



FOURTH EDITION

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Chemical Engineering Design



VOLUME 6

R K SINNOTT

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VOLUME 6
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R. K. SINNOTT



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Preface to Fourth Edition

It is now over 20 years since this volume in the Coulson and Richardson Series was first published. In this fourth edition I have followed the same approach as in the previous editions; no major change has been made to the overall structure of the book. The work has been brought up to date and some new material added. In particular, the chapter on costing has been comprehensively updated.

The biggest change in the practice of design since the first edition has been the extensive development of CAD programs. Most organisations now have access to commercial programs for process simulation and equipment design. Used sensibly, with the application of engineering judgement, developed from experience, these have removed the need for tedious and often inaccurate manual calculations. Used without thought they can lead to disaster.

Another major development has been the easy access to information on the World-Wide-Web. References to sources of design information on the Web have been included in this edition.

The computer programs for material and energy balances, which were included in the appendices of the previous editions, have been deleted. If any department or individual would still like copies of these programs, they can be obtained on a floppy disc from the author, who can be contacted via the publisher.

It is no longer worthwhile writing short computer programs for the solution of repetitive problems; such problems are better solved with the use of spreadsheets. This technique is illustrated in some of the example solutions included in this edition. It is difficult to reproduce the actual spreadsheets used in the book itself, so they have been made available in the support material for the book on the publishers' website: <http://books.elsevier.com/manuals>.

No author can hope to cover the full range of methods and techniques needed for the design of a modern chemical processes and plant. I have followed the practice in the earlier editions of providing numerous references to back-up methods given in the text. These references have been brought up to date in this edition.

This book is used internationally. In recognition of this, and with the continued development of European and international standards, I have reduced references to British Standards. Readers should consult their own national standards, if available; or the BS and international standards using the World-Wide-Web.

Once again, I must thank all those individuals who have assisted and supported me throughout my career as a professional engineer and teacher; particularly to Professor Richardson for his support with this volume of the Series.

I recall that when Professor Richardson suggested that I wrote a book on design to complement the other volumes in the Series, I said 'I do not like any book I have read on design and probably would not like one I wrote myself'. Twenty-five years on and after the sale of many thousand copies, you, the readers, have changed my mind.

I have now retired from teaching, so this is likely to be last edition that I will author. I hope the next edition will co-authored by engineers who have the experience to contribute to the continuing value of this book.

EUR ING R. K. SINNOTT

SELECTED SOLUTIONS AND SUPPORT MATERIAL

This text is accompanied by selected worked solutions and support material.

To access this material please go to <http://books.elsevier.com/manuals>

Preface to Third Edition

This edition follows the same approach to the teaching of design as the earlier editions. All the chapters have been updated and new material added to most chapters.

Sample problems have been included in Chapters 1 to 13. These can be used to practice the design methods and procedures covered in the chapter. Problems were not included with the chapters in the earlier editions, as true design problems will not yield a single, unique, answer. Most of the problems now included are sufficiently constrained to give a unique solution. Engineering judgement will need to be exercised when tackling some of the problems included in Chapters 11, 12 and 13. The full design projects given in the previous editions have been retained.

Overseas sales of this book more than match sales within the United Kingdom. In recognition of this, some amendments have been made to make the presentation more international.

Commercial simulation programs are now readily available to university departments for teaching purposes, and will be used by students for their design project. For this reason, the simple mass balance program discussed in Chapter 4, and included in the appendices, may be considered obsolete. However, from the requests received for copies of this program on disk, it is clearly still of use to institutions in the developing countries, and so has been retained in this edition. Copies of the program, together with the other programs listed in the book, can be obtained from the author.

To make the volume further self-contained, a procedure for calculating the pressure drop in piping systems has been included in Chapter 5. The treatment of pump selection has also been revised and extended.

The data on costs in Chapter 6 has been updated to mid-1998. The data has been presented in both pounds sterling and US dollars, to assist overseas readers and international companies who cost in dollars.

The design of liquid-liquid extraction processes has been added to the discussion of separation processes in Chapter 11.

In Chapter 12, an alternative method for the preliminary design of thermosyphon reboilers has been included. Further research has disclosed limitations in the application of the previous method. The discussion of plate heat exchanger design has been extended and a design example given.

Less emphasis has been placed on the use of British Standards in Chapter 13. With the growth of international standards, it is more appropriate for the reader to refer to their own national standards, or an accepted international standard.

I would again like to emphasise my indebtedness to all those colleagues and teachers who assisted me throughout my career as a professional engineer.

EUR ING R. K. SINNOTT
March 1999, Gowerton

Preface to Second Edition

THE first edition of this book was well received and has become an established text for teaching process and plant design in the United Kingdom and many overseas countries. I am also pleased to find it on the desk of many engineers in industry.

In this second edition I have maintained the same philosophy and style used for the first edition. The chapter headings are the same but all chapters have been revised and updated. Additional material has been included in most chapters.

Process integration, and the use of heat pumps, has been included in Chapter 3. The cost data given in Chapter 6 has been updated to mid-1992 values and a section added on step-counting techniques for preliminary cost estimation. The chapter on safety and loss prevention has been rewritten to reflect current legislation and practice. The discussion of phase equilibria in Chapter 8 has been revised and expanded to give more help in the selection of thermodynamic routines for computer aided design packages. Heat transfer in agitated vessels is now covered in Chapter 12 and the discussion of plate heat-exchangers and fired-heaters extended.

