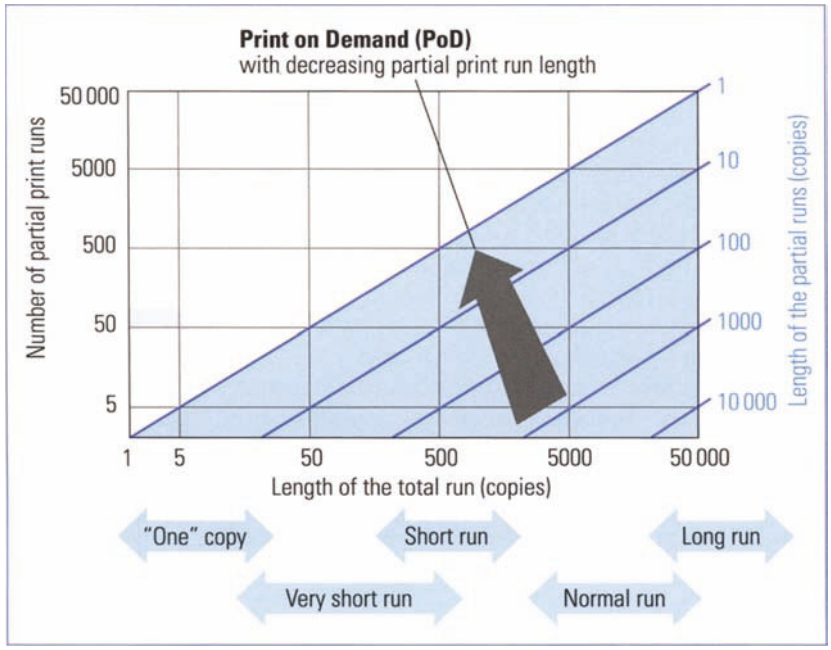


Fig. 9.1-9
Dividing the total run up into partial print runs

individual print runs is quickly decreasing in virtually all areas of print media, as well as in other media, such as the music business. This *individualization* of information demands new business concepts both from the information suppliers, such as publishers and from manufacturers of operating manuals. PoD is a technical process that can be structured into the following areas of application:

- *Very short print run length.*
  Only very few copies of the information to be printed are needed.
- *Normal and long print runs.*
  - *Continuous reprint*: to eliminate physical stock the information can be stored in a database and printed individually when needed.
  - *Sample prints in advance*: a short test run should be printed prior to the planned main print. If successful in the market a longer print run is then produced conventionally.
  - *Reprint*: as soon as the main run is used up a small additional print should be published.
  - *Topicality prints:* if the content of a printed product is subject to regular alteration, the latest version of the print can be printed "on demand."

Although PoD concepts have been discussed since the end of the 1980s, PoD printing still only represents a very small proportion of total printing production. This is also due to the fact that the economic potential of the applications for normal and long print run length is overestimated. Although in the book business, for example, between 25% and 40% of the printed edition cannot normally be sold and is eventually written off by the publishers, the costs associated with this are not as high as expected. This is because for a comparison of technologies only the manufacturing costs of conventional printing methods and those for PoD methods need to be considered (see fig. 1.9-7) and argumentation is not based on the book's end price. Since the costs for digital printing processes that are capable of PoD with variable image from print to print are still relatively high compared to conventional printing (see fig. 1.9-6), there is very little room to maneuver for the economic application of PoD. The only area where PoD has been able to achieve a significant market share is with printed products that require regular updates, such as computer handbooks.

There are also further problems regarding the application of PoD production concepts that are often not given the attention they deserve when considering potential applications:

- *Finishing of PoD products.* Only in a small number of cases is it possible to complete a printed product

merely through printing. In most cases more or less extensive finishing operations are necessary to complete the printed product. Technical solutions for economically attractive finishing of individual products are still in their infancy. For the production of books there are already systems for simple book design variations and medium quality demands available on the market. However, these bring a multitude of limitations to the design of the product that have to be tolerated.

- *Costs of developing contents.* Alongside its technical realization a printed product obviously requires a content that must first be generated and processed. For this, the work of authors, copy editors, layout artists, and so on, is normally necessary. For short print runs the costs associated are in most cases much higher than the technical costs and drives up the total costs significantly; these can only be distributed over a very small number of copies. The market for those products where this cost is either borne by the authors themselves (e.g., scientific publications) or where the customers are prepared to pay high prices for the product is limited.
- *Overhead and handling costs.* Processing a print job in a printshop requires a multitude of accompanying business processes ranging from the acceptance of the order, technical coordination right through to drawing up the bill. The costs involved in these processes must be included when calculating the total costs of a PoD job. While the mean proportion of these costs in conventional production come to a maximum of around 20%, they can easily be significantly higher with PoD production.

To implement a successful concept for PoD production, solutions must be found for the problems listed above. These normally take the form of a specific selection of the product range that takes account of the limitations of the technical equipment and the cost relationships for the total added value chain.

In the future, however, clear improvements can be expected in all areas. On the technical side, the printing costs of computer to press digital printing systems will continue to go down and flexible and economic solutions for finishing will become increasingly available. Using the Internet and an electronic workflow control system, the processing of PoD jobs will become increasingly automated and the associated costs will be reduced. Even for the preparation of contents, future developments such as digital libraries in connection with automatic content generating techniques will lead to new PoD-capable products.

An accurate prediction of who will provide what service in the PoD sector cannot be made at this stage. It is not only traditional printing companies that invest in PoD technology; prepress and finishing companies, copy services, and newly established printshops with those alien to the industry are trying to get a foot in the door of the PoD market. The actual "*content providers*", such as publishers, for example, base some of their production on PoD methods. There are wholesalers and book distributors that have started to offer services where books are stored electronically and where the book is printed and delivered on demand – that is, "*book on demand*" (fig. 9.1-6). Bookstore chains are attempting to bring the PoD business directly into the book shop by using compact printing and finishing systems.

9.1.4 Personalization

Viewed from a technical standpoint, print on demand and personalization are closely related since a subdivision of a total print run length is carried out for both of them. While with PoD the subdivision into partial runs (segments), which can be processed one after the other, is done according to time, with "*customizing*" (also known as "*targeting*" since the product aims at certain target groups) the total print run length is divided into "*versions*" with *certain portions of variable content.* Classical applications are, for example, language versions where the main run remains constant with regard to images and layout but the text is printed in different languages. Other applications, such as regional price versions, where various price information is printed in the catalogs, or dealer versions containing advertising that is actually the same, but where individual information such as a dealer address is added.

In conventional printing these kinds of products are either produced by changing individual printing plates (usually the black plate) during the entire print run while the other colors do not have to be changed. So-called "flying imprinting units" have been developed for this kind of application where it is possible to switch between impression cylinders. While the one cylinder prints, the other can be fitted with the plate containing the new version. Another conventional technical solution is to use imprinting units that are installed in the press in addition to the normal printing units in order

to print extra information on a usually relatively small printing area in a flexographic process. These imprinting units can also be equipped with a "flying" replaceable cylinder; they are used in web offset printing and gravure printing (see fig. 2.2-32; see also chap. 6/hybrid printing systems). This process ceases to be economical with very short partial runs since the makeready times of the replaceable printing cylinders impair productivity too greatly here.

Another way of producing special versions is "*selective binding*". Here, the individual print sheets are altered during gathering, which means that the bound product consists of different content sections. A typical area of application is the production of demographic versions where, depending on the delivery address, the end product has different contents. The technical limits of selective binding are set by the number of gathering stations that are necessary for the different sheets of the version. There are gatherers in use in the USA that have up to one hundred stations. However, with large numbers of different versions there are also economic limitations, since the volume of individual sheets per version then becomes low, which makes their production more expensive. If possible, total print runs consisting of different versions are produced in one operation without interruption.

Completely new areas of application with diverse demands on the variable, individual information sections of the printed product can be explored using digital printing technologies. The main part of the information to be printed normally remains unchanged while a few parts can vary from product to product. Personalization in its simplest form is used to print different addresses and information on individual pages of otherwise identical content (fig. 9.1-10; see also sec. 6.3).

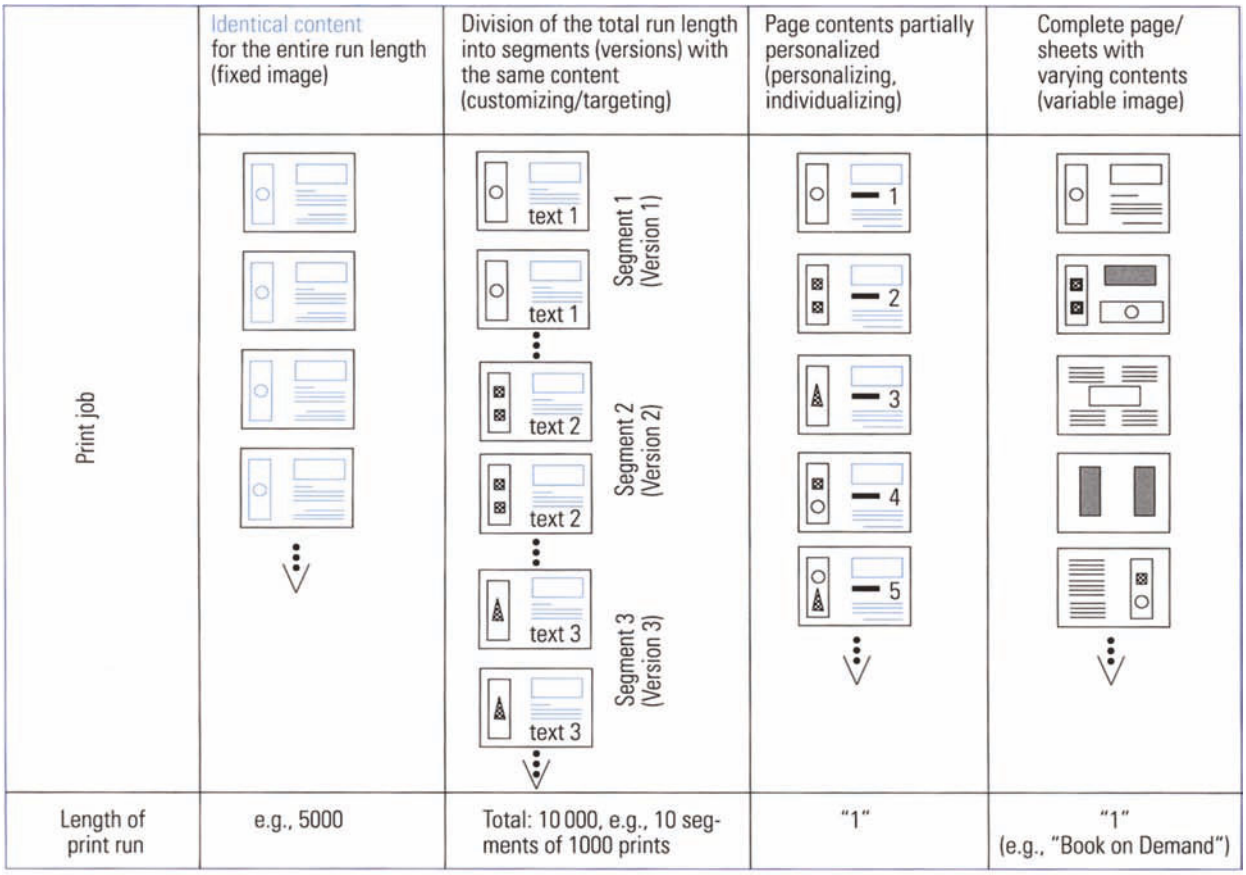


Fig. 9.1-10 Examples of print jobs with identical and variable content

Where to draw the line between classifying a printed product as a part of a long print run with individually variable contents and referring to it as an independent product (individual run, single copy) is not absolutely clear. In practice it very much depends on the production system in place.

Different terms are used for customer-specific versions and personalization according to type and extent of the variable contents. In the simplest case it is merely a matter of the imprinted numbers that are altered on the documents. This is known as *numbering* and can also be achieved using mechanical numbering boxes for consecutive numbering. To print complex numbering systems, that is, *coding* (e.g., for dispatch) only digital printing systems (at present mainly ink jet systems) can be used. Numbering or coding systems usually have a small inscription width of just one or several lines. When setting up the press for the job they are positioned at the correct location on the web. Typical applications are lottery tickets, entrance tickets, and securities.

When addressing (also *personalizing*), portions of text are written into the printed product, like addresses and individual greetings in an otherwise identical letter (see sec. 5.5, fig. 5.5-10 and chap. 6, fig. 6.3-7). Digital processing is necessary here to alter the content for each print. In the office this application is termed "personalized standard letter" and is printed in a relatively small number of copies. If larger portions of content are changed, such as if different advertisements are changed in accordance with the recipient, this is also known as "*individualization*". With individualization the content is not just text, but can also contain graphics or pictures. Figure 9.1-10 shows an example of how the page contents can differ within a print job.

Two different manufacturing methods for the printing of business form letters in large numbers (e.g., bills with personal content and address or *mailings*) are shown in figure 9.1-11 as an example of production with personalization. In variant a, the business form printing method is applied to produce the unchanged contents, normally in large numbers in an offset printing process. In a separate, second production process that takes place in "lettershops", the preprinted semi-finished product is provided with the individual infor-

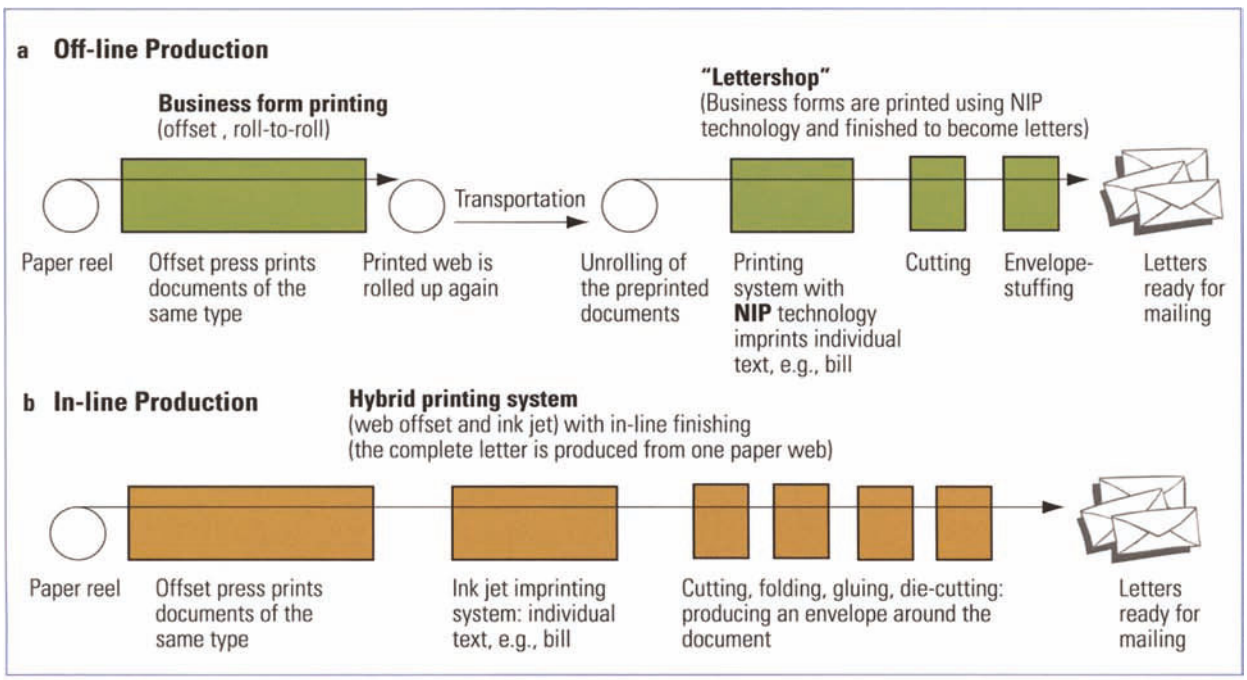


Fig. 9.1-11 Production concepts for the production of business form letters in large numbers.
a Off-line production;
b In-line production

mation, such as the text of a bill, and finished to make letters. The print is carried out in jobs of one letter/sheet with NIP printing systems. With "in-line-finishing production" (variant b in fig. 9.1-11) the same product is produced in an integrated production system (hybrid printing system), whereby the unchanged contents are first printed using offset printing and the variable part is then directly added with an ink jet imprinting system. Finally, the web is processed in-line and made into a letter, consisting of an envelope and inserted form (see chap. 6, e.g., fig. 6.3-8).

Labeling is a special form of personalization/individualization where the individual content is printed on labels (for example blank labels or self-adhesive labels) in a separate procedure. These labels are then added to the product during the printing or finishing process.

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9.2 Production Systems

Various basic concepts for the production of print media were described in section 9.1. It is particularly those parameters defined by the market and the clientele, but also those characterized by the location and internal conditions, that should be formulated into a framework for the orientation of a manufacturing operation, also taking account of strategic aspects.

In a second step these concepts must be implemented in *production systems* (where "production systems" are understood to include all the technical equipment needed to produce a certain product). A constant production process from developing to manufacturing right up to delivering the product must be defined here. Alongside the strategic considerations of which production concept to implement, the availability and economic viability of the potential means of production, that is above all the printing and finishing equipment and prepress devices, are decisive parameters involved when making a decision regarding production systems (fig. 9.2-1). Since it is the exception that there is only one decision-maker, such as a single company, responsible for all means involved in the production of a printed product, and far more common for various companies to be involved in various sections of the added value chain, the definition of interfaces at system boundaries must be taken into consideration when making decisions regarding the production system.

In addition to organizing the actual production stream as a production system, two control and coordination levels have to be integrated between the individual means of production:

- The coordination of technical parameters between individual means of production is not dependent on the products currently manufactured. Technical characteristics such as dot gain, folding characteristics, print formats and so forth must be harmonized within a production system and if necessary also adapted dynamically to one another in the running production process.

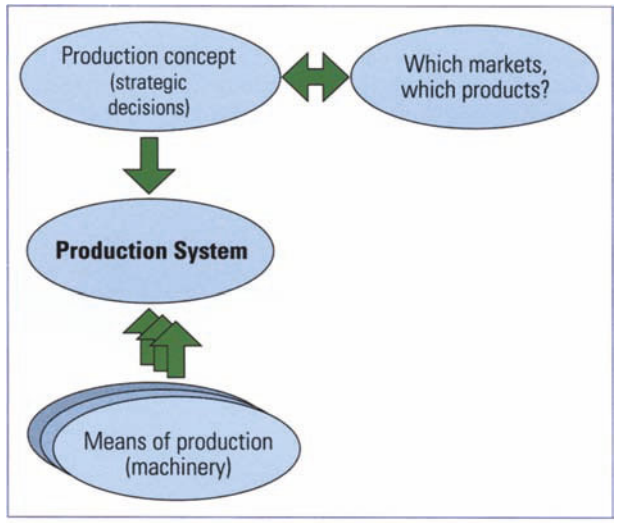


Fig. 9.2-1
Production systems between strategic parameters and available means of production

- The exchange of job-specific production data such as length of print run, colors and so on is necessary to enable capacity control and an optimal job manufacturing sequence.

While matching these parameters normally takes place manually in traditional printing companies, modern production systems have integrated software components to take over these tasks. These software components are often referred to as workflow systems (see sec. 8.2). Figure 9.2-2 shows the main components within the production flow for producing print media.

In printing companies the system analysis of production processes is usually still approached very pragmatically. Technical/strategic concepts are frequently reduced to single purchase decisions of machines or units that can also have the effect of unconsciously prejudg-

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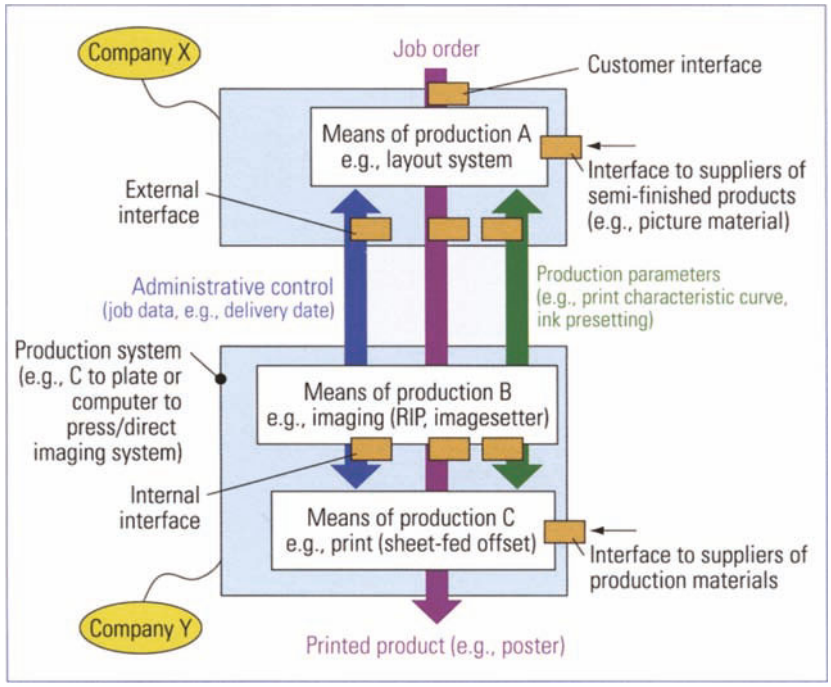


Fig. 9.2-2
Schematic representation of components used to produce print media (Computer to Press system with integrated RIP and digital imaging system)

ing and limiting later development potential. Together with the multitude of printing products demanded by the market and the hugely diverse production concepts evolved from this, almost every printing operation has its own individual production system that has come about from the company's own history of development.

Printing is a central stage in the added value chain of printing production. The rapid technological development in the field of new digital printing technologies resulted in a broad spectrum of potential production technologies that can be employed to create extremely diverse production systems. These *variants for digital printing* are described below.

Digital Printing Systems. The basic technical concepts for printing presses used in digital printing are shown in figure 9.2-3. There are different variants in each case where the units for image processing (raster image processor RIP, see sec. 3.2.6), handling of the image carrier, and the actual printing units represent a *production system* with which the printed sheet can be produced from a data file (the system boundaries can be extended by adding finishing and/or prepress processes). Differentiation should be made between the following principles/variants:

- *Computer to plate* (C to plate): The imaging of the image carrier takes place off-line from the printing press in a separate unit (see sec. 4.3). The plate is fitted mechanically into the printing press and cannot be erased, that is the plate can only be used once.
- *Computer to press/direct imaging* (C to press): Imaging and printing are integrated in one machine while still remaining two separate process steps. Various methods are used for imaging (see sec. 4.4) and printing is generally carried out using an offset process. The image carriers, which are either metal or polyester plates, contain a permanent image and are changed after the print job. The dotted "computer to press" section in figure 9.2-3 suggests that computer to press/direct imaging is also possible without needing to change the plate using a re-imageable master. Here, the image on the plate cylinder or other image carrier is erased after the print job and re-imaged for the next job (see sec. 4.4.2).
- *Computer to print* (C to print): Imaging and printing are integrated in a close process in one machine. According to the type of press used, the printing process is based on different NIP technologies (see

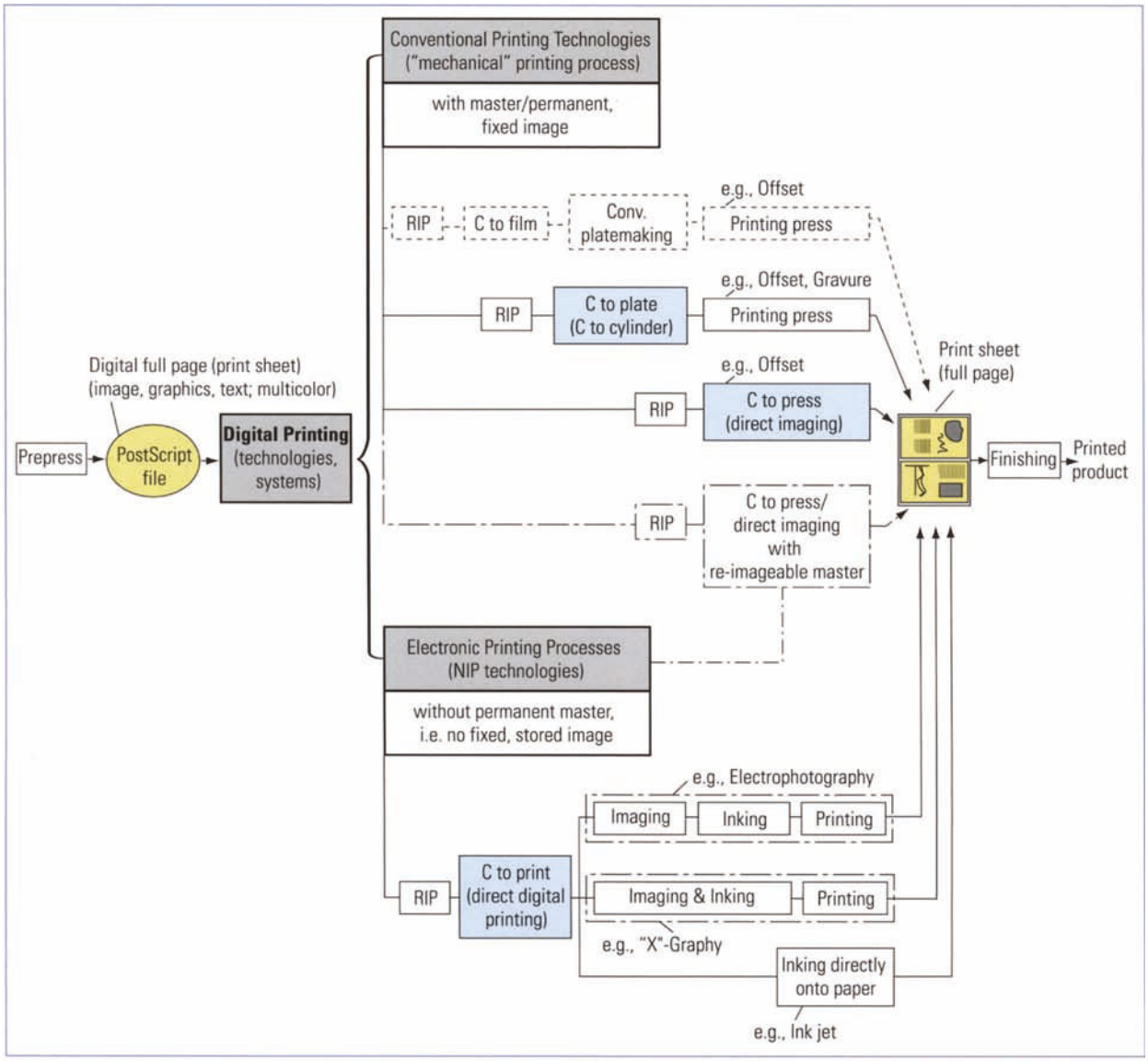


Fig. 9.2-3 Digital printing: processes, components, variants, and systems

sec. 4.5 and chap. 5). A latent image, for example, is generated on the image carrier (e.g., electrophotography) which is automatically erased after each print and needs to be re-imaged for the next impression (even when printing the same content again).

- To enable a comparison, figure 9.2-3 also shows the *conventional production system* where the information to be printed is first imaged onto film material using *computer to film* that must then in turn be copied onto the printing plate. The production process with computer to film (see sec. 4.2) will increasingly be replaced by computer to plate in the future.

Table 9.2-1 is a comparison of the most important characteristics for the various production systems.

Table 9.2-1
Conceptual features of printing systems

	C to Plate Computer to plate	**C to Press** Computer to press (direct imaging)	**C to Print** Computer to print (direct digital printing)
Printing process	Offset	Offset	NIP (e.g., Electrophotography)
Image on the master	Permanent	Permanent	Latent, self-erasing
Where imaging takes place	external	in the press	in the press
Mechanical plate change	Yes	Yes	No
RIP: Computing speed influences job change	No	Yes	No
RIP: Computing speed affects printing speed	No	No	Yes

(RIP: Raster Image Processor)

Due to the latent imaging, there is no makeready time with a computer to print system. The image is newly created for each print and then erased. This means that multi-page jobs with the run length "1" can be printed without interruption for any number of different image contents per page. A computer to print system can, however, only be as fast as the constantly changing image information provided by the EDP (electronic data processing) system. The printing speed of computer to print systems is therefore limited by the performance of the raster image processor (RIP), the data transfer systems, and the control electronics. Modern commercial high-performance printing systems can print at a data rate of up to around 100 MB/s.

With computer to plate, the printing system is not dependent on the computing/processing speed of the imaging system since the imaging takes place off-line. The makeready time is determined by the time required for the mechanical replacement of the plate. Even if this time can be minimized by using automated systems, it is still a decisive factor for the productivity of the system in the case of short print runs. The printing speed itself is limited only by the actual printing process. Conventional printing presses are significantly faster in the actual printing process than computer to print systems. The processes of imaging and printing, which are separated with computer to plate, need, however, to be adapted in their capacity potential, so that economic production is actually possible.

With computer to press systems (direct imaging), the imaging takes place in the printing press. The aim of this concept is to be faster and also more cost-effective than changing the plate mechanically. As is the case with conventional printing systems, the printing speed is dependent only on the printing process. With a computer to press system, however, the imaging unit and the printing unit are directly linked to each other, so that the imaging unit cannot be used during the printing procedure. Imaging units are very cost-intensive with higher quality requirements (particularly if a high imaging performance is targeted in order to reduce makeready times). Therefore, long print runs on a computer to press system can become uneconomical compared to a computer to plate system (off-line platemaking) since the latter system's separate imaging unit can process other jobs during the printing procedure. For short print run length, on the other hand, makeready times play a decisive role, which can make computer to press systems more profitable.

Clustered Printing Systems. As explained in section 9.1.2.2, a distributed production concept can bring advantages. In color printing, production systems have been introduced where a group of small printers is controlled in parallel by a RIP and a common control system ("*clustered printing systems*", fig. 9.2-4). Alongside the positive effects of a distributed production system mentioned in section 9.1.2.2, direct cost advantages can

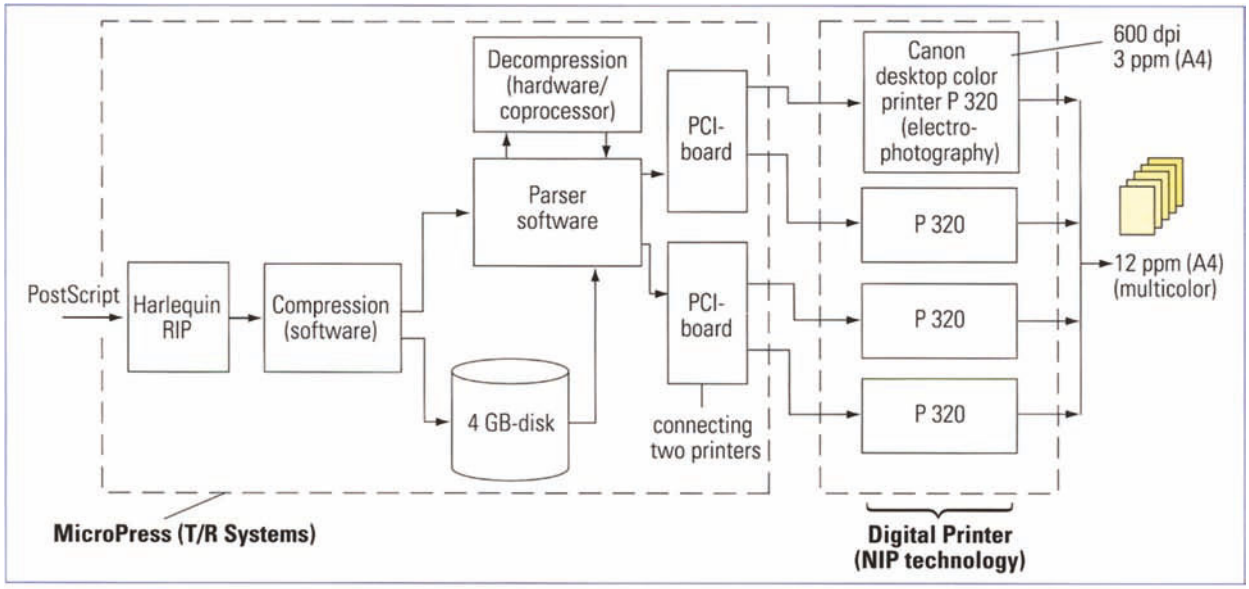


Fig. 9.2-4 Clustered printing system (MicroPress/P320, T/R Systems/Canon)

also come about here since the small printers, which are typically used in office environments, are relatively cheap because they are mass-produced and with limited performance. This cost advantage must not only apply to the investments costs of the installation, but also to the variable cost of consumables, particularly the costs of toner, photoconductor drums, and service.

Examples of Print Production Systems. The following is a description of different *production systems* – systems containing the printing and finishing processes as well as systems that have prepress, printing, and finishing integrated in one production unit.

Figure 9.2-5 shows a *web offset* installation; the printing process (heatset web offset printing with hot-air



Fig. 9.2-5
Web-fed offset printing system (M-600, Heidelberg)

drying) and finishing (cutting, folding, stitching) are combined in one production system – on which completely finished multi-page brochures can be produced.

Non-impact printing technologies have the advantage that the ink (toner) on the paper is already dry after printing and finishing can therefore be carried out immediately. Figure 9.2-6 shows the integration of prepress, print, and finishing in diagrammatic form. Figure 9.2-7 shows a multicolor printing system based on the non-impact printing technology of electrophotography. High-speed non-impact printing systems based on electrophotography for single-color printing are shown in figures 9.2-8, 9.2-9, 9.2-10, and 9.2-11. Printing systems with such a high level of integration could be defined as follows: "digital job data enters the system and the finished product comes out of the system"/"*data in, product out*" (fig. 9.2-12).



Fig. 9.2-7
Digital multicolor printing system (electrophotography) for the production of multi-page brochures (CLC 1000/FN4 Remote, Canon/Nagel)

Hybrid Printshops. As illustrated in section 9.1, printing companies are increasingly making use of independent, different printing systems where conventional printing methods (such as offset) are combined with printing systems based on non-impact technology. Figure 9.2-13 shows one such printshop in which a sheet-fed offset press and a computer to print unit operate alongside each other (the combination of conventional printing methods and NIP-based technologies within *hybrid printing systems* is described in chap. 6).

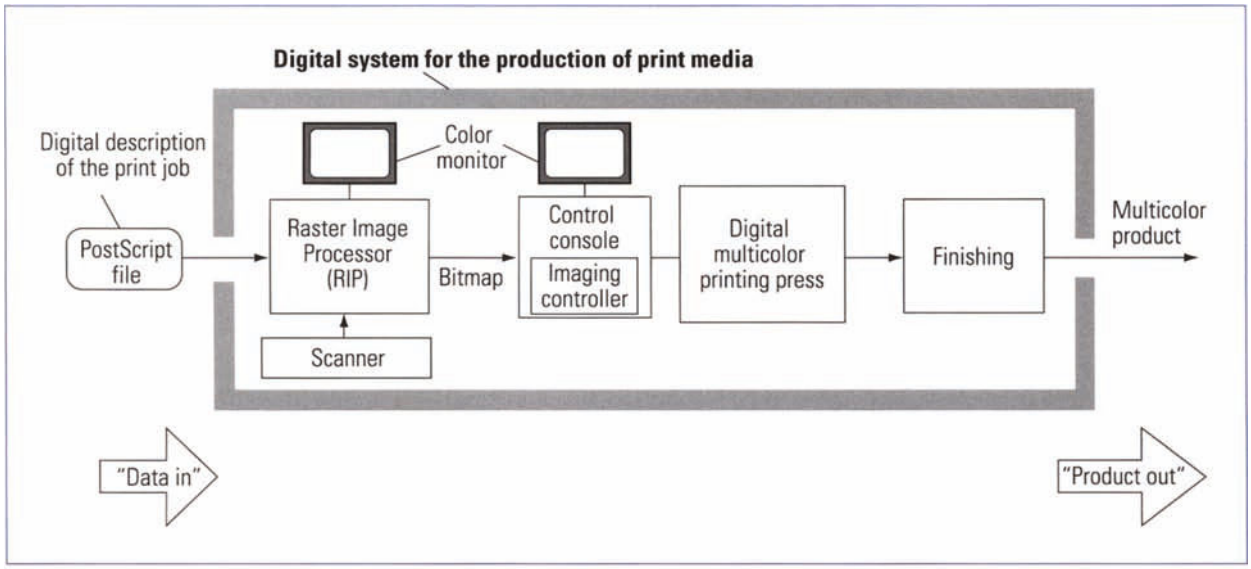


Fig. 9.2-6 Block diagram of a production system with integrated prepress and finishing unit

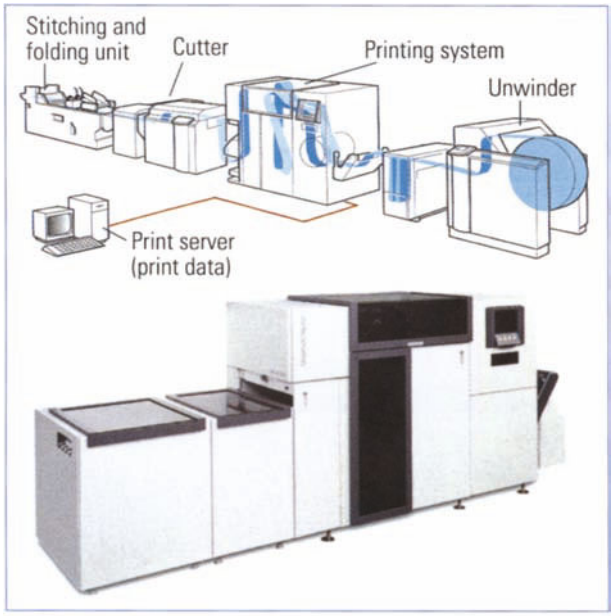


Fig. 9.2-8
Production system (electrophotography) for single-color printing on web material with finishing components for "book on demand" production (DemandStream 6000 DI, Océ)



Fig. 9.2-9
Printing system (electrophotography) for single-color printing on sheet material with integrated finishing components and scanner (DocuTech 135, Xerox)

Fig. 9.2-10
Printing system (electrophotography) for single-color printing on sheet material with in-line finishing system (Digimaster 9110, Heidelberg; see also fig. 4.5-11)



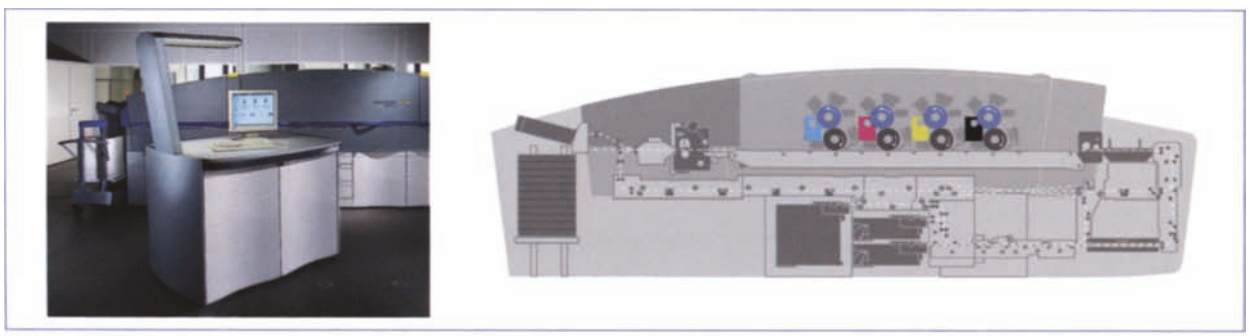


Fig. 9.2-11
Digital production multicolor sheet-fed printing system (electrophotography, 600 dpi, multiple gray values per pixel, LED imaging system, unit construction/singlepass design, intermediate blanket cylinder, format A3+/portrait, 70 A4 pages/min, 2100 A3 pages/h) with perfector for in-line printing on both sides of the sheet (NexPress 2100, Heidelberg/ Kodak)

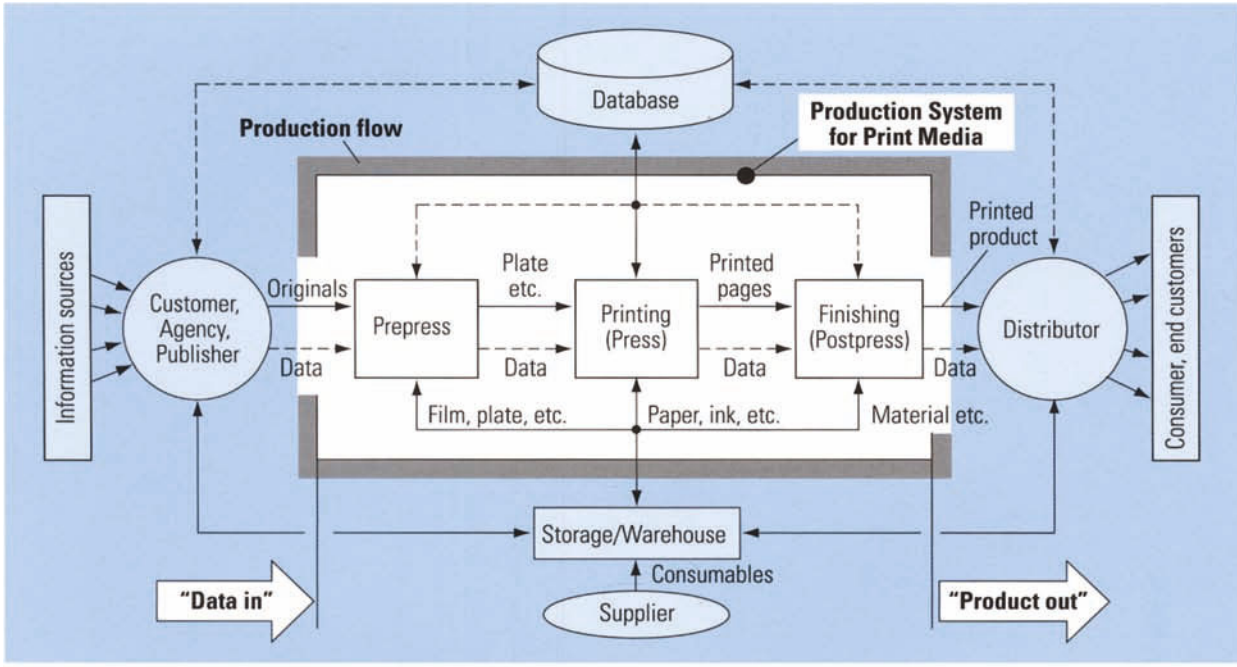


Fig. 9.2-12 Workflow for producing printed products as the basis of a digital, integrated production system for "data in", "product out"



Fig. 9.2-13
Printing company with conventional (offset) and digital (electrophotographic) printing systems (Speedmaster and DCP/32D, Heidelberg/Xeikon)

10 Comparison of Printing and Production Technologies for Print Media

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10.1 Introduction

Figure 10.1-1 shows a summary of the *production flow* for the production of print media and in particular the interaction between prepress, printing (press), and finishing (postpress). The individual process steps are linked by the flow of materials and data. The *logistics* within the production flow for the provision of materials and data are of special importance.

In accordance with the diagram shown in figure 10.1-1, the different technologies, equipment, and materials are explained in detail in the previous chapters. In particular, technological possibilities with different levels of *digital integration* of production equipment and production flow are discussed, that is, the linking of the individual production steps can be achieved to a greater or a lesser extent via data.

In chapter 3, both analog (conventional) and digital *prepress* is dealt with, as well as common features and potential for further development with a view to increasing digital integration.

An indepth description of the various *printing technologies* that produce the entire print run length with the same print image based on a permanent image carrier is given in chapter 2. Non-impact printing technologies, which require no master and can therefore produce a print content that differs from print to print, are described mainly in section 4.5 and chapter 5.

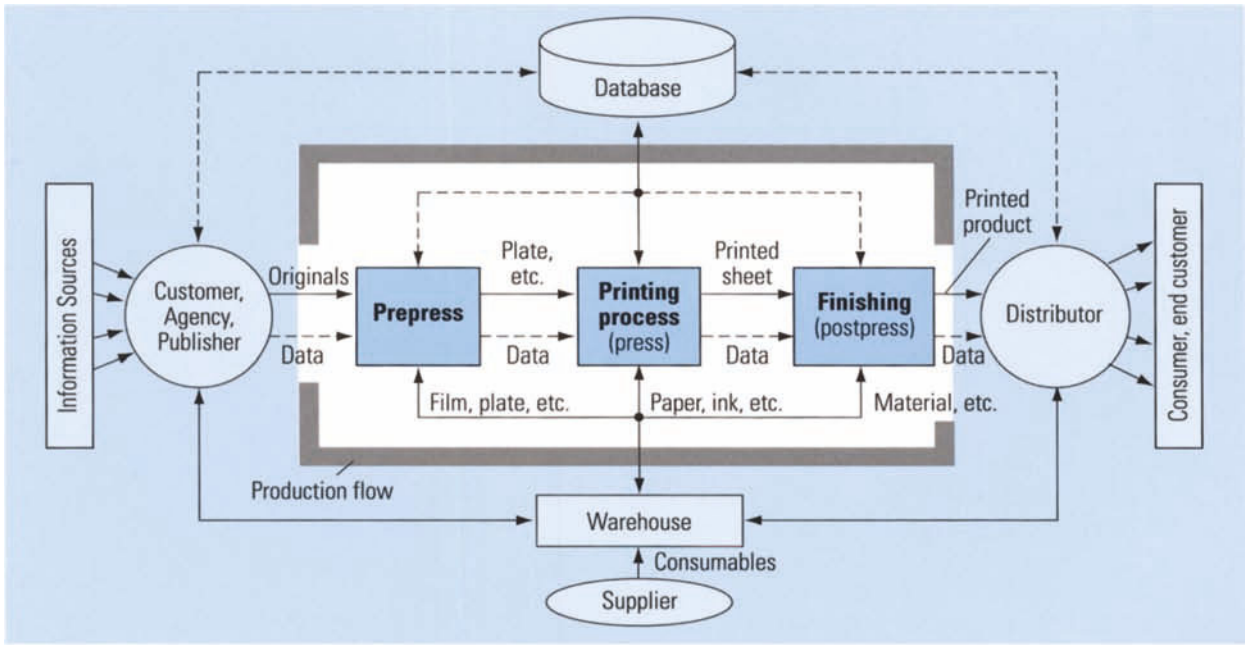


Fig. 10.1-1 Production flow for producing print media

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The many and diverse possibilities and equipment for *finishing* are explained in chapter 7.

The *flow of data and materials* and the logistics in the individual areas for the production of print media and in the company as a whole are described in chapter 8.

Based on the different printing technologies and production methods, *strategies* for the production of print media are discussed in chapter 9.

The following chapters give an overview, while further details and additional information are contained in the aforementioned chapters. *Comparisons* are carried out, *positionings* worked out, and *trend statements* summarized.

10.2 Overview of Methods and Technologies for the Production of Print Media

The *printing process* is of central importance in the production flow for the production of printed products. Figure 10.2-1 shows a general overview of the *printing technologies*.

Conventional printing technologies using a master and *non-impact printing technologies* requiring no master are shown together with their different technologies. In particular, possibilities for the configuration of

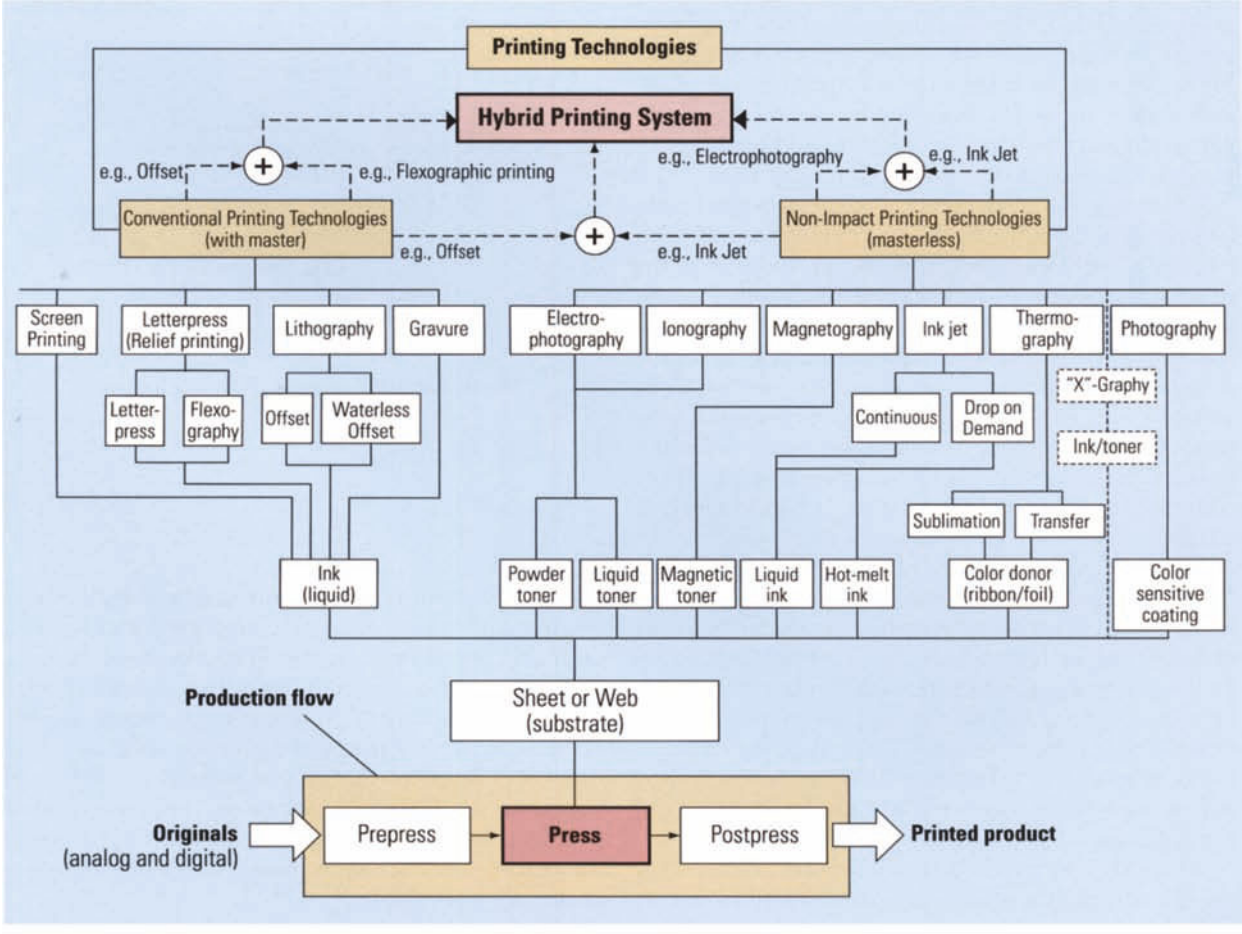


Fig. 10.2-1 Overview of printing technologies (and their use for the set-up of hybrid printing systems)

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hybrid printing systems were included in this overview. Hybrid printing systems, combining different printing technologies in one printing system, are capable of producing special printed products while maintaining a high level of economic efficiency and productivity (see chap. 6).

Printing takes place on *sheet or web material* as shown in figure 10.2-1. The question of whether web-fed or sheet-fed printing systems are to be used essentially depends on the run length. Sheet-fed printing systems are generally characterized by a higher degree of format flexibility, web-fed systems by a higher productivity.

The evolutionary development in the graphic arts industry, in printing companies, and in publishing houses was essentially determined by the *digitization* in all stages of the production process.

In particular in prepress, the change from analog to digital technology has been of outstanding importance and resulted in a considerably changed mode of operation. The *digitization of prepress*, which made it possible to describe the entire print job with text, graphics, and single- or multicolor images (fig. 10.2-2) completely digitally, was the driving force and the basis for the development of new productive equipment.

Figure 10.2-3 shows what is called *computer to ... technologies*. Based on the digitally defined/described print job, the production process for the production of the printed products can be digitized to various extents, and that the number of production stages can be reduced. It ranges from computer to film to computer to plate and, finally, to computer to press systems, which enable production of the printed product directly upon acceptance of data in the press without a separate prepress stage for film or plate making. These computer to ... technologies are described in detail in chapter 4.

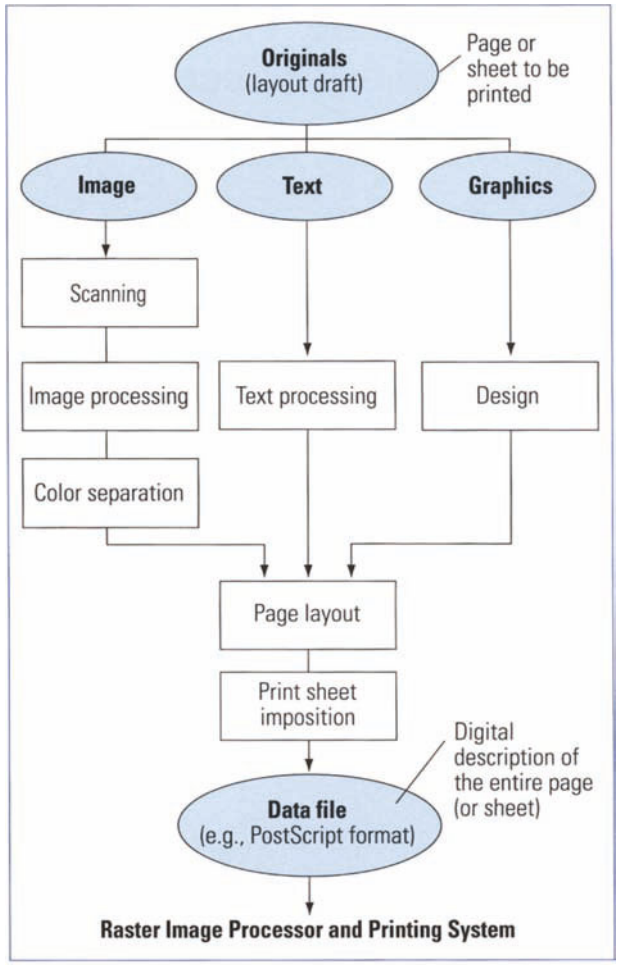


Fig. 10.2-2 Digital prepress

Print media are being produced to an increasing extent by what is called *digital printing*. Figure 10.2-4 again shows the various possibilities, methods, components, and systems for digital printing. Depending on the technology used, there is a difference in the levels of integration of digital techniques in production. What they all have in common is that the printed product is produced by equipment that can be controlled and operated on the basis of the complete digitally described print job.

Which *systems* are used *for digital printing* depends on the company's order structure as well as on its technical equipment, possibilities available to cooperating companies, and associated production steps, such as prepress or postpress. What is essential is that, when using the technical possibilities and the modular system structure of production equipment, the increasing standardization of materials, data, and productive equipment enables continuous expansion of companies as digital integration for the production of print media grows. *System solutions* and *flexible production concepts* are increasingly becoming the state of the art.

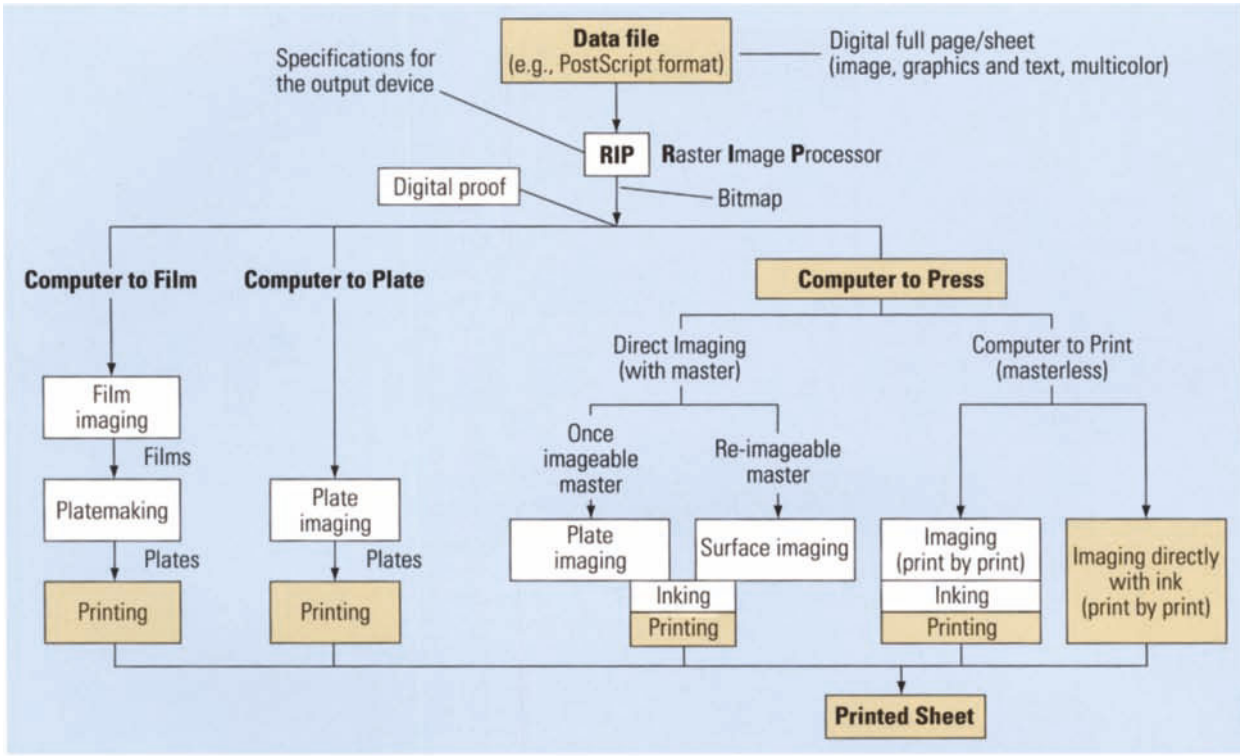


Fig. 10.2-3 Computer to ... technologies

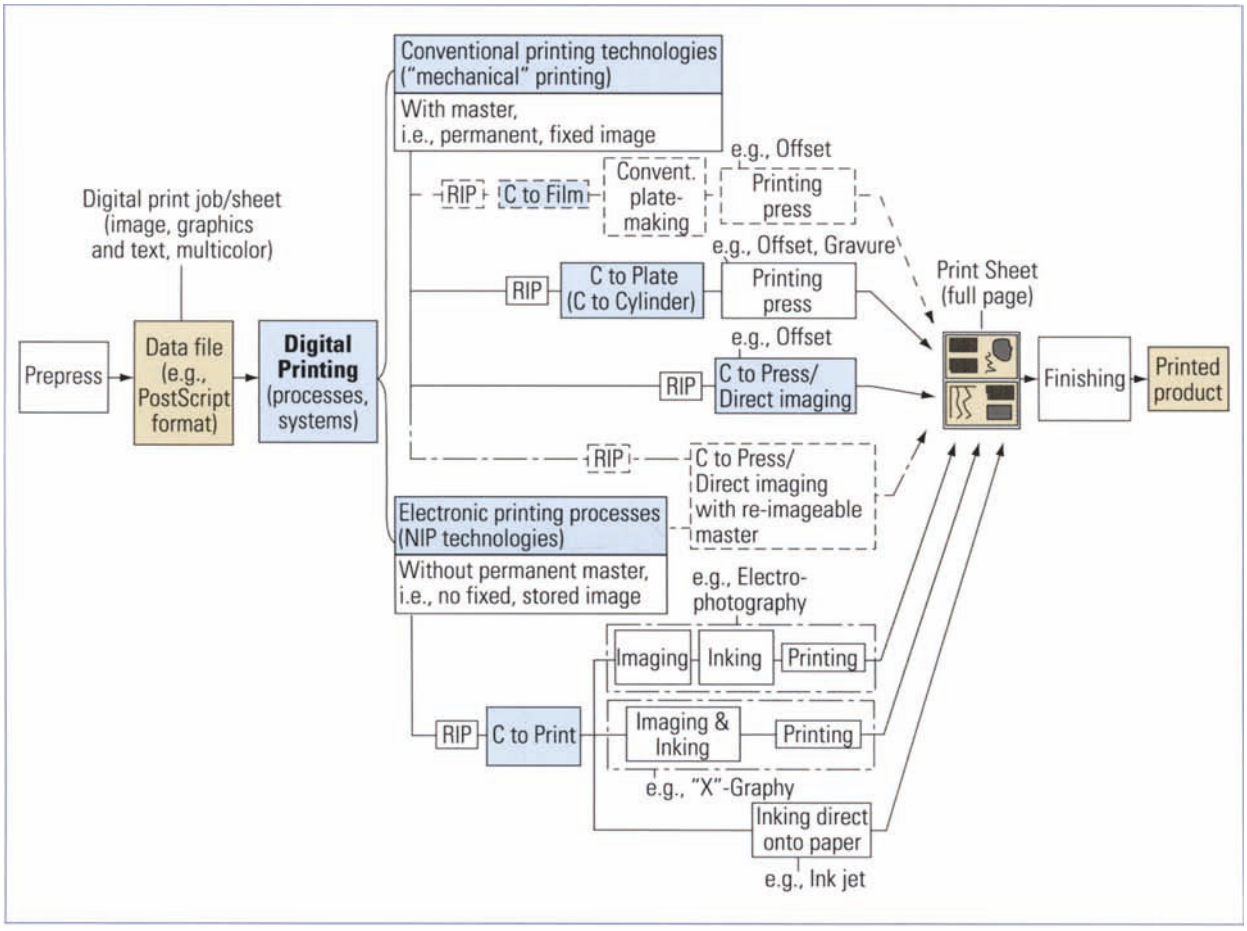


Fig. 10.2-4 Digital printing: Possibilities, components and systems

10.3 Production Methods and Strategies

Figure 10.3-1 shows the *production flow* for the production of print media in greater detail, to complement figure 10.1-1 corresponding to section 8.2. The functional blocks in figure 10.3-1 correspond to production steps that can be combined by digitization to an ever increasing extent.

As explained before, digitization has made it possible, particularly in *prepress*, for typesetting production, image capture and processing, as well as graphics preparation and page or sheet assembly to be performed completely digitally, while further processing is performed by the various computer to ... technologies shown in figure 10.2-3.

In the *printing section*, the production steps of plate making and printing are being brought together more and more by digitization using computer to plate and direct imaging technologies. In particular the use of computer to print systems that are based on non-impact printing technologies enables the production of print media without master.

The data of the digitally described print job can also be used to control production steps in *off-line finishing* for increased economic efficiency and quality. In the case of computer to print systems, finishing can be integrated relatively easily (dry ink on the sheet, variable image, low production speed) so that the complete production of a printed product (e.g., a brochure of several pages) can be performed *in-line*.

The overview in figure 10.3-2 shows that all types of equipment in the entire workflow can be controlled and operated on the basis of the *digitally described print job* as per figure 10.2-2. In the prepress stage, for example, *digital proof* and *computer to film* systems are operated using the same data file. In the prepress department or in the press room *computer to plate* systems are also used for the production of plates for sheet-fed or web-fed

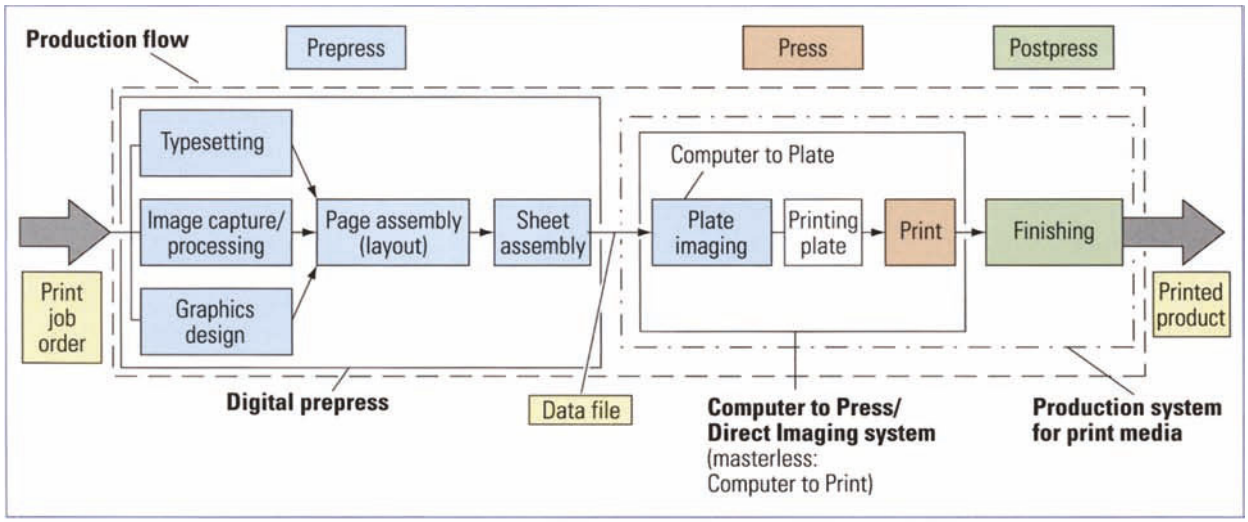


Fig. 10.3-1 Workflow (production flow) for the production of print media

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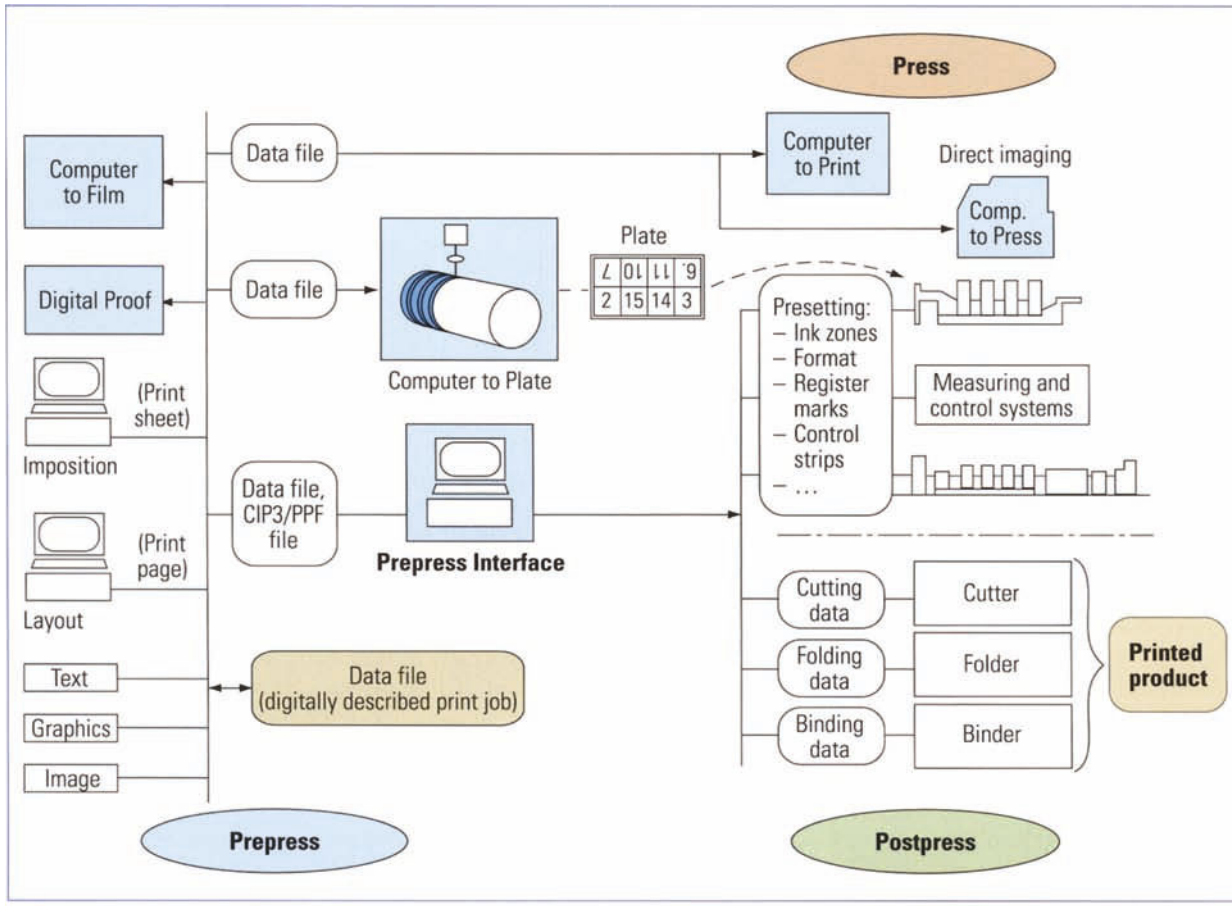


Fig. 10.3-2 Digital process control and networking different means of production within the digital workflow

presses. Using the same data file, the *computer to press/direct imaging system* or *computer to print systems* can be operated via suitable raster image processors.

For *presetting* presses and finishing systems, relevant items of information can be filtered out of the data of the print job via an appropriate *prepress interface* and then used for automatically performing fast, precise, and job-specific presetting on production equipment.

Figure 10.3-3 again shows in compact form how production systems for print media can be set up on the basis of the structure shown in figure 10.1-1 using available technologies with prepress, press, and postpress integrated in one single system. How systems of this type operate can briefly be described as "*data in, product out.*"

Figure 10.3-4 shows different *production methods* and *distribution options* for print media. The digitization of prepress and the possibility of describing the print job completely digitally has created new methods and strategies for distributed production of print media. It is now possible to print short run jobs at different locations *close to customers* both simply and cost-effectively. *Centralized printing* of the entire print run length, which is then transported to the different distribution locations, is still of great economic importance. However, depending on the product and the location, companies employ both the "*print and distribute*" and the "*distribute and print*" production strategies.

In particular for *distributed printing*, figure 10.3-4 shows how production can be performed at various lo-

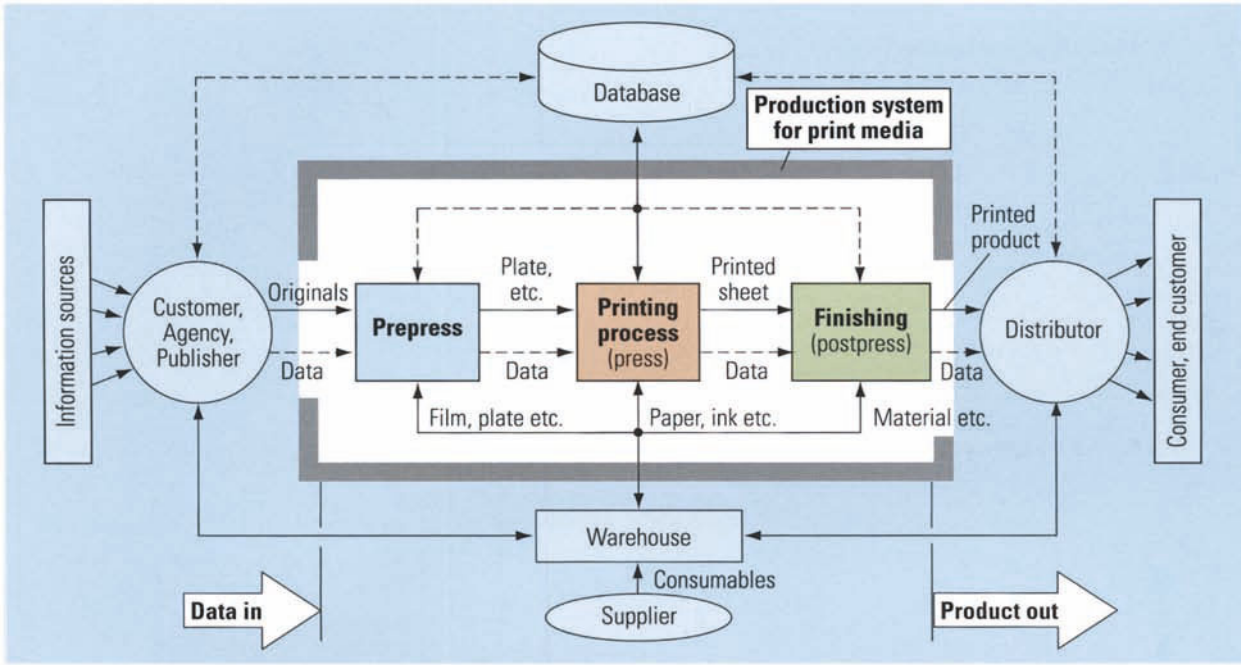


Fig. 10.3-3 Production systems for print media ("data in, product out")

cal printing companies and organizations on the basis of digital job data and with *different levels of digital integration of the equipment*. The possibilities range from digital prepress to digital film or plate production and conventional printing up to "book on demand" production, where one single book can be produced from the first through to the last page by means of non-impact printing technologies with data transferred via the network.

In the case of *centralized print production*, the printing section of the company can, of course, be equipped in accordance with the variants for machinery equipment as shown in figure 10.3-4b. As mentioned above, in many companies both production methods – centralized and distributed – are used depending on customers and products.

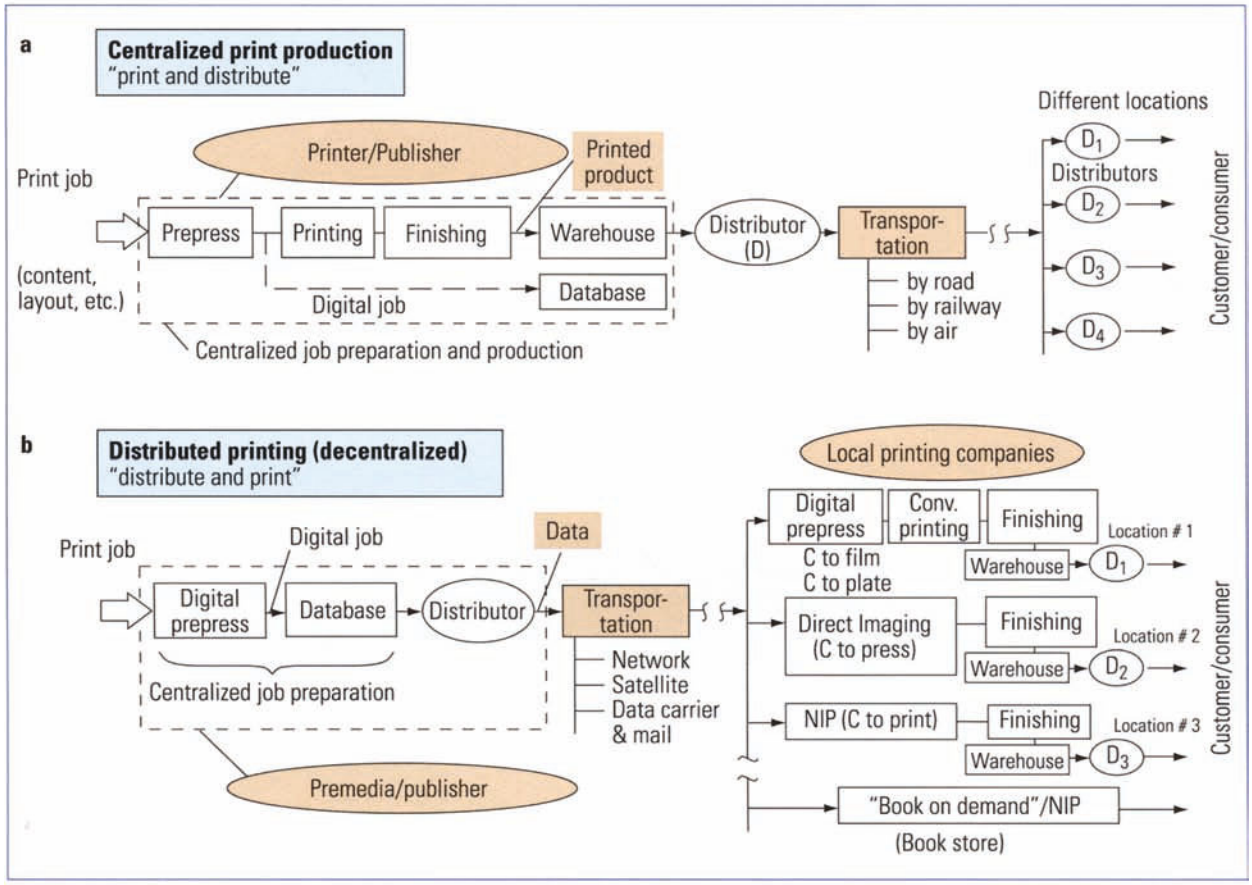


Fig. 10.3-4 Production methods and strategies with distribution channels for print media.
a Print and distribute;
b Distribute and print

10.4 Criteria for the Selection of Printing Technologies and Production Methods

The various printing technologies and production possibilities complement rather than compete with each other. The selection of specific technologies depends, among other factors, on the printed product and the markets, the locations and the qualification of the operating staff, as well as on the infrastructure of the company's operations.

Figure 10.4-1 shows some of the *criteria and subject areas* that must be taken into account if decisions about investments in new productive equipment and new production methods are to be made.

In figure 10.4-2, *decision criteria* and detailed *questions* are listed that need to be answered in order to make decisions about investments into new equipment and production methods.

The main factors to be taken into consideration are the *type of print jobs* to be processed, the *contractor/customer*, and the *form* in which the *order/print job is received.*

As regards the printed product, the *question of costs*, as well as of *deadlines* and *quality*, is particularly important.

The *production system* itself must be critically reviewed as regards *productivity* and *reliability* and meet the specified requirements (particular caution must be employed when making decisions about excess dimensioning/reserve, measured against the requirements of the current planning).

Quality and costs are determined by the *consumables* and *services* required to operate a production system or a system within the process chain for the production of print media.

Also of special importance are the demands placed by the production system on the *qualification of the operating staff* as well as an assessment of the *acceptance* of necessary operating routines and working techniques required by the system from the operator.

The level to which new equipment can be *integrated* into the printing company's already existing equipment and its potential for expansion is also important.

The actual *technology* – including all its details – which is integrated into the production system for performing its task is of minor importance for decision-making. The realised technology within the system

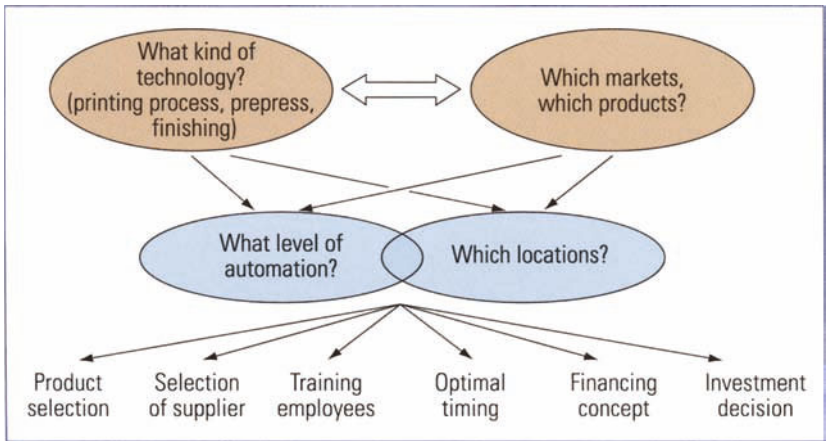


Fig. 10.4-1
Criteria for strategic decisions and subject areas concerning investments in production equipment and production methods

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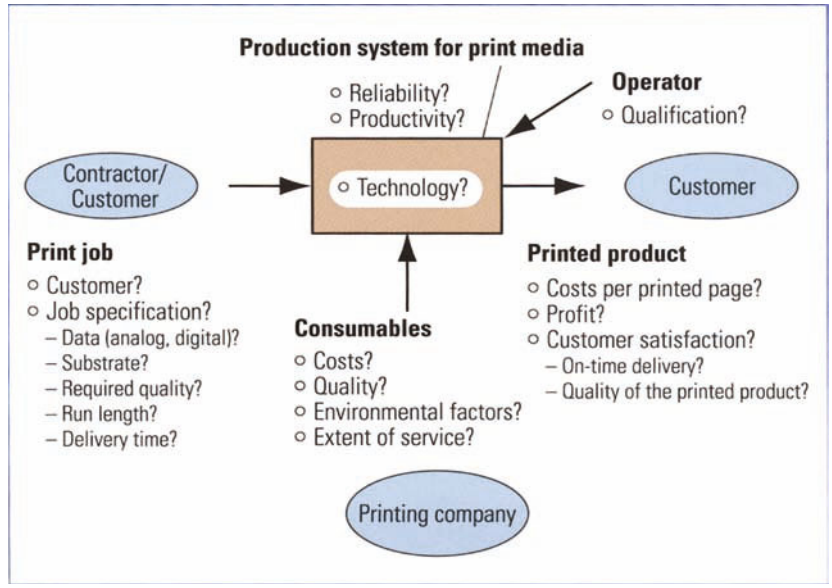


Fig. 10.4-2
Criteria and questions concerning investment decisions for equipment and production systems within a printing company

must result in a fulfillment of the requirements placed on the system, in particular as regards the *costs per print page*, *reliability* of the system, *productivity*, and *quality* of the printed product. The technology must guarantee that the system is optimally integrated into operations, and that the system can be operated so that the printed products and fulfillment of the specifications as required by the customer are met in terms of costs, quality, and deadlines, while maintaining economically successful operations.

