A Course in

ENERGY ENGINEERING

C. E. HAMRIN, JR., R. I. KERMODE,
and J. T. SCHRODT
University of Kentucky
Lexington, Kentucky 40506

THE COURSE BEGAN BEFORE the students went home for the Christmas holidays. We asked them to find the cost of energy sources such as coal, heating oil, gasoline, natural gas, and electricity in their hometown. In addition to passing out the course outline and reading assignments, the first class period was spent tabulating the students' data. It was interesting to learn that two students from Kentucky came from homes heated by coal, and the cost of this coal was \$29 and \$31.50/ton. This was quite a jump from the 1971 national average of \$7.07/ton! A student volunteered to summarize the data on ditto masters along with the latest national averages and on the common basis of ¢/10^6 BTU.

Another assignment in this first part of the course was to find an energy forecast for U. S. consumption in 1985 or 2000. It was an eye-opener for all of us to see the difference in Inter Technology Corp.'s prediction of 99.3 x 10^{15} (a composite of 56 predictions) and Chase Manhattan Bank's 135 x 10^{15} BTU/year for 1985. The hazards of forecasts were further spelled out by the required reading of Doan's article (see references at end of article).

PRIOR ENERGY RESEARCH

KENTUCKY WITH VAST COAL reserves relies heavily on mining for a large fraction of its gross State product. In the interest of preserving these markets the University of Kentucky (UK) received State funding starting in 1972 for coal research. This money was to be used for economic and technical studies related to Kentucky coals.

Projects in the department of chemical engineering included such topics as high temperature sulfur removal from gases, certain aspects of high and low BTU gasification, sulfur removal from coal, and a study of the agglomerating characteristics of coal. Thus in the Fall of 1972 four graduate students, three undergraduates and three post doctoral fellows were carrying out coal research under the direction of four faculty members. These numbers were augmented the following October when the department received an NSF-RANN grant in conjunction with the Ashland Oil Corporation. The focus of the research was liquefaction, and four separate projects in this area were initiated at that time.

During the summer of 1973 it became apparent that an increasing number of students and faculty would be involved in energy research. It was decided that two courses should be offered, one being an advanced undergraduate—M. S. level course, the other an M.S.—Ph.D. level course. The first was to be a complete survey of all types of energy and energy conversion processes. The second would be a course in fundamental chemical engineering principles applied to energy engineering.

COURSE OBJECTIVES

TO PROVIDE THE BROAD background needed to understand the nature of the problems we designed the first course as a series of lectures and class discussions that would accomplish the following:

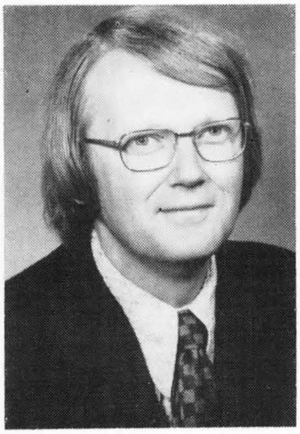
- **Familiarize the learners with the scope of the energy problem.**
- **Refresh them with the basic engineering principles needed to ferret out those energy problems requiring engineering skills for solution from those that require other skills for solution.**
- **Provide the opportunity to review in a systematic fashion certain facets of interest, opportunity and promise in the energy area.**
- **Educate them to the energy based raw material needs of commerce and industry, particularly the CPI.**
- **Evaluate the short and long term potentials of established and novel energy conversion and conservation processes and practices.**

In the short time in which we instigated this first course we foresaw that a consort of teaching faculty would be needed to handle both the broadness and depth of the course. Prerequisites were

Charles E. Hamrin, Jr. received his B.S., M.S., and Ph.D. degrees in Chemical Engineering from Northwestern University. He worked at the Y-12 Plant of Union Carbide for six years before joining the faculty of the University of Denver. He has been at the University of Kentucky since 1968 where his teaching has emphasized student involvement and discovery. (BELOW)

R. L. Kermode received his undergraduate education at Case Institute of Technology, and an M.S. and Ph.D. (1962) from Northwestern University. He has teaching experience at Carnegie-Mellon University and the University of Kentucky. His research interests are in the areas of process control and coal liquefaction. (LEFT PHOTO)

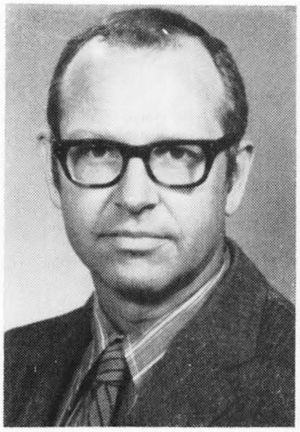
J. Thomas Schrodt is an Associate Professor of Chemical Engineering at the University of Kentucky. He received the B.Ch.E. degree in 1960 and a Ph.D. in 1966 from the University of Louisville and a M.S. degree in 1962 from Villanova University. Dr. Schrodt worked as a Senior Research Engineer for the Tennessee Eastman Company prior to joining the faculty at U.K. His teaching and research interests in fundamental thermodynamics and heat and mass transfer. (RIGHT PHOTO)

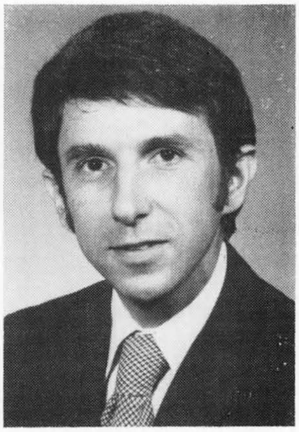


established for this faculty; each had to have a proficiency in the basic principles and each had to have an expertise in one or more of the elected areas of energy conversion or consumption. This required in several cases that faculty from other departments—Professors Cremers, Hahn, and Stewart from the ME Department—had to be called into the association. The prerequisites for students taking the course for credit amounted to an understanding of classical thermo, fluids and process principles or some equivalent thereof. Students from other disciplines desiring to audit the course were welcomed to sit in. The final class makeup consisted of 15 undergraduates, 14 Ch.E's and 1 Ag.E. and 16 Ch.E. graduate students.