Since the publication of the first edition, several books have been published on the mechanical design of process equipment. These are cited in Chapter 13 and can be consulted for the detailed design of pressure vessels and heat exchangers. Chapter 13 can be used for the preliminary design of equipment.

The contemporary concern with protection of the environment is reflected in the revisions and additions made to Chapter 14.

The appendices in the first edition have been extended to include a computer program for energy balances, illustrations of equipment specification sheets, and heat exchanger tube layout diagrams. The physical property data bank has also been revised and extended.

Where space, or the author's lack of expertise in the subject, have limited coverage of a particular topic, adequate and up-to-date references to design methods available in the general literature are provided.

The fundamental chemical engineering principles that underlie process and plant design are covered in Volumes 1, 2 and 3, of the Coulson and Richardson series. Where appropriate, reference is made to the current editions of these volumes: the fourth editions of Volumes 1 and 2 and the third edition of Volume 3. Alternative texts from the general chemical engineering literature are also cited. However, my aim has been to make this book self-contained, even if this has led to some repetition of material. The design procedures can be used without the need for reference to the other volumes, or other books.

Since the first edition was published the use of personal computers has become widespread in all phases of design. To accommodate this, the programs in this edition are written GWBASIC, suitable for PC's. Illustrations are also given in several chapters to encourage the use of spreadsheets for the solution of design problems.

Standards and codes of practice are an essential part of engineering and the relevant British Standards are cited. The codes and practices covered by these standards will be applicable to other countries. They will be covered by equivalent national standards in most developed countries. Where an American standard is an accepted international standard, this has been quoted as an alternative to the British Standard.

As in my preface to the first edition, I would like to acknowledge my debt to those colleagues and teachers who have assisted me in a varied career as a professional engineer. I would particularly like to thank Professor J. F. Richardson for his help and encouragement with both editions of Volume 6. Also, my wife, Muriel, for her help with the typescripts of both editions.

January 1993, Gowerton

EUR ING R. K. SINNOTT

Preface to First Edition

THIS book has been written primarily for students on undergraduate courses in Chemical Engineering and has particular relevance to their design projects. It should also be of interest to graduates of other disciplines who are working in the chemical and process industries. In writing it, I have drawn on my experience of teaching design at the University college of Swansea, and on some years of experience in the process industries.

Books on design tend to fall into two categories. There are those written by academics, that are largely philosophical discussions of the nature and methodology of the design process, and which are usually of little practical use. And there are handbooks (cookbooks) covering design methods, information, and data, which are often derided by academics. As this book is intended to be used, the emphasis has been put on providing useful design methods and techniques. Clearly, it is not possible to cover in detail in one book the whole range of techniques and methods needed for the design of a chemical manufacturing process. Nor could this be within the range of experience and expertise of any one author. The approach taken has been to give sufficient detail for the preliminary design of processes and equipment, and to back this up with references, both to authoritative texts and articles that cover the topics more thoroughly and to those that give detailed design methods.

The explanations that are given of the fundamental principles underlying the design methods are necessarily very brief. The scientific principles and unit operations of Chemical Engineering are covered in Volumes 1, 2 and 3 of this work, and in other textbooks cited in this volume, to which the reader is referred.

The chapters in this book can be grouped under three main topics. Chapters 1 to 9 and 14 cover process design, and include a brief explanation of the design method, including considerations of safety, costing, and materials selection. Chapters 10, 11 and 12 cover equipment selection and design. Chapter 13 covers the mechanical design of process plant.

Chapters 1 to 12 can be used as a text for courses on process and equipment design, omitting Chapter 2 and the first part of Chapter 3 for students who are familiar with material and energy balance calculations. Chapter 13 will give Chemical Engineering students some appreciation of the mechanical aspects of equipment design.

The art and practice of design cannot be learnt from books. The intuition and judgement necessary to apply theory to practice will come only from practical experience. I trust that this book will give its readers a modest start on that road.

In closing, I would like to express my appreciation to all those friends and colleagues who have influenced my own development as a professional engineer, and so contributed to this book.

R. K. SINNOTT

Series Editor's Preface

THE earlier volumes of this Series (Volumes 1, 2 and 3 and the Solutions Manuals) dealt with the theoretical background to chemical engineering processes and operations and with the functioning of particular pieces of equipment. This volume completes the series and extends the treatment of the subject, by showing how a complete process is designed and how it must be fitted into the environment. It therefore includes material on flow-sheeting, piping, mechanical construction, safety and costing. It relies heavily on the earlier volumes for a discussion of the background theory, though in order to make the work complete in itself it includes illustrations of equipment items which have already featured in the previous works; furthermore, the treatment of distillation and heat exchanger design is expanded. Whilst the book is directed primarily to undergraduate students of chemical engineering, it should also be valuable to chemical engineers in industry (and particularly to those studying for the Design Project) and to chemists and mechanical engineers who have to tackle problems arising in the Process Industries.

The design engineer must use a wide range of information taken from a variety of sources and must take into account many conflicting requirements—technical, economic and environmental. Within the time span available to him, he must effect a satisfactory compromise and it should always be borne in mind that there is never a unique “best” solution to any design problem. Furthermore, what is a satisfactory design for one location may be totally unsuitable elsewhere. Although it is impossible to convey a complete philosophy through the medium of a single book, an attempt has been made to make the reader aware of many of the diverse factors which must be incorporated into any one design. This volume provides only an introduction but gives an indication of sources of more detailed information on individual branches of the subject.

J. F. RICHARDSON

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