10.5 Performance Criteria of Printing Systems and Trends in Print Media Production

10.5.1 Quality and Productivity/Run Length

The portfolio as in figure 10.5-1 shows a positioning of printing technologies and corresponding printing systems for multicolor printing. Positioning is done in terms of *print quality* and *run length*.

It can clearly be seen that maximum print quality is achieved using *conventional printing technologies* with a master. These are also preferred, however, on account of their economic efficiency in long run lengths. The corresponding printing technologies and production systems for gravure, web-fed and sheet-fed offset printing are described in detail in the previous chapters (principally in secs. 2.1.6 and 2.2.2). Because of their special applications and quality specification, flexo printing and screen printing are not included in this

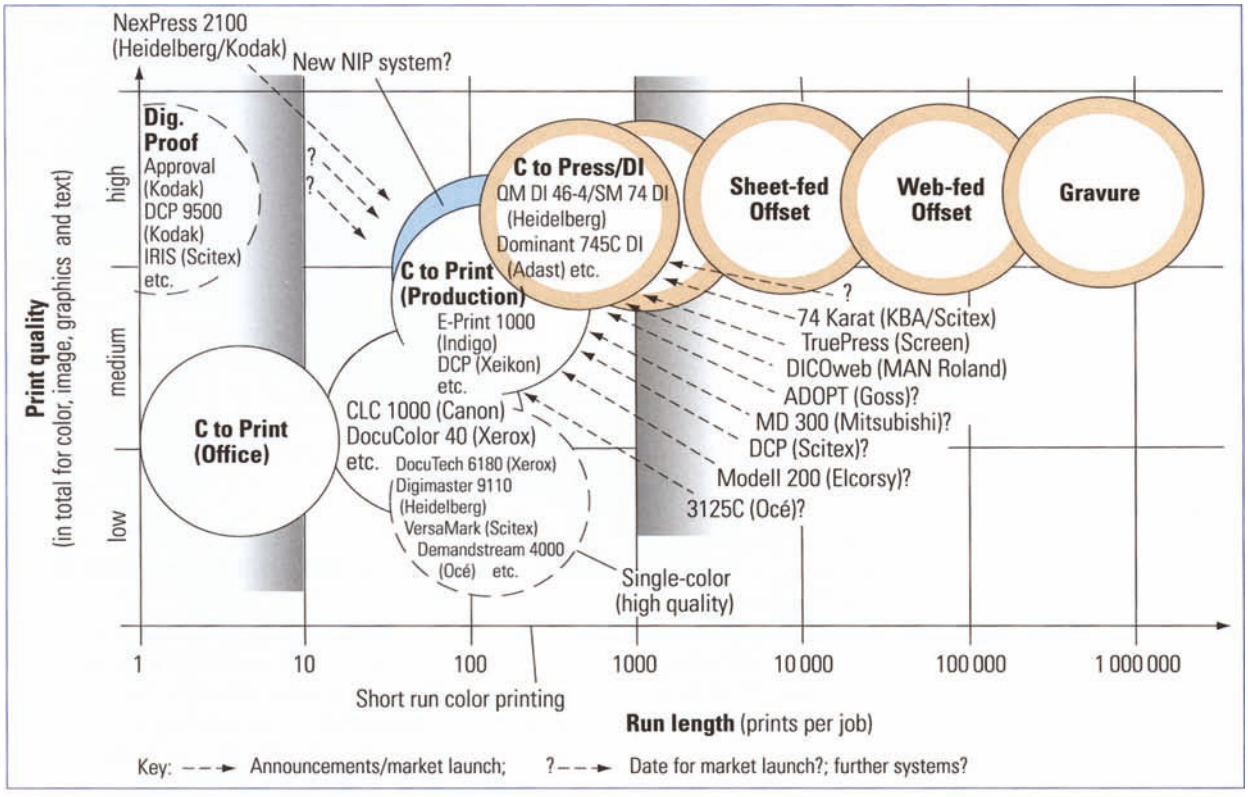


Fig. 10.5-1
Positioning of printing processes and technologies for multicolor printing, with product examples and product announcements (selection, status: 1999)

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description. Explanations of the application can be found in sections 2.3.3 and 2.4.3.

Based on *computer to press/direct imaging technologies* (C to Press/DI), printing systems using a master have been developed that are generally used for relatively short run length demanding high quality. The corresponding systems are described in section 4.4.

Printing systems based on *non-impact printing technologies* (C to Print) that do not need a master are suitable for very short run length. For process-inherent reasons, however, the quality level attained is low in comparison with printing systems using a master, as shown in fig. 10.5-1. The digital printing systems developed during the last few years, which are based on non-impact printing technologies, are designed for higher productivity than systems for office or DTP applications (see sec. 4.5). They enable economical and fast (on demand, just in time) production in what is known as "*short run color printing*". The print quality of these systems is good and meets the requirements of numerous applications/print products, yet does not equal the quality of methods requiring a master, in particular the high-level quality achieved by offset printing. As indicated in figure 10.5-1, it can be expected that, by using innovative, improved non-impact printing systems of high productivity, further improvements of the print quality will be achieved as well.

A very high print quality can also be achieved with non-impact printing technologies, for instance, with systems for *digital proofing*, mostly in connection with special substrates. Explanations and examples of systems are given in sections 3.2.11, 5.5 and 5.6.

According to the explanations in the previous chapters regarding new system concepts and *product announcements*, the illustration in figure 10.5-1 contains indications concerning the positioning of the announced systems as regards quality and length of run, in particular for additional computer to press/direct imaging and computer to press systems. There is also information with which new developments of multicolor printing systems can be expected for new systems, based on existing high-speed systems for single-color printing. Relevant information is given in chapters 5 (NIP Technologies) and 6 (Hybrid Printing Systems).

10.5.2 Productivity

As shown in the diagram in figure 10.4-2, the productivity of a system and its reliability are of special importance. Depending on the length of run, the printing speed is an essential factor. *Printing speed* and the *makeready time* required for preparing the press for a print job must be assessed together with the length of run.

The printing speed alone is not decisive for the *productivity* of a printing system. The makeready time required for a job change must also be taken into account. In addition, the extent to which the press is available, that is, how long it can be used for production, is important. The rate of utilization based on the order situation and working method must also be taken into account.

This means that an *evaluation of the productivity* of different printing systems is a complex process that will not be dealt with in this chapter (see also sec. 9.1.2.3). Figure 10.5-2 is a *comparison*, only by way of example, between *printing systems* for digital multicolor printing on the basis of non-impact printing technologies and printing systems using a master such as the direct imaging system and the conventional sheet-fed offset printing press. (In the case of the conventional sheet-fed offset press, it was assumed that the masters had already been produced off-line and could be mounted directly in the printing units, while imaging of the masters is included in the makeready time in the case of the direct imaging systems.)

It is evident in figure 10.5-2 that printing systems using a master have longer makeready times than non-impact based printing systems, yet they produce the job in a shorter time even with a relatively short run length due to their considerably higher production speed. NIP-based computer to print systems have, of course, the advantage that they can print a different content from print sheet to print sheet, that is, that a run length of "one" is possible in a cost-effective and customer-specific manner.

10.5.3 Production Costs per Printed Page

By way of an example, figure 10.5-3 shows the costs per print page as a function of the run length for different printing technologies and printing systems. The costs include consumables, such as ink and paper, as well as financing and depreciation costs for the printing system, distribution and administration costs, cost of office and workshop space, and the costs for operating staff, service, and maintenance. The sum of these costs, which is known as *total cost of ownership* (TCO), is de-

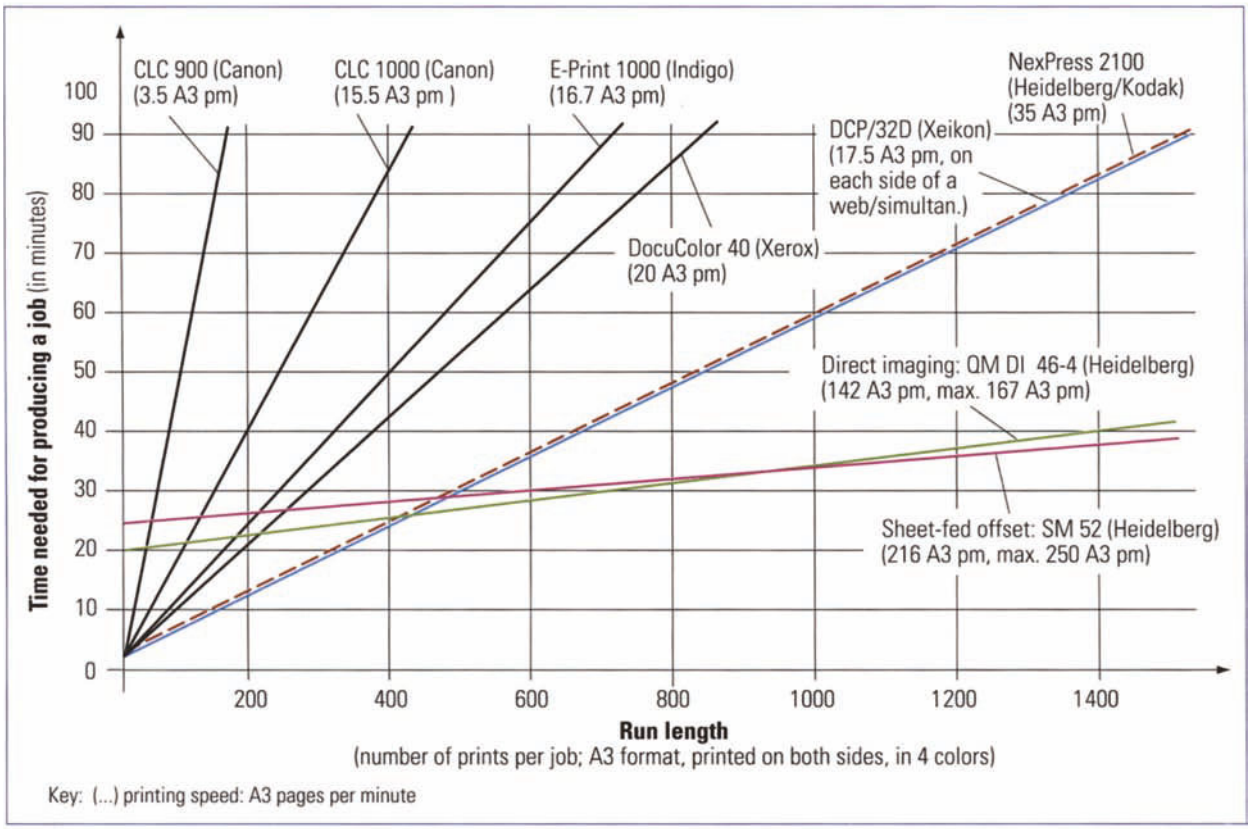


Fig. 10.5-2
Comparison production times (A3 format, multicolor, printed on both sides) when using different printing systems (selection, status: 1999)

cisive for the selection of a printing system, and not merely the necessary expenses for consumables or the initial cost of the printing system itself.

Only trends/tendencies and relations are shown in the illustration in figure 10.5-3. Absolute costs will change with the systems' improvements and the consumables required.

The *break-even points* in the comparison between different printing systems, as shown in figure 10.5-3, are a relatively good indication of when which system will be of advantage in terms of costs, that is, how long the run should be to produce at minimal costs. As a rough guideline, it can be said that *non-impact printing systems* with a relatively high productivity are more cost-efficient in production up to a run length of about 350 than *computer to press/direct imaging systems* (however, with a lower quality as explained in fig. 10.5-1). A comparison between computer to press/direct imaging printing systems and *conventional multicolor sheet-fed offset presses* results in a break-even point of approximately 5000 prints per job, in particular due to the higher initial cost. As expected, the use of *web-fed offset printing systems* results in the lowest production costs with a run length of more than about 30 000 prints per job.

Summary/Conclusions

The aforementioned comparison criteria of *printing quality* and *run length*, *printing speed* and *run length*, and *total cost of ownership* and *run length* show, by way of example and in terms of trends, where the strong points of the different printing technologies lie and where they are therefore *mainly used*.

It is essential to take into account that the use of different printing technologies and printing systems depends on the *company's order structure*. However, it is also of strategic importance and essential for safe-

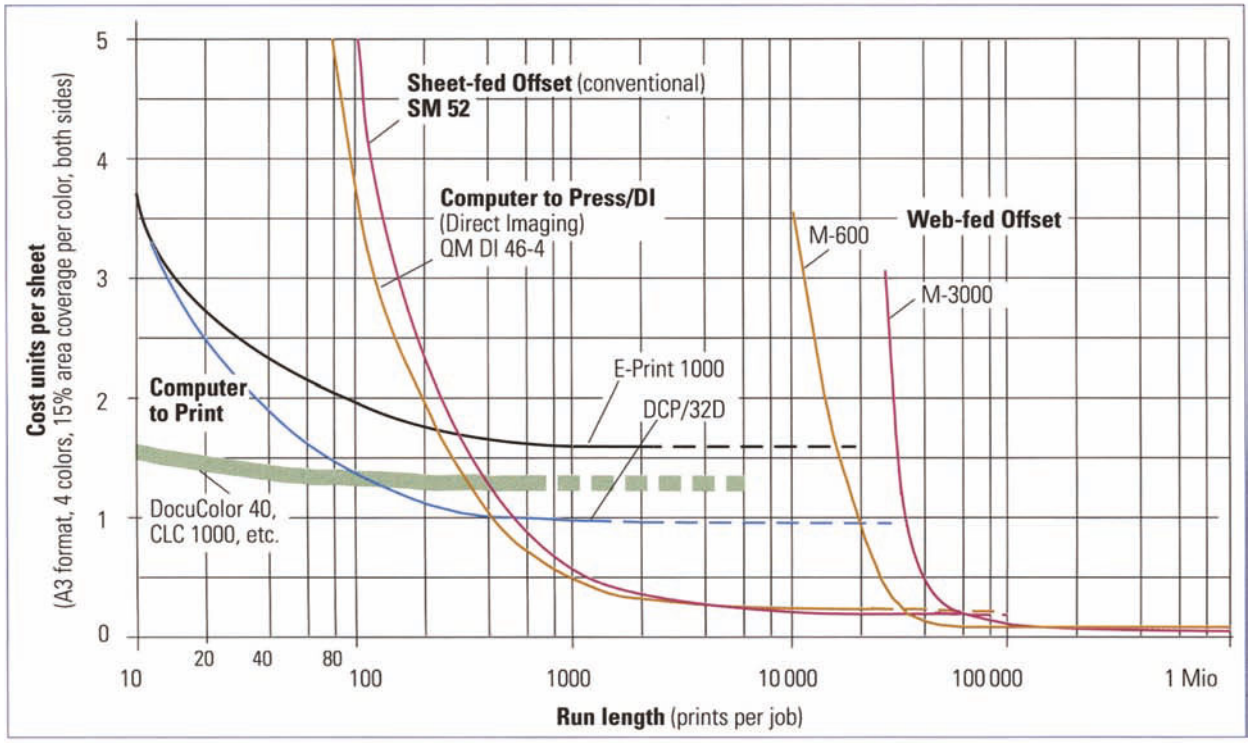


Fig. 10.5-3
Comparison of the total cost of ownership (TCO) for multicolor printing (A3 format, printed on both sides), using different printing technologies and selected printing systems (status: 1999, based on information from various manufacturers, unconfirmed)

guarding a company's future for an adequate level of *flexibility* to exist as regards the production possibilities.

This leads to a *mixed machinery pool*, that is, the installation of different printing technologies and printing systems and the use of *hybrid technologies* for special printed products.

It is true that printing companies will, in the future, produce more and more on the basis of *digital data* and with an increasing level of digital integration in the *workflow*, but they will also have to deal with mixed order specifications of their customers, that is, *analog and digital print jobs* will have to be processed, and prepress will have to be flexible as regards systems and qualification of the staff.

10.5.4 Trends in Print Media Production

Based on the previous statements and comparisons of printing technologies and printing systems using different criteria for evaluation, it was determined that all printing technologies, implemented as *state-of-the-art printing systems*, have strong points in the production of specific printed products. The main printing technologies, therefore, have corresponding shares in the market, and it is of interest to estimate how their use for the production of printed products will develop in the future.

As already explained in sections 1.1.4 and 1.1.5, the *demand for printed products* is also set to increase significantly in the long term. The question is which of the various printing technologies will be used for production and what will their respective shares in the market be.

Figure 10.5-4 shows an estimate of the extent to which the different printing technologies are used for the production of print media vs. the value of the printed products sold to the end user (i.e., not the value of investments in machinery).

It can be seen that *gravure printing* has a constant market share due to its high printing quality. However

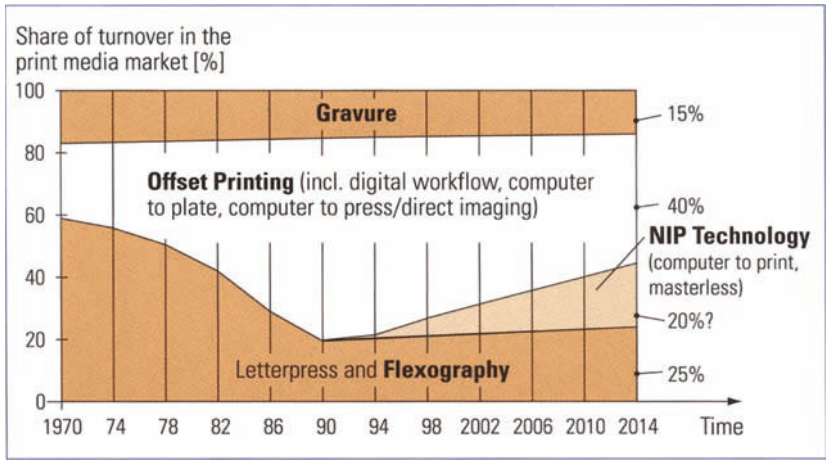


Fig. 10.5-4
Proportion of the use of various printing technologies, based on the value of printed products sold (share of turnover in the print media market; national and international estimates and analyses, status: 1999)

this share is comparatively low since this method is only economical with very long print runs due to the high costs for producing the gravure cylinders. For a long time, *offset printing* experienced an increasing share in the market at the expense of letterpress printing. This was, in particular, a result of cost-effective platemaking, increased use of automation technology, a considerable reduction of makeready times, and printing at maximum quality level.

Due to developments made in *flexo printing*, which led to a distinct increase in printing quality, and with the growing use of flexo printing, for instance, in package printing, letterpress printing saw a slight increase.

Offset printing, in particular in the field of sheet-fed printing, is losing market shares to printing systems based on *non-impact printing technologies* and flexo printing. The spread of the NIP technologies results from their advantages when printing short or very short print run lengths and the possibility of new production strategies, such as "print on demand," "book on demand," and personalization, as well as improvements in printing quality and productivity.

Offset will remain the dominant production method, and this will be connected with an increasing digitization of the *workflow* and a spread of the *computer to press/direct imaging technology*.

It should be noted that, as shown in figure 10.5-4, there will be a relative change in the proportional distribution of the individual printing technologies but with a decline in offset printing. However, due to the clearly increasing demand for print media the absolute figure for offset printing will rise.

As already explained in section 1.1.5 (see fig. 1.1-8), *electronic media* will show a higher growth rate than print media but the demand for *print media* will significantly increase for a long time into the future. This will result in additional innovations in the setup of printing systems and in the provision of production concepts and solutions for economical production close to the customer and at the required quality.

Chapter 12 gives a comparison of the distribution and use of print media and electronic media.

11 Electronic Media and Multimedia

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11.1 Media Concepts

Electronic media and *multimedia* include the latest developments in Internet, World Wide Web (www), and CD-ROMs. They also cover the more conventional forms of radio and television, the recording forms connected with them (recording and storage media), such as video and audio recordings, and computer-generated animation. Beginning with the description in sections 1.1.2 and 1.1.3, a transmission chain for electronic media and multimedia can be defined (fig. 11.1-1) that also includes *print media as a part of the multimedia* distribution of information.

This transmission chain begins with the information contents and relevant sources of information, and the ideas and output operations, which ultimately lead to an electronic media document. The data keeping of the individual components plays an important role today, because these databases are often affected by property rights. The management of valuable databases, called *"asset management"*, is particularly important in this connection. Assembling this data into one document finally generates a media or multimedia product. Different production cycles play a role, depending on the form of the media product.

The question of *distribution* will also be addressed in different ways according to the type of product. For example, distribution is direct via a transmitter in the

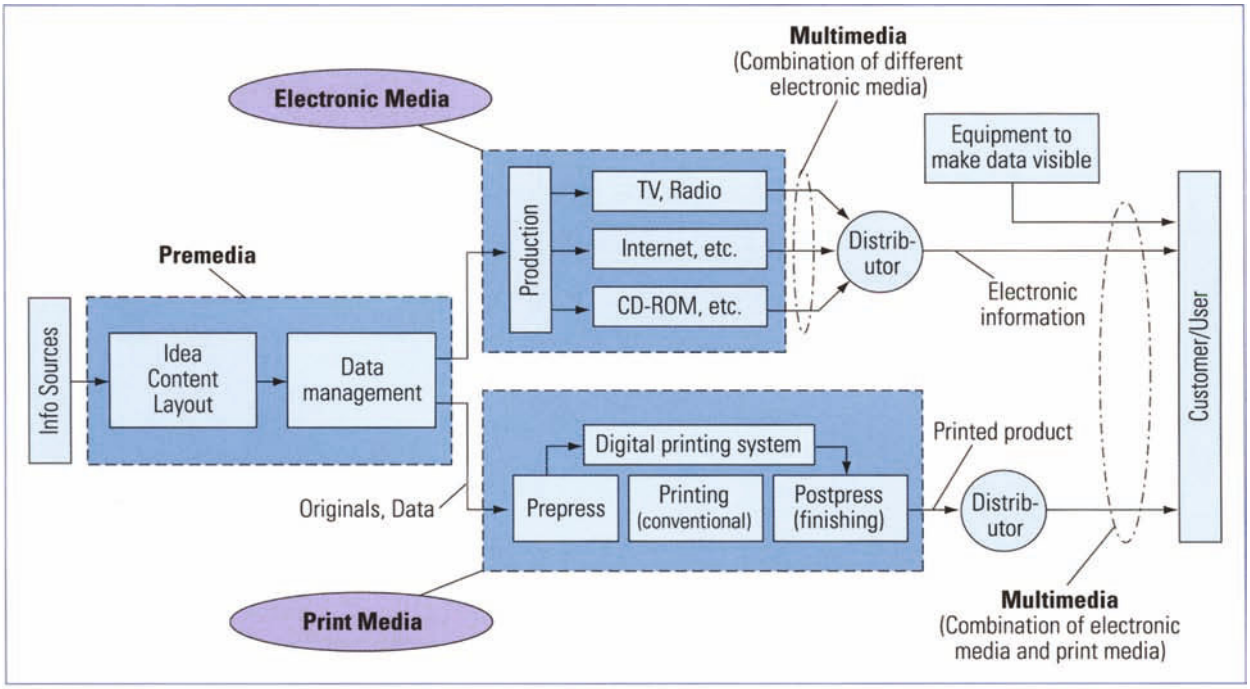


Fig. 11.1-1 Structure of the production of electronic media, print media, and multimedia documents ([11.1-1])

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case of television and radio, or alternatively information is communicated on data carriers such as video or audio tapes. The same applies to multimedia products, which can be distributed both via networks, such as the Internet, or via data carriers, such as CD-ROMs. The term "media" is used in another sense to describe "data carriers", that is the storage medium (see also sec. 11.3).

Electronic media and multimedia are made up of different types of data that can be used separately or in combination. There is a difference between still and moving images. Data volumes play an important role for the various data types, and have a decisive effect on the distribution channels. The use of compression procedures is essential in this area, both for transfer through networks, to minimize the transfer times, as well as for storage on data carriers, in order to cope with the available capacity.

From the point of view of the user, this transmission chain ends with *output devices,* for instance, with a multimedia workstation (fig. 11.1-2). These output systems are usually defined by the format of the output area, the image and color resolution for the visual channel, and the need for appropriate output devices for the other senses of perception, for instance, for radio.



Fig. 11.1-2
Multimedia workstation (electronic media and print media)

References in 11.1

[11.1-1] Kipphan, H.: Status and Trends in Digital Multicolor Printing, Technologies, Materials, Processes, Architecture, Equipment and Market. NIP 13: International Conference on Digital Printing Technologies (Proceedings). The Society for Imaging Science and Technology (IS&T), Springfield (VA) 1997, pp. 11–19.

11.2 Data Types, Data Structures, and their Applications

There are basically seven different data types in electronic media. When we speak of "*multimedia*" we mean a combination of several of these *data types*:

- *Texts* consist of letters, numbers, punctuation marks, and special characters of a particular character set (e.g., ASCII). They may have a preset format (layout) but this is not essential.
- *Graphics* in the sense of electronic media are images that are assembled from geometrical shapes, such as lines, rectangles, ellipses, and curves.
- *Images* are digitally stored illustrations of natural scenes (photos) or computer-generated illustrations that cannot be reduced to simple geometric shapes.
- By *audio* we mean digital storage and reproduction of natural or electronically produced sounds.
- *Videos* show moving, digitally stored, scenes from life/the real world. They consist of many single images shown quickly and consecutively.
- In contrast to video, *animations* consist not of natural, but of artificial moving scenes, which are created from a series of graphics or computer-generated pictures.
- *Virtual Reality* (VR) is a computer-generated three-dimensional environment. With the help of additional equipment, such as a data glove and a stereoscopic display placed on the head (head mounted display), the user can move in an artificial interactive world. VR takes place in real time, that is, it is interactive. Stored forms of VR scenes on data carriers therefore correspond to scenes from animations.
- *Augmented Reality* (AR) is the overlaying of VR information onto reality, for instance, to support maintenance work.
- *Multimedia* is the integration of different data types and presentation forms (including print media) for a common application.
- *Documents* are objects that contain combinations of the described data types in structured form and which can also contain integrated active components.

11.2.1 Text

Simple *text data files* contain text without formatting. A text data file can contain all the characters of a particular character set (ANSI, ASCII), including space signs and paragraph markers. Simple text data files can be imported into all programs that can process text – regardless of the computer platform – and are, therefore, the preferred text exchange format between application users (e.g., Microsoft Office, Star Office from Star Division) and platforms (e.g., Apple Macintosh, PC, Unix workstation). Umlauts and special characters, however, are not correctly reproduced when *exchanging text* between different platforms. That becomes clear when an e-mail that has been written, for example, on a Mac is opened on a PC. There is room for further development and improvement in this area.

RTF (Rich Text Format) contains instructions for *text formatting*, such as font, font size, format of paragraphs, and so on. These instructions can be read and interpreted by RTF-compatible word processors, graphics, and layout programs.

Word processing programs (e.g., Microsoft Word, Star Office) use non-standardized data file formats that, in addition to formatting, can also contain information on document structure, as well as graphic elements and embedded images. These formats cannot normally be imported from other programs, or only with loss of information, and are, therefore, not suitable as exchange formats.

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11.2.2 Graphics

There is a basic difference between pixel and vector graphics [11.2-1], (see also sec. 3.2.9).

Pixel graphics use a grid or screen of small (conceptional) square (occasionally for technical reasons also rectangular) picture elements (pixels) for displaying graphics. Each pixel has a particular position and a particular color value. Because the total number of pixels in an image is always the same, the resolution is reduced if the image is enlarged and the image then often looks "jagged" or, if an interpolation is used, smooth but not as sharp. Pixel graphics are created in drawing programs such as Microsoft Paint and MacPaint.

Vector graphics (or more precisely contour graphics) are created from mathematically defined lines (vectors) and curves (in graphics they are almost exclusively Bézier curves that can be processed directly in PostScript). Vectors draw pictures on the basis of their geometrical characteristics. Vector graphics are not defined by a fixed number of pixels and are, therefore, not dependent on resolution. During expansion the contours are scaled without affecting the quality of the pictures or increasing the quantity of data. Vector graphics are always displayed or printed in the resolution of the relevant output device and are, therefore, suitable for showing sharp contours and details [11.2-2].

Well-known *vector graphic programs* are Macromedia Freehand, Adobe Illustrator, and CorelDraw. *Exchange formats* for vector graphics are, for instance, EPS (Encapsulated PostScript), WMF (Windows MetaFile), and MacPICT. These formats are metafiles, that is, they can contain vectors as well as bitmaps. Scaleable fonts (Type 1 Fonts, True Type Fonts) are also made from vectors. Figure 11.2-1 shows a comparison of vector graphics and pixel graphics.

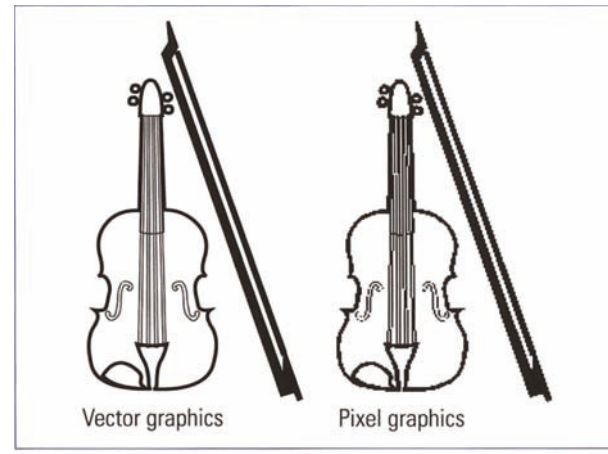


Fig. 11.2-1
Comparison of vector (contour) graphics and pixel graphics

11.2.3 Image

Because the *pixel formats* (depending on the display formats) usually show a rectangular matrix of color values, they are the most suitable data formats for contone images (photos; see also figs. 3.2-27, 3.2-13). As far as resolution is concerned, the same limitations apply as for pixel graphics. For that reason an image must be created from the beginning with the minimum resolution necessary for the intended use (e.g., an appropriate choice must be made of scanner or digital camera). It is important to remember that the size of the image data file is increased fourfold by doubling resolution. Resolution can be reduced afterwards. Subsequent raising of resolution is theoretically possible but does not result in an improvement of image quality because the information content in the image remains the same; if necessary, image impression can be improved by an appropriate interpolation algorithm.

Basically there are differences between image modes and image formats. Image modes describe the kind of data that is set out in image formats. Image modes are described below, followed by the description of data file formats. The various *image modes* (table 11.2-1, figs. 11.2-2 to 11.2-4) are based on a particular color model/color range for the drawing and reproduction of colors [11.2-1]. Each image mode has a particular number of channels appropriate to the color range (see sec. 1.4.1). The channels display the *basic colors* out of which the image is constructed. If an image consists of several channels, the colors of a pixel image will be made from the combination at this point of the color values of three channels.

Each channel has a particular *color depth*. The color depth determines the number of color values, or color intensity values, that can make up a pixel. In the case of an eight bit color depth, $2^8 = 256$ colors (color values) per channel can be shown. The color depth and the number of channels in combination affect the data file size of an image.

The most important image modes are specified in table 11.2-1. The millions or billions of different color values in RGB, CMYK and Lab images are only theo-

Image mode	Channels	Color depths	Number of reproducible colors	Use
Bitmap	1	1 bit	2 (black and white)	Line drawings
Gray values	1	8 bit	256 (gray values from black to white)	Single-color contone images, e.g., black-and-white photos
RGB	(red, green, blue)	3x8 bit	$256^3 = 16.78$ millions	Multicolor contone images (e.g., color photos) for display on screen
CMYK	4 (cyan, magenta, yellow, black)	4x8 bit	$256^4 = 4.29$ billions	Multicolor contone images (e.g., color photos) for four-color printing
CIE Lab-color	3 (brightness, red-green value, blue-yellow value)	3x8 bit	$256^3 = 16.78$ millions	Device-independent storing of multicolored contone images
Indexed	1	1–8 bit	2–256	Graphics for the Internet; special effects

Table 11.2-1 Image modes and specifications (selection)

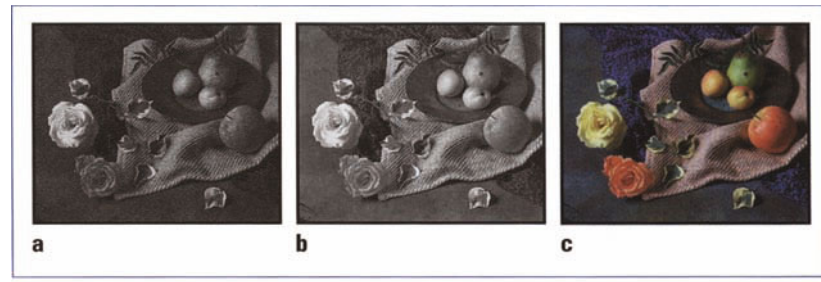


Fig. 11.2-2
Comparison of various image modes.
a Bitmap image (two gray values);
b Grayscale image (up to 256 gray values);
c Color image: RGB (for display on a monitor) or CMYK (for four-color printing)



Fig. 11.2-3
Three channels (red, green, blue) of an RGB image for output on a monitor (in accordance with fig. 11.2-2c)

retical color values. The actual number of colors that can be shown is limited by the physical properties of the output device – according to the specification/technology of the color monitor, for example (see also figs. 1.4-16 and 1.4-25). Consequently, the range of colors (or the resolution) defined by the data cannot always be achieved. The range of colors in printing is also more limited than the range of colors on a monitor. Since four basic colors are used in high-quality printing, the CMYK data files are always larger than the RGB data files for the monitor that works with three basic colors (see sec. 1.4.2) [11.2-3].

In addition to the image modes, we distinguish between different *image data file formats* for special applications in which images can be stored [11.2-4]. The most important are:

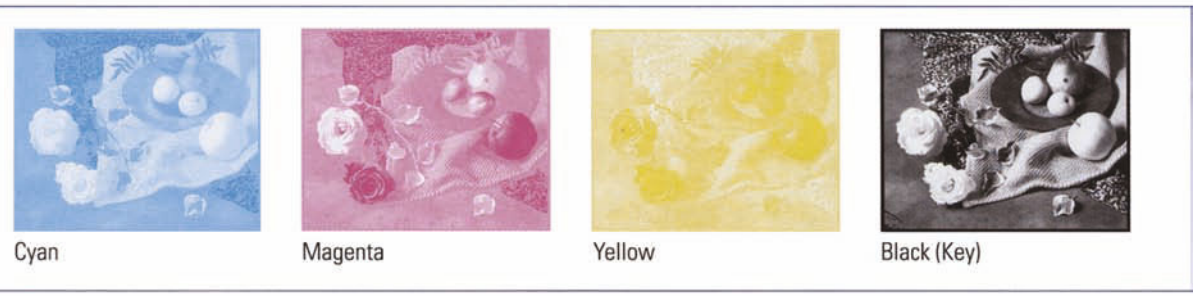


Fig. 11.2-4 Four channels of a CMYK image for four-color printing (in accordance with fig. 11.2-2c)

- *TIFF* (Tag Image File Format). After EPS, TIFF is the most commonly used data file format for the insertion of images into graphic and layout programs as well as for exchange between different computer platforms. It is used particularly for printing.
- *EPS* (Encapsulated PostScript) is based on the page description language PostScript and is used for the same applications as TIFF. Because EPS is a metafile format (see sec. 11.2.2), vector data can also be stored together with image data. EPS is, therefore, the only picture format where it is possible to isolate sections, that is contents of pictures (e.g., to change the background of a picture while retaining the presentation of people).
- *JPEG* (Joint Photographic Experts Group) is a highly condensed data file format that is, however, subject to data loss. The higher the compression levels, the greater the information loss of the picture. If a picture is saved again after editing, further losses arise. The quality of JPEG is normally sufficient for screen displays, but is rarely used for printing and as an intermediate storage medium on quality grounds. JPEG is always used when storage space is limited (e.g., for CD-ROM publications) or when quick transmission is required (e.g., Web publishing). JPEG was extended for the Internet and World Wide Web as a progressive image mode, which does not build up to maximum quality line by line, but in several stages from coarse to sharp. It is, therefore, possible to recognize a picture before the transmission is finished. JPEG was specially developed for fine-structured, natural color or grayscale images, but is less suitable for images with large one-color surfaces or computer-generated color gradation. In such cases artifacts may appear that result in a poor image quality. More detailed descriptions of image compression processes are given in 11.5.2.
- *GIF* (Graphics Interchange Format) was specially developed for the use of images for online services and the Internet, where the need is for quick data transmission. It uses indexed (selected) colors, so that the size of the data files for full-color pictures is strongly reduced (fig 11.2-5; see also sec. 11.5.2). However, a large proportion of the color information is lost. GIF is therefore mainly used for display, or reproduction of logos, graphs, and screen shots (e.g., multicolor pictures on monitors) in *HTML (Hyper-*

Fig. 11.2-5
Comparison of a full-color CMYK image with an indexed color image reduced to 64 colors (6 bit), (image data file format: GIF)



text Markup Language) documents, which usually consist of only a few colors. (HTML does not support vector data, so that all vector graphics must be changed into pixel format.) JPEG is preferred on the Internet for contone pictures (photos), [11.2-3].

11.2.4 Audio

By *sound* we mean changes in pressure (acoustic waves) in gases, liquids, or solids. The human acoustic faculty can perceive sound in the frequency area of between 20 and 20 000 Hz. The greatest sensitivity is at around 1 kHz, the approximate frequency at which the largest part of spoken communication takes place.

In order to record acoustic signals, the sound signal is usually converted into an electric signal (e.g., by a condenser microphone). If the signal is needed in a digital form, the acoustic/electric signals are scanned and quantified (sample and hold operation). In the case of an *audio CD* this is carried out at a scanning rate of 44100 Hz. Each scanning value is broken up linearly into a dynamic range of 16 bits (i.e., 65536 values). For two (stereo) channels there is a data rate of 44100 Hz × 16 bit × 2 channels = 1.41 Mbit/s when the CD is played [11.2-5 to 11.2-7].

If only a medium speech quality is aimed at, as is usual in the case of the *telephone*, one gets a data range of 8000 Hz × 8 bits × 1 channel = 64 kbit/s from an 8000 Hz sample frequency and an 8-bit dynamic range.

11.2.5 Video

By video we mean the recording of a chronologically arranged *sequence of pixel images*. The resolution and the number of images per second are determining factors for the amount of data. Although, analog recording and transmission is still common in the case of *television*, digital formats are playing an increasing role. This process will accelerate, since all videos that are distributed via the Internet are digital. In addition to formats specific to manufacturers, standardized formats are gaining important ground in this area. Examples are the *Coding Standards* Motion JPEG and *MPEG (Moving Picture Experts Group)*, [11.2-8].

Motion JPEG is particularly used where further processing, for instance, at a cutting station, is to be done. *MPEG* is not well-suited for cutting because of its special coding, which only transmits variations of preceding pictures. MPEG also allows the coding of a synchronized audio signal in addition to the video (i.e., picture and sound sequence), [11.2-8].

11.2.6 Animation

Animation concerns the *artificial generation by computer of objects in scenes* (fig. 11.2-6). The sequence of movements, the viewer position, and the line of vision determine the chronological course of the scene. The sequence is predetermined and cannot be changed by the viewer. Animation uses 3D visualizing technology and proceeds via extensive rendering processes (*rendering* means the generation of pictures from digitally available scenes) back to a series of halftone images, which, depending on the quality, can achieve displays almost in photographic quality. As a result it is not always clear whether one is looking at a video or an animation. Animations are usually distributed as videos.

11.2.7 Virtual Reality (VR)

If one combines output production data of *animations* – that is, scenes consisting of objects with appropriate characteristics and movements – and adds an *interactive component* (e.g., joystick, 3D mouse, headset, or data glove) and the possibility to enter into this virtual world (this process of entering into virtual reality is known as "immersion"), then one has arrived at the requirements for virtual reality [11.2-9 to 11.2-13]. On the hardware side, it requires sophisticated projection or display technologies as well the possibility to *change the position and the viewing angle* using a suitable tracking system. The variety of projection technologies ranges from "*data helmets*" worn on the head/head mounted display (fig. 11.2-7) to projection rooms called "CAVEs" (CAVE Cave Automated Virtual Environment), (fig.11.2-8), [11.2-9]. As in the case of animation the basis for the necessary software is 3D visualization technology.

In contrast to animation, where the calculations happen independently of the time of display, the *calculations* for VR must be *carried out in real time*, that is, at the same time as it is displayed. This has resulted in recent years in an enormous development of special graphic hardware that produces the required performance and can calculate these displays in real time. This is important because the position and line of vision of

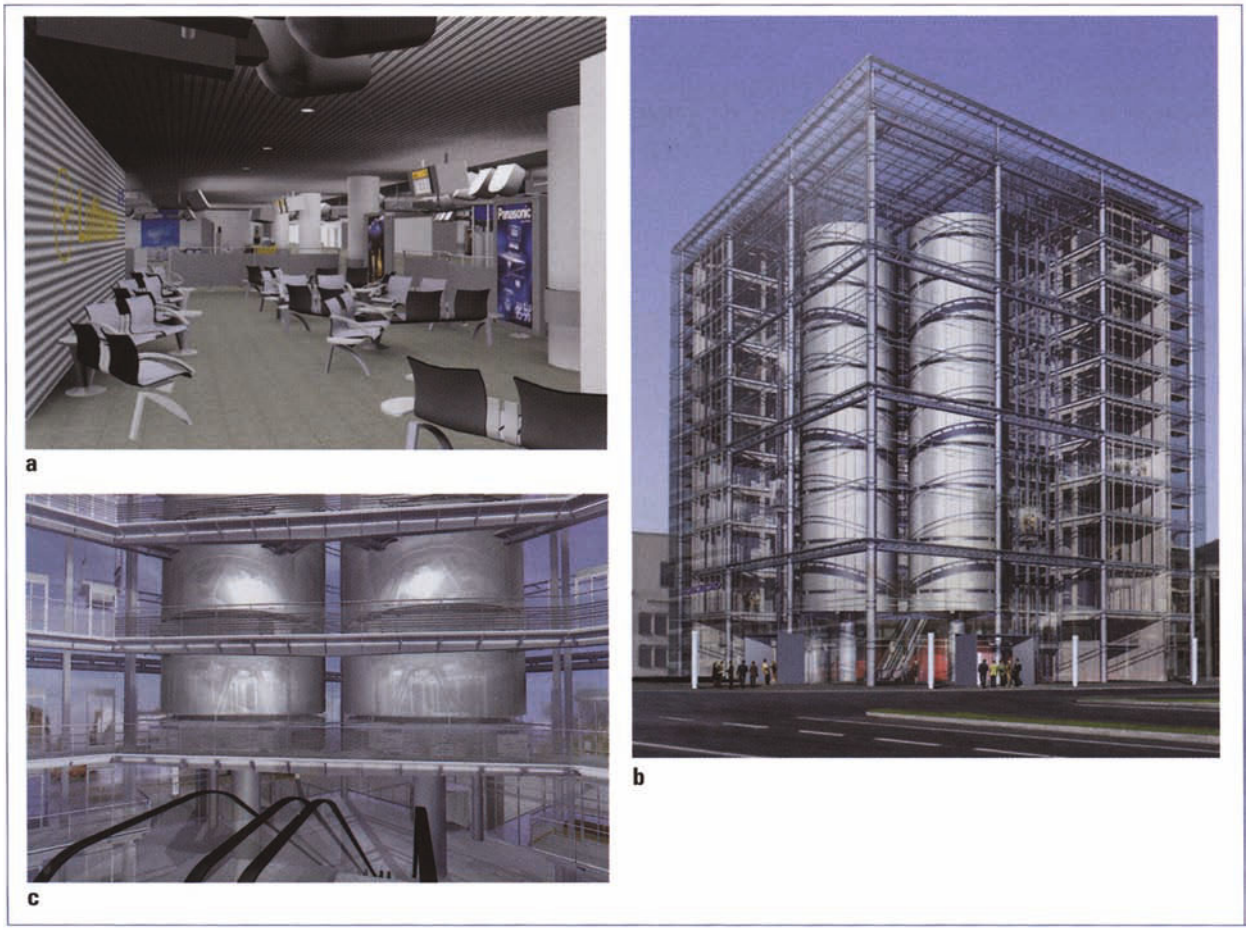


Fig. 11.2-6 Computer animation.
a Interior of Frankfurt Airport;
b Building/architecture animation (Heidelberg, Print Media Academy);
c Print Media Academy interior (Heidelberg)

the viewer form the dynamic camera position, and cause a constant changing of these parameters and a constant recalculation of the field of vision. Uses of VR range from simulation and training systems (flight simulators and driving simulators) to design review (as in manufacturing cars) and entertainment systems.

11.2.8 Augmented Reality

In recent times VR technology has undergone an *extension in the direction of reality* that has become known by the catchword "*Augmented Reality*" [11.2-14]. A virtual reality view is brought in line with reality, so that certain works can be simplified by the insertion of VR views. An example of this is servicing work, in which a technician can receive, via semi-transparent goggles, inserted information that corresponds with his view of the real thing, namely the machine to be serviced. He receives an accurate indication of the next operation necessary for completing his task; he sees the condition of the invisible interior of the object. This technology requires more sophisticated calculating performance than is already necessary for VR, because calculations



Fig. 11.2-7
Components for interaction (man and machine) in virtual reality: data glove and data helmet including head mounted display



Fig. 11.2-8
Virtual Reality: Interactive (real time) simulation for assembling a car door in a CAVE (Cave Automated Virtual Environment: special projection system on ceiling, floor, and side-walls). The two people have special goggles that assist with spatial interaction and 3D perception.

must constantly be made to geometrically align the virtual image with reality (e.g., via a recorded video picture out of sight of the user), (fig. 11.2-9).

11.2.9 Multimedia

Multimedia means the *integration* of several of the technologies already described [11.2-15]. This can be integration of text, graphics, fixed images, and moving pictures (videos and animation) and audio, as is common on Compact Discs and on the Web. It can also mean *integration of different types of publications* such as a CD with a book (see fig. 11.7-1 – and the book in hand), or a combination of CD and web-sites. This use of various presentation media (output media) for a publication is called "*cross-media publishing*". A particularly interesting question in this area is how the data can be adapted to the various output media. For example, the requirements for the production of contone images on paper are completely different from those for a production on the Internet with regard to the color reproduction, resolution, and format (see also fig. 11.1-1).

11.2.10 Document

A document is a structured collection of components of information (e.g., from the previously described data types) that can include one or several forms of presentation (e.g., book, CD-ROM, Web presentation, VR),

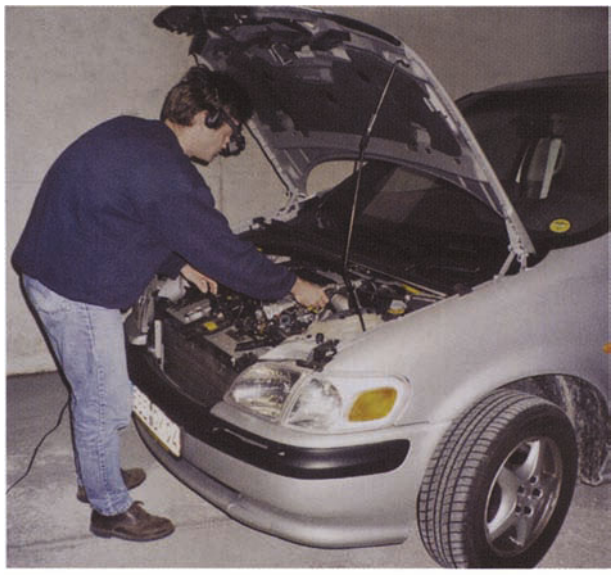


Fig. 11.2-9
Augmented Reality: In the area of servicing complex technical equipment, in this case a car engine, the mechanic is supplied with important additional information via special goggles (semi-transparent) fitted to a data helmet, serving as the interface between man and the computer.

[11.2-16]. These presentation forms are interactively or passively changeable. Components in documents can also be active elements, such as programs or program excerpts that run under certain conditions to create certain presentation objects. Examples are applets (executable programs, e.g., an animation) in web documents. In extreme cases a complete simulation can be defined as a document.

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11.3 Data Carriers

11.3.1 Hard Disk Storage Units

Hard disks are either built into the computer or are externally connected magnetic data carriers with high storage capacity and high reading and writing speeds. The operating system is stored on the hard disk, as is usually the case with software programs and data that is in process. The hard disks of servers provide data and software programs for connected workstations or online and Internet services. The storage capacity of the most commonly used hard disks lies between 5 GB and 80 GB (gigabyte).



Fig. 11.3-1 Data carriers in the multimedia sector

11.3.2 Rewritable, Removable Storage Units

Rewritable, removable storage units are data carriers that can be taken out of the drive and upon which a permanent writing and reading access in the same drive is available. They are most often used for off-line transfer of data between computers. The most important removable storage units are shown in table 11.3-1 (see also sec. 3.2.7).

Nowadays, in all PC models there is a built-in 3.5" diskette (floppy disk) drive with a storage capacity of 1.44 MB. For the quantity of data arising in the areas of graphics and multimedia, diskettes are no longer adequate. Removable storage units have, therefore, been developed that have greater storage capacities and much shorter access times. These storage media are sometimes called "removable hard disks." An incalculable number of removable storage media has been developed in recent years, but unfortunately none has yet been established as a universal standard.

11.3.3 CD-ROM and DVD-ROM

CD-ROM (Compact Disc Read Only Memory) and DVD-ROM (Digital Versatile Disc Read Only Memory) are *optical storage media* with a diameter of 5.25". In contrast with the data carriers described in the previous sections, reading and writing access on the same

Table 11.3-1
Rewritable removable storage units/disks (selection)

Medium (Data carrier)	Technology	Capacity	Size
Diskette (floppy disk)	magnetic	1.44 MB	3.5"
Iomega ZIP	magnetic	100 MB, 250 MB	3.5"
Iomega Jaz	magnetic	1 GB, 2 GB	3.5"
SyQuest Cartridges	magnetic	44, 88, 200, 230 MB 1 GB, 1.5 GB	5.25", 3.5"
Magneto-Optical Disk	magneto-optic	128, 230, 650 MB 1.3 GB, 2.6 GB	5.25", 3.5"

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drive is not possible. In addition to those which can only be written once, there are also *rewritable* CDs (CD-RW; Compact Disc Rewritable) and DVD-RW (or DVD-RAM). A special recorder is essential for writing.

The storage capacity of CD-ROMs is 650 MB. With the recorders currently available DVD-ROMs can be written with up to 4.7 GB, but the actual storage capacity is considerably greater. CD-ROMs can also be read in DVD-ROM drives. Typical uses for these data carriers are storage of software, pictures, reference works, multimedia applications, and so forth, as well as data back-ups and archiving. Because of their high-storage capacity DVD-ROMs are particularly suitable for videos, films, and other data-intensive multimedia applications.

11.3.4 Magnetic Tapes

Magnetic tapes (*DAT Digital Audio Tape*) are storage media with capacities of between 4 GB up to 70 GB and permit writing and reading access. Access to data is, however, slow, because the tape must be reeled to the point at which the required data is located. For this reason magnetic tape is almost exclusively used to back up large quantities of data. The tapes only need to be read in the case of a loss of data on the hard disk, in order to recover the original database.

11.4 Networks

11.4.1 Internet

The Internet is a world-wide connection of many local and regional computer networks that are linked to each other through data lines [11.4-1 to 11.4-4]. The development of the Internet first began in the 1960s for military reasons as part of the search in the USA for a command and control network that would be secure in time of crisis. In 1969, this development led to ARPANET being founded (ARPA Advanced Research Project Agency; founders of the network of the same name), the "mother of the Internet." In the 1970s the standardized internet protocol NCP (Network Control Program, today called TCP/IP Transmission Control Protocol/Internet Protocol) was introduced. In 1986 the National Science Foundation Network (NSFNET) was founded and the five *Internet Domains* introduced: *.gov* (government), *.mil* (military), *.edu* (universities), *.com* (commercial organizations), and *.org* (non-commercial organizations). Outside the USA there are additional various *country designations*: *.de* for Germany, *.at* for Austria, *.ch* for Switzerland, and so on. Small firms and individuals who do not have their own Internet Server can now connect up via the closest link in the net, for instance, using a modem or an ISDN connection (ISDN Integrated Services Digital Network), (fig. 11.4-1).

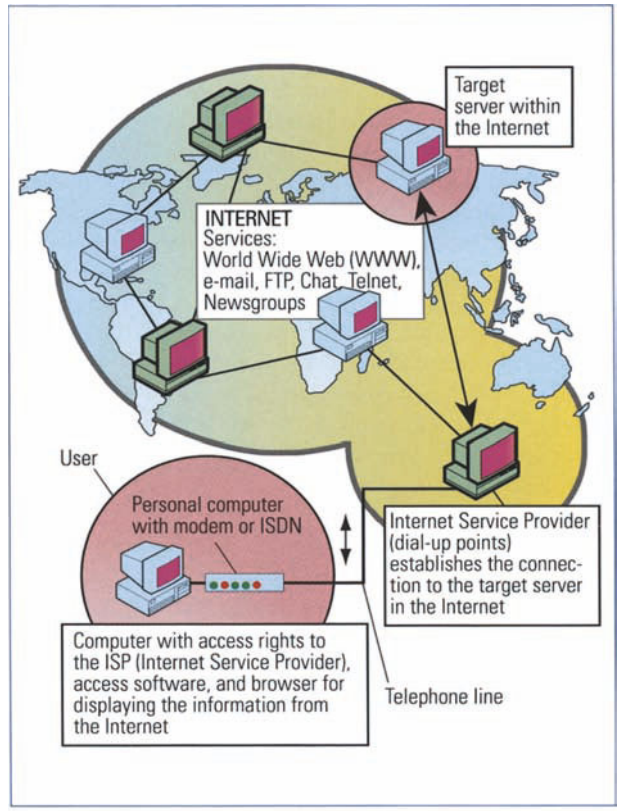


Fig. 11.4-1 Internet and user connection

The following *services* are currently available on the Internet:

- *E-Mail* is now the most frequently used Internet service, which enables the sending of news and data files from a sender to a recipient. Anyone who wants to use this service needs his own e-mail address, which is recognized by an "*at*" sign (@) in the middle of the designation.
- *Chat* (IRC Internet Relay Chat) also serves to transmit news. In contrast to e-mail the news is transmitted and displayed to all linked participants as soon as it is entered onto the keyboard. This makes it possible to have a "conversation" in real time.
- *Telnet* enables remote logging into a computer via the Internet and starting programs. However, in contrast to the FTP service described below one cannot download data from this computer.

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- The *File Transfer Protocol (FTP)* has a special function, making it possible to log in on an Internet server and to download data onto one's own computer or to upload data onto the server.
- *Newsgroups* are electronic "noticeboards" on which one can post news, which all registered participants can read. Each Newsgroup deals with a particular area of interest. There are currently more than 20 000 newsgroups on the Internet.
- The *World Wide Web (WWW)* – one of the most recent developments on the Internet – is a hypermedia information system (i.e., the extension of the WWW by multimedia components, such as text, graphics, animation, sound, and film or video) that also enables access to other Internet services (e.g., e-mail, chat, etc.). The use of the WWW is simple and unified. With the help of *web browsers*, that is, special software program systems (e.g., Netscape Navigator, Microsoft Internet Explorer) one can navigate through complex hypermedia structures by choosing marked places in a document (hyperlinks). Uniformity is achieved by the use of the standardized *document language HTML* (Hypertext Markup Language), [11.4-5], which is independent of the platform and in which WWW documents that can be interpreted by all web-browsers are composed.

New developments are moving in the direction of *Extensible Markup Language (XML)*, a writing language that is derived from the internationally standardized *SGML (Standard Generalized Markup Language)*, [11.4-6] and permits the writing of considerably more flexible data structures and formatting with the help of "style sheets" [11.4-7].

Communication between clients and servers on the WWW is regulated by the HTTP protocol (Hypertext Transfer Protocol), which runs on the TCP/IP Protocol [11.4-8].

Each *computer* on the Internet has a unique *address* of 4 bytes (e.g., 158.12.188.75). Via "name servers" this address is converted into an easily remembered name (e.g., pc200.igd.fhg.de). Each *document* on the Internet has an unambiguous *address* (URL Uniform Resource Locator) with the following structure:

protocol://computer name/path/.../document
Examples:
http://www.igd.fhg.de/index.html
ftp://ftp.igd.fhg.de/incoming/readme.local

11.4.2 Intranet, Extranet

Intranets are information and communication systems inside a company or organization that use the basic service of the Internet under the TCP/IP Protocol [11.4-9]. They are usually protected from outside penetration by "*firewalls*" and are not accessible via the Internet.

An *extranet* is an extension of an intranet to other people and companies – such as to customers, dealers, or suppliers. It gives a defined user-group limited access to data that is relevant to it [11.4-9].

11.4.3 Broad Band Networks

Broad band network means a *high-speed network* with a data rate that is higher than the "primary multiplex rate" (in Europe currently 2048 Mbit/s). For *real time applications*, which are increasingly required for *multimedia* – particularly videos – an extremely high data communication infrastructure performance is necessary, with high transmission band width and very limited delay times.

In the case of broad band transmission, the bandwidth of the transmission medium is divided into very many frequency bands. The individual frequency bands can be dedicated to particular tasks (sending or receiving) or types of communication, which can be either analog or digital.

Table 11.4-1 gives an overview of types of connections and their data rates. For better comparison narrow band connections are also listed, as they are often used for end-user links to the Internet. In addition there are asymmetric links, such as ADSL (Asymmetric Digital Subscriber Line), which use various data rates depending on the direction of data transfer: sent out at a high data rate (up to 8 Mbit/s) to the user (such as Video on demand), but sent back at lower data rates (up to about 1 Mbit/s).

Table 11.4-1
Overview of the types of links to the network and the corresponding data rates (in bit/s), [11.4-10].

Type of link	Data rate	Application
Analog modem	56 kb/s	Telephone
ISDN	64 kb/s	Telephone (digital)
n × B channel ISDN	n × 64 kb/s	Grouping of ISDN-lines
Primary Rate ISDN	32 × 64 kb/s = 2 Mb/s	ISDN
Ethernet	10 Mb/s	Local Area Networks (LAN)
WAN ATM	34 Mb/s	Wide Area ATM
Ethernet	100 Mb/s	LAN
OC3 ATM	155 Mb/s	LAN/WAN
OC12 ATM	622 Mb/s	LAN/WAN
Ethernet	1 Gb/s	LAN
OC48 ATM	2.4 Gb/s	WAN

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11.5 Data Compression

11.5.1 Compressed Data Archives

Archives are data files that contain a data file or a group of data files in *compressed* form. As a result these data files require less storage space and can be transmitted more quickly. For *archiving* it does not matter which data type or format the data files are. Examples of *archive formats* are Zip and BinHex. To create an archive it is necessary to have a program such as WinZip or StuffIt. The software for *decompression* of the archive can be part of the archive data file (self-unpacking archive) so that decompression does not require an additional program. However, the compressed data files cannot be opened directly from the application program [11.5-1, 11.5-2].

11.5.2 Compression Processes for Image Data Files

In contrast with archives, images that have been compressed by special image compression processes are automatically decompressed on opening of the data file by an image processing program or by printing it on a printer.

- *Run length encoding* is a loss-free type of compression that is particularly suitable for pictures with large single-color areas. A sequence of value pairs is created, consisting of the color value and the number of pixels which have the stated color value in the same line.
- *LZW* (Lempel Ziv Welch) is a loss-free type of compression, that is, all picture information is retained. This process was invented in the 1970s and constantly further developed up to the present time. Compression is based on the principle that repeating data file elements are put together. Optionally, TIFF images can be compressed using the LZW method, resulting in average compression rates of 2:1; LZW is also used for the GIF format (see sec. 11.2.3). There are a few other loss-free compression algorithms, but they are less frequently used than LZW [11.5-1, 11.5-2].
- In *JPEG processes* (Joint Photographic Experts Group) image data that is not essential for the display is identified and rejected. JPEG compression is, therefore, subject to loss. The higher the compression rate, the greater the losses. Compression rates of between 5:1 and 15:1 are just about acceptable regarding the picture quality. At higher compression rates, changes to the original pictures occur that are clearly visible to the eye. JPEG is not only a compression process, but also a data file format (see also sec. 11.2.3). It is also possible to compress pictures within EPS files (Encapsulated PostScript) or PDF data files (Portable Document Format) with the help of JPEG (fig. 11.5-1), [11.5-3, 11.5-4].
- *GIF* (Graphics Interchange Format by CompuServe) is a compressed file format that converts a picture into indexed colors (selected single color tones) and then compresses it using the LZW method [11.5-5]. "Indexed colors" means that an image is analyzed according to the most commonly occurring colors, which are then put into a table. The picture is then composed of the colors in the table. The number of colors used can be determined by the user and lies between 1 and 256. The number of channels is reduced to one instead of three as in the case of RGB. Colors that are not in the table are replaced by the most similar color in the table (see also fig. 11.2-5). Alternatively, the missing color can be composed using the dithering method; that means that a combination of pixels of other colors is used to display the color. Because of the reduction of colors, GIF is only a suitable means for storing contone images to some extent (see also table 11.2-1).

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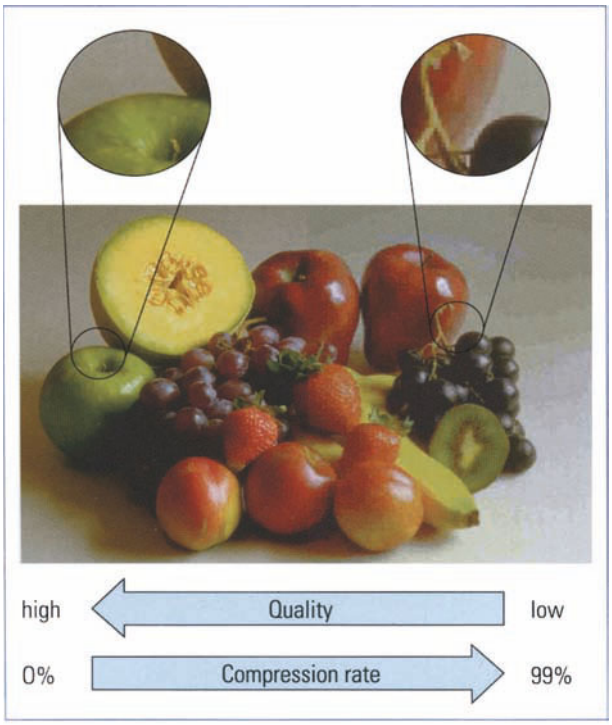


Fig. 11.5-1
Compression of data: effect on image quality (resolution)

The size of a file is very much reduced by indexing. An image indexed with 256 colors has only a third of the file-size of the corresponding RGB image with 256^3 colors. The file is still further reduced by LZW compression.

In addition to loss-free compression algorithms and those subject to loss there is a further possibility for reducing image data. *Fractal image encoding* boasts a high compression ratio of image files [11.5-6, 11.5-7]. The process is based on the description of the image content with the help of mathematical formulae. On the one hand very good compression ratios are achieved which theoretically facilitate unlimited resolutions, but on the other the images are synthetically produced and, therefore, show image contents that were in reality not there. Fractal image encoding has not gained ground so far, because compression of image data takes too long even on modern computers. Depending on the desired resolution, the decompression of fractal images requires considerably less time than the encoding of the image contents, so that even today its use in special circumstances may be appropriate.

Because of the ever growing storage capacity of modern media (hard disks, CD, DVD) the subject of "compression" is becoming increasingly less significant. This development is accompanied by greater bandwidths in modern networks. However, when sound and video data are digitally stored or need to be transferred, compression algorithms are still indispensable.

11.5.3 Compression Processes for Audio

As explained in section 11.2.4, an audio CD has a data rate of 1.41 Mbit/s when it is played. For average speech quality a data rate of 64 kbit/s can still be achieved [11.5-8 to 11.5-10].

Because digital data carriers or transmission channels often have less capacity or bandwidth than described in the previous examples, a reduction of data volume by compression is often required. A loss-free compression of acoustic information is practically impossible. Other methods of data reduction are required than for pictures and video – the physiological effects of human perception and in particular the production of speech have to be taken into account.

Different methods are used for the compression of speech than for audio in general (e.g., music). The *compression of speech information* is based on models of speech synthesis and recognition. There are processes having the individual characteristics of a (human) speaker that are able to reduce spoken text to less than 1 kbit/s. A CD with around 650 MB capacity could, therefore, contain a recording of over sixty days continuous speech.

For the *compression of music* current processes are based on the principles of psychological perception. Acoustically imperceptible components are removed from the signal and are left out of the recording and transmission. A good example of this is the MP3 encoding (MPEG Audio Layer3, MP3 for short [11.5-11]; MPEG Moving Picture Experts Group). A piece of music is compressed with an average of less than 2 bits per sampling value (in other words, the data volume is reduced to around a tenth) without any significant loss of quality. Fifteen hours of music of stereo HiFi quality can, therefore, be stored on one CD.

11.5.4 Compression Processes for Video

In the case of video material there is a difference between production and archiving, on the one hand, and

the form that is used for transmission to the end-user on the other. In the case of production, uncompressed video data is usually preferable. Further processing and particularly cutting procedures are simpler in the uncompressed form. Occasionally compression of individual pictures is acceptable, which at least does not present problems for cutting (intra-encoding: Motion JPEG, MJPEG [11.5-3, 11.5-12]), but not an encoding that takes advantage of the redundancy of images occurring in chronological sequence (inter-encoding: MPEG [11.5-12]).

Cutting processes and post-processing operations are not normally of any significance for transmission to the end user. High compression without perceptible quality loss is the primary objective because the transmission costs are determined by the amount of data to be transferred. For this reason the ISO MPEG-2 video encoding process is used in digital TV and HDTV (high definition television), since it permits high compression with good quality by taking advantage of the redundancy of picture sequences.

Video often encodes an integrated audio signal together with the transmission of a sequence of pictures. This audio signal must obviously be synchronized with the flow of video data so that picture and sound are presented at the same time.

For the PAL (Phase Alternation Line) format used with television, data volumes would be as follows: a resolution of 720 × 576 pixels corresponds to 414720 pixels; at a color depth of 24 bit and 25 pictures per second (equivalent to 50 half-pictures per second), the gross data rate would be around 249 Mbit/s; for a compression of color information by YUV (the color system/color format used in European television; Y contains the brightness signal, U and V the color information) in the ratio 4:2:2, it means a net data rate of 166 Mbit/s. For higher resolution and higher image rates the data rates obviously rise correspondingly.

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11.6 Output Devices for Electronic Media and Multimedia

At the end of the transmission chain for electronic media there is always an output system suitable for providing a display of the appropriate quality and speed. This means that a computer with the adequate performance must be available (fig.11.6-1).

Output devices for electronic media may be screens, video projectors, or equipment that projects the image directly onto the eye of the viewer (e.g., head mounted display). Important quality criteria for such output systems are spatial and color resolution. Color resolution of 24 bit has become almost standard; more limited color depths are now only found on very inexpensive PCs. The situation is different for spatial resolution, where there are still big quality differences [11.6-1, 11.6-2].

11.6.1 Screen Output

Screens are roughly divided into two classes: screens based on the cathode ray tube (CRT cathode ray tube, television tubes) and those based on semi-conductor displays (LCD liquid crystal display). While television tubes usually permit a greater screen diameter, semiconductor displays are usually brighter and flicker-free. The limit on the screen size is caused by the error rates in the manufacture of semiconductor displays. The most important LCD technology used at present is based on thin film transistors (TFT). These displays are active matrix displays, whose pixels are implemented by individual transistors and which have good color display and work at high speed. New technologies based on organic LEDs (Organic Light Emitting Diodes), called "OLEDs" [11.6-3] give cause for hope

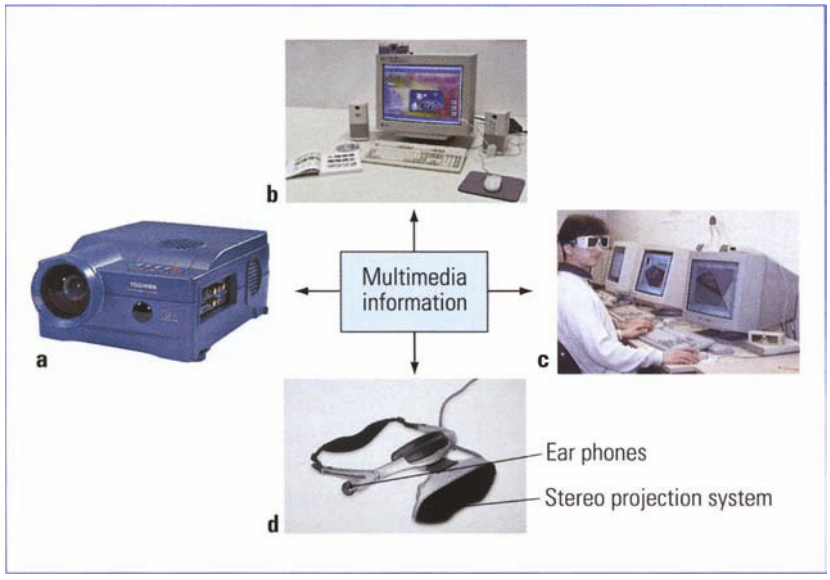


Fig. 11.6-1
Output of multimedia information (selection).
a Projection system/beamer (Toshiba);
b Multimedia workstation;
c Stereo output via shutter goggles;
d Display to be worn directly on the head (Sony)

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that the problem of size will be solved in the future. We can expect that even wall-sized displays will not meet with insuperable difficulties.

11.6.2 Projection Equipment

Video projection includes projectors on the basis of CRT technologies, projectors with digital controllable mirrors (Digital Micromirror Devices, DMD), various types of liquid crystal projectors (TFT and polysilicon LCDs), light valve projection, and laser projection.

CRT Projectors

Video projectors based on CRT normally work with three cathode ray tubes with color filters (RGB) whereby projection and mixing takes place via optics. This technique permits flexible adaptation to the required resolution.

Digital Micromirror Device (DMD)

A DMD consists of very small mirrors (16 µm × 16 µm) that are micro-mechanically produced and arranged in an array (e.g., of 1280 × 1024 elements) at a distance of 17 µm. This device gives an even and high brightness, because very effective reflecting micromirrors are used [11.6-4], (see also figs. 5.2-4 and 5.2-8).

LCD Technology

There are two competing LCD technologies: first TFT-LCD (Thin Film Transistor), and secondly polysilicon LCD technology.

TFT-LCD Technology/Single TFT. Projection systems with single TFT displays are well suited to project data. TFT active matrix technology stands out for its good quality and clear reproduction. Fast moving sequences can be well displayed by projection techniques based TFT. There is no afterglow, which was common with the older passive matrix technology. These displays are cheap and well established but have very low transparency (only 5% of light gets through).

Polysilicon LCD Technology. This technology is based on three small individual displays of around 1.3" to 5.8" in the basic colors of red, green and blue. The emphasis here is on high transparency and the brilliant color reproduction associated with a metal vapor lamp.

Light Valve Projection

The RGB signals (red/blue/green) are transmitted per color to a cathode ray tube (CRT) or more recently to a reflecting LCD matrix (not suitable for projection of large images because of the still too limited light performance). With the pictures from CRT and LCD, non-matrixed liquid crystal layers in the light valves are addressed via a photo-sensitive layer. The polarized light of a projection lamp, which has penetrated the light valves from the front, is directed by the liquid crystal molecules to dielectric mirrors integrated into the valves, and reflected forwards. The images created are then mixed together onto a lens via a filter. The mixing can be carried out either in the system or on the screen. Light valve technology combines the advantages of CRT technology (no pixel structure, color, and contrast) with great brightness.

Laser Projection

The light of three lasers for the colors red (620–690 nm), green (510–540 nm), and blue (430–460 nm) is modulated in its intensity by means of electro-optical modulators. The three modulated laser beams are projected onto the projection surface by means of a deflecting unit. The three laser beams are collimated (i.e., dot not diverge), so that the distance of the projection unit from the image level is not fixed and focusing is not necessary. A zoom lens is used to avoid long projection distances caused by the limitations imposed on the projection angle by deflection technology.

The advantages of laser projection as against all other digital systems are undisputed because of its superior image quality. However, its introduction into products is proceeding very slowly. It has the following advantages:

- a much wider color gamut,
- no visible pixel structure and a greater resolution potential,
- very high depths of focus,
- projection on crooked surfaces,
- separation of laser unit and projection head (flexible handling),
- very high efficiency.

11.6.3 Stereo Output

Stereo output is possible on normal displays and projections. The viewer has to wear goggles that can direct

the separate stereo pictures to the correct eye (e.g., by deferred projecting for each eye in the form of shutter goggles, or by different polarization of the light for each eye). With VR systems the position and line of vision of the user is tracked in order to be able to carry out the correct stereo calculations for the viewer. This has, however, the disadvantage that the display is only correct for the viewer who is wearing the tracking device [11.6-5, 11.6-6].

11.6.4 Projection Directly to the Eyes

There are different forms of projection systems that project the images directly onto the eye. It is possible to direct the appropriate images (stereo) to each eye and by this means to combine them into a stereo picture. This is often achieved using so-called head mounted displays. Some of these systems take the form of goggles containing small LCD displays that are brought to the correct viewing distance via a lens. Augmented reality applications use systems with semi-transparent mirrors that project directly onto the retina [11.6-7].

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11.7 Multimedia Applications

Based on the technologies described previously there are many different types of multimedia applications. Important applications are, for example, encyclopedias in which video clips, sound documents, or small animations (e.g., to illustrate the functioning of a technical machine) are integrated along with the classical text and image components of an encyclopedia. Other areas that should be mentioned are certainly the entertainment (games) and educational markets, because the attraction of a product can be significantly increased by multimedia components. Computer-based training (CBT) and distance learning (e.g., via the WWW) are already offering practical multimedia components that can make learning substantially easier. Multimedia components on CD-ROM are also used in combination with printed material, as in the case of this book or a magazine, to widen the scope of communication (figs. 11.7-1, see also fig. 11.1-1). Other applications of multimedia technology include design review in the industrial environment, perhaps even virtual reality, although this is the exception at present.

The boundaries between the different electronic media are increasingly disappearing. Television and interactive media, which are nowadays accessible via the computer such as the Internet are tending to merge. Interactive television is a possible outcome.

Selling books on the Internet has become an important branch of "e-commerce". In addition to the marketing of printed books via electronic channels we should also mention the electronic book (e-book). This makes the contents of a book (which is in digital form and can be down-loaded from the Internet) available on a system similar to a computer (modeled on the shape of a book), (see also sec. 12.3).



Fig. 11.7-1 Book with CD-ROM as a multimedia product

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12 Print Media and Electronic Media

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12.1 Examples of Print Media and Electronic Media

To a very large extent, *communication* in the business and private spheres takes place via print media and electronic media. Previous chapters have dealt with the different media and the relevant production techniques in detail.

Section 1.1 (Communication Technologies) gives an overview of print media and electronic media, describing their use and areas of application together with their spread in the market (see sec. 1.1.4).

Newspapers, magazines, books, and catalogs, in particular, hold the most important share of the market, and advertising packaging, and commercial printed matters make outstanding use of print media. Figure 12.1-1 shows some examples of *print media*.

Print media is usually produced in medium to long print runs. Production technologies enable high quality and economic production. Although the information content of print media (text, images, and graphics) is fixed/static and cannot be quickly changed interactively, new production technologies increasingly enable content to be personalized and prepared according to customers' specifications. This means that the demands of different target groups (the customers and users) can be met to a large extent. Print media's particular strength (when compared to electronic media) is that it is easy to use in many locations and almost every environment – without recourse to any special equipment.

Electronic media and multimedia applications are described in detail in chapter 11. Electronic storage and transmission media allow for the integration of audio and video, that is, speech, music, and animations, into the information document (e.g., on CD-ROM) along with text, graphics, and image information (data types). This gives the user many ways of interacting with the information: it is possible to make selections and add components – the content is dynamic. Special equipment, however, is required for using electronic information, particularly when recording, playing back, and displaying data. Figure 12.1-2 illustrates the many diverse possibilities and applications for electronic media, in particular multimedia use, with data carriers, networks, and display devices.

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Fig. 12.1-1 Examples of applications and the spread of print media.
a Books, leaflets, catalogs, magazines, etc.;
b Paper bags;
c Packaging;
d Labels

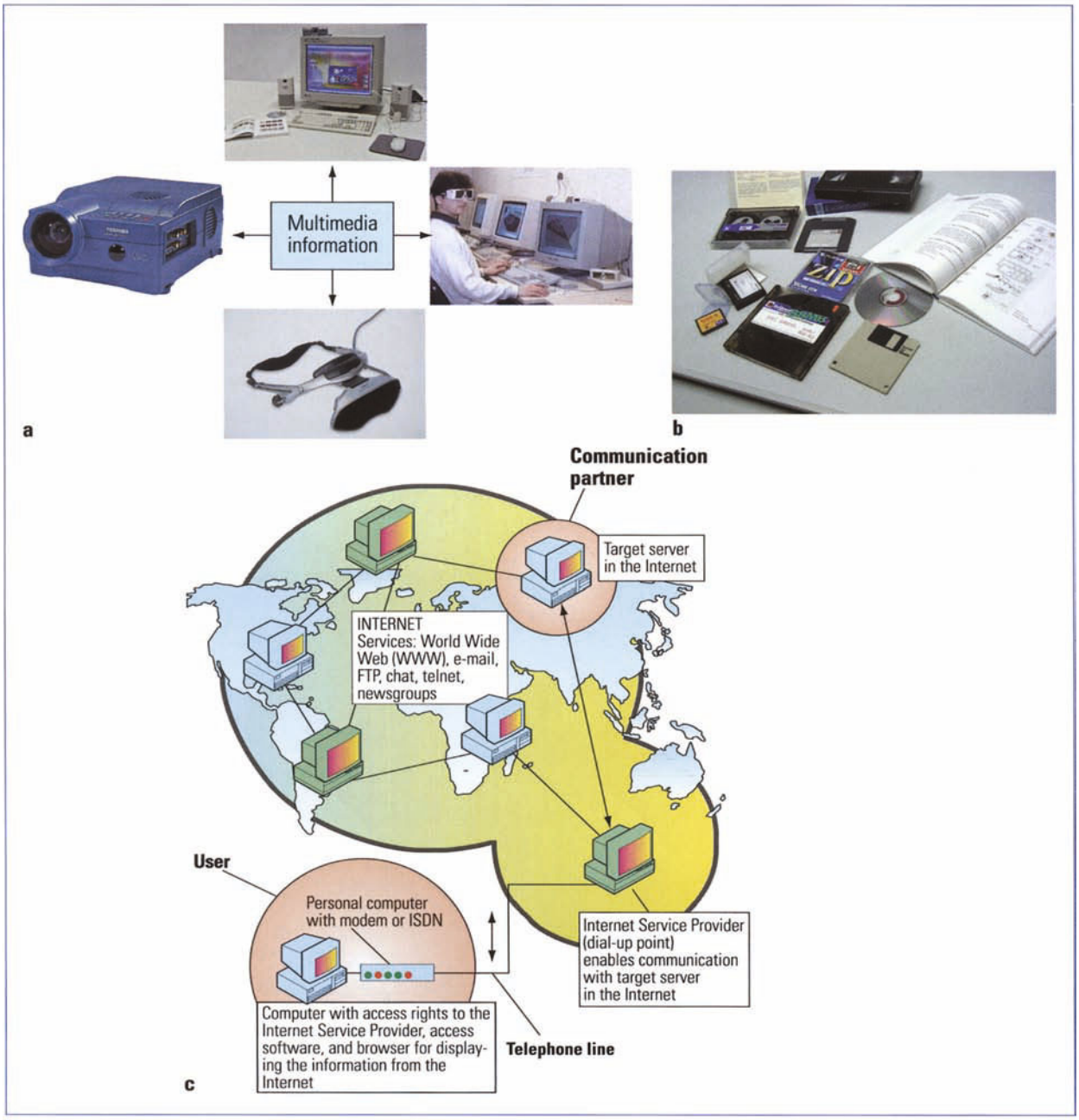
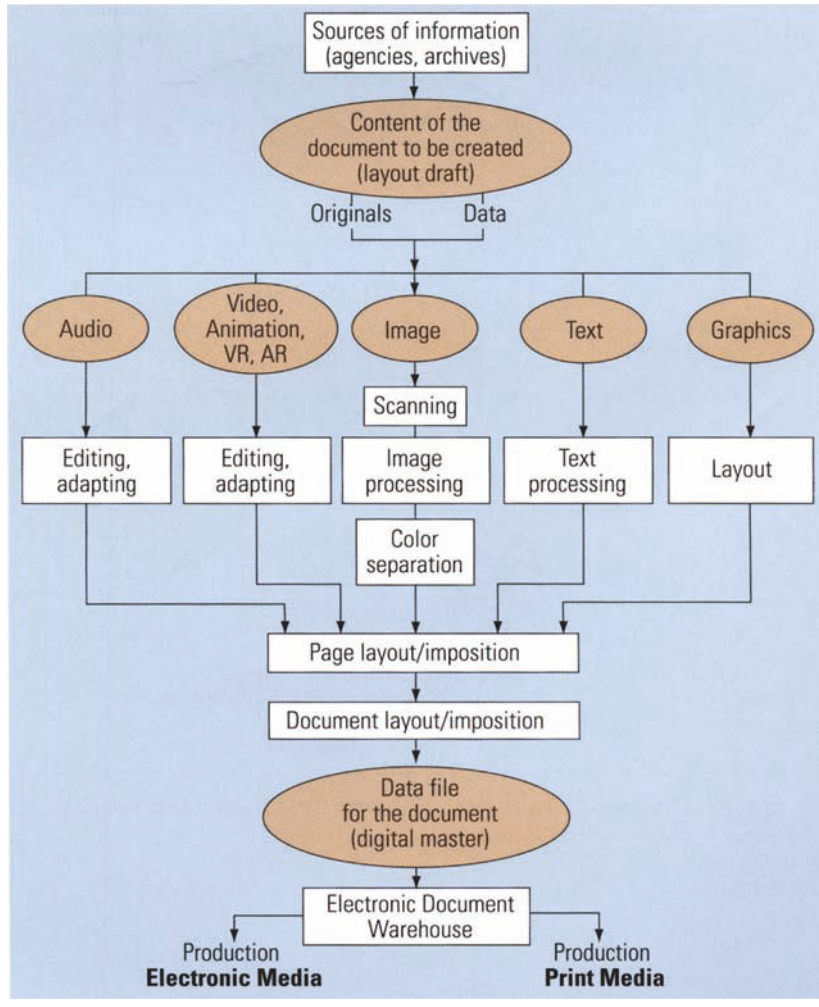


Fig. 12.1-2 Electronic media: multimedia applications, data carriers, and networking.
a Electronic media, multimedia applications;
b Data carriers;
c Networks

12.2 The Production of Print Media and Electronic Media

Figure 12.2-1 shows that the various components of a document, that is, text, images, and graphics, as well as audio (speech, music, sound) and video (with animation, virtual reality, and augmented reality) can be combined into one digital document. This figure represents an extension of figure 3.2-2, which demonstrates and explains the preparation of a completely digital print order within digital prepress (sec. 3.2.1).

