CEE

chemical engineering education

VOLUME XIV • NUMBER 3 • SUMMER 1980

CHEMICAL ENGINEERING DIVISION OF AMERICAN SOCIETY FOR ENGINEERING EDUCATION

CHE AT OREGON STATE

BOB TANNER OF VANDERBILT

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Gainesville, Florida 32611

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Chemical Engineering Education

VOLUME XIV NUMBER 3 SUMMER 1980

CHEMICAL ENGINEERING EDUCATION is published quarterly by the Chemical Engineering Division, American Society for Engineering Education. The publication is edited at the Chemical Engineering Department, University of Florida. Second-class postage is paid at Gainesville, Florida, and at DeLeon Springs, Florida. Correspondence regarding editorial matter, circulation and changes of address should be addressed to the Editor at Gainesville, Florida 32611. Advertising rates and information are available from the advertising representatives. Plates and other advertising material may be sent directly to the printer: E. O. Painter Printing Co., P. O. Box 877, DeLeon Springs, Florida 32028. Subscription rate U.S., Canada, and Mexico is $15 per year, $10 per year mailed to members of AIChE and of the ChE Division of ASEE. Bulk subscription rates to ChE faculty on request Write for prices on individual back copies. Copyright © 1980 Chemical Engineering Division of American Society for Engineering Education. The statements and opinions expressed in this periodical are those of the writers and not necessarily those of the ChE Division of the ASEE which body assumes no responsibility for them. Defective copies replaced if notified within 120 days.

The International Organization for Standardization has assigned the code US ISSN 0009-2479 for the identification of this periodical.

ChE department

OREGON STATE UNIVERSITY

Submitted by

CHARLES E. WICKS
Oregon State University
Corvallis, Oregon 97331

OREGON'S TRADITIONAL COMMITMENT to quality higher education was established in 1868 when Oregon State University (then known as Corvallis College) became qualified under the Morrill Act as a land-grant college. The U.S. Congress defined the purpose of the land-grant schools in these words: "The leading object shall be, without excluding other scientific and classical studies, to teach such branches of learning as are related to agricultural and the mechanic arts, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life." Since its founding, the university has grown in scope and diversity, accepting the challenge of the Morrill Act while seeking to free people's minds from ignorance, prejudice and provincialism and to stimulate instead a lasting attitude of inquiry. Oregon State University is currently recognized as a university composed of schools in which the liberal arts are pursued, together with professional and technological schools which depend chiefly on the sciences and social sciences.

The 400 acre Oregon State University campus, composed of 54 major buildings surrounded by

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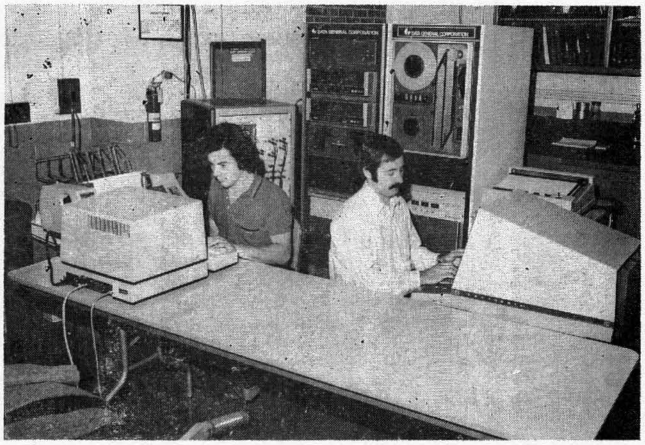
expanses of lawns, tall shade trees and flowering shrubs, is located in Corvallis, the heart of the Willamette Valley. This city of 45,000 people is situated between the snow-capped Cascade Mountains which rise to the east and the forested Coast Range to the west, beyond which lie the headland and scenic beaches of the Oregon Coast. These mountains and beaches provide a wide variety of outdoor activities throughout the year. These are balanced by the many cultural events and facilities found on campus. Oregon State offers a quality education in a relaxed, coherent atmosphere within a state that is proud of its leadership role in protecting the environment.

DEPARTMENT ROOTS

INSTRUCTION IN ENGINEERING began on the campus in 1883 with supervision vested in the mathematics department. In 1889, the Engineering Curricula was established involving civil, electrical, mechanical, and mining engineering. The first Chemical Engineering instruction followed the appointment of Professor Floyd Roland in 1914; at that time, Chemical Engineering was a separate school. The first bachelor of science degree in Chemical Engineering was awarded by this academic unit in 1917. After the addition of graduate courses, the first masters degree was granted in 1931 and the first Ph.D. degree in 1946. Chemical Engineering remained a separate school until the reorganization of the State System of Higher Education in 1932, when the school was brought into the School of Engineering. An important milestone in the emergence of the Chemical Engineering Department at Oregon State University was in 1942 when the Department became fully accredited.

Since its birth, the department has grown under the leadership of several outstanding individuals; noteably George Gleeson—who later became Dean of the School of Engineering—and Jesse Walton. The Chemical Engineering program now occupies an eminent position in the School of Engineering, enrolling over 270 undergraduates and 35 graduate students. The department has been located in its own building since 1955; this facility makes available over 35000 square feet for instruction and research.

Flexibility in its academic and research programs continues to be the keystone to the department's development. Rather than adhering to any narrow field of specialization, the department has sought to shift its technical emphasis over the years so that its graduates could meet the challenges of the future, using the most newly developed technology. Due to this philosophy and the accomplishments of the department's faculty members, chemical engineers have filled several of the university's high administration positions. Currently, the Associate Dean of Engineering and Director of the Experiment Station and the department chairmen of agricultural, chemical and mechanical engineering have Ph.D. degrees in Chemical Engineering. The Associate Dean, Jim Knudsen, is also the national president of the American Institute of Chemical Engineers.



Dr. Kayihan and Brice Dardell using departmental minicomputer in their computer graphics developmental work.

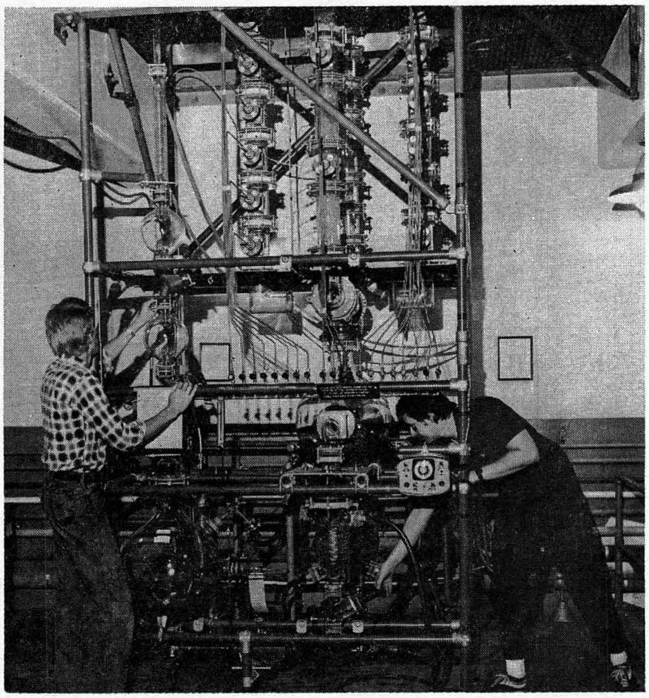
Since our first graduate in 1917, the department has provided the education of several outstanding engineers and scientists who have continued to make important contributions in industrial, governmental, and academic circles. The department is particularly proud of two of our earlier undergraduates who have recently been honored by Oregon State University for their distinguished services to society. Linus Pauling, the only chemical engineer to receive two Nobel prizes

Flexibility in its academic and research programs continues to be the keystone to the department's development. Rather than adhering to any narrow field of specialization, the department has sought to shift its technical emphasis over the years so that its graduates could meet the challenges of the future, using the most newly developed technology.

