Preface

The need for a modern textbook in the field of refrigeration and air conditioning has been felt for a long time. This book presents a basic as well as applied thermodynamic treatment of the subject in a very comprehensive manner based on years of teaching and learning effort at the Indian Institutes of Technology, Mumbai and Delhi, and interaction with the industry.

The book is intended to serve as a text for undergraduate and to some extent postgraduate students of engineering. It should also serve as a useful reference for practising engineers. A few texts follow the extremely rigorous approach, whereas others are restricted to merely the elementary and empirical form. In this text a conscious effort has been made to maintain a reasonable level of rigour, but at the same time to employ simple techniques for solving fairly complex problems. Throughout the book, emphasis has been laid on physical understanding while at the same time relying on simple analytical treatment. A sound physical basis has also been laid for obtaining fairly precise estimates of refrigeration and air-conditioning equipment.

The presentation of the subject follows the classical line of separately treating the topics in refrigeration and air conditioning, the two being linked via the medium of the refrigerant evaporator. Accordingly, Chapters 1 to 13 are devoted to refrigeration and Chapters 14 to 22 to air conditioning. Chapters 23 and 24 deal with motors and controls and applications of refrigeration and air-conditioning process in food preservation.

The text and illustrative examples are in SI units throughout the book. Charts and tables, such as pressure-enthalpy diagrams for refrigerant 11 and carbon dioxide, enthalpy-composition diagrams for ammonia-water and lithium bromide-water systems, tables for solar radiation heat gain through glass, equivalent temperature differentials for walls and roofs, etc., have been adapted in SI units and are provided along with others, such as pressure-enthlapy diagram for refrigerant 12, psychrometric chart, etc.

Any claim to originality that may be advanced for the material presented here in refrigeration is with respect to (i) Ewing's construction to find the suction state for maximum COP, (ii) a comparison of refrigerants based on normal boiling points thus introducing the concept of thermodynamic similarity, (iii) a study of azeotropes,

(iv) class of service of compressors, (v) illustrative examples on both air-cooled and water-cooled condensers, (vi) the sizing of the capillary tube according to Fanno-line flow, (vii) the influence of a refrigerant on the augmentation of boiling heat transfer, (viii) heat-transfer analysis of both dry and flooded evaporators, (ix) the simulation of the vapour compression system, and (x) the analysis and calculations for mixtures in the vapour-absorption system using enthalpy-composition diagrams.

The approach to the subject of air conditioning is both fundamental and practice-oriented. A basic calculation procedure is given for the preparation of psychrometric charts. Lucid explanations, expressions and diagrams are given to develop the understanding of sensible, latent and total heat processes and loads. A separate chapter is devoted to solar radiation, leading not only to the study of solar-heat gains and cutting-solar load, but also to provide to the reader the basic knowledge to enable him to design systems for solar-energy utilization. The chapter on air-conditioning equipment design makes use of the concept of enthalpy potential involving simultaneous heat and mass transfer. Examples on air transmission include the static regain method of duct designing which leads to a balanced air-distribution system.

Chapter 23 adequately fills the need to provide essential information on the electrical aspects of the control of refrigeration and air-conditioning equipment. It also gives methods for the control of room conditions at partial loads. Finally, Chapter 24 takes up typical applications of refrigeration and air-conditioning to food preservation. These include chilling, freezing, freeze-drying and heat-drying.

The twentieth century saw large scale development in commercial refrigeration and air conditioning, particularly after du Pont introduced a family of chloro-fluoro-carbons, the so-called CFCs with the trade name of Freons. Now, as the new century begins, another revolution is taking place in the industry for replacing these very CFCs with alternatives on account of the ozone-depletion-potential of these refrigerants. The author, therefore, considers that it is his duty, and he owes it to the readers to present this updated version with exhaustive revision of the contents of the book.

Many research and postgraduate students are interested in evaluating thermodynamic properties of new refrigerants and refrigerant mixtures. The basic procedure to evaluate the thermodynamic properties of *pure refrigerants* is, therefore, given in Chapter 1, and the same for *ideal and non-ideal mixtures* and particularly *Propane/Isobutane mixtures* in Chapter 4. Chapter 4 on refrigerants contains an exhaustive treatment of the topics *substitutes for CFC Refrigerants*, particularly CFC 12, and *Non-isothermal Refrigeration* using non-azeotropic mixtures of refrigerants. In addition, empirical relations for thermophysical properties of refrigerants, and *supercritical vapour compression cycle* for CO_2 as refrigerant with a potential to substitute for CFCs are also given in this chapter.

Chapter 9 on Evaporators includes many illustrative examples for *simulation and design of flooded and direct-expansion chillers* which include pressure drop calculations and use of *Slipcevic correlations* for tubes with roughened surfaces.

Since water-lithium bromide system has recently gained some popularity with the use of waste heat for refrigeration, the representation of vapour absorption cycle on *lnp versus 1/T* diagram and practical *single-effect* and *double-effect water-lithium bromide vapour absorption cycles* have been described in Chapter 12 on Vapour Absorption System.

