Preface

This monograph deals with mixed refrigerant processes that operate at temperatures less than 123 K. Most conventional cryogenic refrigerators and liquefiers operate with pure fluids, the major exception being natural gas liquefiers that use mixed refrigerant processes. The fundamental aspects of mixed refrigerant processes, though very innovative, have not received the due attention in the open literature in view of commercial interests. Hundreds of patents exist on different aspects of mixed refrigerant processes for the liquefaction of natural gas and the composition of mixtures for Joule–Thomson (Linde–Hampson) and other refrigerators. It is difficult to piece together the existing information to choose an appropriate process and an optimum composition for a given application. The main purpose of this monograph is to explain all the aspects of mixed refrigerant processes and the methods for choosing the composition of refrigerants using robust analytical methods based on sound thermodynamic principles.

All concepts required to design and evaluate mixed refrigerant processes including exergy are introduced from first principles in the first chapter. The performance of traditional cryogenic processes that operate with pure fluids such as Linde–Hampson and Kapitza and the reasons for the low exergy efficiency of these processes are also presented in the first chapter.

Cryogenic processes differ from general chemical processes in several ways. The use of multistream heat exchangers with internal pinch points makes it necessary to use somewhat different approaches to simulate mixed refrigerant processes. The methods for simulating and optimizing cryogenic processes using a process simulator are presented in the second chapter.

The need for using refrigerant mixtures over pure fluids is presented in the third chapter with reference to simple refrigeration and gas cooling processes. The more complex refrigeration processes are presented in the fourth chapter. A unified design approach has been evolved for optimizing mixed refrigerant process refrigerators and liquefiers and is presented in the fifth chapter. The different natural gas and nitrogen liquefaction processes are presented in the sixth and seventh chapters, respectively.

Optimum operating pressures and mixture compositions have been determined for a variety of mixed refrigerant process refrigerators and natural gas/nitrogen liquefiers. In some cases, the performance of processes with different alternate mixture

compositions and operating pressures has been presented to help understand these processes thoroughly. The performance of different processes is evaluated in terms of exergy losses in different components. Most of the examples and case studies presented are largely unpublished.

The examples presented in this monograph were solved using Aspen Plus, a commercial process simulator, and CRYOSIM, a cryogenic process simulator developed in-house. It should be possible, however, to use any process simulator with optimization capabilities to solve the examples independently. The reader can also use the data presented in the examples as the starting values (estimates) in his or her own optimization studies. Those who are familiar with process optimization will appreciate the value of good estimates that allow the optimizer to start from a feasible point and converge rapidly. Many of the examples provided are nearly optimal solutions. However, students and practicing engineers are encouraged to find even better solutions as a part of their learning exercise. Practicing refrigeration and cryogenic engineers will benefit from this monograph and would be able to apply the methods presented to design optimum mixed refrigerant processes. This monograph can also be used as a textbook for a graduate course on advanced refrigeration or cryogenic processes. No prior knowledge of refrigeration/cryogenic processes is required to read this monograph. Some knowledge of thermodynamics and optimization is helpful, but not necessary. Access to a process simulator is, however, necessary to design mixed refrigerant processes.

The material covered in this monograph has been drawn largely from my research on refrigerant mixtures for over 15 years. I used the material presented in a graduate course on advanced cryogenic systems at IIT Madras.

I am grateful to my senior colleague Prof. S. Srinivasa Murthy of IIT Madras, my friend and collaborator Prof. L. R. Oellrich of Universität Karlsruhe, and my Ph.D. supervisor Prof. Sunil Sarangi of IIT Kharagpur for their support and encouragement at different stages of my career, including the writing of this monograph.

I would like to thank my colleague Prof. K. Ramamurthi, who read the manuscript and offered useful comments. Thanks are also due to Prof. K. D. Timmerhaus, Editor of the International Cryogenics Monograph Series, for reviewing the manuscript critically.

I gratefully acknowledge the contributions of my graduate students and the technical staff of the Refrigeration and Airconditioning Laboratory, IIT Madras, especially Mr. R. Elangovan, in fabricating and testing different mixed refrigerant prototypes over the years. They are too large a number to be acknowledged individually.

My mother, Samrajya Lakshmi, encouraged me to write this monograph and supported me through times of despair. My wife, Suchitra, and son, Akhil, enthusiastically sacrificed all their time and allowed me to work long hours on this monograph for several years. This finalized text would not have been possible without their love and unstinting support.

http://www.springer.com/978-0-387-78513-4

Cryogenic Mixed Refrigerant Processes
Venkatarathnam, G.
2008, XIII, 262 p., Hardcover
ISBN: 978-0-387-78513-4