(one for his contributions in the field of chemistry and one for his efforts toward world peace) and Paul Emmett for his research in surface chemistry and heterogeneous catalysis and the famous B.E.T. theory on adsorption of gases.

THE UNDERGRADUATE PROGRAM

CONSISTENT WITH THE department's policy of technical flexibility and adaptability, the present undergraduate curriculum has been developed to maintain a strong emphasis on the physical and engineering sciences and to provide



Jeff Pitzer and Doug Larsen, seniors, working in the Chemical Engineering Lab.

laboratory and design experiences in solving today's practical engineering problems. A total of 204 term hours is required in the undergraduate curriculum; this includes year sequence courses in the engineering sciences of thermodynamics, transfer and rate processes, mechanics of solids, and electrical fundamentals as well as the more traditional chemical engineering courses of stoichiometry, applied fluid and heat transfer, mass transfer operations, chemical reaction engineering, process dynamics and control, and chemical plant design. Elective courses are available from other departments in specific engineering fields of air pollution, pulp and paper processes and wastewater engineering.

Computers have been an integral part of the Chemical Engineering curriculum. Freshmen are introduced to our computing facilities with an extensive FORTRAN programming course; this is followed with a computer-aided stoichiometry course. Several of the other undergraduate courses utilize the computer on either a required or optional basis. Students have access to the department's real-time and analog computers as well as the university's computer system using departmental terminals. Every office and classroom has been wired so that the terminals can be made readily accessible.

Also available is the senior project option which typically involves the student in an on-going departmental research project or in the development on new computer methodology. Our faculty believe this "hands on" experience in a specialized field will help motivate the good students and hopefully encourage them to continue their education towards an advanced degree.

Considerable faculty effort is devoted to our undergraduate program. This is evidenced by the textbooks authored by members of our faculty. Octave Levenspiel has written the following texts: "Chemical Reaction Engineering," "Fluidization Engineering," "The Chemical Reactor Minibook," and "The Chemical Reactor Omnibook." Jim Knudsen has co-authored the textbook, "Fluid Dynamics and Heat Transfer," and Charles Wicks has co-authored a textbook with two other Oregon State professors, "Fundamentals of Momentum, Heat and Mass Transfer." Teaching does not take second place to research; this is evidenced by the honors and teaching awards won by our faculty. Octave Levenspiel was honored as an outstanding lecturer by the American Society for Engineering Education. Both Bob Mrazek and Charles Wicks have received the Carter Award for being the most inspirational teachers in the School of Engineering for a given academic year. In 1978, Bob Mrazek was honored by the university with the Elizabeth Ritchey Award as the university's outstanding teacher and advisor. In 1979, Charles Wicks was recognized by the OSU IFC as the outstanding university teacher and Jim Knudsen received the OSU Alumni Award as the most distinguished professor.

THE GRADUATE PROGRAM

THE OREGON STATE Chemical Engineering Department offers programs leading to the M.S. and Ph.D. degree, with either the thesis or non-thesis option available at the master's level. The

An informal academic atmosphere is maintained with opportunity for the graduate students to give and take with the faculty and for joint work with environmental engineering, earth sciences, oceanography. and atmospheric sciences.

graduate student is provided with a broad selection of courses in all areas fundamental to chemical engineering. Course selection is made by the student in consultation with the graduate student advisor or with the major professor.

An informal academic atmosphere is maintained with opportunity for the graduate students to give and take with the faculty and for joint work with environmental engineering, earth sciences, oceanography, environmental sciences and atmospheric sciences. We believe that science and technology have a responsibility to make this a better world.

The environment of our graduate program also provides a unique opportunity for cultural exchange. We are currently supporting students from over a dozen countries with fellowships, teaching assistantships, and research assistantships.

Our graduate students carry out most of their research work in their own individual laboratories or in the four-story chemical engineering laboratory located in the departmental building. We are fortunate to have the laboratories of the U.S. Bureau of Mines, U.S. Environmental Protection Agency, the OSU Forest Product Research Center, the OSU Marine Science Center, and the OSU Radiation Center nearby where some of our students have conducted their research. These interdisciplinary research projects will continue as the technological problems facing society require increasingly sophisticated solutions.

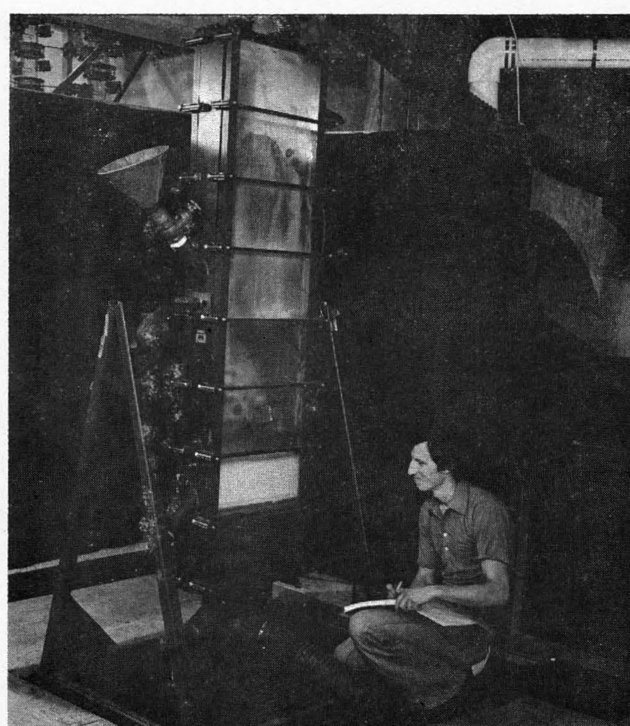
Beyond their usual interaction with the Oregon State faculty, our graduate students have the opportunity to informally meet with and listen to many visiting professors in our graduate seminars. In recent years, distinguished chemical engineers from the United States and many foreign countries, such as Russia, England, Italy, Australia, Italy, etc., have presented seminars to the OSU faculty and students.