Fig. 12.2-1
Components for creating a digital document as a basis for the production of print media and/or electronic media.
VR: Virtual Reality
AR: Augmented Reality



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Digital prepress processes representing the basis for the digital workflow. Dynamic content such as animations, virtual reality (VR), and augmented reality (AR) sequences can be added to the static content (text, images, and graphics) (see also sec. 11.2).

The content of the document intended for production is compiled from information sources (agencies, archives, etc.) by, for instance, the publisher in cooperation with the author (fig. 12.2-1). The content can be transferred physically, as originals, or electronically, as a digital data file. Systems with the necessary equipment can process this information and set up a data file for the complete document.

The data file for the complete document ("*digital master*") can be made available via a database (Electronic Document Warehouse) both for the production of print media and electronic media. The data must be adjusted to the desired output media, for instance, paper or Web Page – color, resolution, and image and data format are of particular concern.

As already explained in detail in figure 1.2-1 and in previous chapters, the production of print media and electronic media is based on the content that has to be prepared for the document. The production section for the creation of a digital master containing the information can – as shown in figure 12.2-2 – occur in the *premedia area*. The document created in the premedia area provides a data file that is the basis for the production of both electronic and print media. Figure 12.2-2 shows that the print products (*print media*) can be used by the customer/user directly (the information is available on paper), whereas *electronic media* (e.g., CD-ROM or network as a medium) require special equipment for its visualization (monitor, computer, connection to the network).

Figure 12.2-2 also demonstrates that a *multimedia document* can be set up by using and combining several forms of electronic media (the medium is understood as a transmission system), such as television, radio, Internet, and CD-ROM. The document can contain, in a static and dynamic form, the relevant components of information – text, images, graphics, and sound. Of considerable importance is the fact that multimedia documents with a high degree of customer use can also be produced as a *combination of electronic media and print media*. The information is therefore available to the user in the form of paper/printed product as well as electronic media, along with the corresponding storage media and display equipment for image and sound.

Digital communication technologies and processes for designing and producing information as print

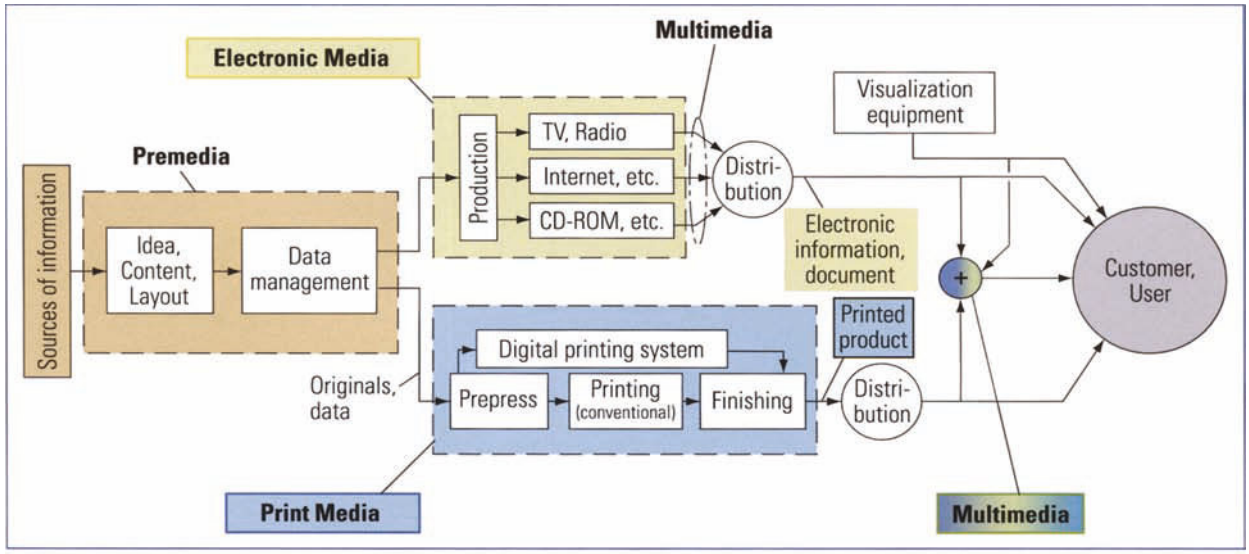


Fig. 12.2-2
Premedia as a basis for the production of electronic media, print media, and multimedia documents with workflow and transmission media for customer use

media or electronic media are penetrating the market. This means that the production processes for both groups of media are closely interconnected by a common basis, the premedia production section. The *premedia* area prepares the content and produces a digital document that may, to a large extent, be used in both sectors of production; "*cross-media publishing*" has become possible and is in place in the printing, publishing, and communication industries.

12.3 "Electronic" Books, "Electronic" Ink, "Electronic" Paper

The transfer of information, documents, and content via *electronic media* (CD-ROM or Internet) creates a varied array of interesting and useful applications. Electronic media can provide innovative alternatives to *print media*. Due to its small size and practicality, a CD-ROM version of an encyclopaedia or directory is much easier to use than a conventional book. Such a medium can offer search programs and links with further sources of information, and with its potential for integrating video clips, animation, and audio contents alongside information and graphics, electronic media can greatly increase interactivity. All of these features increase value and provide additional, high quality information. Skillful and instructional components can also be integrated to guide the user. The general book (fiction and poetry, specialist books, etc.) and newspaper markets are also interesting fields of application where electronic media can be well exploited. Effort is being made to find solutions that could make electronic media as user-friendly and attractive as conventional printed material.

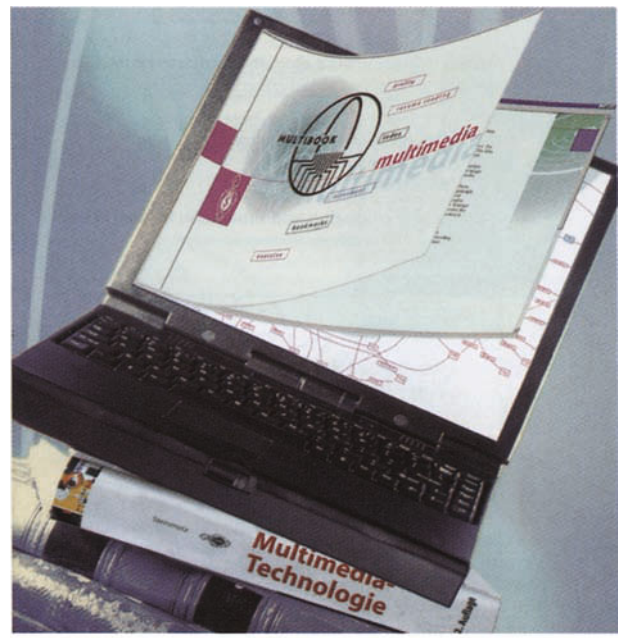


Fig. 12.3-1
Reading books and interactive learning using the laptop (Multibook/Multimedia Book, Research project: BMBF/Springer)

12.3.1 "Electronic" Books (E-Books)

Providing books on CD-ROM is state of the art, and it is no longer unusual to read publications of this sort on a *PC or laptop* (fig. 12.3-1). In contrast to the simple, flexible handling of the common book, however, digital playback of reading material can be relatively complicated and awkward. Using suitable software, it is possible to establish a convenient reading environment, but as previously mentioned, machines generally lack book-like handling and it is a disadvantage that output devices are required. (Fig. 12.3-1 contains a visionary representation of flexible screens designed for *book-like products*.)

Numerous concepts and developments have been elaborated for establishing the *electronic book* (e-book). In comparison with PC or laptop use, these innovations will make it easier for the reader to peruse an e-book. Existing models include the Rocket eBook (NuvoMedia), Softbook (Softbook Press), and EB Study Model (Everybook). Figure 12.3-2 shows an example of the Rocket eBook, which has a convincing, user-friendly size. Additionally, by mastering a few key functions, the user can operate this eBook in a variety of places, thus making network-independent reading simple. The memory capability of such e-books is sufficient to download extensive electronic books from networks or data storage machines.

The example of the product in figure 12.3-3 shows that suitable software tools and interactive user interfaces

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Fig. 12.3-2 Electronic Book (Rocket eBook, NuvoMedia)

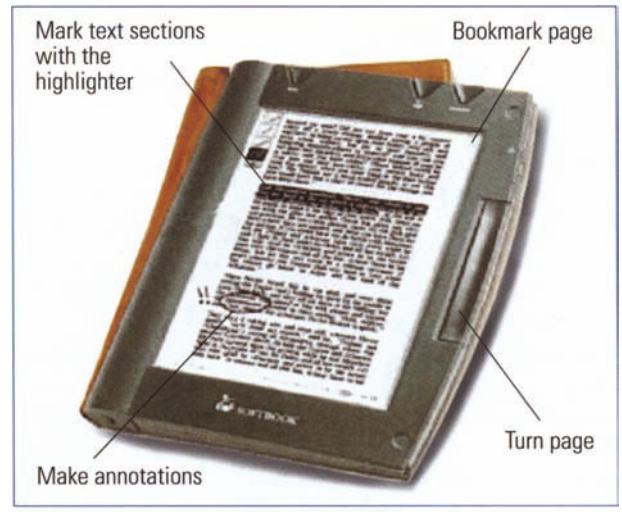


Fig. 12.3-3
Electronic Book, showing the ways the user can mark the text pages (Softbook, Softbook Press)

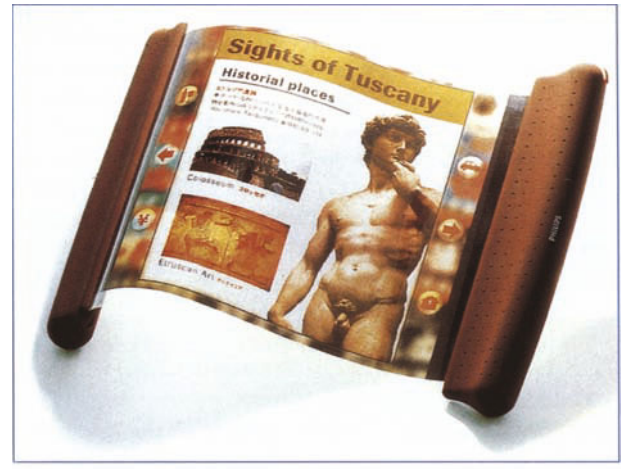


Fig. 12.3-4
Concept study for an Electronic Book with roll-out screen; in this example used as an interactive travel guide (Philips; status: around 1996)

will enable the text passage to be marked with circling, highlighting, or page markings. Without a doubt, these are measures that will improve the *acceptance* of electronic books. However, the rigid, non-flexible screen and the type of picture and page set-up do not give the user the kind of quality offered by the flexible pages of a book or newspaper. Figure 12.3-4 shows a concept study for an electronic book (Philips) that employs a *flexible screen* set-up to achieve "paper-like" characteristics.

A further design study for an "*electronic*" *newspaper* (IBM) is shown in figure 12.3-5. The electronic newspaper would compile sixteen newspaper pages into a "book" having double-sided, *flexible*, and "illustratable" *screens*. A newspaper of this type could load texts, graphics, and pictures from the Internet.

Clearly, developers and manufacturers are looking for possibilities to reproduce paper in the form of flex-



Fig. 12.3-5
Design study for an Electronic Newspaper (IBM; status: around 1999)

ible screens or *rewritable paper-like materials* with storage capability. The following sections provide information about a few technological solutions, concepts, and projects concerned with the realization of new types of screens (visualization media) that may one day act as paper-like information carriers.

12.3.2 "Electronic" Ink (E-Ink), "Electronic" Paper (E-Paper)

Today, various concepts and development activities are contributing to the creation of *paper-like materials* that can be imaged with text, picture, and graphic information via electronic signals. These materials will also be designed to have storage capacity – that is, after imaging they will be network/energy-independent and will permit multiple use (erasing, re-imaging, etc.).

Electronic Ink (E-Ink)

In 1996, MIT (Massachusetts Institute of Technology, Cambridge, MA) published the results of research concerning the development of special materials designed for books that the reader could image with the desired contents using digital data [12.3-1 to 12.3-3].

Figure 12.3-6 presents two variants with simplified drawings of the principles based on earlier publications. The "paper" is constructed of several layers whose main components are small spheres (about 100 μm in diameter) that have two sides – a white and a black part of the surface. The dipolar formation of these spheres (fig. 12.3-6a) allows them to be altered via electrical signals. Therefore, the medium's surface – which originally appears white – can be digitally imaged with information by turning the corresponding, minute spheres from white to black. The status of the spheres' position is stored automatically, and no additional energy or aids are required for reading or making the information visible. Electronic signals also facilitate the process of erasing or writing information anew. Along with the basic problem of designing and embedding the spheres, the multi-layer substrate presents particular difficulties for electrical control, for instance, a matrix of invisible signal lines or something similar is required. The paper, therefore, is given chromophore components, thus permitting the concept to be referred to as "electronic ink" or "electronic paper."

This type of storage medium permits a book of several pages to be set up, which, as shown in figure 12.3-6a, can download and store content from the Internet or a CD-ROM; the book is then available for network-independent use without a power supply. This development concept has been under discussion for a long time, and work is being done to make it reality.

It is well known that a start-up company (E Ink Corp.) was founded in 1999 and that its first product was large display boards, established on the basis of "e-ink."

Recent news from E Ink in cooperation with MIT illustrates a further concept of using spheres to change the color of the surface of the "paper." As shown in figure 12.3-6b the spheres have a transparent shell. They are filled with a dark colored liquid (e.g., blue) and very small pigment particles that are electrically, for instance, positively, charged. Under the effect of an electrical field, the white pigment parts can move to the "surface of the paper" and cause it to become white. If the electrical field is reversed, the charged white pigments move away from the surface towards the opposite side and the dark (e.g., blue) color shows on the surface.

It is estimated that electronic books based on e-ink technology will be available for selected applications within the next ten years.

"Gyricon," Electronic Paper (E-Paper)

Xerox is carrying on further research into electronic paper/electronic ink. Research is taking place on "Gyri-

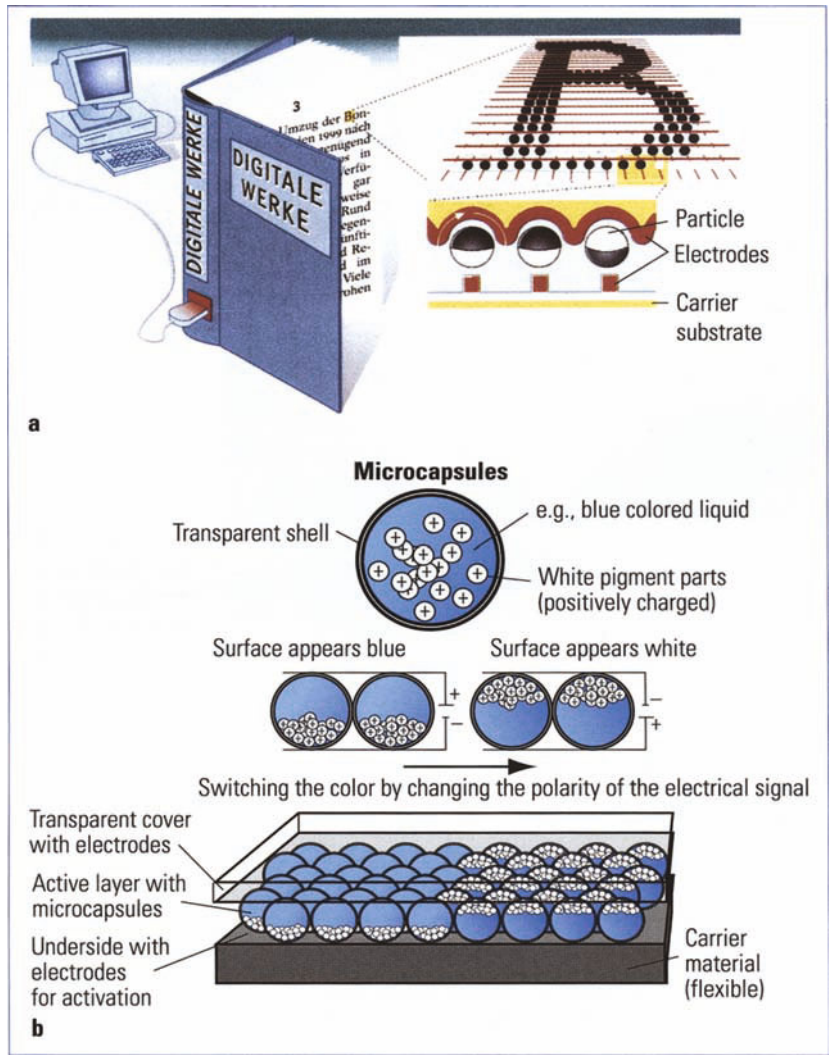


Fig. 12.3-6
Electronic Ink (e-ink) for setting up electronic books.
a Concept with rotating spheres (MIT, [12.2-1]);
b Concept with microcapsules filled with a coloring agent (E Ink Corp./MIT); status: end of 1999)

con" [12.3-4, 12.3-5] in the Xerox-PARC (Palo Alto Research Center, Palo Alto/CA). This electronic paper is based on similar concepts to the ones described above and derives from an early Xerox patent. Once more microspheres are the key components of the "electronic paper." One half of their surface is colored white and the other black. One side is charged positively and the other negatively (dipole). The spheres can be aligned in an electrical field and digital imaging of the medium is then performed with electrical signals by turning the spheres from their black surface onto their white half. (The name "Gyricon" is derived from the Greek words "gyro", to rotate, and "icon", symbol.)

Since around 1995 intensive work has been carried out to put this application into practice. Figure 12.3-7 shows how "black-and-white" picture elements are set up using small spheres (diameter about 100 µm, thus corresponding to about 250 dpi resolution). A consortium now exists for this project (Xerox, 3M) and is dealing with implementing the concept; it intends to provide e-paper in several forms, in particular on a roll. (At the end of 2000 the spin-off company Gyricon Media Inc. was founded by Xerox for further development, production and marketing of this e-paper.)

Both technologies (e-ink and Gyricon) concentrate primarily on achieving black-and-white, that is,

monochrome displays. Color reproduction may also be possible, and concepts that use color filters and reduce the sphere diameter to around 30 µm are under discussion.

"E-ink" and "e-paper" concepts designed for creating book pages that can receive and store data using digital information, can certainly provide a variety of other useful applications. In addition to single-sided imaged documents, *new types of monitors*/electronic screens, large display boards and billboards could be developed. (E-Ink is already in its launch phase.)

Because it is energy-independent or requires a minimum of energy after imaging, the device's storage capability, rewritability, and flat design are particularly attractive. Other areas of technology will find further use for these concepts.



Fig. 12.3-7
Electronic Paper "Gyricon" as a flexible medium for presenting digitally transmitted information.
a Example of a "printed page";
b Detail in a picture showing the small spheres for single-color reproduction of information (sphere diameter about 100 µm), (Gyricon, Xerox)

High Flexibility LED and LEP (OLED) Screens

In the last few years CRT screens (CRT Cathode Ray Tube) have been increasingly replaced by LCD technologies (LCD Liquid Crystal Display). Although it has been possible to produce extremely flat screens in large formats, screen flexibility is not yet possible. The latest development activities are attempting to prepare flexible color screens on an LCD basis (e.g., Minolta [12.3-6]).

The previously explained innovations regarding "e-paper" and "e-ink" also demonstrate potential for constructing flexible screens, in which the image results from the reversible re-orientation of chromophore elements in the material layer and which can be stored in the image-generating layer.

Another approach is based on so-called *Organic Light Emitting Diodes* (OLEDs) used in tandem with the electro-luminescence of polymers [12.3-7]. This process causes the polymer to take on multicolor brilliance in a nonlinear and material-dependent way. In order to set up a colored, flexible screen on the basis of OLED, various color-sensitive polymers are added to the multi-layer substrate for the colors blue, green, and red. (Researchers at Seiko-Epson (JP) and the Cavendish-Laboratory (UK) are currently discussing concepts intended to accomplish this with a special ink jet printing system.)

An example of a flexible polymer display from the development laboratory is shown in figure 12.3-8. In

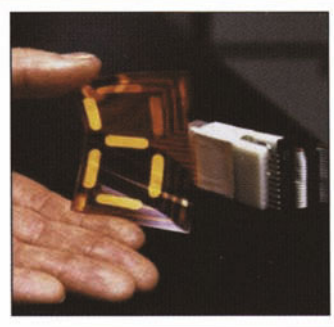


Fig. 12.3-8
Flexible display, made up of organic light emitting diodes (OLED) on polymer basis (Cambridge Display Technology)

comparison with the concepts for e-ink and e-paper, displays of this type have no storage capacity; that is, the polymers maintain their brilliance/luminous intensity, image composition, and display qualities only when connected with a source for energy. Recently the acronym LEP (*Light Emitting Polymer*) was used to describe technology for highly flexible, flat screens based on organic compounds (OLED).

The idea of a high level of flexibility, which permits a screen to be rolled up with a relatively low bending radius (examples of less than 15 mm have been cited), is fascinating. However, effort still needs to be made to find a means of increasing the service life of these flexible screens. Multicolor, luminous organic LEDs are an essential component (see fig. 12.3-4) of the flexible screen and electronic books.

Rewritable Paper

It is known that certain physico-chemical effects permit heat to produce a *reversible color change* in multilayered, polymeric materials. Various companies have published reports [12.3-3, 12.3-7, 12.3-8, and 12.3-9] and patents (e.g., RICOH [12.3-10]) detailing the set-up and use of such papers/materials .

Thermally sensitive papers contain a carrier layer, a recording layer, and a protective layer (fig. 12.3-9). Thermal print heads [12.3-10], as used for NIP technology thermal transfer (see sec. 5.6), or the light of thermal laser diodes [12.3-11] supply the heat necessary for achieving a temperature-dependent alteration of the transmission behavior.

Thermally sensitive polymers can become more or less transparent due to the effect of heat (fig. 12.3-9). For example, when heated, a light-impermeable (dark) layer applied to a carrier substance (e.g., a white surface) can become transparent (light), and, therefore, a contrast corresponding to the image develops. This alteration to the transparency is reversible – that is, by heating the entire surface of the substrate to a higher temperature level, a homogeneous (dark) surface state can be achieved again. Figure 12.3-9 shows the temperature-dependent procedures for imaging and erasing.

This type of material can be used to set up an electronic book in such a way that the rolled-up material is imaged using thermal print heads (see the device concept in the design study given in fig. 12.3-4). "Turning" pages could take place by first bringing together and then pulling apart both parts of the reading device; this action would enable the erasing and rewriting of information onto the "paper." Another possibility, keyboard-controlled rolling and unrolling of the rewritable paper, could replace the "page-turning." Such thermally sensitive materials (also known as *thermochromic materials*, i.e., TC materials) can be used for sheets in electronic books as well as for displays and films in backlight.

Status/Trends

The examples already given about the development of electronic books on the basis of "*electronic ink*," "*electronic paper*," flexible displays, and rewritable paper show that great efforts are being made to develop stor-

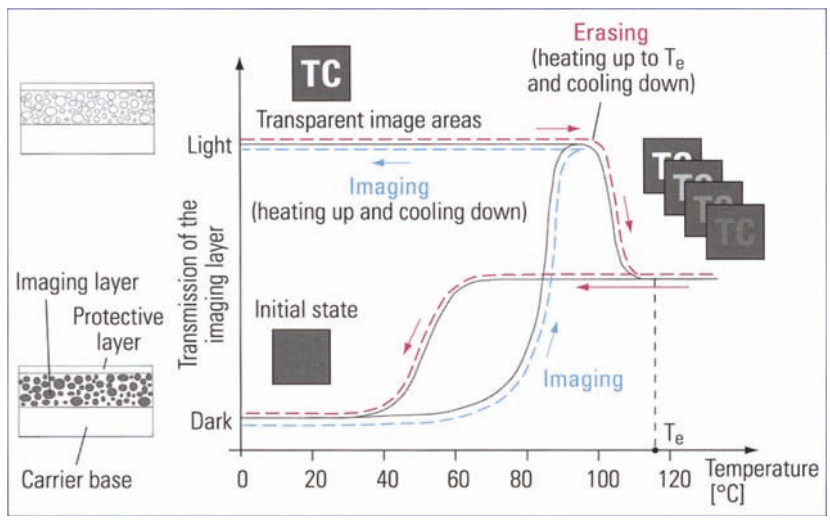


Fig. 12.3-9
Imaging and erasing processes for rewritable papers (Thermochromic Technology (TC), RICOH [12.3-10])

age media that can be imaged electronically. The goal is to give the reader the impression that he is using paper and, additionally, to permit reading to occur comfortably – as is the case with books and other print media – in various environments and locations and using no special equipment, power, or data connections. Although the reality of such products being mass-produced is far away, it cannot be ignored.

In the future, an "*e-book*" will not, as is the case with today's existing electronic media, be a replacement for print media such as books and newspapers. It is, however, certain that these new technological opportunities will offer the user additional, interesting means of communicating and obtaining information in a content-dependent and application-oriented environment. Setting up *multimedia products* by combining print media with new electronic technologies can lead to useful *hybrid solutions* for new media.

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12.4 Market Shares and Trends

The fascination of new technologies and the increased opportunities for communication and dissemination of information with electronic media is certainly influencing the print media market. A careful analysis of the existing market is needed to predict the future trends and requirements in print media and electronic media.

Factors that Impact the Print Media Requirement

Figure 12.4-1 shows the chief *factors* that impact the market for print media. In the long run, it is essentially the global economy, worldwide trade, changes in population, and political influences that lead to increased worldwide democratization, enable the global and more liberal use of information, and facilitate an almost borderless means of communication. Education and culture will continue to experience an increasingly higher status and standard in all classes of society. Additionally, the desire for life-long learning and the need to adapt to fast-changing work and economic situations will also influence the requirement for printed products. Ecological needs and demands further shape humankind's relationship with the environment, thus affecting or altering the use and further development of the media. The media landscape is becoming more varied and offers a wider range of possibilities, while beginning to focus more on groups and individuals. The influence of technologies and innovations is of particular importance.

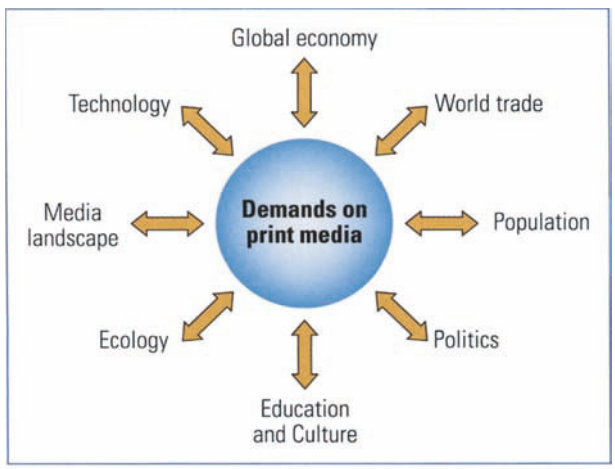


Fig. 12.4-1 Factors which impact demands on print media

Generally speaking, further developments and changes in technology, economy and society lead to an altered use and new requirements concerning information and documents in the form of print media and electronic media.

The most important factors affecting the demands on print media are listed in figure 12.4-1; the bi-directional arrows also show that the possibilities and effects of print media certainly have a retroactive influence on the given subject fields (impacting factors). The content and design of print media can create new opportunities that may make a fundamental contribution to the economic, social, and private environment by increasing the standard of living and securing and augmenting our culture.

As explained and determined in previous chapters, both print media and electronic media have their preferred applications and market segments. Furthermore, only to a certain extent is there competition in these sectors. In the last few years analysis of the demands on print media has clearly shown and repeatedly confirmed that, with the growing spread of electronic media, the *demand for print media* is increasing. For example, in order for electronic media to retain their functionality and be used meaningfully, the product(s) in question must be supplied with handbooks, descriptions, and supplementary information covering content and operation. High-quality print media therefore greatly supplements electronic media, in particular regarding the representation of the contents and the design.

H. Kipphan (ed.), *Handbook of Print Media*
© Springer-Verlag Berlin Heidelberg 2001

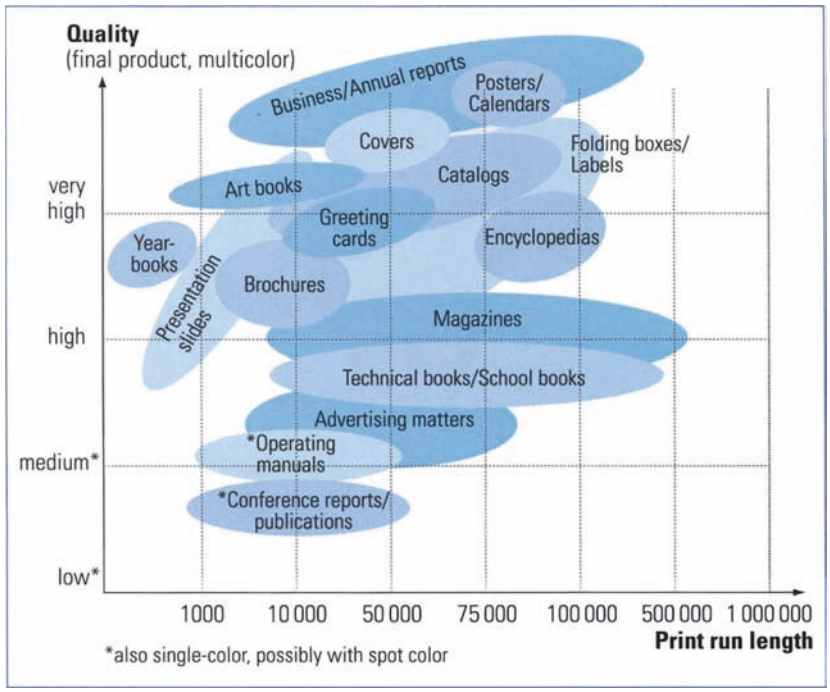


Fig. 12.4-2
Selected product groups of print media with quality requirements and typical run lengths (produced primarily with sheet-fed printing systems)

Figure 12.4-2 shows excerpts of product groups for print media in addition to the desired quality demands and common run lengths. Although such a variety is typical of the great demand for print media, it is also characteristic of the necessary production technologies that emerge from this demand, and that enable a high quality product to be manufactured economically to the great advantage and benefit of the customer.

Corresponding to the information presented in section 1.1.4, figure 12.4-3 shows, based on worldwide studies and predictions, a selection of print products and their market shares (fig. section a). Additionally, figure 12.4-3b illustrates the results of a survey that estimates the future demands for print media worldwide (see also sec. 1.1.5). Figure 12.4-3c displays statistics on the time-related use of different types of media in leisure time (simultaneous media use, e.g., reading and listening to music at the same time, has not been taken into consideration here). It is no surprise that radio and TV predominate as the most popular means of acquiring information. Using print media also occupies a large portion of time.

Future developments in the usage of print media will depend on the future design and range of print media on offer. Changing tendencies in culture, education, and leisure time also play an important role, and it is expected that these areas will experience a *renaissance in reading*, and a further spreading of print media in comparison with watching TV and using electronic media will take place. Supported by past and current developments, the predictions for the year 2015 indicate that there will be an increase in the use of electronic media.

Electronic media and online services have made *electronic business* (e-business), *electronic commerce* (e-commerce), and so forth, possible. This has had a positive effect on trading with print media. As the example in figure 12.4-4 shows, books can be ordered electronically worldwide, a service that has established itself as a successful branch within e-business.

The sales of magazines, books, and other print media in bookshops and kiosks is also supported by the installation of electronic directories. Information is displayed, for example, on terminals ("Infopoint"), enabling available titles and excerpts from descriptions of contents to be displayed (fig. 12.4-4b).

Predictions in Market Share, Growth, and Trends

Electronic media, print media, and multimedia as well as a combination of print and electronic media, in par-

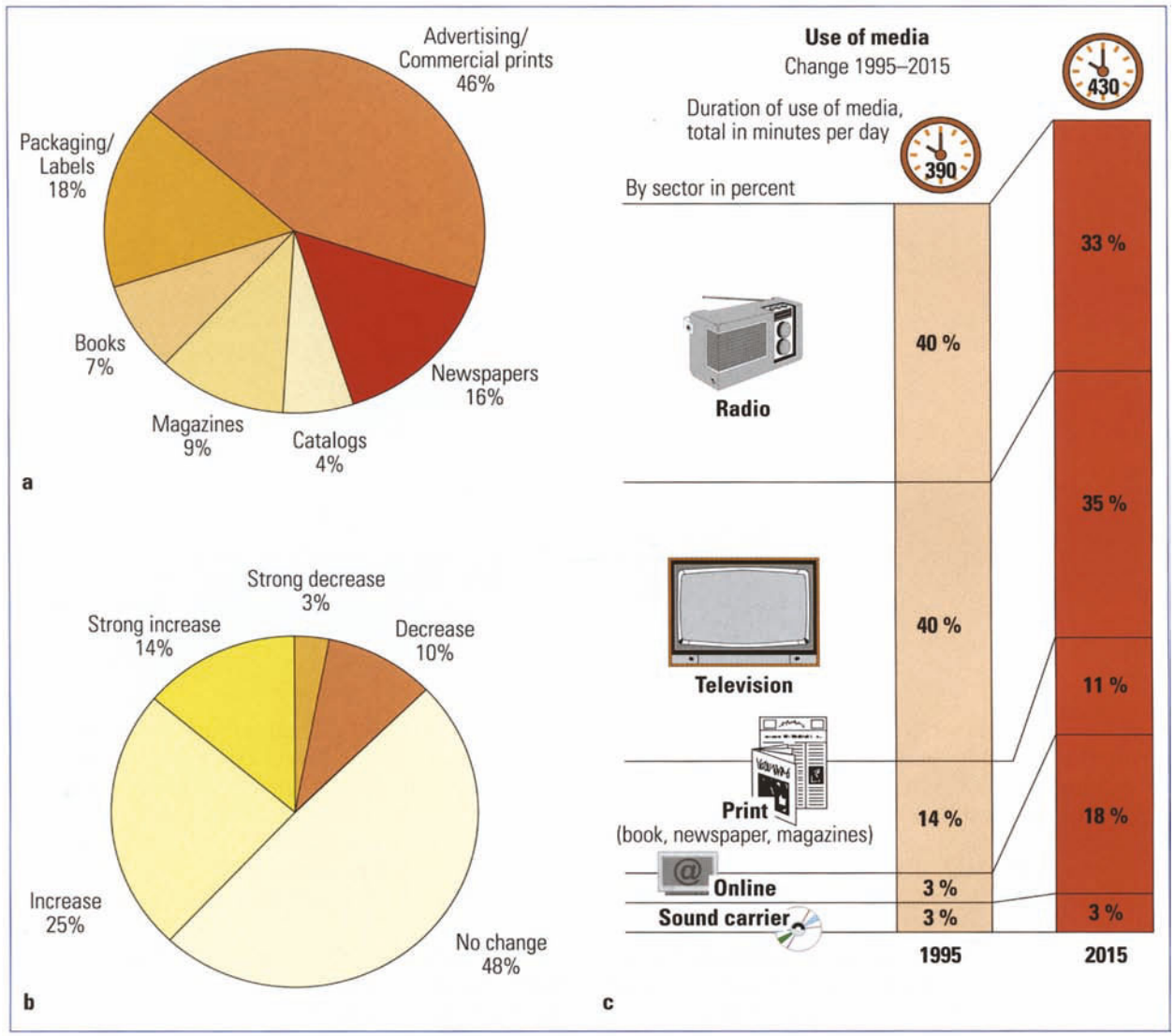


Fig. 12.4-3 Market shares of print media and predictions for the future use of the media.
a Market shares of various print media product groups (estimated by Heidelberg based on worldwide information sources);
b Predictions for using print media [1.1-3];
c Duration of use of media in leisure time (Fraunhofer-Institut ISI, Handelsblatt No. 144/1999)

ticular, are a reality, and their popularity is increasing. Figures 12.1-1, 12.4-2, 12.4-3, and 12.4-4 offer examples of the variety that is demanded of print media and how electronic media can be used with its various data carriers and networks (fig. 12.1-2).

As important elements of today's lifestyle, print media and electronic media ensure communication and provide sources for obtaining and transferring information. Additionally, these are vital for maintaining the quality of our life and culture and for preserving an infrastructure that functions well in order to retain a successful, global economy.

The strength of print media lies in its simple use, its high quality standard, and economical production. Elec-



Fig. 12.4-4 Electronic media for promoting the distribution of print media.
a E-business for ordering books (amazon.de);
b Terminal for searching for magazine titles and for studying the contents for selection and ordering (Infopoint/Wiesbadener Konzeptgruppe)

tronic media stands out owing to its topicality, simple handling (e.g., with directories), and, in particular, interactive, flexible use in local and global networks. Many chapters of this book give detailed information on the production and application of the various media.

Based on new technologies and the factors that impact print media, an attempt is being made worldwide to predict how the structure of the media market will appear in the future.

Figure 12.4-5 shows, as section 1.1.5 has similarly demonstrated, how a *prediction* was obtained from international studies that took many impacting factors and evaluations, plus both optimistic and pessimistic scenarios, into consideration.

Because of innovation and changes in technology, business, and society, the demand for information via print media and electronic media is clearly increasing worldwide. In relation to print media, electronic media is experiencing strong growth. The ratio between the market shares of print media and electronic media is becoming more balanced. There is now a strong move towards electronic media, and long term predictions point to a 50:50 ratio between print media and electronic media (around 60:40 in the year 2000, after starting at 70:30 in 1995).

An important question will be whether the increasing demand for print media can be satisfied through *innovative production techniques and materials,* both from the viewpoint of production means and systems for print media and also on the part of print media producers. All partners in the printing and publishing industry will have to adapt to customer-specific solutions and the market situation.

New technologies and production strategies as well as changing specifications in print media (regarding content and print volume) will certainly bring about a different positioning of production equipment and technologies employed. Figure 10.5-4 in chapter 10 (Comparison of Printing and Production Technologies for Print Media) shows that there is a particular increase in the use of production systems for print media based on non-impact printing technologies, with offset printing, however, still being the dominant technology.

The previous illustrations addressed examples of various *product groups* of print media (see also figs. 12.4-2 and 12.4-3a). Although the relative proportion of print media in the media market is declining on the whole, demand is increasing (see fig. 12.4-5). Most notably, the strongest growth has occurred in the area of packaging, magazine and newspaper, and advertising. Business forms can expect less of an increase. The prediction for the book market based on a pessimistic scenario is: It should experience stagnation or a slight de-

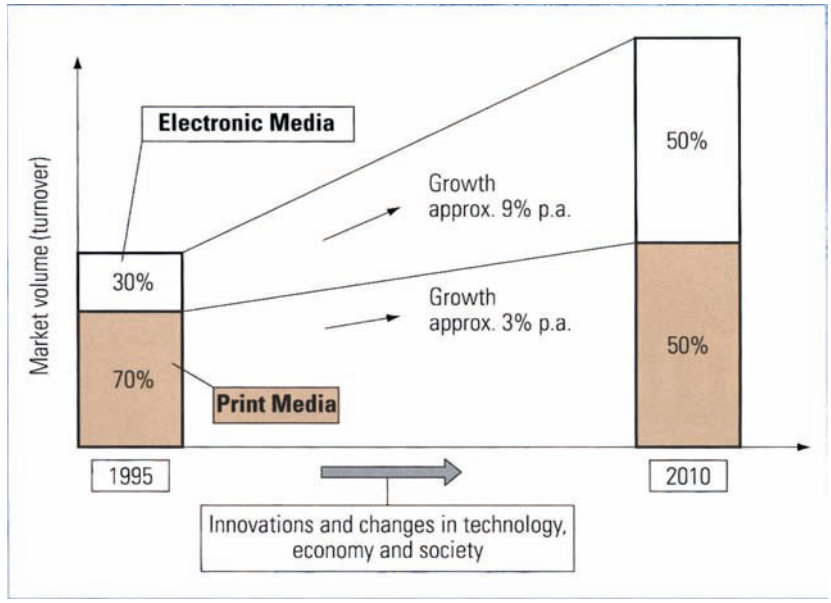


Fig. 12.4-5
Market shares and growth of print media and electronic media (Heidelberg, several international studies and predictions)

cline. (More detail on markets and trends for the individual product sectors of print media are explained in sec. 13.3.)

Because of the increasing demand of publishing houses and printing companies for both print and electronic media, the production of print media will go hand in hand with the production and distribution of electronic media, based on the digital print order from the *premedia* section (see fig. 12.2-2).

The production of print media by the printing company will result from a variety of heavily digitized production means. Basically, this means that master-based printing technologies (computer to plate and direct imaging systems) will be used for more extensive and medium-sized runs. Furthermore, non-impact printing systems will most likely take over short print run length, that is, those for personalized products being characterized by "print on demand" or decentralized production (see for example the installation in figure 3.2-58 in sec. 3.2.8 on the subject of "Networks").

The "House of Publishing" in figure 12.4-6 indicates that a publishing house – an operation that concentrates on the production of documents – will produce more and more in the future on the basis of digital (but including analog) information. Additionally to print media, it will also supply electronic media products directly to its customers/market. As briefly explained in figure 12.4-6, the *information publisher* (producer of media) will concentrate his equipment on the premedia section, within which the content and design of documents are determined, and the installation of poerful, high perfomance databases (*Electronic Document Warehouse*) takes place. Production systems with highly competitive/powerful hardware and software systems are required for the production of print media and electronic media based on the digitally-described document. The *digital workflow* enables the linking of all levels of production, thus it encourages the inexpensive, fast, and high quality production of information and products for both print media and electronic media (*cross-media production, cross-media publishing*). The use of local, wide area, and global networks is of particular importance when marketing products, since this is the basis for successful product distribution and for obtaining information and content.

The "House of Publishing" (fig. 12.4-6) shows the potential of cross-media production of print media and electronic media "under one roof." On the whole, however, a company of this type will not be a typical case. Today, large enterprises are not alone in trying to meet customer and market requirements, a fact that will certainly not change much in the future. Along with large companies, production will be distributed among small- and medium-sized companies. These companies will have to remain steadfast, single-minded, and open to investments for innovative production systems

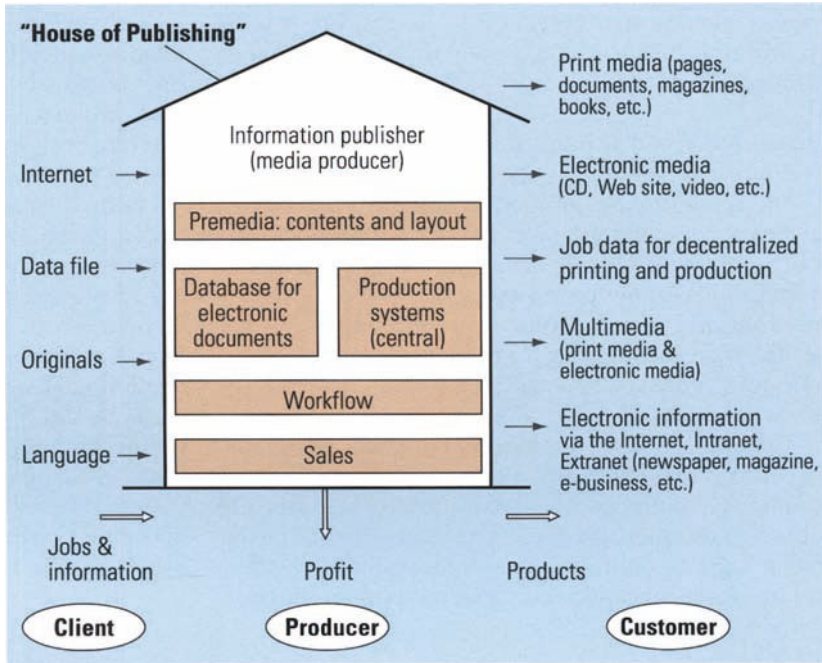


Fig. 12.4-6
House of Publishing; production of print media, electronic media, and multimedia documents when using digital technology for product preparation, production, and distribution

and to the use of new production concepts and strategies. Such qualities are necessary if they wish to assert themselves in the market place and work in worldwide cooperation with other companies and their customers.

Due to various innovations, technologies, and developments in information and communication technology taking place worldwide, the time we live in at present is frequently described as the *information age*. Future developments and innovations in the markets, commerce, technologies, and social life are increasingly characterized by the use of technologies, opportunities, and products for the procurement and exploitation of information and knowledge in all areas of business, education, and entertainment.

The *information age* (characterized by data, communication technology, and digital procedures for the production of media using global networks) will extend far into the new millennium. From the manifold scenarios not even a single one indicates that the importance, influence and use of print media in harmony with electronic media might decline in the distant future. In our *information and knowledge-based society*, media technologies will, by and large, be of increasing importance and will further penetrate all areas of life. The countless developments, projects, and visions for innovations and synergies in print media, electronic media, and multimedia products and the development of technologies that facilitate the handling and accessing of information will make information, communication, and the dissemination of knowledge possible in a more targeted and comprehensive way.

As mentioned in section 1.1, it is appropriate to conclude with a *few statements made in the past* that spoke against the spread of print – as we know today, these predictions soon turned out to be *glaringly incorrect*:

- Around 1920: Radio will replace print.
- Around 1950: TV will replace print.
- Around 1980: The computer will replace print.
- Around 1990: The Internet will replace print.

Each of these statements was based on a fascination with new technologies, which eventually led to speculative, one-sided predictions that new media would replace the old. Such attitudes neglected the creative and innovative potential found in synergy effects and making use of product-specific advantages of individual technologies. None of these predictions have come true because product innovations and synergies have taken

place – developments that clearly increase opportunities for multimedia-based use and transfer of information and documents.

Status and Trend. Print media is still predominant and will remain so in the long term.

The demand for print media guarantees the sector's lasting success and progress: the printed product cannot be replaced. New opportunities for print media and applications for multimedia products will arise in connection and combination with electronic media. Rather than encouraging the reduction of print media, electronic media supports and fosters demand for print product.

The results of such analyses and predictions not only confirm that print media will continue to retain its dominance but also provide an incentive to critically observe customer and market needs, to determine the technological conditions required for establishing new information concepts, and for developing production systems and strategies, which themselves, on the other hand, use these new information technologies and production possibilities in order to cover the vast demands of the industry and provide the customer with friendly service and high quality (but inexpensive), state-of-the-art printed products.

The high standards required of print media and electronic media for excellent content quality and information production are an integral and essential part of our lives today and in the future. In meeting these demands, we can maintain quality of life and the ability to interact globally. Such goals provide the energy, motivation, and need to constantly refine and optimize methods and systems of communication and information technology. Print media have a prominent share in the challenges and requirements placed by the customer/end user of print media and/or electronic media on the producer of information and its publication using different types of media.

13 Special Topics

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Special Topics

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13.1 History, Education, Research

13.1.1 History of Technology (Press and Prepress)

13.1.1.1 Offset Printing and Offset Printing Presses

In the beginning there was the *Solnhofen stone – stone printing*. It is a touching story of a laundry list that *Alois Senefelder* (1771–1834) wrote on the said stone in Munich for his mother since he had no paper at hand, thereby inventing "polyautography," which later became known as "lithography." It all sounds very improbable, but is actually historically authenticated. This was, however, only the final dramatic act in the longer history of the playwright and actor Alois Senefelder, whose real aim was the relief etching of a cheap letterpress printing form for his own use.

It was during his attempts to develop an inexpensive reproduction technology for expensive sheets of music that in 1797 he discovered that Solnhofen limestone reacted differently to grease and water and that printing using the greasy drawing no longer required the stone to be etched in relief, but only had to be kept constantly damp after prior blackening as well as a light one-off etching and treatment with a gum solution.

Senefelder also invented a special hand press for his new printing process, the so-called "*lever press*" (fig. 13.1-1a). This applied the impression by sweeping over the successive sheets of paper positioned on the stone with a type of swiveling wooden blade, to avoid the sensitive stone being too heavily loaded by a platen. Because this lever press was difficult to operate, he constructed another version with a large *impression cylinder* (fig. 13.1-1b) several years before *Friedrich Koenig* registered the *cylinder design* for his automatic cylinder press in London (replacing the platen principle). Both systems existed side-by-side for a long time, probably for reasons of cost.

The first *lithographic automatic cylinder presses* were produced in France. The year 1846 is given for Nicolle's press. Georg Sigl's press followed in Vienna in 1852 (fig. 13.1-2). Alexander Dupuy built his first lithographic automatic cylinder press in Paris in 1860. He employed Louis Faber and Adolf Schleicher, both from Swabia, who later became his partners. The Franco-German war of 1870/71 drove Faber and Schleicher out of France, whereupon they set up their own workshops in Offenbach am Main to build lithographic printing

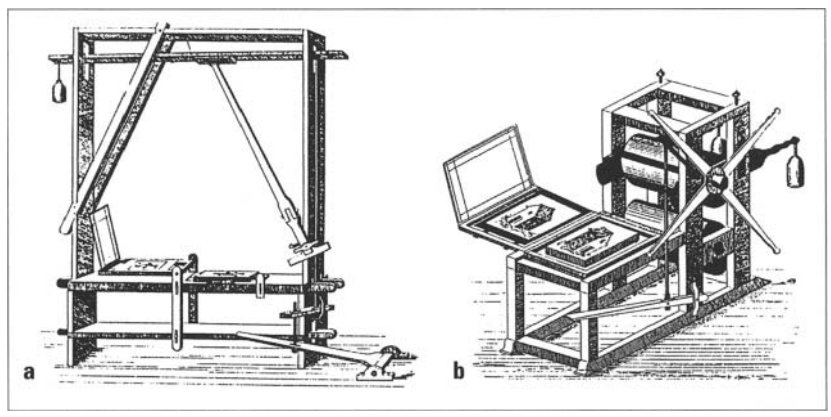


Fig. 13.1-1
Hand presses developed by Alois Senefelder at the end of the eighteenth century.
a Lever press;
b Cylinder press

H. Kipphan (ed.), *Handbook of Print Media*
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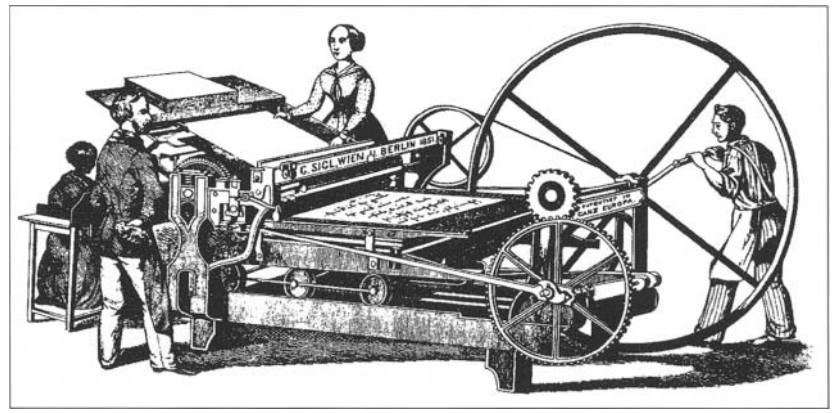


Fig. 13.1-2
A lithographic automatic cylinder press with thrust crank drive from around 1815, such as continued to be used for a long time for art prints (posters). Operation involved 3 persons: one for driving the wheel (on the right), one for feeding the sheet, and one for catching the sheet (on the left, rear); the supervisor is standing in front

presses – the sheet-fed offset press section of present MAN Roland Druckmaschinen AG.

Senefelder had already developed ideas as to how the flat form of the stone plates could be replaced by a *round form*, by milling the stone material and applying it to flexible metal plates with solvent, for example. But it was only the discovery of the *zinc plate* with a light-sensitive coating as a suitable image carrier and the accompanying "zinc rotary" (fig. 13.1-3) that brought success. The first of these is attributed to Ruddiman Johnston in Edinburgh in 1886. The first patent, taken out by a Frenchman, had already been in existence since 1835. To replace the slow back-and-forth motion of the heavy stone came the rotating cylinder with the clamped-on, light weight, flexible metal plate. The Americans later replaced zinc by aluminum, because they had the raw material and suitable rolling mills.

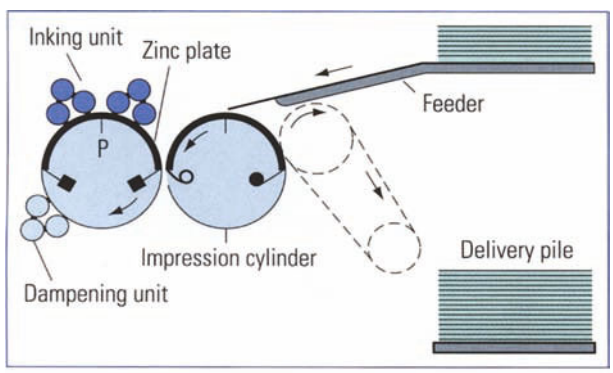


Fig. 13.1-3
The basic principle of the "Zinc Rotary" using a bent printing plate for lithographic printing, in the middle of the nineteenth century (IFRA)

The invention of the *offset printing*, developed from *indirect letterpress* in order to print tin substrates (fig. 13.1-4), is attributed to two inventors: an American, *Ira W. Rubel*, and a German immigrant, *Caspar Hermann*, who both had the idea around 1904 of printing from lithographic plates indirectly, that is, via a blanket cylinder.

Rubel ran a small lithographic and zinc plate printing works in Rutherford, NJ (USA). According to reports, problems arose one day when printing hard bank note paper with halftone images. To achieve a better print result Rubel therefore had a soft rubber blanket mounted on the impression cylinder. The feeder operator sometimes missed out a sheet through inattention, resulting in the ink impression being unintentionally deposited on the blanket. It was transferred from there

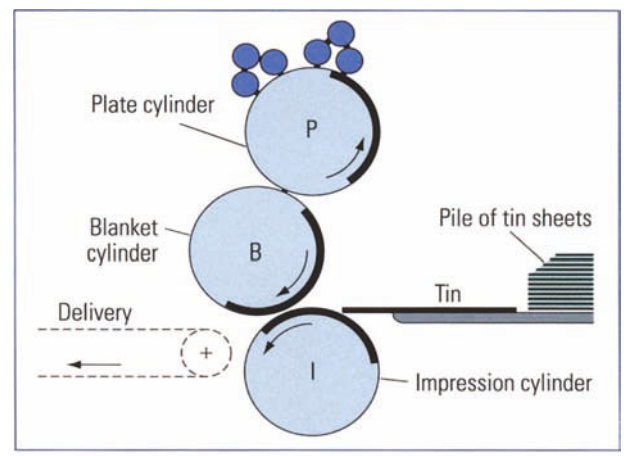


Fig. 13.1-4
The indirect letterpress technology for tin (sheet metal) printing (IFRA)

to the reverse side of the following sheet. When Rubel inspected one of these misprints more closely, he found to his astonishment that the impression on the reverse side, though a mirror impression, was considerably better than that on the front. Further tests confirmed his observations. He gave up his printing works and devoted himself henceforth solely to the construction of *indirect lithographic printing presses*, for which he was soon using the term "offset printing" (fig. 13.1-5).

Hermann, the other person to whom the same invention is attributed at the same time (in practice, the idea was in the air as a result of prior inventions arising from tin printing), offered at the end of 1904 to adapt the letterpress sheet-fed rotary presses of the brothers Alfred and Charles Harris for offset printing. A cooperation agreement was signed in Niles, Ohio (USA) at the beginning of 1905 and the Harris Automatic Press Company then became the first offset press factory alongside that of Rubel and was, in fact, considerably more successful than Rubel's.

Hermann developed further new ideas for multicolor printing presses, web offset presses, and presses for simultaneous printing on both sides of the web (perfecting). In May 1907 he returned to Germany since he saw no chance of furthering these developments in the USA at that time. Four days before he was awarded a patent by the Imperial Patent Office in Berlin. He alone realized the implications of this. It involved the construction of *blanket-to-blanket presses* for simultaneous printing on both sides of the web (perfecting), (fig. 13.1-6).

Just as Friedrich Koenig a century before had had to travel all over Europe to find financial backers for his inventions, Hermann wrote to all leading press facto-

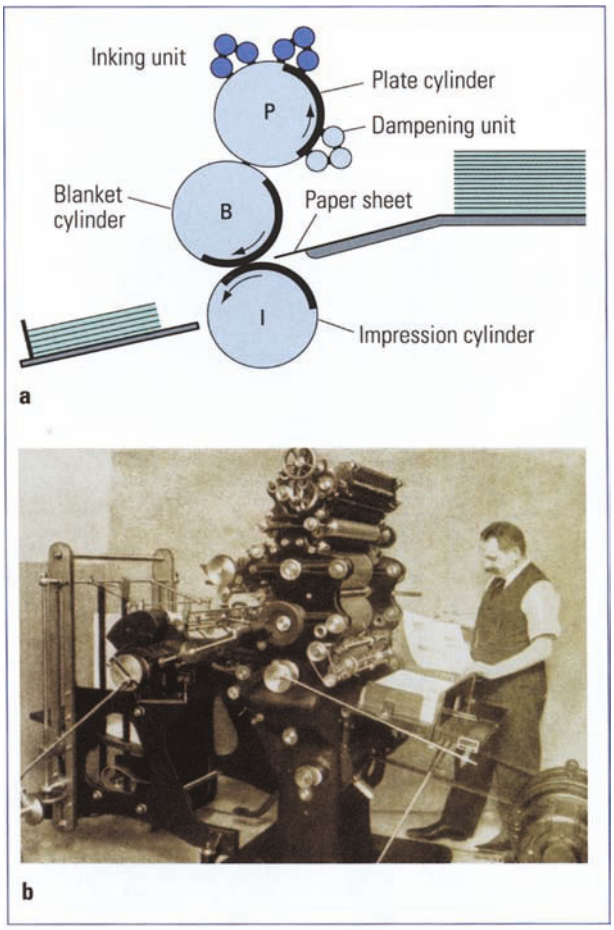


Fig. 13.1-5
Indirect lithography (offset printing), invented by Ira W. Rubel and Caspar Hermann around 1904.
a Diagram of the printing unit (IFRA);
b Caspar Hermann and the first German offset printing press, the "Triumph", 1907

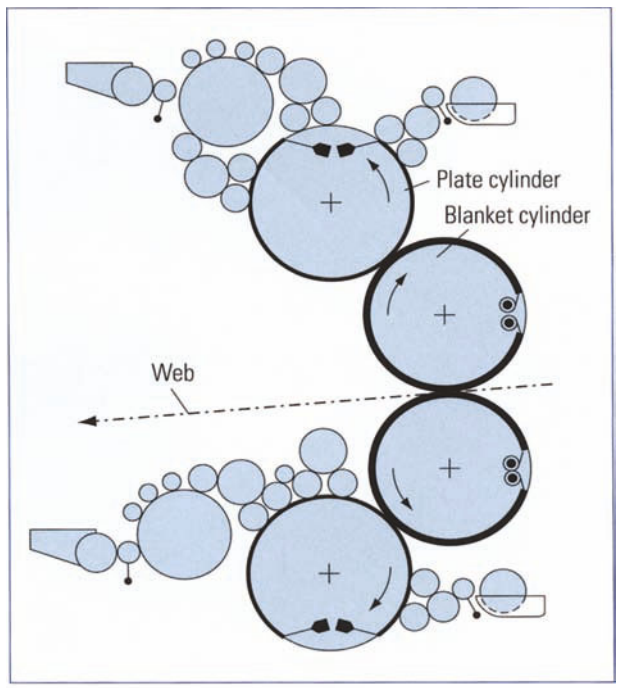


Fig. 13.1-6
Offset printing for printing on both sides of the web (blanket-to-blanket printing). Caspar Hermann was granted the patent in 1907

ries in Central Europe, but without success. Only in September 1910 did Ernst Herrmann, who at that time owned the well-known Felix Böttcher rubber coating factory in Leipzig, reply to Koenig's advertisement.

Ernst Herrmann was so convinced of the concept of a *web offset press* (fig. 13.1-7) that he then and there commissioned VOMAG (Vogtländische Maschinenbau AG), a press factory in Plauen/Vogtland (for which he was the general agent in his own area), to design and build a web offset press on his own account. In June 1912 the press, which was given the name "Universal", was presented at Felix Böttcher in Leipzig (fig. 13.1-7b). It was set up at the exhibition "Bugra 1914" in Leipzig, where it won recognition with many publishers and printers. In this way VOMAG became the first web offset press manufacturer and with Caspar Hermann's patent the company soon came to dominate the market. Figure 13.1-8 shows a further development of the first web offset press.

13.1.1.2 Gravure Printing and Gravure Printing Presses

The "ancestors" of gravure printers are *copperplate engravers* and *etchers*, which means that the origins of gravure printing are rather vague. This process was also kept secret for a long time, in order that imitations of expensive *engravings* (to which an embossed rim was later added) could be sold at high prices. Gravure print-

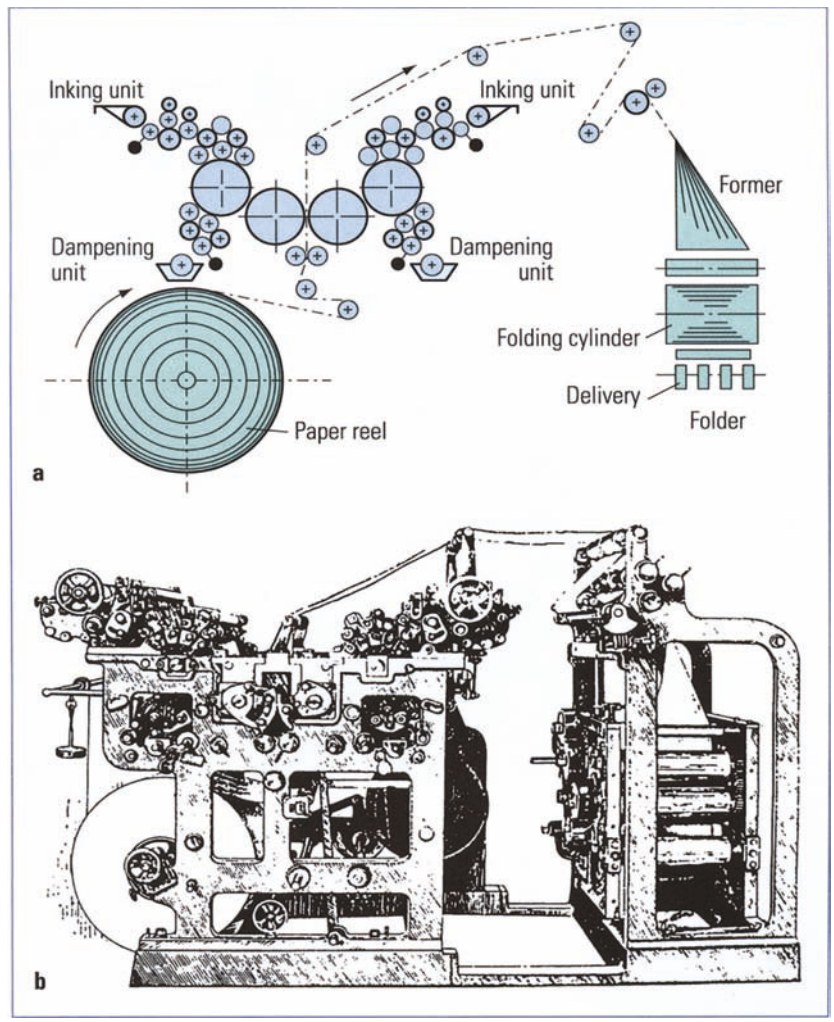


Fig. 13.1-7
The world's first web offset press. The basic principle had been conceived by Caspar Hermann before 1907 and tallied with the blanket-to-blanket printing patent.
a Basic principle;
b "Universal" web offset press (1912)

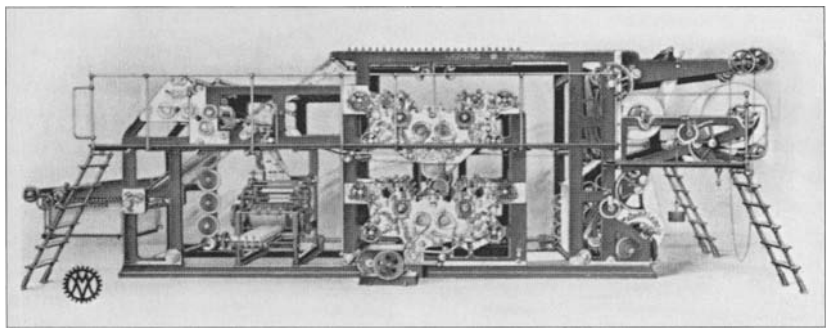


Fig. 13.1-8
Web offset press based on Caspar Hermann's patent made by VOMAC, around 1916

ers were also foreshadowed by calico printing, for which, as early as 1783, Thomas Bell received an English patent on a cloth printing press that used recessed printing plates.

According to Otto M. Lilien, the technical historian and former head of development at Axel Springer Verlag, the first gravure printing press intended for paper printing was invented in Paris, where in 1860 *Auguste Godchaux* took out a patent on a gravure printing press for printing on both sides of the web (perfecting). Subsequent research resulted in this press actually being built and operated. There is even proof that at least two presses were built in line with this patent and produced for many years.

It is surprising how very similar the gravure printing press designed at that time by Auguste Godchaux is, in principle, to the gravure presses which were built much later. Continuing development in subsequent years concentrated even more on process technology. Following the discovery of the art of *etching* in the early part of the sixteenth century and the arrival of screen copying in 1857 (inventor M. Bechtold), came the discovery in 1864, by an Englishman called Joseph Wilson Swan, of a way of transferring *gelatin images* to metal, and in 1879 the discovery of the so-called "*dust-graining heliogravure*" by *Karel Klic* from Bohemia. It is not possible to prove conclusively whether Klic was the actual inventor of "*heliogravure*", as gravure printing was initially called. However, he was the first person who did not work alone and in secret, but gave instruction to others on his process for a substantial fee, and brought knowledge and skill in this field from Vienna to London. It was here that Klic joined forces with the chemical graphic artist Samuel Fawcett, which resulted in the first *industrial gravure printing company*, the *Rembrandt Intaglio* Printing Company Ltd. in Lancaster, which, as a result of stringent secrecy measures, retained a monopoly on *halftone gravure printing* for more than ten years.

In Germany, before the turn of the century, two men had begun to tackle this problem and apply for the relevant patents: *Eduard Mertens* and *Ernst Rolffs*. But it was not until 1907 that the two of them were both able to take up practical production applying their process (fig. 13.1-9). As early as 1904 mechanically printed halftone gravures, called "mezzotinto gravures", made by F. Bruckmann in Munich began to appear on the market. In England an Austrian called Theodor Reich combined forces with the machine manufacturer John Wood to collaborate on making a first gravure printing press, the second of which Reich took to F. Bruckmann in Munich and the third of which was exported to Philadelphia in the USA, where the American Photo-

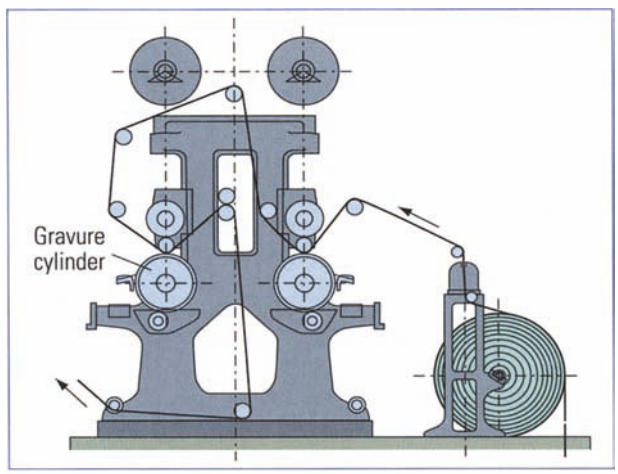


Fig. 13.1-9
The first gravure printing press for printing on both sides of the web, developed by Eduard Mertens (around 1907)

gravure Company was formed in 1904. The more widespread construction of gravure printing presses began from copies of this.

To return to Mertens and Rolffs: by 1897 Mertens had already founded the "Graphische Gesellschaft" in Berlin to manufacture press rollers for textile and wallpaper printing, while Rolffs was likewise devoting himself to *textile printing* at his textiles factory in Siegburg. It was not until 1906 that he made commercial prints on paper at the Deutsche Photogravure AG in Siegburg, which had been set up in the meantime. At the turn of the century intensive work was also underway at various other locations in Europe to unravel the secrets of the English Rembrandt prints.

Soon after the Deutsche Photogravure AG had been set up, and following the secondary agreement between Rolffs and Mertens, the latter concentrated on the development of *gravure printing for newspapers*. For this reason he moved to Mühlhausen in Alsace in 1907, where the "Elsässische Maschinenfabrik" was based. On Easter Sunday 1910 the letterpress-printed "Freiburger Zeitung" appeared in Freiburg in Breisgau with a circulation of 20 000 copies including two four-page supplements, which had *gravure-printed images* placed within the normal letterpress printed text. The *hybrid press* on which these impressions were produced consisted of a VOMAG letterpress newspaper rotary that had been connected up with a gravure printing unit designed by Mertens and made by the Elsässische Maschinenfabrik in Mühlhausen.

From that time on, gravure printing became the preferred process for newspaper illustrations, from which independent gravure periodicals (magazines) developed. On 19 September 1910 the "Hamburger Fremdenblatt" announced that the Mertens printing license had been acquired, and on 19 February 1911 the "Frankfurter Zeitung" appeared with four full-page, gravure-printed advertisements. This was followed in May 1912 by the introduction of gravure printing at Rudolf Mosse in Berlin to print the twice-weekly supplement "Der Weltspiegel".

The first *sheet-fed gravure press* was produced in 1913 in the Kempewerk in Nuremberg on the plans drawn up by Carl Blecher. Since the Elsässische Maschinenfabrik did not make folding equipment or open sheet delivery units (sheeter), a collaboration agreement was concluded between it and the Schnellpressenfabrik Koenig & Bauer in Würzburg. In May 1913 the International Gravure Printing Syndicate was formed, in which the four process developers established at the time, Int. Tiefdruck GmbH in Berlin, Mertens Tiefdruck GmbH in Mannheim, Rotogravure Deutsche Tiefdruck GmbH in Berlin and Tiefdruck GmbH in Berlin, merged with the machine manufacturers Kempewerk, Elsässische Maschinenfabrik, Johannisberg, and Koenig & Bauer. Outside this syndicate or monopoly there was the Schnellpressenfabrik Frankenthal, Albert & Cie. in Frankenthal, where around 1910 lithographic automatic cylinder presses were being converted into sheet-fed gravure printing presses and by 1913 Palatia presses (figs. 13.1-10 to 13.1-12) had been specially developed for this purpose (the plate being a gravure printing form).

Rotogravure printing presses (fig. 13.1-13), which were to form the basis of the company's later strength, were already being made in Frankenthal at this early date. In the course of the years the productivity of rotogravure presses increased constantly through the development of ever wider and faster presses (fig. 13.1-14).

Carbon tissue transfer and cylinder etching were replaced by *the electromechanical cylinder engraving* developed by *Rudolf Hell* at the beginning of the sixties, so that gravure printing is now a printing process for mass-produced products which also offers very high quality reproduction.

13.1.1.3 Letterpress Printing and Letterpress Printing Presses

Letterpress printing (sometimes also called book printing) is now considered to be a largely "extinct" process, except for its descendent, *flexographic printing*, which is winning more and more of the packaging printing market, just as indirect letterpress printing also prevails in certain parts of this sector. In spite of this, it deserves equal treatment with the other two printing processes in this historical section, because it was from letterpress printing that everything else developed.

It has still not yet been proven conclusively whether *Johannes Gutenberg* accomplished his pioneering discovery between 1440 and 1450 in Mainz or in Strassburg, so both towns honor Gutenberg equally. His invention is based on three things: cast *print types*, a *hand-casting instrument* to make these types, and a *printing press* designed for this purpose, which was adapted from the wine presses of the time (fig. 13.1-15, see also fig. 13.1-28).

Figure 13.1-15b shows the press room of the Plantijn printing shop in Antwerp in the style of the sixteenth and seventeenth centuries, as it can still be visited today.

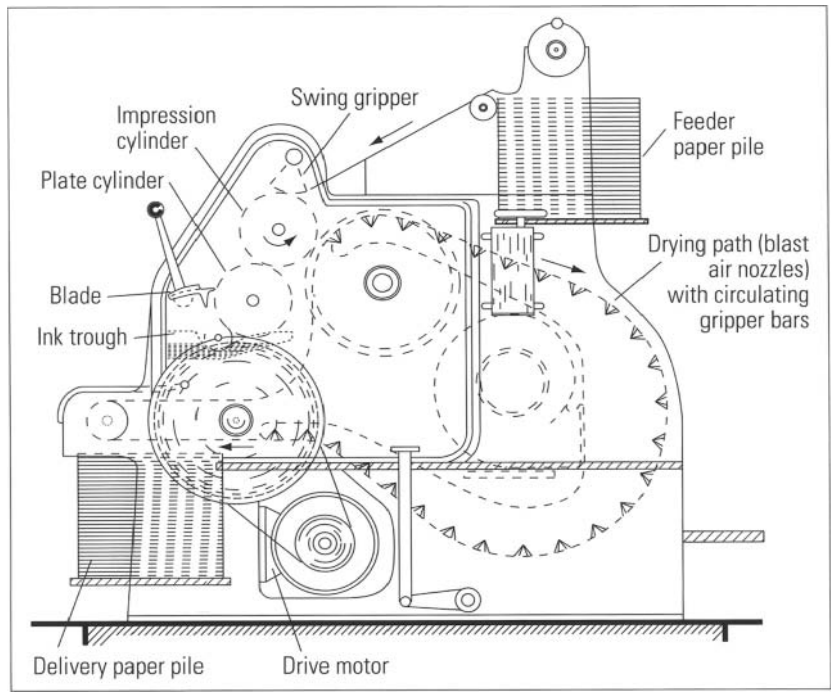


Fig. 13.1-10
Schematic diagram of the first compact sheet-fed gravure press, named "Palatia-Automat" and built by Schnellpressenfabrik Frankenthal, Albert & Cie. (1913)



Fig. 13.1-11
The "Palatia" sheet-fed gravure printing press (as illustrated in fig. 13.1-10) printed from copper plates clamped onto the plate cylinder (fig. 13.1-12). The photo shows the plate clamping process

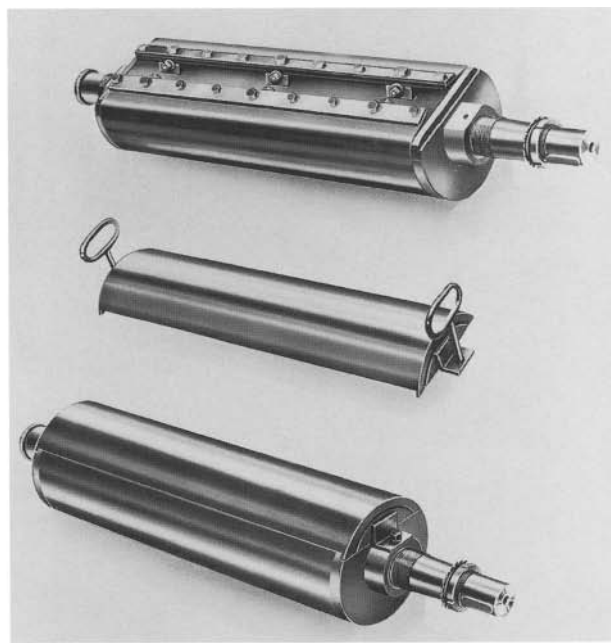


Fig. 13.1-12
Plate cylinder of the "Palatia" sheet-fed gravure printing press

Fig. 13.1-13
The first gravure printing press made in Germany in 1913 by Schnellpressenfabrik Frankenthal Albert & Cie.

