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.

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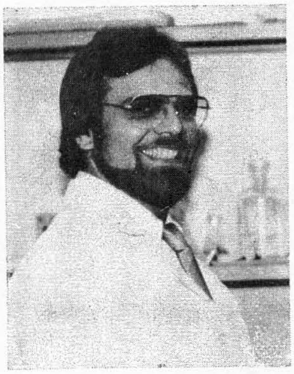
‡Presently at Montana State University

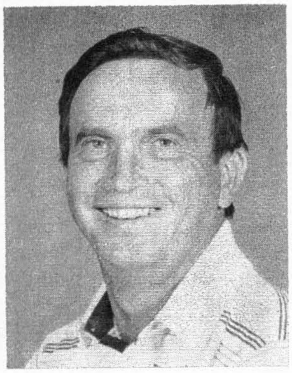
phase and chemical equilibrium. It has a new approach to the development of the second law by using a pseudoconservation equation, in parallel to the energy balance for the first law. This perhaps causes the instructor some difficulty, but less to the student. As with many instructors, we desire more example and illustrative problems.

DESIGN

Throughout their school years, most students have learned to examine a problem by searching for the appropriate equation(s) needed to solve the problem. Conceptualizing the control volume and stating reference conditions, are new modes of problem solving. The students are often confused by errors such as thinking all liquids are saturated liquids, not understanding the meaning of a sign on an answer, or misinterpreting the steps of a flow process on a p-H diagram.

To help alleviate these types of errors, to interrelate thermodynamics with other engineering course material, and to motivate the students, we try to integrate basic concepts with a design problem. Often the problem may be multi-faceted and the same design may be studied from a different point of view in a companion course. Designs we have used have focused on chemical equilibrium limits in reactors, physical properties of materials for portable heat paks, calculation of ionic acitivity coefficients for solubility limits, and process efficiencies.

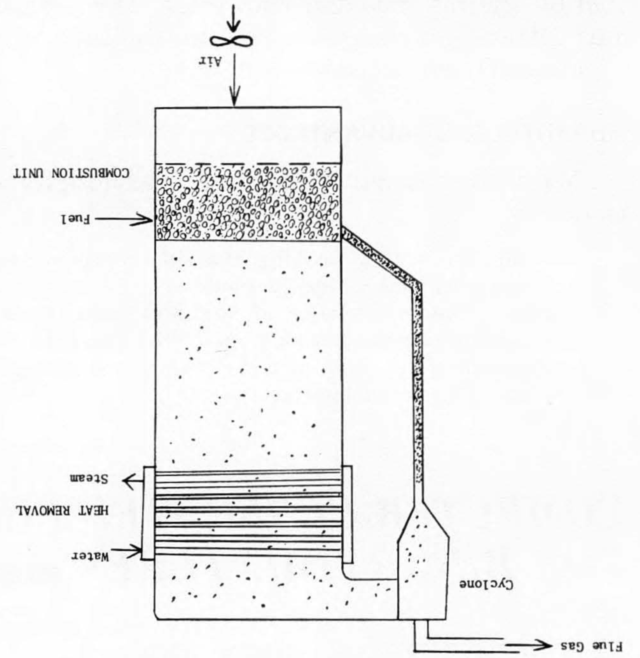




Eugene V. Cilento is an Assistant Professor at West Virginia University. He did his undergraduate work at Pratt Institute, receiving his BChE in 1973. His graduate studies were performed at the University of Cincinnati, where he received his M.S. in 1976 and PhD in 1978. His research interests are in biomedical engineering and include projects in biological transport phenomena using whole organ perfusions and in vivo microscopy. (L)

John Sears, Professor and Head of Chemical Engineering at Montana State University, has been active in educational innovation for over a decade. He helped organize the PRIDE program at West Virginia University upon which this paper is based. (R)

. . . we try to integrate basic concepts with a design problem. Often the problem may be multi-faceted and the same design may be studied from a different point of view in a companion course.