We are a small department, having only seven full-time faculty members. By and large, we are practically oriented, with a desire to make research relevant to the needs of man. And perhaps it is because we live in Oregon that we are concerned about the environmental impact of what we do. Our research projects include a study to find out how rivers get supersaturated with nitrogen, resulting in the death of migrating salmon, and how coal can be efficiently burned without polluting the atmosphere with sulfur dioxide, as well as the more conventional studies in the areas of heat and mass transfer, mixing, reactor design, corrosion, thermodynamics, process control, systems optimization, fluidization, extractive metallurgy and chemical reaction engineering.

As examples of current research, four of the current research programs are described below:

Fluidization

In 1974, Octave Levenspiel and Tom Fitzgerald were approached by the Electric Power Research Institute (EPRI) with the suggestion of extending the correlations in his text, "Fluidization Engineering," to larger particles and higher velocities which could be used in designing fluidized bed combustors. Large fluidized beds, approximately a square meter in cross section, were constructed to fluidize gravel-sized particles at velocities as high as 4 meters/second in the presence of immersed tube bundles. Specialized instrumentation systems were developed to make



Steve Crane, graduate student, collecting data from one of the four fluidized beds within the department.

A new reactor has been used to study simultaneous mass transfer and reaction between two fluid phases under the direction of Octave Levenspeil. The unique features of this reactor are the uniformity of composition of the two phases and the ability to independently adjust the individual phase resistances to mass transfer.

transient heat transfer and tube stress measurements, and to trace the flow of solids and gas. Parallel heat transfer studies were initiated in the Mechanical Engineering Department by Jim Welty. The research effort in fluidization at OSU has led to comprehensive models for coal burning in atmospheric fluidized bed combustors, for elutriation of particles from high-velocity fluidized beds and for predicting bed to tube heat transfer coefficients. Current fluidized bed combustion research is sponsored by the U.S. Department of Energy, EPRI, Babcock and Wilcox and the Aerospace Corporation.

Control

Saving energy in distillation is a major question in our profession. Ferhan Kayihan is looking into this problem from the controller design aspect. He is using intermediate heat exchangers on a specially designed laboratory column to examine the relative merits of new control strategies.

Because of Bob Mrazek's interest in determining physical properties and applying thermodynamics to metallurgical processing, he is currently involved with the complete instrumentation and computer interfacing of a low-temperature calorimeter. This project will permit computer control and automatic data acquisition and its reduction for measurements over a temperature range of 5 to 300°K.

Heat and Mass Transfer

Under the joint sponsorship of National Science Foundation and Heat Transfer Research Institute, Jim Knudsen has been conducting extensive research on waterside fouling resistance inside condenser tubes. This project has provided fundamental information on fouling characteristics of cooling tower water.

Charles Wicks is looking at cross-current contactors as a means of saving energy in separation processes by reducing the pressure drop required for a specific thru-put and separation. In other mass transfer projects, he has studied the mass transfer of surface gases due to jet streams plunging into a liquid pool; this study verified the reasons why there were supersaturated nitrogen levels in our rivers and provided the necessary information for optimizing an aeration pond.

A new reactor has been used to study simultaneous mass transfer and reaction between two fluid phases under the direction of Octave Levenspiel. The unique features of this reactor are the uniformity of composition of the two phases and the ability to independently adjust the individual phase resistances to mass transfer. Octave also continues his work in the field of chemical reactor design; his contributions in this special field were recognized by A.I.Ch.E. when he was awarded the 1979 Wilhelm Award.

Combustion

Research in pyrolysis and combustion of wood is the prime interest of Ferhan Kayihan. Pyrolysis converts up to 80% of dry wood into combustible gaseous products. The kinetics of reactions producing various volatile gases become the critical part of any reactor model dealing with the conversion of energy from wood. Experiments under high heating rates have been conducted to identify the kinetic behavior of different wood types. It has been shown that the pyrolysis and combustion phenomena are highly affected by, and in turn alter, the porous structure of wood particles.

Hopefully, the reader will not gain the impression that only work is involved in chemical engineering at Oregon State. If you were to join the faculty and graduate students on one of our weekend jaunts to Octave Levenspiel's beach cabin, you would encounter a spirited volleyball game, chess tournaments and explorations of the aquatic shorelines. Other excursions are taken in the Cascades for cross-country skiing or weekend camping and mountain climbing trips.

For three years, our graduates have remained undefeated in the university intramural soccer league. And whenever Oregon State has a home basketball game, the department building empties as the students forego their studying to root the Beavers on to another victory. □

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ChE educator

Bob Tanner of Vanderbilt

DENNIS THREADGILL*
Vanderbilt University
Nashville, TN 37235

For Bob Tanner, Associate Professor of Chemical Engineering at Vanderbilt University, education has broad objectives. His ideas about the purposes of education color every facet of his job. He believes that a teacher's role is "to provide the spirit, the motivation for *continuous* learning. Education should be a life-long experience," he explains.

"I think of my role as a teacher as having two related functions. Of course I want to impart specific knowledge and specific skills so that my students can practice their profession; but I am not teaching a trade. I am teaching a way of learning and of approaching problems. The ultimate learning situation I seek for all of my students, graduate and undergraduate alike, is one of self-sufficiency. I try to lead them to that point where they can begin to teach themselves. That is the basis of life-long learning, and as in life itself, it means learning from mistakes as well as successes."

Nine seniors completed the laboratory work and designed a plant which could provide enough lysine-enriched yeast to meet all the protein needs of the population of Nashville, plus enough by-product alcohol to supply large-scale energy demands.

Creating a provocative educational climate in which this kind of learning can best take place has been a primary objective for Bob while at Vanderbilt. He sees the university environment as special, open surroundings in which new ideas are aired and questions are encouraged.

ACTIVE STUDENT PARTICIPATION

ONE CLASSROOM example of this philosophy in action developed into a senior plant design project that earned the students and their instructor a place on the cover of *Vanderbilt Alumnus* in June, 1976. Nine seniors completed the laboratory work and designed a plant which could provide enough lysine-enriched yeast to meet all the protein needs of the population of Nashville, plus enough by-product alcohol to supply large-scale energy demands. Additionally, it could produce carbon dioxide to supply a dry-ice plant, while

*The author acknowledges the special assistance of Laura Hasselbring, formerly of the Vanderbilt Office of Public Instruction, in the preparation of this paper.

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the waste products generated could fertilize a crop of tomatoes to be grown in five greenhouses. According to their calculations, the whole operation would require a plant covering about ten acres, and it would be profitable.

"I gave them a lot of freedom to define the problem," Bob recalls, "and in the beginning they floundered. They were being called upon to put into use almost everything they had learned in the previous three years of their chemical engineering course work. At the semester's end, all of us, the class-members, Professor Dennis Threadgill, the faculty member in charge of the plant design course work, and I, were pleased with their efforts."

Bob's interest in exposing students to new ideas and to professional role models who stimulate the imagination, led him to develop a seminar program for seniors and graduate students that brought approximately fifty prominent outside speakers to Vanderbilt in recent years. "I invited people who like their work," he explains, "who are excited about it, who like to talk about it, and who open new vistas of experience for the students. I sought fine practitioners, people who are outstanding in their respective specialties, and asked them to talk about how they approach problems and how they deal with the problems they choose."

