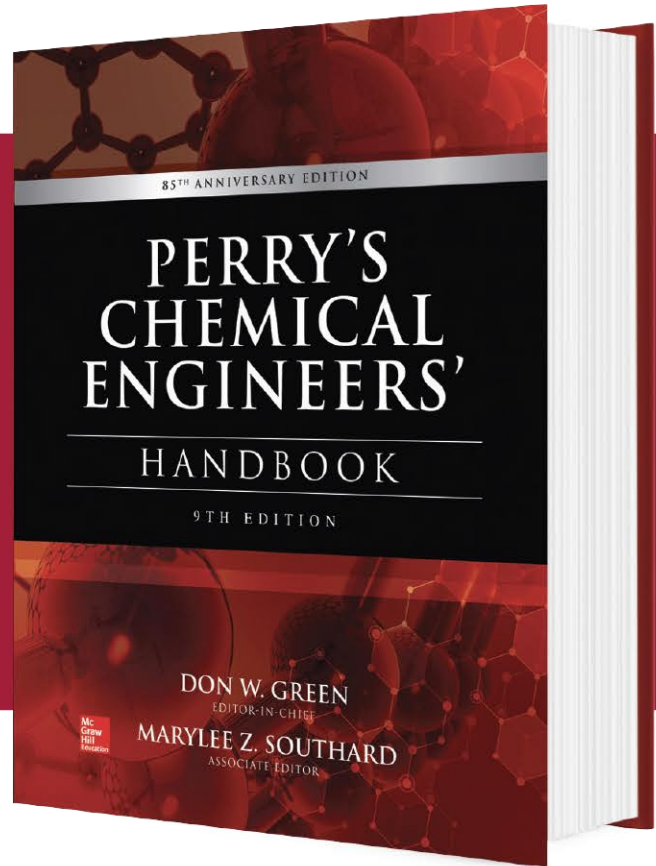


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Preface to the Ninth Edition

"This handbook is intended to supply both the practicing engineer and the student with an authoritative reference work that covers comprehensively the field of chemical engineering as well as important related fields."

—John H. Perry, 1934

Chemical engineering is generally accepted to have had its origin in the United Kingdom (U.K.) during the latter part of the nineteenth century, largely in response to the industrial revolution and growth in the demand for industrial chemicals. To answer this demand, chemical companies began to mass-produce their products, which meant moving from batch processing to continuous operation. New processes and equipment, in turn, called for new methods. Initially, continuous reactions and processing were implemented largely by plant operators, mechanical engineers, and industrial chemists. Chemical engineering evolved from this advancement of the chemical industry, creating engineers who were trained in chemistry as well as the fundamentals of engineering, physics, and thermodynamics.

As an academic discipline, the earliest reported chemical engineering lectures were given in the United Kingdom. George Davis is generally recognized as the first chemical engineer, lecturing at the Manchester Technical School (later the University of Manchester) in 1887. The first American chemical engineering courses were taught at MIT in 1888. Davis also proposed an appropriate professional society that evolved with the industrial and academic profession, ultimately called the Society of Chemical Industry (1881). His initial proposal was for a society of chemical engineers but the name was changed because so few chemical engineers existed at that time. From there, the American Institute of Chemical Engineers, AIChE (1908), and the U.K.-origin Institution of Chemical Engineers, IChemE (1922), were created.

As the discipline advanced, important approaches to describing and designing chemical and physical processes developed. George Davis is credited with an early description of what came to be termed "unit operations," although he did not use that specific term. Arthur D. Little coined the phrase in 1908 in a report to the president of MIT and developed the concept and applications with William H. Walker. Walker later defined "unit operations" in his 1923 seminal textbook published by McGraw-Hill, *Principles of Chemical Engineering*, coauthored with Warren K. Lewis and William H. McAdams. Other concepts developed over time, including chemical reactor engineering, transport phenomena, and use of computers to enhance mathematical simulation, have increased our ability to understand and design chemical/physical industrial processes. Chemical engineering concepts and methods have been applied in increasingly diverse fields, including environmental engineering, pharmaceutical processing, microelectronics, and biological/biosimilar engineering.

The first known handbook of chemical engineering was in two volumes, written by George Davis, and published in the United Kingdom in 1901. A second edition followed in 1904. The emphasis was on materials and their properties; laboratory equipment and techniques; steam production and distribution; power and its applications; moving solids, liquids, and gases; and solids handling. In the preface, Davis acknowledged the advances in industrial chemistry made in Germany, especially in commercial organic chemistry. He also noted the "severe competition" coming from America "in the ammonia-soda industry." The first US handbook was edited by Donald M. Liddell and published by McGraw-Hill in 1922. It was a two-volume book with thirty-one contributing writers. It dealt with many of the same topics as in the Davis handbook, but also had significantly more emphasis on operations such as leaching, crystallization, evaporation, and drying.