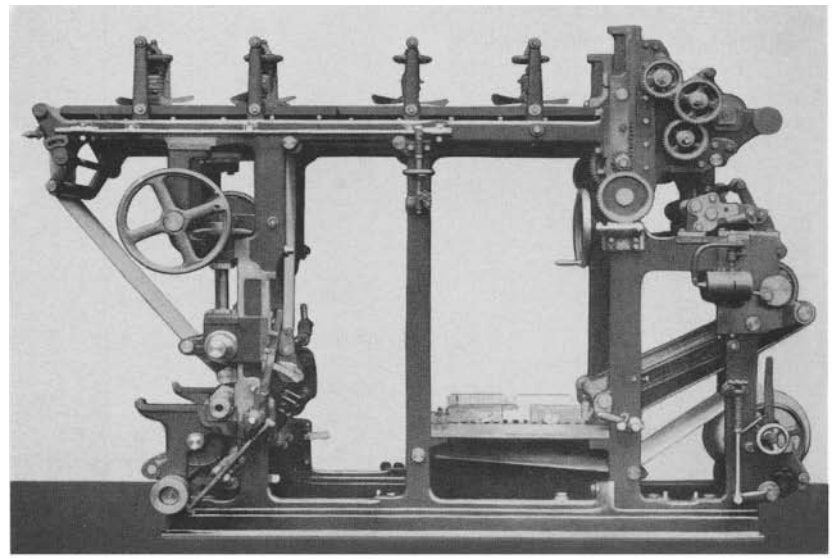
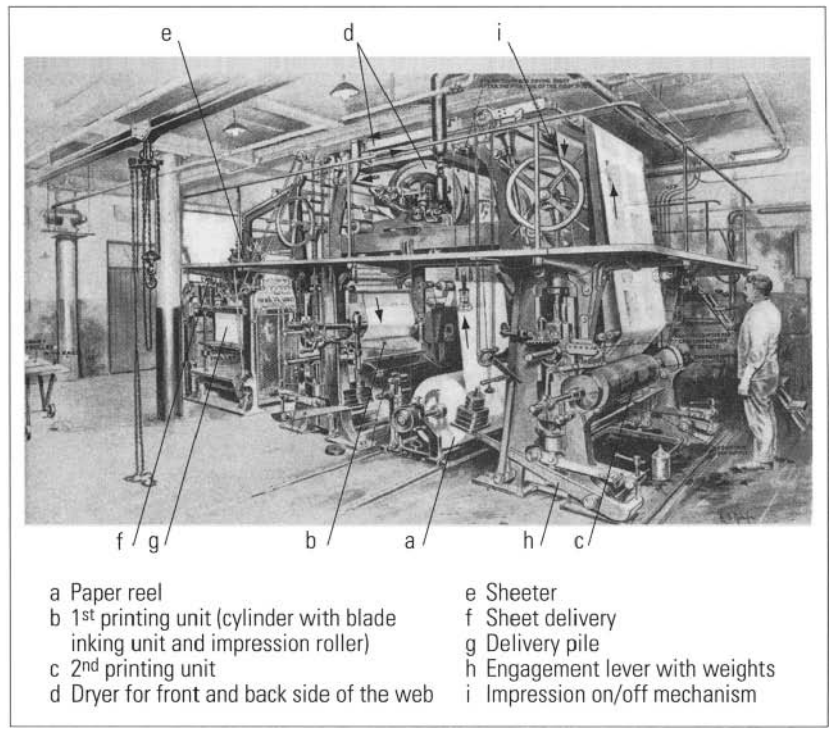
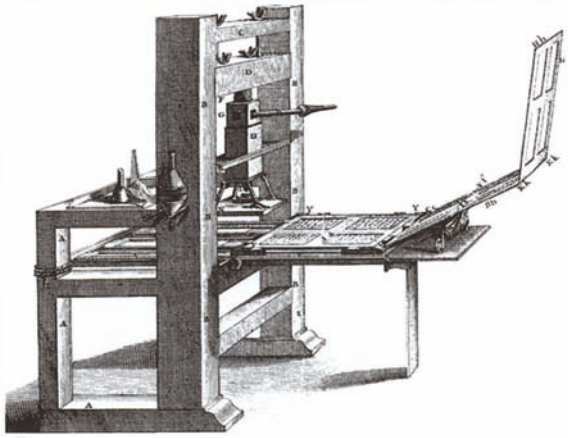


Fig. 13.1-14
The contemporary portrayal of an 8-page rotogravure press from around 1913 at "Illustrated London News", 6000 sheets per hour



For many centuries, the *platen design* of this hand press remained the only design for printing presses and basically only underwent various refinements with the change from the printing principle of the threaded spindle to the toggle lever principle, and of the structural material from wood to metal (fig. 13.1-16).

The golden age of printing press construction did not start until about 350 years after Gutenberg, when



a



b

Fig. 13.1-15 The first letterpress printing machines.
a The wooden printing press of Johannes Gutenberg from around 1445 as it may have looked (Walter Wilkes, Darmstadt);
b Press room of the Plantijn printing company in Antwerp in the style of the sixteenth and seventeenth centuries (Plantijn-Moretus Museum and the municipal copperplate engraving collection of the city of Antwerp)

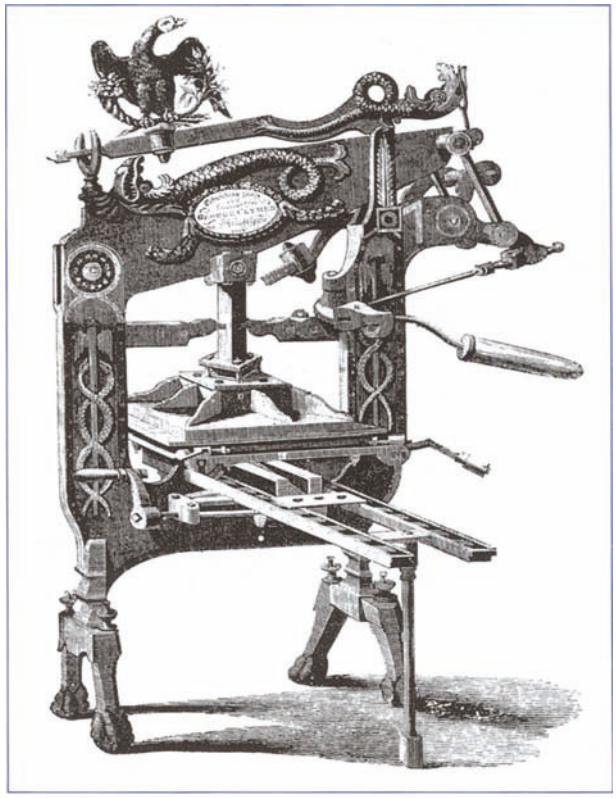


Fig. 13.1-16
Columbia press from 1817 (based on the platen design) for letterpress printing: one of the first press models of sturdy design (cast iron) for transmitting high printing forces created through the knee lever mechanism (see also fig. 13.1-19b)

Friedrich Koenig set about mechanizing the hand press completely, which led to the pioneering invention in 1811/12 of the first *automatic cylinder press* (fig. 13.1-17).

In the course of the following years both the *drive mechanism* (e.g., "rack drive", "railway motion", and circular motion – i.e., planetary drive) and the *operating principle* (fig. 13.1-18) of *cylinder printing presses* underwent constant development. In the latter respect, we should distinguish the most important forms: stop-cylinder, single-revolution, and two-revolution presses. Common to them all was the back-and-forth motion of the printing form bed, the "carriage." The flat letterpress printing form was attached to it in a lock-up form. The carriage ran on rollers and, apart from the two-revolution presses, was moved back and forth by a thrust crank. An impression cylinder positioned above it, which in the case of the single and two-revolution presses rotated continuously, produced the contact pressure (for single-revolution presses it had a double-sized impression cylinder and one revolution per printed sheet, and for two-revolution presses it had a correspondingly smaller impression cylinder and two revolutions per printed sheet); the sheet of paper was brought into contact with it by using a so-called "swing gripper". These sheet feeders in particular underwent

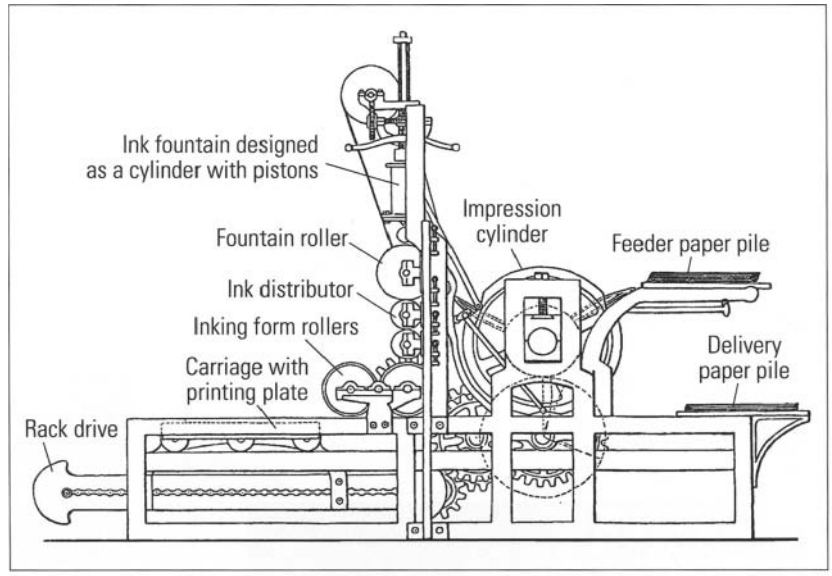


Fig. 13.1-17
Basic principle of the automatic cylinder press (letterpress) made by Friedrich Koenig in London in 1811 (sturdy design, with impression cylinder and flat-bed printing plate)

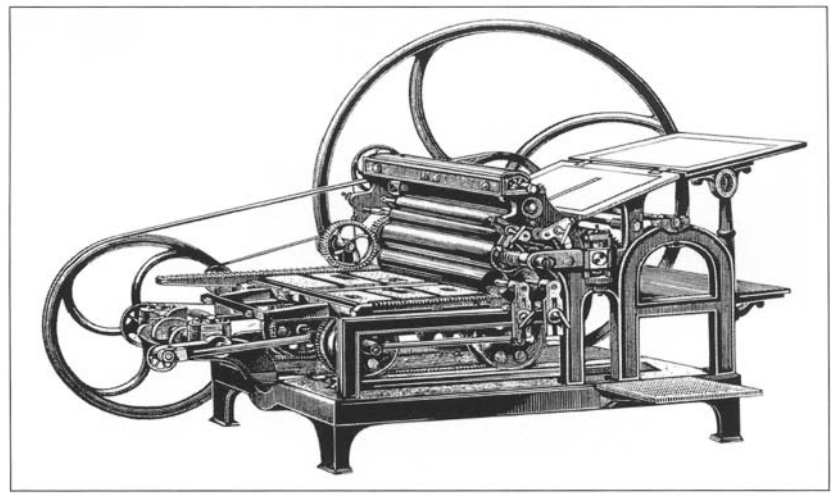


Fig. 13.1-18
Typical automatic cylinder press (letterpress) with manual drive, "railway motion" drive mechanism and a large fly-wheel from the period of industrial expansion (Reichenbach'sche Schnellpresse).

numerous further developments up to full automation.

Automatic printing presses were also produced from the hand presses using the *platen principle*, instead of the cylinder principle, even though they were for smaller print runs, such as frequently occur in job printing. First there was the *Gordon press*, invented by Geo Ph. Gordon, an American, around 1850, in which the platen and the base had two separate shafts and folded onto each other during impression throw-on. The *Liberty press* invented in 1857 by Otto Degener, a German emigrant to the USA, reduced the motion of platen and base to a spindle, which considerably simplified the kinematics to a motion similar to that of a hinge, but the movement on both sides remained. In Boston, in 1850, J. Golding then made the *Boston press*, named after the city. The base of this press was fixed in a vertical direction and the platen folded onto it for impression throw-on by means of a shaft located under the base. Its only disadvantage – and even this is not certain – was the angled throw-on motion, which could lead to dot fringes during imprinting. Therefore,

around 1870, John M. Gally invented the *Gally press*, in which the base was arranged in a vertical direction as with the Boston press, but where the platen occupied a position parallel to the base shortly before printing, using an eccentric gear with guide mechanism.

It was Gilke, a book printer from Cologne, who first managed to produce an automatic sheet feeder for platen presses, and he obtained a patent on it for a Boston press in 1913. With this fast rotating *propeller-type gripper* using "Maltese cross" gearing, the already legendary *Original Heidelberger Tiegel* (fig. 13.1-19) became important from 1914 onwards, especially since with a *toggle lever transmission* its printing pressure could be increased and with a *dual feeder* its output could be increased to 2600 sheets per hour. The Heidelberg platen press was manufactured in *assembly line production* as early as around 1920 (fig. 13.1-20). The production of this letterpress machine continued for as long as seventy years. It is still used even now, especially for special work such as embossing and die-cutting.

When Friedrich Koenig delivered his famous double-cylinder press to "The Times" of London in 1814, he had already had thoughts on what a *web printing press* might look like. In 1811 he had even been granted a patent for a press called a "roundabout", in which the flat form ran through on a carousel beneath eight star-shape configured, conical impression cylinders.

But, for it to be a true *rotary printing press,* a curved or round printing form was necessary. The first person who wanted to create this round form by stringing together *wedge-shaped type* on a cylinder was William Nicholson, an Englishman who had a patent granted on his idea as early as 1790. It was not until 1846 that the English Postmaster-General, Sir Rowland Hill, became the first person to put the idea of wedge-type rotation into effect, although he had been granted a patent for printing "the endless reel" eleven years earlier. In Paris in 1829 Jean B. Genoux had succeeded in inventing the "wet" *flexible mold,* called "flong", to which Firmin Didot had given the name "stereotyping". James Dellagana from Switzerland learnt about the process in Paris from Genoux, and in London in 1855 he started a company manufacturing flat stereotype with his brother. While this was going on he must also have had the idea of bending the mould round, because experiments were carried out from 1856 at "The Times" with this kind of round form on the Applegath press (fig.13.1-21) instead of the usually installed form cylinders with wedge-shaped types. The Applegath press has a vertically arranged form cylinder that is put together with fitted, wedge-shaped types. Eight different sheets are printed on both sides in eight separate stations as shown in figure 13.1-21.

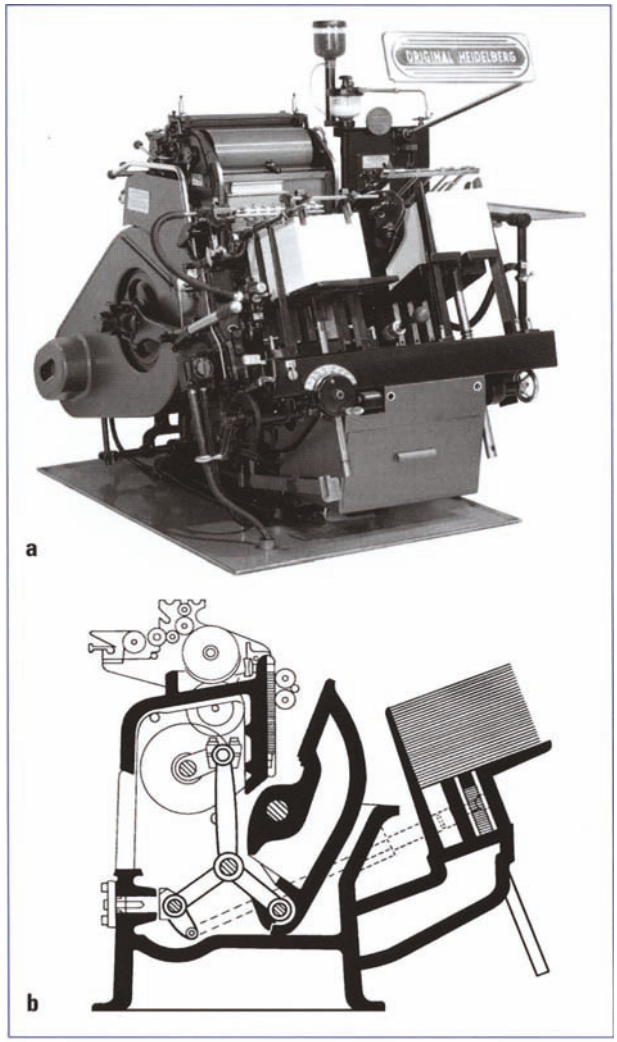


Fig. 13.1-19
More than 160000 Heidelberg platen presses were manufactured between 1914 and 1984, the highest number for any letterpress printing press in the world.
a Original Heidelberger Tiegel;
b Basic principle (with knee lever mechanics/toggle lever transmission)

News of the "wet" flexible mold/flong reached the USA via a Charles Craske and he succeeded in making *half-round stereotype plates* for the "New York Herald" using this method in 1854. The first version of a *web-*

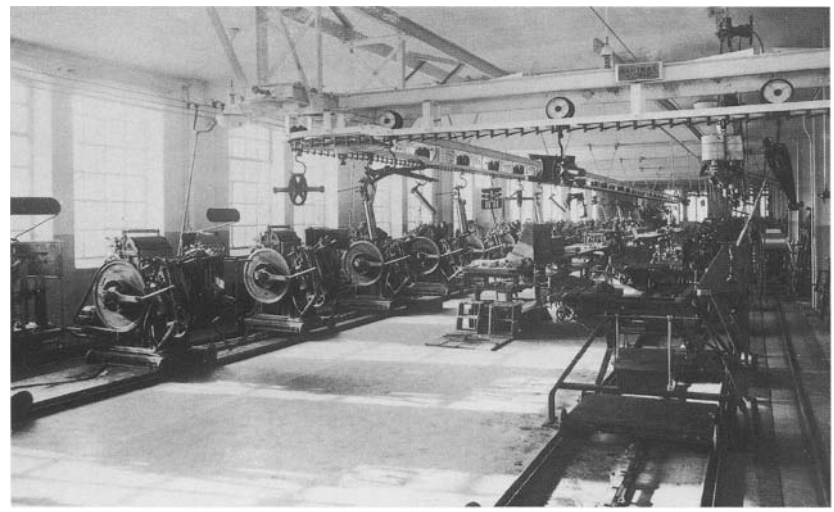


Fig. 13.1-20
Production of the original Heidelberg platen press on the assembly line in Heidelberg around 1930 (Heidelberg)

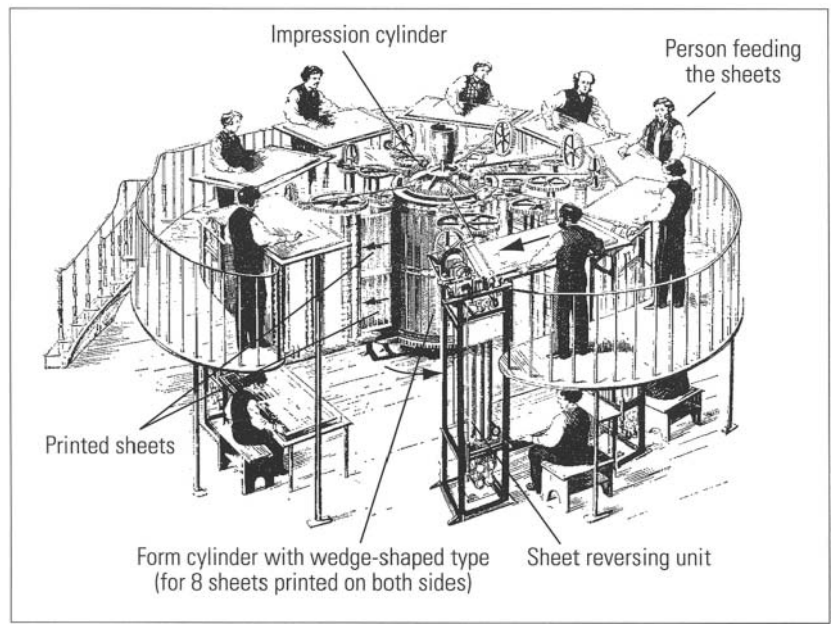


Fig. 13.1-21
The rotary printing press made by Applegath in London (for sheet-fed printing) used a vertically arranged plate cylinder (with 16 letterpress plates)

fed printing press suitable for this method was presented as a prototype (in accordance with the patent application) in 1859 by its inventor, *William H. Bullock* (fig. 13.1-22). The first press of this kind was installed at the "New York Tribune" in 1863. Bullock set up his own printing press factory, in which he by and large had to do everything himself. In April 1887 he supervised the commissioning of a rotary press supplied by him to the "Philadelphia Public Ledger" in Philadelphia, during which his foot was caught so badly by the press's drive belts and so seriously injured, that he died from the injury nine days later. But his company, the Bullock Printing Press Company in Pittsburgh, continued in existence for many years in spite of very severe competition from R. Hoe & Company, as well as from many other manufacturers to whom he had provided the decisive impetus for the development of newspaper printing based on letterpress technology.

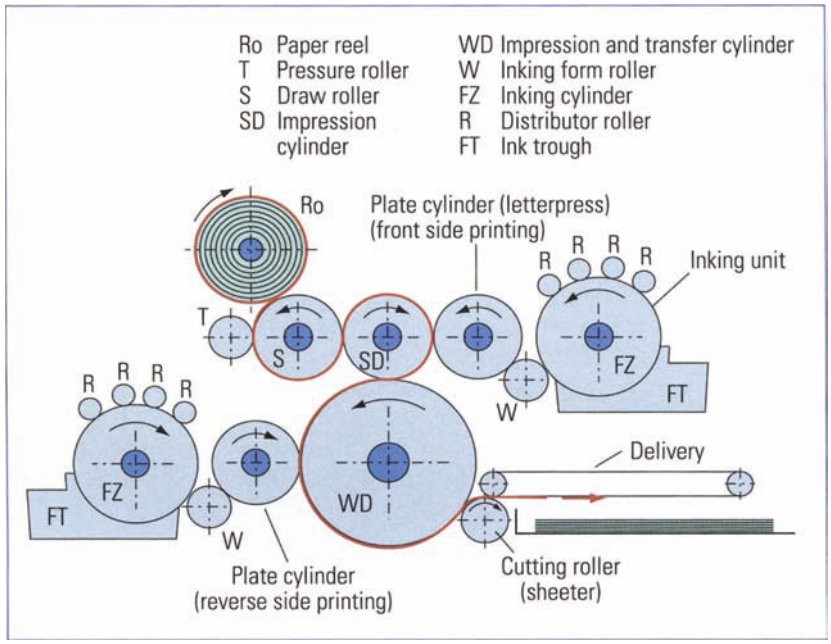


Fig. 13.1-22
The first web-fed rotary letterpress machine for printing on both sides was invented by William H. Bullock in Pittsburgh, PA (USA) in 1859

In 1866 the son of *John Walter*, publisher of "The Times" of London, had a rotary printing press designed and made to his own instructions by J. Calverley, a mechanic (fig. 13.1-23). Immediately after Walter's press had been put into operation, a second, improved version was built for Liverpool under the name "Victory Press" and a third was supplied to "Die Presse" in Vienna in 1871. This served as a warning for German printing press manufacturers. In the same year, the board of management of MAN in Augsburg decided to send the chief designer of automatic cylinder presses, *Gustav Bissinger*, to England, which resulted in the construction of the first MAN rotary press in 1873. In 1876 *Friedrich Koenig, jr.*, the son of the inventor of the automatic cylinder press, also introduced rotary printing press construction at Koenig & Bauer in Würzburg.

13.1.1.4 The Historical Relationship of the Printing Press Manufacturers

Koenig & Bauer in Oberzell Monastery near Würzburg is the undisputed cradle of international printing press construction. When Friedrich Koenig also wanted to

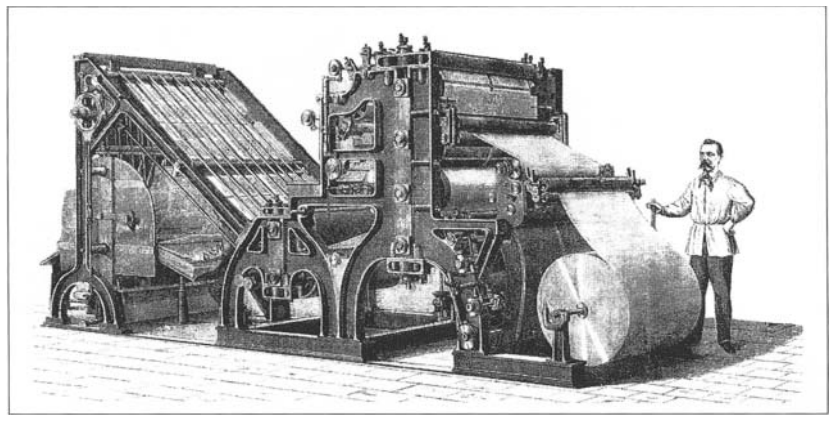


Fig. 13.1-23
Web-fed rotary letterpress machine (with sheeter), invented around 1866 by John Walter, jr., London

run a paper mill in Schwarzach, he dispatched his nephew, Fritz Helbig, to manage this place. He must have been dissatisfied with the latter's management, however, because Koenig dismissed him amidst discord. He then joined forces with Leo Müller from Vorarlberg, who had also been employed by Koenig & Bauer, and the two of them then set up a printing press factory in Mödling, near Vienna (which now belongs to the Koenig & Bauer Group).

Another of Friedrich Koenig's nephews, Helbig's stepbrother, set up his own company and was successful. His name was Carl Reichenbach. With his brother-in-law, Carl Buz, he purchased the Sandersche Maschinenfabrik in Augsburg, which from then on was called *C. Reichenbach'sche Maschinenfabrik* and made printing presses as well as steam turbines, water turbines, and the most diverse processing machines. Shortly before the turn of the century, this company joined forces with the Maschinenbaugesellschaft Nürnberg company established in 1841 by Johann Friedrich Klett to become the *Maschinenfabrik Augsburg-Nürnberg AG*, abbreviated to *MAN*, which was the forerunner of the present-day "MAN Roland Druckmaschinen AG."

Heidelberger Druckmaschinen Aktiengesellschaft was also founded around that time.

Andreas Albert began his apprenticeship in 1835 at the press manufacturer Koenig & Bauer in Oberzell where he was later promoted to foreman. In 1845 he changed over to Carl Reichenbach's machine factory in Augsburg. As mentioned before, Reichenbach was Friedrich Koenig's nephew and was also occupied with the construction of automatic cylinder presses.

Andreas Albert stayed in Augsburg for fourteen years as an assembly foreman, designer, and plant manager. One of his business trips brought him to Frankenthal in the Palatinate in 1856, where he met *Andreas Hamm* who had a *bell foundry and a machine factory since 1850* (fig. 13.1-24).

In 1859 Andreas Albert put together a plan to set up his own business as a manufacturer of automatic cylinder presses. In Andreas Hamm he found a partner who had a modern machine factory with foundry. Albert and Hamm first agreed on loose cooperation in 1861 before they founded the Maschinenfabrik Albert & Hamm on 1 April 1863 for the manufacture of automatic cylinder presses. Andreas Albert and Andreas Hamm terminated their cooperation on 31 March 1873. They both continued to manufacture presses; Andreas Hamm by himself and Albert entered into a new partnership with the businessman Wilhelm Molitor.



Fig. 13.1-24
Front page of the price list from Schnellpressenfabrik A. Hamm AG, Heidelberg, stating the year of foundation: 1850 in Frankenthal

After the death of Andreas Albert in 1882, Molitor continued to run the company *Albert & Cie.* together with Alois Albert and Jean Ganss and restructured it into a public limited company. In 1891 Molitor left Albert & Cie. and founded the Molitor & Cie. machine factory together with Philippine Arnold, a widow, who left the company six months later to be replaced by the engineer Wilhelm Müller who came from Albert & Cie.

Andreas Hamm died on 22 June 1894. His son Karl did not want the company to continue operating on the same scale and on 19 August 1895 he signed an agreement with Wilhelm Müller, Molitor's partner, for the disposal of the automatic cylinder press and machine factory. On 15 September 1895 Wilhelm Müller took over the company and was entitled to carry on under the name of "A. Hamm" with the addition of "Schnellpressenfabrik & Eisengießerei" (automatic cylinder presses factory & iron foundry).

After Wilhelm Müller bought Hamm's company in Frankenthal, Molitor and Müller liquidated the Maschinenfabrik Molitor & Cie on 22 May 1896. The very same day A. Hamm OHG was incorporated in the commercial register in Heidelberg. With this, *Heidelberg became the company base of the Schnellpressenfabrik A. Hamm* (fig. 13.1-25), although the plant in Frankenthal continued to exist for some years as a branch. The Schnellpressenfabrik A. Hamm AG was transformed into a public limited company in 1899 and renamed the "*Schnellpressenfabrik AG Heidelberg*" in 1905. Since 1967 the enterprise has been trading under the name of "Heidelberger Druckmaschinen AG". The former Heidelberg site (fig. 13.1-26) today accommo-



Fig. 13.1-25
Historical document (7 November 1898) of the Schnellpressenfabrik A. Hamm, Heidelberg



Fig. 13.1-26
The premises of the Schnellpressenfabrik AG Heidelberg in Heidelberg (around 1914)

dates the headquarters, the research and development center (fig. 13.1-27), and the "*Heidelberg Print Media Academy,*" which opened its doors officially on 14 April 2000 (see fig. 13.1-41) in the context of the 150th anniversary celebration of the company's foundation.

It is also possible to find links with Maschinenfabrik Winkler, Fallert & Cie., abbreviated to *WIFAG*, in Bern, Switzerland: Fritz Fallert, Winkler's partner when the company was set up in 1904, had previously worked at the Heidelberger Schnellpressenfabrik, and in 1898 the engineer Josef Hauss from Frankenthal had co-founded the "Dresden-Leipziger Schnellpressenfabrik", called *Planeta*.

13.1.1.5 Prepress

When Johannes Gutenberg invented his printing system (letterpress printing with movable types of metal) around the middle of the fifteenth century, the *hand-casting instrument* he created (fig. 13.1-28) was just as impressive as the printing press. Until the beginning of the nineteenth century this was the only method of casting print types, storing them in letter cases, and assembling them into lines of text in the compositor's composing stick.

It was not until 1807, at which time the English engineer *William Church* was working intensively on it, that the initial *typesetting machine* concept came into being, and it was fifteen years later, in February 1822, that he was granted a patent on a typesetting machine. However, the first typesetting machine actually to be put into practical typesetting use was the design known as "*Pianotype*" (fig. 13.1-29), for which James H. Young and Adrian Delcambre were granted a patent in March 1840 in England. This was the beginning of a varied sequence of more than two hundred typesetting machine inventions, which all had the disadvantage of allowing



Fig. 13.1-27
Premises of Heidelberger Druckmaschinen AG (headquarters, research and development center, training center, product showrooms, etc.) at the main station (at the bottom of the photograph) in Bergheim, a district of Heidelberg (photo: Aug. 1999). Note: The building site of the Print Media Academy (with construction cranes) can be seen in the foreground; the opening ceremony took place on 14 April 2000.

relatively soft lead type to circulate between typesetting and distributing, leading again and again to obstruction of the guide tracks and channels.

The idea of sending *stable female molds* into circulation instead of lead types first occurred to *Ottmar Mergenthaler*, a German immigrant to the USA, when he began experiments in 1876 that led to the introduction of the first *rod set and casting machine* in May 1884. In the very same year the National Typography Company was founded and the typesetting machine was improved to become the Blower machine (fig. 13.1-30), which went into operation at the "New York Tribune" on 3 July 1886. The Mergenthaler Printing Co., which merged with the National Typography Co. in 1890 to become the *Mergenthaler Linotype Co.*, came into being in the same year. It is said that the name "*Linotype*" was coined by Whitelaw Reid, the publisher of the "New York Tribune", when he called out on glancing at the first cast line emerging from the Blower machine: "Oh, a line of types!"

The Linotype typesetter took on its final form with the "Linotype-Simplex", and with copies and improvements in rival products such as Intertype and Neotype and simplified variants such as the Typograph typesetting machine from Rogers, it was essentially to keep this form for almost a century. A separate single-letter typesetting machine development led to the "Monotype" from Tolbert Lanston in 1887–1893, the first of which was exhibited in 1893 at the Columbian Worlds Fair in Chicago and the patent for which Lanston sold to the Earl of Dunraven in Salsford, England in 1897, whereupon the Lanston Monotype Corporation came into being.

Following some earlier inventions, the history of *photocomposition and phototypesetting* began in 1898, when W. Friese-Greene in London had the idea of producing letters by photography and etching instead of typesetting. Several inventions along these lines followed and were patented without any commercial breakthrough. Particularly spectacular was Edmund Uher's venture around 1930 with his Uhertype, as he was even able to persuade the famous machinery construction company MAN in Augsburg to become financially involved in the development process. Functioning prototypes were constructed, but the collabo-

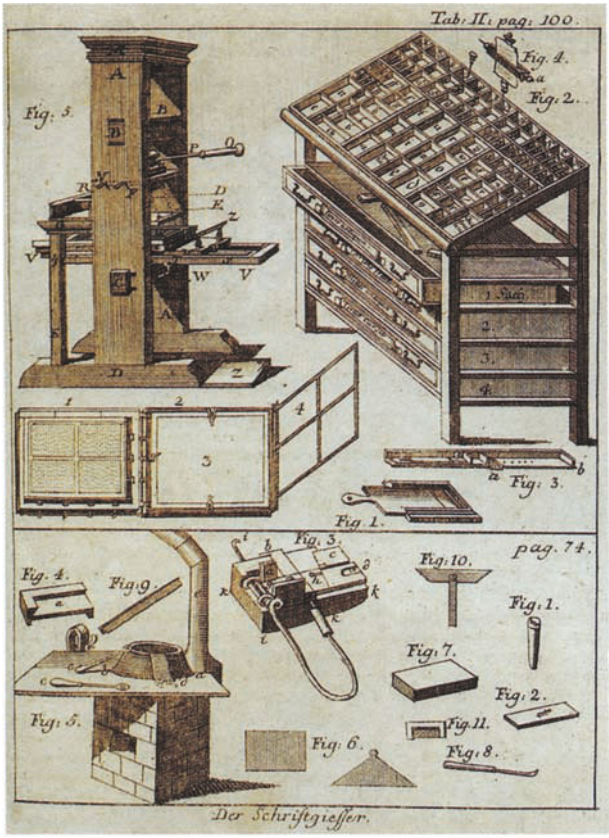


Fig. 13.1-28
Type foundry around 1760 showing the basic equipment.
Top: fig. 2 type case, fig. 5 hand-operated letterpress printing press;
Bottom: fig. 2 female mold for forming the type, fig. 3 casting tool, fig. 5 casting furnace, fig. 9 composing stick for planing the type side

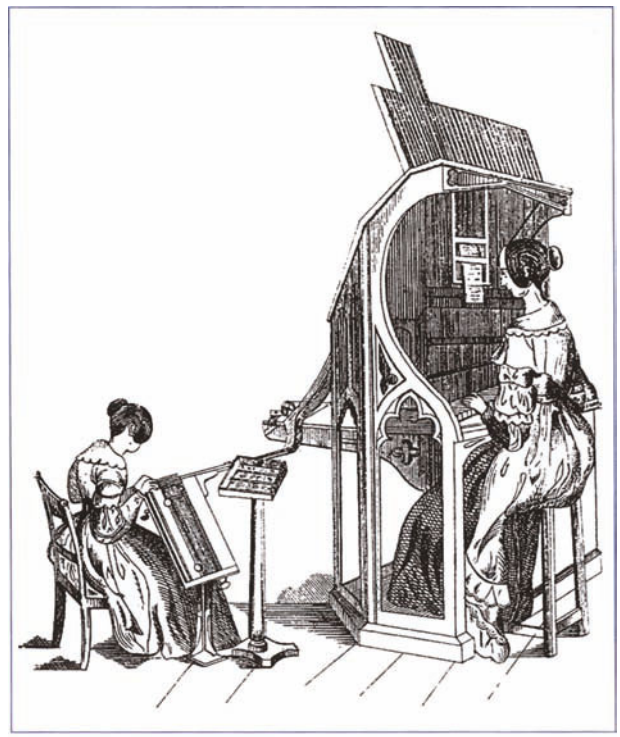


Fig. 13.1-29
The Pianotype lead typesetting machine invented by Young and Delcambre from the year 1843

ration ended in 1939 and the start of the Second World War impeded its continuation by third parties.

The next big venture came after the Second World War from the Frenchmen René Higonnet and Louis Moyroud, who by 1944 had applied for a patent on a *phototypesetter* called the "Lumitype" (fig.13.1-34), but the development work proved to be longer and more expensive than expected. Photon Inc. was founded in 1951 and an initial series of prototypes (Photon 100) was put into service. Not until five years later was the first fully developed version produced under the name of Photon 200. Parallel to this, the traditional typesetting machine manufacturers Intertype and Monotype were adapting their machines that had actually been designed for hot-metal composition with *photo-matrices* to create "Fotosetter" and "Monophoto", while Linotype launched the phototypesetters "Linofilm", "Linofilm Quick", and "Linofilm V-I-P" (fig. 13.1-31), which were specially designed for this purpose (figs. 13.1-32 and 13.1-33).

Whereas the first generation of *phototypesetting machines* featured adapted hot-metal composition machines (fig. 13.1-32) and the second specially created machines (fig. 13.1-34), the third generation at the beginning of the 1960s featured photographic storage and was introduced with brand names such as Linotron 1010, 505, and 303, Compugraphic Videosetter and Crosfield Magnaset.

From the mid-1960s, as a result of electronic storage, phototypesetting machines developed into *light beam/CRT*, with the Hell-Digiset 50 T1, RCA Videocomp 830, Autologic APS-2, Harris-Fototronic CRT (fig. 13.1-35), MGD Metro-set, Linotron 606, and Compugraphic 8600 CRT trademarks.

With the arrival of laser-output technology (fig. 13.1-36) via RIP (Raster Image Processor), the fourth

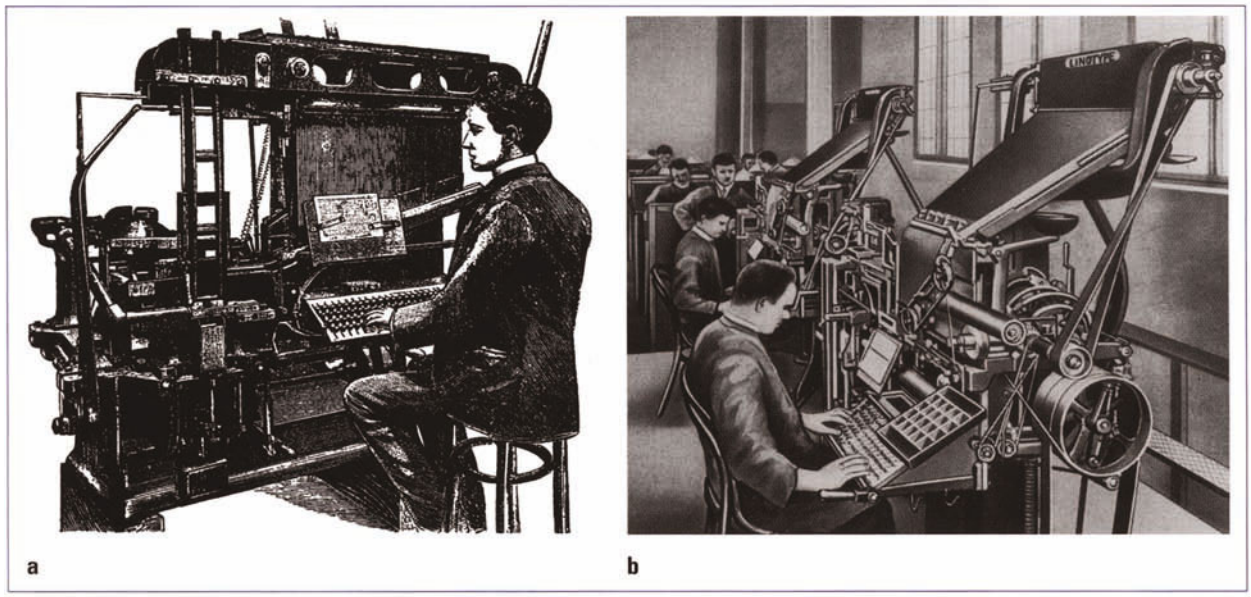
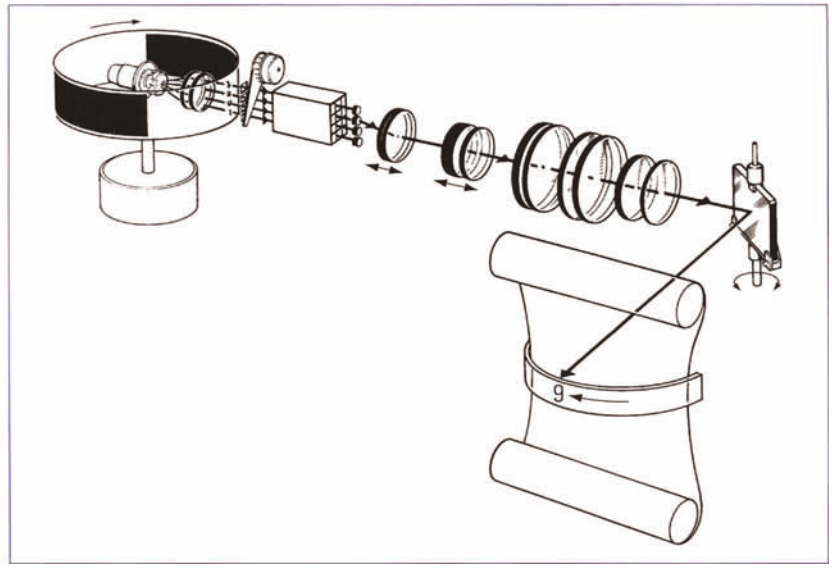


Fig. 13.1-30 Blower lead typesetting machines.
a Model invented by Ottmar Mergenthaler from the year 1886;
b Model of Mergenthaler's Linotype Co. around 1900

Fig. 13.1-31
Exposure process in the "Linofilm V-I-P" phototypesetter



generation of typesetters finally entered the field in the 1970s and early 1980s. Particularly worthy of mention here are the Monotype Lasercomp, the Itek-Digitek, the Camex BitSetter, and the Linotron 101, which later developed into the Linotronic 100 and 300. The model names were changing faster and faster at this time and the manufacturers were also constantly changing because of takeovers and mergers.

The transition from *digital laser typesetters/film imagesetters* (computer to film) to *plate imagesetters*

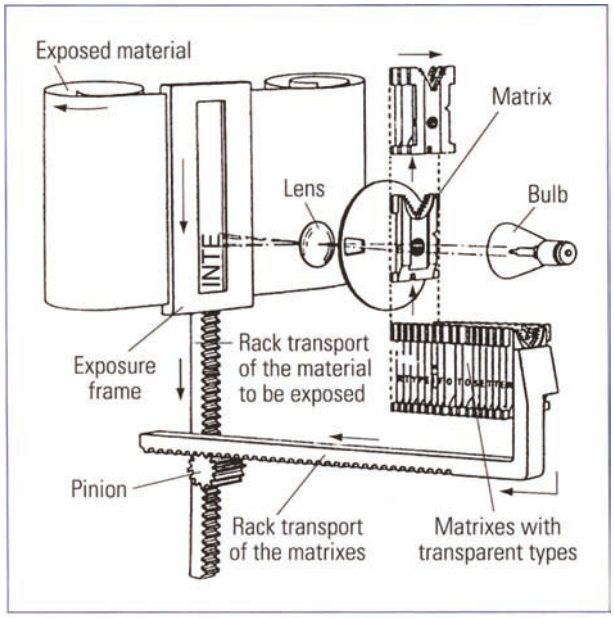


Fig. 13.1-32
Basic principle of the phototypesetter by Intertype; metal mask/photo matrix for film exposure, around the mid-1960s (IFRA)

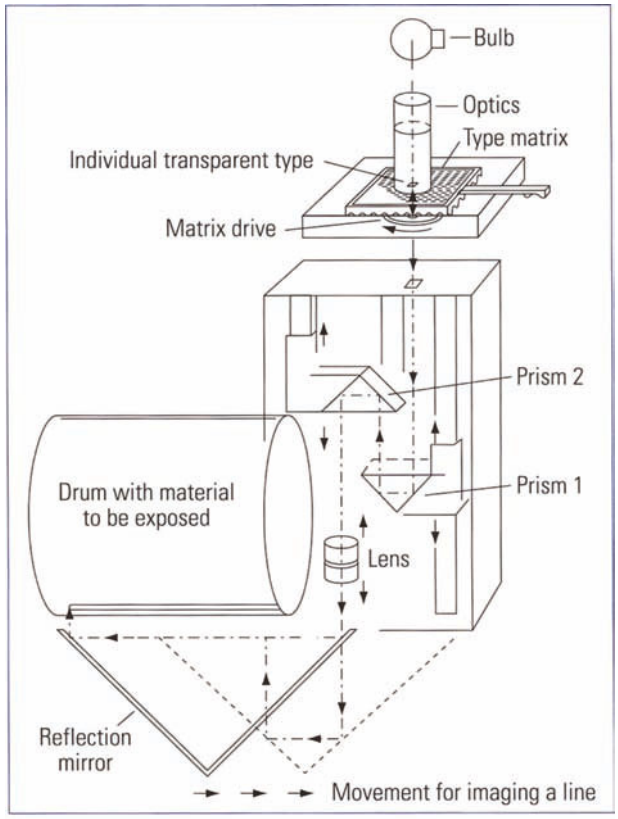


Fig. 13.1-33
Basic principle of the "Monophoto" phototypesetting machine from Monotype

(computer to plate) since about 1990 is a logical move towards fewer process stages in prepress and profitable high quality production; computer to print is the logical extension of the variety of production methods.

Editing systems, that is, the input side of phototypesetting and digital light typesetting machines, have proved to be just as exciting. The first screen terminal, the already legendary "Harris 1100", was exhibited at an ANPA Show in the USA in 1970. The "Hendrix 5200" and the "Mergenthaler CorRecTerm" followed a year later. Pioneering work leading up to the WYSIWYG (what you see is what you get) technology was undertaken by SII (Systems Integrator Inc.) with its Coyote Terminals in System 55 and the Bedford Computer Corp.

Though the first *typesetting software* was created for the large mainframe computers of IBM, Control-Data, and Sperry-Univac, the trend towards so-called mini-computers began from 1970, the major representatives here being Digital Equipment Corporation with "DEC-PDP 8" and "DEC-PDP 11", and Data General's "Nova". Not until the end of the 1980s were these systems superceded by more and more powerful Personal Computers (PCs) and networks. This trend was fuelled by the desire to be part of the trend

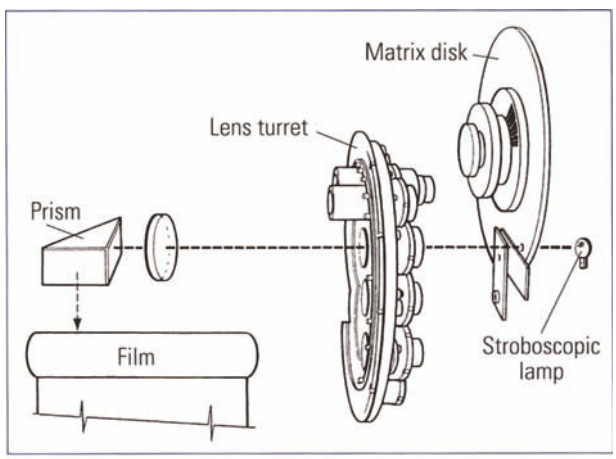


Fig. 13.1-34
Basic principle of the "Lumitype" phototypesetter from Higonnet and Moyroud



Fig. 13.1-35
Digitally exposed type of the "Fototronic CRT" light beam/CRT typesetting machine from Harris

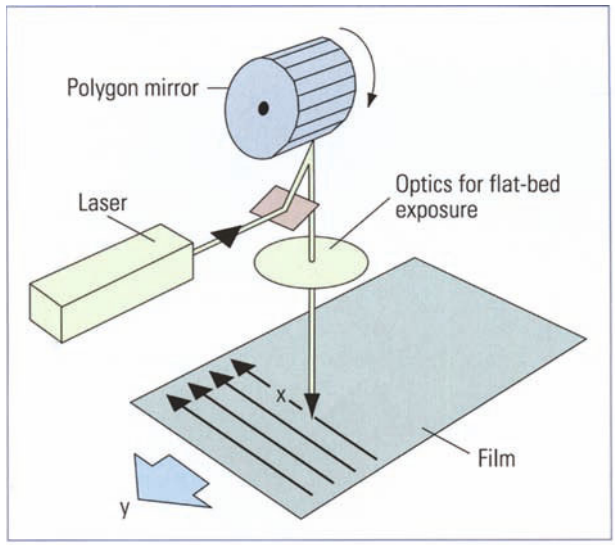


Fig. 13.1-36
The basic principle of a flat-bed laser film imagesetter (Computer to Film)

in office automation towards constantly being up-to-date with state-of-the-art technology and also being able to use mass-produced, good value hardware. The Xerox Integrated Computer System 9700 (XICS), derived from the Xerox "Star" program, the Tandy/Radio Shack, the Commodore, the IBM-PC, and the Apple Macintosh with LaserWriter are milestones along the way.

The entire reproduction process of editing, layout, imaging and imposition systems was also carried along by this wave. Whereas at first there had been only four manufacturers worldwide of electronic reproduction systems with connected scanners, image processing, and imagesetters, namely Crosfield, Dainippon Screen, Hell, and Scitex, all Apple Macintoshes from one minute to the next suddenly became suitable for reproduction, to be shortly followed by all PCs with off-the-shelf programs such as Photoshop. As one of the first film imagesetter manufacturers, Linotype opened up the way into professional companies for these *DTP (Desktop Publishing) devices*, by making it possible for Apple Macintoshes to be connected up to their imagesetters. Linotype-Hell has been part of Heidelberger Druckmaschinen AG since 1997.

The enormous transformation that modern information technology has accomplished in the field of printing technology is even more apparent in these prepress developments than in printing presses. However, the written word has remained the basic code for storing and conveying printed information, and it seems as though this type of coding will remain irreplaceable in the future.

13.1.2 Education and Qualifications (Career Profiles, Courses)

13.1.2.1 The Printing Industry as an Employer

An analysis of the printing industry's training system requires that one examine the characteristics of the industry. Most notable are:

- high labor and capital intensity, which fit uneasily with
- its small to medium-sized business structure.

One could certainly class printing as manufacturing, although as an operation that takes on orders it could be classed as a borderline service sector industry. Furthermore, the great and fast change in production technologies, systems, and markets for communication products should be highlighted as a special characteristic of this industry.

High Labor Intensity

The printing industry is very diverse, and the following quantitative statements apply not only to Germany, but are typical of other industrial nations. The printing industry is labor-intensive, which consequently reflects the high contribution of labor costs to the overall total compared to the average for industry as a whole.

This contribution is explained by the following statistics. Through the manufacture of newspapers, magazines, publicity and business literature, books and brochures, the German printing industry achieved an annual turnover of DM 31.6 billion (US $ 17.4 bn) in 1997. This is less than two percent of the turnover of industry as a whole. Yet, at the same time, the employment level in this sector, at 2.5 percent, is clearly higher. The main reason for this high level of employment is the still relatively low degree of automation at a large number of small businesses. Areas that are still particularly labor-intensive are prepress and finishing.

The relatively high wages paid in the printing industry, attributable to the traditionally high wage level and the large proportion of employees with specialized vocational qualifications, notably printers and prepress employees, add further to the level of personnel costs. The unusual levels of qualification are shown by the high proportion of white-collar workers and skilled workers – 37.8% and 34.2% respectively for 1997 (fig. 13.1-37).

For these reasons, the proportion of labor costs is 38%, which is relatively high compared to other industries (e.g., manufacturing at 20%), as illustrated in figure 13.1-38 below.

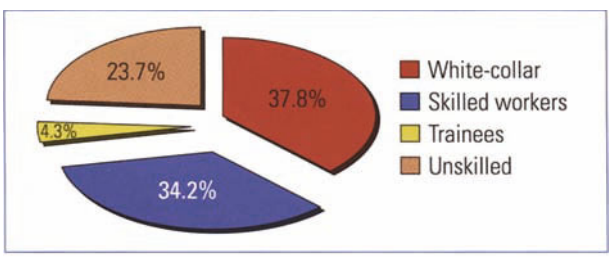


Fig. 13.1-37 Employees in the printing industry 1997 [13.1-1]

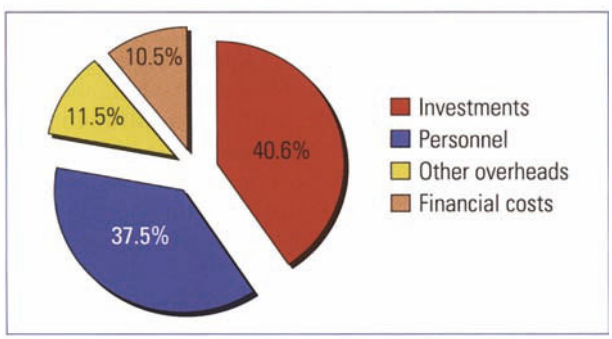


Fig. 13.1-38 Cost structure in the printing industry [13.1-2]

High Capital Intensity

The printing industry is not only labor-intensive, but also capital-intensive. At six or seven percent, investment (share of investment to turnover) within the printing industry is clearly higher than the average for industry overall. This primarily involves investment in modernization aimed at a competitive edge over direct rivals and investment to exploit new production methods, as well as adaptation to the growing number of suppliers providing alternative products, such as electronic media.

Small to Medium-Sized Business Structure

Businesses in the printing industry are characteristically small to medium-sized, as figure 13.1-39 illustrates. In other words, around 85% of companies have fewer than 20 employees, and 26% of all employees work in companies with a workforce of less than 20.

Changing Production Technologies and Markets

There is hardly any other industry where production technologies have been subject to such a fast process of change, particularly since about 1985. This is unprecedented in the five-hundred-year history of printing. Digitization of equipment and workflow has brought new options for producing print products, the core business of the printing industry. For managers running printing companies this means in many cases a complete overhaul of equipment and a considerable challenge to employees in mastering new techniques. New production and communication technologies reveal not only new print media manufacturing processes, but also new communication media (electronic media), some of which are in direct competition with print media.

This leads to the conclusion that training and further education has an essential role to play in this industry. The small to medium-scale structure of the printing industry demands above all that middle and particularly higher management levels possess relatively broad know-how, since the widespread use of specialists is considerably limited for financial reasons.

13.1.2.2 Educational Requirements and Options

When looking at training requirements one must remember that work structures, particularly (although not exclusively) in the graphics industry, are undergoing fundamental changes, as a result of the consolidation of media production technologies. Traditional, single-function production is ostensibly breaking

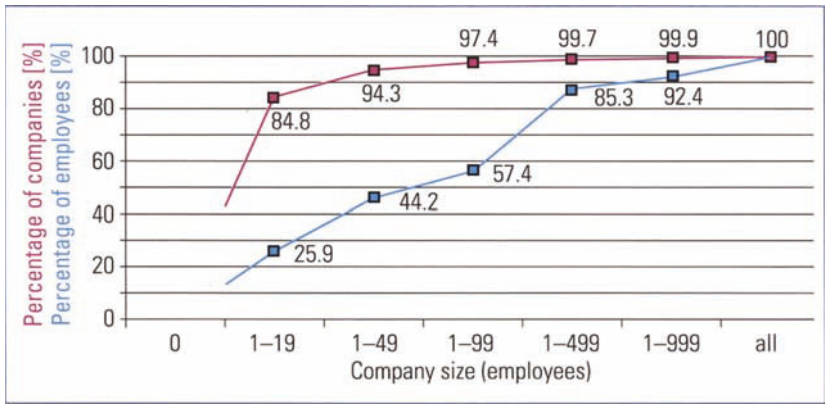


Fig. 13.1-39
Company size structure in the printing industry 1997 [13.1-1]

down. Text, images, graphics, and most recently also sound, video, and animation are brought together by multi-skilled individuals. It should be taken into account that, in reality we are not likely to see "Media Generalists" who are skilled in all aspects of media production, starting with writing the storyboard, via CD-ROM and video production through to gravure cylinder production. Thus, as before, production requires specialists who act as information processors, but are also geared towards teamwork and cooperation. Therefore what is needed is a mixture of broad-based and specialized training [13.1-3].

In addition to specialist expertise, broader based qualifications, such as creative problem-solving, flexibility, teamwork, to mention just a few, are concepts that can aid receptiveness to technical developments and complex organizational structures [13.1-3].

13.1.2.3 Vocational Training

Germany

Vocational training can be classified into three areas:

- initial training,
- ongoing training, and
- retraining.

Training approaches leading to qualified jobs within the printing industry are outlined in figure 13.1-40. Two "training locations" typify the German vocational training system, namely companies on the one hand and vocational training centers on the other.

This duality within the training system originates from apprenticeships in the craftsmen's trades and guilds of the Middle Ages for company life, and from the religious and vocational Sunday schools of the sixteenth and seventeenth centuries. Also characteristic of these origins is the cooperative content-related production of new training schemes and the further development of the existing training schemes at federal, state, employer, and employee level.

In Germany there are around 370 officially recognized trainee occupations, of which eleven can be regarded as belonging to the print media sector. As table 13.1-1 shows, the number of traineeships rose by 16% between 1997 and 1998, in the year before that by about 12%. This underlines the increasing interest in the graphic arts industry with its new innovative technologies. The absolute figure of about 15000 is, however, still lower than at the beginning of the nineties (almost 20000).

Media Designer. The new training occupation of media designer introduced since 1 August 1998 will replace the traditional prepress occupations, such as platemaker and typesetter in the medium-term. The media designer training scheme represents a radical shift from the principle of initial on-the-job training, which is still primarily geared to imparting knowledge on individual technical skills at a production level. Instead, the training objective for a media designer is to gain "comprehensive media skills". In addition to specialist and technical skills, organizational, creative problem-solving, and communication skills and teamwork, as well as IT (information technology) know-how, are regarded as primary training objectives [13.1-6].

Training is flexible in structure, and in the third year of training there is a division into specialist areas:

- media consultancy,

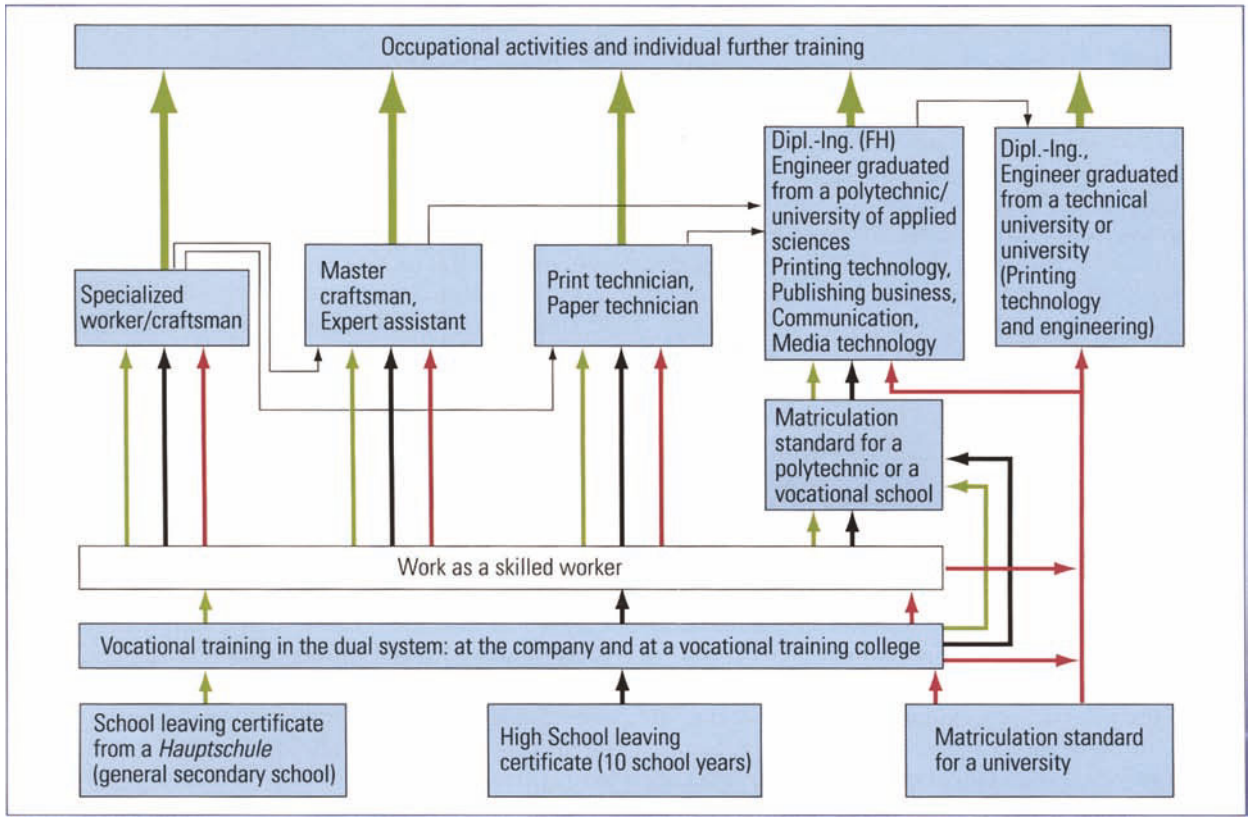


Fig. 13.1-40 Education paths in the German printing industry [13.1-4]

Table 13.1-1
Number of traineeships in the printing and paper producing industry in Germany [13.1-5]

	1997	1998	Change
Media Design	**5116**	**6394**	**25.0%**
Media design for digital and print media	–	2680	
Advertising and media copy layouter	1848	1568	
Repro makers	1290	818	
Typesetters/flexo graphic designer	1806	1204	
Repro graphic designer	172	124	
Printing Technology	**4373**	**4655**	**6.4%**
Printer	3760	3985	
Screen printer	596	649	
Wall paper printer	17	21	
Finishing	**2169**	**2453**	**13.1%**
Book binder	1248	1396	
Packaging technician	921	1057	
Paper Making/Paper Maker	**773**	**863**	**11.6%**
Others	**103**	**142**	**37.9%**
Total	**12534**	**14507**	**15.7%**

- media design,
- media operating,
- media technology.

Through its modular options, the training program makes it easier for companies to adapt the training to their operational requirements. It also represents a benchmark for further training. In the further training sector, individual qualifications can be attained that can later be put together to make a full new extra career qualification.

Master Craftsman/Foreman. Paragraph 46, section 2 of the German Handicrafts Regulation Act says: The master craftsman's qualifying examination is used to determine whether the candidate is able to run a workshop independently and to train apprentices in a proper manner; in particular he or she must demonstrate the ability to carry out everyday tasks in his/her trade skillfully in addition to having the required specialist knowledge and know-how in business, commercial, legal, and professional training matters.

People are admitted to the examination if they have passed the apprentice's examination, and worked in their trade for a number of years, or else have the necessary professional qualification to train apprentices in this trade.

Printing/Paper Technician. Training takes four semesters for printing and paper technicians. A trainee must have completed secondary school as well as vocational training in the relevant trades; he or she should have at least two years of practical experience. The responsibilities of printing/paper technicians are concerned with production coordination. The profession is ranked between that of a master craftsman and a graduate engineer (FH, from a polytechnic/university of applied sciences). However, past experience has shown that this has become a gray area [13.1-7].

Employees with qualifications as a printing/paper technician are increasingly doing administrative jobs. This somewhat anachronistic concept can be compared with the job of a "product manager" in the trademarked goods industry, whose duties encompass both representing customer interests during the production process as well as acting as customer contact.

The largest German technical colleges for printing technology are located in Frankfurt/Main, Nuremberg, and Stuttgart. Other technical colleges can be found in Biberach, Bielefeld, Düsseldorf, Munich, Pößneck, Ravensburg, Tettnang, and, for paper technology, Altenburg and Munich.

Great Britain

In England and Wales the NVQ (National Vocational Qualification) system was introduced in the 1980s, and has been widely acclaimed on an international level. In 1997, 3% of the employed population qualified via this system [13.1-8]. The NVQ and SVQ (Scottish Vocational Qualification) systems define requirements at five levels in around eight hundred occupations spanning eleven industries.

The idea is for the candidate to be able to offer proof of a certain level of qualification. In principle it does not matter where, how or in what order the required modules have been attained. However, in most cases, training is preceded by one-to-one consultation. The candidate is free to choose the place of study, which can be in or near his or her workplace, a college, at a public or private training center, or a similar institution. Trainees may be grouped in courses of instruction; however, this is not a necessity and in this sense they are dissimilar to school or college students. The sequence of flexible modules is geared in essence to current training offers or to individual needs. Training can be suspended and resumed at will.

Critics of the system find fault with the amount of time spent on exams, especially for small and medium-scale companies, and the lack of transparency [13.1-8].

13.1.2.4 Course of Study

The objective of *engineering courses for print and media technology* is to impart knowledge through practically oriented training that enables the graduate to manage a company in the communications industry. Training must fundamentally encompass a wide range of diverse company structures, production techniques, and product and market variety. This means identifying particular areas, opportunities, and limitations of available technologies, and being able empirically to assess them and the technological and economic implications for the company in light of defined business objectives. Correspondingly, areas of study are largely process-oriented.

The main areas of investment in engineers in a given specialist field within small to medium-sized companies in the printing industry are as plant managers and, in larger companies, production managers, sales engineers, and production planners in middle management.

Globalization of world markets and the international qualifications required has meant greater mobility on the part of students, graduates, and scientists. This has fortunately meant that national borders are becoming less defined as regards vocational and academic education. In *Europe* this was set out in the *Maastricht Treaty* (Art. 126). That is not to say that the training system has become uniform; on the contrary, traditional training systems should be preserved. Measures are necessary to facilitate cross-border study and adaptability of training systems. The most important are:

- setting up international courses and
- the introduction of a "credit system".

The *structure of international courses* is geared towards the Anglo-American training system, typified by a graded program. The first-degree program lasts three years, at the end of which a "*bachelor's degree*" is awarded. The next level up prescribes a one to two-year period of further study, leading to a "*master's degree*". In particular those who wish to continue in higher education or research may then opt for a doctorate, leading to the award of a *PhD* (Doctor of Philosophy).

The *credit system* is a kind of "currency" for academic achievement. Passing a certain course of study entails amassing a certain number of credits. On the basis of credit points accumulated, qualifications are recognized from one institution to another when switching colleges. The credit system can be explained in the context of the Council for National Academic Awards (CNAA), which was introduced in 1986, and the application of the recommended CATS (Credit Accumulation and Transfer Scheme). According to this, an "*unclassified, ordinary bachelor's degree*", roughly comparable to graduating from a German "Fachhochschule" (polytechnic/university of applied sciences), requires a total of 360 credits. Of these, at least 60 must be attained in the third year (level 3) and not more than 120 in the first year (level 1). The "*bachelor's degree with honors*" by contrast requires that 120 credits be attained at level 3.

The EC-advocated ECTS (European Credit Transfer System) is fundamentally the same as CATS, the only difference being that the CATS scores are halved, since the yearly number of attainable ECTS credits is 60 as opposed to 120 with CATS.

We must not, however, lose sight of the inherent difficulties that can accompany studying in a foreign country. They range from additional costs to language problems, unfamiliar lecture times and subject matter, and specific levels of academic involvement, all of which could be dealt with by a basic grounding in the expected cultural differences. Nevertheless overseas study has proven successful and there are no plans to restrict its implementation.

Some *features of comparable study courses* in Germany, Great Britain, and the USA are illustrated in the following paragraphs. Details of individual institutions of study can be found in section 14.5.

Germany

In Germany it is possible to study printing and related disciplines at "Fachhochschulen" (polytechnics), "Gesamthochschulen" (comprehensive universities), "Technischen Universitäten" (technical universities), and universities. These are all engineering courses at the end of which the graduate is awarded an engineering degree and obtains the title of "*Diplom-Ingenieur*" (when the course of study has been completed at a "Fachhochschule", with the supplement "*(FH)*"). The course normally takes four to five years including exams.

For admission to a *printing course* at a *polytechnic* the following foundation course requirements must be satisfied:

- the *general university matriculation level,* or
- the *subject-related university matriculation level,* or
- the *polytechnic matriculation level,* or
- an educational background approved by the Ministry for Education and the Arts.

Unlike at a polytechnic a prerequisite for *study at a university or technical university* is the general or subject-related matriculation level. While polytechnics use practical instruction to prepare for occupations requiring academic knowledge and methods, universities are moreover concerned with the advancement of knowledge through research, theory, and study, as well as with supporting the next generation of scientists.

A university course normally takes ten semesters, including exams – one semester longer than at a polytechnic. Course details are available from the respective institutions. Contact addresses can be obtained from the listing in section 14.5.1.

The number of graduates in the area of printing, commercial printing, and media studies fluctuates quite significantly, but averages between 250 and 300 per annum – in other words one for every thousand of the total number employed in printing as a whole. Career prospects are currently excellent.

Those wishing to enter *teaching* can take special courses in "printing technology" at the Technische Universität Darmstadt, the Technische Universität Chemnitz and the Bergische Universität-Gesamthochschule Wuppertal.

Great Britain

Universities in Great Britain and Northern Ireland are independent, self-governing institutions. Accordingly they are entitled to make their own decisions regarding not only admission of applicants and the appointment of teaching staff, but also the development and introduction of new courses, and the awarding of their own degrees.

Courses at British higher education establishments are divided into yearly levels, at the end of each of which the student is awarded a professional qualification. One year's study leads to the *Certificate of Higher Education* and two years' study to the *Diploma of Higher Education*. On completion of a full three years' study the *Bachelor's degree* is awarded, for instance, *Bachelor of Engineering* (BEng) or *Bachelor of Science* (BSc). This first degree can be awarded either as an *ordinary degree* or as an *Honors degree* (Hns); nowadays most courses of study are aimed at an honors degree.

After obtaining a first degree (Honors degree) there is the option to take a "*postgraduate course*" of varying length. This can take the form of a vocational course of between nine and twelve months, at the end of which either a *Postgraduate Certificate*, a *Postgraduate Diploma*, or a *Master's degree* is awarded. With a Master's degree the choice is between a *taught Master's degree* and a *research Master's degree*. The research master's degree includes the preparation of a *thesis* in addition to the taught course element. This is correspondingly longer, lasting around two years, at the end of which an MPhil (*Master of Philosophy*) is awarded.

More recently a number of universities have also started providing science-based and technical four-year courses leading directly to a master's degree. Some Universities provide the opportunity to graduate one year earlier with a bachelor's degree, and others offer a separate program from the third year, which leads to a master's degree.

The final level of academic study is the doctorate, which leads to the *Doctor of Philosophy* (PhD or DPhil). The entry requirement is usually a very good master's degree.

The academic year in Great Britain is traditionally broken up into three terms of ten to twelve weeks. However, an increasing number of universities are turning to semesters with lecture-free periods around Christmas and Easter. The academic year begins in September/October, and admission to the spring, or summer terms is only permissible in exceptional cases and for part-time study applications.

Among institutions for printing technology and related disciplines in Great Britain a key position is held by the London College of Printing (LCP). The LCP is the largest of five Colleges (faculties) that were merged in 1986 under the umbrella of "The London Institute". The London Institute itself is internationally one of the largest training institutions for Business Studies, Graphic Design, Media (Film, Video, and Journalism), Distributive Trades, and Professional Studies (Tourism, Marketing, and Advertising).

The required level of English depends on the purpose of the study period. On an exchange scheme under the *Socrates/Erasmus* European University Co-operation Program (see sec. 13.1.2.5), this is less than for a full study-period. Students admitted can improve their language skills by taking free language classes in the Language Center both before and during their studies. The IELTS (International English Language Testing System) test may be used to assess general language skills as well as those required for study purposes. These tests can be taken at varying times and locations in the student's country of residence.

Institutions in Great Britain are funded partly through tuition fees totaling a maximum of £1000 per annum for a home student or a student from any other EU country for a "Full-Time Undergraduate Course". In the case of British native students it actually depends on the parents' income. The increased level of fees for international students reflects the actual cost of study, set at between £5000 and £10000 per annum for courses with intensive tuition in workshops and laboratories. General information on the fees for postgraduate studies cannot be given since they are set by the institutions themselves and must therefore be obtained directly from them. The same applies to student exchanges of between one and three terms in length. No tuition fees apply to students participating in a student exchange through the Erasmus program (see sec. 13.1.2.5).

Living costs for the London area are calculated at between £7000 and £9000 per annum.

USA

Structure of the Education System. The American education system is characterized by its broad base

and variety of study requirements in the state-accredited institutions of higher education. In spite of that, the educational structure is relatively uniformly regulated:

Elementary and High Schools: School is generally compulsory up to the age of sixteen. Elementary and high school education covers twelve years, which can normally be broken down as follows:

- elementary school, 5–6 years;
- junior high school, 2–3 years;
- high school, 3–4 years.

At the end of high school the *High School Graduation Diploma* is awarded. A prerequisite for this is the election of at least sixteen units of study or subjects, as well as passing a final written exam. A unit lasts an hour each day, five days a week, and thirty-six weeks of the school year, in other words 180 hours.

The exams are assessed as follows:

A excellent,
B good,
C average,
D pass,
F fail.

Grade C is the minimum requirement for admission to study at an institution of higher education.

On graduating from high school at seventeen to eighteen years, the options are either

- two years of further education, possibly leading eventually to a changeover to an institution of higher education, or to a professional qualification (two year colleges or vocational and occupational institutions) or
- a four-year *undergraduate course* leading to a *Bachelor's degree*. This takes two forms:
  - four-year liberal arts colleges or
  - universities.

While *colleges* only cover undergraduate courses, *universities* also offer *post-Bachelor degree education*, in other words postgraduate courses, leading to a *Master's degree* or *PhD (Doctor of Philosophy)*.

Awards. There are two awards:

- *Bachelor's degree.* A Bachelor's degree requires four study elements:
  - a major or concentrated area of study,
  - general education, generally encompassing mathematics, physics, English and perhaps a modern language, and a social science and humanities subject,
  - a compulsory subject as part of the major,
  - an elective.

  The student chooses the subjects, which must then be approved by the institution.
- *Master's degree.* Admission to a Master's degree program requires a relevant Bachelor's degree. In many cases the candidate must also take a standardized test, perhaps produce evidence of relevant work experience, and submit an academic testimonial.
  The study period is usually one year, often extending to two, and occasionally more. The Master's degree usually involves deeper exploration, through a combination of seminars and independent work, of a subject already covered by a Bachelor's degree.
  The study period concludes with a final exam to demonstrate a comprehensive grasp of the subject matter. In exceptional cases, such as the Rochester Institute of Technology (RIT), (see below), the presentation of a *Master's thesis* forms an integral component.
  Assessment of individual student performance at American institutions of higher education occurs through a *credit point system*, from which the grade point average (GPA) is calculated. The GPA is a weighted mark average, the weighting factor consisting of the number of lectures enrolled for. These are assigned grades, ranging from 4.0 for grade A to 0 for grade F. Dividing the sum of the score by the sum of the credits gives the GPA. The example in table 13.1-2 serves to clarify this. Admission to further education requires a GPA of between 2 and 3.

Study Costs. Higher education institutions in the USA are funded both by the state and via tuition fees, the proportion of state funding being relatively high at state-run institutions. The opposite applies to private institutions. A statistical survey for the academic year 1994/95 shows, for example, that the annual cost of attendance at a state-run institution by a student from that state cost $9000; $2700 of this covered tuition fees. For students from a different state, tuition fees increased by $2000 to $3000. The remaining $6300 was for accommodation in a subsidized student residence,

Subject	Credits (hours)	Grade	Value	Points
Mathematics	4	C	2	8
Physics	6	B	3	18
Electronics	4	A	4	16
Information Technology	5	C	2	10
Mechanical engineering	4	D	1	4
Business studies	3	C	2	6
Total/**GPA**	26		**2.4**	62

Table 13.1-2
Example of calculation of grade point average (GPA), as used at American institutions of higher education

for living costs, and for modest personal expenses. For the same period, average tuition fees were $12000 per annum for private colleges. Currently, approximately half of all undergraduates receive either private or state financial support on the basis of need. (Please refer to the list of higher education institutions in sec. 14.5.1.)

Comparative Overview

Below is an overview of final examinations in Germany, the UK, and the USA.

The American High School Graduation Diploma corresponds to the British GCSE (General Certificate of Secondary Education) if the average mark for GCSE subjects is not less than grade C.

The US marking scheme ranges from A to F (for "Fail"). Therefore, grade A corresponds to the German grade 1, "Excellent" and F to the German grade 5, in other words a fail.

The American High School Graduation Diploma roughly corresponds to the German "Realschulabschluss"/"Mittlere Reife", in so far as candidates achieve at least grade 3 ("Satisfactory") in GCSE-comparable subjects.

The German specialized "Hochschulreife" certificate equates with the BTEC/SCOTVEC National Diploma (Business and Technical Education Certificate or Scottish Vocational Education Certificate, respectively). A good average is enough to satisfy the entry requirements for a Bachelor's degree. In the final analysis it is at the discretion of the higher education institution.

The "Abitur" certificate (general "Hochschulreife" certificate, matriculation standard for a university) equates to GCEA-Level (General Certificate of Education at Advanced Level). It satisfies the general entry requirements for a Bachelor's degree, should the combination of major and basic subjects and an average mark satisfy the academic requirements of the course.

A German "Fachhochschule" (polytechnic/university of applied sciences) diploma equates with an American or British Bachelor's degree (ordinary degree). A good grade can open the way to a postgraduate course.

A "Diplom," "Erstes Staatsexamen" or "Magister-Artium degree" awarded at a German University or "Technische Hochschule" generally equates to a British Honors degree or an American Master's degree.

A German "Doktor" is the equivalent of a British or American PhD or DPhil (Doctor of Philosophy). "Habilitation"(habil.) awards for those wishing to make a career as a university lecturer and leading to university professorship are not usual in Anglo-Saxon countries.

13.1.2.5 Scholarships for International Study Programs

Socrates/Erasmus

The *European Union* sponsors cooperation in higher education through the "Socrates/Erasmus" programs. An important aspect of this is to encourage mobility of European students. To this end, part of the grant is intended to cover extra costs incurred through travel and life abroad. A bilateral cooperation contract between the institutions concerned is necessary to take this course. The contract is usually for one year. The home institution must recognize awards conferred by the host institution. Under the terms of the program the study period must be between three and twelve months. It should be noted that a subsidy is only available after the first semester.

Students interested in taking part in the Socrates/Erasmus scheme should consult their institution's European representative or overseas study office, in order to ascertain whether an agreement exists between that institution and one at which the student wishes to study. Sometimes such a partnership requires active encouragement. Study at a foreign institution is best planned well in advance. Besides, a plan of study should be drawn up and agreed upon well before applying.

The Socrates/Erasmus Program is not confined to EU Member States, although it is restricted to Europe. For example, those wishing to study in the USA must arrange this outside the European program. This means that

- there is no European representative on hand to supply information on study opportunities,
- tuition fees are considerably higher than partner institutions would be allowed to charge under the Socrates program,
- there are significant bureaucratic obstacles to negotiate.

International Circle

The International Circle of Educational Institutes for Graphic Arts, Printing and Management can be of help in arranging worldwide contacts with other institutions to study printing technology. The International Circle is a confederation of around one hundred teaching and research institutions with printing, communications technology, and similar courses in around forty countries worldwide. The aim of this international institution, founded in 1957, is the exchange of experience through practical interdisciplinary courses as well as research. To this end, the International Circle arranges regular annual conferences on the member institutes' sites. Furthermore the International Circle promotes student and staff exchanges, although only in an advisory capacity. There is no sponsorship, since the International Circle does not have funds at its disposal.

Scholarships (Germany)

Students are advised to approach the *Deutsche Akademische Austauschdienst* (DAAD) for scholarships. The DAAD produces a brochure entitled "Förderungsmöglichkeiten im Ausland für Deutsche" (Sponsorship Opportunities for Germans Abroad) on a yearly basis. This brochure can be obtained from the particular institution's foreign study office, or the DAAD itself. Scholarships are normally only partial awards, although they do cover tuition fees and travel costs to the foreign institution.

Outstanding pieces of work, such as academic papers, dissertations, and "Habilitation" theses submitted to one of the German universities can be awarded a sponsorship prize by the *Dr.-Ing. E.h. Hubert H. A. Sternberg Foundation* (former CEO, chairman and shareholder of Heidelberger Druckmaschinen AG). The annual amount available funds seven people. Proposals must be submitted by the various institutions by 1 September each year. The Sternberg Foundation also provides scholarships for the USA.

Excellent and good academic papers and theses on printing and paper technology or on graphic communication can be awarded several individual financial prizes through the *Stiftung Druck- und Papiertechnik* (Printing and Paper Technology Foundation). The application procedure is similar to that of the Sternberg Foundation.

13.1.2.6 Heidelberg Print Media Academy

Heidelberger Druckmaschinen AG has had an international training center since the year 2000: the Print Media Academy (fig. 13.1-41). This training center was the brainchild of Heidelberger Druckmaschinen AG, representing a high-level investment by the company in promoting, developing and securing the future of the graphic arts industry and the print media. The Print Media Academy opened its doors on 14 April 2000 as part of the company's 150th anniversary celebrations – in the year of Johannes Gutenberg's 600th birthday.

Its extensive *training potential* is geared towards all those who are involved or who wish to become involved in *printing, publishing, and media work.* The Academy's main target is Heidelberg customers, employees, partners of the Heidelberg Group, and every group with a need for training.