"It is gratifying to watch seniors come out of a seminar excited by the speaker's enthusiasm for his work," Bob remarks. "I hope that my students will come to understand that learning through exploration is the best part of any job.

SPECIAL INTERESTS ARE VARIED

BOB'S OWN CURRENT RESEARCH interests reflect a journey of personal exploration along varied avenues of professional endeavor. He earned the Ph.D. degree from Case Western Reserve University. From that environment he developed two, long-term interests. His dissertation, under the direction of Coleman Brosilow, taught him sophisticated mathematical modeling techniques, while a private conversation with Department Chairman Robert Adler on the production of single cell protein from hydrocarbons, sparked a continuing interest in biochemical processes, particularly fermentation. Today, Bob is primarily concerned with modeling the dynamics of fermentation processes.

His interests are diverse. An association with Harry Broquist, Professor of Biochemistry and Chairman of the Nutrition Division of the Biochemistry Department at Vanderbilt, started Bob thinking about a simple, exceptionally low-cost way of increasing lysine content in yeast which then could be used in breads and other foods as a protein supplement.

By manipulating the temperature and acidity during fermentation of baker's yeast or glucose, the lysine content of yeast can be increased by 25 percent. Lysine is an essential amino acid needed for correct nutrition and is deficient in corn and many grains and their derived foods.

"By increasing the lysine content of yeast, less yeast would be needed to obtain the minimum daily requirement of lysine, thus avoiding some of the nutritional problems associated with high amino acid intake from single cell protein, namely uric acid poisoning and gout," Bob points out.

This research opens the door to an easily applied engineering approach to increase the nutritional value of food and introduces an alternative to the genetic approach. Baker's yeast can be grown throughout the world on a variety of raw materials.

A second area of interest which he has been studying for ten years and which is directly related to food and protein alternatives is kinetic hysteresis in enzyme and fermentation systems.

A second area of interest which he has been studying for ten years and which is directly related to food and protein alternatives is kinetic hysteresis in enzyme and fermentation systems. Hysteresis is defined in physics as "the failure of a property that has been changed by an external agent to return to its original value when the cause of the change is removed." The word comes from the Greek word, *husteresis*, a shortcoming.

"It has been shown that kinetic hysteresis can be a useful tool in elucidating mechanisms in both enzyme and fermentation systems," Bob reports. Hysteresis may be particularly helpful in suggesting the presence of an enzyme not previously suspected in a fermentation system. Moreover, as a tool for discrimination between models, hysteresis can be used to imply the presence of parallel pathways, of additional intermediate states, and of proteases countering the primary enzyme systems.

Hysteresis may even be used to infer rates of enzyme induction, possibly suggesting constitutive and induced mechanisms. Used cautiously, in keeping with the limitations of the data, hysteresis curve analysis appears to aid in experimental design by reducing the number of experiments needed for the elucidation of fermentation mechanisms.

THE KUDZU QUEST

A THIRD AREA OF INTEREST, less pedantic than either lysine-enriched yeast production or kinetic hysteresis in fermentation systems, is Bob's curiosity about kudzu, a tenacious, escaped vine that is present throughout the rural Southeast.

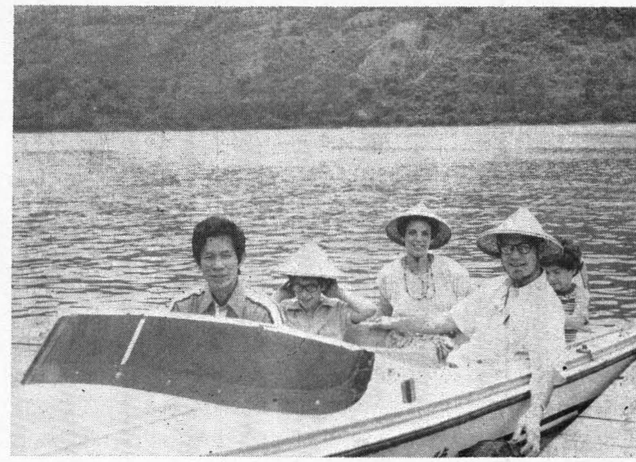
Kudzu grows at a phenomenal rate and thrives best in a climate defined by the hot, humid summers and mild winters common to the South. Originally introduced to the region as an answer to soil erosion, kudzu has been known to grow as much as a foot a day and seventy feet a summer. The plant has been referred to as "King Kong Kudzu, Menace to the South," and has received attention in poetry, fiction, film and in numerous articles.

The July 24, 1979 issue of *The Wall Street Journal* reports:

> **"Kudzu has become a Southern joke, but the laughter is tinged with bitterness. Southerners say that kudzu is the only plant whose growth is measured in miles per hour. They assert that the beanstalk that Jack climbed wasn't a beanstalk, but a kudzu stem. And farmers insist that the best way to plant kudzu is to 'throw it over your shoulder and run.'"**

The questions Bob hopes to answer concern potential uses for the ubiquitous plant. He proposes to use the starchy root as a fermentation medium in order to develop a commercial outlet for kudzu, thereby adding a starch supplement to our renewable food and fuel supplies. Preliminary experiments indicate that the root provides a vitamin-enriched source of starch for ethanol and yeast fermentations. In addition to the traditional use of kudzu for hay as an animal feed, Bob suggests that the woody, thicker vines may be used, along with coal, for the production of steam

A third area of interest . . . is Bob's curiosity about kudzu . . . Bob suggests that the woody thicker vines may be used, along with coal, for the production of steam in electric power plants.



Professor S. Y. Huang of the National Taiwan University shows Bob and his family how to relax Taiwan-style.

in electric power plants. As a low-sulfur, fast-growing renewable resource, kudzu plants could provide a partial local solution to the twin problems of environmental pollution (by blending with high sulfur coal, the total sulfur content can be reduced to meet air pollution regulations) and an indigenous source of energy for the South.

Bob's interest in kudzu has made him an authority on the vine, a position he views with humor. The implications for the plant's potential as a presently unused agricultural source for alcohol-based fuels, however, are significant. He receives regular inquiries from the media and from research centers across the country for new information.

BOB, THE COLLABORATOR

WHILE AT VANDERBILT, Bob has maximized the opportunities for collaborative research efforts with other faculty members. "I enjoy sharing ideas with my colleagues," he explains, "I like a situation with give-and-take. I gain new insights when I work with people in other disciplines, as well as with other chemical engineers."

Bob and Philip Crooke, Associate Professor of Mathematics, have collaborated on numerous kinetic modeling studies. They have published several papers jointly, and several more are currently underway. Bob and Phil are the objects of good-natured ribbing for their daily working lunches by other members of the Math faculty whose lunchtime conversations often reflect more down-to-earth concerns.