Perry's Chemical Engineers' Handbook originated from a decision by McGraw-Hill in 1930 (during the Great Depression) to develop a new handbook of chemical engineering. Receiving support for the project from DuPont Company, they selected John H. Perry to be the editor. Perry had earned a Ph.D. from MIT in 1922 in Physical Chemistry and Chemical Engineering. He subsequently worked for the US Bureau of Mines, next as a chemist for a DuPont subsidiary in Cleveland, OH, then moved to Wilmington, DE, to work for DuPont as a chemist in the company's experimental station, and back to

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xvi PREFACE TO THE NINTH EDITION

Cleveland, still with DuPont. Family lore says that Perry was a very hard worker, dedicated to chemical engineering, and willing to basically live two lives: one as a full-time engineer for DuPont and the other as editor of the handbook. On weekends he would hitchhike to New York, go to the Chemist's Club with a packet of galley proofs and a carton of cigarettes, and work all weekend, sometimes for 24 hours at a time. His work on the book extended through 1933, leading to publication of the first edition in January 1934. There were 63 contributors, 14 from the DuPont Company and 21 from different universities, all experts in their respective technical areas. The first sentence in the preface was applicable then as well as for this ninth edition: "This handbook is intended to supply both the practicing engineer and the student with an authoritative reference work that covers comprehensively the field of chemical engineering as well as important related fields."

Several chemical engineers, serving as editor or coeditor, have guided the preparation of the different editions over the years. John H. Perry was editor of the first (1934), second (1941), and third (1950) editions before his untimely death in 1953. The position of editor passed to his only child, Robert H. Perry (Bob), a notable chemical engineer in his own right. Bob had a Ph.D. in chemical engineering from the University of Delaware and was working in industry at the time of his father's death. In 1958, he took a position as professor and later chair of the Department of Chemical Engineering at the University of Oklahoma. He was the editor of the fourth (1963) edition, coedited with Cecil H. Chilton and assisted by Sidney D. Kirkpatrick, and the fifth (1973) edition, coedited with Chilton.

For the sixth edition, Bob asked Don W. Green, his first Ph.D. student and now a professor of Chemical and Petroleum Engineering at the University of Kansas, to assist him. Tragically, Bob Perry's work on the handbook ceased when he was killed in an accident south of London in November 1978. Green assumed responsibility as editor and completed the sixth edition (1984), assisted by a colleague at KU, James O. Maloney. The first five editions were titled *The Chemical Engineers' Handbook*. Beginning with the sixth edition, the book was renamed *Perry's Chemical Engineers' Handbook* in honor of the father and son. Green was also editor of the seventh (1997) and eighth (2008) editions, with Maloney assisting on the seventh edition. Robert H. Perry was listed as the "late editor" for the seventh and eighth editions; honoring his ideas that carried over to these recent editions. To create the ninth edition, Green brought on Marylee Z. Southard, a colleague with industrial, consulting, and academic experience in chemical engineering.

The organization of this ninth edition replicates the logic of the eighth edition, although content changes are extensive. The first group of sections includes comprehensive tables with unit conversions and fundamental constants, physical and chemical data, methods to predict properties, and basics of mathematics most useful to engineers. The second group, comprising the fourth through the ninth sections, covers fundamentals of chemical engineering. The third and largest group of sections deals with processes, including heat transfer operations, distillation, gas-liquid processes, chemical reactors, and liquid-liquid processes. The last group of sections covers auxiliary information, including waste management, safety and handling of hazardous materials, energy sources, and materials of construction.

In 2012, McGraw-Hill launched Access Engineering (ACE), an electronic engineering reference tool for professionals, academics, and students. This edition of *Perry's Chemical Engineers' Handbook* is a part of ACE, as was the eighth edition. Beyond the complete text of the handbook, ACE provides:

- Interactive graphs
- Video tutorials for example problems given in the handbook
- Excel spreadsheets to solve guided and user-defined problems in different areas, such as heat transfer or fluid flow
- Curriculum maps for use in complementing engineering course content

All 25 sections have been updated to cover the latest advances in technology related to chemical engineering. Notable updates and completely new materials include:

- Sec. 2 includes new and updated chemical property data produced by the Design Institute for Physical Properties (DIPPR) of AIChE
- Sec. 4 on thermodynamics fundamentals has been redesigned to be more practical, and less theoretical than in earlier editions, to suit the practicing engineer and student pursuing applications
- A new Sec. 20, "Bioreactions and Bioprocessing," has been added in response to the significant, large-scale growth of commercial processes for nonfood products since the end of the twentieth century
- Sec. 21 on solids handling operations and equipment has been rewritten by industrial experts in their field

A group of 147 professionals, serving as section editors and contributors, has worked on this ninth edition. Their names, affiliations, and writing responsibilities are listed herein as part of the front material and on the title page of their respective sections. These authors are known experts in their field, with many having received professional awards and named as Fellows of their professional societies.

Since the publication of the eighth edition, we have lost two major contributors to *Perry's Chemical Engineers' Handbook*. Dr. Adel F. Sarofim died in December 2011. He was a section coeditor/contributor in the radiation subsection from the fifth edition (1973) through this current ninth edition. Dr. Sarofim, a Professor Emeritus at MIT, was a recognized pioneer in the development of combustion science and radiation heat transfer. He received numerous U.S. and international prizes for his work.