OPERATION:
Air—Constant
Fuel—Variable
Bed—B1-Modal Size Distribution
  Large Particles for Large U_{Mf}
  Small Particles for Elutriation and Sensible Heat Transfer
 —Combustion without Internals Disturbance
Cyclone—Return Small Particles to Bed
Heat Removal—Steam Generation

$$\frac{h_{\text{air/entrained particles}}}{h_{\text{air}}} > 1$$

FIGURE 2
Schematic: Recirculating Solids Boiler

Figs. 1 and 2 illustrate a recirculating solids boiler design concept we analyzed three years ago. This project was analyzed by the students in conjunction with a unit operations course. The students were broken into small groups to analyze and discuss the advantages or demerits of a recirculating waste boiler as compared to a conventional fluidized bed boiler. Discussion of the fluid flow through a packed/fluidized bed, cyclone, and heat transfer could be emphasized by the unit operations course. Process efficiency and Rankine-cycle efficiency as a function of turn-down ratio can be discussed from a thermodynamic viewpoint. The advantages of a 6:1 turndown ratio with good operability, lack of heat-exchange tube burnout and reduced start-up can be discussed in terms of process efficiency. The problem is open-ended, limited by student time and knowledge. The project was extremely well-received by the students, who became very interested in the design.

ADVANTAGES-DISADVANTAGES

Major advantages of the integrated design include

- **student motivation—making the subject more concrete, rather than an abstract subject**
- **emphasis on interrelation of variables (such as efficiency) with process design operability concepts**
- **reinforcement of particular thermodynamic concepts by use in the design analysis.**

An ultimate test is whether the students feel more comfortable and able using thermodynamics in subsequent work. In one case of design problem subsequently on separations, the students used Debye-Huckel theory to calculate mixed-salt ionic activity coefficients to find solubility limits in a crystallization problem.

Disadvantages are mostly time committments. Design takes class time, and the philosophical decision on such time must be made as to the worth of design integration at that point in a curriculum. If the design is done in conjunction with a second course, then some planning and integration between faculty instructors is necessary. If an individual instructor decides to add this design element to his course independently, then a full understanding should be present that this component replaces some more details on particular topics.

We are convinced that this approach is a worthwhile concept. ☐

COMPUTER-GENERATED PHASE DIAGRAMS FOR BINARY MIXTURES

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AND JEFFREY T. HASEMAN[2]
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PREVIOUS PUBLICATIONS [1,2,3,4,5] have described programs that generate projections of thermodynamic phase surfaces through computer graphics. Using these techniques, we have produced diagrams representing the properties of water and steam and the pressure-volume-temperature behavior of most of the common equations of state. These programs have been used successfully with a variety of output devices, such as CalComp and Versatec plotters, Tektronix storage terminals, and an Evans and Sutherland Multi-Picture System. In addition to making possible phase diagrams that have previously been unattainable, our programs also offer several options that enable the user to emphasize thermodynamic features of special interest.

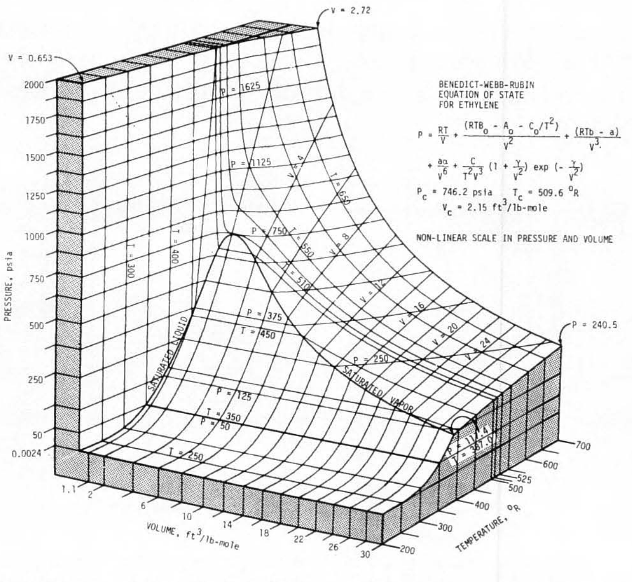

FIGURE 1. Benedict-Webb-Rubin equation of state for ethylene.

Fig. 1 presents a P-V-T diagram drawn with this technique. The surface is generated by the Benedict-Webb-Rubin equation as applied to ethylene. A two-phase region consistent with that equa-

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[1] On leave 1981-82 at the University of California at Berkeley. [2] Currently with Eli Lilly and Company, Lafayette, Indiana.