In addition, Bob's collaborative research at Vanderbilt has included the investigation of the surface chemistry behavior of crack detection penetrant dyes for use in non-destructive testing with Paul Packman, formerly a member of the Materials Science faculty, and presently Chairman of the Department of Civil and Mechanical Engineering, Southern Methodist University, and the development of a rapid method for the identification of pathogenic microorganisms in wastewater with George Malaney, Professor of Environmental Biology. Bob is presently working with David Wilson, Professor of Chemistry, on hysteresis in adsorption processes, and with Donald Pearson, also a Professor of Chemistry on a process to convert alcohols into hydrocarbons.

In 1978, Bob was asked by the former Dean of Engineering, Howard Hartman, to initiate a collaborative energy research project between Vanderbilt and Oak Ridge National Laboratory. Today Bob both coordinates the research efforts and administers the Department of Energy grant to the University.

A glance at the books on his shelves shows Bob's eclectic nature. Apart from engineering and related scientific titles, he has volumes dealing with geology, fibers, medicine, and China, as well as magazines such as Mother Earth News **within reach.**

Bob has remained in contact with colleagues at Merck, Sharp and Dohme Research Laboratories, where he worked for five years before joining the Vanderbilt faculty. A continuing interest in pharmacokinetics prompted an ongoing study with Joseph Bondi of Merck's West Point facility that applies dynamic modeling techniques to drug metabolism.

TAIWAN TRIP SERVES DOUBLE PURPOSE

CONTRACTS MADE AT THE USA/Republic of China Joint Seminar on Fermentation Engineering at the University of Pennsylvania in 1978 led to a very exciting plus for collaborative research. Bob's conversations in Philadelphia with two members of the Chinese delegation, S. Y. Huang, Professor and Head of the Department of Chemical Engineering at National Taiwan University, and C. H. Lin, Professor and Chairman of the Department of Chemical Engineering at Tunghai University, resulted in the commitment to a mutual research project. The groundwork for the project was established in the summer of 1979 when Bob, his wife Ruth, and their sons, David and Benjamin, traveled to Taiwan to meet with his Chinese colleagues. While the family shared the excitement of travel in the Far East, Bob and Professors Huang and Lin agreed to study solid and semi-solid fermentations, building on the Orient's special knowledge of fermented foods. Additionally, one of Professor Lin's graduate students, Chia-Jenn Wei, is continuing his graduate training with Bob at Vanderbilt.

"The trip was a wonderful experience for us," Bob recalls. "Not only did we leave Taiwan feeling as though we had left family behind, so constant was the Chinese warmth and hospitality, but I found Professors Huang and Lin to typify the energy and devotion of Taiwan's researchers to developing and strengthening their country's scientific and industrial base."

On the home front, Bob is an active participant in technical societies. Currently, he serves as Chairman of the Microbial and Biochemical Technology Division of the American Chemical Society. A personal interest in alcohol-based fuels led him to invite a Brazilian researcher to the Washington, DC meeting in September 1979 as a distinguished speaker on his country's work on gasohol.

Bob says that because he gets so much pleasure from his job, he really doesn't separate "work" from "outside activities." In Taichung, Taiwan, while strolling through the open market, he stumbled upon a Chinese medicine shop whose youthful proprietor sold kudzu root as a medicinal

Bob, his wife Ruth and two sons do some sightseeing on their 1979 trip to Taiwan.

staple. The druggist's well-thumbed pharmaceutical index revealed that kudzu broth, made from the dried root, quenches thirst and accelerates perspiration in a feverish patient, combats alcoholism and soothes headaches. "My 30¢ purchase there was the best souvenir of our trip to Taiwan I could buy," Bob admits with a smile. "It's the kind of discovery that adds an extra dimension of pleasure to my research."

Conversation reveals that Bob very much enjoys local events. He has traveled around Tennessee attending local festivities, such as old-time fiddlers' contests and performances at bluegrass music parlors. Civil War history also captures his interest. He and his family particularly enjoy visiting national and state parks, from battlefields to Mississippian Indian digs and ante-bellum homes ornamented with battlescars.

A glance at the books on his shelves shows Bob's eclectic nature. Apart from engineering and related scientific titles, he has volumes dealing with geology, fibers, medicine, and China, as well as magazines such as *Mother Earth News* within reach. This eclectic approach to life and science characterizes him as a scientist and researcher. □

Process Flowsheeting

A. W. Westerberg, H. P. Hutchison, R. L. Motard, and P. Winter

"From a definition of the process units and their interconnection, the authors show how the computer can be used to develop and solve equations based on chemical components and operating conditions and model the steady-state performance of the plant by generating the heat and mass balance. . . . It fills a gap in the literature and gives a sound account of . . . the underlying technology of process flowsheeting systems and the mathematics needed for modelling a process." Chemical Engineering. **139 tables and diagrams.**

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Texas Tech University, Department of Chemical Engineering, seeks applicants for a tenure-track position. Ph.D. in Ch.E. required. Industrial experience is desirable but not required. Candidates should have an interest and talent for teaching and research, with the ability to develop a self-supporting research program. An appointment effective January 1, 1981 is possible. Interested candidates should submit resumes and references to: Chairperson, Department of Chemical Engineering, Box 4679, Texas Tech University, Lubbock, TX 79409. Texas Tech University is an equal opportunity/affirmative action employer.

ChE book reviews

TURBULENT MIXING IN NON-REACTIVE AND REACTIVE FLOWS

Edited by S. N. B. Murthy
Plenum Press, New York (1975). 464 pages
Reviewed by William E. Ranz
University of Minnesota

This volume, intended to be a good sampling of science and art in 1974, consists of twenty-four papers by separate authors prepared as proceedings of a Project Squid Workshop on Turbulent Mixing in Non-reactive and Reactive Flows, held at Purdue University, May 20-21, 1973. The workshop was sponsored by the Office of Naval Research and the Air Force Office of Scientific Research.

Content is dominated by continuing developments in statistical fluid mechanics, supported by a modest amount of experimental measurement and by engineering modeling. The next largest group of papers represents rising interest in large scale structures which persist at high Reynolds numbers and resist analysis by probability concepts. Edited discussions which follow each paper help to unify the disparate presentations. They also show a growing division between two schools of thought, those who advocate probability distribution functions and those who chase eddies to achieve better understanding of a mixed-up subject.

Species concentration, diffusion, variation, and structure in mixing flows and with chemical

Continued on page 136.

CHEMICAL ENGINEERING DIVISION ACTIVITIES

EIGHTEENTH ANNUAL LECTURESHIP AWARD TO KLAUS D. TIMMERHAUS

The 1980 ASEE Chemical Engineering Division Lecturer was Klaus Timmerhaus of the University of Colorado. The purpose of this award lecture is to recognize and encourage outstanding achievement in an important field of fundamental chemical engineering theory or practice. The 3M Company provides the financial support for this annual lecture award.

Bestowed annually upon a distinguished engineering educator who delivers the Annual Lecture of the Chemical Engineering Division, the award consists of $1,000 and an engraved certificate. These were presented to this year's Lecturer at the Annual Chemical Engineering Division banquet, held at the University of Massachusetts, Amherst, MA, on June 24, 1980. Dr. Timmerhaus' lecture was entitled "Fundamental Concepts and Applications of Cryogenic Heat Transfer."