The training is also aimed at printers, instructors, service technicians, and sales staff from Heidelberg. They need to acquaint themselves with all technical and market-specific aspects of *printing, prepress, and finishing systems* in order to make use of their quality, efficiency, and productivity.

Focal points regarding training activities are the workflow, new technologies, consolidating a system philosophy, and understanding solutions. A second area is *management training*, particularly relating to printing and media companies as well as to system houses/companies. The point is to demonstrate ways and means of optimizing production and business processes rationally, as well as to ensure competitiveness by actively shaping future markets. This management training is geared towards company owners and management, as well as graphics customers. One other target group comprises agencies, publishers, and students and teachers at schools, colleges, and universities. Heidelberg Print Media Academy's courses are complemented by the advanced "*Print Manager*" course of study with an internationally recognized final qualification based on international cooperation with technical colleges and universities.

The lecturers are subject experts invited from industry, associations, agencies, business schools, institutions of higher education, and universities. Naturally they are also recruited from the Heidelberg Group itself.

Fig. 13.1-41
Print Media Academy, center for communication, qualification, and knowledge, in Heidelberg.
a Computer animation (Status: 1998);
b The building with "S-Printing Horse", an art work by Jürgen Goertz (March 2000) (Heidelberg; see also fig. 13.1-27)



In addition to training and qualification, congresses, conferences, conventions, forums, and so on are held at the Print Media Academy, the center for communication, qualification, and knowledge.

Other countries around the world have a range of regional academies, which together with the Print Media Academy at Heidelberg form a network (see section 14.5.3). Within this network synergies are intensively exploited and regional particularities are taken into account.

13.1.3 Science and Research (selected Examples)

In this section, several examples from the field of sheet-fed offset printing presses are dealt with, showing how scientific methods are being used in current research. The following examples and methods are just a selection to give an impression of the versatile means of production (hardware and software) employed in prepress, press, and postpress for the production of print media.

The aim of industry-oriented science and research is systematically to find innovative solutions and improvements within the framework of new developments and product enhancements and also to save on time and experiment costs through intensive theoretical investigation and research.

13.1.3.1 Subjects, Methods, and Cooperations

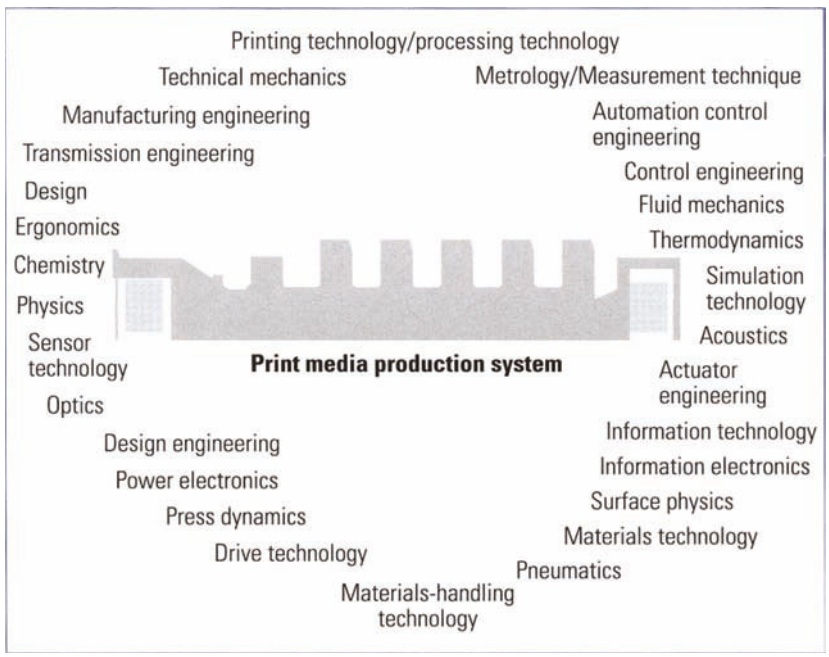
The print quality (see sec. 1.4) and productivity required of an offset printing press today make high demands on its precision and reliability. Maximum tolerances of some 0.00005 mm in the ink layer thickness during production or position deviations of color separations for multicolor motifs to one another and relative to the sheet edge of a maximum of 0.02 mm are close to the limit of what is technically feasible in view of general conditions and the many relevant process parameters.

Such demands can only be met through intensive research into the core processes of offset printing, which in turn fosters the development and production of printing presses. The complexity of both the printing process and the presses themselves demand the involvement of a multitude of scientific disciplines. Figure 13.1-42 gives an overview of scientific fields involved in printing press manufacture.

Besides the adaptation of findings from non-printing press-specific research activities for printing press engineering, there are also printing press-specific research activities undertaken by printing press/printing system manufacturers and numerous research institutions

Fig. 13.1-42

Relevant scientific fields for printing press/system engineering



worldwide (see secs. 14.5 and 14.6). Industry and research institutes also enter into joint research projects aimed at fundamental research and at product enhancements and further developments (see also sec. 13.1.3.5).

The latest tools and methods are used for these experimental and theoretical investigations; research activities also include the development of new tools and methods for further research work.

13.1.3.2 Inking Units

The inking units used in offset printing transport the ink from a supplies container and ink up the printing plate with a ink film of a defined thickness. The quantity of ink to be transferred depends on the image to be printed and therefore also varies in a transverse direction to the print direction. For this reason the ink supply is normally controlled in zones (see fig. 2.1-126). Due to the accuracy requirements of the ink layer thickness mentioned in section 13.1.3.1 and the prevention of retroactive effects (no ghosting, see fig. 2.1-17), the inking units are technically extremely complicated and complex press components.

The aim of every offset press development is to design an inking unit that best meets the following requirements:

- high level of evenness of the ink layer on the printed sheet in a longitudinal and transverse direction,
- fast reaction to adjustments,
- low deviations of ink film thickness during production, that is, low susceptibility to disruptive influences (e.g., temperature and humidity changes),
- large range for the control variable of ink and dampening solution quantity,
- economic viability.

The design parameters are the material, the diameter, the arrangement and kinematics, and the number of rollers. The multitude of possible inking unit configurations makes an empirical, experimental approach in the development and optimization of inking units extremely costly in terms of both time and money. Therefore, systematic investigation into the procedures in the inking unit and their regularities was begun at an early stage, in order to establish the basis for a theoretical and in many cases mathematical design of an inking unit.

Calculation and Simulation Methods

In 1960 Mill [13.1-9] first presented a method of calculating the ink layer thicknesses in the inking unit. The formulation of ink quantity balance equations for each nip results in an equation system where the ink layer thicknesses are the unknown quantities. A mathematically simpler method, based on determining the ink layer thickness from inking unit geometric coefficients, was developed by Ruder [13.1-10].

With both methods, however, only the average ink layer thickness can be calculated. It was not possible to determine the thickness gradients (ink film profile) on the rollers and the printing plate in a circumferential direction. This was first made possible by a computer-aided method presented by Rech in 1971 [13.1-11].

For this calculation, based on an angular increment method, all the roller and cylinder circumferences are divided into increments of equal size (fig. 13.1-43). The ink layer thicknesses on the individual roller nips are determined in increments by forming and solving linear equation systems. Based on this, further calculation programs came about, which took more and more inking unit parameters into account and should thus better simulate reality. Crucial in making the simulation as realistic as possible is the validity of the regularities and parameters on which the ink transfer is based.

The *INKTEAM simulation program*, developed by Patzelt and Ruder [13.1-12 and 13.1-13] during a FGD research project (FGD is the German Printing Machines Research Association, see sec. 14.6.2), reflects the latest state of the art. The following parameters are taken into account:

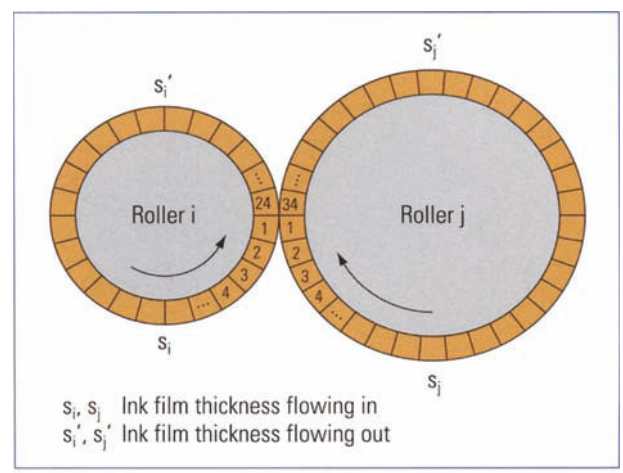


Fig. 13.1-43
Calculation model for the incremental determination of ink layer thicknesses [13.1-11]

- inking unit geometry (geometry, arrangement, and number of rollers),
- continuous or interrupted ink feeding (ductor-type or continuous/film-type inking units),
- material transport (ink and dampening solution) in a circumferential and a transverse direction,
- dampening solution feed and evaporation effects,
- temperature (influence on the ink-splitting function),
- lateral distribution,
- ink acceptance (full tone and halftone images).

The inking unit shown in figure 13.1-44 was modeled and simulated in INKTEAM. Starting with the empty inking unit (no ink on the rollers), the ink splitting and the ink transport in the entire inking unit and printing unit is calculated anew with each simulation calculation run until the ink thickness profile on the printed sheet no longer changes, that is, until a stable condition is reached. Figure 13.1-45 shows the ink thickness curves calculated and measured from printing tests for two inking unit configurations over the length of the printed sheet.

In the first case, where all the ink form rollers and the dampening form roller are engaged with the plate cylinder, the conformity between *simulation and experiment* is not wholly satisfactory. This can be attributed to the interaction of the multitude of parameters to be considered and the accuracy of their assumption. Simply changing the ink-splitting factor/ratio by a few per cent leads to completely different results.

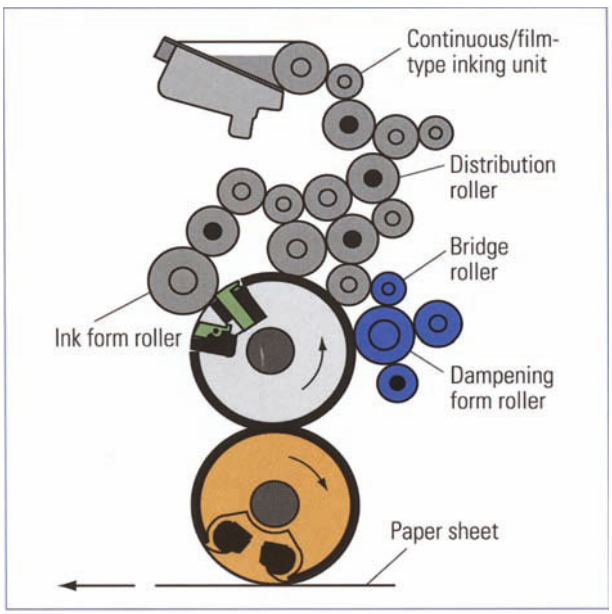


Fig. 13.1-44
Model inking unit for simulation with INKTEAM [13.1-14]

The simulation does, however, offer good results if ink and dampening solution are only applied to the plate cylinder by the dampening form roller, that is, as shown in figure 13.1-44 where the three ink form rollers are disengaged and the transfer of ink onto the plate takes place via the bridge roller between the dampening unit and inking unit and the dampening form roller (corresponding to a simple inking unit design with just one ink form roller).

In order to gain as accurate values as possible from the simulation, it is necessary to include all influencing factors correctly in the simulation model. In order to assure this, extensive work to verify and adapt the simulation tool is necessary.

A different type of simulation is suggested by Jiang [13.1-15], where the *inking units* are described *as a transfer system* within a controlled process. Here, the ink supply represents the input signal, and the ink application onto the substrate the output signal. Disruptive signals are the intermittent ink feed, the plate cylinder gap, and the individual print image. The entire transfer function of the inking unit is made up of the individual transfer functions of the roller couples. Simulation takes place in the frequency domain. Ink splitting is seen as the proportional element, and ink transport as a delay element. Due to the time variance and nonlinearity, it is rather difficult to record the ink transfer onto the plate and it can only be achieved with simplified linearization.

In the first place the calculation produces results regarding the time response of the inking unit when altering the ink supply (control process). Optimization of the evenness of the ink thickness profile is not possible.

Experimental Investigations into Ink Transfer

Since the regularities on which the ink transfer is based play such an important role in the design of inking and dampening units, experimental investigations in this field were started at an early stage. The latest results were ascertained by Brötz and Hars [13.1-16 and 13.1-17] during two FGD research projects. Amongst other things, one aim of these projects was to determine concrete *ink splitting quantities* (factors for determining

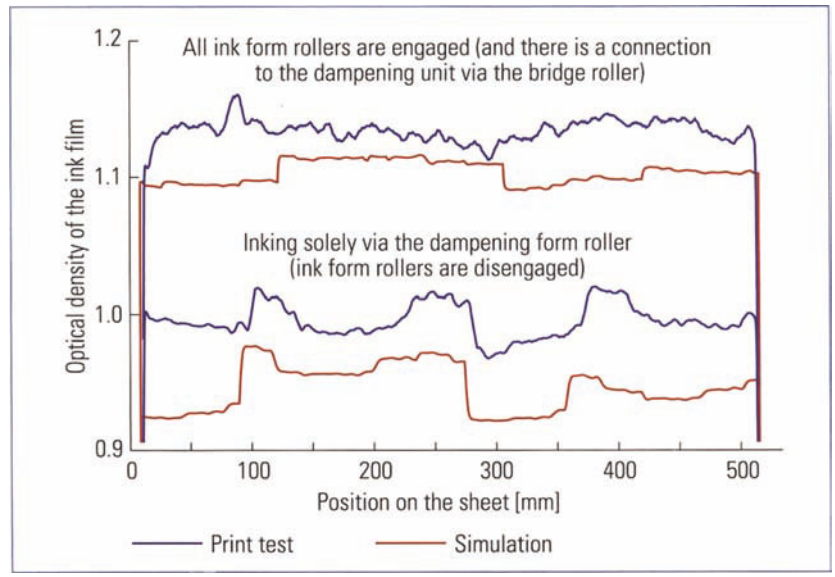


Fig. 13.1-45
Comparison of measured and simulated optical density of the ink film on the paper in the direction of print for printing units in accordance with fig. 13.1-44 [13.1-14], (for reasons of easier comparison the graph pairs have been moved on the ordinate in vertical direction)

the ink layer thicknesses running out at the nip; see also sec. 2.1.1.3, fig. 2.1-8) for the simulation program developed by Patzelt and Ruder [13.1-13].

For the experimental and separate investigation of all the relevant influencing variables of the ink-splitting quantities, a complex test stand was developed and set up (fig. 13.1-46). It consists of a continuous-type inking unit with cantilevered bearing of the rollers (on account of the better accessibility), ink distributor temperature control, a printing unit (plate, blanket, and impression cylinder), and a paper unwinding and rewinding unit.

The *measurement of the ink layer thickness* is of particular importance and should be of a non-contact type. In addition to a conventional lithometer (a device for measuring the ink layer thickness), a measuring system developed at the institute in accordance with [13.1-17] was used to measure the ink layer thickness. The *lithometer*, developed by FOGRA (see sec. 14.5.2), works with infrared light, since the maximum absorption values of dampening solution and ink lie in this wavelength range. Since the absorption spectrums of dampening solution and ink overlap in the maximum range, a complete separation of the signals, and thus an absolute measurement of dampening and ink layer thicknesses, is only possible subsequent to a complex calibration process. Since measurement with the lithometer is only possible on printing plate material, additional rider rollers are needed for measuring the

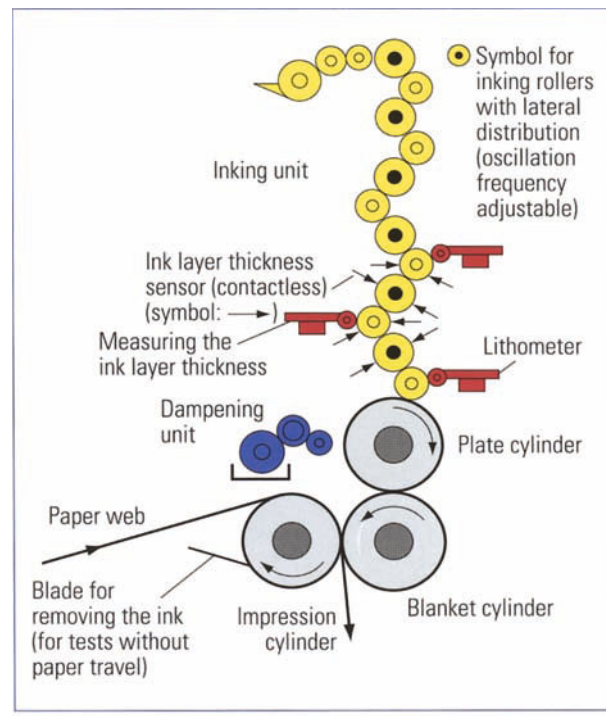


Fig. 13.1-46
Test stand for investigations into the ink-splitting factor/quantity [13.1-16]

layer thicknesses on elastometer rollers. This led to the development of the above mentioned ink layer thickness sensor, which uses visible light, but can only be used for experiments without dampening solution. Both measuring systems are calibrated for determining layer thickness by means of weighing.

The total layer splitting factor α or the difference layer splitting factor β are used as parameters for describing the ink transfer in accordance with the following equations and figure 13.1-43:

$$\alpha_{ij} = \frac{s_j'}{s_i + s_j} = \frac{s_j'}{s_i' + s_j'}, \qquad \beta_{ij} = \frac{s_j' - s_j}{s_i - s_j} = \frac{s_i - s_i'}{s_i - s_j} = \frac{w}{s_i - s_j}$$

(α_{ij} total layer splitting factor, s layer thickness, β_{ij} difference layer splitting factor, w transported ink layer thickness)

The multitude of variant parameters (such as velocity, ink, roller diameter, roller material, temperature, etc.) makes both carrying out the experiment and a clear, comprehensive representation of the results more difficult. Therefore, experiments and their representation remain limited to the alteration of one parameter while leaving the remaining factors constant.

Figure 13.1-47 contains an example of the dependence of the ink-splitting factor on the ink distributor oscillation frequency at constant printing speed. The ink-splitting factor can be seen to increase more sharply with the ink distributor frequency in the experiments with dampening solution feed than in those without this solution. (Note: the approximation of a constant ink splitting factor is usually assumed as $\alpha = 0.5$; fig. 13.1-47 reveals the inaccuracy of this assumption.)

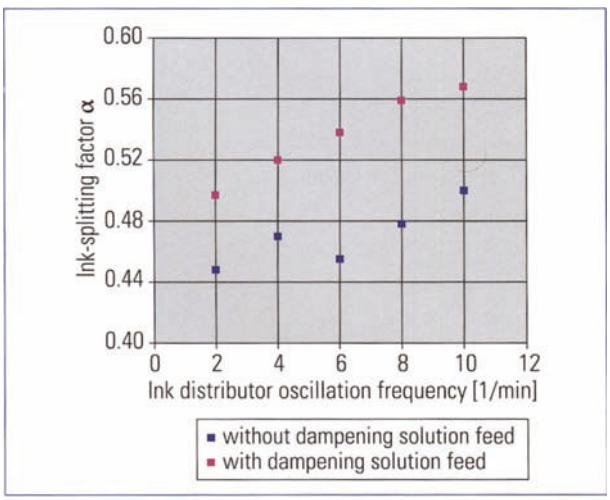


Fig. 13.1-47
Ink-splitting factor, dependent on the ink distributor oscillation frequency (stroke: about 35 mm), with and without dampening of the printing plate (printing/surface speed v = 1m/s) [13.1-16]

For investigations with a large number of parameters, the methods described in *Design of Experiments* [13.1-18] are today being applied more and more. These allow a reduction in the number of experiments with simultaneous increase to their significance through multi-variate approach, that is, the alteration of several parameters from experiment to experiment.

The experiments to date have led to a notable advance of the level of knowledge with regard to dampening solution and ink transfer. However, a complete description in a set formula, taking all relevant parameters into account, has still not been achieved.

13.1.3.3 Printing Units

Modern offset printing presses are built on a modular basis from individual printing units, the significant elements being the base frame, side frames, plate and blanket cylinders, as well as impression cylinders and paper transport cylinders with gripper systems on sheet-fed printing presses. The precision of these elements in terms of geometry and interaction (dynamics) determines to a great extent the achievable *print quality*, in particular regarding halftone dot definition, register, and doubling (see also sec. 2.1.1.4, fig. 2.1-17). This places equally high demands on the development, manufacture, and assembly of printing units. These can only be met with the most accurate knowledge of the process and the use of the latest technologies in all fields.

The print quality is, however, also influenced significantly by the printing substrate itself, which is subjected to a multitude of stresses during the printing process. Being aware of these stresses, and of the geometric and physical alterations of the printed sheets resulting from them, is a significant prerequisite when setting out the printing process conforming to the required print quality standards, and the materials and press components.

Experimental and Mathematical Vibration Analysis on Printing Presses

Every printing press represents a system subject to vibration in a large number of potential forms. Vibrations induced in the printing press or parts of it through variable torques or forces, might effect print

quality, the service life of components, and noise emission. To *reduce vibrations*, the following options are usually available:

- reducing the excitation,
- increasing the rigidity,
- reducing the moving mass,
- optimizing the dampening.

In each case, an accurate understanding of the type of vibrations and their amplitudes is a prerequisite for being able to judge their effects. To *analyze vibrations*, the following basic procedures exist:

- mathematical modal analysis,
- mathematical running mode vibration analysis,
- experimental modal analysis,
- experimental running mode vibration analysis.

The first vibration analyses can already be carried out during the conception and design phase of a new press by setting up vibration models and subsequent simulation calculations. This is annotated on the basis of the torsional vibrations of a multicolor sheet-fed offset press (e.g., see fig. 2.1-18).

For the purpose of synchronization all the cylinders and inking units of the press are driven by a continuous gearwheel train. They therefore represent an extensive torsional vibration system.

In a *vibration model* for calculating the torsional vibration eigenfrequencies and eigenforms, both torsional and bending vibrations must be taken into account. Due to the large bending stretch the bending vibrations cannot be neglected. The schematic structure of a vibration model for a printing press consisting of two printing units is shown in figure 13.1-48.

The model parameters, such as mass, turning mass, rigidity, and dampening can be determined mathematically or experimentally, whereby the experimental determination (especially of rigidity and dampening) increases the mapping quality of the model. Modeling and calculation normally takes place with one of the *simulation programs* commercially available. In the case shown in figure 13.1-48, the *finite element program* in accordance with [13.1-19] was used, since it enables rotational and translational degrees of freedom to be taken into account. With this simulation, *eigenforms* and *eigenfrequencies* can be determined.

The calculation of torsional vibrations can, for example, determine a first eigenform of the printing press

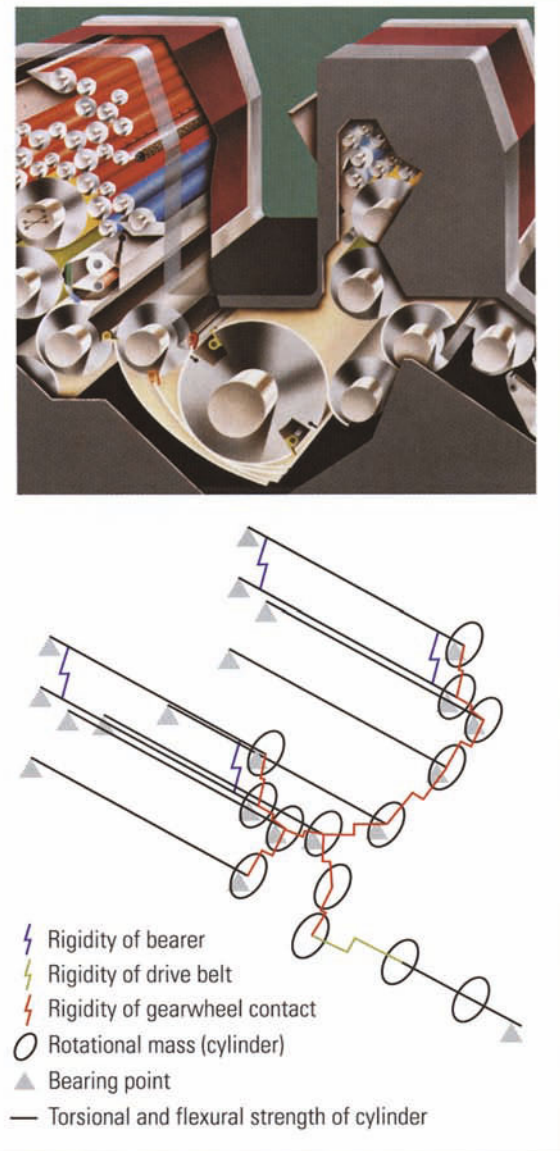


Fig. 13.1-48
Diagrammatic section of the vibration model of a two-color sheet-fed offset printing press (Heidelberg)

where the cylinders of the front part of the press vibrate against those of the rear part (seen in paper travel direction). In the press center there is a vibration node. The frequency of this eigenform should be high enough not to be stimulated significantly during print operation. The second eigenform already has two vi-

bration nodes and a higher frequency. A *sensitivity analysis*, where all the relevant model parameters are changed within definite boundaries, reveals which structural modification of the press has the greatest influence on vibration behavior.

Alongside the calculation of the eigenforms and eigenfrequencies, theoretical *running mode vibration analysis* under actual service conditions is also possible. For this, the model is strained with the external forces and torques and the torsions and displacements of the model calculated using the angular increment method. The complexity of the model and the multitude of possible excitations, however, limit the realism of such simulation calculations.

To investigate true vibration behavior and to verify the model, absolutely precise *angle of rotation measurements* are carried out on printing presses. For this, encoders are fitted to several cylinder journals. At various printing speeds, absolute and differential angle gradients of the cylinder are measured simultaneously over several rotations. For the analysis, the signals are transformed into the frequency range and depicted in a so-called "*cascade diagram*" (fig. 13.1-49).

The significant portions of the signal lie with integral orders (i.e., integer multiple, e.g. of impression cylinder revolutions), that is, the relative torsions are identical from rotation to rotation, which brings a high torsional reproducibility, at the same time indicating that no doubling effects caused by torsional vibrations are to be expected. The higher the printing speed, the higher the amplitudes. This can be attributed to the increasing energy content of the excitation. The first eigenfrequency can be recognized on the local banking of the amplitudes along a line of constant frequency.

While the running mode vibration analysis investigates the original structure through the excitation occurring during production, the *experimental modal analysis* generates a synthetic excitation, either of a continuous nature (pulser, shaker) or with an impulse hammer. The running mode vibration analysis shows the types of vibrations under actual service conditions, which can be represented as linear combinations of the system-immanent eigenforms. The modal analysis produces the eigenforms themselves, which has advantages for the elaboration of structural modifications resulting in reduced vibrations. Classification is generally made into the phase resonance process and the phase separation technique [13.1-20].

With the *phase resonance process*, the natural vibration forms (eigenforms) are separated in the experiment. In complex vibration tests, the structure is excited by several exciters in an eigenfrequency through correctly phased, sinusoidal stimulation, which makes possible direct determination of the natural vibration form (eigenform) at certain points of the structure.

The *phase separation technique* is used more often. With this method the eigenforms are separated mathematically. This technique is annotated on the basis of the *modal analysis* of the printing unit on a sheet-fed printing press.

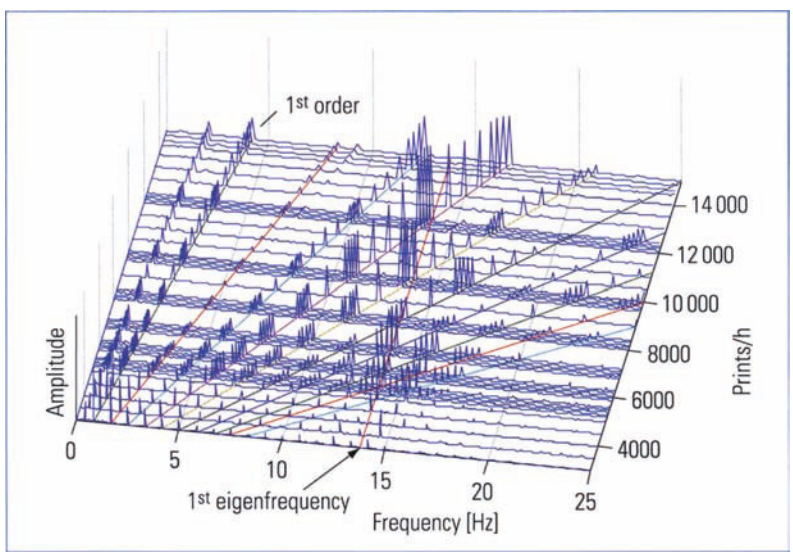


Fig. 13.1-49
"Cascade diagram" of difference angle spectra on an sheet-fed offset printing press (vibration analysis, "running mode vibration analysis")

In the experiment, the *side frame* is stimulated at a defined point by means of an electrodynamic shaker with a sinusoidal signal with continuously changing parameters (frequency, amplitude) and the accelerating signals are measured simultaneously at several points on the side frames. Based on the transfer functions between excitation and response calculated, the modal parameters are determined by means of curve fitting, whereby the mathematical separation of the eigenforms takes place. The eigenforms can be shown in a computer animation with increased amplitude. Figure 13.1-50 depicts the reversal positions of a eigenform. At a further stage, the effect of structural reinforcing measures on the eigenforms of the printing unit can be investigated.

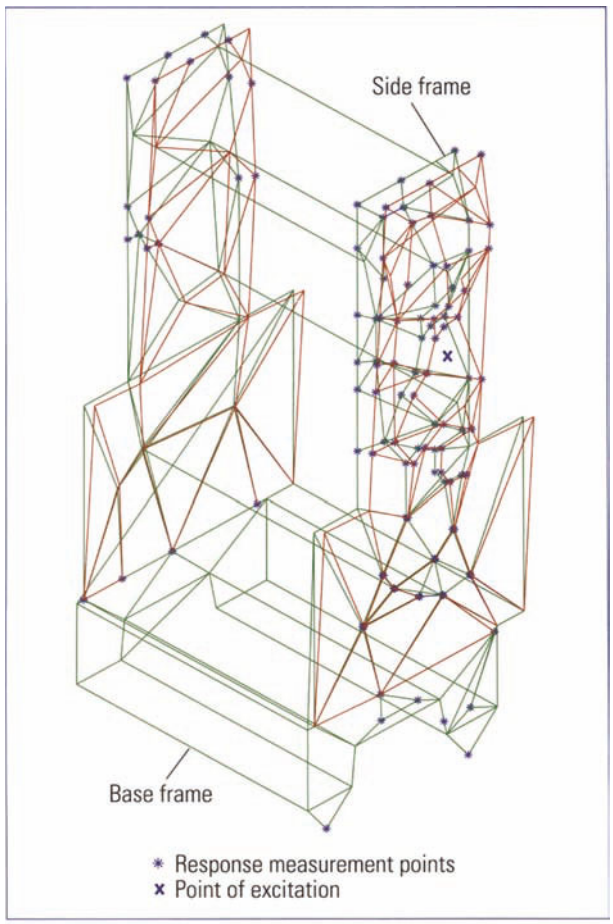


Fig. 13.1-50
Vibration eigenform of a printing unit as result of a modal analysis (phase separation technique); shown are the reversal positions of the side frames (Heidelberg)

Stresses on Paper in the Printing Process

During the printing process, the print sheet undergoes the following local stresses on its entire surface:

- compression in the printing nip,
- shearing stress in the printing nip,
- compression in the gripper,
- bending stress when the sheet is released from the blanket,
- tensile stress between blanket cylinder and gripper.

Numerous investigations have tried to determine these stresses and their effect on the printing material.

The tensioning of the sheet between blanket cylinder and gripper, resulting from adhesion to the blanket (*sheet after-travel*, fig. 13.1-51, see also fig. 2.1-54), is of particular interest, since it stretches the sheet while, at the same time, this tension must be applied by the grippers to prevent the sheet from slipping.

To *measure* this force, a bending bar is generated from milled recesses in the area of a gripper pad of the impression cylinder. Subsequent to the calibration of the press at a standstill the tensile force generated at the gripper pad during operation can be determined by measuring the bending elongation using a strain gauge. The point of measurement and the course of the tensile force for a full-surface printing plate is illustrated in figure 13.1-51. The tensile force increases sharply at the start of print and goes down the greater the angle of rotation due to the increasing wrap of the sheet on the impression cylinder.

In a research project sponsored by FGD (see secs. 14.6.2 and 13.1.3.5), the strain on the print sheet in the printing nip was investigated both theoretically and also experimentally [13.1-21]. To summarize the results, the intensity of the influence of the process parameters with regard to paper, blanket, ink, and print on the effects of

- adherence to the blanket (sheet after-travel),
- tensile force of the grippers,
- slurring (dot deformation),
- dot gain, and
- printed image length

is illustrated in a sensitivity matrix (table 13.1-3), determined by both calculation and experiment. The pro-

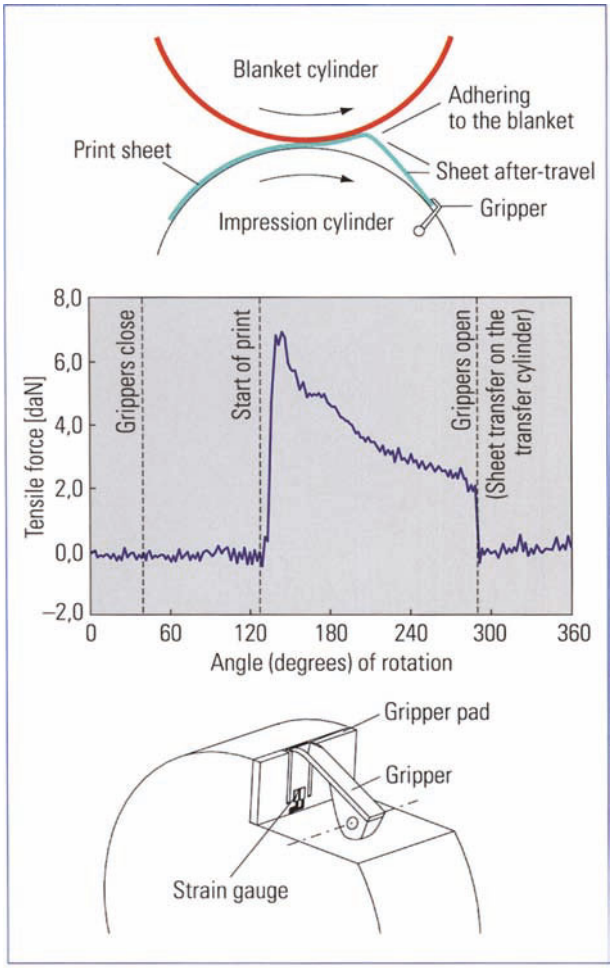


Fig. 13.1-51
Measured graph of the tensile force on a gripper pad of the impression cylinder [13.1-21]

ject produced a simulation model for the actions in the nip while, at the same time, experiments also yielded results that could be directly utilized in practice.

13.1.3.4 Sheet Transfer

The transfer of the print sheets from the feeder pile to the first printing unit, from printing unit to printing unit and from the last printing unit to the delivery pile, determines the print quality *to the same extent* with regard to the feed and transfer registers as well as to smear-free transportation of sheets. The trend towards longer presses with up to twelve printing units for perfecting, as well as coating and drying units for in-line finishing in the face of rising print quality demands, has been and is a challenge for sheet transfer technologies. Stable and smear-free sheet travel for the most diverse types of printing substrates requires the use of complex technologies. Without constantly further improvements and developments based on intensive research, this technology could not be mastered.

Reducing Vibration through Harmonic Synthesis of Cam Drives

To generate *non-uniform motions* in printing presses, cam drives are predominantly used (gripper mechanisms, suction head, impression on/off mechanism, etc.). The high demands on the drives with regard to dynamics bring about laws of motion that represent a compromise between the required motion on the one hand and justifiable vibration excitation on the other.

An effective means of *vibration reduction* is the harmonic synthesis method [13.1-22], which is explained in the following by the example of a *forwarding sucker gear on the suction head* of a sheet-fed offset printing press (see also fig. 2.1-27).

The forwarding suckers take over the sheet lifted by the lifting suckers at a standstill, accelerate it in the direction of the feeder table in a translational motion, and pass it on. After this, the forwarding suckers return to their initial position. On large-format presses, several forwarding suckers are arranged on a bar transversely to the direction of print, to aid better sheet guidance. Since the movement of the forwarding sucker occurs at a maximum print speed of 18000 impressions/hour with up to 5 Hz, there is the risk that the forwarding sucker bar will be stimulated to natural vibrations, which ultimately results in resonance disruption.

The *harmonic synthesis* begins with calculating the maximum permitted order in the spectrum of the acceleration sequence. The forwarding sucker gear in question has an initial bending eigenfrequency of $f_{E_1} = 40$ Hz ($\omega_{E_1} = 2 \cdot \pi \cdot f_{E_1} = 251\ s^{-1}$), the maximum angular velocity of the drive is $\Omega_{max} = 31.4\ s^{-1}$ (printing frequency 5 Hz). In accordance with the harmonic synthesis, only those orders (harmonics) are permitted in the law of motion that cannot excitate the eigenfrequency. The highest harmonic *nh* permitted in the law of motion can therefore be formulated as

$$nh \leq \frac{\omega_{E_1}}{\Omega_{max}} .$$

Process parameters		Effects				
		Adhering to the blanket	Gripper pulling force	Slurring	Dot gain	Printed image length
Paper	1. Thickness	+ +	+ +	++ –		
	2. Travel direction (grain direction)	++	+/++	+	–	+
	3. Surface properties	+++	++	+	+++	+
	4. Deformation behavior	++ +	+ +	–		+
Blanket	1. Thickness			+		
	2. Deformation behavior	+	+	++ +++	++	+/++
	3. Surface properties	[–]				
Ink	1. Layer thickness	+			[+]	[–]
	2. Tackiness/ viscosity	+ ++	++ ++	+	++	+/++
Printing parameters	1. Cylinder-diameter	++ ++	 ++	–	+	+
	2. Blanket height (blanket cylinder diameter)	+ +	+/++ +	++ ++	++	+/++
	3. Contact pressure	+ +	+ +	++ ++	+	+
	4. Print speed	+ +	+ +	+ ++	++	+

\+ Findings from experiments
\+ Findings from simulations
[ ] Findings from literature

+++ Very large influence
++ Large influence
\+ Little influence
– Negligible influence

Table 13.1-3 Sensitivity matrix of paper strain in the printing nip with offset printing [13.1-21]

The law of motion can then be described as an expansion in series:

$$s_x(\varphi) = a_0 + \sum_{k=1}^{nh} a_k \cdot \cos k \cdot \varphi + b_k \cdot \sin k \cdot \varphi.$$

For the forwarding sucker gear in question, a law of motion was developed in a conventional manner (polynomial law of motion), using the harmonic synthesis method, where the harmonics above the seventh order are absent.

The vibration curves of the two outer forwarding suckers shown in figure 13.1-52 were calculated on a substitute model applying both laws of motion. They reveal that, with the law of motion based on the har-

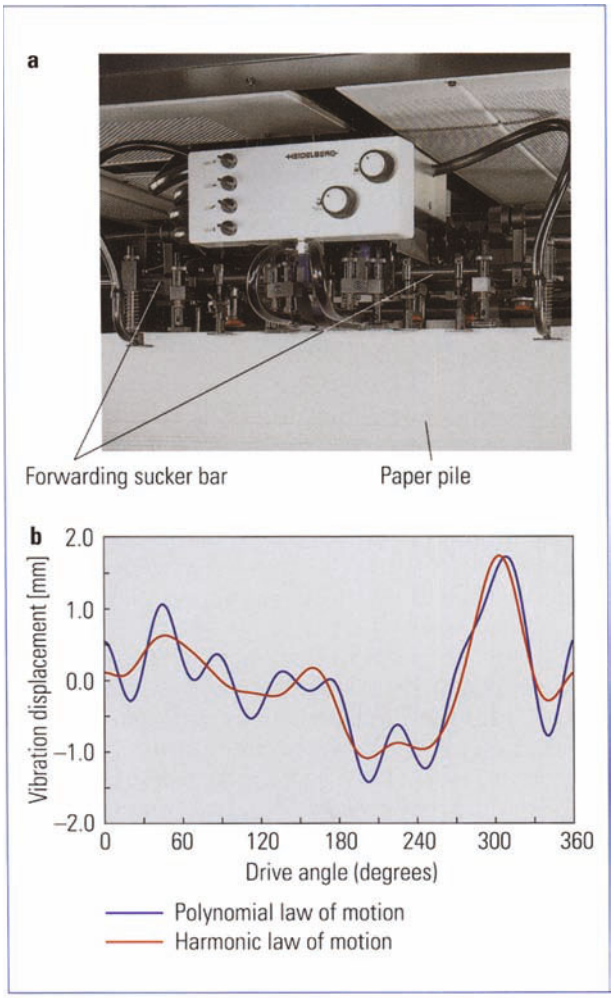


Fig. 13.1-52
Reduction of vibration amplitudes of the forwarding sucker bar on the suction head of the sheet feeder through harmonic synthesis of the cam-driven drive (see also fig. 2.1-27).
a Suction head on the feeder of an sheet-fed offset press;
b Vibration displacements of the outer forwarding suckers with different laws of motion of the cam disk control (Heidelberg)

monic synthesis method, there are no vibrations that can damage through their high frequency. The differences in the contour of the cam discs are so minimal that they can only be recognized in the form of faint differences in the course of acceleration.

To employ harmonic laws of motion successfully, the following factors must be considered:

- The influential elasticity must be located between cam gear unit and production means (elastic output of the drive).
- Vibration excitation through pulse-like acting forces cannot be compensated.
- "Dwell sections"(no motion of the production means) can only be achieved to a certain degree (residual ripple).

The synthesis method, developed in intensive research, is now in widespread use.

Non-Smearing Sheet Guidance using Ventilation

On its way through the printing press, the print sheet is subjected to various forces that can induce contact of the printed sheet with press components and thus cause smearing of the (in general not yet dry) printing ink:

- inertia forces (gravity, centrifugal force, and accelerating force),
- bending forces,
- impulse forces from the air blades and dryer nozzles.

The use of *air flow fields* is the only way of guiding the print sheet through the press and avoiding surface contact, in spite of these forces acting upon it. For this reason, sheet guide plates equipped with air nozzles (fig. 13.1-53), are used between the printing units (see fig. 2.1-38) and in the delivery area (see fig. 2.1-56). The type, quantity, and location of the nozzles used must be sufficient to generate an air flow that counteracts the external forces acting on the print sheet. The following facts represent a challenge for the design of sheet guide plates and air flow technology:

- The physical properties of the substrates vary significantly (bending strength 1:1000, grammage 1:20).
- There is a distinct interactive effect between the air flow and the print sheet topography (surface structure).
- The sheet must not touch the sheet guide plate but at the same time must not be too far away from it.
- The mechanics of three-dimensional, particularly of turbulent flow fields are extremely complex.

In *fluid mechanics*, the flow field is described through the non-linear Navier-Stokes equations. Formulation

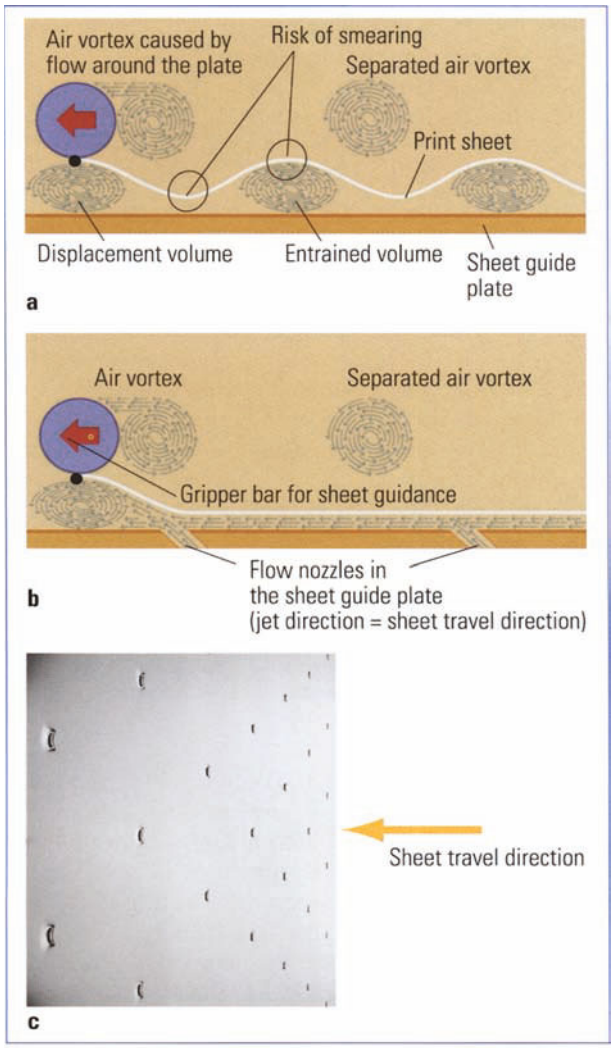


Fig. 13.1-53 Sheet travel in the delivery (see also fig. 2.1-56)
a with conventional sheet guide plate;
b with blast-air supported sheet guidance;
c Sheet guide plate for air-cushion sheet guidance (Heidelberg)

and *analytical solution* of Navier-Stokes equations can only be applied in relatively simple cases of fluid technology.

With complex flow fields, it is necessary to fall back on *computer-aided simulation* [13.1-23]. The approaches used in these computer programs are the *finite element method*, known from structural mechanics, and the *finite volume method*. For numerical calculation, a flow field is divided into many small cuboid cells. With the finite element method, the fluid quantities are calculated at the corner points of the cells, with the finite volume method in the center of the cells. The accuracy of the calculation depends very much on the quality of the model structure. Laminar flows can be simulated more accurately than turbulent ones. Experimental validation of the results of the calculation is always advisable.

The numerical simulation of the flow field between sheet guide plate and print sheet is not actually possible by current means, but the flow profile of individual nozzles can be determined numerically, which provides a means of designing the nozzle geometry.

The *pressure field* on a nozzle and in its immediate surrounding area can be determined through *pressure measurements* along a grid of measurement points and represented in the form of a *color chart*. The pressure field shown in figure 13.1-54 gives a clear idea about the homogeneity and therefore the support performance of the air cushion.

To judge the quality of sheet travel, *high speed cameras* are employed. Alongside simple visual smoke processes for the visualization of the flow itself, there are also complex methods extending as far as *particle image velocimetry (PIV)* [13.1-24]. Here, the air flow is charged with very tiny particles, just a few micrometers (μm) in size, and the velocity and motion of theses particles is determined from sequential snapshots applying image processing techniques. The results of this type of measurement are displayed in the form of two-dimensional vector graphs.

13.1.3.5 Industrial Joint Research

Organizations and bodies involved in industrial joint research are listed in section 14.6.2. The way in which bodies and joint organizations of this kind function is explained below.

Industrial joint research can be carried out by the collaboration between interested companies that all contribute to the cost of the project, though in various countries and regions there is also the option of using government sponsorship for financing.

Options for the Implementation of Research and Development Projects

Product development and improvement mostly occurs as a result of company-specific research and development activities. Research and development work is done within the company, and also jointly with exter-

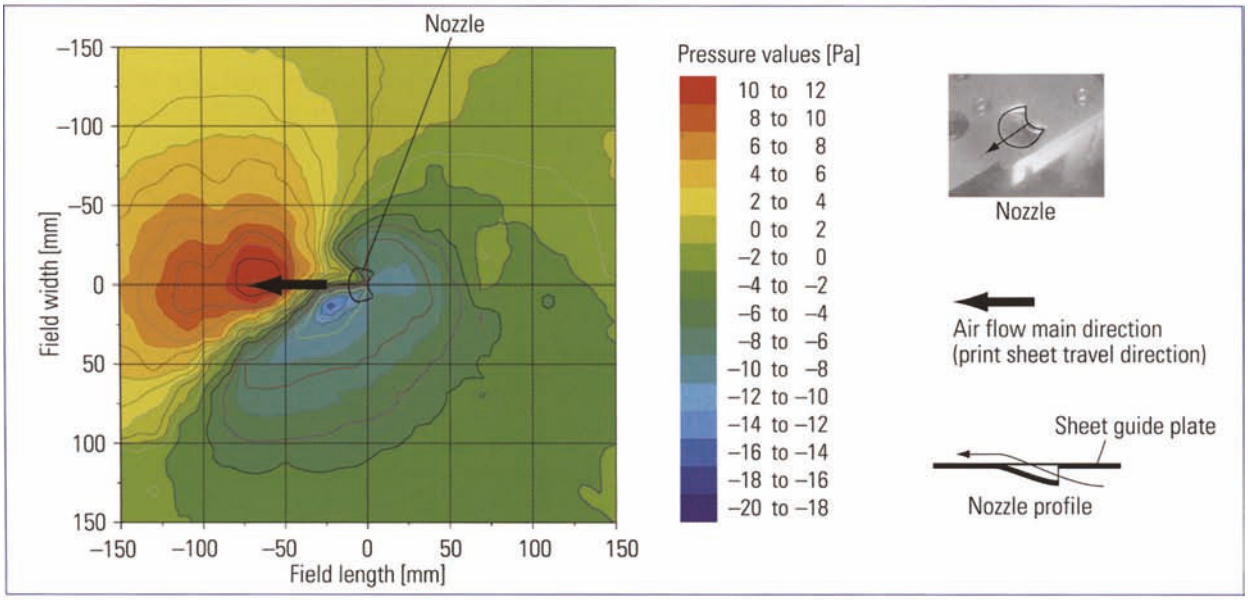


Fig. 13.1-54 Color chart of the measured pressure field on the nozzle and its surrounding on a sheet guide plate (Heidelberg)

nal research units/organizations, companies, and institutes, more often than not exclusively for the client. In spite of the sometimes inevitably requested confidentiality there are numerous problem areas that can be dealt with jointly inside the industry and also jointly with direct competitors. The platform for doing so is the establishment of joint research.

Joint Research

The basis for joint research is that companies with common interests join forces to cooperate on work and problem-solving. Collaboration of this kind can only work if every partner can see and experience its advantages, that is, a so-called strategic alliance is established.

The Objectives of Joint Research

Summed up, the objective of joint research is to obtain research findings of high quality quickly, more efficiently, economically and in a form that they can be exploited in the specific products for the benefit of customers and suppliers. Achieving the following individual objectives will bring this about:

- working out scientifically verified principles in a form not affected by competition in the preliminary stages and/or as a supplement to the company's own and product-specific research and development,
- a significant supplement, but not an alternative to the company's own research,
- avoiding double work,
- widely effective research from which medium-sized and small companies will benefit, too,
- working out standards and basic knowledge that can be standardized,
- exchanging experiences between industry and research institutes, establishing the transfer of knowledge and technology,
- exchange of experience between the companies involved and between the research organisations themselves,
- collaboration with other international research organizations conducting joint research,
- observing trends and detecting weaknesses,
- promoting innovations and the effects of synergy,
- industrial promotion of field trial/practice-oriented research in the universities,
- field trial training of junior technical/scientific members of staff,
- strengthening competitiveness in international business,

- cooperation with international scientific and practice-oriented institutions and associations.

Benefits for Member Companies/Cooperative Partners

The usefulness for each individual company is primarily determined by the degree to which it and its experts are involved in the joint research projects and how it introduces, transfers, and applies the results of the joint research work to the individual departments and projects of the company.

The list below shows the possible basic benefits and acts as an aid for members to assess critically how far they have utilized the advantages of joint research and what could be optimized in the future:

- Basic research is done externally,
- the feasibility of product-specific research generally depends on facilities within the company in terms of personnel, equipment, and finance, and is sometimes only possible by joint research projects,
- optimal use of own personnel, materials, and capital resources,
- saving time and costs of internal basic research,
- the grants available from public promotional resources virtually double the research company's own funds for implementing the projects; the resources and know-how of member companies and research units are also brought in,
- influence on/involvement in decisions about selecting and dealing with topics, new projects,
- initiation of new research projects from company-internal knowledge of the problem areas,
- representation of companies and customers interests when handling projects,
- take-over and application of research findings for company-specific research and development projects and for product optimization,
- influence on and safeguarding of standards and guidelines – on an international basis as well,
- time advantage gained as a result of the transfer of knowledge and results (prior to general publication of the findings),
- joint use of patents arising from the joint research,
- protecting/developing and reinforcing the industry/products in the face of international competition,
- positive effect on company prestige and product quality as a result of supporting joint research and collaboration,
- the transfer of knowledge and information through discussion with specialist colleagues from the industry and the research organisations/institutes,
- consolidating manufacturer/supplier contacts,
- removal of company-specific "blinders" as a result of external contacts,
- employee advanced training/education,
- option of dealing with topics outside the public domain with financing by interested companies and organizational processing by the research association.

As a result of the contacts with the institutes in the context of joint research, opportunities arise to conduct and to have conducted special investigations that are solely in the company's own interests, or for the company to utilize consultancy services on its own behalf, such as:

- The opportunity to deal with (even exclusively) company-specific problems,
- to commission short-term special studies to institutes,
- advice from experts in the research centers,
- the use/loan of equipment,
- direct contact with the institute's employees and the negotiation of opportunities for later industrial activity,
- collaboration with partners in industrial research.

Expenditure of Member Companies as a Result of their Involvement in Joint Research

Efficient, successful collaboration of member companies in joint research committees is only possible if there is open discussion and if the confidentiality with respect to internal company activities is restricted to what is really necessary. Collaboration in joint research will only receive the sustained support of all parties if the use of resources is efficient and can be proven to be successful and if the usefulness completely outweighs the expense. To give a brief summary, the benefits listed above are counterbalanced by the following demands and resources:

- Sending employees to committees and working groups (releasing personnel resources),
- collaboration in the optimal selection of research topics,
- bringing the company's own know-how into the research organisations and research projects,
- advising research organisations employees during implementation of the project,

- material support for the research organisations in special cases with materials, parts manufacture, subassemblies, and the loan of special equipment,
- supporting the research organisations in carrying out practical trials on industrial installations,
- financial support through member fees and donations.

Transfer of Knowledge and Findings

Joint research will only endure and be strong if the results obtained can be put into successful effect in the member companies. Information is best transferred via the active collaboration of company members in the working groups dealing with and implementing the research project. They must ensure and take care within their own companies that the information received is disseminated and used there.

The organization within the industrial joint research committees/associations, and the way in which a research project is dealt with ensure that a variety of information sources is offered that are of assistance in transferring knowledge and findings and putting them into effect in companies.

Such sources of information are essentially:

- Working group meetings, minutes, reports,
- meetings of members, management reports,
- research organisations/institutes,
- meeting of advisory boards and board meetings, minutes,
- head offices,
- project drawings, project documents,
- interim reports on current research projects,
- final reports on research projects,
- applications for new research projects,
- cooperative contacts among members.

The Focus of Research Activities/Topic Groups

The following is an overview of research topics and projects using as an example the *Forschungsgesellschaft Druckmaschinen e.V.* (*FGD*)/German Printing Machines Research Association [13.1-25, 13.1-26] research partnership, which operates on the above principles.

A fund of knowledge has been built up as a result of concluded, current, and planned research projects and is constantly being extended.

The range of topics covers many fields, processes, and interests of printing press construction and also includes investigation and research into consumables and commodities. This means that the requisite attention is given to machinery manufacturers and suppliers as well as to customers, and an attempt is made to examine all the process stages within the production chain from the original to the end product. (It is not explained how the individual projects are assigned to these topic groups since this can be deduced directly from the research topics.)

Research subjects/projects (selection):

- Examination of the rheological processes and ink distribution during the flow of ink in the printing units (integral and local) with a view to optimizing equipment and materials and assuring and increasing quality,
- static and dynamic stress on the materials in production plants with a view to optimizing quality and process reliability,
- physical/chemical investigation and establishing models for process investigation, as well as understanding the ongoing processes in the interests of optimizing procedure and materials,
- the development of simulation procedures and theoretical models for designing and optimizing processes and modules,
- analysis and optimization of drive conditions and materials conveyance systems, especially with a view to reducing vibration and noise,
- developing measuring techniques and systems for machinery adjustment/setting, process monitoring, and control,
- investigating process boundaries and developing new processes within the process chain in order to create printed products,
- optimizing processes with a view to saving on resources and complying with environmental protection requirements and/or developing preventive measures,
- investigations aimed at safeguarding the future, recognizing the potential for innovation and synergy effects within printing press construction and the prepress and finishing stages involved,
- investigations into the use of new types of materials and into incorporating new, innovative procedures and processes into the design of printing systems,
- considering trends in electronic media and investigating how to position and improve print media, also as a component of multimedia communication and information transmission,
- research into printing processes without a permanent master, non-impact printing technology, in

particular their importance with regard to high-quality multicolor printing and the design of hybrid printing systems.

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13.2 Environment, Safety, Standardization

13.2.1 Environmental Protection in the Printing Industry

Environmental issues within the printing industry are regarded and handled very differently at local, national, and international levels; the variety of printing materials and chemicals is very large and evaluations of their relevance to the environment sometimes vary. For these reasons, it can only provide a brief summary here. Detailed information can be obtained from the contacts listed at the end of this chapter, by referring to the listed literature, and from the trade associations and government authorities responsible for any particular printing company.

13.2.1.1 Introduction

The industrial production of goods always has an impact on the environment. The production of printed matter is also relevant to the environment and exploits resources. Responsible handling of the *resources*, such as energy, water, and air, and the two most important primary products ink and paper, as well as the other substances required, is one of the most important tasks of the printing industry, the manufacturers of printing systems, the sub-contracting industry, and waste disposal firms.

To this day many successful environmental protection measures have been implemented in the printing industry. The following are some examples:

- In *printing inks*, substances are used that are as environmentally compatible as possible and do not endanger human health. In 1993, ink manufacturers voluntarily pledged to refrain from using certain pigments, colorants, solvents, softeners, and toxic substances. Today, the inks used in sheet-fed offset presses consist of more than 60% renewable raw materials; ink manufacturers are working to increase replacement of mineral oils by vegetable oils (soybean oil). In the case of gravure inks, the toluene used may not contain more than 0.1% benzene. The chlorine content of inks is less than 0.5% on average. Only small amounts of heavy metals are still contained in certain types of inks, for instance, iron and manganese in mineral pigments, cobalt as a drying agent, and copper in organic blue and green pigments, and these amounts can be considered environmentally safe.
- To reduce *VOC (Volatile Organic Compounds) emissions*, an initiative was launched by the German printing industry. Printing press manufacturers, manufacturers of wash-up devices, and roller manufacturers pledged to use low-emission cleaning agents in all wash-up devices built after 1995. An independent testing institute (FOGRA at present) checks cleaning agents for non-toxicity, compliance with safety regulations, and environmental and material compatibility and issues a test certificate. Solvent emissions from washing operations have decreased markedly since 1995. At the initiative's regular meetings, which are organized by the Berufsgenossenschaft Druck und Papierverarbeitung (German Institution for Statutory Accident Insurance and Prevention in the Printing and Paper Converting Industry), other subjects are also discussed, such as alcohol reduction in the dampening solution for offset printing, or reduction of the powder used for delivery-pile dusting (to prevent the unwanted transfer of ink that is still not completely dry). Expansion of the initiative to other European countries began in 1998.
- *Paper* almost always consists of wood fiber. Other substances such as filler and pigments can make up as much as 35% of the contents. Wood is a renewable raw material and about 8% of all the wood felled worldwide is used for paper production. Tropical wood is not used in the paper industry because its fibers are unsuitable. For years the printing industry has called for and supported wood-

H. Kipphan (ed.), *Handbook of Print Media*
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felling based on the conservation requirements of any particular wooded area.

The voluntary pledge made by the paper industry in 1994 to increase *waste paper recycling* to 60% by the year 2000 was more than fulfilled when 83.1% was reached as early as 1997. In papermaking, until a few years ago, elementary chlorine was used to bleach the wood-pulp. Owing in particular to waste water contamination, most European papermakers have converted their bleaching processes to oxygen and hydrogen peroxide.

- *Returnable systems* (which are returned for reuse) for containers and cleaning cloths have already been widely established in many countries, or are in the setup phase. Standardized containers are used, which are put in circulation in the recycling system based on payment of a deposit refundable on return of the container after use.

Practising Environmental Protection

In figure 13.2-1 the general processes in a printing plant are illustrated in a diagram. First of all, the recycling processes will be explained in more detail (fig. 13.2-2).

Recycling is to be understood as the reuse and processing of products or parts of products in a circulatory system [13.2-1]. Recycling produces secondary raw

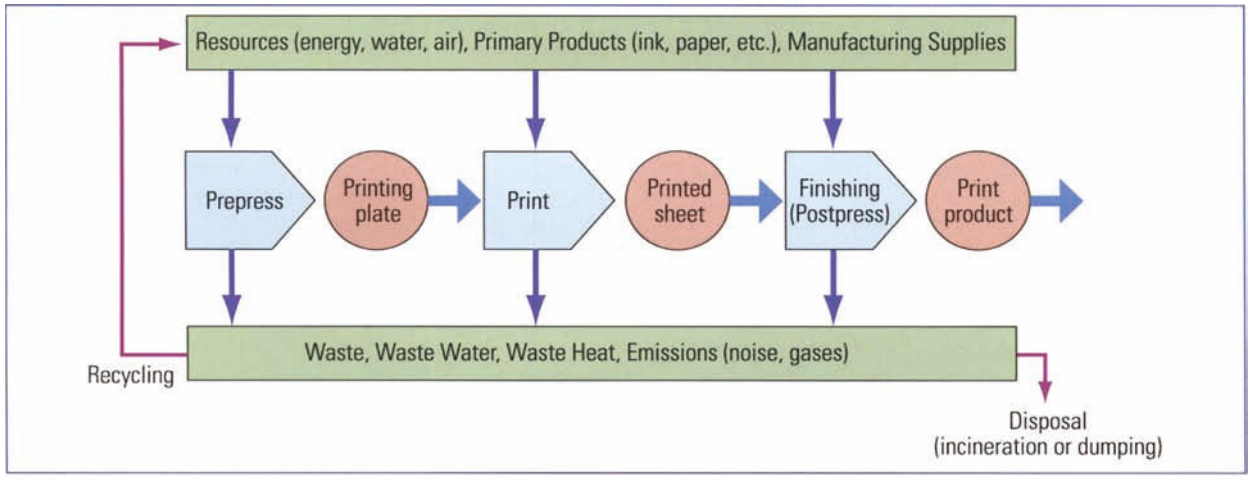
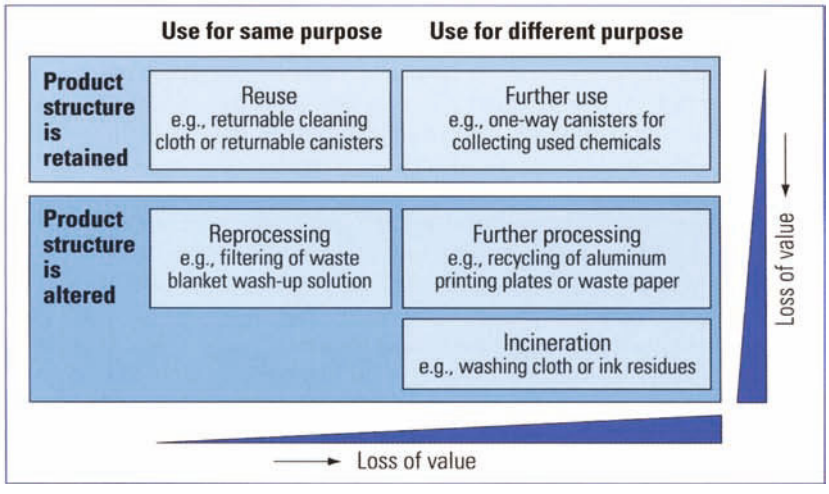


Fig. 13.2-1 Diagram of material flow in a printing plant

Fig. 13.2-2 Recycling processes



materials and in this way resources are saved. The reduction in the quantity of waste means that less demand is placed on available dumping-ground capacities.

The term *use* is characterized by retention of the product structure and a minor loss of value. *Reusing* involves the product being used for the same purpose (e.g., returnable cleaning cloths or reusable canisters for printing chemicals), and *further use* means that the product is used for another purpose (e.g., one-way canister for collecting hazardous liquid wastes).

The term *processing* is characterized by the conversion of the product structure, which means that there is a greater loss of value. In the *reprocessing* process, waste material or returned production material is reused in a production process similar to the one it has been passed through before (e.g., recycling of used cleaning agents). *Further processing* generates secondary raw materials (e.g., waste paper recycling, the recycling of aluminum printing plates or empty ink canisters).

Incineration (e.g., of washing cloths or ink residues) for the production of energy is another type of recycling.

Environmental aspects are explained in more detail below with reference to *offset printing*, the most widely-used printing process. The other printing processes are then considered somewhat more briefly.

13.2.1.2 Environmental Protection in Offset Printing

Prepress (Repro, Composition, Film, and Platemaking)

Methods of *photographic reproduction* in prepress require the use of *developing and fixing baths* with which the silver-based film is treated as a master for the printing plates. The service life of the developing bath can be extended by *developer-saving systems* and *long-life chemicals*. In this way, the quantity of used developer requiring disposal, which is classified as hazardous waste that must be closely monitored, is reduced considerably. In the case of the fixer, circulatory systems with electrolytic desilverization extend its service life substantially; in this way the mass of hazardous waste can be reduced here, too. The recovered silver is recycled.

Recycling of *recovered silver* is also possible for films and photographic papers with a blackening factor of more than 30%. On the other hand, when blackening is less than 30% or in the case of mounting films, we are dealing with non-hazardous waste for recycling (household waste).

When *computer to plate* or *computer to press* systems are used, the need for photochemicals and photomaterials is partly or even completely eliminated. An annual input/output summary (25 orders per day, 250 workdays, one-shift operation) for a direct imaging press printing in A3 format (Heidelberg's Quickmaster DI 46-4, see figs. 4.4-8 and 4.4-9), in which thermoplates are imaged by IR laser diodes, revealed that about 3500 liters of photochemicals and 55000 liters of waste washing water are eliminated, which (if the permitted limit values are exceeded) are classified as hazardous wastes and must be disposed of at high cost. Also eliminated are about 4000 m^2 of silver halide-based repro film material and the dampening solution together with its disposal, since the machine uses a dry offset printing process. The used PE-based plate may be disposed of as household waste.

Liquid wastes from small offset printing systems, residues of deletion fluid, and plate cleaning agent, as well as used plate developing solutions, must be disposed of as hazardous wastes. Through the use of long-life developers/de-coaters for metal plates made of aluminum, the mass of waste can be reduced. Today, dichromate-coated printing plates, which cause heavy waste-water contamination, are no longer used, while multi-metal plates are now only seldom used.

Printing

The process-induced emissions occurring in offset printing are VOC (*volatile organic compounds*) emissions and result mainly from evaporation of the IPA (isopropyl alcohol) contained in the *dampening solution*, to which it is frequently added as an 8 to 15% dosage, and from the *cleaning agents* for the rollers, rubber blankets, and other press components. These emissions can be effectively diminished by reducing the alcohol content through the use of suitable substitutes (e.g., glycol) and/or the use of *hydrophilic* dampening rollers and other technical improvements (e.g., reverse-osmosis water processing, inking system temperature control) to between 4 and 8% or even further, as practised in some companies. The emissions from volatile cleaning agents can be reduced in most cases when these are replaced by highly viscous and therefore low-emission, high-boiling mineral oils or chemically refined vegetable oils.

Information on suitable *cleaning agents* can be obtained from printing press and wash-up device manufacturers. In addition, the FOGRA Institute in Munich publishes up-to-date lists of released cleaning agents at "http://www.fogra.org" on the Internet.

New accurate *IPA measuring instruments* (e.g., measuring the IR absorption spectra in the gaseous phase or measurement of the acoustic velocity), which have been commercially available for some little time, can replace the inaccurate "alcohol stabilizer" (which is based on the density measuring principle) used in present-day additive metering units. Only then is controllable IPA reduction possible.

In *waterless offset printing* the need for a dampening solution is eliminated, and therefore there is no IPA; in addition, considerably fewer developing chemicals are required when using thermal plates (see also sec. 2.1.7.2).

The *inks* used in *offset printing* (sheet-fed offset and *coldset* web offset) are VOC-free, because the oils used as solvents do not evaporate at ambient temperature. The UV inks that are sometimes used are VOC-free, too. However, older UV dryers emit ozone if no exhaust system is provided downstream.

In *web offset* (*heatset*), 99% of the solvents evaporating when hot-air dryers are used are incinerated in a state-of-the-art afterburning process. Through the use of heat exchangers, the hot, purified waste air can be used for heating purposes, including water heating. It is also possible to use catalytic or regenerative afterburning processes for waste air purification.

Empty *metal ink containers* are recycled via the scrap trade. Ink containers whose contents have not been entirely consumed are to be disposed of as hazardous waste. Through the use of large containers, ink pumps, and ink cartridge systems, or through the use of fresh inks, the mass of waste can be substantially reduced.

Waste sheets and reel cores may be transported to waste paper dealers for recycling. Through appropriate automation, such as ink key presetting systems, control station technology, register control systems, or color measuring systems, the generation of waste is reduced to a minimum and in this way paper and energy are saved.

Residual dampening solution with or without alcohol is (if the permissible limit values specific to the location are exceeded) to be disposed of as hazardous waste.

Residual cleaning agent from the wash-up devices is hazardous waste. In large printshops these remnants, especially those from brush-type wash-up devices, are recovered through filtration. They can then be recycled, generally with the addition of a suitable additive, but sometimes without. Soiled filters, one-way cleaning cloths, and washing cloths from the wash-up devices must be disposed of as hazardous waste. Returnable cleaning cloth systems (rental service) offered by various service providers enable cleaning cloths to be reused.

Aluminum or multi-metal *printing plates* can be transported to scrap dealers for recycling; polyester-based printing plates can be disposed of as domestic waste.

Print Finishing (Postpress)

In print finishing, which includes the operations of coating, cutting, folding, stitching, gluing, packaging, and so on, the environmental repercussions are considered to be slight. For coating, dispersion and UV varnishes are mostly used. The environmental effects are similar to those of printing. Waste sheets, paper cutting and die-cutting waste, and packaging materials are recycled. In gluing, dispersion, hot-melt, and polyurethane adhesives predominate. In the processing of these adhesives, removal of the vapors by suction is recommended in the case of unpleasant odors. Hardened adhesive residues are classified as household waste, and non-hardened adhesive residues as hazardous waste.

13.2.1.3 Environmental Protection in Gravure Printing

In *printing cylinder production*, a distinction must be made, from the ecological viewpoint, between the *etching* and the *engraving* of a gravure cylinder. The electroplating of the cylinders is the same in both processes: dechroming, decopperizing, degreasing, pickling (chemical polishing), copper-plating, and chroming. Process-controlled electroplating lines nowadays generate little waste water, regenerating units ensure that the processing baths remain operative, and that the copper and chrome baths very seldom need to be replaced and recycled. Engraving, which meanwhile has come to be used almost exclusively instead of etching, has substantially reduced the environmental impact by eliminating the need for photochemical and etching operations.

Gravure inks contain *toluene*, which makes up about 80% of the contents. In the dryers the toluene is exhausted and transferred to the recovery system; the recovery rate is now over 98%. Because gravure presses are encapsulated, the amount of toluene escaping into the work room as diffuse emission is almost nil. A part of the recovered toluene is reused in the printshop for diluting the printing ink delivered in concentrated form. The surplus is returned for recycling to the ink manufacturer. Through new residual toluene-reduced inks (R inks),

the toluene content in the printed products is reduced and the recovery rate is further increased.

Water-based gravure inks are rarely used owing to web guide and register problems as well as the fact that drying requires three times more energy. At present it is not possible to predict when the VOC-free hot-melt inks presently under development will be widely introduced onto the market.

13.2.1.4 Environmental Protection in Letterpress and Flexographic Printing

In *letterpress printing*, photopolymer printing plates made of synthetic material are increasingly being used, and metal printing plates ("etching plates" made of zinc, magnesium, or copper), which are manufactured using various critical chemicals (chromic acid, nitric acid, etc.), as well as lead type have diminished considerably in importance. In the case of *plates made of polymer material*, the solvent-containing washing-out solutions can be used repeatedly after recovery of the solvent through distillation. Use of perchloroethylene as a solvent should in any case be avoided.

Letterpress inks are VOC-free and the printing process does not generate waste water. Low-emission cleaning agents that have proved to be suitable in offset printing can be used.

In *flexographic printing*, *photopolymer printing plates* are widely established today, as opposed to the rubber plates and engraved rubber rollers used earlier. The environmental impacts are similar to those of polymer letterpress plate manufacture. For detacking, radiation with UV-C light should be preferred to a bromine bath, which is detrimental to the environment. The new laser engraving process for platemaking is also environmentally compatible to a high degree.

Solvent-containing (VOC-containing) *flexographic printing inks* contain mainly alcohol (ethanol) and often ethyl acetate, special grades of petroleum spirit, toluene, IPA, and acetone as well. Methanol is no longer used owing to a voluntary pledge on the part of manufacturers. Toluene is used less and less. Increasingly, *water-based* (*VOC-free*) *flexographic printing inks* are predominating in printing on absorbent materials. VOC-free UV flexographic printing inks are also used. However, the quite high degree of worker protection required and the formation of ozone should be mentioned as disadvantages of their use.

For washing, a large variety of substances is used, depending on the type of ink and the purpose. The resulting waste is always hazardous waste.

Thermal or catalytic waste-gas cleaning installations are state-of-the-art in environmental technology.

13.2.1.5 Environmental Protection in Screen Printing

In *stencil making*, waste water is produced that contains the organic emulsion particles and – if, in addition, dichromate salts are used as sensitizers – chromium (VI, chem. valency number) salts. This therefore needs to be disposed of as hazardous waste.

VOC-containing *inks*, low-VOC water-based inks, and UV-curing (VOC-free) inks are used.

For cleaning the screen, systems designed as fully enclosed units with solvent recovery should be used, since the use of open systems is associated with the loss of large quantities of cleaning agent and a heavy burden is placed on the operating personnel and the environment.

13.2.1.6 Environment-oriented Business Management

For forward-looking companies, *environmental protection* is an integral part of management. Environmental concerns are not dealt with on an ad-hoc basis; rather, they are incorporated in the overall strategy of the company [13.2-2 to 13.2-5]. The aim and object of *environmental management* is to plan and control the company's performance in environmental matters with the aim of continually improving the company's environmental protection.

This means in concrete terms that, when setting up an *environmental management* system, the *relevant environmental consequences* are determined, organization structure, responsibilities, and processes are defined, and an environment program with targets, deadlines, and responsibilities is documented (e.g., reduction of the quantity of waste water by "x" percent by the end of the business year; for this the "xy" department will be responsible). For all relevant areas, instructions (e.g., on the handling of hazardous substances or monitoring/servicing/maintenance) are prepared for the employees concerned, and a list of all statutory and other requirements is drawn up.

When setting up *environmental management systems*, companies in Germany mainly follow the guidance of the EC's Eco Management and Audit Scheme (EMAS). At the international level ISO standard 14001 predominates.

As a rule, there are several factors that prompt a company to install an *environmental management system*:

- Orders placed by customers are coupled with queries and requests for environmentally compati-

ble production – and very much so in the case of printshops. This means it is not only because of the resulting image enhancement that company environmental protection is becoming a factor of competition.

- Experience has often confirmed that spending money on setting up and developing an environmental management system makes economic sense. Potential cost savings appear when processes are systematically examined and weak spots revealed. A good valuation basis for this is obtained by tracking material flows in production according to their relevance to the environment, while at the same time considering material input/output.
- Up to now, environmental protection in companies has been based on compliance with the numerous laws and regulations, that is, the companies' reaction to these requirements. As opposed to this, the EC Eco Management and Audit Scheme and ISO 14001 appeal to corporate management's sense of responsibility. Setting up an environmental management system involves, in addition to establishing environmental hazards, the incorporation of environmental legislation into company objectives and policy, thus paving the way for more legal security in environmental matters.

Setting up an *environmental management system* is performed in several phases: At the beginning, the *corporate management's general environmental policy* needs to be set out in writing. To determine strengths and weaknesses, an initial environmental inspection is carried out as a comprehensive investigation of the environment-related problems on site. The results obtained determine the *environment program*, which is keyed to continual improvement of the *company's performance on environmental issues*. The *eco audits*, which are carried out at regular intervals, give a clear idea of the degree to which the environmental program has been implemented.

Within the framework of EMAS, as opposed to ISO 14001, companies are obliged to draw up an *environmental statement* informing the public about their environmental policy, input/output data, their environmental program, and their environmental management system. The environmental statement is examined by an independent environmental certifier and validated. With this, the company is registered at the appropriate institution (in Germany the Chamber of Industry and Commerce) and is recognized as a site with a valid environmental management system.

In the European Union, *site-related environmental statements*, which are published at least every three years, are the type of environmental reporting [13.2-6] preferred by large organizations as well as by many small- and medium-sized companies. On the other hand, *environmental reports* are preferred as a form of reporting by large companies with several locations/sites, and in most cases appear annually (examples: Ringier AG in Switzerland, Mohndruck Graphische Betriebe GmbH, Heidelberger Druckmaschinen AG or Eastman Kodak in USA) [13.2-6 and 13.2-7]. Today many companies also use the *Internet* to publish their environmental policy and their environment program (for example Heidelberger Druckmaschinen AG: www.heidelberg.com in the section Company, Environmental Protection).

13.2.1.7 Legal Foundations

In more than twenty countries (industrial nations) of the world (in particular Germany, Austria, Denmark, Switzerland, the Netherlands, Sweden, Belgium, Great Britain, Finland, Norway, France, Luxemburg, Ireland, Italy, Portugal, USA, Canada, Japan, Australia and New Zealand), environmental protection is regarded as especially important. (This is known from various sources, e.g., EU experience with environmental directives, international pollution control legislation, public and private expenditure on environmental protection, signatories to the Montreal report on the protection of the ozone layer, extent of environmental research, etc.) All twenty countries are members of the OECD (Organization for Economic Cooperation and Development). In eighteen of the twenty countries, annual per capita economic output is more than US $ 10 000. In 1993, about 14% of the earth's population lived in these twenty countries, which produced more than 80% of the world's printing output [13.2-8].

International Environmental Laws

International *environmental problems* cannot be overcome by means of national environmental laws, so this must occur at international level. For this, international law and European law are available [13.2-9 and 13.2-10].

International Law

This covers all *legal stipulations* that regulate the relations between nations and international organizations. The problem here is that their effectiveness depends on their being recognised and converted into national law by the nations concerned and at present there is no way to enforce this. A positive example is the agreement on

wide-ranging cross-border air pollution of 1979; this was converted into German law in 1982 and 1983.

European Law

European Union (EU) *regulations* are provisions that are binding on all EU states. An example is the EC Eco Management and Audit Scheme of 1993, which is presently being amended and harmonized with ISO 14001.

EU *directives* are binding on all member countries insofar as they are instructions whose contents must be adopted individually in the legislation of EU countries. An example of this is the "VOC Directive on the Limitation of Volatile Organic Compound Emissions (which are generated in certain operations and in certain installations when organic solvents are used)" which was issued in 1999. The new additions to this directive concern heatset printing, gravure printing, flexographic printing, rotary screen printing, laminating, and transparent varnish applications. For these processes emission limit values for waste gases and diffuse emissions are fixed above a certain threshold value. Sheet offset machines are not concerned.

EU *recommendations and statements* should be observed; however, they are not binding.

European *environmental protection requirements* sometimes vary considerably. This prompted the EU to lay down high-level environmental standards – Best Available Techniques (BAT) – that are valid Europe-wide for all industrial sectors (see further reading).

In Europe there is a large number of other *environmental laws* that concern the printing industry; here are just a few examples of national laws:

- As of 1 January 2000, a so-called "VOC control levy" of 2 Swiss francs has to be paid for every liter of isopropyl alcohol or cleaning agent (with a flash point below 100 °C) in *Switzerland*. The tax will be increased in the following years.
- In *Scandinavia*, especially in Denmark and Sweden, European or international laws or agreements will be tightened up at national level or new environmental issues will be taken up. Earlier than agreed on an international basis, from 1 January 1998 onwards Sweden has put a ban on the use of CFC (chlorofluorocarbon) R22 as a coolant, for example, in additive metering units. In Denmark, a list of undesirable chemicals was published by government authorities at the end of 1998, which could well be adopted by the EU legislature and thus influence the composition of some printing chemicals.
- In *France*, too, ecological awareness is on the rise. This will be reflected in legislation with tightened limit values and other restrictions from the year 2000 onwards. In particular, waste separation and recycling will increase owing to restrictions on dumping that are to be introduced soon.

