AN INTEGRATED APPROACH

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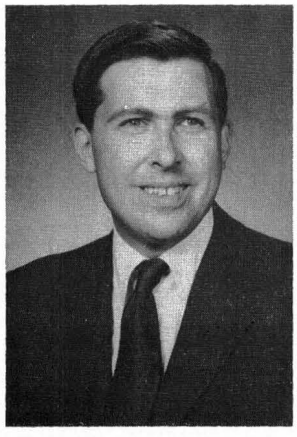
SINCE 1972 THE CHEMICAL Engineering Department at Penn State has attempted to eliminate compartmentalization of basic course material by providing a presentation which attempts to show students the relationships between the various parts of the sophomore and junior level required courses. Thermodynamics has been the integrating factor in many respects. In brief the following integration has taken place.

The first law of thermodynamics is combined with the material balance and industrial chemical processes as has been the case at most universities for many years. After this point, the study of the second law and its applications is carried out concurrently with the study of fluid mechanics and heat transfer such that some of the applications can be seen immediately. Phase equilibria is studied in the same course with mass transfer, while chemical equilibria is covered in the basic course in chemical kinetics and reactor design. Table 1 notes a brief outline of the material in these courses. As Penn State moves to a semester system in 1983, we intend to continue this approach with the exception that the first law will have to be separated from the stoichiometry and coupled with the second law.



Thomas E. Daubert, Professor of Chemical Engineering at Pennsylvania State University, has been at Penn State since 1961. His teaching and research interests are in the area of physical, thermodynamic, and transport properties. In addition to the text described in this paper he has co-authored two other books.

TABLE 1
Curriculum Content

PRINCIPLES OF CHEMICAL ENGINEERING I, II, III
- Chemical Process Industries and Stoichiometry
- First Law of Thermodynamics and Applications
- Organic and Inorganic Chemical Processes in Brief
- Material Balances
- Fluid Mechanics including mass, energy, and momentum balances and compressible flow.
- Heat Tranfer including basic modes of conduction, convection, and radiation and design of systems
- Equations of State
- Thermodynamic Properties of Real Fluids
- Entropy and the Second Law of Thermodynamics Relations among Properties and Diagrams
- Engines, Compressors, Refrigeration, Liquefaction
- Chemical Process Thermodynamics

MASS TRANSFER AND PHYSICAL EQUILIBRIA
- Homogeneous fluid mixture properties: Fugacity and Activity
- Phase Equilibria and Diagrams
- Equilibrium Stage Separations: Single and Multiple
  - Gas-Liquid (Absorption, Distillation)
  - Liquid-Liquid (Extraction)
  - Fluid-Solid (Leachng, Adsorption)
- Interphase Mass Transfer-Diffusion
- Differential Continuous Contacting
- Equipment Dimensions
- Simultaneous Heat and Mass Transfer

CHEMICAL EQUILIBRIA, KINETICS, AND REACTOR DESIGN
- Chemical Reaction Equilibria in chemical process systems for homogeneous and heterogeneous systems and single and multiple reactions
- Chemical Kinetics and Equilibrium-basic principles and relationships
- Chemical Reactors and Systems
- Homogeneous Reactions in ideal batch, continuous stirred tank, and tubular reactors including design of reactors
- Introduction to heterogeneous (catalytic) reactions, models, and reactor designs

Does such an approach have merit? Our experience shows that two of the perennial student impressions are alleviated, i.e., "Thermodynamics is not relevent to actual situations" and "I've never seen that equation or method before." Whether such a method better promotes a fundamental understanding of thermodynamics in the long run cannot be proven except that feedback indicates

the student acceptance of thermodynamics of equilibria are much improved by the inclusion of this material together with mass transfer and kinetics.

Following up the integrated approach is a senior-level elective in thermodynamics which stresses and reenforces broader applications of the basic principles as well as giving a deeper treatment of equations of state and more sophisticated calculational methods. Included is the use of both a physical and thermodynamic property data base package and subroutines for solving various equations of state for various thermodynamic parameters with main programs supplied by the students.

BASIC TEXTBOOK ON THERMODYNAMICS

"Introductory Thermodynamics for Chemical Engineers" is a first level textbook which attempts to summarize the aspects of thermodynamics necessary to formulate, design, operate, and control chemical processes of the 1980's. Continuous advancement of thermodynamics has occurred at such an increasingly rapid pace that no textbook can attempt to cover the entire field. The book developed is a textbook, not a research monograph, and does not advance new theories; it does attempt to summarize the salient features of current research which will be helpful in using the thermodynamic methods which are currently most accurate and convenient.