Klaus Timmerhaus earned B.S., M.S., and Ph.D. degrees from the University of Illinois, where he also competed in three athletic sports: cross-country, hockey, and track. He is still an occasional jogger and was a member of the University of Colorado Chemical Engineering Department's four-mile relay team which captured the AIChE F. J. Van Antwerpen trophy this past year.

After spending two years with Chevron as a process design engineer, he joined the chemical engineering faculty at the University of Colorado in 1953. He presently is associate dean of engineering for graduate and research activities, director of the Engineering Research Center, and professor of chemical engineering. During 1979-1980 he is also serving as chairman of the Department of Aerospace Engineering Sciences.

Over the past twenty-five years Dr. Timmerhaus has edited the Advances in Cryogenic Engineering **series and has coedited the** International Cryogenics Monograph Series. **His work has accounted for a total of 48 books and some 70 refereed papers to-date.**

He has served as director and president of AIChE, served as chairman for the AIChE Dynamic Objectives Study, and as chairman of several of AIChE's national committees. He has also served as executive director and chairman of the Cryogenic Engineering Conference Board for 12 years. He is a member of the National Academy of Engineering, and a Fellow of AIChE. During 1972 and 1973 he served as section head of the Chemistry and Energetics Section of NSF's Engineering Division. He was a charter member of NSF's Advisory Council.

He is the recipient of the S. C. Collins Award for outstanding contributions to cryogenic technology, the ASEE George Westinghouse Award for outstanding teaching, the AIChE Alpha Chi Sigma Award and the AIChE Founders Award.

LECTURE TOUR

Funds are available to have Dr. Timmerhaus deliver his Award lecture at three locations in the U.S. The locations are to be selected from schools requesting the presentation of the lecture. Requests for this outstanding lecture will be received until September 1, 1980. The request should include suggested times, the audience to which the lecture will be presented, and whether or not the school could participate in some of the costs associated with a lecture tour. Funds are available from 3M, but they are limited. Please send your request with the required information to Dr. Homer Johnson, ChE Department, University of Tennessee, Knoxville, TN 37916.

NOMINATIONS FOR 1981 AWARD SOLICITED

The award is made on an annual basis with nominations being received through Feb. 1, 1981. The full details for the award preparation are contained in the Awards Brochure published by ASEE. Your nominations for the 1981 lectureship are invited. They should be sent to Dr. James E. Stice, ChE Dept., U. of Texas, Austin, TX 78712.

NEW DIVISION OFFICERS ELECTED

The newly elected ChE Division officers are: James Couper, Chairman; John C. Biery, Past Chairman; W. D. Baasel, Chairman Elect; Phillip Wankat, Secretary-Treasurer; Dr. Dee H. Barker and William Beckwith, Members at Large; and James Townsend, Industrial Member at Large.

ChE'S RECEIVE HONORS

A number of ChE professors were honored with awards a the ASEE meeting. William B. Krantz of the University of Colorado was presented the George Westinghouse Award and Clark K. Colton of MIT was awarded the Curtis W. McGraw Research Award. The Distinguished Service Citation was awarded posthumously to Fred N. Peebles. Three Western Electric Fund Awards were presented to Nicholas A. Peppas (Purdue), Richard K. Toner (Princeton), and W. Fred Ramirez, Jr. (Colorado). Phillip C. Wankat (Purdue) received the Dow Outstanding Young Faculty Award.

HANDLING LARGE CLASSES: ISN'T IT NICE TO BE POPULAR?*

R. NEAL HOUZE
Purdue University

MOST OF US ARE PERSONALLY aware of the large increase in chemical engineering undergraduate enrollments. A recent ECPD survey showed an increase from about 15,000 undergraduates in 1974-75 to approximately 26,500 in 1977-78, a 74 percent increase. During this same period, inflation and limited financial support, among many factors, have prevented significant expansion of faculties and facilities to handle the increased loads, at least at pre-invasion levels. These, together with other pressures, have forced us to cope as best we can with much larger classes than we had previously experienced.

Many "challenges" and "opportunities" come with these larger classes. Do large class sizes automatically mean a poorer-quality educational experience for our students? What differences actually occur due to increased class sizes? How do we maintain quality in the students' educational experiences? Can we take advantage of the increased class sizes to actually improve learning? How do we personalize what is perceived by many students as an increasingly impersonal process? How can we more effectively utilize our facilities? What instructional innovations could be employed to counter the negative effects of large class sizes?

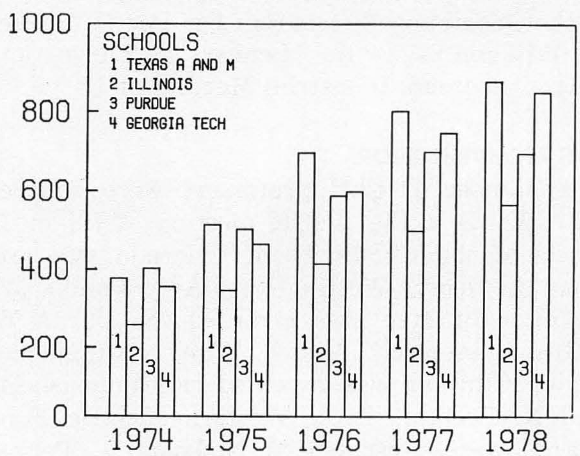

FIGURE 1. Chemical Engineering Undergraduates.

If we, as educators, have the great wisdom, knowledge and foresight which our students hope to discover in us, we might actually come up with some possible solutions. In this matter, I suppose we all qualify as experts, since we have all been forced to cope with and adjust to increased class sizes.

A group of concerned chemical engineering educators gathered at the ASEE Annual Conference at Louisiana State University to consider and discuss this very important problem. The authors, having agreed in a weak moment to serve as panelists, discussed what their respective institutions are doing to solve the problems encountered by increasing enrollments, and the following is the account of their presentations.

As a prelude to presenting the methods some of us are using to cope, let's first consider the magnitude of the problem. Figure 1 presents the enrollment statistics for the four institutions represented by the authors, Georgia Tech, Texas A & M, University of Illinois-Urbana and Purdue University. Over the past four years, the number of undergraduate chemical engineering students has more than doubled. Since the faculty sizes have not increased proportionally, the result has been a dramatic increase in class size and a strain on our facilities, particularly in laboratory space. The four institutions represented by the authors have taken two basically different approaches to cope with the increasing undergraduate classes. One is to increase the faculty and the other is to accept larger classes as a *fait accompli* and institute various methods to attempt to reduce the problem of insufficient student/faculty contact. The philosophy and attempts of each institution to cope are described in the following sections.

*Presented at the 1979 ASEE meeting, Baton Rouge, LA.