COURSE CONTENT

THE COURSE CONTINUED as shown in the course outline. Thermodynamics was summarized in a handout of 20 important equations for energy conversion, conservation, entropy flow, and material transport. Sample problems were worked using a steam turbine to illustrate energy





balances and a chemical equilibrium problem with three simultaneous reactions occurring. Three homework problems covering a steam turbine, compressible fluid flow, and gasifier reaction equilibria were assigned and represented the quantative portion of the course.

Flow sheets and gasifier design for low-BTU and pipeline quality gas, and for liquefaction, were presented during the next several weeks. Data from the Morgantown Gasifier of the USBM, for the first time using a caking coal (Kentucky No. 9), were presented to the class. The outlet gas composition was shown to compare favorably with a simple model of an adiabatic reactor in which the water-gas shift reaction was at equilibrium and methane was being produced by the reaction

$$C + 2H_2 \rightarrow CH_4$$

Details of gas cleanup processes including liquid absorption, dry oxidation, and dry adsorption were also discussed. Current research at UK in this latter area was also detailed.

In addition to the text, *New Energy Technology* (by Hottel and Howard), a key reference to processes for producing pipeline quality gas was that of Bituminous Coal Research (see references). Gasification processes essentially consist of five major units: gasifier, water-gas shift reactor acid-gas removal system, methanator, and dryer. Discussion of the various AGA-OCR-USBM pilot-plant processes emphasized the unique features of each in terms of these five units. Liquefaction coverage was limited to the Sasol plant in South Africa and the H-Coal process.

In many instances novel learning techcniques were used to draw the students into class participation. For example, the group process technique of role-playing was used to discuss solvent refining of coal. Five groups were formed with leaders being chosen based on highest first exam scores. In 1/2 hour, each group was asked to come

up with a process to remove sulfur from Western Kentucky coal (4% S, about half organic sulfur and half pyritic sulfur). A 2-minute presentation was to be made to the Governor and his aides trying to sell them on this process as part of his $50 million energy package. (This bill was eventually signed in the Chemical Engineering Department's Unit Operations Laboratory.) Having received the assignment, one group left the room, and we wondered if they would return. The groups in the room became actively engaged in discussion, and those students doing coal research projects were particularly vocal. It was the first time for many to verbalize their ideas of coal processing based on class lectures and outside reading. No new processes evolved but a valuable learning experience occurred.

The remaining course topics were covered in one or two sessions except for nuclear which was presented in three lectures. Professor Bill Conger of our department covered the hydrogen economy concept based on his research in collaboration with Dean Funk.

Two special classes were those led by distinguished visitors to the Engineering College. Professor Jimmy Wen, Chairman of the Dept. of Chemical Engineering at West Virginia, gave an excellent overview of the short and long term solutions to the U. S. energy problem. Near the end of the semester, Professor Jack Howard, co-author of the text, gave an extemporaneous talk on tar sands and oil shale which supplemented the heavy emphasis on coal during most of the course.

Table 1

ENERGY ENGINEERING COURSE OUTLINE

I. Energy Consumption, Demand, Transportation, Storage, and Costs (CEH)
II. Thermodynamic Laws Governing Conservation and Availability of Energy (JTS)
III. Fossil Fuel to Fuel Conversion
  A. Low-Btu Gas (JTS)
  B. Pipeline Quality Gas (RIK)
  C. Synthetic Crude Oil (RIK)
  D. Solvent Refined Coal (CEH)
IV. Dependence of Industry on Hydrocarbon Feedstocks
  A. Petrochemical (JTS)
  B. Steel, Glass, Fertilizer, etc. (RIK)
V. Electrical Power Generation
  A. Non-Nuclear (OWS)
  B. Nuclear (OJH)
VI. Other Energy Sources
  A. Geothermal (JTS)
  B. Magnetohydrodynamics (CJC)
  C. Solar (CEH)
  D. Fuel Cells (RIK)
  E. Hydrogen economy (WLC)

CACHE COMPUTER PROBLEMS

CHEMICAL ENGINEERING EDUCATION, in cooperation with the CACHE (Computer Aides to Chemical Engineering) Committee, is initiating the publication of proven computer-based homework problems as a regular feature of this journal.

Problems submitted for publication should be documented according to the published "Standards for CACHE Computer Programs" (September 1971). That document is available now through the CACHE representative in your department or from the CACHE Computer Problems Editor. Because of space limitations, problems should normally be limited to twelve pages total; either typed double-spaced or actual computer listings. A problem exceeding this limit will be considered. For such a problem the article will have to be extracted from the complete problem description. The procedure to distribute the total documentation may involve distribution at the cost of reproduction by the author.

Before a problem is accepted for publication it will pass through the following review steps:

1) Selection from among all the contributions an interesting problem by the CACHE Computer Problem Advisory Board
2) Documentation review (with revisions if necessary) to guarantee adherence to the "Standards for CACHE Computer Programs"
3) Program testing by running it on a minimum of three different computer systems.

Problems should be submitted to:

Dr. Gary Powers
Carnegie-Mellon University
Pittsburgh, Penn. 15213