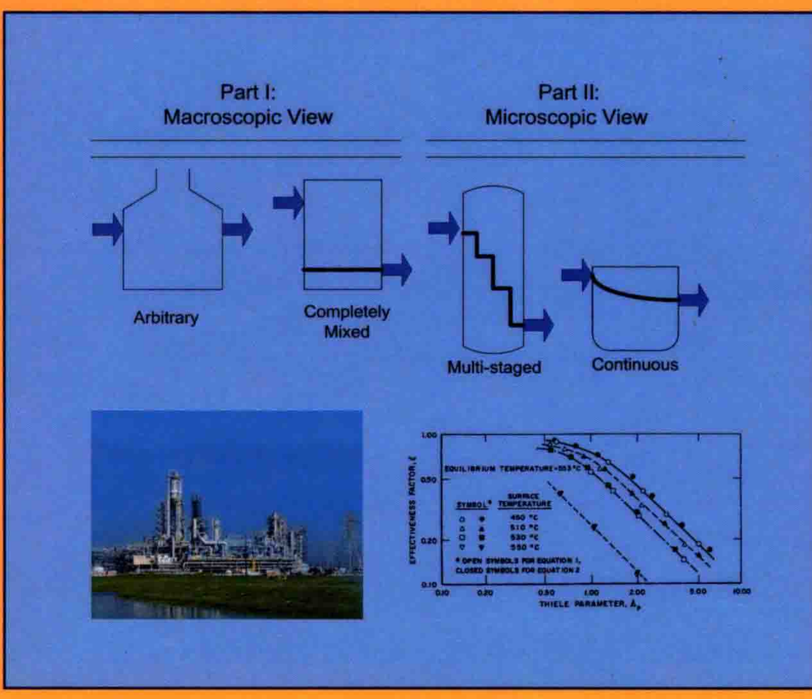
Principles of Chemical Engineering Practice

George DeLancey



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This book is dedicated to my darling wife, Lynn, who nurtured every page and every moment with her generosity, encouragement, and unfaltering support.

PREFACE

This book is about the application of scientific principles and engineering experience to chemical processing. Major chemical engineering operations are organized under the principles of analysis in order to facilitate the consideration of new technologies from a chemical engineering point of view.

New applications have emerged in chemical engineering practice. Microchemical systems, for example, require attention to design parameters not important at larger scales. The shift from commodity chemicals to chemical products by many smaller companies is creating a demand for chemical engineers with a broader view of design than the traditional capstone design experience (Cussler and Moggridge, 2001). Biocatalysis and the chiral technology industry call for the support of undergraduate curricula. Opportunities for the chemical engineering graduate in the development of medical devices and drug manufacture call for more emphasis on the life sciences and physiology.

There is therefore a call to introduce a degree of flexibility into traditional undergraduate chemical engineering curricula for those who wish to serve a broader industrial base. An alternative is to concentrate the basic chemical engineering training in a minimal core designed to secure the distinguishing technical character of the chemical engineer and to provide the ground both for further specialization in traditional chemical engineering and for coherent studies in other areas. The minimization decisions regarding the required topics and the depth of coverage are local decisions that reflect the mission of the program.

This text can support such a local decision process as a consolidation of normally separate courses in material and energy balances, transport phenomena, reactor design, and separations. While not a replacement for these courses, it is a functional treatment of the underlying skills that characterize them. The selection of major operations reflects the intention of establishing a minimum competency level required to be differentiated as a chemical engineer in an undergraduate engineering curriculum.

Although the book is primarily meant for chemical engineering undergraduates, it may be appropriate for conversion programs designed to prepare graduates of other engineering and science programs for matriculation in chemical engineering master's programs.

