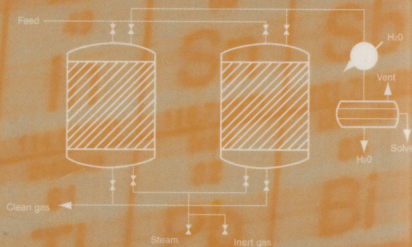


UNIT OPERATIONS of  
UNIT OPERATIONS  
of  
CHEMICAL  
ENGINEERING

SIXTH EDITION



MCCABE SMITH HARRIOTT

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# UNIT OPERATIONS OF CHEMICAL ENGINEERING

SIXTH EDITION

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SECTION II Fluid Properties	
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	Applications of Fluid Statics
	Symbols
	Problems
	References
SECTION III Fluid Flow Phenomena	
2	Laminar Flow, Shear Rate, and Shear Stress
	Rheological Properties of Fluids
	Turbulence
	Boundary Layers
	Symbols
	Problems
	References

## PREFACE

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This sixth edition of the text on the unit operations of chemical engineering has been extensively revised and updated, with much new material and considerable condensation of some sections. Its basic structure and general level of treatment, however, remain unchanged. It is an introductory text, written for undergraduate students in their junior or senior years who have completed the usual courses in mathematics, physics, chemistry, and an introduction to chemical engineering. An elementary knowledge of material and energy balances and of thermodynamic principles is assumed.

Separate chapters are devoted to each of the principal unit operations, grouped into four sections: fluid mechanics, heat transfer, mass transfer and equilibrium stages, and operations involving particulate solids. One-semester or one-quarter courses may be based on any of these sections or combinations of them. The order of the first 16 chapters has not been changed; later ones, dealing with mass transfer and operations involving solids, have been rearranged in a more logical order.

Nearly all equations have been written for SI units, and the Newton's law conversion factor  $g_c$  has been eliminated except in the few instances where it must be included. Symbols for dimensionless groups have been changed to  $Re$  for  $N_{Re}$ , for example,  $Pr$  for  $N_{Pr}$ , and so forth. Many new examples and problems have been added, some reflecting the importance of biochemical engineering processes. Material on handling, mixing, and grinding particulate solids has been greatly condensed and dealt with in a single chapter. The number of appendixes is reduced from 22 to 19.

Derivations of the differential equations for continuity and momentum balances, leading to the Navier-Stokes equation, have been added, as well as the differential forms of Fourier's law and Fick's law, emphasizing the analogies among momentum, heat, and mass transfer. The chapter on adsorption has been expanded to include new material on chromatography and ion exchange, and renamed "Fixed-bed Separations." Other new material has been added on viscoelastic fluids, laminar flow in annuli, drag coefficients, affinity laws for pumps, high-efficiency agitators and motionless mixers, plate-type heat exchangers, boiling by submerged tube bundles, cooling towers, aqueous phase extraction, cross-flow filtration, and many other topics.

Many of the problems at the ends of the chapters are new or revised. Most are expressed in SI units. Nearly all the problems can be solved with the aid of a pocket calculator; for a few, a computer solution is preferable.

McGraw-Hill and the authors thank Dr. N. T. Obot for his many suggestions regarding fluid mechanics and heat transfer, and Professor Charles H. Gooding of Clemson University for his detailed and helpful review of the manuscript.

Julian C. Smith  
Peter Harriott

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