German Environmental Laws

Starting out from the bills passed by the federal and state governments, the minister responsible for the area concerned issues the *regulations* (in which, for example, limit values or procedures are laid down) made necessary by the law.

General *administrative regulations*, which may also be called "technical directions" or "technical directives", are either also issued by the respective ministers or by institutions or associations that are more familiar with the technical fundamentals.

To enumerate and describe the environmental laws and regulations, administrative provisions and directives that concern the printing industry in Germany would go beyond the scope of this book (according to the Federal Government, in 1996 there were already 800 environment-related laws with 2770 regulations and 4690 administrative provisions). Detailed information can be obtained by referring to [13.2-11], [13.2-2], and [13.2-9]. Here is only a short list of the most relevant laws:

- Federal Law on the Prevention of Emissions,
- Industrial Code,
- Law on Toxic Substances and Dangerous Goods,
- Law on Water Economy, Waste Water Tax Laws, and Regional Water Laws,
- Law on Recycling Management and Waste, and Regional Waste Laws,
- Building Law,
- Soil Protection Law,
- Law on Liability for Pollution Damage.

Furthermore, there are *industrial safety* laws and regulations that are directly related to environmental matters, such as the Equipment Safety Law, the Law on the Protection of Employees, or the Code of Social Law with its regulations for the prevention of accidents.

American Environmental Laws

Legislative powers in the USA, like those in Germany, are parallel, that is federal laws can be tightened up at state and local levels [13.2-12].

Legislation is centered more around possible threats to human *health* than endangering the environment. For this reason, warnings of all possible dangers are issued as a matter of principle (also because of product liability), while in Europe an attempt is made directly to avert or reduce the danger by technical means. The main environmental legislation includes laws on clean air, environmental liability, water pollutant control, prevention of drinking water pollution, handling of hazardous substances, and treatment and avoidance of waste.

For the *disposal of hazardous waste* there are federal and state programs; registration procedures are laid down, and employees must be trained in the handling of wastes and the following of technical instructions. Disposal costs are higher than, for example, in Germany.

For the *prevention of air pollution* there are also regulations at the federal (e.g., the Clean Air Act for the maximum permissible VOC emissions, or the USEPA (United States Environmental Protection Agency) directives for the maximum IPA content of dampening solutions or the permissible VOC content of cleaning agents), state and local level. There are also directives issued by local authorities (e.g., in the Los Angeles district for the VOC content of dampening solutions and cleaning agents).

The *pollutant waste water load* is governed by laws and regulations. Local sewage treatment plants can introduce further limitations. It is the responsibility of the companies concerned to measure the extent to which they have observed limit values and waste-water regulations, and to transmit the results quarterly to a controller.

Japanese Environmental Laws

In its environmental legislation, Japan closely follows the example of Germany. In addition to the "Basic Environment Law" there is a series of other laws that concern the printing industry, such as:

- Law against Air Pollution,
- Law against Water Pollution,
- Law for the Protection of Lakes,
- Law for the Reduction of Water for Use in Industry and Noise Reduction,
- Law for the Reduction of Vibrations,
- Law against Unpleasant Odors,
- Law about the Set-up of Production Facilities,
- Law for the Processing of all Kinds of Exhausts,
- Law about Recycling.

Compliance with the laws is not as strictly controlled as in Germany or the USA. Country-wide recycling systems do not exist so far. As a rule, waste is incinerated and the remains are dumped.

In the future restrictive regulations are expected in many areas, for instance, for plastic packaging, film laminating, and printing with UV inks.

13.2.1.8 Support and Advice for Environment-relevant Measures

Support Programs and Financial Assistance

Support programs and financial assistance for environmental investments are, for example, offered by the European Union, the Deutsche Bundesstiftung Umwelt (German Federal Trust for Environmental Protection), the Deutsche Ausgleichsbank (German Equalization Bank), the Kreditanstalt für Wiederaufbau (Reconstruction Loan Corporation), and various institutions of the German Federal States. In many countries there are other ways of obtaining support, which cannot be enumerated here and which are often limited in time. An example from the Netherlands: through the VAMIL (Vrije Afschrijving Milieu Investeringen) depreciation program, environmental protection investments by printing companies, for instance, the purchase of computer to plate systems, are supported.

Contacts in the Printing Industry for Environmental Issues

In Europe:

- Berufsgenossenschaft Druck und Papierverarbeitung, Wiesbaden (Germany); telephone: +49(0)611/131-0, Internet: www.bgdp.de
- Bundesverband Druck und Medien e.V., Wiesbaden (Germany); telephone: +49 (0)611/803-0, Internet: www.bvd-online.de
- Fachverband der Photochemischen Industrie, Frankfurt (Germany), telephone +49(0)69/2556-1408.
- FOGRA Institute, Munich (Germany); telephone +49(0)89/43182-0, Internet: www.fogra.org
- Hauptverband der Papier-, Pappe- und Kunststoffverarbeitenden Industrie, Frankfurt (Germany); telephone: +49(0)69/978281-0.
- Industriegewerkschaft Medien, Executive Board, Work Ecology, Stuttgart (Germany); telephone +49(0)711/2018-0.

- Internationaler Verein für Zeitungs- und Medientechnologie (IFRA), Darmstadt (Germany); telephone: +49(0)6151/7005-0, Internet: www.ifra.com
- Febelgra, Brussels (Belgium); telephone: +32(0)25123638.
- Intergraf, Brussels (Belgium); telephone: +32(0)2308646, Internet: www.intergraf.org
- Grafisk Arbejdsgiverforening, Odense (Denmark); telephone: +45(0)66127000.
- Graafisen Teollisuuden Liitto, Helsinki (Finland); telephone: +358(0)922877200.
- Fédération Française de l'Imprimerie et de la Communication Graphiques, Paris (France); telephone: +33(0)144086446.
- Hellenic Federation of Printing Industries, Athens (Greece); telephone: +30(0)18212300.
- British Printing Industries Federation (BPIF), London (Great Britain); telephone +44(0)171/9158300, Internet: www.bpif.org.uk
- Health and Safety Executive (HSE), East Grinstead (Great Britain); telephone +44(0)134/2334200.
- Pira International, Leatherhead (Great Britain); telephone: +44(0)1372/802080, Internet: www.pira.co.uk
- Scottish Print Employers Federation, Edinburgh (Great Britain); telephone +44(0)12204353.
- Samtök Idnadarins, Reykjavik (Iceland); telephone: +354(0)51155550.
- Associazione Nazionale Italiana Industrie Grafiche, Cartotecniche e Transformatrici (ASSOGRAFICI), Milan (Italy); telephone: +39(0)24981051.
- Hrvatska Udruga Poslodavaca, Zagreb (Croatia); telephone: +385(0)1424284.
- Association des Maîtres Imprimeurs du Grand-Duché de Luxembourg (Luxembourg); telephone: +352(0)42451122.
- Koninkliijk Verbond van grafische Ondernemingen (KVGO), Amstelveen (Netherlands); telephone +31(0)205435678.
- Grafiske Bedrifter Landsforening, Oslo (Norway); telephone: +47(0)22478870.
- Verband Druck und Medientechnik, Vienna (Austria); telephone: +43(0)15126609.
- Polska Isba Druku, Warsaw (Poland); telephone: +48(0)226248749.
- Associação Portuguesa das Indústrias Gráficas e Transformadoras do Papel, Lisbon (Portugal); telephone: +35(0)18491020.
- Grafiska Företagens Förbund, Stockholm (Sweden); telephone: +46(0)87626800.
- EMPA/UGRA, St. Gallen (Switzerland); telephone: +41(0)71/2747343, Internet: www.ugra.ch
- Schweizerischer Verband für visuelle Kommunikation (VISCOM), Zurich (Switzerland); telephone +41(0)1/2662424, Internet: www.viscom.ch
- Verband der Schweizer Druckindustrie (VSD), Bern (Switzerland); telephone +41(0)313511511.
- Federación Empresarial de Indústrias Gráficas de España, Madrid (Spain); telephone: +34(1)5229084.
- Federation of the Hungarian Printers, Budapest (Hungary); telephone: +36(0)13521788.

In USA:

- Graphic Arts Technical Foundation (GATF), Sewickley (PA); Internet: www.gatf.org (or www. gain.org)
- Printing Industries of America (PIA), Alexandria, (VA); telephone: +1(0)7035198100, Internet: www.gain.org
- United States Environmental Protection Agency (EPA), Washington (D.C.); Internet: www.epa.gov

Others:

- Printing Industries Association of Australia (PIAA), St. Leonards, NSW (Australia); telephone: +612(0)3721222, Internet: www.printnet.com.au
- Associaçao Brasileira da Indústria Gráfica (ABIGRAF), Sao Paulo (Brazil); telephone: +5511/2314733.
- Japanese Federation of Printing Industries; Tokyo, (Japan); Internet: www.jfpi.or.jp
- Printing Industries Federation of South Africa, Honeydew (South Africa); telephone: +2711/7943810.

13.2.2 Safety Resources

13.2.2.1 Health and Safety

Accidents happen while driving, at leisure, and at work. People are usually quick to put accidents down to fate, and give little thought to how they could be avoided in the first place.

Responsibility is apportioned differently at work or in leisure time. Manufacturers can only turn out machines that conform to *"state-of-the-art technology"*. It is the responsibility of the companies to ensure that machines are used only for the purpose for which they were designed; workers must maintain and observe all safety measures.

Product safety and *industrial safety* is not the same thing. In order to make a product "safe" for operation, work and health protection requirements have to be observed.

There is still a degree of disparity between the *legal requirements* of different countries; but the objective is the same everywhere, that is, to maximize product quality and output "without compromising health." Intensive efforts are being made to adjust and set up international rules and regulations in the relevant official bodies; in many cases the European sets of rules and regulations have already been combined to form an international set of rules.

Safety is an executive function and as such must be observed by those in positions of responsibility.

13.2.2.2 International and European Directives (Laws) and Standards

Worldwide, a whole host of arrangements and quality signs regarding *product safety* regulate the applicable measures.

In the American sphere these are, among others:

- OSHA (Occupational Safety and Health Administration),
- ANSI (American National Standards Institute),
- ETL (Electrical Testing Laboratories),
- UL (Underwriters Laboratories Inc.), and
- CSA (Canadian Standards Association),

and in Eastern European these are, among others:

- CPT (Marks of Conformity of the Russian Federation) and
- SKTC (Slovak Testing Center).

Here follows a description of the set of European rules, whose principles also deal with worldwide safety issues.

European (EU) Directives

European industrial safety measures are in essence addressed in the form of directives; these directives are born of the following *basic principles*:

- The directives are restricted to defining *fundamental safety requirements*.
- The committees responsible for European standardization (CEN: Comité Européen de Normalisation, CENELEC: Comité Européen de Normalisation Electrotechnique) are charged with preparing *technical specifications* in compliance with the fundamental safety requirements set out in the directives.
- These technical specifications are called *standards*. Application of these standards is voluntary.
- The supervisory bodies are bound to accept that in the case of such products, manufactured in accordance with *harmonized standards*, an agreement is in place regarding the basic safety requirements set out in the directives.

Compulsory requirements for *unification* of European Union safety standards for the protection of workers and consumers are drawn up according to EU directives. These directives are incorporated into national law, as is the case with such standards as the Machinery Directive, the EMC (Electromagnetic Compatibility) Directive, and the Low-Voltage Directive.

EU Machinery Directive (Law)

The *machinery directive* [13.2-13] has the function of ensuring free trade in machinery and individual safety components within the European Union. For this purpose it introduces harmonized quality requirements and conformity evaluation procedures, which have to be fulfilled when manufacturers want to introduce new machines onto member states' markets.

The Machinery Directive is a piece of *European legislation*, which was completed after several drafts. This opens the way for the removal of trade barriers in Europe. The basic health and safety requirements regarding machinery are contained in Appendix 1 of the Machinery Directive and form the actual working basis for manufacturers.

European Standards

In order to achieve a high degree of protection in the area of health and safety, *European standards* are created in which the basic requirements of the directives are specified. A new concept was created in the area of technical harmonization and standardization. The essential guiding principles can be broken down as follows:

- Directives contain basic safety requirements.
- Harmonized standards contain technical defini-

tions regarding product conformity with the basic requirements.

Harmonized standards are to be regarded as exactly that, compiled on behalf of the European Union and published in their official journal. They must be taken on board by national standardization committees and published as national standards. The technical requirements described in them include detailed regulations. Applying them in component design means that the basic requirements of the directive are adhered to.

The manufacturer demonstrates adherence to the directive by outlining the manner in which the product conforms to the appropriate standards. Adherence to harmonized standards thus ensures conformity with basic requirements, which are set out in the respective directive.

Standards are divided into three main groups:

- *A-standards* contain basic safety concepts and principles, which apply to all types of machinery (e.g., EN 292, [13.2-14, 13.2-15]).
- *B-standards* determine safety aspects, which apply to a whole range of machinery (B1-standards; e.g., safety clearances EN 294 [13.2-16], electrical equipment of machinery [13.2-17]) or contain safety definitions regarding components that are used with different types of machinery (B2-standard; e.g., separating protective devices [13.2-18]).
- *C-standards* contain safety specifications, which apply to a machine or group of machines (e.g., for printing and paper processing machines EN 1010, [13.2-19]). These standards refer, where possible, to standards type A, B1, or B2.

13.2.2.3 Safety-conscious Design

Safety Objectives

To make the co-existence of people and machines in the workplace as safe as possible, safety engineering requires that hazardous areas and risks are avoided. Following the so-called "three-level method" (table 13.2-1) for safety-conscious design in the context of the total conception of a design, safety objectives have been prioritized.

Important Concepts

The following concepts are relevant in the area of safety-conscious design of printing and paper-processing machines:

- A *machine* is a whole entity composed of interconnected parts and components, at least one of which is moving, as well as, if necessary, drive components, control and power circuits, and so forth, which are combined to perform a certain function, such as processing, treating, transporting and conditioning of a material, for instance, sheet offset printing press [13.2-14].
- A *hazard* is a source of possible injury or health risk.
- *Hazardous areas* involve the stationary or moving parts of a technical product that may pose a risk of injury; typical hazardous areas are crushing, shearing, cutting, draw-in, trapping, and pierce and impact points.

Level	Safety objectives	Measures	Effectiveness
1	**Direct safety engineering:** Avoid danger!	The machine is designed so that no danger to life and limb exists when the machine is used sensibly, in the manner for which it is intended.	No hazardous areas or risks (e.g., flanged drive motors in place of fan- or drive-belts).
2	**Indirect safety engineering:** Safeguard hazardous area!	Protective devices safeguard against hazardous areas or risks in such a way that reasonable safety is achieved but not at the expense of operability.	Hazardous areas are secured; e.g., nip points on the inking unit secured by an electrically locked safety grid. Risks are avoided; e.g., an ozone outlet on a UV dryer.
3	**Safety notes:** Indicate danger!	Only applies where the first two levels are not possible. Conditions under which it is safe to use tools and equipment outlined, or attention drawn to residual dangers.	Hazards still exist, since safeguarding (e.g., labeling noise areas, and warning against contact with hot objects) is behavior-dependent.

Table 13.2-1 Prioritizing of safety measures

- *Sources of risk* involve powered machinery, from which parts of the equipment, work-pieces, or other tools, waste, and so on, may become loose or accidentally fall off with the chance of injury.
- A *danger zone* is an accessible zone in which hazardous spots and sources of risk are present.
- *Protective devices* are devices for protecting against hazards, which arise from contact with hazardous areas or from sources of risk. A protective device can take the form of a housing, cover, door, lining, profile, and so forth. Figure 13.2-3 shows the nip (infeed gap) as a hazard on a set of rollers, together with a possible protective device.
- *Pushbuttons* are operating elements, which are effective for the duration of their operation (not self-holding). They shut themselves off upon release.
- *Interlocks* (with or without tumbling) are electrical, mechanical, or other types of device, which prevent a mechanism from operating under certain conditions. A dangerous motion, which is safeguarded by the protective device, cannot occur if the protective device is not closed [13.2-20].
- *Interlock without tumbling* functions as follows:
  - If the protective device is opened during operation, a halt command is triggered (the machine shuts off as soon as a grid is opened).
  - If the protective device is closed, a hazardous motion, secured by the separating protective device, can be started.

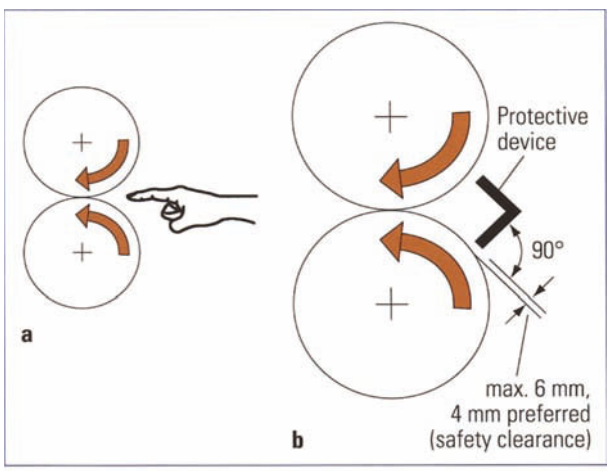


Fig. 13.2-3 Danger zone of moving rollers and safety measure.
a Danger zone at the roller infeed (infeed gap);
b Finger protective device as basic safety measure

- *Interlock with tumbling* functions as follows:
  - The protective device remains closed, locked, and held shut, until such time as hazardous motion ceases; the protective device can only be opened at a standstill.
  - Once the protective device is closed, hazardous motion, safeguarded against by the separating protective device, can be started.
- *Safety clearance* is the minimum distance between a danger zone and a protective mechanism; values are illustrated in [13.2-16], (example in fig. 13.2-3).

Position Switches with Personal Protection Function (Safety Limit Switch)

Position switches with personal protection functions (safety limit switches), which are used for the *interlock of the protective device* in use, must fulfil special requirements (e.g., [13.2-17]). In the case of machines without operationally regular intervention into hazardous areas, it is sufficient for the interlock to be carried out merely by operation of a position switch for each separating protective device [13.2-19].

Requirements for *safety limit switches*:

- Design and location of safety limit switches ensures safeguarding against unintentional operation, position changes, and damage. Securing of the switch and the cam is possible by positive means of fastening (e.g., round holes, dowel pins, stops).
- They must be secured by their manner of activation or their integration into the control system in such a way that they cannot be manipulated easily. Position switches must be switched as "*openers*" (i.e., activating the switch interrupts operation of the device).
- It must be possible to check for their correct functioning. They must be easily accessible.
- They may not be used as a mechanical stop.
- Position switches are to be fastened in such a way as to protect them from foreseeable damage by external factors.
- The activation travel must be set in accordance with the positive opening travel as specified by the manufacturer. The same applies to the minimum tappet travel in order to guarantee the contact gap needed for the positive opening operation.
- If *proximity switches* are used as position switches with personal protection function, these must display the same degree of safety as the mechanical safety limit switches (i.e., they must be one-error

safe, category 3 compliant with EN 954-1 [13.2-21]; "*one-error safe*" means that, on operation of the safety limit switch, despite the occurrence of a fault in the system, the desired safety function is triggered).

Control System

On the basis of risk evaluation, safety-related parts of the control system must be designed to be one-error safe or self-monitoring; "*self-monitoring*" means that a fault is detected and indicated to the operator.

Printing and paper-processing machines are rated as machinery where danger zones do "not need to be accessed regularly for purposes of operation". "Regular operational access" means with each work cycle; for instance, with manually fed guillotine cutters and die-cutters.

In compliance with EN 1010-1 "Safety of machinery; safety requirements for design and construction of printing and paper-processing machinery" [13.2-19], safety parts – for regular non-operational access to the hazardous zone – of hydraulic and pneumatic controls must correspond to category 1 and safety parts of electrical or electronic controls to category 3.

In figure 13.2-4 the *allocation to categories* is described in diagrammatic form.

Category 1 means that components and principles that have been tried and tested for safety must be used. The components must conform to the state of the art and be selected so as to withstand anticipated effects.

Category 2 means that the safety functions must be checked in suitable time intervals by the machine control.

Category 3 means that the system control must be designed in such a way that a single fault occurring in the control system will not result in a loss of safety function. Certain errors must be detected, as far as this can be done appropriately (*one-error safety* with partial error detection). In EN 1010-1 [13.2-19] category 3 is specified with reference to printing and paper-processing machines. At the very least, faults in the auxiliary relays and auxiliary contactors in the control circuit must be detected and result in disconnection.

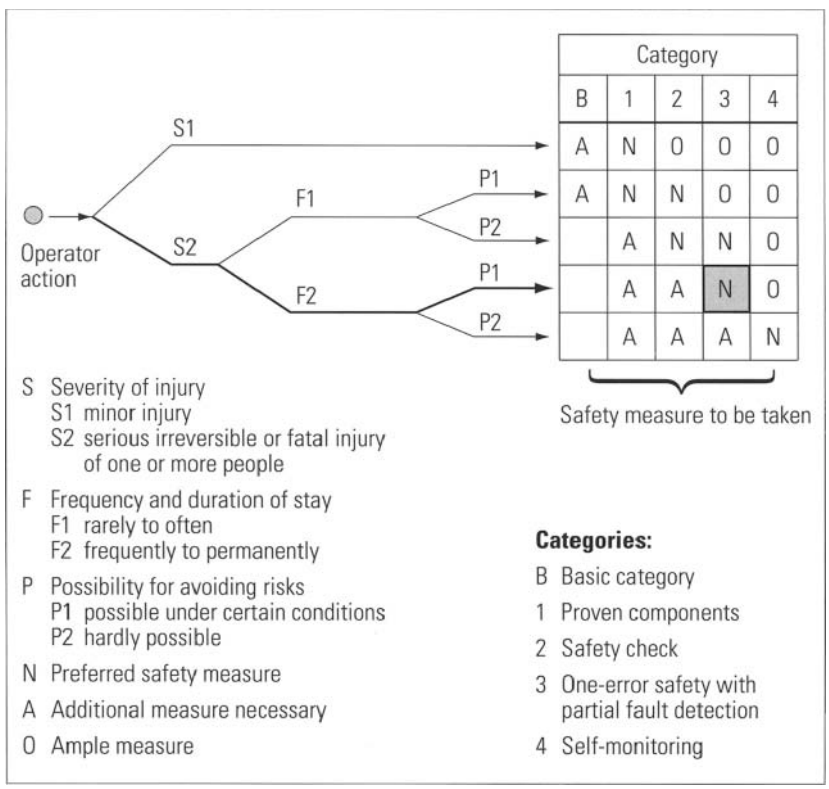


Fig. 13.2-4
Categories for the safety of mechanisms for the user's protection (according to [13.2-21])

When using a computer or programmable controller as a *safety regulator*, safety-related malfunctioning must be detected and result in disconnection. Safety-relevant control parts are, for example, emergency circuit breakers, electrical interlock circuits, and travel and speed limitations in inching mode.

With machines with regular operational access (e.g., guillotine cutters), the safety-relevant parts of the electrical/electronic control must comply with category 4.

Category 4 includes self-monitoring [13.2-19].

Work Platforms, Access, Passages, and Raised Workplaces

If work cannot be carried out from the ground level on account of height, appropriate ascent aids and work platforms must be made available. A precise definition of safe workplaces including access and passage are contained in EN 12437 parts 1 to 4 "Safety of machinery – fixed access to machines and industrial installations." In figure 13.2-5, a platform with steps and railing is illustrated, as is required, for example, in the folding section of a web offset printing system. General requirements are:

- Railings with handrail, knee and foot rail must have the following dimensions: Railing height 1100 mm, foot rail at least 100 mm, distance from knee rail to foot rail and handrail < 500 mm.
- Usable width of machine walkways at least 600 mm.
- At a height of more than 300 mm suitable means of ascent must be made available.
- Railings for walkways with a height of 500 mm and more.
- Floor coverings must be anti-skid.
- Access and passages must have a clear height of at least 2 m (if this height cannot be kept for design reasons, parts restricting the passage height must be padded and be clearly marked with a yellow/black danger sign). With staircase landings the clear passage height is 2.10 m.
- Raised permanent workplaces must have a surface area of at least 1.5 m^2 per person and a minimum width of 1 m.
- The access gradient (steps) must normally not exceed 45°; depending on an analysis of the risk, steeper gradients are permissible (risk analysis in compliance with [13.2-19, appendix C]).

13.2.2.4 Requirements for Separating Protective Devices

Protective devices must protect machine operators against hazards that could not be avoided in the machine's design. Protective devices designed for this purpose meet the following conditions:

- *Reliable function.* Protective devices must be kept securely in a closed position and safeguard people from hazards stemming from danger areas.

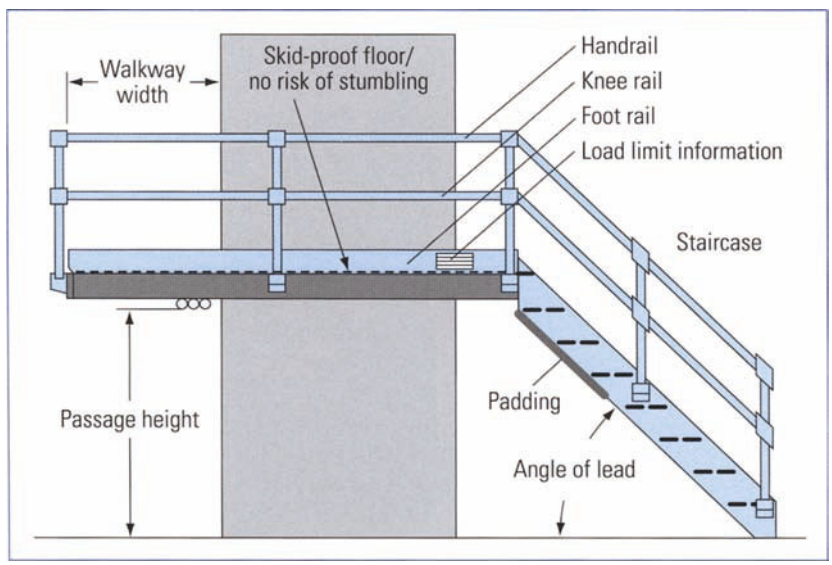


Fig. 13.2-5
Platform, railings, and steps (e.g., for the folder superstructure of a web offset printing system)

Furthermore, they protect against dangers such as noise, radiation, and flying parts.

- *Interlock mechanism.* Interlocks create a positive dependency between the mechanism of movable protective devices and dangerous motion. Protective devices that must frequently be removed or opened for makeready work must be interlocked with the potentially dangerous motion. It must not be possible to manipulate the interlock easily.
- *Safety clearances.* When designing protective devices, safety clearances must be kept in compliance with EN 294 [13.2-16]. Protective devices must prevent any possibility of accessing the danger areas behind them.
- *Stability.* Protective devices must consist of stable, resistant material and be dimensioned so as to withstand the anticipated rigours from the ambient and operating conditions. These features must be maintained during the entire service life/lifespan of the machine.
- *Attachment.* For protective devices that are never or infrequently opened, or only need to be opened for maintenance work, it is sufficient for them to be fastened in such a way that they can be detached with a tool. Quick-locking mechanisms, screw handles, knurled screw, and wing screws are not permissible. After the fastening device has been loosened, the protective device must not remain in a protective position but must provide access to the guarded area.
- *Locking.* Movable separating protective devices should be fastened to the device in such a way that they are kept safe by hinges, guides, and so forth, in an open position. Positive fastening devices are preferred. Gas-pressurized springs are a proven design feature (fig. 13.2-6); for larger, broad protective devices at least two gas-pressurized springs should be used.
- *Accessibility of operating elements.* Operating elements for intervention in running machines must be located and arranged in such a way that they can easily be operated while the machine is running. If necessary, it is appropriate to equip the adjusting mechanisms with servo-motors, or to locate the mechanism at a safe distance (e.g., with bowden cables or cardan shafts).
- *Handles.* Functional handles are necessary for operating the protective device; Machine parts are not handles. Levers and handles, whose longitudinal axes run parallel to the swivel axis, make for easy handling in all positions.

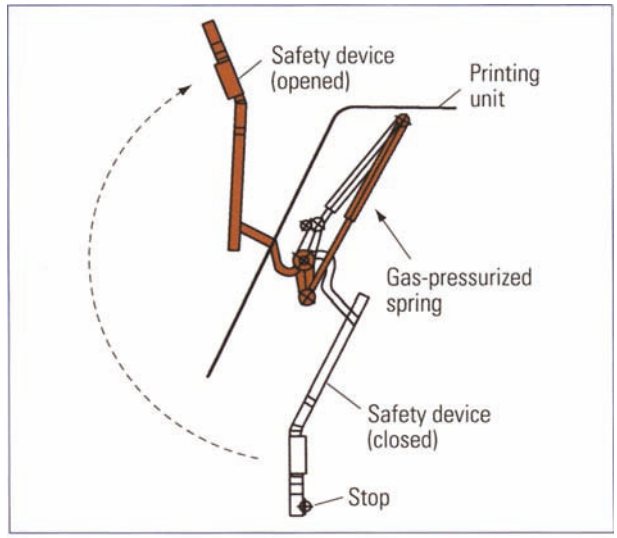


Fig. 13.2-6
Application of a gas-pressurized spring on a moving protective device attached to a printing unit (e.g., see fig. 13.2-7)

- *Handling.* Protective devices should be user-friendly and easy to handle. Movable protective devices should be easy to move with one hand and a minimum amount of effort. A well-designed protective device can be operated easily with one hand and be held securely in the open position.
- *Visibility.* If processes behind the closed protective device are to be observed, the protective device should allow for this. To ensure visibility, protective devices should be made of wire grid (e.g., see fig. 13.2-7) rather than other transparent materials (e.g., acrylic glass or plastic), which in the course of time turns yellow or opaque, or scratches or cracks easily. Reflections and optical distortions impair the view of the work area and give the observer eye strain. A perforated plate with a large number of holes facilitates monitoring, especially if it is dark-colored (e. g., matte-black) and the background is bright; it is perhaps also useful to install glare-free electrical lighting on the inside.
- *Predictable misuse.* When designing protective devices, misuse that can reasonably be predicted must be taken into account; for instance, people's reflex behavior in the event of a malfunction, an incident, a failure, and so on, when using the machine. The right type of material and purposeful shapes is necessary when designing protective devices.



Fig. 13.2-7
Guards, handles, catwalks, and footrests on a sheet-fed offset press (Speedmaster SM 74-2-P, Heidelberg)

In figure 13.2-7 a sheet-fed offset machine is shown, together with security-related features.

13.2.2.5 Hazard Analysis, Risk Assessment

In compliance with EU machine directive [13.2-13] the designer must carry out a risk assessment of his machine; that is, all potential hazards must be addressed and their risk evaluated. This requires a thorough, systematic analysis.

This *hazard analysis* must be carried out and documented in writing. It is the responsibility of the designer and inspections are only carried out by supervisory bodies where necessary.

Risk assessment comprises a series of logical steps, thus enabling the designer systematically to identify hazards and to determine the level of risk posed. In this way, suitable design or protective measures need to be selected, which afford the operator the greatest possible level of work and health protection. Furthermore, potential residual risks must be determined in the context of the risk assessment, so that the operator can be informed in detail about the residual hazard. The following factors may typically form the basis of the risk assessment:

- Probability of an incident that causes damage (probability of occurrence),
- frequency and duration of exposure to hazard,
- severity (degree) of possible damage (consequences),
- technical and human scope for minimizing or preventing damage.

The *legal basis* for risk assessment is contained in the EU Machine Directive 98/37/EC [13.2-13], EN 292-1 [13.2-14], and EN 1010 [13.2-19].

The responsible manufacturer/designer will not shelve the complex issue of risk assessment until all residual problems of risk evaluation have been solved on a European level. He must systematically determine in each individual case which hazards and dangers can occur and identify the best safety precautions for preventing potential injury or damage to health. The objective is to make the machine as safe as possible for the user. *Residual dangers* are to be identified in this manner and the user alerted (e. g., warning notes in the manual), so that he can adjust to it correctly.

After a systematic and realistic identification and evaluation of the risks that arise, statements can be made about meaningful measures and acceptable residual hazards. There *is no such thing as absolute safety*, but, if thoroughly worked out, a relatively high degree of safety can be achieved at reasonable cost.

13.2.2.6 CE and GS Marks of Conformity

Having the *CE mark* (CE: Communité Européenne) on machines means that conformity to the EU Machine Directive is clearly documented. The Machine Directive states that the manufacturer must declare in writing that *his machine* meets basic health and safety requirements. This declaration of *EU conformity must contain* the following:

- Manufacturer's name and address (or that of a representative based in the Union),

- machine specification (make, model, serial number, etc.),
- all relevant regulations governing the machine (all directives pertaining to the machine must be specified),
- signatory details (title and position held in company),
- where necessary, the name and address of the accredited testing and certification body that carried out a check.

If a machine or machine part or unit is *installed in another machine* or if a machine or machine part is joined to other machines (or parts thereof) and this machine or machine part cannot function independently, a declaration by the company or representative must be attached to the machine or part or unit thereof (*manufacturer's declaration*).

For *delivering machines* to the user the following *requirements* must be satisfied:

- A declaration of EU conformity must be attached to the machine, in which the manufacturer declares that the machine meets safety requirements and that the prescribed procedures set out in the declaration of EU conformity are adhered to.
- The *CE mark* must be clearly visible on the machine, legible and non-removable; it comprises the letters CE (see fig.13.2-8).
- The machine must be accompanied by the original operating instructions, together with a set in the language of the country in which it is being used.

The *CE mark of conformity* is intended for use by authorities of member states for control purposes. It is not a quality or safety label. This is the purpose of the *GS mark of conformity* with *BG PRÜFZERT label*, the latter recognized outside Germany (PRÜFZERT is derived from the German for checking and certifying "Prüfung und Zertifizierung", GS stands for "geprüfte Sicherheit" "safety checked" and BG for "Berufsgenossenschaft" "professional association").

It is useful on an international level to attach the GS mark or BG PRÜFZERT label visibly to products in addition to CE marks of conformity (fig. 13.2-8).

Checking the machine and displaying the GS mark of the BG PRÜFZERT label is also associated with production monitoring (e.g., by means of a quality assurance system, restriction of test certification validity followed by renewed tests or additional sampling).

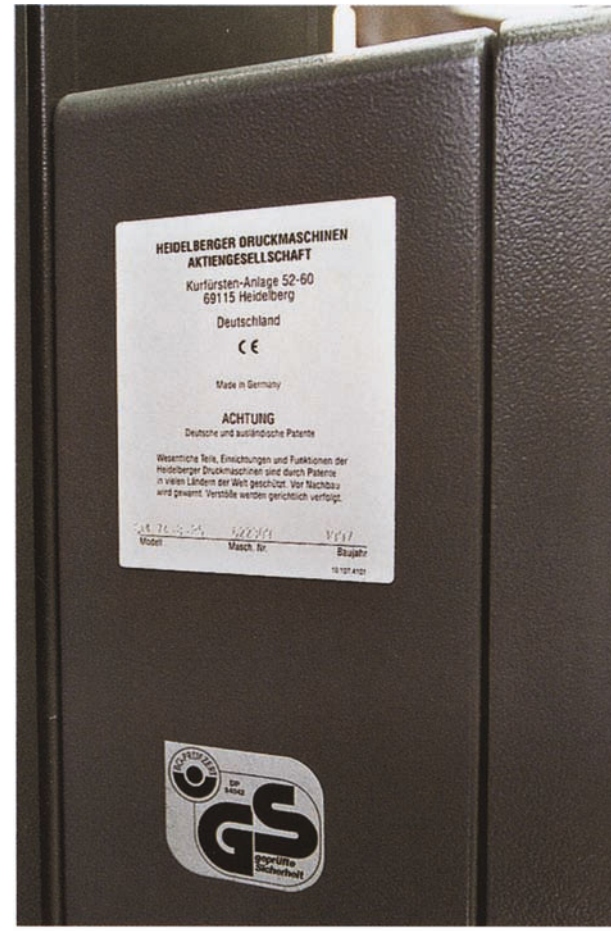


Fig. 13.2-8
CE and GS marks of conformity (the GS mark with BG PRÜFZERT label) on a sheet-fed offset press (SM 74-4-P, Heidelberg)

The professional associations in Germany have created a common product *testing and certification* and quality assurance (BG PRÜFZERT) system. This embraces testing and certification bodies of the professional specialist committees as well as the Professional Institute for Health and Safety at Work (BIA „Berufsgenossenschaftliches Institut für Arbeitssicherheit). The testing and certification body of the printing and paper-processing specialist committee is included in the BG PRÜFZERT. Testing covers printing and paper processing machines.

The BG PRÜFZERT is characterized by the fact that specialists in the various test areas are active in Euro-

pean standardization, alongside the carrying out of tests in their own specialist fields. Furthermore these specialists in member companies of the professional associations can gain experience alongside operators regarding the operability of the machines. They are familiar with the occurrence of accidents with the various machines and through their experience they have compiled real-world operational solutions. In this way a high level of quality is achieved. Customers can be informed at any time of the latest development in the field of *protective device standards*.

The testing and certification body of the specialist committee for printing and paper processing sees its function as aiding manufacturers of printing and paper processing machines, and setting out prerequisites for proving *conformity with the directives*. It issues the GS mark of conformity to ready-to-use products and the BG PRÜFZERT label to constructors of non-standalone machine assemblies.

If a product test proves successful, a *detailed test report* is drafted by the testing and certification body, which sets out which danger areas to safeguard with which protective device. This accompanies an important document to the manufacturer that sets out which directives and standards are fundamental and how danger areas and hazardous areas are to be safeguarded. This document is an important part of the *technical documentation*, as required in the EU Machine Directive.

13.2.2.7 Intended Use

Printing presses, as well as all devices that are needed for production of print media, are in general not *all-purpose machines* for carrying out all desired processes. The technical designer assigns a specific function to the device, for instance, for printing sheet, flexible printing materials constructed and manufactured within an established range of thickness of the material.

Design considerations not only have to take on board the need for subsequently maximizing *production in economic terms*, but also need to ensure that the user suffers *no accident* or *ill-effect* from using machines as intended. It concerns complex functions in organizing and producing systems for print media production, which currently can only be carried out by a team of experienced specialists. World-wide there are not so many manufacturers developing and producing printing presses and systems, that fulfill all the requirements for safety and meet the expectations of operator and owner of a printshop.

The *technical instructions* set out in the manual deal with intended use and must allow for a reasonable amount of predictable misuse [13.2-14].

An important document for the operator is the *manual*, which the manufacturer must provide in the user's language. The manual [13.2-14] forms an important basis for the *instruction* that the owner must give to employees using the machine. Misuse as well as disregard of regulations and safety indications endanger life and limb of machine operators as well as risking damage to the machines and their devices.

13.2.3 Industry Standards, Codes of Practice, and National/ International Standards

What traveller has not experienced frustration when the plug of his or her electrical equipment does not fit into the socket provided? Every country seems to use a different system. This example clearly demonstrates the need for standardization: over twenty years ago a new plug was developed and approved by electrical specialists for the purpose of international standardization. It was technically superior to all the existing national plugs and yet it was not introduced due to political resistance to the costs associated with the change-over. The change-over costs would have paid for themselves long since – because larger series are cheaper and special packaging for individual countries would no longer have been required.

The *regulations published* and used for *technical standardization* can be divided by their publishers into these categories: industry standards, code of practice, and standards issued by a national, European, or international standards organization.

Industry Standards

Industry standards usually go back to the company standards of a market leader or a consortium of firms. There are some examples:

- the characteristics of the IBM-compatible PC,
- the programming language PostScript from Adobe [13.2-22], the first format to make data exchange between different platforms (devices, systems) much simpler,
- the data formats TIFF [13.2-23] and PDF from Adobe [13.2-24]; the former is a pixel-oriented format, preferably for transmitting images, the latter is a universal transmission format for page data,

- color management specifications from the International Color Consortium, ICC [13.2-25], see section 3.2.10,
- the CIP3/PPF conventions of the same-named consortium of firms, see section 8.2.3,
- the so-called Euro standard by System Brunner.

The advantage of an industry standard is that, seen as a whole, the best technical solution can be agreed upon during the drafting stage and, moreover, it can be implemented very quickly. On the other hand, the disadvantage is that a company standard is not supported from the outset by an industry-wide consensus to be an industry standard. This may happen later due to a company's market leadership or the technical superiority of the concept. With a consortium of firms as supporting institution there is already a broader basis. The German institute for standardization, DIN, (see sec. 14.6.1), makes its infrastructure available to support this work. The point is to integrate these documents as quickly as possible by means of a publicly transparent procedure into national and international standardization.

Codes of Practice

Codes of practice are usually established by associations in lengthy committee meetings in a more or less democratic way using the consensus principle. This means acceptance of these codes is generally guaranteed from the outset. Examples of codes of practice are:

- standardization by BVDM/FOGRA (see sec. 14.6.1) for offset printing [13.2-26], newspaper printing [13.2-27], business forms printing [13.2-28], and screen printing [13.2-29],
- the SWOP directives (SWOP Specifications for Web Offset Publications) from the US for web offset publication printing (see sec. 14.6.1), [13.2-30],
- the SNAP directives (SNAP Specifications for Non-heatset Advertising Printing) from the US for coldset publication printing [13.2-31],
- the FIPP directives (FIPP Fédération Internationale de la Presse Périodique) for European publication printing (see sec. 14.6.1), [13.2-32],
- the press inspection directives from the German Printing and Media Industries Federation (BVDM) for web offset [13.2-33] and sheet-fed presses [13.2-34].

The before mentioned examples 1 to 4 deal with four-color reproduction and printing, although numbers 2, 3, and 4 do not give any binding guidelines for production printing. *Standardization by BVDM/FOGRA* for offset printing [13.2-26] is the only one that has dealt with the complete process for twenty years, from the "interface" film or data files, test print or proof, through platemaking, to production and aspects of finishing relevant to image appearance. The fundamental elements of standardization by BVDM/FOGRA have been integrated within the *international series of standards* ISO 12647. However, the interests of the USA and Japan have also been taken into account. Parts 1 (the basics) and 2 (offset process) of the series of standards have been incorporated into the German body of standards as the corresponding parts of DIN ISO 12647; others will follow.

The *SWOP specifications* [13.2-30] also go back a long way; they were initially drawn up in the late seventies to ensure uniform appearance of advertisements produced in publication printing with heat-set web offset (with negative-acting plates). In view of the lightweight coated (LWC) paper normally used in publication printing, approximately 65 g/m², a relatively low color saturation was selected with SWOP. The tone value increase (dot gain), which is actually too low for the negative plate with SWOP, can be explained by the fact that the proof prints for a US-wide advertising campaign are produced in a short run of approximately fifty copies on sheet-fed presses and at least in part without having taken into account the production printing. It was accepted here that the production printing would turn out somewhat darker due to the higher tone values and that the customer might be disappointed. At least one can say that this is the case with all advertisements. The data of the SWOP printing inks were taken into account in the relevant standard for printing inks, ISO 2846-1. In this respect SWOP is incorporated within this ISO standard, although the tone values of the SWOP proof print are contained in a special column in ISO 12647-2 under the heading "Negative platemaking with special measures to minimize the tone value increase."

The *SNAP specifications* [13.2-31] have been brought out by the newspaper industry in the US as an equivalent to SWOP.

The *press inspection directives* of the German Printing and Media Industries Association (BVDM) for web offset [13.2-33] and sheet-fed offset presses [13.2-34] concern a sensitive area: They give specific instructions on technical execution, values aimed at, and tolerances to be adhered to. Purely printing-related as well as me-

chanical inspections are provided for. The directives are supported, at least partly, by the competent/manufacturing association VDMA (German Machinery and Plant Manufacturers Association, see sec. 14.6.1) responsible.

Standards

Compared with the codes of practice, the generation of true standards requires an even higher degree of consensus. Other basic principles are:

- voluntariness,
- full publicity,
- participation of all interested groups,
- uniformity and consistency,
- focus on the state-of-the-art in technology.

Thus standards are not laws; they only have legal significance if adherence to them is made the subject of a contract or if a law determines this.

Standardization is not organized centrally but functions independently in various areas, such as in electronic technologies and telecommunications. However, it does have the same focus and follows the same fundamental principles.

The *national institutions* in Germany are DIN and VDE (Association for Electrical, Electronic and Information Technologies), figure 13.2-9 (see sec. 14.6.1). Within *Europe* there are CENELEC (Comité Européen de Normalisation Electronique; the European Committee for Electrotechnical Standardization), ETSI (European Telecommunication Standards Institute), and CEN (Comité Européen de Normalisation; the European Committee for Standardization), figure 13.2-10.

In the *international* arena these correspond to the umbrella organizations IEC (International Electrotechnical Commission), ITU (International Telecommunication Union), and ISO (International Organization for Standardization) (see sec. 14.6.1), figure 13.2-11. Worldwide standardization in the color measurement area is based on the guidelines of the CIE (Commission Internationale de l'Eclairage), which has its headquarters in Vienna (see sec. 14.6.1).

The German Information Center for Technical Regulations (DITR Deutsches Informationszentrum für technische Regeln) within DIN publishes an annual overview of German and international standards along with technical regulations, of which there are approximately 57 000, from approximately 250 organizations in Germany and internationally. It is available in catalog form and as a CD-ROM ("Perinorm") [13.2-35]. The American Association for Suppliers of Printing and Converting Technologies NPES (see sec. 14.6.1) publishes a good overview of the international and US-American standards in the graphic arts field [13.2-36].

Standardization work is organized so as to ensure that the trade public is informed in the most effective way possible. This includes publication of a *draft standard with an option for anyone to object* (as is the case with a patent), a standardized liaison to standards committees



Fig. 13.2-9 Logos of the national associations (Germany):
DIN Deutsches Institut für Normung (German Institute for Standardization);
VDE Verband der Elektrotechnik Elektronik Informationstechnik (Association for Electrical, Electronic, and Information Technologies)



Fig. 13.2-10 Logos of the European standards institutions:
CEN Comité Européen de Normalisation;
CENELEC Comité Européen de Normalisation Electronique;
ETSI European Telecommunication Standards Institute



Fig. 13.2-11 Logos of the worldwide standards institutions:
ISO International Organization for Standardization;
IEC International Electrotechnical Commission;
ITU International Telecommunication Union

operating in related fields, as well as an intensive review of a draft standard for cases of conflict with other standards and errors, such as incorrect references, and so on.

Standards are checked every five years by the *standards committee* responsible with regard to their relevance in the field and whether they need to be revised. Each year, for example, there are approximately 1000 new DIN standards and an additional 1000 are revised. During the last ten years the national committee's work has been intensively focused on the preparatory work for European and worldwide standards, with European projects predominating (fig. 13.2-12).

The German standards institute is mainly financed by sales of standards (two thirds), the rest is borne by the sponsors of the standards committees as well as by the federal government.

The following DIN standards committees are particularly relevant to the *printing industry*:

- DIN-NDR, standards committee for printing and prepress technology,
- DIN-NPA, standards committee for paper and cardboard,
- DIN-FNF, standards committee for color,
- DIN-NAM, standards committee for machine engineering,
- DIN-photokinonorm, standards committee for still and motion picture.

The work of the DIN-NDR, which is particularly important for printing technology, is divided into the following areas (see also sec. 14.4 for further information):

- terminology (3 standards),
- prepress (13 standards),
- printing processes (11 standards for formats, printing plates, control strips),
- media/materials (30 standards from the printing ink and measuring technique areas),
- screen printing (3 standards).

The work of DIN-NDR occurs almost exclusively in the international arena, and consequently DIN agreed to run the secretariat of the ISO committee *TC 130 (TC Technical Committee)* for graphic technology.

In a national context NDR's standardization work has been successful in the so-called "European color scale for printing inks", DIN 16539 (see sec. 14.2.2), the first standards worldwide for printing blankets, DIN 16621, and for densitometers for printing, DIN 16536. The standards for ink fastness properties, DIN 16524-1 to 16524-7, and for the offset platemaking, DIN 16620-2, have become the basis for ISO standards.

Contrary to widespread belief, the *European color scale*, DIN 16539: 1971, did not define the color appearance of the process inks for printing; rather, it specified the color of printing inks on special paper not in common usage. The testing can only be carried out in a well-equipped ink laboratory. The European color scale has

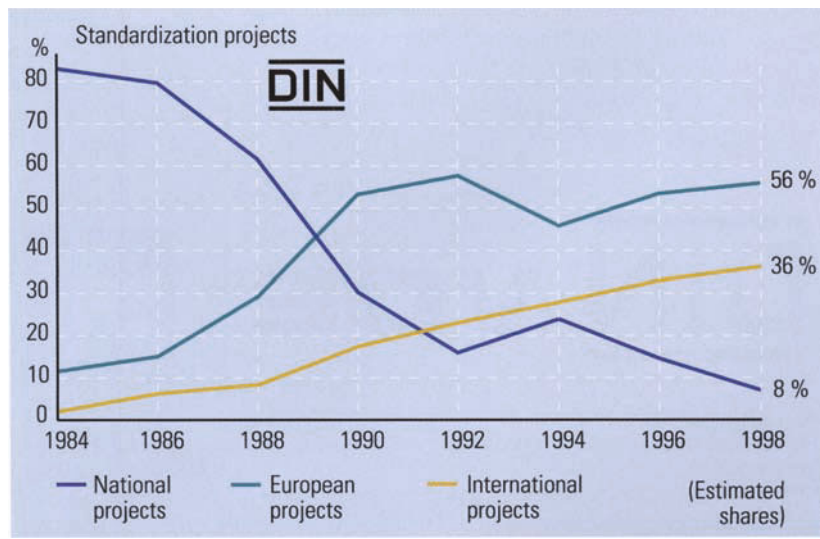


Fig. 13.2-12
Development of the standardization projects supported by DIN.
DIN Deutsches Institut für Normung (German Institute for Standardization)

now been superseded by the new standard ISO 2846-1, and this will be detailed later. The important DIN standards for the printing industry are listed in section 14.4 together with the relevant and further ISO standards.

The scope of a DIN standard with international significance may be extended to the European Union, EFTA (European Free Trade Association), and the Czech Republic if required. A standardization process must be initiated at CEN (European Committee for Standardization) in Brussels in this case. European standards are given the reference letters EN (European Standard/Norm) or ETS (European Telecommunication Standard) and they are made available in the EU languages German, English, and French. EN standards have priority within their jurisdiction, where conflicting national standards have to be amended or withdrawn. However, at present there is no standardization committee at CEN for the printing industry. European standardization is progressing rapidly; see figure 13.2-13.

Another option for *internationalizing* a successful national standard is to transform it into a worldwide standard that is then published by ISO, which has its headquarters in Geneva (Switzerland). Of course the reverse procedure is also possible: ISO standards can be transformed into national standards if there is a demand; EN standards already possess the status of a national standard. If the ISO standard is taken over word for word, the number of the original standard is retained and in Germany the abbreviation DIN is placed before it. Examples are DIN ISO 12647-2, the process standard for offset printing or the standards of the well-known DIN ISO 9000 series for organizing and documenting quality assurance (in international literature the abbreviation ISO is often used without DIN).

For *worldwide standardization* by ISO or IEC, particular importance is attached to attaining a wide consensus of specialists and nations. Before a draft standard is finally published, it has to survive a total of four rounds of voting, within which a majority of at least two-thirds of the participating nations must agree. These are those participating members who have declared themselves prepared to collaborate on standardization projects.

The ISO working areas are divided into around two hundred TCs (Technical Committees), and each com-

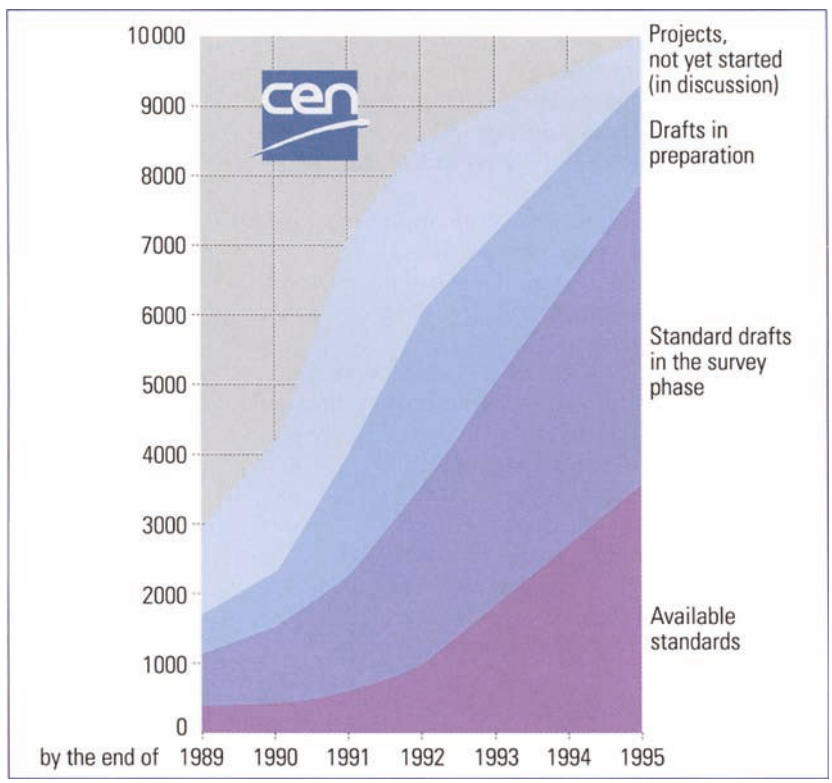


Fig. 13.2-13
Development of standardization at CEN. CEN Comité Européen de Normalisation

mittee's secretariat is taken over by a national standards body.

The following ISO/IEC committees are important for the *printing industry*:

- ISO TC 130 graphic technology, secretariat: DIN Berlin,
- ISO TC 42 photography,
- ISO TC 6 paper, board and pulps,
- IEC TC 100 audio, video, and multimedia systems and equipment.

In the case of ISO TC 130, working groups for "Terminology," "Data exchange in prepress technology," "Process control and related measuring techniques," and "Media and materials," as well as "Press safety" have been set up since DIN took over the secretariat in 1986. Experts from Europe, Israel, the USA, Japan, and Brazil are working together in ISO TC 130.

The following work has been particularly successful:

- the definition of a new *color scale* for offset printing ISO 2846-1 (see sec. 14.4.2), which includes the well-known European color scale, the American "SWOP scale" [13.2-30] and the "Japan 90" scale,
- the standards series ISO 12647 (see sec. 14.4.7) containing guidelines for the *process control* from prepress to production printing and the standardization as per BVDM/FOGRA as well as the SWOP directives,
- the unified color *measuring conditions* in the graphics industry, ISO 13655 (see sec. 14.4.7),
- the recommendations on the use of *densitometry and color measurement* during process control, ISO 13656 (see sec. 14.4.7),
- the ISO 12641 and ISO 12642 standards (see sec. 14.4.1) with *test forms* for characterizing the input and output of the electronic image processing for the purpose of color management,
- the TIFF/IT format for pixel images, ISO 12639 (see sec. 14.4.1),
- the testing conditions for *printing blankets* (ISO 12636), (see sec. 14.4.4) and *printing inks* (ISO 2834, ISO 2835), (see sec. 14.4.2),
- specifying the *offset platemaking* in ISO 12218 (see sec. 14.4.7).

Additional relevant ISO standards are listed in section 14.4.

The ISO standards series ISO 2846 (see sec. 14.4.2) deals with regulations for *testing printing ink* in laboratory conditions. The DIN ISO 12647 (see sec. 14.4.7) process standard series specifies which colors are to be obtained in practical usage with the *ISO inks* for the different papers and printing processes. In the case of offset, CIELAB color values are indicated in DIN ISO 12647-2 for five typical types of paper in use. These differ greatly, of course, for art paper und uncoated paper.

In the interests of a consistent structure for the printing process, important progress has been made. In DIN ISO 12647-1 it has been acknowledged worldwide that the purpose of *on-press or off-press proofs* is to simulate production printing as well as is technically possible.

DIN ISO 12647-2 concerns offset printing with screen frequencies from 45/cm to 80/cm. The following processes are covered: sheet-fed offset, heat-set web offset, and four-color business forms printing. The standard begins with prepress and therefore also contains specifications that are found in the specifications for prepress work by the German Printing and Media Industries Federation (BVDM), (see sec. 14.6.1), [13.2-26]. A guideline for the color register of films is new. Some of the new films with dry development require special provisions for measurement and platemaking because of their high fog level, particularly when these films are used together with traditional films on the same plate type. The standard goes into more detail about this.

There is no guideline in DIN ISO 12647-2 for *platemaking*. However, this is contained in ISO 12218. This standard originated from DIN 16620-2, it practically corresponds to the standardization as in BVDM/FOGRA [13.2-26], for instance, microline indication of 12 µm to 15 µm for positive acting plates.

DIN ISO 12647-2 also emphasizes how important a *substrate* match is for a match of proof to production. Five typical types of paper are defined that should preferably be used for proofing. The paper and its required coloration correspond to these of the BVDM color standards [13.2-26]. However, in DIN ISO 12647-2 *colors of solids* are not specified by color standards but by *colorimetric values*. The use of colorimetrics permits the specification of tolerances for the matching of solids between proof and production. It is only logical that the solid variations in production are also measured on the basis of colorimetry.

For the first time the *color register* of the films and the printing is mentioned in DIN ISO 12647-2. Here 0.02%

of the image diagonal or half a screen ruling apply as a tolerance. The tone value increase basically matches that of the standardization by BVDM/FOGRA [13.2-26], which again is based on statistics from practical values. In addition, graphical means are provided that make it possible to change over from a *tone value increase*, measured at one screen frequency, to the corresponding value of the tone value increase, measured at another screen frequency. This is important when comparing tone values that have been measured in control patches with different screen frequencies. The remaining parts of the process standard ISO 12647 follow the basic scheme given in parts 1 and 2.

ISO 12647-3 regulates four-color *newspaper printing* and ISO 12647-5 *screen printing*; a corresponding standard for *gravure printing* is being prepared as part 4.

The process standards series ISO 12647 has particular significance for *color management*. Since it indicates average printing conditions encountered in common usage for all important parameter combinations (e.g., commercial offset, positive acting plates, screen frequency 60/cm, paper type 1 = gloss coated paper, 115 g/m^2), it is exactly these conditions that should form the foundation of color management profiles. In other words, when listing *characterization tables* for output as per ISO 12642, the appropriate reference values in each corresponding standard part of the series ISO 12647 should be adhered to with the smallest possible tolerances. The characterization table is then used for generating a color management profile. It characterizes the normal process for the respective parameter combinations.

It makes no sense to characterize each printing press with a special profile, since the differences between the parameter combinations are greater than those between two printing presses. It may well be correct that older and larger format presses print with a higher tone value increase (dot gain) than others. However, there are also just as big and even bigger differences in the tone value increases between printing inks and paper types. In the traditional way of working it is possible to move a job to another press even at the last minute, and this flexibility must not be lost with color management. It is conceivable that, in the future, with such a change of arrangements the data can be converted in just a few minutes for another press. Until this time arrives, however, characterization tables should be used, which derive from a few internationally harmonized standard conditions. For offset and newspaper printing, tables recommended by the German Printing and Media Industries Federation are already available [13.2-37].

It is important to reach an industry-wide agreement about *color matching and measuring conditions*, and not only for the purposes of color management. ISO 3664 (see sec. 14.4.1) defines here that for *color matching* a reflection copy should be backed with black and illuminated with D_{50} illuminant. These conditions also apply to color measurement, for which ISO 13655 (see sec. 14.4.7) stipulates in addition "Geometry 45/0 or 0/45, and 2° observer, CIELAB system." ISO 5-4 and DIN 16536-1 (see sec. 14.4.7) define a black backing for densitometry, too. The reason is the reverse side printing showing through with thin substrates, a phenomenon that customers often complain about. If at the proofing stage a black backing is used or simulated, this prevents subsequent disappointment on the part of the customer because of deficient color intensity and "dirty paper white." Moreover, the show-through of reverse side printing structures is greatly reduced.

Quality assurance (*QA*) has a very high standing especially in the production of packaging for pharmaceutical and food products. The standards series ISO 9000 (see sec. 14.4.7) has particular significance here. In this the essential quality constituents, especially with regard to the organization and documentation thereof, are precisely defined and the series may be used in the most varied sectors and fields. Special matters are introduced in the quality handbook [13.2-38], which contains work procedures, inspections, and other organizational regulations.

The standards are as follows (see sec. 14.4.7):

- ISO 9000 gives an overview of the QA models 9001 to 9003.
- ISO 9001 contains twenty regulations for development, manufacture, inspection, and servicing. Suitable for firms with product development and service.
- ISO 9002 contains eighteen regulations for manufacture, inspection, and servicing. For production firms only.
- ISO 9003 contains twelve regulations for final inspection of firms that only have limited or no production, and that carry out a final check.
- ISO 9004 gives recommendations for installing a quality management system and comments on the possible QA elements.

Many companies attach importance not just to operating a QA system as per ISO 9000, but also to having their proven consistency *certified* every three years by an authorized independent institution. In Germany,



Fig. 13.2-14 Marks of conformity:
a DIN marks of conformity;
b "Product conforms to equipment safety law";
c "Product conforms to European standards";
d "Product conforms to EU directives"

for example, DQS (see sec. 14.6.1) or TÜV (see sec. 14.6.1) conduct appropriate audits to check whether the documented procedures and working instructions as prescribed in the QA handbook are actually put into practice [13.2-39], and [13.2-40].

Matching a product with one or several *standards* can be confirmed for a customer with a mark of conformity on the product. Associations' logos as per figure 13.2-9 signalize a traditional declaration of manufacture; use thereof must previously have been registered. Certificates and certification marks indicate even greater trustworthiness. They are a visible indication that an independent competent body has carefully inspected the product's conformity. These include the symbols shown in figure 13.2-14.

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13.3 Markets and Development Trends for Print Media

This section offers a worldwide overview of the demand for and the development of the most important print media (newspapers, magazines, books, catalogs, advertising, packaging, documents) in the different markets. Each individual segment also contains an analysis of the influence of electronic media on the traditional printing markets.

13.3.1 Newspaper Market

The newspaper markets vary considerably from country to country. Readership and circulation vary depending on the *type of newspaper* (Dailies, Sundays, etc.) and *target group*.

The greatest number of *newspaper titles* appears in the United States, followed by China and Germany (fig. 13.3-1). If we look at the corresponding *circulation figures*, we obtain the same result. To understand these initially surprising results, a more thorough analysis of the various types of newspapers is necessary. In the United States, alongside the dominant dailies, there is an extremely large number of Sundays with a weekly circulation of approximately 60 million copies. In Germany, on the other hand, free papers are the dominant force. Of these publications, 1331 appear in Germany alone with a circulation of 88.2 million copies. The newspaper markets in Brazil and Poland, on the other hand, consist predominantly of weekly papers. In Poland there are 141 of these newspapers with a total circulation of 28.5 million copies. The situation is different in Great Britain and Australia. Free papers and Sundays dominate in these countries. In all other countries the number of newspaper titles is divided relatively evenly among the various individual types of newspaper (fig. 13.3-2).

What does the future hold for the development of newspaper printing? To answer this question one should have a look at advertising expenditure, paper consumption and the electronic media.

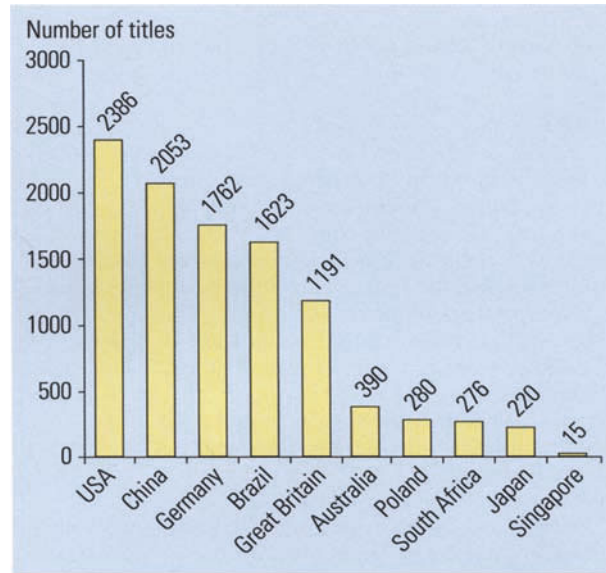


Fig. 13.3-1 Number of newspaper titles per country [13.3-1, 13.3-2]

Since 63% of the total production of printed products depends either directly or indirectly on the *advertising expenditures* of the economy, the proportion of the total advertising budget spent on newspaper printing must be examined more closely [13.3-2]. The comparison of the figures for the year 1998 with the forecast for 2001, shows that the proportion of advertising expenditure for newspapers remains relatively constant. Yet, when comparing the individual countries with one another, great differences can be seen. In Singapore, the proportion of advertising is around 50% and dominates other media, such as TV and Radio. In Poland, however, newspapers represent the lowest proportion of advertising at 13%, but it is growing (fig. 13.3-3).

The growing trend towards printing newspapers in several colors can be clearly recognized. This trend

H. Kipphan (ed.), *Handbook of Print Media*
© Springer-Verlag Berlin Heidelberg 2001

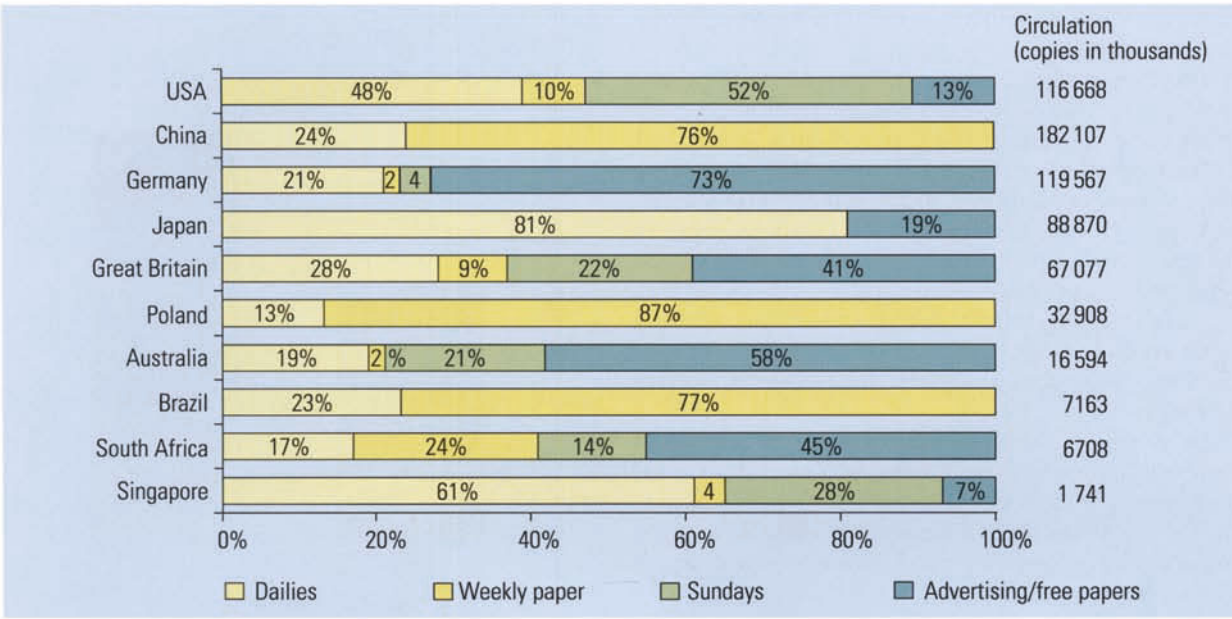
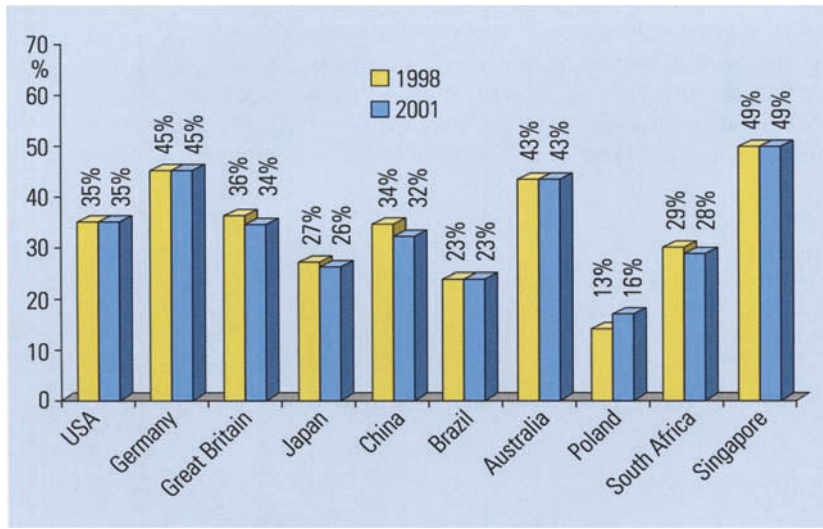


Fig. 13.3-2 Circulation of newspapers in each country (copies in thousands) in terms of type of newspaper [13.3-1, 13.3-2]

Fig. 13.3-3
Proportion of total advertising expenditure spent on newspaper advertising [13.3-2]



must, however, be accompanied by increased print quality. In addition to maintaining economic viability, a *multicolor* newspaper has to compete with the high quality of single-color newspaper printing, on the one hand, and with modern multicolor commercial printing on the other.

The importance of newspaper advertising in Great Britain, China, South Africa, and Japan is declining the most, whereas in the United States, Germany, and Australia the level of advertising remains constant. Looking at the overall situation, the advertising budgets for newspapers are continuing to rise, meaning that the

newspaper will remain an *important advertising medium* in the future.

The level of *paper consumption* in the newspaper industry also lends credence to this finding [13.3-3]. With the exception of the United States, Japan, and Poland, all other countries have been able to increase their paper consumption in the last few years, some of them significantly. The countries with the greatest increase from 1990 to 1997 were China with 186%, Singapore with 180%, and Brazil with 99% (fig. 13.3-4). This clearly demonstrates, using newspapers as an example, how rapidly the demand for print media has developed in the emerging nations in the last few years.

Between 1995 and 2010, worldwide paper consumption will increase by approximately 140 million tons. This represents a growth of 51% or 2.8% p.a. From figure 13.3-5 one can determine that the emerging nations in particular will experience an above average increase in their paper consumption.

Many publishers are already publishing newspapers on the *Internet*. In 1998, the number of newspapers issued worldwide on the Internet was around 3500 [13.3-4] (end of 1999: around 5000). The principal reason for this surely lies in the up-to-the-minute nature of the information. Contrary to all the euphoric reports, many newspaper publishers are losing considerable amounts of money with their online services. According to investigations by Forrester Research, *online newspapers* have only been able to cover some

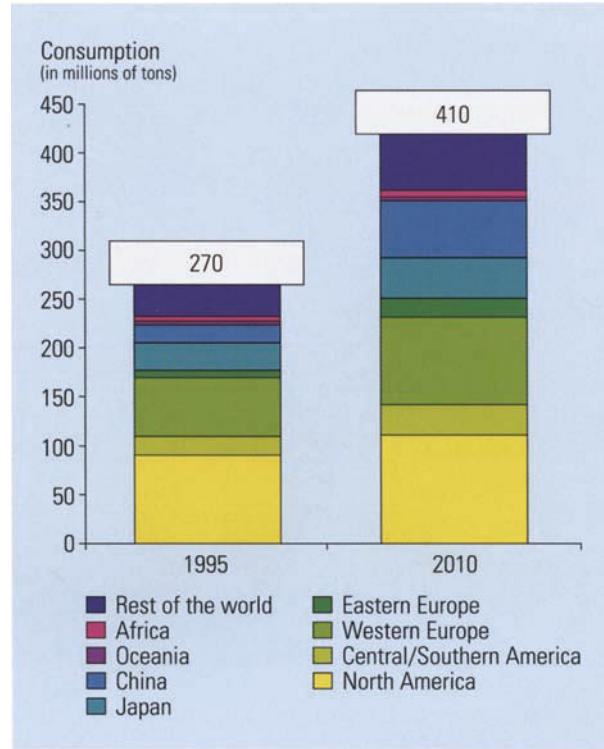
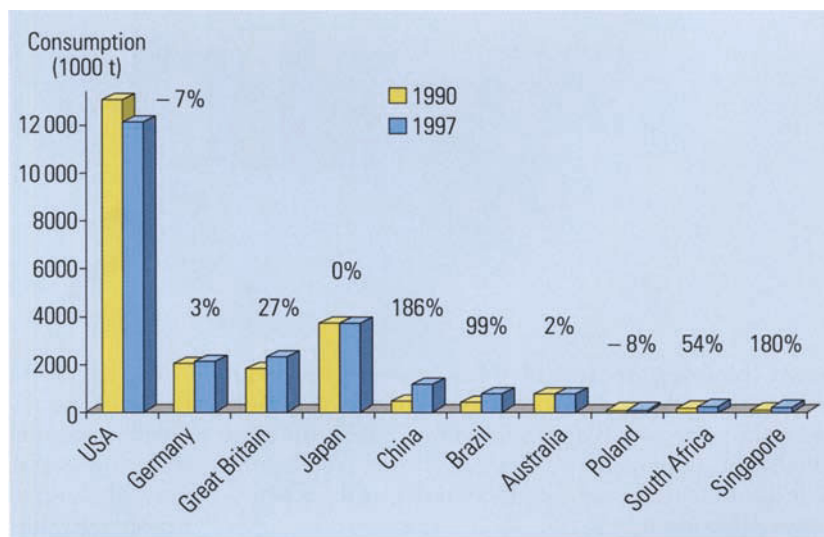


Fig. 13.3-5
Worldwide paper consumption (in millions of tons) [13.3-3]

Fig.13.3-4
Levels of newspaper paper consumption (in thousands of tons) and its development [13.3-3]



30% of their costs with income from advertising [13.3-5]. An advertising company's online services budget is still extremely limited due to Internet newspapers' small readership and, therefore, meager consumer group. It remains to be seen whether a newspaper reader will even realize that online newspapers exist and then take the time to read an entire on-screen issue. In any event, publishers may only publish a selection of articles or summaries of the headlines online.

13.3.2 Magazine Market

The market for *magazines* is very similar to the newspaper market. According to international experts' estimates, it is set to grow by approximately 2–3% annually during the next few years. When considering magazines we should differentiate between those that have high circulation figures and a large target audience and those specialist magazines that pursue a small and selective readership.

China has the largest number of published magazines. With a 700% rate of increase since 1987, the number of magazines has risen to 8135 in 1999. In contrast, Japan publishes a surprisingly small number of magazines (fig. 13.3-6). How is the magazine industry set to develop? At this point, an analysis of the advertising budget for magazines also seems sensible.

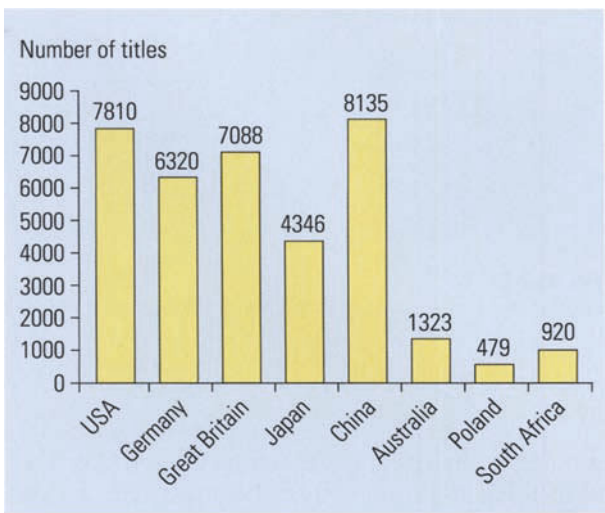


Fig. 13.3-6 Number of magazine titles per country [13.3-6]

For most countries the proportion of total *advertising expenditure* spent on magazines in the future is set to remain constant or fall back slightly. Exceptions are China, Japan, Brazil, and Poland. Immediately apparent are the large differences in advertising levels between the individual countries: Figures vary from 25% in Germany to 2% in China (fig. 13.3-7). According to advertising companies the magazine is set to remain an important advertising medium in the future. The more specialized and personalized the magazine, the more advertising will take place. The challenge lies in developing new readerships and addressing groups with similar interests and needs. In the United States the amount of advertisement expenditure invested in these kinds of special interest magazines has grown in the last few years to US $ 3.5 billion, a sum which suggests a yearly growth rate of approximately 5% [13.3-7].

This trend points to qualitatively *high-grade products* and *short print run lengths*. The growing demands placed on the quality of printed magazines can be most easily met by increasing use of *colors*. For the printing system sub-contracting industry this means an increasing demand for presses with more printing units and high-grade prepress devices.

The *influence of electronic media* can also be seen in magazines. Magazines are already appearing on the Internet, and this trend is set to continue. Magazines that emphasize up-to-date information and scientific publications are well suited to this form of publishing. Diverse specialist or fashion magazines are, however, somewhat unsuitable for the Internet.

Due to the time constraints Internet users will, in general, subscribe to online magazines only if the information is recorded efficiently and offers a *clear advantage* over the printed version. This could be achieved by exploiting the "weakness" of the magazine publishers. In the future online magazines have to make a great effort to tie the customer to their websites. This will only be possible, however, if the "normal services" (such as newsletter, archive, search engine, and discussion forum) are complemented with additional features (e-mail service, downloads, auctions, virtual marketplaces, and clubs).

"Hybrid forms" should, however, be able to establish themselves in the marketplace as *multimedia products* for conveying information and entertainment. For example, a printed magazine may come with a CD-ROM which contains video sequences, and so forth. Another multimedia combination is to add on a printed page

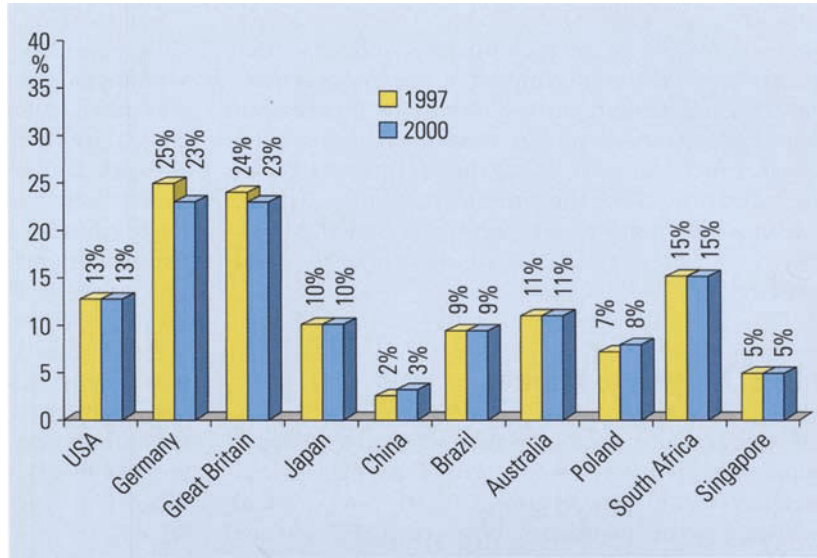


Fig. 13.3-7
Proportion of expenditure for magazine advertising to the total advertising expenditure

a code (visible or invisible/digital watermarking for example) which can be read electronically to build up the link to the Internet for receiving additional electronic information.

13.3.3 Book Market

The market for books is even more heterogeneous worldwide than that of the newspaper and magazine. In addition to the classifications hardback/hardcover and paperback, books must also be categorized by genre, that is, light reading, textbook, reference work, and so forth.

According to international experts' estimates the worldwide book market is set to grow by around 2% p.a. by the year 2005. Each country's growth, however, varies considerably. Some of the emerging nations/markets, for example, exhibit two-figure growth rates while most markets in the industrial nations show only slight growth or are stagnating. The textbook industry has accounted for the greatest growth in the last few years, which should continue in the future.