In Chapter 20 on Design of A/C Apparatus the treatment of the topic has been greatly extended to include determination of *air-side heat transfer coefficient* and *cooling tower selection*. Examples include those on induced-draft counterflow and crossflow atmospheric cooling towers.

Prominent features added in the second edition were

(i) *Standard rating cycle for domestic refrigerators and second law efficiency* in Chapter 3
(ii) *Calorimetric method of determining refrigerating capacity of hermetic compressors* in Chapter 6, *R22 centrifugal compressors* in Chapter 6 also due to the present trend of their use as substitutes for R11 chillers
(iii) *Linde–Hampson process for liquefaction of gases* in Chapter 11; also, *reversed stirling cycle* in this chapter due to the application of this cycle in a big way in Philips Liquefier
(iv) *Clean spaces* in Chapter 16 and processing and transmission of air in clean rooms in Chapter 21
(v) *Flat-plate solar collector* in Chapter 17 as an extension of the topic of solar radiation
(vi) *Water vapour transmission* and use of vapour barriers in Chapter 18
(vii) *Building design features* and measures for conservation of energy in Chapter 19
(viii) *Static regain method* of *duct design* in Chapter 21
(ix) Example on *conversion of split-phase motor into capacitor-start motor* to increase starting torque which may help using compressor of one refrigerant with another refrigerant in Chapter 23
(x) *Freeze-drying of Yoghurt* in Chapter 24

Further, a major contribution to this edition is in the form of a detailed Appendix which is now presented in three parts as follows:

A. *Correlations* on thermodynamic properties of refrigerants R12, R134a, R152a, R22, R290 and R600a
B. *Tables* on thermodynamic properties of the above and other refrigerants, R290/R600a mixtures, etc.
C. *Charts*

When the second edition was published in 2000, the refrigeration and air-conditioning industry was embarking on to an era of new refrigerants. Due to the problem of the depletion of the ozone layer, CFC refrigerants R11, R12, R113, R114, and R502 were to be phased out on 31.12.2000, and alternative HFC and HCFC refrigerants were to be used from 1.1.2001.

The second edition did provide a study of the alternative refrigerants which were planned. But since 2000, certain new refrigerants have taken their place as substitutes. They have come to be accepted by the industry, and plants working on them have been designed and installed. For example, HFC 134a now occupies place of pride as a substitute for CFC R12. However, HCFC R22 continues to be used and loved by the industry, although an HFC blend R410A is also favoured by some. At the same time, there is a newfound enthusiasm for ammonia. Further, HCFC R123 has now replaced CFC R11. Both the HCFCs, R22 and R123, are permitted for use till 2030.

Hence, it had become absolutely necessary to revise the book.

In this revision, topics on R11 and R12 have been retained to an extent for the sake of comparison. But there is greater emphasis on R123 and R134a. Emphasis on R22 and ammonia remains as such. Detailed comparisons have, however, been made between HCFC R22 and HFC alternatives R410A and R407C. Similarly, comparisons have been made between HCFC R123 and the HFC alternative R245fa. Accordingly, a number of comparison tables, and solved problems have been introduced in Chapters 3, 4, and 6 in the edition.

For the same reasons, tables of properties of HCFC R123, and HFCs R134a, R404A, R407C, R410A, and R507A have been added in Appendix B. In addition, vapour-region pressure-enthalpy diagrams of R123 and R134a have been included in Appendix C.

There are other inclusions in this edition. 'Scroll compressors' are the new positive displacement machine. They were developed a decade ago, but have become very popular only in recent years. They are being employed with R134a, and with R22 in low-to-medium capacity machines in the range of 1 to 12 TR. Hence, a section on the working of scroll compressors has been devoted in Chapter 6 on compressors.

Also, taking note of the need of students to learn more about the practical aspects of a system, a detailed section on 'Installation, Service, and Maintenance' has been included in Chapter 10 on Complete Vapour Compression System.

An interesting feature of air conditioning is the 'comfort zone'. As it forms the basis of design, an ASHRAE 'Comfort Chart' has now been included in Chapter 16 on Design Conditions.

Lastly, to ignite the imagination of the student on the wide variety of Industrial air-conditioning applications, three typical HVAC applications, 'Tunnels Ventilation', 'Station Air Conditioning', and 'Mine Ventilation and Air Conditioning' have been described in Chapter 20 on Applications.

I bow with gratitude before the Divine Father, Mother, Friend, and Beloved, the source of all knowledge, Who made me an instrument to write this book.

At this juncture, I remember my father's words: "My investment is in my children". Truly speaking, the benefits of this book flow from the investment made by my father.

I want to express my heartfelt gratitude to the Divine for the Love, Kindness and Affection bestowed on me through my children and their spouses: Sangeeta–Vivek, Smita–Rajat, Shubhra–Hemant, and Amitabh–Shailaja and grandchildren Himali, Ishika, Vaibhav, Aakriti, Shreya, Atyant, and two new and loving grandchildren, Anisha and Rishi, born since the publication of the last edition.

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May this wonderful subject of Refrigeration and Air Conditioning, and this book inspire teachers, students, and practicing engineers to explore new vistas in the field. Please feel free to send in your feedback at the book's website.

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