CHEMICAL ENGINEERING DESIGN

PRINCIPLES, PRACTICE AND ECONOMICS OF PLANT AND PROCESS DESIGN

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B/H

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Preface

This book was first published as Volume 6 of the *Chemical Engineering* series edited by Coulson and Richardson. It was originally intended to be a standalone design textbook for undergraduate design projects that would supplement the other volumes in the Coulson and Richardson series. Emphasis was placed on the practice of process and equipment design, while the reader was referred to the other volumes in the series and other chemical engineering textbooks for details of the fundamental principles underlying the design methods.

In adapting this book for the North American market, we have followed the same philosophy, seeking to create a comprehensive guide to process plant design that could be used as part of the typical chemical engineering curriculum, while providing references to more detailed and specialized texts wherever necessary. The design procedures can be used without the need for reference to the other books, research papers, or websites cited.

We recognize that chemical engineers work in a very diverse set of industries, and many of these industries have their own design conventions and specialized equipment. We have attempted to include examples and problems from a broad range of process industries, but where space or our lack of expertise in the subject has limited coverage of a particular topic, references to design methods available in the general literature are provided.

In writing this book, we have drawn on our experience of the industrial practice of process design, as well as our experience teaching design at the University of Wales Swansea, University of Manchester, and Northwestern University. Since the book is intended to be used in practice and not just as a textbook, our aim has been to describe the tools and methods that are most widely used in industrial process design. We have deliberately avoided describing idealized conceptual methods developed by researchers that have not yet gained wide currency in industry. The reader can find good descriptions of these methods in the research literature and in more academic textbooks.

Standards and codes of practice are an essential part of engineering; therefore, the relevant North American 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, and in some cases the relevant British, European, or International standards have also been cited. Brief

summaries of important U.S. and Canadian safety and environmental legislation have been given in the relevant chapters. The design engineer should always refer to the original source references of laws, standards, and codes of practice, as they are updated frequently.

All of the costs and examples have been put on a U.S. basis, and examples have been provided in both metric and conventional units. Where possible, the terminology used in the U.S. engineering and construction industry has been used.

Most industrial process design is carried out using commercial design software. Extensive reference has been made to commercial process and equipment design software throughout the book. Many of the commercial software vendors provide licenses of their software for educational purposes at nominal fees. We strongly recommend that students be introduced to commercial software at as early a stage in their education as possible. The use of academic design and costing software should be discouraged. Academic programs usually lack the quality control and support required by industry, and the student is unlikely to use such software after graduation. All computer-aided design tools must be used with some discretion and engineering judgment on the part of the designer. This judgment mainly comes from experience, but we have tried to provide helpful tips on how to best use computer tools.

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

Ray Sinnott
Gavin Towler

How to Use This Book

This book has been written primarily for students in undergraduate courses in chemical engineering and has particular relevance to their senior design projects. It should also be of interest to new graduates working in industry who find they need to broaden their knowledge of unit operations and design. Some of the earlier chapters of the book can also be used in introductory chemical engineering classes and by other disciplines in the chemical and process industries.

As a Senior Design Course Textbook

Chapters 1 to 9 and 14 cover the basic material for a course on process design and include an explanation of the design method, including considerations of safety, costing, and materials selection. Chapters 2, 3, and 8 contain a lot of background material that should have been covered in earlier courses and can be quickly skimmed as a reminder. If time is short, Chapters 4, 6, and 9 deserve the most emphasis. Chapters 10 to 13 cover equipment selection and design, including mechanical aspects of equipment design. These important subjects are often neglected in the chemical engineering curriculum. The equipment chapters can be used as the basis for a second course in design or as supplementary material in a process design class.

As an Introductory Chemical Engineering Textbook

The material in Chapters 1, 2, 3, and 6 does not require any prior knowledge of chemical engineering and can be used as an introductory course in chemical engineering. Much of the material in Chapters 7, 9, 10, and 14 could also be used in an introductory class. There is much to be said for introducing design at an early point in the chemical engineering curriculum, as it helps the students have a better appreciation of the purpose of their other required classes, and sets the context for the rest of the syllabus. Students starting chemical engineering typically find the practical applications of the subject far more fascinating than the dry mathematics they are usually fed. An appreciation of economics, optimization, and equipment design can dramatically improve a student's performance in other chemical engineering classes.

If the book is used in an introductory class, then it can be referred to throughout the curriculum as a guide to design methods.

Supplementary Material

Many of the calculations described in the book can be performed using spreadsheets. Templates of spreadsheet calculations and equipment specification sheets are available in Microsoft Excel format online and can be downloaded by all readers of this book from http://books.elsevier.com/companions.

Resources for Instructors

Supplementary material is available for registered instructors who adopt *Chemical Enginering Design* as a course text. Please visit http://textbooks.elsevier.com for information and to register for access to the following resources.

Lecture Slides

Microsoft PowerPoint presentations to support most of the chapters are available free of charge to instructors who adopt this book. To preview PDF samples of the slides please register with the site above. A complete set of slides on CD, in customizable PowerPoint format, will be sent to qualifying adopters on request.

Image Bank

A downloadable image bank of artwork from the book to use in lecture presentations is available.

Instructor's Manual

A full solutions manual with worked answers to the exercises in the main text is available for download.

Acknowledgments

As in my prefaces to the earlier editions of this book, 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 earlier editions of this book. Also, my wife, Muriel, for her help with the typescripts of the earlier editions.

Eur. Ing. R. K. Sinnott
Coed-y-bryn, Wales

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We are grateful to Aspen Technology Inc. and Honeywell Inc. for permission to include the screen shots that were generated using their software to illustrate the process simulation and costing examples. Laurie Wang of Honeywell also provided valuable review comments. The material safety data sheet in Appendix I is reproduced with permission of Fischer Scientific Inc. Aspen Plus®, Aspen Kbase, Aspen ICARUS,

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CONTENTS

1 INTRODUCTION TO DESIGN

Chapter Contents

Key Learning Objectives

- How design projects are carried out and documented in industry
- Why engineers in industry use codes and standards and build margins into their designs
- How to improve a design using optimization methods
- Why experienced design engineers very rarely use rigorous optimization methods in industrial practice