Figure 13.3-8 serves only as a means of orientation and should be treated with caution. Since many titles appear in several languages in multilingual countries and each edition is entered into the statistics, the figures from the UNESCO (United Nations Educational, Scientific and Cultural Organization) survey are difficult to interpret, and therefore the actual diversity of titles in an international context remains suspect. By breaking these figures down according to category, we can determine that worldwide most titles

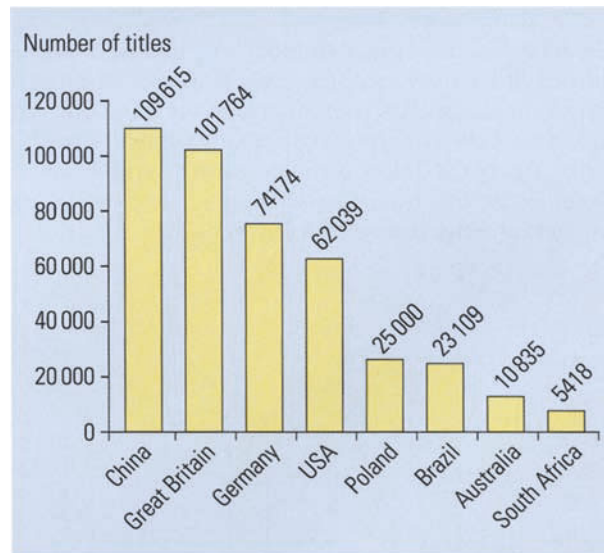


Fig. 13.3-8
Number of titles produced annually for the book market [13.3-9], (approximate figures)

appear in the social science and fiction/genre categories.

The proportion of paperback books published also varies considerably from country to country. In Germany the *proportion of total units* produced in 1997 was 9.2%. In the United States the *proportion in terms of value* corresponded to 57%. Because advertising expenditure going into books is extremely low, such statistics can therefore be ignored.

What significance will the *electronic media* have for the book market? In the area of light reading, the Internet will have scarce impact because reading a lengthy book on a computer screen is too inconvenient. Online excerpts or book reviews are, however, conceivable in the area of fiction/genre. In general, books are still highly valued for their transportability and simplicity (they can be read anywhere, in almost any environment) – a fact that will not change significantly in the future.

It makes sense that CD-ROM references (*dictionaries and encyclopedias*), which take advantage of the medium's full range of multimedia capabilities, are seeing increased use alongside printed editions. In the long term these electronic encyclopaedias, featuring vast array of multimedia extras (animation, sound, etc.), could replace the printed editions. (See also chapter 12: Print Media and Electronic Media, especially section 12.3.2).

The influence of the electronic media is also growing among *textbooks*. In the United States computers are firmly integrated into the curriculum beginning with the first grade. Individual learning programs cater to a student's personal needs in special lessons. By combining text, image, and sound, these programs make learning easier for the pupil. In the future this development will also become increasingly widespread in Europe.

In the field of international education (e.g., online universities) and the international discussion platforms associated with it, electronic *publication on the Internet* will become more and more significant because of worldwide book availability and the up-to-date nature of the online information. Scientific articles have already been published directly online worldwide. When manufacturing textbooks, the ability to "*print on demand*" or publish a "*book on demand*" is of significant importance: Because print run lengths of "one" are possible (e.g., content digitally delivered via a network) one can update or personalize a single book as necessary.

13.3.4 Catalog Market

Catalogs, some of which can be extremely substantial, are used to present companies and the private consumer with information about products and services, normally at no charge. According to international forecasts, as a whole this market will continue to increase slightly in size. For catalogs, the use of CD-ROMs or publication on the Internet seems to be particularly relevant. Due to its ability to store vast quantities of data, the CD-ROM is an ideal medium for catalogues with a large amount of images, sound, or image sequences. On the Internet, readers can make use of special search engines to target and aid a search, and the order itself can be placed directly from the customer's own PC via e-mail.

The German mail-order company "Quelle", for example, had already produced 350 000 CD-ROMs in 1997, the "Otto" company 250 000 units [13.3-9, 13.3-10]. But in 1998 the majority of catalogs were still being produced in paper form, just as before. Mail-order companies' marketing experts believe this is useful because customers may be inspired to purchase other items when thumbing through a printed catalog; such an impulse would be unlikely when using an Internet search engine. As additional advantages, printed catalogs offer the highest image quality and are easy to flip through.

According to numerous forecasts, *hybrid forms combining* print and electronic media may well have the greatest market opportunities. For mail-order companies that cannot do without extensive photographic images, a product combining a printed edition and a CD-ROM has great potential. For mail-order companies, the increased use of CD-ROMs in the past three years represents a further step towards interactive television or business via the Internet. Their web pages are also being visited very frequently. Speedy data transfer, clear layout of the web pages, and up-to-date contents will continue to boost the use of online catalogs. An element of risk still remains when ordering goods via the Internet today, and therefore individual customers will only accept online catalogs when data lines and methods of payment on the Internet have become safe enough.

13.3.5 Advertising Printing Market

Information about companies' products and services is normally presented to the end customer in printed

form. This information can be divided into classes, such as advertising mail/direct mail, brochures, direct distribution advertising, inserts, flyers, and so on. The country with the largest market in the advertising printing industry is the United States with a volume of around US $ 46 billion, followed by Germany with a volume of US $ 6.8 billion (figures from 1998). This industry is still weakly developed in the emerging nations.

In terms of volume, direct mail advertising is the most important within the entire advertising printing market, and it is this *direct mail advertising* in particular that will gain importance. Direct mail advertising can either contain specific information requested by the customer or simply unsolicited information. According to an investigation by Veronis, Suhler & Associates in 1997 [13.3-7], growth of around 6% p.a. in this field is expected in the United States between 1996 and 2001. Advertisers gladly accept the additional expenses occurring from such growth because, with the opportunity to target a specific group with direct mail advertising, they can stimulate and increase interest in their products.

According to the forecasts, *inserts* in both magazines and newspapers can expect to see consistent and further use.

Classified directories and "yellow pages", victims of the electronic media's success, are likely to suffer the greatest losses. This branch of the advertising printing industry turned in huge growth rates at the start of the 1990s, but has had steadily increasing competition since 1996 from CD-ROMs and the Internet. Similar to the trends in the catalog market, online versions are becoming increasingly popular due to speedy data transfer, easy-to-use search engines, and up-to-date data stocks. In Asia and South America, where the telephone infrastructure is expanding, the demand for printed telephone/address directories will rise, but worldwide the Internet will probably reduce the printing market for directories more and more.

13.3.6 Packaging Market

The market for *packaging printing* is huge: Every kind of packaging requires print of some kind. In the past, the packaging industry has proven stabile in the face of economic fluctuation. According to international experts' estimates, growth of around 4.5% p.a. can be expected for the next few years. In south-east Asia and China, double figure growth rates could also be achieved in this field. Relative to the 1997 level, the worldwide volume of the packaging industry will have doubled by the year 2002 if the worldwide per capita packaging consumption is just half that of Europe.

These figures clearly demonstrate the *potential* of the packing printing industry. Due to changing lifestyles, the introduction of new products (e.g., the increasing amount of ready meals and microwave meals in the food industry) and the rising qualitative and creative demands of the consumer goods market, this market also remains attractive for the future. This positive outlook not only stimulates future printing onto paper or board but also increased printing of the most diverse materials.

It can be seen from figure 13.3-9 that the relative level of packaging printing for each of the individual packaging types is very similar in all countries. Some 65% of all packaging printing comes from paper and board and flexible packaging. Only the *consumer goods packaging* market was chosen for the analysis. This makes up approximately 70% of the total packaging market. The most dynamic area in the field of packaging printing is that of *label printing*, with an annual growth rate of around 10%. Fifty percent of the label market makes use of paper and board and 50% of plastic.

Since 1996 the market for "*intelligent packaging*" has been displaying the greatest growth rates in the entire field of packaging printing but is, however, at a very low level. "Intelligent packaging" is classed as packaging or labeling that fulfills *additional functions* alongside providing the actual product information. The label contains variable information about when and where the product was produced, its "best before" date, or whether the correct consumption temperature has been reached. Latest developments in the field of material and labeling technology make it possible for a label to display whether a wine is at the correct temperature or a deep freeze product is fully frozen, for example.

Electronic media do not play any significant role in this segment of printing, a fact not set to change in the future.

13.3.7 SOHO Market

SOHO stands for "*small office/home office*" and includes the market for devices, consumer goods, and services that are used in small operations (fewer than fifty employees) and private work areas, for instance, for telephone workplaces. The market includes table-top printers, and scanners, photocopiers, fax machines,

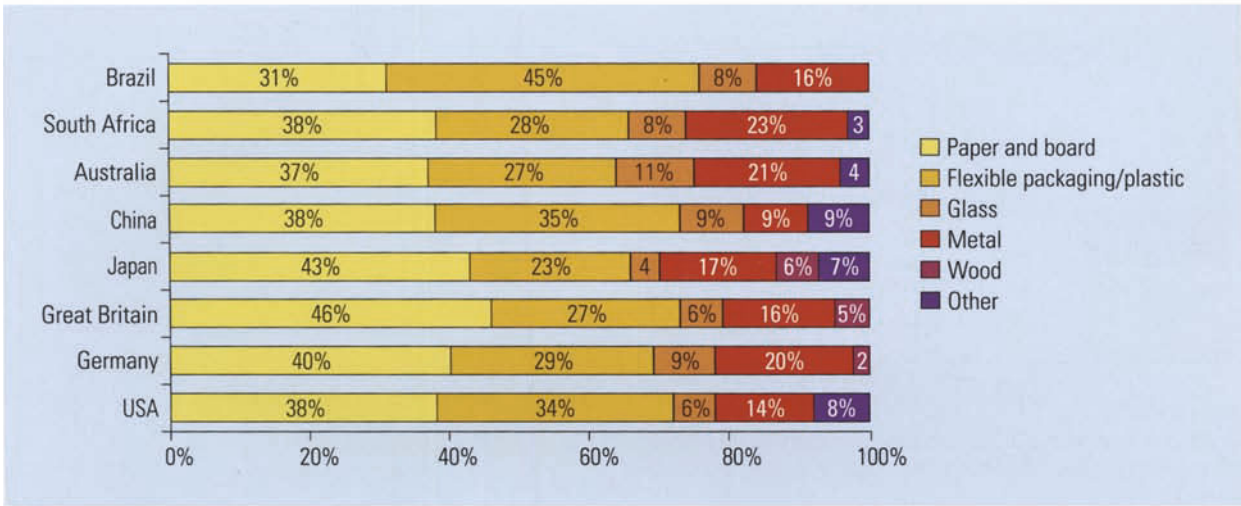


Fig. 13.3-9
Breakdown of consumer goods packaging according to packaging material [13.3-11, 13.3-12, 13.3-13]

computers (including peripheral devices or online services), sheet paper, ink jet and toner cartridges, and so forth [13.3-14].

The number of small operations in North America is estimated to be at six to seven million. Ninety percent of these businesses have PCs and printers. It is assessed that the number of home offices is over thirty million, more than approximately 90% of which have PCs and printers.

The growing importance of the SOHO market also influences the *requirement for paper and expendable items* in particular. The paper turnover of SOHO applications in the United States is set to reach 30% of the total US market for sheet offset paper by the year 2000, corresponding to a growth rate of 13% p.a.

The turnover from *ink jet cartridges and toner cartridges* for electrophotographic printers in 1996 came to around US $ 1.9 billion and is set to continue growing at around 14% p.a., assuming that the growth of *electrophotography* will continue to exceed that of the ink jet, which is continuing to grow in importance.

At first glance, this SOHO market seems to have little to do with the classic print media market. However, here we are also concerned with *printed documents*. The simplification of communication offered by digital media has simultaneously increased both the need and ability to send, process, and print electronic documents. This leads to a situation where some printing is shifted from the commercial printer to photocopiers or to ink jet or electrophotographic based printers via the PC; other printed products are produced that would not have been generated without PC availability. Forms or letter heads that were kept as blanks are now generated (along with the corresponding contents) on desktop printers, and personalized documents in print run length of up to one copy can be created at a competitive price.

Small offices and home offices do not merely use their special printers/output systems, but also take advantage of local quick printers, copy shops, and job printers for products like business cards, color copies, letter paper, brochures, presentations, and the like. CAP Ventures (US based company) estimate the turnover from the SOHO market at around 10% of the entire US printing volume.

Further Information and Summary

In sections 1.1.4 and 1.1.5 further information and comments regarding the outstanding *importance of the print media* and their trends are given. The electronic media support and promote the requirement for print media rather than reducing or threatening its use in individual applications. Chapters 10 and 11 provide further information about print media, electronic media, and their market position, as well as statements about

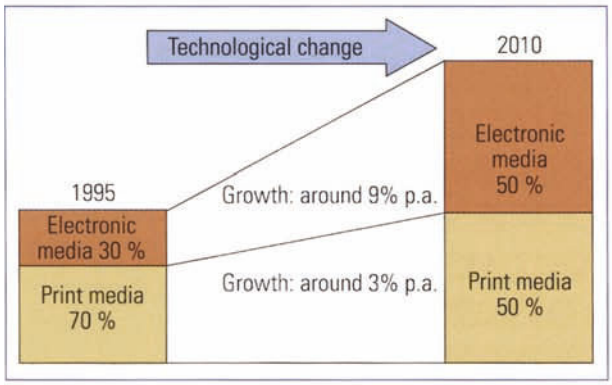
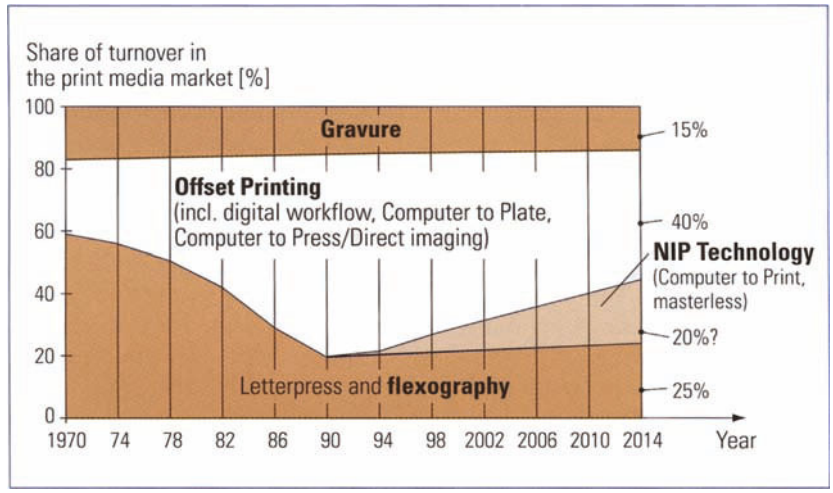


Fig. 13.3-10
Development trends for the print media and electronic media market (turnover); status: 1999 (Heidelberg, several international studies and forecasts)

Fig. 13.3-11
Proportion of various print technologies implemented, in accordance with the value of printed products sold (proportion of turnover in printed products/print media market; national and international estimates and analyses, status: 1999)



development trends. Essential trends are condensed in figures 13.3-10 and 13.3-11, as already explained in sections 1.1.5.2 and 10.5.4.

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14.1 Explanation of Specific Terms

14.1.1 Glossary

This short glossary contains only a small selection of important terms from the fields of technologies, production processes for print media, electronic media, communication, and information technology. A limited selection and description is given here of those terms which have been described in detail in the main section of the book; the index can be used to look them up.

In addition to the glossary, reference is made on page 1129 to a small selection of further material for terms used in the graphic arts industry and communication technology.

Only some of the common abbreviations are listed and explained in this section; a detailed listing is given in section 14.1.2.

The abbreviations used for companies and organizations in the source references of figures and tables are available in section 14.1.3.

Absorption
Soaking in or penetration of liquid components of the ink into the pores of an absorbent substrate (a type of physical drying, like evaporation).

Aniline Printing
An earlier name for flexography, based on the use of the aniline inks that were initially used.

Area Coverage Value/Area Coverage
Ratio of area coverage (area covered with image elements) to the entire area. The area coverage value is normally stated as a percentage. With reflection originals, differentiation is made into the effective area coverage value determined by optical measurements (tone value) and the geometric area coverage value determined by area measurements (with positive originals/films normally somewhat lower due to the lack of light-gathering).

Baud
Measure of the rate of data transfer. Number of bits per second (bps) that can be sent from one digital device to another.

Bit
The smallest addressable storage unit. Eight bits form 1 Byte.

Bit Depth (Depth of Data)
Defined by how many bits each pixel is described and therefore the number of gray values per pixel. Two gray values can be described by one bit (0 or 1), 256 gray values with 8 bits.

Bitmap
Image content made up of pixels where the pixels contain the information for position, size, angular position, and color and can be addressed individually.

Booklet
Book-binding product with small number of pages, often used for short-lived literature where the cover is glued or stitched directly to the spine of a block.

Brochure
Book-like finished product, normally of eight to forty-eight pages. The single or multi-layer block (folded sheets joined to one another) is inserted into a board cover (e.g., pasted in or stitched).

Browser
General: Software program that enables browsing through large amounts of data stocks.
The term browser is mostly used in connection with the Internet. Here the main task of the browser is to enable access to the World Wide Web, to locate, edit, and display web sites.

CIE Color Space
Device-independent color space in which each color to be reproduced is described by its standard color values X, Y, Z (with the coordinates Y and the standard color ratios x,y).

CIELAB Color Space
Device-independent color space in which the CIE color values Y, x, y (see CIE color space) have been converted into uniform (the human color perception is recognizing color deviations within similar – but not equal – tolerance ranges) chromaticity scale values L*, a*, b*. Here, L* represents the lightness, a* is the red-green proportion, and b* the yellow-blue proportion.

CIM (Computer-Integrated Manufacturing)
Computer-integrated manufacturing of products (also of printed products)

Cliche
Common term for the plate used in pad printing.

CMYK
Standardized base colors (process colors) for four-color printing: Cyan, magenta, yellow, black. K stands for black (key color) since black is often used as a reference color for adjusting the other colors to ensure correct register/overprinting.

Color
The aspect of visual perception by which an observer recognizes optical appearance. Color is defined by three values, for instance, hue, saturation, and brightness, or L*, a* and b*.

Color Management
Process/system for calibrating the individual devices and machines that are involved in the workflow from color image processing right through to the finished printed product. Serves to guarantee correct color rendering from the input (e.g., scanner) right up to the output on various media and with various printing technologies (e.g., monitor; through printing equipment or printing presses based on various technologies on various substrates).

Color Mixing
- Additive: light of various colors is superimposed, added by the receiving device and perceived as color. Additive primary colors are red, green, and blue (e.g., color television). If all the colors (ideal colors) are superimposed with identical intensity, the result is white.
- Subtractive: various color components within the visible spectral range are extracted from white light (e.g., through optical transmission filters). Subtractive primary colors are cyan, magenta, and yellow (e.g., for printing). If all colors (corresponding to the filtering of the white paper through transmission of the colors cyan, magenta, and yellow) are printed above one another, the result is black.

Color Separation
Splitting a color copy into the primary colors of cyan, magenta, yellow, and black (previously with the aid of color separation filters but today also possible on computers taking the digital description of the original with colorimetric data as a basis).

Commercial Printing/Commercial Printing Presses
Single- or multicolor, single- or multi-page print products such as leaflets, catalogs, notepaper, flyers, or business cards, normally in small numbers and of high quality. It is hard to define clear boundaries between illustration printing, packaging printing, form printing, an so on.

As compared to special printing systems such as newspaper presses, commercial printing presses are flexible and can be used for a whole range of applications (sheet-fed or web-fed printing).

Composition
Term used for the manufacture of the text portion of a print product/the setting of type. (Completition of the page with the text, images, and graphics is called page make-up or imposition).

Computer to ... Technologies
These technologies describe direct imaging from a data file either onto film (computer to film), the printing plate (computer to plate), a printing screen (computer to screen), a closed, cylindrical image carrier such as in gravure printing (computer to cylinder), and the plate of a printing press in-line (computer to press/direct imaging) as well as via a latent image (without fixed printing master), for instance, with electrophotography, or directly onto the substrate, such as with ink jet (computer to print, sometimes also called computer to paper).

Continuous Tone (Contone)
The tone of an area not divided into image elements or non-image elements, where the small pixels/image elements are not visible to the human eye and the tone values appear continuous (e. g., analog photography, in contrast to screened halftone print images).

Copy
The reproduction of an original, whether transparency, photo, print, document, or halftone or continuous-tone film, on the same or different material.

Cross-Media
Multiple use of print data (or data describing the information content) for various media. The data can be used to create print products and web sites for the Internet, but also for the contents of CD-ROMs. The digital information generated in the "premedia" section within the production workflow can, therefore, be used to generate print media and/or electronic media.

Cylinder Rolling
The effective circumference of the plate, blanket, or impression cylinder. The rolling of the cylinders in contact with one another must be balanced and ideally identical. Rolling errors can cause dot deformation, doubling, differences in print length, register differences, and increased printing plate wear.

Densitometer
A device for measuring blackening or density values in transmission with films or reflection in the print. The measuring effect is based on a reduction in the light density as it passes through layers.

Density (Optical Density)
An ink layer's imperviousness to light. Mathematically the logarithm of opacity in order to simulate the sensitivity of human seeing (see also opacity).

Descreening (Unsharp Scanning)
To avoid moiré effects when scanning screened originals, the originals are scanned outside the zone of sharp focus of the scanner (therefore unsharp). The image is then sharpened again in the computer. Descreening can also be done on the computer using special image processing programs.

Developing
The chemical/physical treatment of a photosensitive layer to make visible the latent image that was created during the exposure (e.g., in film imagesetting, plate imagesetting or within the electrophotographic process in the NIP technique of electrophotography).

DI (Direct Imaging)
Process of directly imaging printing plates/cylinders in the printing press (computer to press).

Di-litho
Direct printing process developed especially for newspaper printing using offset printing technology, where the paper is printed directly from the printing plate (without an intermediate blanket cylinder).

Dispersion
1. In chemistry: mixture of two or more substances where one substance serves as a dispersant in which another substance is finely distributed (dispersed)
2. In optics: defraction (wave length depending) of white light into its spectral colors when passing through the boundary between two optical media with a special alignment and beam direction (e.g., prism).

Dithering
- In the digitally created print image the color tones are generated from the gray values for each color separation, whereby the gray values of the neighboring pixels are chosen so that the average gray value obtained in this way is as true to the respective image spot of the original as possible and hence the desired color effect is brought about.
- Resolution of gray values in a pattern of black and white microdots (e.g., in FM screening) in order to simulate a smooth/continuous transition between gray levels.

Dot Gain
Difference between the tone value (in percent) of the print and the corresponding tone value (in percent) of the film that is the basis for the image carrier (plate, etc.). With filmless production (computer to plate) or production without a master (NIP printing processes), the dot gain relates to the tone values of the base data for the color separation.

Doubling
A printing defect in offset printing products (and other indirect printing processes) that manifests itself as a doubled or multiple (shadow-like) contour of the image elements. Mechanical vibration and register deviations during the printing process can cause doubling. Doubling can occur in single-color printing but is a special danger in multicolor printing. As is the case with slurring, doubling results in dot gain.

DTP (Desktop Publishing)
The technology of electronic publishing (can be done in an office-like environment). Entire print pages are created on a PC with the aid of word and image processing programs and are then output on a printer or imagesetter or transmitted directly to the printing press. To be equated with digital reproduction technology today.

Duotone
Printing of images where two colors (e.g., with the inks black and gray) are printed from one original where differing screen angles, tone values, and tonal gradations are selected. Due to the better tonal gradation, a duotone print creates a better three-dimensional effect than a single-color print and is near to photographic quality.

Duplex Printing
Term for printing on both sides (face and back/front and reverse side printing) mostly used in connection with NIP processes (see also perfector).

Electronic Publishing (EP)
The creation of printed products on the basis of a digital description of the contents using digital printers/printing presses (see DTP).

Emulsion
Mixture of ink and dampening solution where the dampening solution is normally dispersed in small, equally distributed droplets in the ink (emulsified).

EPS (Encapsulated PostScript)
File format. An EPS file consists of a main file with a preview image in low resolution plus individual files containing the fine data (high resolution).

Ethernet
The most common type of network that is principally used to network all kinds of computers within a building as a so-called LAN (local area network). Thin coaxial or twisted pair cables are used for data transmission. The maximum cable length is 185 m (around 610 ft) with coaxial cables or 100 m (around 330 ft) with twisted pair cables. The data transmission rate is 10 Mbits/second. Fastethernet has transmission rates of 100 Mbits/second with twisted pair cables and 1 Gbit/second with fiber-optic cables.

Facsimile
Perfect copy/reproduction of the original (ink, screening, paper, etc.)

Fan-Out Effect
Widening of the paper web in a web-fed press, normally caused by dampening but also by printing pressure. It can theoretically occur in sheet-fed printing, too.

Film
- Negative film: the image areas without coloring are blackened
- Positive film: the areas carrying color image information (i.e., which are not white) are blackened. This means the film resembles a black-and-white image of the original.

Film Copy
Transparency (with positive or negative image) for platemaking. Each original contains all the information of a sheet to be printed for one color.

Fine Data
High-definition data that is needed for printing to ensure optimal print quality, particularly important with image data (see low-resolution data).

Full-Sheet Output
Output of the data file for the description of a complete printed sheet (one or more imposed printed pages) that can be used either for film exposure or directly for platemaking (computer to plate) without the need for further editing or producing of a complete film. See also imposition.

Fuser/Fixing Device
Subassembly in non-impact printing systems that serves to fuse powder toner and fix it on the paper. Fusers (fixing devices) normally consist of heated rollers that have an ink-repelling covering and are in contact with the substrate. Non-contact fusers with IR radiation are also common.

Ghosting
A repetitive, unwanted shadow-like manifestation in the direction of print of a previous image element. The ghost image manifests itself by over- or under-inking in comparison to its immediate surrounding area. Ghosting is influenced by the ink distribution in the inking unit, particularly on the ink form rollers. If, due to ink resplitting of the image on the printing plate, the ink profile is not reduced sufficiently (i.e., evened out) prior to the next inking process (next revolution of the roller), a partial transfer of the already printed image section into another image area will occur on the printed sheet.

Gloss
Perception based on the physical, optical property of a surface to reflect projected light more or less specularly.

Gradation (Gamma Value, Contrast)
Measurement of the ability of a light-sensitive layer of a film to reproduce density gradations. The division into gradations is made from soft to ultra-steep. An ultra-steep film material can only reproduce a very high density or the clear film. A soft film material, on the other hand, can reproduce many intermediate stages.

Gravure
Process for the manufacture of gravure printing masters/cylinders where e.g., an electromechanically controlled stylus cuts recesses (cells) into the copper layer of the gravure cylinder. The size and depth of the cells are varied in accordance with the image. The engraved cells are filled with ink in the printing process and the ink is then transferred to the substrate.

Gravure Impression Roller (Presseur)
Gravure impression cylinder used for gravure printing, consisting of a steel core covered with an elastomer coating. It presses the substrate against the plate. An electrostatic charge on the impression roller fosters the transfer of the ink out of the cells on the gravure cylinder and onto the substrate.

Guilloches
Complex geometrical, interwoven, fine, continuous line patterns on security papers and documents that make them more difficult to counterfeit.

Halftone Dot
Picture element of a screen, for instance, circular, elliptical, diamond or square-shaped. Below the middletone, the halftone dots are isolated in the image areas. Above approximately 50% area coverage the dots connect with each other.

Highlights
The bright tones of a positive image and the corresponding areas of the negative (film).

Hybrid Technology/Process
The linking of various, normally separate technologies within one functioning unit, for example, the combination of analog and digital technology or, in the case of print media production, the combination of various print technologies in a single production system (e.g., offset and flexographic printing or offset and NIP technology).

Hydrophilic
Water-receptive. In offset printing the non-image areas on the printing plate that are repellent to ink (oleophobic).

Hydrophobic
Water-repellent. In offset printing the image areas on the printing plate that are receptive to ink (oleophilic).

Illuminant
Expression used for light with a precisely defined relative spectral distribution, such as color temperature T=5000 K as the D50 illuminant, or T=6500 K as D65 (average daylight). Ascertaining the illuminant is important for the matching of color prints.

Illustration Printing
Printing of magazines that appear regularly (as periodicals).

Image Carrier
Appliance whose surface is prepared in such a way that the selected areas transfer ink to the substrate (directly or indirectly via an intermediate carrier).

Imposition
Arranging the individual pages on a print sheet, taking the folding layout and finishing into account. (The arrangement of text, graphics and images within one page is called page layout/make-up.)

In-Line
Carrying out processing steps with a hardware and software connection (linking) of the units to the printing press. Devices for coating, folding or stitching can be linked to the press. (In-line quality control means that the measuring device is integrated in the press and the quality is measured and checked within the production stage).

Ink
Substance (liquid, pasty, solid or pulverized) which generates visually perceivable information on the substrate. (Specific for each printing process.)

Ink Fading
Term used in offset printing for the variation in the ink density (uneven ink film) in the direction of print (as a consequence of inking unit design and content of the printing sheet).

Interface
Connection between subassemblies, for example, individual electronic components or programs.

Job Ticket
Term used for a digital "job docket" containing information on the operations in prepress, printing and in finishing. It specifies the print job and the means of production and contains technical, organizational, scheduling, and administrative information.

JPEG (Joint Photographic Experts Group)
Data format and compression algorithm for color images. Often used in digital cameras (photography). Offers advantages for Internet applications due to the relatively small amounts of data involved.

Justifying
Altering the space between individual letters or words in order to make the line fit a length specified in the layout.

Latent Image
An image that is present but not visible (hidden) on the exposed, still undeveloped film of a printing plate or on the photoconductor in electrophotography.

Letterset
A printing process using a metal relief plate from which the image is transferred to the substrate via a blanket cylinder.

Long Grain
Term used for a print sheet that has been cut from the paper web in such a way that the grain of the paper runs along the long side of the sheet (direction in which the paper web runs during production. See also short grain).

Low-Resolution Data (Low-Res)
Data for displaying low-resolution images and text, used solely for design and layout purposes. The advantage of this rough data is that relatively small amounts of data, which can be processed quickly, are involved. This is especially useful with image data (e.g., original data/fine data (high-res) for an A4 color image is around 40 Mbytes and with low-res data around 2.5 Mbytes).

Matrix (die)
A type of mold used in letterpress and flexographic platemaking. Depending on the type of cast (stereo), various materials are used for the matrix, such as cardboard, plastic, lead, wax, and so on.

Misting (Flying)
Side effect of ink film splitting within an inking unit, in particular on rapidly-rotating inking rollers. Here, extremely small droplets (diameter of 10 to 50 µm) of ink are released from the ink layers on the exiting nip. They form an aerosol with the ambient air, can lead to printing defects,

and contribute to soiling of the press. Misting is very much dependent on the rheology, in particular the tackiness, of the ink, as well as on the velocity of the ink-carrying surface and the geometry of the rollers. (See also spraying for comparison.)

Modem
Interface (normally serial) between a telephone network and computer. A modem is both transmitter (output of computer data to the net) and receiver (of data sent). The term modem originates from broadcast engineering and is created from the terms MOdulator and DEModulator.

Moiré
Undesired pattern (interference) in halftone (normally multicolor) images, which is normally caused by incorrect screen angles, register errors, or special patterns in the original in connection with the screen angle.

Mottling
1. Scanning: surface effect in the entire image. Often caused by focusing too strongly. This means that the individual pixels or even the grain of the film become visible.
2. Printing: spotty, mottled appearance of prints due to differing ink absorption into the paper. Particularly noticeable in multicolor prints.

Multiple-Ups
In printing technology the number of identical copies on the same sheet. In reproduction technology (step-and-repeat copying) the aligning of identical motifs at certain distances apart in one or two directions by photograph shots or copying.

NIP (Non-Impact Printing)
Printing processes that require no permanent printing master and are therefore able to generate a different image with every print. The most important NIP processes are electrophotography and ink jet.

OCR (Optical Character Recognition)
Computer-aided system for optical character recognition. The text recognized can then be used in a text processing program (similar: MCR/magnetic character recognition, where automatic reading takes place via magnetic sensors when printing with magnetic ink).

Off-Line
Individual modules (devices/machines) of a system are not directly linked to one another (are not mechanically and/or electrically linked), but a data link is quite possible. For the creation of printed products, i.e. individual finishing operations like folding or trimming printed sheets are performed separately from the printing process outside the press and independent of its momentary application.

Oleophilic
Surface property based on interfacial effects; oil-receptive, ink-accepting/receptive.

Oleophobic
Surface property based on interfacial effects; oil-repellent, ink-repellent.

On-Press Proof
Sample print on a printing system in a small run length that shows the result of the reproduction process, whereby the technology of the proofing system corresponds to the printing process used for the print run/job.

Opacity/Opaque
- In general: the ability of a material to absorb light. The measurement for opacity is the reciprocal of the degree of transmission (transparency)
- Measurement of imperviousness to light by paper and other materials. Significant when printing on both sides of paper. A high opacity of paper is achieved both by the addition of fillers such as kaolin, talcum, or titanium dioxide as well as by using a greater proportion of wood. This means that the print image of the front side does not show through to the reverse side.
- Offset inks are generally not opaque. They are translucent.

OPI (Open Press Interface)
A server-aided interface that enables a low-resolution version of the image to be produced when displaying PostScript files for layout purposes. These previews are used for further processing of the layouts and image assembly. The previews are then automatically replaced during imaging (film, plate) by high-resolution images.

PDF (Portable Document Format)
Part of the Adobe Acrobat data format that enables a platform and program-independent exchange of documents.

Perfecting (Face and Back Printing)
Printing both the front side (face) and reverse side (back) of a sheet in single pass on a printing press (see also Duplex printing).

Perfector
Printing press with a sheet turning device enabling both the front and reverse side of the substrate to be printed in one pass (in particular machines based on the NIP technology are referred to as duplex printers).

Personalizing (Individualizing)
A printed product whose content has been totally or partially generated for one specific customer. In its simplest form this can be just the address (text portion personalized), but it extends to brochures that are compiled to represent the special interests of the recipient, such as guidebooks with routes, accommodation, and time scales

specific to an individual. Parts of the content remain constant and identical to other editions and other parts are adapted, altered, or added to meet specific requirements.

Photopolymer
Plastic that is cross-linked (hardens) under the influence of light.

Piling
Undesired build-up of printing ink on ink transfer surfaces of the printing unit, for instance, on the blanket in multicolor wet-on-wet printing.

Pixel
Created by breaking down an image into discreet picture elements. The pixel is the smallest picture element that can be processed (addressed) by an electronic system (e.g., monitor, printer, imagesetter, scanner, digital camera). The term is derived from **pic**ture **el**ement.

Pixel Format
Format for saving image data where each pixel is described by corresponding data. The most common pixel format is TIFF (Tagged Image File Format). The pixel format is suitable for images, although a large amount of memory may be required, particularly with high image quality (high resolution).

PostScript
Device-neutral page description and programming language developed by Adobe Systems for texts, graphics, and continuous tone images. Also format for text and image information.

Preflight Check
Inspection of a file for the description and definition of a print job, for instance, for the production of films or plates, to ensure that all the image and text information (e.g., status, correct fonts, imposition, acceptance when transmitted to various production units, etc.) is present and complete.

Primer
Colorless varnish with low viscosity used as a base coat on the substrate (to improve wetting and bonding). Primer is applied prior to the actual varnish to enhance the gloss, particularly in connection with UV varnishes or prior to the application of glue for improved adhesion.

Print Characteristic Curve
The diagrammatic representation of the relationship between the tone values of the prepress products, for instance, halftone data (tone values) of the film or the printing plate (normally this applies to the tone values of films), and the corresponding tone values in the print. (The phenomenon – increasing tone value in the print compared with the tone value in the film – called dot gain is derived from this.)

Print on Demand (PoD)
A print product is not printed for the total run length in one run and then stored, but is printed as required or at least in part runs. The extreme scenario is when single copies are printed upon the customer's request.

Printing Pressure (Contact Pressure)
Physical pressure that is generated in the nip to enable the ink transfer from the printing plate to the substrate or from the printing plate to the blanket and then from the blanket to the substrate.

Process Colors (for four-color printing)
Yellow, cyan, magenta, and black (see C, M, Y, K).

Proof (Proofing)
Process used for quality control in prepress and printing regarding color reproduction, register, text and image layout, or as a specimen for the production run. Proofs are differentiated into analog and digital according to the type of original. Analog proofs are produced photomechanically from films that have been exposed, for instance, using color foils. Digital proofs are produced using a NIP technology-based color printer (normally based on ink jet or thermal sublimation processes) from the digital data file. The expected print result on a production press should be reproduced as accurately as possible. This is supported/ achieved by using color management systems (see on-press proof).

Register
1. Positional accuracy of the print images on the front and reverse side of a print sheet in relation to one another. In perfecting the term perfecting register is also used.
2. In multicolor printing the position of the color separations relative to one another (color register).
3. Term used for the positional accuracy of the color separations on the printed product with reference to the outer edges of the sheet or web section. Circumferential register is used for the direction in which the substrate runs, for example the plate cylinder revolves; lateral register is at right angles to it.

Rendering
- Another expression for screening (see screen)
- The term continues to be widely used for the conversion of three-dimensional scenes into two-dimensional images. Here, rendering refers to the process of illustrating a three-dimensional scene (with bodies and their illumination) in a two-dimensional view (e.g., monitor display) with light and shadows. Rendering is also required with animated images and virtual reality representations where each individual image is rendered.

Reproduction Technology
- Analog: technology using predominantly photomechanical, chemical, and physical means for image processing.

- Digital: technology where electronic means such as scanners, computers (including software), imaging devices, and so forth, are used for image capturing and image processing.

Resolution/Addressability
Number of image elements (dots, pixels) per unit length that can be reproduced on a monitor, film, an image carrier (printing plate, etc.) or on paper. Normally expressed in units (dots) per cm (dpcm) or inch (dpi). High resolution means good rendering of detail.

Resolution Capability
Defined in photography by the number of separate lines per millimeter that can be reproduced with a tone value of 50% (dark and light lines with the same width).

Rheology
Study of the flow and deformation behavior of liquid as well as solid or gaseous substances. One rheological parameter for the description of fluids is viscosity.

RIP (Raster Image Processor)
The information of a page (digital structure in image, text, and graphic elements, and positional commands) arriving in the RIP is converted into a bitmap file. The significant processes here are the screening and generation of data for addressing the output device.

Run Length
Number of copies to be printed in a print job.

Scanning
An original is analyzed and captured line by line to convert the analog image information from an original into digital data. This can be further processed in the computer. The term scanning is also used for the transfer of information (e.g., by light or by ink) to a carrier substrate via a moving imaging system.

Screen
Area broken down into printing and non-printing picture elements (halftone dots or lines) where the size and/or number of dots per area varies according to the tone values of the original. The two main kinds of screening are amplitude-modulated and frequency-modulated screening. Screening a continuous-tone original to generate a halftone image is today predominantly an electronic process.

Screen Frequency (Screen Definition, Screen Ruling)
Number of print picture elements such as halftone dots and screen lines per unit length in the direction that yields the greatest value. Measured in cm^{-1} or lines per inch (lpi). Therefore, in a 60 lines/cm (150 lpi) screen (typical value in offset printing), 60 halftone/screen cells formed by screen lines lie within a length of 1cm.

Scumming
In offset and NIP printing processes, the inking/printing of areas outside the print image that do not correspond to the print image. This can be caused by surfaces of the image carrier accepting ink in the wrong areas or by the blanket (indirect printing) having a defective surface and transferring ink to the wrong areas.

Server
Computers that offer certain services in a network as a component of a client/server system. In the area of prepress powerful computers are employed as data servers to store comprehensive amounts of text and high resolution image data centrally.

Sharpness
Reproduction quality of contrast gradients, particularly lines and contours of a picture or line art original. Normally given as definition or detail rendering (reproduction). The output resolution of reproduction or printing devices serves as a reference.

Shore Hardness
Measurement of the hardness of materials such as elastomers (roller sleeves made of rubber, flexographic printing plates, etc.) defined in accordance with ISO 868. The greater the value of shore hardness (in degrees), the greater the hardness of the material. Depending on the hardness of the material, various conditions are applied for testing. Shore A, for example, is used for soft rubber and Shore D for hard plastic.

Short Grain
Term used for a print sheet that has been cut from the paper web in such a way that the grain of the paper runs along the short side of the sheet (travel direction of the web during papermaking). This holds true for other materials, such as plate material for printing plates (see also the opposite, i.e., long grain).

Signature
1. Used to mark the first and last page of the folded sheet (e.g., 17 and 32 for the second folded sheet in 16-page format) to support the correct location and sequence during finishing to produce book blocks (several folded sheets collated and bound). The signature is normally removed when trimming the block.
2. Term commonly used for a print sheet which when folded and cut forms a group of pages. In web printing term meaning a web section printed in accordance with the print format.

Sleeve
Printing master or blanket sleeve. Sleeves allow the cylinders to roll smoothly against one another since they eliminate the cylinder gaps which are normally present on the circumference of the cylinder. Sleeves enable continuous

printing and reduce trim waste since image-free areas can be avoided.

Slurring
Slurring is a printing defect that occurs in offset printing. It manifests itself as changes in the geometry of the halftone dots. Round elements may be deformed and become oval. Slurring in the direction of print is classed as circumferential slurring and slurring at right angles to this as lateral slurring. This effect is related to the rolling behavior between plate, blanket, and impression cylinders and to influences of the materials.

Spectrophotometer
Term for a measurement device used to determine color values, such as chromatic value, (h*: hue) brightness (L*), and saturation (C*:chroma), with which color can be clearly classified quantitatively in accordance with the color perception of the human eye (in contrast to densitometers, which can only determine ink film thickness via the optical density).

Spot Color
Special colors. Used in addition to or instead of process colors (C, M, Y, K) to enable the printing of special hues without mixing the primary colors. Often also the only chromatic ink used in black-and-white printing.

Spraying
When large ink particles (diameter roughly greater than 80 µm) are thrown off the rollers in the inking unit or the printing plate, particularly with presses that run at high speeds (see also misting for comparison).

Spreads and Chokes (trapping/choking)
In reproduction technology the term spreading is used to describe the overlapping of two bordering inked areas. The areas are placed close to one another so that register errors do not become visible in the form of undesired white areas. This is also called trapping. Choking can then become necessary if negative structures (e.g., text) are printed in a multicolor area.

Substrate
The material on which the image is printed.

Suspension
Liquid in which the extremely fine solid particles are "suspended" (solid component in a liquid carrier component, not solved).

Tabloid Format
Half-size format in newspaper printing (half the web width) compared to the broadsheet format (full web width). The paper web is split on the former and the partial webs are laid above one another, after that a parallel fold (also called tabloid fold) is performed. One way of recognizing a tabloid-format newspaper is that the punctures of the needles are at the sides (with the broadsheet format the punctures are at the bottom). Newspapers in the broadsheet format are folded lengthwise in the former and crosswise in the folding cylinder.

Tack
A property of printing inks that describes the cohesion that exists between particles of the ink film, the force required to split an ink film or, in other words, its stickiness.

TIFF (Tagged/or Tag Image File Format)
The most common pixel format; it is supported by virtually all systems. Among other things, this format is suitable for the data exchange of color images and gray values as well as various levels of resolution and sizes.

Tone Value
Unit of measure of the optical impression of a screened area, stated as a percentage, where the unprinted surface represents a tone value of 0% and the solid tone surface a value of 100%. When screening, the tone value represents the ratio (in percent) of the halftone dots to the entire area.

Transmission Copy
Original copy (film) for platemaking on a transparent substrate whose image information is either transferred to the printing plate in direct contact or through optical projection.

Transparency
The property of a material to allow radiation (e.g., light) to pass through.

Transparent Ink
Translucent ink layer, the opposite of opaque ink. Printing inks are predominantly transparent inks. The translucent, color filter effect is a prerequisite for subtractive color mixing.

Trapping
1. Ink-trapping characteristics with multicolor overprinting.
2. Spreads or chokes in reproduction technology when generating the image (see spreads).

Types of Sheet
- Print sheet: printed sheet, as it comes out of the printing press.
- Bookbinding sheet: sheet trimmed after the printing process, input sheet for the folder.
- Folded sheet: folded bookbinding sheet, product of the folder.

Vector Format
Digital data format with which line images (line art, text) are not saved in the form of individual picture elements (pixels), but rather in the form of line elements, defined by the starting and end point ("vectors") and line width. Advantages compared to the pixel format are usually scalability without any loss of image definition and the fact that significantly less memory is required.

Version (customizing/targeting)
The entire print run of a printed product is divided into partial runs (versions), for example, by changing the content or language of text portions of otherwise identical content, such as addresses of an organization or a company group with various regional sites or various language versions (such as the same text in partial run 1 and English text in partial run 2). It is then not individual persons that are addressed directly (as in personalizing), but rather groups of customers or target groups.

Viscosity
The viscosity describes the property of a substance to flow and be deformed irreversibly under the influence of mechanical stress. The dynamic viscosity (η) is generally given to classify the rheological property of fluids, such as ink.

- Dynamic viscosity (η), measured in Pa·s, is the quotient of the pressure in the layer surface and the velocity gradient.
- Kinematic viscosity (ν), measured in m^2/s, is the quotient of the dynamic viscosity and density of the substance.

VOC (Volatile Organic Compounds)
International term for volatile organic (containing carbon) compounds with the exceptions of methane, carbon monoxide, and carbon dioxide. In offset printing, IPA dampening solution alcohol and solvents used for cleaning are by far the most important VOCs used in terms of quantity. In gravure printing, methylbenzene (toluene) is the most common one.

Wet-on-Wet Printing
Printing in multicolor presses. The printing of the second or another ink takes place on the previous ink, which has not yet dried.

Workflow
Description, organization, and monitoring of operations; process steps for the production of goods. The working areas/process stages (sections) of premedia, prepress, press, postpress, roughly speaking describe the stages of production from the idea right through to the finished print product. The workflow can be networked to varying extents. With a digital workflow, documents are transmitted from one stage of operations to the next with the aid of a computer system/network.

14.1.2 Abbreviations and their Meaning (Selection)

Abbreviation	Meaning
ADSL	Asymmetric Digital Subscriber Line
AFM	Atomic Force Microscope
AGV	Automated Guided Vehicle
AGVS	Automated Guided Vehicle System
AM	Amplitude Modulation
ANSI	American National Standards Institute
AOM	Acousto-Optic Modulator
API	Application Programming Interface
APS	Advanced Photo System
AR	Augmented Reality
ARPA	Advanced Research Projects Agency
ASCII	American Standard Code for Information Interchange
ASIC	Application-Specific Integrated Circuit
ASTM	American Society for Testing and Materials
ATM	Asynchronous Transfer Mode
BIOS	Basic Input/Output System
Bit	Binary Digit
bps	Bits per Second
BSI	British Standards Institute
CAD	Computer-Aided Design, Computer-Assisted Design
CAM	Computer-Aided Manufacturing, Computer-Assisted Manufacturing
CAP	Computer-Aided Publishing, Computer-Assisted Publishing
CAPI	Common (ISDN) Application Programming Interface
CBT	Computer-Based Training
CCD	Charge-Coupled Device
CD	Compact Disc
CD-DA	Compact Disc Digital Audio
CD-R	Compact Disc Recordable
CD-ROM	Compact Disc Read-Only Memory
CD-RW	Compact Disc Rewritable
CEN	Comité Européen de Normalisation
CEPS	Color Electronic Prepress System
CGM	Computer Graphics Metafile
CIE	Commission Internationale d'Eclairage
CIM	Computer-Integrated Manufacturing
CIP3	Cooperation for the Integration of Prepress, Press and Postpress
CIP4	International Cooperation for the Integration of Processes in Prepress, Press and Postpress
CISC	Complex Instruction Set Computer
CLUT	Color Look-Up Table
CMM	(1) Color Matching Method, (2) Color Management Module
CMOS	Complementary Metal Oxide Silicon
CMP	Cross-Media Publishing
CMS	Color Management System
CMYK	Cyan, Magenta, Yellow, Key color (Black)
cpm	(1) Copies per Minute, (2) Characters per Minute
CPSI	Configurable PostScript Interpreter
CPU	Central Processing Unit
CRD	Color Rendering Dictionary
CRT	Cathode Ray Tube
CtF	Computer to Film
CtP	Computer to Plate
CVD	Chemical Vapor Deposition
D2T2	Dye Diffusion Thermal Transfer
DARPA	Defense Advanced Research Projects Agency
DAT	Digital Audio Tape
DCS	Desktop Color Separation
DDAP	Digital Distribution of Advertising for Publications
DDCP	Direct Digital Color Proofing
DDES	Digital Data Exchange Standards
DDL	Document Description Language
DEF	Device Exchange Format
DI	Direct Imaging
DIN	Deutsches Institut für Normung (German Institute for Standardization)
DMD	Digital Micromirror Device
DoD	Drop on Demand
DoE	Design of Experiments
dpi	Dots per Inch
DRAM	Dynamic Random Access Memory
DRUPA	International Fair Printing and Paper (Internationale Messe Druck und Papier/Print Media Messe; Düsseldorf)
DSL	Digital Subscriber Line
DSP	Digital Signal Processor
DTP/DTR	Desktop Publishing/Desktop Reproduction
DVD (-ROM)	Digital Versatile Disc (Read-Only Memory)
EBC	Electron Beam Curing
EBCDIC	Extended Binary Coded Decimal Interchange Code
EC	(1) European Community (2) European Commission
EDP	Electronic Data Processing
EN	European Standard (Norm)
EPS	(1) Encapsulated PostScript, (2) Electronic Publishing System
EPSF	Encapsulated PostScript File
ETS	European Telecommunication Standard

ETSI	European Telecommunications Standards Institute
EU	European Union (formerly known as the European Community)
FDDI	Fiber Distributed Data Interface
FEM	Finite Element Method
FGD	Forschungsgesellschaft Druckmaschinen e.V. (German Printing Machines Research Association)
FIFO	First In First Out
FIPP	Fédération Internationale de la Presse Périodique
FM	Frequency Modulation
FOGRA	Forschungsgesellschaft Druck e.V. (Graphic Technology Research Association)
FPD	Flat-Panel Display
FKM	Forschungskuratorium Maschinenbau e.V. (Cooperate Research Organization for German Mechanical Engineering Industry)
FTP	File Transfer Protocol
FVA	Forschungsvereinigung Antriebstechnik e.V. (German Research Association for Power Transmission Engineering)
GB	Gigabyte
GCR	Gray Component Replacement
GIF	Graphics Interchange Format
GMR	Giant Magnetoresistance
GPRS	General Packet Radio Service
GPS	Global Positioning System
GS	Geprüfte Sicherheit (Certification for Safety)
GSM	Global System for Mobile Communications
GUI	Graphical User Interface
HDTV	High Definition Television
HKS	Hostmann-Steinberg, K+E, Schmincke
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
IARIGAI	International Association of Research Organisations for the Printing, Information and Communication Industries
ICC	International Color Consortium
IEC	International Electrotechnical Commission
IFEN	Intercompany File Exchange Network
IFF	Image Interchange Facility
IFRA	International Association for Newspaper and Media Technology (INCA-FIEJ Research Association)
IGAS	International Graphic Arts Show (Tokyo, JP)
IMF	Ifra Message Format
IP	(1) Internet Protocol (2) Intellectual Property
IPA	Isopropyl Alcohol
IPEX	International Print Exhibition (Birmingham, UK)
IPX	Internet Packet Exchange
IRC	Internet Relay Chat
ISBN	International Standard Book Number
ISDN	Integrated Services Digital Network
ISO	International Organization for Standardization
IT	Information Technology
IT8 Standards	Standards by Information Technology Committee 8
JDF	Job Definition Format
JES	Job Entry Subsystem
JPEG	Joint Photographic Experts Group
JTP	Job Ticket Processor
LAN	Local Area Network
Laser	Light Amplification by Stimulated Emission of Radiation
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
LEP	Light-Emitting Polymer
lpi	Lines per Inch
LUT	Look-Up Table
LW	Line Work
LWC	Light Weight Coated (paper)
LZW	Lempel-Ziv-Welch (image data compression)
Mac	Apple Macintosh Computer
MB	Megabyte
MBE	Molecular Beam Epitaxy
Mbps	Megabits per Second
MCR	Magnetical Character Recognition
MEMS	Micro-Electro-Mechanical System
MIDI	Musical Instrument Digital Interface
MMP	Mixed Media Publishing
MOD	Magneto-Optical Disc
MODEM	Modulator/Demodulator (device)
MOEM	Micro-Opto-Electro-Mechanical (device/system)
MOPY	Multiple Original Print Copy
MOSFET	Metal Oxide Semiconductor Field-Effect Transistor
MP 3	MPEG Audio Layer 3
MPEG	Moving Picture Experts Group
MTBF	Mean Time Between Failures
MVS	Multiple Virtual Storage

NCP	Network Control Program
NPS	Network Picture System
NIP	Non-Impact Printing
NSF	National Science Foundation
OCR	Optical Character Recognition
OEM	Original Equipment Manufacturer
OLED	Organic Light-Emitting Diode
OPA	Open Publishing Architecture
OPC	Organic Photoconductor
OPI	Open Prepress Interface
OS	(1) Operating System, (2) Optical Storage
OSI	Open System Interconnections
PAL	Phase Alternation Line
PC	Personal Computer
PC-Card	see PCMCIA
PCI	Peripheral Computer Interconnect
PCL	Printer Control Language
PCMCIA	Personal Computer Memory Card International Association
PDA	Personal Digital Assistant
PDES	Product Data Exchange Standard
PDF	Portable Document Format
PDF/X	Portable Document Format/blind Exchange
PIM	Page Imaging Model
Pixel	Picture Element
PJTF	Portable Job Ticket Format
PMT	Photomultiplier Tube
PoD	Printing on Demand
PPD	PostScript Printer Description
PPF	Print Production Format
ppi	Pixels per Inch
PPM	Parts per Million
ppm	Pages per Minute
PPML	Personalized Printing Markup Language
PMA	Print Media Academy
PS	PostScript
PVD	Physical Vapor Deposition
RAL	RAL Deutsches Institut für Gütesicherung und Kennzeichnung e.V. (Reichsausschuß für Lieferbedingungen)
RAM	Random Access Memory
RFIDT	Radio Frequency Identity Tag
RGB	Red, Green, Blue
RIP	Raster Image Processor
RISC	Reduced Instruction Set Computer
RIT	Rochester Institute of Technology
ROI	Return on Investment
ROM	Read-Only Memory
ROS	Raster Output Scanner
RTF	Rich Text Format
SCSI	Small Computer System Interface
SDML	Standard Music Description Language
SEM	Scanning Electron Microscope
SGML	Standard Generalized Markup Language
SI	International System of Units (Système Internationale)
SIP	Special Interest Product
SMD	Surface-Mounted Device
SMS	Short Message Service
SNAP	Specifications for Non-Heatset Advertising Printing
SPOOL	Simultaneous Peripheral Operations on Line
STM	Scanning Tunneling Microscope
SVGA	Super Video Graphics Array
SWOP	Specifications for Web Offset Publications
TAGA	Technical Association of the Graphic Arts
TCO	Total Cost of Ownership
TCP/IP	Transmission Control Program/Internet Protocol
TFT	Thin Film Transistor
TIFF	Tagged (Tag) Image File Format
TIFF/IT	Tagged (Tag) Image File Format/Image Technology
TQM	Total Quality Management
TV	Television
UCA	Under Color Addition
UCR	Under Color Removal
UMTS	Universal Mobile Telecommunications System
URL	Uniform Resource Locator
USB	Universal Serial Bus
VCSEL	Vertical-Cavity Surface-Emitting Laser
VDE	Verband der Elektrotechnik Elektronik Informationstechnik e.V. (Association for Electrical, Electronic & Information Technologies)
VDT	Variable Dot Thermal Transfer
VGA	(1) Video Graphics Array, (2) Video Graphics Adapter
VHS	Video Home System
VOC	Volatile Organic Compounds
VR	Virtual Reality
WAN	Wide Area Network
WAP	Wireless Application Protocol
WWW	World Wide Web
WYSIWYG	What You See Is What You Get
XML	Extensible Markup Language

14.1.3 Abbreviations for Source References Information

The source references information in figures and tables includes the names of the equipment illustrated and the manufacturer in accordance with the actual illustration. Names of organizations and public institutions are also given, as are references to literature and other sources of information.
The source data in the brackets typically following the text that describes the illustration is set out as follows:

- (product name, source), e.g.: (Speedmaster CD 102-6, Heidelberg);
- (product, source 1/source 2), e.g.: (Trendsetter 3244, Heidelberg/Creo);
- (product 1/ product 2, source 1/source 2), e.g.: (QM DI 46-4/DP9500, Heidelberg/Kodak).

Due to the amount of space required and in the interests of consistency, the shortened forms of the product, company, and organization names are usually given.

In the majority of cases the full name of the company or organization can easily be determined from the shortened form since the shortened form usually also forms part of the company name. Additional information on organizations can also be found in the lists in sections 14.5 and 14.6.

Around two hundred different companies are referred to directly in the source reference information. A small selection of shortened forms and full names is listed below.

This selection covers companies referred to relatively frequently, company names that are more difficult to determine from the shortened form, companies that may be less familiar and any possible ambiguities. This list by no means represents a comprehensive or complete classification of the sources and implies no ranking.

Names are given in the alphabetical order of the shortened form. Address details have not been included (with a few exceptions).

Shortened Form	Full Name
ADAST	Adast Blansko AS (Blansko, Czech Republic)
AGFA	Agfa-Gevaert N.V.
Barco	Barco Graphics NV (Gent, Belgium)
BASF	BASF Drucksysteme GmbH
Creo	Creo Products, Inc.
Datametrics	Datametrics Systems Corporation (Chatsworth (CA), USA)
Domino	Domino Amjet, Inc.
Elcorsy	Elcorsy Technology, Inc. (Montreal, Canada)
G & D	Giesecke & Devrient GmbH
GOSS	Goss Graphic Systems, Inc.
Gretag	Gretag-Macbeth AG
Heidelberg	Heidelberger Druckmaschinen AG
Hirose	Hirose Electric Co., Ltd. (Tokyo, Japan)
HP	Hewlett-Packard Company
KBA	Koenig & Bauer AG
Kodak	Eastman Kodak Company
KPG	Kodak Polychrome Graphics
MAN Roland	MAN Roland Druckmaschinen AG
Matan	Matan Digital Printing, Ltd. (Petach-Tikva, Israel)
MIT	Massachussetts Institute of Technology
Océ	Océ Printing Systems GmbH (Poing, Germany) Océ-Netherlands B.V. (Venlo, Netherlands)
PGI	Polaroid Graphics Imaging
Presstek	Presstek, Inc. (Hudson (NH), USA)
Scitex/KBA	Karat Digital Press GmbH
Screen	Dainippon Screen Mfg. Co., Ltd.
Spectra	Spectra, Inc. (Hanover (NH), USA)
W & H	Windmöller & Hölscher KG

Further Reading for 14.1.1

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14.2 Physical/Technical Quantities and Conversions

14.2.1 Quantities and Units in the SI-System (Selection)

(SI: Système International; International System of Units)

Quantity	Abbreviation (usual)	Unit	Name
Base quantities of the SI-system:			
Length	l	m	Meter
Mass	m	kg	Kilogram
Time	t	s	Second
Luminous intensity	I	cd	Candela
Electric current	I	A	Ampere
Amount of substance	n	mol	Mol
Temperature	T	K	Kelvin
Temperature in degrees Centigrade (°C) = Temperature in Kelvin –273.2			
Mechanics:			
Velocity	v	m/s	Meters per second
Acceleration	a	m/s^2	
Force	F	N	Newton
Torque	M	N · m	
Work, energy	W, A	J = N · m	Joule
Power	P	W = J/s	Watt
Pressure	p	$Pa = N/m^2$	Pascal
Stress	σ	$Pa = N/m^2$	Pascal
Strain	ε	‰	per mil
Young's modulus	E	N/mm^2	
Density	ϱ	kg/m^3, kg/dm^3	
Coefficient of friction	μ	–	
Number of revolutions	n	s^{-1}	Revolutions per second
Frequency	f	Hz	Hertz, cycles per seconds
Spring constant	c	N/m	
Viscosity, dynamic	η	Pa · s	Pascal · second (1 Pa · s represents 10 Poise)
Viscosity, kinematic	ν	m^2/s	(dyn. viscosity/density)
Optics:			
Luminous flux	ϕ	lm = cd · sr	Lumen, Candela · Steradiant
Illuminance	E	$lx = lm/m^2$	Lux
Luminous exposure	H	lx · s	
Gradation	γ	–	Gamma

Quantity	Abbreviation (usual)	Unit	Name
Optics: (continued)			
Wavelength	λ	nm	Nanometer
Reflectance factor	β	–	
Transmittance	τ	–	
Absorptance	α	–	
Focal length	f	mm	
Refractive index	n	–	
Electrotechnology:			
Voltage	U	V	Volt
Charge	Q	C	Coulomb
Resistance	R	Ω	Ohm
Electric field strength	E	V/m	Volts per meter
Magnetic field strength	H	A/m	Ampere per meter
Polarization	P	C/m^2	Coulomb per square meter
Information technology:			
Unit of information		bit	Bit (8 bit = 1 byte)
Transfer rate of communication channels	Bd	bit/s	Bits per second (Baud)
Printing technology:			
Addressability (resolution)	–	dpi	Dots per inch
Ink-splitting factor	α	–	
Optical density	D	–	
Halftone value	φ	–	
Area coverage value (halftone value)	F	%	
Resolution	R	L/cm, cm^{-1}, dpi	Lines per centimeter, dots per inch
Spatial frequency	f_s	cm^{-1}, lpi	lines per centimeter
Screen frequency (Screen ruling)	f_s, L	cm^{-1}, lpi	Lines per centimeter, lines per inch
Contrast	K	–	rel. contrast in printing
Lightness	L	–	
Hue	h	°	Hue angle
Chroma	C	–	
Color location (CIE)	Y, x, y	–	
Color location (CIELab)	L*, a*, b*	–	
Color location (CIELCH)	L*, C*, h*	–, –, °	
Color difference	ΔE	–	
Color temperature	T	K	Kelvin
Surface tension	σ	N/m	
Water hardness	H	°d	German water hardness
pH value	pH	–	
Grammage	m_A	g/m^2	Grams per square meter
Hardness (of elastomers)	HS	Shore (A or D)	Shore A or Shore D
Web tension	σ_B	N/cm	Force per length unit (of web width)

Exponents on the Basis of 10

(Prefixes of the SI-system)

Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deca	da
10^{0}	–	–
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

Paper Sizes/Formats

A-Format. The basic sheet of the A series, size A0, has an area of one square meter. The proportion of the sheet sides are 1 to 1.414 (1 to $\sqrt{2}$).

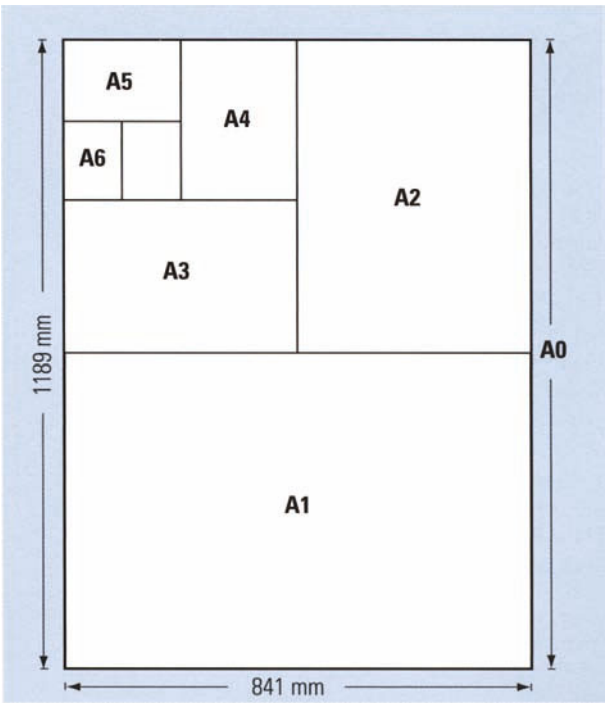
B-Format. B sheet dimensions are used when the change in size between two A sheets is too great. B sheet dimensions fall about halfway between A sheets. The proportion of the sheet sides is also 1 to 1.414.

These paper sheet sizes are based on the ISO Standardization (ISO 216). There are additional standards on the market which vary from country to country.

A-Format		
Size	**Millimeters**	**Inches** (approx.)
A0	841 × 1189	33⅛ × 46¾
A1	594 × 841	23⅜ × 33⅛
A2	420 × 594	16½ × 23⅜
A3	297 × 420	11¾ × 16½
A4	210 × 297	8¼ × 11¾
A5	148 × 210	5⅞ × 8¼
A6	105 × 148	4⅛ × 5⅞
B-Format		
Size	**Millimeters**	**Inches** (approx.)
B0	1000 × 1414	39⅜ × 55⅝
B1	707 × 1000	27⅞ × 39⅜
B2	500 × 707	19⅝ × 27⅞
B3	353 × 500	12⅞ × 19⅝
B4	250 × 353	9⅞ × 12⅞
B5	176 × 250	7 × 9⅞
B6	125 × 176	5 × 7

Further Formats	
• letter size	216 mm × 280 mm, 8½"×11"
• legal size	216 mm × 356 mm, 8½"×14"
• double letter	280 mm × 432 mm, 11" ×17"
• executive	184 mm × 267 mm, 7¼"×10½"

Selection of Typical Newspaper Formats (size of the page)	
• Berlin	315 (320) mm × 470 mm
• Rheinisch	350 mm × 510 mm
• Nordic	400 mm × 560 mm
• American	320 up to 420 mm × 578 mm (usual width 346 mm)
• Asian	440 mm × 546 mm



14.2.2 Conversion between the SI-System and the Imperial System (Metric/Imperial)

Quantity	SI-System	US-System (Imperial)	Name	US-System	SI-System
Length	1 mm	0.03937 in	inch (")	1 in	25.4 mm
	1 m	3.28084 ft	foot (')	1 ft (1 ft = 12 in)	0.3048 m
	1 km	0.62138 mile	mile	1 mile	1.60934 km
	1 m	1.0936 yd	yard	1 yd	0.9144 m
	1 µm	0.0394 mil	mil (1 mil = 1/1000 in)	1 mil	25.4 µm
Area	1 cm^2	0.15500 in^2	square inch	1 in^2	6.4516 cm^2
	1 m^2	10.76391 ft^2	square foot	1 ft^2	0.09290 m^2
Volume	1 cm^3	0.06102 in^3	cubic inch	1 in^3	16.38706 cm^3
	1 m^3	35.31467 ft^3	cubic foot	1 ft^3	0.02832 m^3
	1 dm^3	0.21997 UK gal	UK gallon	1 UK gal	4.5461 dm^3
	1 dm^3 (=1 l)	0.26417 US gal	US gallon 1 US gal = 231 in^3	1 US gal	3.78541 dm^3
	1 dm^3	61.0234 in^3	cubic inch	1 in^3	0.01639 dm^3
	1 dm^3	1.7598 pint	pint	1 pint	0.56826 dm^3
Velocity (distance/time)	1 m/s	3.28084 fps	feet per second	1 fps	0.3048 m/s
	1 m/min	3.28084 fpm	feet per minute	1 fpm	0.3048 m/min
	1 km/h	0.62138 mph	miles per hour	1 mph	1.6093 km/h
Mass	1 kg	2.20462 lb	pound	1 lb	0.45359 kg
	1 g	0.56439 dr	dram	1 dr	1.7718 g
	1 g	0.03527 oz	ounce	1 oz	28.3495 g
Force	1 N	0.22481 lbf	pound force	1 lbf	4.44822 N
Pressure	1 N/cm^2	1.45038 lbf/in^2	pound force per square inch	1 lbf/in^2	0.68948 N/cm^2
	1 N/cm^2	0.02089 lbf/ft^2	pound force per square foot	1 lbf/ft^2	47.88025N/m^2
	(1 daN/cm^2	0.2089 lbf/ft^2)		(1 lbf/ft^2	4.78803 daN/m^3)
	1 Pa	1.45038×10^{-4} psi	pound force per square inch	1 psi	6894.757 Pa
	(1 bar	14.50377 psi)		(1 psi	0.06894 bar)
Power	1 kW	1.34102 hp	horse power	1 hp	0.74570 kW
	1 kJ/h	0.94781 BTU/h	British Thermal Unit per hour	1 BTU/h	1.05505 kJ/h
Density (mass/volume)	1 kg/dm^3	0.03613 lb/in^3	pound per cubic inch	1 lb/in^3	27.6799 kg/dm^3
Grammage (mass/area)	1 kg/m^2	0.2048 lb/ft^2	pound per square foot	1 lb/ft^2	4.882 kg/in^2

Conversion of Centigrade (°C) in Fahrenheit (°F) and vice versa:
$°C = (°F - 32)/1.8$
$°F = 1.8 \times °C + 32$

14.3 Bibliography

The bibliography in 14.3.1 is based on the structure of this book and gives the page numbers where the listings of the corresponding bibliographical references (quotes in the text/references and/or further reading) start.

Section 14.3.2 contains a consolidated list of selected further reading that deals with individual subjects in more detail. This list includes selected references and readings that were given in the chapters themselves and extra bibliographic references dealing with a broad field of subjects (giving an overview), as well as literature on specific topics. The list is sorted in alphabetical order.

14.3.1 List of References to Readings on the Chapters and Sections in this Handbook

Topic	*Page*	
1	**Fundamentals**	
1.1	Communication Technologies	13
1.2	Production of Print Media	39
1.3	Printing Technologies	67
1.4	Print Quality	115
1.5	Print Media Materials	144
1.6	Printing Presses and Printing Systems	165
1.7	Drying Methods	179
1.8	Products of Print Finishing	
1.9	Aspects of Management and Business Models	202
2	**Printing Technologies with Permanent Printing Master**	
2.1	Offset Printing	358
2.2	Gravure Printing	394
2.3	Letterpress Printing	408
2.4	Screen Printing	422
2.5	Special Printing Technologies and Product Specific Applications	448
3	**Prepress**	
3.1	Conventional Prepress	502
3.2	Digital Prepress	577
4	**Computer to ... Technologies**	
4.1	Survey of the Technologies	592
4.2	Computer to Film	596
4.3	Computer to Plate/to Cylinder/to Screen	625
4.4	Computer to Press/Direct Imaging	656
4.5	Computer to Print	674
5	**Printing Technologies without a Printing Plate (NIP Technologies)**	
5.1	Principles and Basic Components	688
5.2	Electrophotography	700
5.3	Ionography	
5.4	Magnetography	
5.5	Ink Jet	730
5.6	Thermography	741
5.7	Electrography	745
5.8	Photography	748
5.9	"X"-Graphy	757
6	**Hybrid Printing Systems**	
6.1	Overview of Printing Methods and Technologies	762
6.2	Combination Variants of Hybrid Printing Systems	764
6.3	System Concepts and Examples of Implementations	770
6.4	Hybrid Techniques for In-line and Off-line Print Production	
7	**Print Finishing Processes**	
7.1	Classification of Print Finishing Processes	781
7.2	Process Steps and Procedures for Print Finishing	861
7.3	Process Structuring in Print Finishing	901

	Topic	Page
8	**Material and Data Flow in Print Media Production**	
8.1	Material Logistics	922
8.2	Networking and Data Flow	936
9	**Production Strategies for Print Media**	
9.1	Production Concepts	951
9.2	Production Systems	
10	**Comparison of Printing and Production Technologies for Print Media**	
10.1	Introduction	
10.2	Overview of Methods and Technologies for the Production of Print Media	
10.3	Production Methods and Strategies	
10.4	Criteria for the Selection of Printing Technologies and Production Methods	
10.5	Performance Criteria of Printing Systems and Trends in Print Media Production	
11	**Electronic Media and Multimedia**	
11.1	Media Concepts	984
11.2	Data Types, Data Structures and their Applications	992
11.3	Data Carriers	
11.4	Networks	997
11.5	Data Compression	1000
11.6	Output Devices for Electronic Media and Multimedia	1003
11.7	Multimedia Applications	
12	**Print Media and Electronic Media**	
12.1	Examples of Print Media and Electronic Media	
12.2	The Production of Print Media and Electronic Media	
12.3	"Electronic" Books, "Electronic" Ink, "Electronic" Paper	1019
12.4	Market Shares and Trends	
13	**Special Topics**	
13.1	History	1074
	Education	1074, 1075
	Research	1074, 1075
13.2	Environment	1100, 1101
	Safety	1100
	Standardization	1101
13.3	Markets and Development Trends for Print Media	1110
14	**Appendix**	
14.1	Explanation of Specific Terms	1129
14.2	Physical/Technical Quantities and Conversions	
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14.4	Standards (Selection)	1143
14.5	Research Associations and Educational Institutions for the Graphic Arts Industry (Selection)	
14.6	Associations and Organizations in the Printing and Publishing Industry (Selection)	
14.7	International Conferences for the Graphic Arts Industry (Selection)	

14.3.2 Selected Literature on Print Media related Topics (General Bibliography and Individual Topics)

The following is only a selection and by no means a complete list of all relevant titles. It is merely a selection of material and regular additions should be made.

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14.4 Standards (Selection)

This section provides a structured listing of standards applicable to the fields of graphic arts technology and quality. In the main it is multinational standards that are covered (some German standards are also mentioned [14.4-1]). The ISO (International Standard) standards are listed first in numerical order, followed by EN (European), and finally the DIN (German) standards. The most important American ANSI standards for print media production that are of international importance have already been converted into ISO standards, and are only listed with their ISO equivalent. We recommend that readers get to know the current status of the standards and their sources with the assistance of database services or the Internet [14.4-2 to 14.4-9]. Section 13.2.3 provides an introduction to standardization.

The following lists give the origin of the standard and its number in each case. If there are several abbreviations – such as DIN EN ISO or EN ISO – the standard has been accepted in the same form word for word or in a translated form by these standards institutions; in this case DIN, CEN (European Committee for Standardization) and ISO. The effective (current) version of the standard is to be applied.

If a work instruction relates to a standard and the latter's date of publication is not expressly stated, then the latest version of this standard must be used. Other versions should only be used if this is especially requested by stating the publication date; in this case this is a "dated reference." ISO standards that are designated ISO/DIS (DIS: Draft International Standard) and ISO/FDIS (FDIS: Final Draft International Standard) are technically perfect drafts, which can already be obtained from the relevant national institutions or from ISO. The number of a part of a standard is separated by a dash from the number of the standard, and this may be followed by the year of publication.

The *ISO standards marked with an asterisk (*)* refer to a corresponding ANSI/US standard.

14.4.1 Prepress

ISO 3664: Viewing conditions – for graphic technology and photography (1999).
ISO 5776: Graphic technology – Symbols for text correction (Trilingual edition), (1983).
ISO 10755: Graphic technology – Prepress digital data exchange – Colour picture data on magnetic tape (1992).
ISO 10756 *: Graphic technology – Prepress digital data exchange – Colour line art data on magnetic tape (1994), (ANSI IT8-2:1988).
ISO 10758 *: Graphic technology – Prepress digital data exchange – Online transfer from electronic prepress systems to colour hardcopy devices (1994), (ANSI IT8-4:1989).
ISO 10759 *: Graphic technology – Prepress digital data exchange – Monochrome image data on magnetic tape (1994), (ANSI IT8-5:1990).
ISO 11084-1: Graphic technology – Register systems for photographic materials, foils and paper – Part 1: Three pin systems (1993).
ISO 12639: Graphic technology – Prepress digital data exchange – Tag Image File Format for Image Technology (TIFF/IT), (1998).
ISO 12640: Graphic technology – Prepress digital data exchange – CMYK standard colour image data (CMYK/SCID), (1997).
ISO 12641 *: Graphic technology – Prepress digital data exchange – Colour targets for input scanner calibration (1997), (also US standard).
ISO 12642 *: Graphic technology – Prepress digital data exchange – Input data for characterization of four colour process printing (1996), (also US standard).
DIN 16507-1: Drucktechnik – Schriftgrößen, Maße und Begriffe – Teil 1: Bleisatz und verwandte Techniken (1998).

DIN 16507-2: Drucktechnik – Schriftgrößen – Teil 2: Digitaler Satz und verwandte Techniken, Maße und Begriffe (draft), (1999).
DIN 16511: Korrekturzeichen (equivalent to ISO 5776), (1966).
DIN 16515-2: Farbbegriffe im graphischen Gewerbe; Photographie (1963).
DIN 16521: Linien im graphischen Gewerbe, Arten und Dicken (1959).
DIN 16543: Aufsichts-Grauskala für die Reproduktionstechnik, 14stufig (1963).
DIN 16544: Drucktechnik; Begriffe der Reproduktionstechnik (1988).
DIN 16547: Rasterwinkelungen bei der Farben – Rasterreproduktion (1983).
DIN 16549-1: Drucktechnik – Druckvorstufe – Teil 1: Korrekturzeichen für Bild und ergänzende Angaben (1996).
DIN 16553: Druck- und Reproduktionstechnik, Paßsystem (1985).
DIN 16604: Zeitungen; Papierformate, Anzeigen-Satzspiegel, Anzeigen-Spaltenbreite, Anzeigenspalten-Zwischenschlag (draft), (1991).

14.4.2 Printing Inks

ISO 2834: Printing inks – Preparation of standardized prints for determination of resistance to physical and chemical agents (1981).
ISO 2835: Prints and printing inks – Assessment of light fastness (1974).
ISO 2836: Graphic technology – Prints and printing inks – Assessment of resistance to various agents (1999).
ISO 2837: Graphic technology – Prints and printing inks – Assessment of resistance to solvents (1996).
ISO 2838: Prints and printing inks – Assessment of resistance to alkalis (1974).
ISO 2839: Prints and printing inks – Assessment of resistance to soaps (1974).
ISO 2840: Prints and printing inks – Determination of the resistance of prints to detergents (1974).
ISO 2841: Prints and printing inks – Determination of the resistance of prints to cheese (1974).
ISO 2842: Prints and printing inks – Determination of the resistance of prints to edible oils and fats (1974).
ISO 2843: Prints and printing inks – Determination of the resistance of prints to impregnation by wax or paraffin wax (1974).
ISO 2844: Prints and printing inks – Determination of the resistance of prints to spices (1974).
ISO 2846-1: Graphic technology – Colour and transparency of ink sets for four-colour printing – Part 1: Sheet-fed and heat-set web offset lithographic printing (1997).
ISO 2846-2: Graphic technology – Colour and transparency of printing ink sets for four-colour-printing – Part 2: Coldset offset lithographic printing (2000).
ISO 2846-4: Graphic technology – Colour and transparency of ink sets for four-colour-printing – Part 4: Screen printing (2000).
ISO 5736: Prints – Determination of resistance to sterilization of prints on metallic substrates (1983).
ISO 5737: Prints – Preparation of standard prints for optical tests (1983).
ISO 11628: Graphic technology – Prints and printing inks – Determination of resistance of prints to acids (1995).
ISO 12040: Graphic technology – Prints and printing inks – Assessment of light fastness using filtered xenon arc light (1997).
ISO/DIS 12632: Graphic technology – Prints and printing inks – Assessment of penetrability, detachment and resistance of printed labels to hot alkaline solution (1996).
ISO 12634: Graphic technology – Determination of tack of paste inks and vehicles by a rotary tackmeter (1996).
ISO 12644: Graphic technology – Determination of rheological properties of paste inks and vehicles by the falling rod viscometer (1996).
DIN 16508: Farbskala für den Buchdruck, außerhalb der europäischen Farbskala; Normdruckfarben und Druckreihenfolge (1967).
DIN 16509: Farbskala für den Offsetdruck, Normfarben (1965).
DIN 16513: Reintoluol als Lösemittel für Tiefdruckfarben (1993).
DIN 16519: Prüfung von Drucken und Druckfarben des graphischen Gewerbes; Herstellung von Norm-Druckproben (1967).
DIN 16519-2: Prüfung von Drucken und Druckfarben, Herstellung von Norm-Druckproben für optische Messungen (1985).
DIN 16524-1: Prüfung von Drucken und Druckfarben der Drucktechnik, Widerstandsfähigkeit gegen verschiedene physikalische und chemische Einflüsse –

Teil 1: Wasser-Echtheit, Lösemittel-Echtheit (1994), (equivalent to ISO 2837).
DIN 16524-2: Prüfung von Drucken und Druckfarben des graphischen Gewerbes; Widerstandsfähigkeit gegen verschiedene physikalische und chemische Einflüsse, Alkali-Echtheit, Seifen-Echtheit, Waschmittel-Echtheit (1965).
DIN 16524-3: Prüfung von Drucken und Druckfarben des graphischen Gewerbes; Widerstandsfähigkeit gegen verschiedene physikalische und chemische Einflüsse, Käse-Echtheit, Speisefett-Echtheit, Paraffin- und Wachs-Echtheit, Gewürz-Echtheit (1965).
DIN 16524-5: Prüfung von Drucken und Druckfarben der Drucktechnik – Widerstandsfähigkeit gegen verschiedene physikalische und chemische Einflüsse – Teil 5: Autoklaven-Sterilisierbeständigkeit (1998).
DIN 16524-6: Prüfung von Drucken und Druckfarben der Drucktechnik – Widerstandsfähigkeit gegen verschiedene physikalische und chemische Einflüsse – Teil 6: Verhalten von Getränkeflaschenetiketten gegen heiße Reinigungslauge, Laugendurchdringung und Ablösezeit (1996), (equivalent to ISO/DIS 12632).
DIN 16524-7: Prüfung von Drucken und Druckfarben der Drucktechnik – Widerstandsfähigkeit gegen verschiedene physikalische und chemische Einflüsse – Teil 7: Verhalten von Getränkeflaschenetiketten gegen heiße Waschlauge, Laugenbeständigkeit (1996).
DIN 16525: Prüfung von Drucken und Druckfarben des graphischen Gewerbes – Widerstandsfähigkeit gegen verschiedene physikalische und chemische Einflüsse, Lichtechtheit (1965), (equivalent to ISO 12040).
DIN 16526: Druckfarben für die Drucktechnik – Kennzeichnung der Eigenschaften der Druckfarben für Hoch- und Flachdruck auf dem Etikett (1994).
DIN 16538: Europäische Farbskala für den Buchdruck; Normdruckfarben und Druckreihenfolge (1969).
DIN 16539: European process colours for offset printing; standard inks (1971).
DIN 55943: Farbmittel; Begriffe (1993).
DIN 55944: Colouring materials; classification according to colouristic and chemical aspects (1990).