The book begins with an introductory chapter which provides necessary background and definitions of common terms and quantities of thermodynamics. The first major chapter treats equations of state (both analytical and corresponding states approaches) in some detail, emphasizing the methods which are now used by industry rather than the historical perspective offered by most texts. This allows immediate use of any equation of state in subsequent chapters on the first and second laws of thermodynamics, phase equilibria, and chemical equilibria. This approach is unusual in that most texts relegate equations of state to a later chapter following the first and second law treatment. The latter treatment requires that all topics must again be considered as only the ideal gas law is available for the first pass.

A unique feature of the book is the chapter on estimation of auxiliary physical properties necessary for thermodynamic calculations. Most equations of state and other thermodynamic methods require critical properties and third parameters. Densities, molecular weights, normal boiling points, and vapor pressures are often also required. Treatment of mixtures is quite necessary in processing calculations. Quite often these data are not readily available and sometimes experimental values do not exist. Thus, drawing on work as co-author of the *Technical Data Book—Petroleum Refining* for the petroleum industry through the American Petroleum Institute and background for the *Data Prediction Manual* for the chemical industry through the AIChE Design Institute for Physical Property Data, the author has included in a separate chapter in the text, the most up-to-date generalized prediction methods for each of these properties.

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The text is arranged in nine chapters. Treatments tend to be brief so that students do not get lost in the prose. Line drawings, diagrams, and plots are included throughout. Exercises for the student are liberally located throughout the text following the appropriate subsections. Such exercises allow a student to more clearly determine his or her understanding of the material and are valuable for both normal classroom instruction or self-study of the material. Lists of problems follow each chapter and references to topics discussed and bibliographies of the most important current literature, reviews, and compendia are included in each chapter. Appendices listing pure component physical properties of common compounds, selected thermodynamic properties of model compounds, thermodynamic properties of steam, and conver-

TABLE 2
Skeleton Table of Contents

sions among different systems of units are included. Table 2 gives as skeleton table of contents including only chapter titles. A complete table of contents is available from the author.

The text is designed for a first course in chemical engineering theromodynamics at the late sophomore or junior college level. No previous thermodynamic study is required. The goal is a balanced treatment between essential thermodynamic principles and the methods actually used in current practice to calculate thermodynamic properties and to use modern equations of state.

THOUGHTS

My philosophy is clear. Beginning chemical engineering thermodynamics should be vital, up-to-date, and presented in as simple a form as practicable to solve problems of industrial importance, while not compromising the underlying principles. Since thermodynamics pervades almost all areas of practice and many students never receive any additional formal study in the field, it is incumbent upon professors to make certain that the beginning courses in the field provide the background for students to function as working chemical engineers.

The mode of presentation of the material is variable; it may be integrated with other subjects or presented by itself, or may be offered traditionally by lecture-recitation or with modern teaching aids or self-study. The most important feature, however, is the content, assuring that our students can effectively practice their profession. □

THERMODYNAMICS WITH DESIGN PROBLEMS

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THERMODYNAMICS IS AN abstract subject, which students have more difficulty in relating to their more concrete career objectives than studies in subjects like unit operations. As most students will utilize thermodynamics in the future in a supporting calculation mode, it was thought desirable to emphasize the important connection of thermodynamics to design concepts in a direct way. Thus the general goals of thermodynamics course work can be stated such that at the conclusion of their studies the students should

- **learn the important fundamental concepts of thermodynamics, and**
- **be able to utilize the concepts of engineering calculation problems (including design).**

Time was made available in the course for both goals.

FUNDAMENTALS

The first goal was covered through standard lectures, using overheads etc., with the accompanying text written by S. I. Sandler, "Chemical and Engineering Thermodynamics." A synopsis of the syllabus covered includes the common concepts:

First Law
Second Law
Real Substances
Multicomponent Mixtures
Gibbs Free Energy
Phase Equilibrium
Chemical Equilibrium

The text served the course well and has many good features. It has an excellent presentation of

FIGURE 1. DESIGN I

TO: Design Group
FROM: L. Brightman, Director Design Services Goal, Inc.
SUBJECT: Recirculating Solids Boiler Concept

Please analyze the recirculating solids boiler concept, outlined on the attached sheet, as compared to a conventional industrial-heat boiler. Dr. R. C. Bailie, consultant, will present complete details at a meeting tomorrow.

List advantages and disadvantages of this system for use in generating steam from coal, oil or waste from our LP-7 plants. The results of your study and recommendations will serve as a basis to determine if further development work is justified.

Include in your analysis the net steam efficiency as a function of fuel feed, the efficiency potential for electrical production of the steam as a function of fuel load, and operational characteristics as a function of fuel capacity.

Your report is due five (5) weeks from Thursday, on December 5th.

‡Presently at Montana State University