

EVOLUTION OF A TEXTBOOK

Introduction to Chemical Engineering Thermodynamics

HENDRICK C. VAN NESS

Rensselaer Polytechnic Institute • Troy, NY

Rarely does a textbook remain in print for anything approaching 50 years. *Introduction to Chemical Engineering Thermodynamics* is the only chemical-engineering text currently in print that has passed the half-century mark. Now extant in a sixth edition, published by McGraw-Hill, and authored by J.M. Smith, H.C. Van Ness, and M.M. Abbott, its origin was at Purdue University in 1945 when Joe Mauk Smith, a newly hired Assistant Professor with a 1943 Sc.D. from MIT, was asked to develop a course for chemical-engineering undergraduates to replace a general thermodynamics course given by Mechanical Engineering. The first result was a paper-covered lithoprinted volume of lecture notes on $8\frac{1}{2}'' \times 11''$ paper. It served at Purdue as a text from 1947 to 1949, and was the forerunner of the first edition of the book, published in 1949 by the McGraw-Hill Book Company, Inc. The purpose of the book is stated in the first paragraph of its Preface:

to present, from a chemical engineering viewpoint, an introductory treatment of thermodynamics which is sufficiently simple and free from mathematical envelopments that it may be understood by the average undergraduate student.

This simple philosophy suffuses all five subsequent editions, and surely underlies the book's long-standing appeal to students.

I joined the Purdue faculty as an Assistant Professor in 1952, coming from a D.Eng. program at Yale University, and used the book for several years in teaching the course for which it had been developed. In doing so I formulated some ideas on the subject of thermodynamics and on its instruction. My proposal to Prof. Smith of a joint effort to produce a *second* edition was accepted, and it appeared in 1959, by which time both authors had left Purdue: Prof. Smith was Chairman of Chemical Engineering at Northwestern University, and I was an Associate Professor at Rensselaer Polytechnic Institute.

In the second edition we revised and enlarged the treatment of basic concepts, the first and second laws, and such

topics as the properties of fluids, power cycles, and refrigeration, but we did not alter in any substantial way the material unique to chemical thermodynamics. I added a chapter on the **Thermodynamic Analysis of Processes**, a feature of the text in all subsequent editions. Some professors do not find time to cover this chapter, but for me it expresses the essence of engineering thermodynamics.

Sixteen years elapsed before publication of the *third* edition. During those years chemical engineering, and thermodynamics as a part of it, evolved rapidly owing to the advent of the computer. In 1959 students were still toting slide rules and becoming adept at trial-and-error calculations. By 1975, students were toting electronic calculators and becoming adept at iteration. (Wrong answers could now be given to 10 significant figures instead of just three.) During the 1950s Prof. Smith's research interests shifted primarily to chemical-reaction kinetics, as evidenced by the McGraw-Hill publication in 1956 of his text on *Chemical Engineering Kinetics*, whereas my research interests developed along the lines of solution thermodynamics. The initiative in revisions of the thermodynamics text after the second edition was therefore mine, though Prof. Smith's very active interest in the work always significantly enhanced the quality of the final product.

The third edition of 1975 incorporated block diagrams to outline systematic solution of complex phase-equilibrium problems, made practical by electronic computation. It also presented a coherent development of the mathematics of solution thermodynamics, and it introduced the reaction coordinate for the systematic solution of reaction-equilibrium problems. All this reflected my own education as the result of an intensive program of thermodynamic research. By this time both Prof. Smith and I were established in our ultimate career locations. Prof. Smith had gone to the University of California at Davis in 1961, and I remained at Rensselaer.

With the *fourth* edition of 1987, we undertook a general revision of the text so as to bring its contents up to date. The treatments of solution thermodynamics and phase equilibria were significantly influenced by my experience in the early 1980s of presenting (with Prof. Michael M. Abbott) a two-

day course for the AIChE Continuing Education Program, titled *Fluid-Phase Equilibria for Process Calculations*. The challenge of developing a full-fledged and meaningful, yet very concise, treatment of these complex subjects led to notational and derivational innovations that greatly increased the efficiency of presentation.

By the time thought was given to preparation of a *fifth* edition, both Prof. Smith and I had retired from teaching. We felt it essential to add a third author who still engaged in this activity. Professor Michael M. Abbott of Rensselaer was the natural choice; as the result of long collaboration with me, he had already influenced the content and style of the third and fourth editions. His special contributions to the fifth edition of 1996 included the introduction in appropriate places of molecular concepts and expansion of the treatment of phase equilibria. The fifth edition was moreover a general revision with emphasis on a writing style that was lucid, coherent, and refined. The present (*sixth*) edition is a further effort with the same objectives, in which major revisions are made in the treatment and application of equations of state.

The order of presentation of the same material has changed with every new edition. This has been in response to curriculum changes, to user feedback, and to our own teaching experience. Changes rarely meet with universal approval, and no change is likely to satisfy everyone. Nevertheless, the tradition of change has continued with the sixth edition, and extensive rearrangements of material are based on reviewer comments and our own sense of what presently seems most logical. Moreover, all figures are redone in a consistent style to replace a conglomerate of figures from the previous five editions.