Dr. Meherwan P. Boyce died in December 2017. He was the editor for the "Transport and Storage of Fluids" section in the seventh edition and co-section editor for the eighth and current editions. Dr. Boyce was founder of Boyce Engineering International. He was also known for his role as the first director of the Turbomachinery Laboratory and founding member of the Turbomachinery Symposium.

On this 85th anniversary of *Perry's Chemical Engineers' Handbook*, we celebrate the memory of its creators, Dr. John H. Perry and Dr. Robert H. Perry. Often referred to as "the Bible of Chemical Engineering," this handbook is the gold standard as a source of valuable information to innumerable chemical engineers.

We dedicate this ninth edition to chemical engineers who carry on the profession, creating solutions, products, and processes needed in the challenging world ahead. We hope this edition will provide information and focus for you—to work for the quality and improvement of human life and the earth we inhabit.

DON W. GREEN
Editor-in-Chief

MARYLEE Z. SOUTHARD
Associate Editor



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ABOUT THE EDITORS

Dr. Don W. Green is Emeritus Distinguished Professor of Chemical and Petroleum Engineering at the University of Kansas (KU). He holds a B.S. in petroleum engineering from the University of Tulsa, and M.S. and Ph.D. degrees in chemical engineering from the University of Oklahoma. He is the coeditor of the sixth edition of *Perry's Chemical Engineers' Handbook*, and editor of the seventh and eighth editions. He has authored/coauthored 70 refereed publications, over 100 technical meeting presentations, and is coauthor of the first and second editions of the SPE textbook *Enhanced Oil Recovery*. Dr. Green has won numerous teaching awards at KU, including the *Honors for Outstanding Progressive Educator* (HOPE) Award and the Chancellor's Club Career Teaching Award, the highest teaching recognitions awarded at the University. He has also been featured as an outstanding educator in ASEE's Chemical Engineering Education Journal. He received the KU School of Engineering *Distinguished Engineering Service Award* (DESA), and has been designated an *Honorary Member* of both SPE and AIME and a Fellow of the AIChE.

Dr. Marylee Z. Southard is Associate Professor of Chemical and Petroleum Engineering at the University of Kansas. She holds B.S., M.S., and Ph.D. degrees in chemical engineering from the University of Kansas. Dr. Southard's research deals with small molecule drug formulations; but her industrial background is in production and process development of inorganic chemical intermediates. Dr. Southard's work in inorganic chemicals production has included process engineering, design, and product development. She has consulted for industrial and pharmaceutical chemical production and research companies. She teaches process design and project economics, and has won several university-wide teaching awards, including the *Honors for Outstanding Progressive Educator* (HOPE) Award and the Kemper Teaching Fellowship. She has authored 1 patent, 15 refereed publications, and numerous technical presentations. Her research interests are in biological and pharmaceutical mass transport. She is a senior member of AIChE and ASEE.



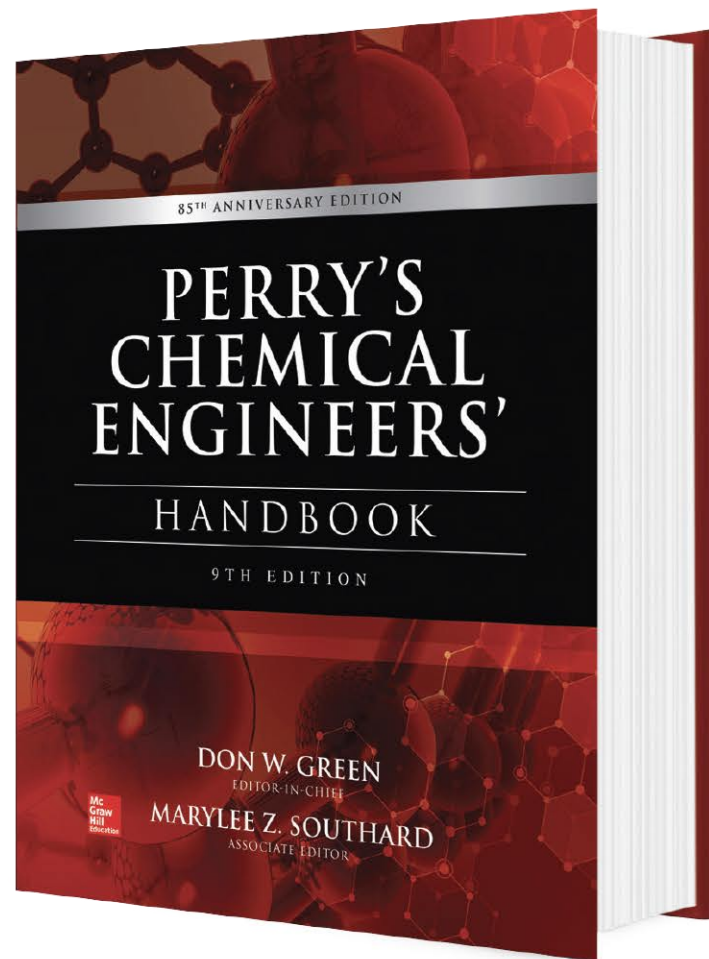
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