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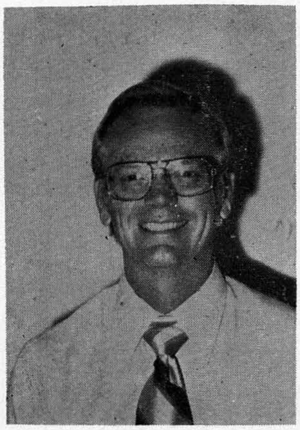
TEXAS A & M UNIVERSITY

RESTRICTING CLASS SIZES

RON DARBY
Texas A & M University
College Station, TX 77843



Ron Darby came to Texas A&M University in 1965 and attained the rank of Professor in 1970. He holds B.A., B.S. and Ph.D. degrees from Rice University. His research and interests include heat transfer, applied electrochemistry, fluid mechanics, polymer rheology, and suspensions, and he is the author of a text on "Viscoelastic Fluids."

THE PHILOSOPHY ADOPTED at A & M to handle increasing enrollments has been to increase the number of faculty and the number of classes to maintain relatively small classes and a high degree of student-instructor contact. Figure 2 illustrates the results of this course of action. Prior to faculty expansion in 1976, class sizes (students/class) and the number of course sections (contact hours/FTE) were increasing. As a result of doubling the faculty (permanent plus visiting) in three years, the average class size has stabilized and the faculty work load (contact hours/FTE) has been reduced from its maximum in 1975-76.

These small class sizes provide effective student-instructor contact and we have thus been able to maintain a traditional approach to each individual class while providing the students with the level of individual attention necessary for a quality education. We have made a conscious effort to maintain quality standards by requiring a minimum grade of C in the first chemical engineering course and enforcing a minimum grade point average to enroll in senior level chemical engineering courses. Industrial recruiters will attest to the high standards and absence of grade inflation and many make upward adjustments in our students' grade point averages when comparing them with graduates of other schools.

The average class size of 28 may be deceiving; our laboratory class size is limited to 20, but the freshman introductory course averages 90. We must offer a large number of laboratory sections, and have almost reached our capacity to handle these courses without scheduling night sections. All graduate students are required to serve a minimum period as a lab instructor or teaching assistant. With a faculty member coordinating a number of lab sections, this provides an acceptable method of offering a large number of laboratory sections. Uniformity between multiple course sections is improved by assigning a course coordinator and, in some cases, giving common examinations.

These approaches have helped us maintain a quality educational experience for our students. It has also helped us keep the faculty teaching load to an acceptable level.

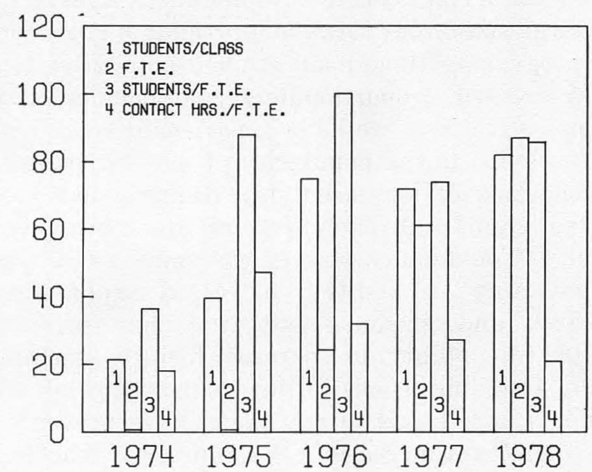
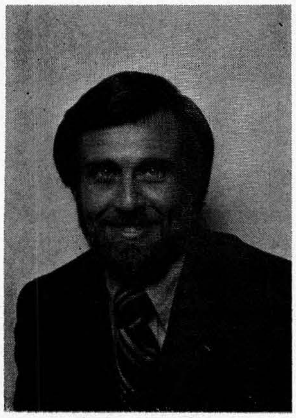


FIGURE 2. Texas A and M Percent Increases From Fall 1973.

The average class size of 28 may be deceiving; our laboratory class size is limited to 20, but the freshman introductory course averages 90. We must offer a large number of laboratory sections, and have almost reached our capacity to handle these courses without scheduling night sections.

PURDUE UNIVERSITY
HANDLING LARGE ENROLLMENTS IN LARGE CLASSES



R. NEAL HOUZE
Purdue University
West Lafayette, IN 47907

R. Neal Houze is Associate Professor of ChE at Purdue University. He received his BSChE from Georgia Tech in 1960 and his MS and PhD from the University of Houston in 1966 and 1968. He is the Cooperative Engineering Education Coordinator for chemical engineering and teaches in the areas of transfer and transport operations. His current research is two-phase, gas-liquid turbulence and mass transfer.

PURDUE HAS TRADITIONALLY HAD relatively large chemical engineering enrollments as a result of the large size of our total undergraduate engineering program. Although our student population has not increased proportionately as much as some other institutions, we have experienced some real squeezes due to the popularity of our curriculum.

The lack of increased state funding has prevented significant expansion of the permanent faculty. The faculty size is the same as it was ten years ago. In addition, increased emphasis on research and graduate education has severely limited the ability to increase faculty teaching loads. Also, limitations in the number of graduate students, and funds to pay them, have prevented any significant increase in the number of teaching assistants. At present, there is neither a mechanism to restrict the number of students selecting chemical engineering at the end of their freshman year nor any grade point average restriction at any point during the curriculum. These factors have forced us to evolve techniques to handle students in large single-section courses.

We have approached the problem (should I say "challenge?") in two ways: We have attempted to exert some influence on the total enrollment and we have attempted to provide better individual contact for the students to ameliorate the perceived impersonal nature of large classes.

The university has traditionally had 45-50% out-of-state students in the Schools of Engineering. Admissions are now being limited, reducing our out-of-state engineering student population to a lower percentage (20-30%). As a state-supported university, we cannot limit in-state admissions, and these have been increasing during the past few years. Consequently, we have experienced continued increases in our total engineering enrollments. Additionally, chemical engineering has increased in popularity, and a larger fraction of the freshman engineering class has been choosing our curriculum.

We have instituted a policy in our first chemical engineering course which we hope will help limit the number of students continuing in the program. The faculty has adopted the policy that this first course should be challenging, with a heavy work load consistent with the course credit. The objective is to introduce the students to the rigors of the curriculum and the chemical engineering profession. As a result of this policy, we find that a significant fraction of the incoming sophomore students withdraw from the course and transfer out of chemical engineering. We have concluded that these students lack the motivation and/or ability to accept the rather demanding nature of the chemical engineering curriculum. In spite of this policy, we find that ever-increasing numbers of students are entering chemical engineering and are able to handle the subject matter and the work load. We shudder whenever we speculate what our student population would have been had we not taken this action.

The university has traditionally had 45-50% out-of-state students in the Schools of Engineering. Admissions are now being limited, reducing our out-of-state engineering student population to a lower percentage (20-30%).

In an attempt to maintain adequate individual attention for the students, we have introduced recitation sessions into many of our large lecture courses. The large class meets in small groups of 30 to 40 students once a week. The purpose of these recitation sessions is to cover homework assignments and answer the students' questions covering the course material. At present, these recitations are staffed by faculty, not teaching assistants, with the course instructor providing coordination by specifying the subjects to be covered during the recitations.