A comparison of the first edition of 1949 with the sixth edition of 2001 reveals little that is the same. However, the original philosophy remains: It is a text designed for student understanding, devoid of unnecessary mathematical complexity and with many illustrative examples. On the other hand, one finds a switch in the sign convention for work and from English to mostly SI units, as well as many changes in notation and terminology. Although a rather large array of symbols is required to accommodate the quantities of thermodynamics, we have made every effort to simplify and keep the notation as clean as possible. It may not appeal to everyone, but it is part of the schooling of the vast majority of chemical engineers. Much material has been added to the book, resulting in an increase in the number of pages of text proper from 372 to 650. The Appendix has grown from nil to 122 pages, incorporating conversion factors, property data, and steam tables. Fold-out graphs for data presentation have given way to tables and equations. Evident also is an evolution in the use of language. This is illustrated by directly comparable introductory passages from the chapter on **Heat Effects** shown on the following page. One notes a reduction in length by about $\frac{1}{3}$, with no loss of content. The simple active-voice sentences are written in the present

tense. This is one reason that even those for whom English is not the native language find the text remarkably clear.

The first three editions were prepared in the traditional way, with a typewritten manuscript, review by a professional editor, typesetting into galleys, and finally rearrangement of the type to incorporate figures, resulting in pages to be printed. Proof-reading was required at each step, because errors could be (and were) introduced at all stages. The fourth edition differed in that I entered the entire text into the main-frame computer at Rensselaer, which then produced a printed manuscript from which the typesetting process could proceed. Thus the computer served merely as a sophisticated typewriter, albeit producing very clear copy, particularly of the mathematical material. The fifth edition of 1996 and the sixth of 2001 were done quite differently in that I entered the text into a desk-top computer; figures, prepared by the compositor, were incorporated into the text, and a type-setting program produced pages exactly as they were to appear in the published book. Once proof-read, corrected, and edited, there remained only the printing and binding. Thus I was responsible for the book's design.

Chemical-engineering thermodynamics has by no means been a static subject over the past half century. In fact, a remarkable evolution has taken place in its content and in its teaching. This evolution is reflected by changes that appear from edition to edition; moreover, the book has often promoted change. Authors must sometimes decide whether the purpose of a text is simply to reflect current practice or to seek to advance it. Changing *current* practice is difficult, but changing *future* practice through influence on the young is a unique opportunity. If, for example, the SI system of units is to be established in the United States, it must be done through students, by whom the *new* is easily accepted. In dealing with the innocent, one has at least a chance to implant ideas and mold behavior. Getting *professors* to change can be quite another matter. Removing the word *free* from *Gibbs free energy* has, for example, proved most difficult. Professors imprinted with this here-meaningless but commercially magic word can't seem to abandon it, even while teaching from a text in which the totally unambiguous *Gibbs energy* is used exclusively.

A book does not go through six editions and remain in print for more than 50 years without being a commercial success. Although *Introduction to Chemical Engineering Thermodynamics* has been translated into Spanish, Portuguese, Greek and Chinese, it is most often used throughout the world in the original English. It is sold in the United States and Canada as a hard-cover volume, but in the rest of the world in paper-back as the International Student Edition. Yearly sales now average about 20,000 copies, and total sales over the six editions exceed a half million, making it the best-selling textbook in the history of chemical engineering. No other comes close.

First Edition:

In nearly every industry of importance to chemical engineers there are operations accompanied by heat effects. These operations may be purely physical or may include chemical reactions. As an illustration, consider the process for the manufacture of ethylene glycol (widely used as an antifreeze agent) by the oxidation of ethylene to ethylene oxide and subsequent hydration of the oxide to glycol. The oxidation process has been found to be most effective when carried out at temperatures in the neighborhood of 250°C. Therefore, it is necessary to preheat the reactants, ethylene and air, to this temperature before they enter the reactor. In order to design a satisfactory preheater, the chemical engineer must be able to compute accurately the heat requirement, which in this case is a sensible heat effect accompanying a purely physical change. The oxidation reaction between the ethylene and oxygen in the air liberates heat. Since temperatures above 250°C result in less effective oxidation, provision must be made for removing heat from the reactor. The problem is further complicated by the fact that some of the ethylene is always oxidized completely to carbon dioxide, and this over-all reaction liberates a much larger quantity of heat than the partial oxidation to ethylene oxide. To design a suitable reactor it is imperative that the chemical engineer be able to evaluate these heat effects.

Sixth Edition:

Heat transfer is one of the most common operations in the chemical industry. Consider, for example, the manufacture of ethylene glycol (an antifreeze agent) by the oxidation of ethylene to ethylene oxide and its subsequent hydration to glycol. The catalytic oxidation reaction is most effective when carried out at temperatures near 250°C. The reactants, ethylene and air, are therefore heated to this temperature before they enter the reactor. To design the preheater one must know how much heat is transferred. The combustion reactions of ethylene with oxygen in the catalyst bed tend to raise the temperature. However, heat is removed from the reactor, and the temperature does not rise much above 250°C. Higher temperatures promote the production of CO₂, an unwanted product. Design of the reactor requires knowledge of the rate of heat transfer, and this depends on the heat effects associated with the chemical reactions.