

Preface

After long and significant efforts of researchers on plasma confinement to realize controlled D-T nuclear fusion on Earth, now the International Tokamak Experimental Reactor (ITER) will soon be ready to demonstrate the fusion reaction producing energy. This research has taken a longer time in comparison with the rapid construction of successful nuclear fission reactors following the discovery of energy release in nuclear reactions. Nevertheless, to realize the fusion reactor as an energy source, many engineering–technological issues remain to be solved. It is unnecessary to say that the most important point is that the fusion reactor must be economically beneficial. The initial or capital cost to construct the fusion reactor is unavoidable, and most of the cost estimates so far indicate that a fusion reactor could be economical and repay its capital investment. But additional costs related to tritium fuel, or to sustaining fuel self-sufficiency in a D-T fusion reactor, and the trade-offs between tritium breeding and electricity production (or energy conversion) and tritium safety, are not small, and considerable effort will be required to reduce these costs. The main purpose of this book is to summarize recent efforts to establish fuel self-sufficiency in a D-T fusion reactor with strict regulation of tritium safety.

In 2013, a book entitled *Tritium in Fusion*, edited by S. Tosti and N. Ghirelli (Nova Publishers, NY, ISBN 978-1-62417-270-0) was published. It focused on the production and treatment of tritium in nuclear fusion equipment and aspects of measurements, dose assessment, and safety of tritium. The present book focuses on more practical aspects to realize a fusion reactor as an energy source. There is no doubt that safety is a concern in the tritium handling system described in the book cited above. To realize the fusion reactor as an energy source, however, there are additional issues related to tritium as a fusion fuel, and those are the subjects of the present book.

Although a tritium handling system has been established for military use, the system might not be directly applied to tritium systems for a fusion reactor, because the amount of tritium to be handled in the latter is much larger than in the former. In addition, owing to its limited availability, full recovery of tritium handled in any tritium subsystems in the fusion reactor is mandatory. For safety, tritium removal is

always required in any existing tritium handling system and removed tritium can be disposed of, whereas loss of tritium in the fusion reactor directly influences its fuel self-efficiency. Therefore, a significantly different approach is required in designing tritium handling in the fusion reactor.

This book is devoted to giving readers an idea and understanding of the characteristics of tritium for fusion in Part I, the current status of R&D on tritium fueling (including breeding) systems in Part II, and consideration of tritium safety in Part III.

In Part I (Chaps.1–5), Chap. 1, is an introductory chapter describing a fusion reactor focusing particularly on the use of tritium as a fuel, followed in Chap. 2 by the introduction of characteristics of tritium as a radioactive isotope of hydrogen. Chapters 3–5 summarize present knowledge of fuel (tritium) behavior in a fusion reactor. Because there is no reactor and tritium burning has not been realized yet, we have to extrapolate all present knowledge obtained from experiments and theories on large tokamaks of JET, JT-60U and TFTR, on various medium-size tokamaks, and in laboratory experiments on tritium behavior in reactor-size machines such as ITER and future power reactors. Chapters 3–5 thus describe overall tritium flow, tritium burning, and the behavior of fuel in a reactor, respectively.

In Part II (Chaps. 6–14), details of tritium handling and processing systems for tritium fueling and recycling maintaining tritium safety are described. Fueling is the key to maintaining burning plasma, as explained in Chap. 6. Both for tritium safety and fueling, tritium accountancy and measurements are indispensable, as described in detail in Chaps. 7 and 8. As discussed in Chap. 8, tritium measurement in plasma is not well established, and significant efforts are required. Tritium must be confined in any tritium handling system. Easy permeation by tritium of structural materials resulting in tritium contamination is a serious concern, noted in Chaps. 9 and 10. Isotope separation, explained in Chap. 11, is indispensable for fueling. To establish fuel self-efficiency, tritium breeding, and recovery are major concerns as set forth in Chaps. 12 and 13.

In Part III, major issues related to tritium safety are discussed. Chapters 14 and 15 deal with safety confinement of tritium and behavior of tritium released into the environment, with the important note that tritium safety for the public would be a minor concern in a fusion reactor.

This book is dedicated to the late Prof. Emeritus Masabumi Nishikawa of Kyushu University. During the editing process, we missed him who, as one of the most active tritium scientists in the world, had devoted significant effort to the initial editing of this book. His distinctive works on tritium breeding and tritium fuel systems for a fusion reactor were often referred to by numbers of scientists and engineers in many fields, not only tritium science and technology, but also plasma physics and reactor engineering and design. All authors of this book acknowledge his great work and leadership worldwide in tritium science and technology.

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