14.4.3 Substrates

EN ISO 536: Paper and board – Determination of grammage (1996).
EN ISO 1924-2: Paper and board – Determination of tensile properties – Part 2: Constant rate of elongation method (1995), (ISO 1924-2:1994).
ISO 8226-1: Paper and board – Measurement of hygroexpansivity – Part 1: Hygroexpansivity up to a maximum relative humidity of 68% (1994).
ISO 8226-2: Paper and board – Measurement of hygroexpansivity – Part 2: Hygroexpansivity up to a maximum relative humidity of 86% (1990).
ISO 8254-1: Paper and board – Measurement of specular gloss – Part 1: 75° gloss (1999).
ISO 8791-1: Paper and board – Determination of roughness/smoothness (air leak methods) – Part 1: General method (1986).
ISO 8791-2: Paper and board – Determination of roughness/smoothness (air leak methods) – Part 2: Bendtsen method (1990).
ISO 8791-3: Paper and board – Determination of roughness/smoothness (air leak methods) – Part 3: Sheffield method (1990).
ISO 8791-4: Paper and board – Determination of roughness/smoothness (air leak methods) – Part 4: Print-surf method (1992).
ISO 9706 *: Information and documentation – Paper for documents – Requirements for permanence (ANSI/NISO Z39.48: 1992), (1994).
EN 644: Paper; untrimmed sizes; primary range and supplementary range designation; expression of direction of manufacture (1993).
EN 645: Paper and board intended to come into contact with foodstuffs; preparation of a cold water extract (1993).
EN 646: Paper and board intended to come into contact with foodstuffs; determination of color fastness of dyed paper and board (1993).
EN 647: Paper and board intended to come into contact with foodstuffs; preparation of a hot water extract (1993).
EN 648: Paper and board intended to come into contact with foodstuffs; determination of the fastness of fluoroescent whitened paper and board (1993).
EN 920: Paper and board intended to come into contact with foodstuffs – Determination of dry matter content in an aqueous extract (1998).

EN 1104: Paper and board intended to come into contact with foodstuffs – Determination of transfer of antimicrobic constituents (1995).
ENV 12281: Paper – Printing and business paper – Requirements for copy paper for dry toner imaging processes (1996).
EN 20187: Paper, board, and pulps; standard atmosphere for conditioning and testing and procedure for monitoring the atmosphere and conditioning of samples (1993), (ISO 187:1990).
EN 20287: Paper and board – Determination of moisture content – Oven-drying method (1994), (ISO 287:1985).
EN 20534: Paper and board; determination of thickness and apparent bulk density or apparent sheet density (1993), (ISO 534:1988).
EN 20535: Paper and board – Determination of water absorptiveness – Cobb method (1994), (ISO 535:1991).
EN 25651: Paper, board and pulps; units for expressing properties (1993), (ISO 5651:1989).
DIN 6721-1: Papiere für die Datenverarbeitung; 40 bis 90 g/m² Papier für Endlosvordrucke, ungestrichen, unbeschichtet; Anforderungen, Prüfung (1986).
DIN 6721-2: Papiere für die Datenverarbeitung; 40 bis 90 g/m² Papier für Endlosvordrucke – Teil 2: Selbstdurchschreibend; Anforderungen, Prüfung (2000).
DIN 6723-1: Papers for data processing – Paper for document reader sorter 90 g/m² substance – Part 1: Uncoated, untreated; requirements, test requirements (1997).
DIN 6723-2: Papers for data processing – Paper for document reader sorter 90 g/m² substance – Part 2: Coated, treated, self copying; requirements, test method (1997).
DIN 6724-1: Papers for data processing – Paper for document reader sorter 65 to 85 g/m² substance – Part 1: Uncoated, untreated; requirements, test method (1997).
DIN 6724-2: Papers for data processing – Paper for document reader sorter 65 to 85 g/m² substance – Part 2: Coated, treated, self copying; requirements, test method (1997).
DIN 6730: Paper and board – Vocabulary (trilingual), (2000).
DIN 19302: Packstoffe – Papiere für allgemeine Verpackungszwecke – Anforderungen, Prüfung (1995).
DIN 19306: Uncoated printing papers; letterpress paper, offset paper, rotogravure paper; technical conditions of delivery (1977).
DIN 53107: Prüfung von Papier und Pappe; Bestimmung der Glätte nach Bekk (1982).
DIN 53130: Testing of paper and board; determination of dimensional stability (1978).
DIN 53140: Prüfung von Papier und Pappe; Bestimmung von Normfarbwerten nach dem Dreibereichsverfahren (1992).
DIN 53145-1: Prüfung von Papier und Pappe; Meßgrundlagen zur Bestimmung des Reflexionsfaktors; Messung von nicht fluoreszierenden Proben (1992).
DIN 53145-2: Prüfung von Papier und Pappe; Meßgrundlagen zur Bestimmung des Reflexionsfaktors; Messung an fluoreszierenden Proben (1992).
DIN 53146: Prüfung von Papier und Pappe; Bestimmung der Opazität (1993).
DIN 53147: Testing of paper; determination of transparency (1993).

14.4.4 Materials (Printing Plates, Blankets)

ISO 12635: Graphic technology – Plates for offset printing – Dimensions (1996).
ISO 12636: Graphic technology – Blankets for offset printing (1998).
DIN 16620-1: Drucktechnik – Druckplatten für den indirekten Flachdruck (Offsetdruck) – Teil 1: Maße (1994).
DIN 16621: Printing technology; blankets for offset printing; terms, specifications, testing, marking (1991).

14.4.5 Printing Technologies and Printing Presses

ISO 4218-1: Printing machines – Vocabulary – Part 1: Fundamental terms (Bilingual edition; Remark: new version under discussion) (1979).
ISO 12637-2: Graphic technology – Multilingual terminology of printing arts – Part 2: Screen printing terms (1997).
DIN 16500: Drucktechnik (Technik des Druckens); Grundbegriffe (1979).
DIN 16500-2: Drucktechnik; Verfahrensübergreifende Begriffe (1987).

DIN 16514: Drucktechnik; Begriffe für den Hochdruck (1982).
DIN 16609: Drucktechnik; Durchdruck; Begriffe (1981).
DIN 16610: Drucktechnik; Durchdruck; Begriffe für den Siebdruck (1984).

14.4.6 Finishing

DIN 16500-11: Drucktechnik (Technik des Druckens) – Teil 11: Druckweiterverarbeitung, Begriffe (1994).

14.4.7 Quality, Quality Specifications, and Measurement Techniques

CIE 15.2: Colorimetry; Second edition (1986).
ISO 5-1: Photography – Density measurements – Part 1: Terms, symbols and notations (Trilingual edition), (1984).
ISO/DIS 5-2: Photography – Density measurements – Part 2: Geometric conditions for transmission density (1999).
ISO 5-3: Photography – Density measurements – Part 2: Spectral conditions (1995).
ISO 5-4: Photography – Density measurements – Part 4: Geometric conditions for reflexion density (1995).
EN ISO 9000-1: Quality management and quality assurance standards – Part 1: Guidelines for selection and use (ISO 9000-1:1994); trilingual version (1994).
EN ISO 9000-3: Quality management and quality assurance standards – Part 3: Guidelines of the application of ISO 9001:1994 to the development, supply, installation and maintenance of computer software (ISO 9000-3:1997); bilingual version (1998).
ISO 9000-4: Quality management and quality assurance standards – Part 4: Guide to dependability programme management (1993).
EN ISO 9001: Quality systems – Model for quality assurance in design/development, production, installation and servicing (ISO 9001:1994); trilingual version (1994).
EN ISO 9002: Quality systems – Model for quality assurance in production, installation and servicing (ISO 9002:1994); trilingual version (1994).
EN ISO 9003: Quality systems – Model for quality assurance in final inspection and test (ISO 9003:1994); trilingual version (1994).
EN ISO 9004-1: Quality management and quality system elements – Part 1: Guidelines (ISO 9004-1:1994); trilingual version (1994).
ISO 9004-2: Quality management and quality system elements – Part 2: Guidelines for services (1991).
ISO 9004-3: Quality management and quality system elements – Part 3: Guidelines for processed materials (1993).
ISO 9004-4: Quality management and quality system elements – Part 4: Guidelines for quality improvement (1993).
ISO 10012-1: Quality assurance requirements for measuring equipment – Part 1: Metrological confirmation system for measuring equipment (1992).
ISO 10013: Guidelines for developing quality management manuals (1995).
ISO 12218: Graphic technology – Process control of platemaking (1997).
ISO 12645: Graphic technology – Test methods for measuring transmission density on half-tone images (1996).
ISO 12647-1: Graphic technology – Process control for the manufacture of half-tone colour separations, proof and production prints – Part 1: Parameters and measurement methods (1996).
ISO 12647-2: Graphic technology – Process control for the manufacture of half-tone colour separations, proof and production prints – Part 2: Offset lithographic processes (1996).
ISO 12647-3: Graphic technology – Process control for the manufacture of half-tone colour separations, proofs and production prints – Part 3: Coldset offset lithography and letterpress on newsprint (1998).
ISO 12647-4: in preparation: Graphic technology – Process control for the manufacture of half-tone colour separations, proofs and production prints – Part 4: Publication gravure printing.
ISO/DIS 12647-5: Graphic technology – Process control for the manufacture of half-tone colour separations, proofs and production prints – Part 5: Screen printing (2000).
ISO 12647-6: in preparation: Graphic technology – Process control for the manufacture of half-tone colour separations, proofs and production prints – Part 6: Flexographic printing.
ISO 12647-7: in preparation: Graphic technology – Process control for the manufacture of half-tone colour separations, proofs and production prints – Part 7: Digital printing.

ISO 13655 *: Graphic technology – Spectral measurement and colorimetric computation for graphic arts images (1996), (also US standard).
ISO 13656: Graphic technology and photography – Application of reflection densitometry and colorimetry to process control in the graphic arts measurements (1999).
ISO/DIS 15790: Graphic technology – Certified reference materials for reflection and transmission metrology – Documentation requirements and recommended procedures (1998).
DIN 4512-7: Photographische Sensitometrie; Bestimmung der optischen Dichte; Begriffe, Symbole und Kennzeichnungen (1993); ISO 5-1:1984.
DIN 4512-8: Photographische Sensitometrie; Bestimmung der optischen Dichte; Geometrische Bedingungen für Messungen bei Transmission (1993); ISO 5-2:1993.
DIN 4512-9: Photographische Sensitometrie; Bestimmung der optischen Dichte; Spektrale Bedingungen (1993); ISO 5-3:1995.
DIN 4512-10: Photographische Sensitometrie; Bestimmung der optischen Dichte; Geometrische Bedingungen für Messungen bei Reflexion (1993); ISO 5-4:1995.
DIN 5033-1: Farbmessung; Grundbegriffe der Farbmetrik (1979).
DIN 5033-2: Farbmessung; Normvalenz-Systeme (1992).
DIN 5033-3: Farbmessung; Farbmaßzahlen (1992).
DIN 5033-4: Farbmessung; Spektralverfahren (1992).
DIN 5033-5: Colorimetry by visual matching (1981).
DIN 5033-6: Colorimetry; tristimulus method (1976).
DIN 5033-7: Colorimetry; measuring conditions for object colours (1983).
DIN 5033-8: Colorimetry; measuring conditions for light sources (1982).
DIN 5033-9: Colorimetry; reflectance standard for colorimetry and photometry (1982).
DIN 5035-6: Artificial lighting; measurement and evaluation (1990).
DIN 6169-1: Colour rendering; general terms (1976).
DIN 6169-2: Colour rendering; colour rendering properties of light sources in the field of lighting (1976).
DIN 6169-5: Farbwiedergabe; Verfahren zur Kennzeichnung der objektbezogenen Farbwiedergabe im Mehrfarbendruck (1976).
DIN 6169-8: Farbwiedergabe; Verfahren zur Kennzeichnung der farbbildbezogenen Farbwiedergabe im Mehrfarbendruck (1979).
DIN 6172: Metamerie-Index von Probenpaaren bei Lichtartwechsel (1993).
DIN 6173-1: Colour matching; general rules (1975).
DIN 6173-2: Colour matching; lighting conditions for average artificial daylight (1983).
DIN 6174: Colorimetric evaluation of colour differences of surface colours according to the CIELAB formula (1979).
DIN 16527-1: Drucktechnik; Kontrollfeld, Kontrollbild, Kontrollmarke; Grundbegriffe (1993).
DIN 16527-3: Drucktechnik – Kontrollfelder – Anwendung im Druck (1993).
DIN 16528: Drucktechnik; Begriffe für den Tiefdruck (1988).
DIN 16529: Drucktechnik; Begriffe für den Flachdruck (1982).
DIN 16536-1: Prüfung von Drucken und Druckfarben der Drucktechnik – Farbdichtemessung an Drucken – Teil 1: Begriffe und Durchführung der Messung (1997).
DIN 16536-2: Prüfung von Drucken und Druckfarben der Drucktechnik – Farbdichtemessung an Drucken – Teil 2: Anforderungen an die Meßanordnung von Farbdichtemeßgeräten und ihre Prüfung (1995).
DIN 16537: Prüfung von Drucken und Druckfarben der Drucktechnik – Bestimmung der visuellen Glanzzahl von Drucken (1998).
DIN 16545: Durchsichts-Grauskala für die Reproduktionstechnik, 20stufig (1960).
DIN 16600: Drucktechnik; Flächendeckungsgrad von Rastertonwerten auf transparentem Material in der Reproduktionstechnik (1991).
DIN 16611: Drucktechnik; Meßgrößen im Siebdruck (1990).
DIN 16620-2: Drucktechnik; Druckplatten für den indirekten Flachdruck (Offsetdruck), Druckformherstellung, Begriffe und meßtechnische Zusammenhänge (1991).
DIN 16620-3: Drucktechnik; Druckplatten für den indirekten Flachdruck (Offsetdruck); Einrichten und Druck; Begriffe (1993).
DIN 67530: Reflectometer as a means for gloss assessment of plane surfaces of paint coatings and plastics (1982).

14.4.8 Safety of Machinery

There are numerous national directives and directives of various associations, e.g., in the EU member states, on safety of machinery that must be taken into account and applied as mentioned in section 13.2.2.

EN 292-1: Safety of machinery – Basic concepts, general principles for design – Part 1: Basic terminology, methodology (1991), (ISO/TR 12100-1:1992).
EN 292-2: Safety of machinery – Basic concepts, general principles for design – Part 2: Technical principles and specifications (1995).
EN 294: Safety of machinery – Safety distances to prevent danger zones from being reached by the upper limbs (1992), (ISO 13852:1996).
EN 953: Safety of machinery – Guards – General requirements for the design and construction of fixed and movable guards (1997).
EN 954-1: Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design (1996), (ISO/IEC DIS 13849-1:1997).
prEN 1010-1: Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 1: Common requirements (1999).
prEN 1010-2: Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 2: Printing and varnishing machines including pre-press machinery (1998).
prEN 1010-3: Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 3: Cutting machines (1998).
prEN 1010-4: Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 4: Bookbinding, paper converting, and finishing machines (1999).
prEN 1010-5: Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 5: Machines for the production of corrugated board and machines for the conversion of flat and corrugated board (1998).
EN 1088: Safety of machinery – Interlocking devices associated with guards – Principles for design and selection (1995), (ISO/FDIS 14119:1997).
EN 60204-1: Safety of machinery – Electrical equipment of machines – Part 1: General requirements (1997), (IEC 60204-1:1997).
EN 60825-1: Safety of laser products – Part 1: Equipment classification, requirement and user's guide (1994), (IEC 60825-1:1993).

14.4.9 Environmental Management

The general aspects of environmental protection in the printing industry are dealt with in section 13.2.1.

ISO 14001: Environmental management systems – Specification with guidance for use (1996).
ISO 14004: Environmental management systems – General guidelines on principles, systems and supporting techniques (1996).
ISO 14010: Guidelines for environmental auditing – General principles (1996).
ISO 14011: Guidelines for environmental auditing – Audit procedures – Auditing of environmental management systems (1996).
ISO 14031: Environmental management – Environmental performance evaluation – Guidelines (1999).
ISO 14040: Environmental management – Life cycle assessment – Principles and framework (1997).
ISO 14041: Environmental management – Life cycle assessment – Goal and scope definition and life cycle inventory analysis (1998).
DIN 33922: Guideline – Environmental reports for the public (1997).
DIN 33923: Guidance for environmental audits – Requirements on check lists for environmental audits (2000).
DIN 33924: Guideline to performing an initial environmental review as part of environmental management activities (1998).
DIN 33926: Umweltmanagement – Produktbezogene Ökobilanzen – Standardberichtsbogen (1998).
DIN 33927: Environmental management – Use of life cycle assessment studies in marketing, advertising and public relations work (2000).

References in 14.4

[14.4-1] DIN-Katalog für technische Regeln 2000. Beuth Verlag, Berlin 2000.
[14.4-2] For ISO: http://www.iso.ch.
[14.4-3] For CIE: http://www.cie.co.at.

[14.4-4] For CEN: http://www.cenorm.be.
[14.4-5] For DIN: http://www.din.de.
[14.4-6] For ANSI: http://www.ansi.org.
[14.4-7] For TAPPI: http://www.tappi.org.
[14.4-8] For ASTM: http://www.astm.org.
[14.4-9] For ICC: http://www.color.org.

14.5 Research Associations and Educational Institutions for the Graphic Arts Industry (Selection)

The following sections 14.5.1 (Universities), 14.5.2 (Research Institutes and Research Centers), and 14.5.3 (Institutions for Teaching/Training and Ecucation) list a selection of addresses of research associations and educational institutions in the graphic arts industry. Some institutions could be assigned to more than one of the three sections. We ask for understanding, should another position in the section give a more appropriate reflection of the contents and responsibilities. Each section is divided into the following regions: Europe, North America, Asia and Australia, and Further Countries. Within each region, the universities and institutions are listed by country in alphabetical order. For each country, the associations are in alphabetical order of the cities, and in the case of the United States, by state.

14.5.1 Universities

A selection of universities offering courses on topics related to print media technology and in some cases also undertaking relevant research is listed below (this list can certainly be complemented and updated regularly).

Europe

Donau-Universität Krems
Abteilung für Telekommunikation, Information und Medien
Dr.-Karl-Dorrek-Straße 30
3500 Krems
AUSTRIA

Technical University of Belorus
(Department of Printing)
ul. Sverdlova, 13 A
220630 Minsk
BELORUS

University of Zagreb
Faculty of Graphic Arts
Getaldiceva 2
10000 Zagreb
REPUBLIC OF CROATIA

University Pardubice
Department of Graphic Arts and Photophysics
Katedra polygrafie a fotofyziky
Doubravice 41
Pardubice – Semtín 533 54
CZECH REPUBLIC

Helsinki University of Technology (HUT)
Laboratory of Graphic Arts Technology
Tekniikantie 3
01250 Espoo 15
FINLAND

Hochschule der Künste Berlin
Fachbereich 5, Institut für Technologie & Planung Druck
Einsteinufer 43–53
10587 Berlin
GERMANY

Technische Universität Chemnitz,
Fakultät für Maschinenbau und Verfahrenstechnik,
Institut für Print- und Medientechnik
Reichenhainer Straße 70
09126 Chemnitz
GERMANY

Technische Universität Darmstadt
Fachbereich Maschinenbau
Institut für Druckmaschinen und Druckverfahren (IDD)
Magdalenenstraße 2
64289 Darmstadt
GERMANY

Technische Universität Darmstadt
Fachbereich Maschinenbau,
Institut für Papierfabrikation (IFP)
Alexanderstraße 8
64283 Darmstadt
GERMANY

Technische Universität Ilmenau
Institut für Medien- und Kommunikations-
wissenschaft i.G.
Postfach 10 05 65
98684 Ilmenau
GERMANY

Gutenberg-Universität Mainz
Institut für Buchwissenschaft
55099 Mainz
GERMANY

Bergische Universität, Gesamthochschule Wuppertal
Fachbereich 5, Kommunikationstechnologie – Druck
Rainer-Gruenter-Straße 21
42119 Wuppertal
GERMANY

Hochschule für Gestaltung
Schloßstraße 31
63065 Offenbach
GERMANY

Moscow State University of Printing Arts
2a Pryanishnikova St.
127550 Moscow
RUSSIA

Technical University Omsk
(Department of Printing)
Prospekt Mira 11
644050 Omsk
RUSSIA

St. Petersburg Institute of the Moscow State University
of Printing
Ul. Dzambula, 13
191180 St. Petersburg
RUSSIA

Slovak University of Technology
Faculty of Chemical Technology
Department of Graphic Arts Technology and Applied
Photochemistry
Radlinskho 9
81237 Bratislava,
SLOVAKIA

ITN Linköping University
Media Technology
601 74 Norrköping
SWEDEN

Royal Institute of Technology (KTH)
Division of Media Technology & Graphic Arts
Drottning Kristinas väg 47
100 44 Stockholm
SWEDEN

Ukraine Academy of Printing Technology
ul. Podgolosko, 19
79020, Ukraine, Ljwow
UKRAINE

North America

Ryerson Polytechnic University
350 Victoria Street
Toronto, Ontario M5B 2K3
CANADA

California State University, Los Angeles
Department of Technology
5151 State University Drive
Los Angeles, California 90032-8154
USA

California Polytechnic State University (CALPOLY)
Graphic Communication Department
1 Grand Ave.
San Luis Obispo, California 93407
USA

Indiana State University
School of Technology (Printing Management)
Terre Haute, Indiana 47809
USA

Murray State University
Department of Printing Management/Graphic Arts
Technology
P.O. Box 9
Murray, Kentucky 42071-0009
USA

Massachusetts Institute of Technology (MIT)
The Media Laboratory
20 Ames Street
Cambridge, Massachusetts 02139
USA

Western Michigan University
Department of Paper, Printing Science and Engineering
1104 Welborn Hall
Kalamazoo, Michigan 49008
USA

Central Missouri State University
Graphic Department
Warrensburg, Missouri 64093
USA

Rochester Institute of Technology (RIT)
(Imaging and Publishing/FIC)
2 Lomb Memorial Drive
Rochester, New York 14623-5604
USA

Carnegie Mellon University
Graduate School of Industrial Administration
(Graphic Communications Management)
RM 135
Pittsburgh, Pennsylvania 15213
USA

Clemson University
Graphic Communications Department
G01 Tillman Hall
Clemson, South Carolina 29634-0711
USA

University of Wisconsin
Stout Graphic Communications Management
Menomonie, Wisconsin 54751
USA

Asia and Australia

University of South Australia
The Levels Campus
Mawson
Lakes Boulevard
Mawson Lakes, SA 5095
AUSTRALIA

Beijing Printing University
Postal Code 102600
Daxing, Beijing
CHINA

Japan Printing Academy (JPA)
Koishikawa 4-13-2,
Bunkyo-ku
Tokyo 112-0002
JAPAN

Chiba University
1-33 Yayoi-cho, Inage-ku
Chiba 263-8522
JAPAN

Tokai University
Hiratsuka-City,
Kanagawa 259-1292
JAPAN

Kyushu Sangyo University
3-1 Matsukadai, 2-chome Higashi-ku
Fukuoka 813-8503
JAPAN

Korea Printing Research Institute
Seogyo-Dong 35226
Mapo Seoul
KOREA

Chinese Culture University
Taipei
TAIWAN

14.5.2 Research Institutes and Research Centers

A selection of research institutes and research centers for the field of print media technology is listed below (this list can certainly complemented and updated regularly).

Europe

Polygrafia
Platchkovitza Str. 3
1164 Sofia
BULGARIA

Printech
Pstrossova 21
11000 Praha 1
CZECH REPUBLIC

Nordisk Forskningsinstitut for Maling og Trykfarver
Nordiska Institutet for Fargforskning (NIF)
Agern Alle 3
2970 Horsholm
DENMARK

KCL; FPPRI, The Finnish Pulp and Paper
Research Institute
P.O. Box 70
02151 Espoo
FINLAND

VTT, Technical Research Center of Finland,
Printed Communications, VTT Information Technology
Tekniikantie 4B
P.O. Box 1204
02044 Espoo
FINLAND

CTP, Centre Technique du Papier
(French Pulp and Paper Institute)
Domaine Universitaire BP 251
38044 Grenoble
FRANCE

CERIG, Centre d'Etudes et de Ressources des
Industries Graphiques
DU 461, Rue de la Papeterie
BP 65
38402 Saint Martin d'Hères Cedex
FRANCE

BAM, Bundesanstalt für Materialforschung und -prüfung
Unter den Eichen 87
12205 Berlin
GERMANY

Fraunhofer-Institut für Graphische Datenverarbeitung
(IGD)
Rundeturmstraße 6
64283 Darmstadt
GERMANY

IFRA
International Association for Newspaper & Media
Technology
Washingtonplatz 1
64287 Darmstadt
GERMANY

IPSI, Institut für Integrierte Publikations- und
Informationssysteme
Dolivostraße 15
64293 Darmstadt
GERMANY

ZGDV, Zentrum für Graphische Datenverarbeitung
Rundeturmstraße 6
64283 Darmstadt
GERMANY

Fraunhofer-Institut für Verfahrenstechnik
und Verpackung (IVV)
Giggenhauser Straße 35
85354 Freising
GERMANY

Sächsisches Institut für die Druckindustrie GmbH
Institut des Vereins POLYGRAPH Leipzig e.V. (SID)
Mommsenstraße 2
04329 Leipzig
GERMANY

ERA, European Rotogravure Association
Swakopmunder Straße 3
81827 München
GERMANY

FOGRA Graphic Technology Research Association
FOGRA Forschungsgesellschaft Druck e.V.
Streitfeldstraße 19
81673 München
GERMANY

PTS, Papiertechnische Stiftung
Heßstraße 134
80797 München
GERMANY

DFTA (Deutschsprachige Flexodruck-Fachgruppe e.V.)
Technologiezentrum an der Fachhochschule Stuttgart,
Hochschule für Druck und Medien
Nobelstraße 10
70569 Stuttgart
GERMANY

Pira International
Randalls Road
Leatherhead
Surrey, KT22 7RU
GREAT BRITAIN

Welsh Centre for Printing and Coating
Department of Mechanical Engineering
University of Wales Swansea
Singleton Park
Swansea, SA2 8PP
GREAT BRITAIN

ENCC
Via Regina Margherita, 262
184 Roma
ITALY

IGT, Reprotest B.V.
P.O. Box 12688
1101 EX Amsterdam ZO
NETHERLANDS

Norwegian Pulp and Paper Research Institute
P.O. Box 115, Vinderen
319 Oslo 3
NORWAY

Papirindustriens Forskningsinstitatt (PFI)
Hogsholeringen 6B
7034 Trondheim
NORWAY

OBRPP, Osrodek Badawczo-Rozwoj
ul. Miedziana 11
58 Warszawa
POLAND

Politechnika Warszawska Wydzial Mechatroniki (IWF)
ul. Chodkiewicza 8
02-525 Warszawa
POLAND

Russian Academy of Sciences
Institute of Physics Lebedev
Leninskiy pr., 53
117924 Moscow
RUSSIA

Russian Research Institute for Graphic Arts (VNII),
INPOL Co.
11, Staropetrovcky pr.
125130 Moscow
RUSSIA

Tidningspappersbrukens Forskningslaboratorium (TFL) AB
Danderydsvägen 95
18265 Djursholm
SWEDEN

IMT, Inst. for Media Technology
Box 5637
Drottning Kristinas väg 51
114 86 Stockholm
SWEDEN

STFI, Swedish Pulp and Paper Research Institute
Box 5604
11486 Stockholm
SWEDEN

UGRA, Verein zur Förderung wissenschaftlicher
Untersuchungen in der grafischen Industrie
UGRA c/o EMPA
Lerchenfeldstrasse 5
9014 St. Gallen
SWITZERLAND

North America

Inst. Comm. Graphique du Québec
(Quebec Institute of Graphic Communications, QIGC)
999 Emile Journault Est
Montréal, Québec H2M 2E2
CANADA

PAPRICAN, Pulp and Paper Research Institute of Canada
570 St. John's Boulevard
Point Claire, Québec H9R 3J9
CANADA

SRI international
(Stanford Research Institute)
333 Ravenswood Avenue
Menlo Park, California 94025-349
USA

Rochester Institute of Technology (RIT)
College of Imaging Arts & Sciences; Imaging and
Publishing/FIC
55 Lomb Memorial Drive
Rochester, New York 14623-5603
USA

NPIRI, National Printing Ink Research Institute
Lehigh University, Building 7
Bethlehem, Pennsylvania 18015
USA

GATF, Graphic Arts Technical Foundation
200 Deer Run Road
Sewickley, Pennsylvania 15143-2600
USA

The Environmental Group
1899 Preston White Drive
Reston, Virginia 20191-4367
USA

Asia and Australia

China Research Institute of Printing Science and
Technology
2 Cui Wei Road
Beijing 100036
CHINA

Research Laboratories of Australia (RLA)
7 Valetta Road
Kidman Park (Adelaide), S. Australia 5025
AUSTRALIA

JAGAT, Japan Association of Graphic Arts Technology
1-29-11, Wada Suginami-ku
Tokyo 166
JAPAN

14.5.3 Institutions for Teaching/Training and Education

A selection of teaching/training and educational institutions for the field of print media technology (polytechnics, colleges, etc.) is listed below. Some of these institutes also undertake research (this list must certainly be complemented and updated regularly).

At the end of this section you can find the addresses of the Print Media Academy network of Heidelberger Druckmaschinen AG (see also sec. 13.1.2.6)

Europe

Fachhochschule St. Pölten
Studiengang Telekommunikation und Medien
3100 St. Pölten
AUSTRIA

Höhere Graphische Bundes-Lehr- und -Versuchsanstalt (VFG-GLV)
Leyserstraße 6
1140 Wien
AUSTRIA

Flemish Innovation Center for Graphic Communication (VIGC)
Spoorwegstraat 7
Turnhout 2300
BELGIUM

DGH The Graphic College of Denmark
The Graphic Arts Institute of Denmark
67 Glentevej
2400 Copenhagen
DENMARK

EFPG, Ecole Française de Papeterie et des Industries Graphiques
Institut National Polytechnique de Grenoble
461, rue de la Papeterie (DU)
BP 65
38402 St-Martin-d'Hères Cedex
FRANCE

Technische Fachhochschule Berlin
FB 10, Studiengang Druck- und Medientechnik
Luxemburger Straße 10
13353 Berlin
GERMANY

Hochschule für Technik, Wirtschaft und Kultur Leipzig
FB Polygrafische Technik (HTWK)
Karl-Liebknecht-Straße 132
04277 Leipzig
GERMANY

Fachhochschule Stuttgart, Hochschule für Druck und Medien
Nobelstraße 10
70569 Stuttgart
GERMANY

The London Institute
London College of Printing
School of Printing Technology
Elephant & Castle
London SE1 6SB
GREAT BRITAIN

Könnyúipari Múszaki Fóiskola Nyomdaipari Tanszék
The Printing Industry Department of the Technical College for the Hungarian Light Industry
Doberdó u 6
1034 Budapest
HUNGARY

GI, Grafisk Institutt Forskningsparken
The Norwegian Institute for the Graphics Arts Industries
Gaustadalléen 21
0371 Oslo
NORWAY

ESIG, Ecole Suisse d'Ingénieurs des Industries graphiques et de l'emballage (esig+)
Rue de Genève 63
1004 Lausanne
SWITZERLAND

North America

The Southern Alberta Institute of Technology and Printing Management
(Print Administration, Management Skills, Bindery)
1301, 16thAvenue Northwest
Calgary, Alberta T2M 0L4
CANADA

Northern Alberta Institute of Technology
Graphic Communications Department
(Graphic Communications Tech, Electronic Prepress)
11762, 106th Street
Edmonton, Alberta T5G 2R1
CANADA

Vancouver Community College,
Graphic Arts Printing Production
250 West Pender Street
Vancouver, British Columbia V6B 1S9
CANADA

Arizona State University
College of Engineering & Applied Sciences (Graphic Communications)
Industrial Technology Department, Technology Division
Tempe, Arizona 85287
USA

Mid-Florida Technical Institute
Printing Department (Photography, Printing, Commercial Art, Desktop Publishing)
2900 West Oak Ridge Road
Orlando, Florida 32809
USA

Idaho State University
School of Applied Technology, Graphic Arts/Printing Technology (Electronic Imaging/Offset Printing)
Vo-Tech Graphic Arts Department
Campus Box 8380
Pocatello, Idaho 83209-8380
USA

Ball State University
College of Sciences & Technology (Graphic Arts Management/Printing Technology)
Department of Industry & Technology
Muncie, Indiana 47306-0255
USA

Vincennes University
Printing Technology Department
Printing Technology (Lithography, Flexography)
PTB-09
1501 N. First Street
Vincennes, Indiana 47591
USA

Purdue University
School of Technology, Technical Graphics (Digital Prepress Publishing)
1419 Knoy Hall
West Lafayette, Indiana 47907-1419
USA

Pittsburgh State University
School of Technology & Applied Science
Department of Graphics and Imaging Technology
1701 S. Broadway
Pittsburgh, Kansas 66762
USA

Mayo Regional Technology Center
Graphic Arts Department
513 Third Street
Paintsville, Kentucky 41240
USA

Ferris State University
Graphic Arts Department College of Technology
915 Campus Drive
Swan 314
Big Rapids, Michigan 49307
USA

Southwestern Indian Polytechnic Institute
Graphic Arts Technology Program
P.O. Box 10146
Albuquerque, New Mexico 87184
USA

New York University,
School of Education, Graphic Communications Management & Technology
239, Green Street
New York, New York 10003
USA

Rochester Institute of Technology (RIT)
College of Imaging Arts & Sciences;
Imaging and Publishing/FIC
55 Lomb Memorial Drive
Rochester, New York 14623-5603
USA

University of Puerto Rico
Graphic Arts Department
P.O. Box 4800
Carolina, Puerto Rico 00987-4800
USA

West Virginia Institute of Technology
Department of Printing
Montgomery, West Virginia 25136
USA

Asia and Australia

Sydney Institute of Technology
Department of Graphic Arts
Jones and Thomas Streets
Broadway, New South Wales 2007
AUSTRALIA

Royal Melbourne Institute of Technology (RMIT)
School of Design and Printing
25–29 Dawson Street
Brunswick, Victoria 3056
AUSTRALIA

Southbank Institute of TAFE
School of Printing and Graphic Arts
Clearview Terrace
Morningside, Queensland 4171
AUSTRALIA

Tokyo Institute of Polytechnics
1583 Iiyama
Atsugi
Kanagawa 243-0297
JAPAN

Auckland Institute of Technology
National School of Printing
Private Bag 92006
Auckland
NEW ZEALAND

NIA, National Institute of the Arts
Center for the Study of Art and Technology
1 Hsuen-Yuan Road, Peitou
Taipei 112
TAIWAN R.O.C.

Rachanee Napamorakot Chulalongkom University
Department of Photographic Science and Printing Technology
Phya-thai Road
Bangkok 10330
THAILAND

Further Countries

SENAI, Serviço Nacional De Aprendizagem Industrial
Escolas SENAI "Theobaldo de Nigris" e "Felicio Lanzara"
Rua Bresser, 2315-Moóca
03162-030 São Paulo SP
BRAZIL

The Jomo Kenyatta Foundation (School Books Publishers and Printers)
P.O. Box 30533
Enterprise Road, Industrial Area
Nairobi
KENYA

Print Media Academy (Heidelberg)

Heidelberger Druckmaschinen AG
Print Media Academy
Kurfürstenanlage 52–60
69115 Heidelberg
GERMANY

Print Media Academy São Paulo
Rua Bresser, 2315-Moóca
03162-030 São Paulo SP
BRAZIL

Print Media Academy
Heidelberg Asia Pacific Pte. Ltd.
G/F Vita Tower
29 Wong Chuk Hang Road
Hong Kong
CHINA

Print Media Centre Shenzhen
Building No. 710
Liantang Industrial Park
Luo Hu District
Shenzhen 518004
CHINA

Youssef Allam & Co.
Print Media Academy Cairo
14, El Obour Building
Salah Salem St. Nasr City
Cairo
EGYPT

Print Media Academy Tokyo
3-21-4 Minami-Oi
Shinagawa-ku
140-8541 Tokyo
JAPAN

Heidelberg Asean Print Media Academy
1A, Jalan 205/Jalan Tandang
46050 Petaling Jaya
Negeri Selangor Darul Ehsan
MALAYSIA

Print Media Academy Moscow
Heidelberg CIS
State University of Printing Arts
2a Prjanishnikova Street
127550 Moscow
RUSSIA

Heidelberg USA, Inc.
Consulting and Training
1000 Gutenberg Drive
Kennesaw, Georgia 30144
USA

14.6 Associations and Organizations in the Printing and Publishing Industry (Selection)

14.6.1 Associations and Organizations

The following section contains a selection of associations and organizations representing the interests of the graphics industry. This list is by no means authoritative, yet it does emphasize the great economic significance of the graphic arts industry. The list will need to be updated regularly, but in its current form does offer an overview and serve as a reference.

The list is organized into the regions of Europe, North America, Asia and Australia, and Further Countries. Within these regions, the associations and organizations are listed by country and in alphabetical order.

Europe

Austria

Association of Bookbinders
Postfach 131
Brucknerstraße 8
1041 Vienna
AUSTRIA

Austrian Federation of the Graphic Arts Enterprises
Grünangergasse 4
1010 Vienna
AUSTRIA

CIE, International Commission on Illumination
(Commission Internationale de l'Eclairage)
Kegelgasse 27
1030 Vienna
AUSTRIA

ÖZEPA, Österreichische Vereinigung
der Zellstoff- und Papierchemiker und –techniker
Gumpendorferstraße 6
1061 Vienna
AUSTRIA

VFG, Verein Forschung für die
graphischen Gewerbe (VFG)
Leyserstraße 6
1140 Vienna
AUSTRIA

Belgium

Belgian Screen Printers Association
F Neuraystraat 40
1060 Bruxelles
BELGIUM

CEPE, Confédération Européenne
des Associations de Fabricants de Peintures,
d'Encres d'Imprimerie et de Couleurs d'Art
Avenue E. Van Nieuwenhuyse 4- Bte 10
1160 Bruxelles
BELGIUM

CEPI, Confederation of European
Paper Industries
306 Avenue Louise
1050 Bruxelles
BELGIUM

INTERGRAF, International confederation for printing
and allied industries
18 Sq. Marie Louise P.B. 27
1040 Bruxelles
BELGIUM

VEGRAB VZW, Flemish Master Printers
Grote Markt 19 bus 3
2000 Antwerpen
BELGIUM

Czech Republic

Association of Czech Printing Industry
Mikulandska 7
11361 Praha 1
CZECH REPUBLIK

Cyprus

Cyprus Master Printers Association
c/o Cyprus Employers, Charalambides Building
30, Grivas Digenis Ave.
P.O. Box 1657
Nicosia
CYPRUS

Denmark

Grafisk Arbeijdsgiverforening
Helgavej 26
5100 Odense
DENMARK

Master Printers in the Provinces of Denmark
Bogtrykernes Hus
Helgavej 26
5100 Odense M
DENMARK

Finland

Kirjapainoteollisuuden Liitto r.y.
(Printing Industry Association)
Arkadiankatu 19 D 49
00100 Helsinki
FINLAND

France

Association of French Screen Printers
15 rue du Chateaudun
75009 Paris
FRANCE

Association of Printing Companies and the Graphics Industries
11 Boulevard des Recollets
31078 Toulouse Cedex
FRANCE

CTP, Centre Technique du Papier
B.P. 251 Cedex 9
38402 Grenoble
FRANCE

FICG, Fédération de l'Imprimerie
et de la Communication Graphique
115 Boulevard Saint Germain
75006 Paris
FRANCE

INIAG, Institut National des
Industries et Arts Graphiques
296 rue de Charenton
75012 Paris
FRANCE

International Federation of Newspaper Publishers
6 rue du Faubourg Poissonniere
75010 Paris
FRANCE

National Association for the Coordination of Actions for the Professional Education of the Graphics Industries
263 rue de Paris
93514 Montreuil Cedex
FRANCE

National Association of Graphic Communication
46 rue de Bassano
75008 Paris
FRANCE

National Association of Gravure and Flexography
3 rue Ste. Elisabeth
75008 Paris
FRANCE

Technical Association for the Development of Flexography
15 rue de l'Abbé Grégoire
75006 Paris
FRANCE

Germany

AEGRAFLEX, Association Européenne des Graveurs
et des Flexographes
Biebricher Allee 79
65187 Wiesbaden
GERMANY

AG.MA, Arbeitsgemeinschaft Media-Analyse e.V.
Wolfgangstraße 92
60322 Frankfurt/Main
GERMANY

AGZV, Arbeitsgemeinschaft Zeitschriftenverlage
(AGZV) des Börsenvereins des
Deutschen Buchhandels e.V.
Großer Hirschgraben 17-21
60311 Frankfurt/Main
GERMANY

AiF, Arbeitsgemeinschaft industrieller Forschungsvereinigungen "Otto von Guericke" e.V. (AIF)
Bayenthalgürtel 23
50968 Köln
GERMANY

BDBI, Bund Deutscher Buchbinder-Innungen
Heinrichsallee 72
52062 Aachen
GERMANY

BDV Berufsverband der Medienvertreter e. V.
Stephanstraße 3
60320 Frankfurt
GERMANY

BDW, Deutscher Kommunikationsverband BDW e.V.
Königswinterer Straße 552
53227 Bonn
GERMANY

BDZV, Bundesverband Deutscher Zeitungsverleger e.V.
(German Newspaper Publishers Association)
Riemenschneider Straße 10
53175 Bonn
GERMANY

BVDM, Bundesverband Druck und Medien e.V.
(German Printing and Media Industries' Federation)
Biebricher Allee 79
65187 Wiesbaden
GERMANY

CITPA, Internationale Konföderation der Verarbeiter von Papier und Pappe in der EG
(International Confederation of Paper and Board Converters in Europe)
Arndtstr. 47
60325 Frankfurt/Main
GERMANY

DFTA, Deutschsprachige Flexodruck-Fachgruppe e.V. (German Flexo Technical Association)
Nobelstraße 5 B
70569 Stuttgart
GERMANY

DGQ, Deutsche Gesellschaft für Qualität e.V.
(German Society for Quality)
August-Schanz-Straße 21 A
60433 Frankfurt/Main
GERMANY

DIN Deutsches Institut für Normung e.V.
(German Institute for Standardization)
10772 Berlin
GERMANY

DQS Deutsche Gesellsch. z. Zertifizierung v. Qualitäts-managementsystemen mbH
Mayenner Straße 33
71332 Waiblingen
GERMANY

ERA, European Rotogravure Association e.V.
Swakopmunder Straße 3
81827 München
GERMANY

EWPA, European Waterless Printing Association e.V.
Schlotthauerstraße 21
81541 München
GERMANY

FBD, Fachverband Buchherstellung und Druckverarbeitung e.V.
Jessenstraße 4
22767 Hamburg
GERMANY

FBM, Fachvereinigung der Bunt- und Metall-Papierfabriken
Widenmayerstraße 39/II
80538 München
GERMANY

FDI, Führungskräfte der Druckindustrie und Informationsverarbeitung – FDI – e.V.
Gräfenhäuser Straße 26
64293 Darmstadt
GERMANY

FOGRA Graphic Technology Research Association
FOGRA Forschungsgesellschaft Druck e.V.
Streitfeldstraße 19
81673 München
GERMANY

GWA, Gesamtverband Werbeagenturen
(German Association of Advertizing Agencies)
Friedensstraße 11
60311 Frankfurt/Main
GERMANY

IARIGAI, International Association of Research Organisations for the Printing, Information and Communication Industries
Radeckestraße 16
81245 München
GERMANY

IFRA, The International Association for Newspaper and Media Technology
Washingtonplatz 1
64287 Darmstadt
GERMANY

International Confederation of Paper and Board Converters in the European Community
Hauptverband der Papier, Pappe u. Kunststoffe verarbeitenden Industrie e.V.
Arndtstraße 47
60325 Frankfurt/Main
GERMANY

IRD, Institut für rationale Unternehmensführung in der Druckindustrie e.V.
(Institute for Rational Management)
Fasaneriestraße 12
63456 Hanau
GERMANY

Printpromotion,
Gesellschaft zur Förderung der Druck- und Papierverarbeitungsindustrie in Entwicklungsländern mbH
(Corporation for the Promotion of the Printing & Paper Converting Industries in Developing Countries)
Lyoner Straße 18
60528 Frankfurt/Main
GERMANY

PTS, Papiertechnische Stiftung
(Paper Technology Foundation)
Heßstraße 134
80797 München
GERMANY

SID, Sächsisches Institut für die Druckindustrie GmbH, Institut des Vereins POLYGRAPH Leipzig e.V.
(Saxon Institute for the Printing Industry)
Mommsenstraße 2
04329 Leipzig
GERMANY

TÜV Product Service GmbH
Niederlassung München
Ridlerstraße 31
80339 München
GERMANY

VDB, Verband Deutscher Buchbindereien für Verlag und Industrie (VDB) e.V.
Jessenstraße 42
2767 Hamburg
GERMANY

VDD, Verein Deutscher Druckingenieure e.V.
(Association of German Printing Engineers)
Lyoner Straße 18
60528 Frankfurt/Main
GERMANY

VDE, Verband der Elektrotechnik Elektronik Informationstechnik e.V.
(Association for Electrical, Electronic & Information Technologies)
Stresemannallee 15
60596 Frankfurt/Main
GERMANY

VDI, Verein Deutscher Ingenieure VDI
(Association of German Engineers)
Graf-Recke-Straße 84
40239 Düsseldorf
GERMANY

VDMA, Verband Deutscher Maschinen- und Anlagenbau e.V. (VDMA)
(German Machinery and Plant Manufacturers Association)
Lyoner Straße 18
60528 Frankfurt/Main
GERMANY

VDP, Verband Deutscher Papierfabriken e.V.
(Association of the Pulp and Paper Industry)
Adenauerallee 55
53113 Bonn
GERMANY

VDW, Verband der Wellpappen-Industrie e.V. (VDW)
(German Association of Corrugated Board Manufacturers)
Hilpertstraße 22
64295 Darmstadt
GERMANY

VDZ, Verband Deutscher Zeitungsverleger e.V.
(Association of German Magazine Publishers)
Winterstraße 50
53177 Bonn
GERMANY

Verband Druck und Medien in Baden-Württemberg e.V.
Postfach 3132
73751 Ostfildern
GERMANY

VVK, Verband Vollpappe-Kartonagen (VVK) e.V.
Arndtstraße 47
60325 Frankfurt/Main
GERMANY

ZAW, Zentralverband der deutschen
Werbewirtschaft ZAW e.V.
(German Advertizing Federation)
Postfach 20 14 14
53177 Bonn
GERMANY

ZELLCHEMING, Verein der Zellstoff- und
Papier-Chemiker und -Ingenieure e.V.
(The German Technical Association of Chemists
and Engineers of the Pulp and Paper Industry)
Berliner Allee 56
64295 Darmstadt
GERMANY

Great Britain

British Association of Print and Copyshops
37 Nottingham Road
London SW17 7EA
GREAT BRITAIN

British Federation of Printing Machinery
and Supplies Ltd. – BFPMS
Queens House
55-56 Lincoln's Inn Fields
London WC2A 3LJ
GREAT BRITAIN

British Printing Industries Federation
11 Bedford Row
London WC1R 4DX
GREAT BRITAIN

EFTA, European Flexographic
Technical Association (UK) Ltd.
7 Limerick Road
Redland Bristol BS6 7PX
GREAT BRITAIN

FESPA, Federation of European Screen Printers
Association
Association House, 7a West Street
Reigate, Surrey RH2 9BL
GREAT BRITAIN

FIPP, The International Federation of the Periodical Press
Queens House
55-56 Lincoln's Inn Fields
London WC2A 3LJ
GREAT BRITAIN

National Graphical Association
Graphic House
63-67 Bromham Road
Bedford, Beds MK40 2AQ
GREAT BRITAIN

Periodical Publishers Association Ltd.
Imperial House
15-19 Kingsway
London WC2B 6UN
GREAT BRITAIN

Printing Trades Alliance
Holroyde House
53 Addington Square
London SE5 7LB
GREAT BRITAIN

Greece

Hellenic Federation of Printing Industries
245 Syngrou Av.
17122 Athens
GREECE

Hungary

Federation of Hungarian Printers
Eotvos u. 12
1067 Budapest
HUNGARY

MTESZ Technical Association of Paper and Printing
Industry – Hungary
Kossuth Lajos ter 6-8
1372 Budapest V
HUNGARY

Iceland

Samt k Idnadarins
Federation of Icelandic Industries
Hallvelgarstig 1
Postholf 1450
121 Reykjavik
ICELAND

Ireland

Irish Master Printers' Association
33 Parkgate Street
Dublin 8
IRELAND

Irish Printing Federation
Baggot Bridge House
84-86 Lower Baggot Street
Dublin 2
IRELAND

National Graphical Association
107 Clonskeagh Road
Dublin 6
IRELAND

Italy

ANCOMAG, National Association of Printing and Related Machinery Importers
Piazza Belgioso 1
20121 Milano
ITALY

ASSOGRAFICI, National Association of Graphic Arts, Papermaking and Converting Industries of Italy
Piazza Conciliazione 1
20123 Milano
ITALY

Technical Association of Italian Graphic Arts
Via Sandro Botticelli 19
20133 Milano
ITALY

Luxembourg

Association des Maitres Imprimeurs de Grand-Duché de Luxembourg
2, Circuit de la Foire Internationale
BP 1604
1604 Luxembourg
LUXEMBOURG

Netherlands

Dutch Association of the Periodical Publishers
Herengracht 257
1016 BJ Amsterdam
NETHERLANDS

FINAT – Brauchevereinigingen Procarton De Europese brauchevereniging voor de vouwkartonindustrie
Laan Copes van Cattenburch 79
2585 EW Den Haag
NETHERLANDS

KVGO, Koninklijk Verbond van Grafische Ondernemingen
Startbaan 10 / Postbus 220
1180 AE Amstelveen
NETHERLANDS

Norway

Norwegian Federation of Graphic Enterprises
Akersgaten 16
Oslo 1
NORWAY

Norwegian Graphic Machinery Dealers' Association
Drammensveien 30
Oslo 2
NORWAY

Poland

Polish Chamber of Printing
ul. Wynalazek 2
02-672 Warsawa
POLAND

Portugal

Associação Portuguesa das Indústrias Gráficas e Transformadoras do Papel
Largo do Casal Vistoso, 2/D-Esc. B
1900 Lisboa
PORTUGAL

Romania

Association of Romanian Printing Industry
Str. Ion Brezoianu Nr. 23-25
Sector 1, Bucharest
ROMANIA

Slovakia

Slovakian Printing Industry Association
Drienova 24
826 03 Bratislava
SLOVAKIA

Spain

Asociación Española de Artes Gráficas, Envase, Embalaje, Embotellado y Afines – GRAPHISPACK
Plaza de España, s/n
08004 Barcelona
SPAIN

Graphic Arts Association
Independenica 4, 50
24001 León
SPAIN

National Association of Paper and Graphic Arts
Fernandez de la Hoz 12
28004 Madrid 4
SPAIN

National Federation of the Graphics Industries (FIEGRAF)
Barquillo, 11-4.-D
28004 Madrid 4
SPAIN

Spanish Association for the Development of the Graphic Arts
Jesus Maestro s/n
28003 -Madrid 3
SPAIN

Switzerland

EUREPRO International
Association for Prepress Industry
Schlosshaldenstrasse 20
3000 Bern 32
SWITZERLAND

IGF, International Graphical Federation
Monbijoustrasse 33
3011 Bern
SWITZERLAND

ISO International Organization for Standardization
1, rue de Varembé, CP 56
1211 Genève 20
SWITZERLAND

SVGU/ASAG, Schweizerischer Verband
Grafischer Unternehmen (SVGU)/
Association suisse des arts graphiques (ASAG)
Carmenstrasse 6
8030 Zürich
SWITZERLAND

UGRA c/o EMPA, Swiss Federal Laboratories for
Materials Testing and Research
Postfach
9014 St. Gallen
SWITZERLAND

VISCOM, Schweizerischer Verband für visuelle
Kommunikation
Alderstrasse 40
Postfach
8034 Zürich
SWITZERLAND

VSD, Verband der Schweizer Druckindustrie (VSD)
Schlosshaldenstrasse 20
3000 Bern 32
SWITZERLAND

VSR/ASR, Verband Schweizerischer
Reprografie-Betriebe (VSR)/Association
Suisse des Ateliers de Reprographie (ASR)
Seefeldstrasse 45
8034 Zürich
SWITZERLAND

VSS/APSS, Vereinigung Schweizer Siebdruckereien/
Association Patronale Suisse de Sérigraphes (VSS/APSS)
Route de Soleure 25
2740 Moutier
SWITZERLAND

Yugoslavia

GIP "Beograd"
Kumodraska 261
11000 Beograd
YUGOSLAVIA

Privredna Komora Jugoslavije Udruzenje Celuloze
Papirne i Graficke Industrije i Izdavacke Delatnosti
Terazije 23
11000 Beograd
YUGOSLAVIA

North America

Canada

Association des Artes Graphiques du Québec, Inc.
65 rue de Castelnau Ouest, bur. 101
Montréal, Québec H2R 2W3
CANADA

British Columbia Printing Industries Association
119 West Pender Street, Suite 108
Vancouver, British Columbia V6B 1S5
CANADA

Canadian Printing Industries Association
75 Albert St., Ste. 906
Ottawa, Ontario KP 5E7
CANADA

Nova Scotia Printing Industries Association
P.O. Box 484
Enfield, Nova Scotia B0N 1N0
CANADA

USA

ANSI, American National
Standards Institute
11 West 42nd Street
New York, NY 10036
USA

Association of American Publishers, Inc.
71 Fifth Avenue
New York, NY 10003-3004
USA
and
1718 Connecticut Ave., NW
Washington, DC 20009
USA

Association of Graphic Communications (AGC)
330 Seventh Avenue
9th Floor
New York, NY 10001-5010
USA

ASTM, American Society
for Testing and Materials
1919 Race St.
Philadelphia, PA 19103
USA

Binders & Finishers Association (BFA)
408 Eighth Avenue, Suite 10A
New York, NY 10001-1816
USA

Book Manufacturers Institute (BMI)
65 William Street, Suite 300
Wellesley, MA 02181-4007
USA

Digital Printing and Imaging Association (DPI)
10015 Main Street
Fairfax, VA 22031-3489
USA

Engineering Reprographic Society
P.O. Box 202121
Bloomington, MN 55420
USA

Flexible Packaging Association
1090 Vermont Ave, NW, Suite 500
Washington, DC 20005
USA

Flexographic Technical Association (FTA)
900 Marconi Avenue
Ronkonkoma, NY 11779-7212
USA

GAA, Graphic Arts Association
1900 Cherry Street
Philadelphia, PA 19103
USA

GAA, Gravure Association of America, Inc.
1200A Scottsville Road
Rochester, NY 14624
USA

GATF, Graphic Arts Technical Foundation
200 Deer Run Rd.
Sewickley, PA 15143-2600
USA

GCA Graphic Communications Association
100 Daingerfield Rd., 4th Floor
Alexandria, VA 22314
USA

International Association for Document
and Information Management Solutions (IBFI)
One Colonial Place, Suite 350
2111 Wilson Blvd.
Arlington, VA 22201-3042
USA

International Graphic Arts Education Association (IGAEA)
200 Deer Run Rd.
Sewickley, PA 15143-2600
USA

International Prepress Association (IPA)
7200 France Ave. South, Ste. 327
Edina, MN 55435
USA

International Society for Optical Engineering (SPIE)
P.O. Box 10
Bellingham, WA 98227-0010
USA

ISCC Inter-Society Color Council
11491 Sunset Hills Road
Reston, VA 22090
USA

NAPIM, National Association of
Printing Ink Manufacturers
Heights Plaza
777 Terrace Avenue
Hasbrouck Heights, NJ 07604
USA

NAPL, National Association of Printers
and Lithographers
780 Palisade Avenue
Teaneck, NJ 07666
USA

National Association of Quick Printers (NAQP)
401 N. Michigan Ave
Chicago, IL 60611
USA

Newspaper Association of America (NAA)
1921 Gallows Road, 6th Floor
Vienna, VA 22182
USA

NPES, The Association for Suppliers of
Printing, Publishing and Converting Technologies
1899 Preston White Drive
Reston, VA 20191-4367
USA

NPIRI, National Printing Ink Research Institute
Building 7-Laboratory
Bethlehem, PA 18015
USA

OSA, Optical Society of America
2010 Massachusetts Avenue NW
Washington, DC 20036
USA

PIA, Printing Industries of America
100 Daingerfield Rd.
Alexandria, VA 22314
USA

Research and Engineering Council of the Graphic Arts
Industry (R&EC)
P.O. Box 639
Chadds Ford, PA 19317
USA

SGIA, Screenprinting and Graphic Imaging
Association International
10015 Main Street
Fairfax, VA 22031-3489
USA

Society for Imaging Science and Technology
(IS&T)
7003 Kilworth Lane
Springfield, VA 22151
USA

SWOP, Inc. (Specifications for Web Offset Publications)
60 East 42nd Street, Suite 721
New York, NY 10165
USA

TAGA, Technical Association of
the Graphic Arts
68 Lomb Memorial Dr.
Rochester, NY 14623-5604
USA

TAPPI, Technical Association of the
Pulp and Paper Industry Inc.
Technology Park/Atlanta
P.O. Box 105113
Atlanta, GA 30348-5113
USA

Waterless Printing Association (WPA)
P.O. Box 59800
Chicago, IL 60645
USA

Web Offset Association (WOA)
100 Dangerfield Road
Alexandria, VA 22314
USA

Xplor International
24238 Hawthorne Blvd.
Torrance, CA 90505-6505
USA

Asia and Australia

Australia

ABPA, Australian Book Publishers Association
Suite 59/60Level
389 Jones Street
Ultimo, NSW 2007
AUSTRALIA

Lithographic Institute of Australia
P.O. Box 857
Fortitude Valley, QLD 4006
AUSTRALIA

Lithographic Institute of Australia
Federal Headquarters, P.O. Box Q36
Queen Victoria Buildings
Sydney, NSW 2001
AUSTRALIA

PANPA, Pacific Area Newspaper
Publishers Association Inc.
P.O. Box 449
Milsons Point, NSW 2061
AUSTRALIA

Printing Industries Association of Australia
Lithgow Street 77
P.O. Box 58
St. Leonards, NSW 2065
AUSTRALIA

Screen Printers Association of Australia
P.O. Box 10
Northgate, QLD 4013
AUSTRALIA

China

China National Printing Technology Association
P.O. Box 782
504 Anhua Li, Andingmenwai
Beijing
CHINA

China Printing Technology Association
B5 Chengongzhuang Street
West District
Beijing 100044
CHINA

Printing & Publishing Equipment Industries Association of China
6 Dong Sheng Hutong
A 49 Dongdan Ertiao
Beijing 100005
CHINA

Screen Printing Association of China
24 Liu Yin Street, Western District
Beijing
CHINA

Shanghai Publishers Association
5 Shaoxing Road
Shanghai 200 020
CHINA

Graphic Arts Association of Hong Kong
Room 1625 Block C
Metropole Building
Wanchai
HONG KONG

Hong Kong Printers Association
1/F, 48-50 Johnston Road
Wanchai
HONG KONG

Society of Hong Kong Publishers
23/F Henan Building
90 Jaffe Road
Wanchai
HONG KONG

India

All India Federation of Master Printers
E-14, Third Floor
New Delhi South Extn. Market Part-II
New Delhi, 110 049
INDIA

Bombay Master Printers Association
216 Neelam
108 Worli Seaface
Bombay, 400 018
INDIA

West Bengal Master Printers Association, Ltd.
32/1A Creek Lane
Calcutta, 700 014
INDIA

Indonesia

Indonesian Master Printing Association
PPGI
c/o PT Sumber Baghagia Gedung
Kramat Centre
Blk D No. 5
Jl Kramat
Raya No. 7
Jakarta Pusat
INDONESIA

Association of Indonesian Printers
Jl Bangka 2-C/3
Jakarta Selatan
INDONESIA

Association of Indonesian Publishers
(Jakarta Raya Branch)
Jl Kali Pasir 32
Jakarta 10330
INDONESIA

Israel

Association of Craft and Industry
Printing and Paper Division
P.O. Box 50295
Tel Aviv 61500
ISRAEL

Book Publishers' Association of Israel
29, Carlebach Street
P. O. Box 20123
Tel Aviv 67132
ISRAEL

Small Industry Association
Printing and Paper Division
16 Merkaz Ba'alei Melacha Street
Tel Aviv 62823
ISRAEL

Japan

Communications Industry Association of Japan
Sankei Building, Annex
7-2, 1-chome, Ohte-machi
Chiyoda-ku,
Tokyo 100
JAPAN

Gravure Cooperative Association of Japan
Nissei Building, 1-2 Ishihara 1-chome
Sumida-ku
Tokyo 130
JAPAN

JAGAT, Japan Association of Graphic Arts Technology
1-29-11 Wada, Suginami
Tokyo 166
JAPAN
and
4-4-2 Nakano, Miyakojima-ku
Osaka 534
JAPAN

Japan Cold-Type Offset Printing Industry Association
Nikkei Building
7-16 Nihonbashi Kodemmacho, Chuo-ku
Tokyo 103
JAPAN

Japan Federation of Printing Industries
16-8 Shintomi, 1-chome, Chuo-ku
Tokyo 104
JAPAN

Japan Printers' Association
Nihon Insatsu Kaikan
16-8 Shintomi, 1-chome, Chuo-ku
Tokyo 104
JAPAN

Japan Printing Ink Makers Association
Tokyo Club Building
2-6 Kasumigaseki, 3-chome, Chiyoda-ku
Tokyo 100
JAPAN

Japan Publishers Association
6-3 Suido, 2-chome, Bunkyo-ku
Tokyo 112
JAPAN

Tokyo Printing Industry Association
Nihon Insatsu Kaikan
16-8 Shintomi, 1-chome, Chuo-ku
Tokyo 104
JAPAN

Korea

Korea Bookbinding Industry Cooperative
614-7 Ahyon-dong, Mapo-gu
Seoul
KOREA

Korea Federation of Printing Industry Cooperatives
c/o Korea Printing Culture Center
352-266 Sogyo-dong, Mapo-gu
Seoul
KOREA

Korea Screen Printing Cooperative Association
Rm. 605, Korea Federation of Small Business Bldg.
16-2 Youi-do-dong, Yongdungpo-gu
Seoul
KOREA

Korean Publishers' Association
105-2 Sagan-Dong, Chongno-gu
Seoul 110-190
KOREA

Malaysia

Malaysia Printers Association
14A Jalan Murai Satu, Off Jl Ipoh
Batu Compleks
Kuala Lumpur 51200
MALAYSIA

New Zealand

Printing Industries Federation of New Zealand Inc.
Huddart Parket Building
Post Office Square
P.O. Box 1422
Wellington 1
NEW ZEALAND

Pakistan

Pakistan Association of Graphic Arts Industry
16-A Mohammed Ali Road
Karachi, 0812
PAKISTAN

Philippines

Philippines Printing Technical Foundation
2nd FL SCC Chevelier Center Building
3892 R. Magsaysay Blvd.
Sta mesa
Manila
PHILIPPINES

Printing Industries Association of the Philippines (PIAP)
Room 302 Mario Co. Building
1945 M Adriatico Street
St. Malate, Manila 1004
PHILIPPINES

Saudi Arabia

Riyadh Chamber of Commerce & Industry
Paper Converting Committee
P.O. Box 6672
Riyadh 11452
SAUDI ARABIA

Singapore

Master Printers Association
68 Lorong 16 Gaylang #04-02
Association Building
Singapore 1439
SINGAPORE

Singapore Book Publishers' Association
c/o Octopus Publishing Asia Pte. Ltd.
37 Jl, Pemimpin #07-04, Block B
Union Ind Building
Singapore 2057
SINGAPORE

Taiwan

China Graphic Arts Association (CGAA)
Room A 6F, No. 71
Jen-Ai Road, Sec.4
Taipei
TAIWAN, R.O.C.

China Printing Technology Association ROC
165 Hsing-An Road
Peitun District
Taichung
TAIWAN, R.O.C.

Taiwan Printing Industry Association
64 Chung-Hsioa Road
Taichung
TAIWAN, R.O.C.

Thailand

Thai Printing Association
158/2-4 New Rama VI Road
Pratumwan
Bangkok 10330
THAILAND

Thai Printing Industry Club and ASEAN Printing & Publishing
c/o Federation of Thai Industries
394/14 Samsen Road, Wachira, Dusit
Bangkok 10300
THAILAND

Further Countries

Argentina

CIGA, Cámara de Industriales Gráficos de la Argentina
Ramon L. Falcon 1657/59
1406 Capital Federal
ARGENTINA

Confederación Latino Americana de la Ind. Gráfica
Aristobulo Dell Valle 1257
1406 Buenos Aires
ARGENTINA

FAIGA, Federación Argentina de la Industria Gráfica y Afines
Ramon L. Falcon 1657
1406 Buenos Aires
ARGENTINA

Bolivia

CABINGRAG, Cámara Boliviana de la Industria Gráfica
Edificio "El Condor" 4 to. Piso
Oficina 408 La Paz
BOLIVIA

Brazil

ABIGRAF, Associação Brasileira da Indústria Gráfica
Rua Do Paraiso 533
CEP 0431-000 São Paulo, SP
BRAZIL

AMERCE, Associação Mineira dos Professionais de Composição Gráfica
Rua Turfa, 1057 Barroca
30480, Minas Gerias
BRAZIL

Chile

Asociación de Impresores de Chile
Canada 253, 2do. Piso
Departamento C
Santiago
CHILE

Colombia

ANDIGRAF, Asociación Colombiana de Industrias Gráficas
Carrera 4A No. 25B-46
Bogotá
COLOMBIA

Costa Rica

ASOINGRAF
Apdo. 8-5930-1000
San José
COSTA RICA

Costa Rican Graphics Arts Association
P.O. Box 1534
1000 San José
COSTA RICA

Dominican Republic

ADIGA Graphic Arts Association of the Dominican Republic
Edificio Mella, Apt. 602
Avenida George Washington
Santo Domingo
DOMINICAN REPUBLIC

Ecuador

AIG, Asociación de Industriales Gráficos del Ecuador
Edificio Las Camaras, 8vo. Piso
Ave. Republica y Amazonas
Quito
ECUADOR

Asociación de Industriales Gráficos de Pichincha
Edificio Las Camaras
Ave. Republica y Amazones
Quito
ECUADOR

Ghana

Ghana Printers & Paper Converters Association
P. O. Box 2869
Accra
GHANA

Guatemala

Gremial de Artes Gráficas Camara de Comercio de Guatemala
10a Calle 3-80, Zona 1
Guatemala City
GUATEMALA

Mexico

ANIDIGRAF, A.C.
World Trade Center
Av. De las Naciones, No. 1
Oficina 21 Piso 19
Col. Napoles 03810
México, D.F.
MEXICO

CANAGRAF, Cámara Nacional de la Industria de Artes Gráficas
Avenida Rio Churubusco 428
Col. del Carmen-del Coyoacan
04100 México, D.F.
MEXICO

Unión de Industriales Litografos de México, A.C.
Cerro de las Torres 265
Campestre Churubusco
04200 México, D.F.
MEXICO

Paraguay

AIGP, Asociación de Industriales Gráficos del Paraguay
Calle Ayolas 1627
Asunción
PARAGUAY

Peru

AGUDI, Asociación Gráfica Unión de Imprentas
Av. Inca Garcilaso de la Vega 1494-2do. Piso
Lima
PERU

Sierra Leone

Sierra Leone Association of Master Printers
c/o Oduntor Printing Press
61 Soldier Street
Freetown
SIERRA LEONE

South Africa

MAPPP SETA (Media Advertising, Publishing, Printing, Packaging, Sectoral Education & Training Authority)
P.O. Box 1084
Honeydew 2040
SOUTH AFRICA

PIFSA, Printing Industries Federation of South Africa
P.O. Box 1084
Honeydew 2040
SOUTH AFRICA

Uruguay

Cámara de Industriales Gráficos AVDA Libertador
La Vellega 670
Montevideo
URUGUAY

CONLATINGRAF, Confederación Latino Americana de la Ind. Gráfica
AIU, Asociación de Impresores del Uruguay
Ciudadela No. 1410
C.P. 11.100
Montevideo
URUGUAY

Venezuela

AIGES, Asociación de Industriales Gráficos
Conglomerado Industrial Melania
Canelones de Melendez, Galpon 13-A
Cumana – Edo Sucre del Estado Sucre
Caracas
VENEZUELA

Asociación de Industriales de Artes Gráficas de Venezuela
Av. Principal Con 2da. Transversal
de los Cortijos de Lourdes
Edif. Centro Empresarial Senderos
Piso 1 – Oficina 107-B
Caracas
VENEZUELA

Asociación de Industriales de Artes Gráficas
Calle Lopez Aveledo entre
Av. Mirand y Paez, Edif. SINCA
Torre A, Piso 2, Ofic. 17
del Edo. Aragua
Caracas
VENEZUELA

CAINGRA, Cámara de Industriales Gráficos
Av. 4 Bella Vista c/Calle 67
Cecilio Acosta Edif. Torre SOCUY
2do. Piso, Maracaido
Edo. Zulia
Caracas
VENEZUELA

Cámara de Industriales de las Artes Gráficas y Afines
Calle Arismendi, Edif. Bonin, P.B.
Inversiones Consolidada de Suministros C.A.
del Edo. Nueva Esparta
Caracas
VENEZUELA

14.6.2 Industrial Joint Research

The following is a list of associations and organizations that support industrial partners within the scope of industrial joint research projects – especially projects dealing with topics of particular significance for the graphic arts industry. Institutions that cooperate closely with partners in such joint projects are also mentioned.

In section 13.1.3.5 the objectives, working methods, possibilities, and benefits of industrial joint research are illustrated with examples of projects. A special reference is also given to the German Printing Machines Research Association (FGD, Forschungsgesellschaft Druckmaschinen e.V.) in that section.

FGD, Forschungsgesellschaft Druckmaschinen e.V.
(German Printing Machines Research Association)
Lyoner Straße 18
60528 Frankfurt/Main
GERMANY

FVA, Forschungsvereinigung Antriebstechnik e.V.
(German Research Association for Power Transmission Engineering)
Lyoner Straße 18
60528 Frankfurt/Main
GERMANY

FOGRA, Forschungsgesellschaft Druck e.V.
FOGRA-Institut
(Graphic Technology Research Association)
Streitfeldstraße 19
81673 München
GERMANY

IFRA, Internationale Vereinigung für Zeitungs- und Medientechnologie
(The International Association for Newspaper and Media Technology)
Washingtonplatz 1
64287 Darmstadt
GERMANY

BVDM, Bundesverband Druck und Medien e.V.
(German Printing and Media Industries' Federation)
Biebricher Allee 79
65187 Wiesbaden
GERMANY

FKM, Forschungskuratorium Maschinenbau e.V.
(Cooperate Research Organization for German Mechanical Engineering Industry)
Lyoner Straße 18
60528 Frankfurt/Main
GERMANY

VFI, Gesellschaft für Forschung und Innovation mgH im VDMA
Lyoner Straße 18
60528 Frankfurt/Main
GERMANY

DFAM, Deutsche Forschungsgesellschaft für die Anwendung der Mikroelektronik e.V.
(German Research Association for the Application of Microelectronics)
Lyoner Straße 18
60528 Frankfurt/Main
GERMANY

VDMA, Verband Deutscher Maschinen- und Anlagenbau e.V.
(German Machinery and Plant Manufacturers Association)
Lyoner Straße 18
60528 Frankfurt/Main
GERMANY

AiF, Arbeitsgemeinschaft industrieller Forschungsvereinigungen e.V.
(German Federation of Industrial Cooperative Research Association)
Bayenthalgürtel 23
50968 Köln
GERMANY

DFG, Deutsche Forschungsgemeinschaft
(German Research Council)
Kennedyallee 40
53175 Bonn
GERMANY

BMWi, Bundesministerium für Wirtschaft und Technologie
Scharnhorststraße 34-37
10115 Berlin
GERMANY

BMBF, Bundesministerium für Bildung und Forschung
Heinemannstraße 2
53175 Bonn-Bad Godesberg
GERMANY

UGRA/EMPA, Verein zur Förderung wissenschaftlicher Untersuchungen in der graphischen Industrie
(UGRA Association for the promotion of Research in the Graphic Arts Industry)
(EMPA Swiss Federal Laboratories for Materials Testing and Research)
Lerchenfeldstrasse 5
9014 St. Gallen
SWITZERLAND

Pira International
Randalls Road
Leatherhead
Surrey, KT22 7RU
GREAT BRITAIN

IARIGAI, International Association of Research Organisations for the Printing, Information and Communication Industries
Radeckestraße 16
81245 München
GERMANY

GATF, Graphic Arts Technical Foundation
200 Deer Run Road,
Sewickley, Pennsylvania 15143-2600
USA

14.7 International Conferences for the Graphic Arts Industry (Selection)

The following list contains a selection of international conferences that are of significance for the graphic arts industry, have achieved high recognition, and are successful in detecting and reporting situations and trends. The conference articles are published by the respective organizations and can be obtained from their offices. Information on conferences and events held by the organizations (such as IFRA, FOGRA, FINAT, etc.) listed in sections 14.5 and 14.6 can be obtained directly from these organizations. The conferences are usually held once a year. They are listed in alphabetical order.

Color Imaging Conference
Color Science, Systems, and Applications
IS&T, Society for Imaging Science & Technology
7003 Kilworth Lane
Springfield, VA 22151
(Internet: www.imaging.org)
USA

Comprint Conference/World Print Congress
Intergraf, International Confederation for printing and allied industries
Square Marie-Louise 18
1000 Bruxelles
BELGIUM

FESPA-Seminar
FESPA, Federation of European Screen Printers Association
Association House
7a West Str.
Reigate, Surrey RH2 9BL
GREAT BRITAIN

GAA Conference
GAA, Gravure Association of America
1200 A Scottsville Rd.
Rochester, NY 14624
USA

GATF Conference
GATF, Graphic Arts Technical Foundation
200 Deer Run Road
Sewickley, PA 15413-2600
(Internet: www.gatf.org)
USA

IARIGAI Research Conference
IARIGAI International Association of Research Organisations for the Printing, Information and Communication Industries
Radeckestraße 16
81245 München
(Internet: www.iarigai.com)
GERMANY

ICPS International Congress on Imaging Science
ICPS, International Committee on the Science of Photography
Reference: IS&T, The Society for Imaging Science & Technology
7003 Kilworth Lane
Springfield, VA 22151
(Internet: www.imaging.org)
USA

IERPC Annual Conference
IERPC
Pira House
Randalls Rd.
Leatherhead, Surrey KT22 7RU
GREAT BRITAIN

IS&T's NIP: International Congress on Digital Printing Technology
IS&T, Society for Imaging Science & Technology
7003 Kilworth Lane
Springfield, VA 22151
(Internet: www.imaging.org)
USA

IS&T/SPIE's Symposium on Electronic Imaging, Science & Technology
SPIE, The International Society for Optical Engineering
P.O. Box 10
Bellingham, WA 98227-0010
(Internet: www.spie.org)
USA
in cooperation with:
IS&T, Society for Imaging Science & Technology
7003 Kilworth Lane
Springfield, VA 22151
(Internet: www.imaging.org)
USA

Japan Hardcopy Conference
ISJ, Imaging Society of Japan
Tokyo Institute of Polytechnic
2-9-5 Honcho
Nakano-ku
Tokyo 164
(Internet: http://psi.mls.eng.osaka-u.ac.jp/isj(e).html)
JAPAN

PICS Conference
Image Processing, Image Quality, Image Capture, Systems Conference
IS&T, Society for Imaging Science & Technology
7003 Kilworth Lane
Springfield, VA 22151
(Internet: www.imaging.org)
USA

Seybold Conference
Seybold Publications
428 E Baltimore Ave
P.O. Box 644
Media, PA 19063
(Internet: www.seyboldreports.com)
USA

TAGA Conference
TAGA, Technical Association of the Graphic Arts
68 Lomb Memorial Dr.
Rochester, NY 14623-5604
(Internet: www.taga.com)
USA

TAPPI Conference
TAPPI, Technical Association of the Pulp and Paper Industry
Technology Park
P.O. Box 10 51 13
Atlanta, GA 30348-5113
(Internet: www.tappi.org)
USA

Xplor Conference
Xplor International
24238 Hawthorne Blvd.
Torrance, CA 90505-6505
(Internet: www.xplor.org)
USA

15 Subject Index

Chapter 15
Subject Index

User Information

The *page numbers* next to individual terms are arranged in ascending order. This is not an indication of the significance or comprehensiveness of the explanation within a particular location. There was deliberately no attempt made to assign *priorities* to the locations. Since prioritizing involves a subjective judgment, the terms are fully subdivided by sub-entries and a limited number of locations were chosen intentionally.

Page numbers refer to both *passages in the text* and *figures* (picture captions and entries) as well as *tables.* In many cases the reference also refers to chapter or section headlines as well as text in italics.

A single *p.* following the page number means that the term is also dealt with on the following page and a *pp.* corresponds to more than one following page.

An *entry* in the index may consist of more than one word. The main entry is followed by separate *sub-entries* separated off by commas which identify a more precise context.

Terms with a large number of independent sub-entries are shown in an abbreviated form with a *dash at the beginning of the line* representing the main entry. A sub-entry follows a comma on each line (–,).

If a sub-entry is specified by further sub-entries, the further sub-entry is introduced at the beginning of the line by the combination of punctuation marks "dash with comma" twice (–, –,).

A *hyphen* after the sub-entry means that the main entry is to be added to the sub-entry.

Abbreviations (or the explanations of abbreviations) are given in *brackets* after the entry, as are synonyms i.e. other names for the term.

If abbreviations and the corresponding detailed spelling of the term or *term and synonym* are listed separately in the index, all locations are given for both entries. In a few cases – if for example there are very many sub-entries – there will be a reference from one term (without page number) to the other (in italics) using *see.*

The terms *see also* or *see* are used to refer to related terms, synonyms or abbreviations contained in the index and are written in italics.

The index also includes some *names of individuals;* these entries refer mainly to the history of the technologies.

Terms explained in the *glossary* (pp. 1115 to 1124) are contained in the index.

The extensive *general index* (table of contents) at the beginning of the handbook can, of course, be used in a similar manner to the subject index to access the subjects dealt with in the book.

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