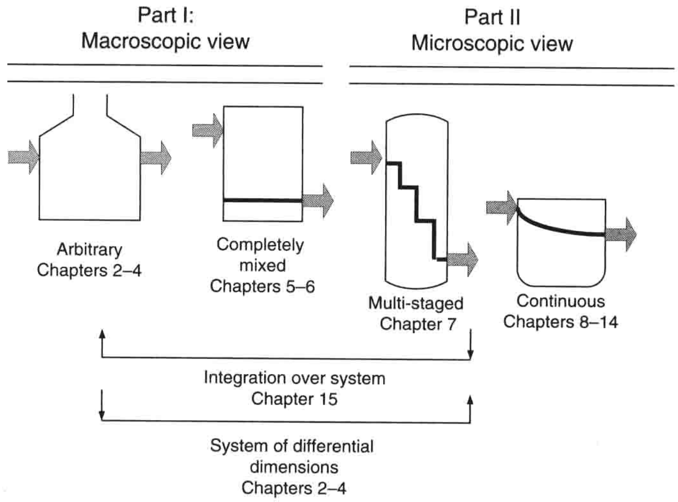
Graduate engineers in both academic and industrial positions may find it convenient to have a single resource with wide coverage.

CONTENT

The principles referred to above consist of the conservation of mass, energy, and momentum at the macroscopic and microscopic levels as well as the principle of the increase of entropy and characterization of equilibrium states by equilibrium thermodynamics. The production of entropy provides an important measure of process efficiency and underpins the conservation laws by providing a theoretical foundation for the nonconvective flows. In addition, the balance equations and equilibrium relations are used to develop models of the chemical process operations from the rate or equilibrium stage point of view, respectively. Efficiency is a link between the two.

The chemical engineering operations that are discussed in the text are as follows:

- Separators
- Heat exchangers.



Organization.

A process flow diagram for the manufacture of acrylic acid is presented at the outset and used for an introduction to chemical processing and equipment. Reference to the acrylic acid process is continued thereafter for presentation of new material in a process context. Example calculations in the text are compared with simulator results pertaining to equipment sizes and operating conditions in the acrylic acid plant.

Heuristics are regarded as fundamental tools and are stated extensively. They are used in calculations and are compared with some independent calculations. Degrees of freedom are employed throughout the earlier sections of the book.

Process control, economics, and safety are not included.

ORGANIZATION

Two major divisions of the subject matter in the text are made on the basis of a macroscopic and a microscopic view: The balance equations for mass, energy, momentum, and entropy are applied at the macroscopic level confined to the equipment ports, through completely mixed and staged systems to the continuous variations within equipment (see Organization).

The "macroscopic view" ensures the conservation of mass, energy, and momentum at the equipment and process levels with consideration only of the conditions at the entrances and exits of the process equipment. The exception is completely mixed systems where the uniform interior conditions appear at the outlet. The macroscopic view is taken at the level of process synthesis where the conditions are consistently set for each processing step to establish the overall process design and economics. The microscopic view is subsequently adopted to arrive at the detailed design of the processing equipment and the final economics. This viewpoint can provide conditions at every location within the equipment boundaries. For multistaged systems consisting of completely mixed subsystems, the conditions vary stepwise throughout the equipment. The microscopic view ensures the local conservation of mass, energy, and momentum. The macroscopic view is therefore the net effect of this local role, which can be seen by integration over the system volume, thereby "closing the circle."

CALCULATIONS

Many examples are provided within the chapters throughout the text to elucidate the discussion. Two process-related threads are carried through the examples (see Tables 1.7 and 1.8) in order to provide a broad process perspective for the calculations. Questions for discussion and encouragement to complete the argument or calculation appear periodically. A variety of problems are suggested at the end of chapters in order to initiate the problem-solving activity as a learning tool and to provide experience with scientific and engineering databases. The collection can be augmented to meet specific course objectives or a desired orientation without modifications to the chapters.

Scientific Notebook (MacKichan Software) and Microsoft Excel are primarily used in the example calculations. Scientific Notebook was chosen because the students who used the notes had prior experience with this software in their mathematics courses and they preferred this software over others that were available to them. Moreover, this software is particularly compatible with the notation used throughout this book.

Excel was used because the ease with which objects could be moved on graphs, the magnification options, and the ability to construct multifunctional plots greatly facilitated stepping off stages and other graphical constructions. The tabular formulation of recursive calculations is readily accomplished in Excel.

Some experience with the use of this software in an introductory course is available in DeLancey (1999).

GEORGE DELANCEY

CONTENTS