We are expanding the number of chemical engineering elective courses offered each year. The increased variety of these courses, as well as the increased number, is intended to provide our students with more opportunity to interact with the faculty in small classes. The major limitation on the number of electives which can be offered is the size of the faculty and the required courses which must be staffed.

Lectures in one of our required courses have been video-taped. These lectures are broadcast on the local TV cable system and the video cassettes are available in our audio-visual center for the students. The use of these video-recorded lectures releases faculty for additional teaching. Selected problem solutions have also been video-recorded for our junior-level Transfer Operations course. The students can view these solution tapes at their convenience, alleviating some of the problems of limited faculty time to answer questions.

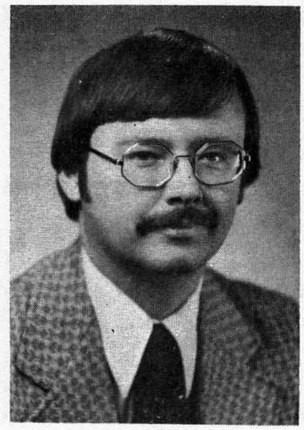
We maintain relatively small laboratory sections with a maximum of 24 students per section. Our laboratory courses are designed to provide the students with an opportunity to apply engineering principles in a pseudo-industrial atmosphere and small groups are essential to the achievement of our objectives in these courses.

The necessity of maintaining large lecture classes has supplied the impetus to provide our students with opportunities for quality learning experiences. The techniques we have employed have effectively ameloriated some of the negative effects of expanding enrollments, but even larger enrollments cannot be accommodated without significant alterations in our curriculum, faculty and/or facilities.

UNIVERSITY OF ILLINOIS

IMPROVING LEARNING OPPORTUNITIES WITH PLATO

MARK STADTHERR
University of Illinois, Urbana
Urbana, IL 61801



Mark A. Stadtherr is Assistant Professor of ChE at the University of Illinois at Urbana-Champaign. He received his BChE from the University of Minnesota and his Ph.D. from the University of Wisconsin-Madison. He teaches courses in process design, process control, mass transfer operations, fluid mechanics, and heat transfer. His research interests include computer-aided process simulation and design, sparse matrix computations, and resource management.

DURING THE 1978-79 ACADEMIC year, enrollment in our required courses was about 120 to 150. In most cases we handle this in one large lecture session, and then once a week break up into small discussion or recitation sessions of about 25 students. Each session is handled by a graduate student teaching assistant. In our laboratory courses, a main problem is simply one of logistics. We have begun remodeling our unit operations lab, both to provide some new experiments and also to restore others to working order. With more experiments running simultaneously, more students can be handled in a single laboratory section. The logistical problem is particularly severe in our process control laboratory, so we are undertaking similar work there; in this case incorporating a number of microprocessors.

A rather unique approach to some of the problems presented by large classes is our use of computer-aided instruction. We use the PLATO computer system, developed at the University of Illinois and now made available elsewhere by Control Data Corp. The PLATO system provides interactive self-paced instruction at a large number of terminals around campus. It has proven quite successful in teaching chemistry, physics, and other subjects.

The use of the PLATO system in our chemical engineering courses is due to the efforts of Professor Charles A. Eckert, who began work about three years ago to develop PLATO lessons for our first chemical engineering course dealing with material and energy balances. The use of these lessons began in earnest several years ago and we now have a full complement of lessons available for this course. Last spring we also began using PLATO lessons in our course on fluid mechanics and heat transfer, and last fall began using them

The use of PLATO in our ChE courses is due to the efforts of Prof. Charles E. Eckert, who began work about three years ago to develop PLATO lessons for our first ChE course dealing with material and energy balances.

in our thermodynamics course.

Each PLATO lesson consists of five or six problems of the sort normally assigned on homework problem sets. The student sits at a terminal and selects a particular problem. The problem appears on the screen and, since PLATO terminals have graphics capability, the student will typically see a diagram of the system on which the problem is based. The student is then asked for input; he may be asked to enter an equation, a numerical answer, or perhaps to touch the appropriate point on a graph or diagram (PLATO terminals have touch-sensitive screens). If the student makes a mistake that the programmer was able to anticipate, he will get feedback indicating what he did wrong. If the mistake was not one of those anticipated, or if the student is stumped at the outset and cannot enter any answer, he can press the HELP key and get a hint as to what he should do. If this hint is insufficient, he can press the HELP key again and again, each time getting a stronger hint, until finally he is essentially told the answer. These lessons are designed to allow students to work homework problems and get immediate feedback, as if he were working through the problem directly with the professor or teaching assistant. It is this kind of direct contact that is becoming increasingly infrequent because of large class size.

It should be emphasized that the PLATO material does not take the place of any lecture material, nor does it take the place of all the homework; conventional homework assignments must still be handed in. The PLATO lessons may be optional or required, at the option of the instructor. The students may work the PLATO problems as often as they like; roughly one-third of the PLATO time is used by students working problems over again. This reflects the students' use of PLATO to review for exams and to get help as they work on the conventional homework assignments. So, in a way, PLATO becomes a sort of consultant to the student, somewhere he can go for help in lieu of direct contact with the professor or teaching assistant.

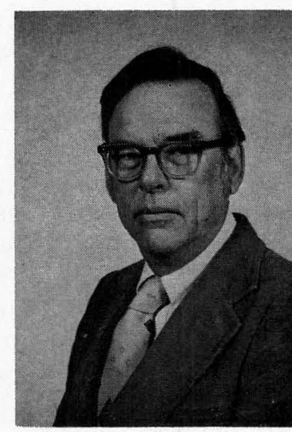
The PLATO material has been rather well received by the students. The most common complaint is one of logistics since students living off-campus find it inconvenient to come to campus in the evening to use the PLATO terminals. In general, however, PLATO seems to have a positive effect on student morale.

Though PLATO may help alleviate the problem of less direct contact between student and instructor by providing an alternate means of direct and immediate feedback, it does not make the course any less impersonal. The increasingly impersonal nature of teaching in chemical engineering is quite disturbing, and there seems to be no readily apparent solution.

GEORGIA INSTITUTE OF TECHNOLOGY

PROVIDING MORE FLEXIBILITY WITH OPEN LABS

ED HARTLEY
Georgia Institute of Technology
Atlanta, GA 30332



Dr. E. M. Hartley is Associate Professor of ChE and chairman of the Pulp and Paper Engineering Program at Georgia Tech. He has been active in the reorganization and instruction of the unit operations laboratories.

UNDERGRADUATE LABORATORIES AT Georgia Tech involving the use of equipment include two in Transport Phenomena, two in Unit Operations, one in Process Control and one in Polymer Science. An undergraduate Kinetics laboratory will be included in the near future. Laboratory courses have been scheduled individually, usually for a 3 hour period during one afternoon each week, with a teaching assistant and faculty member assigned to each lab, each quarter. The large enrollment has resulted in several problems including an increased strain on equipment maintenance, too many students for the space and equipment, and increased problems with scheduling due to conflicts with other courses. A general problem has

The large enrollment has resulted in . . . an increased strain on equipment maintenance, too many students for the space and equipment, and increased problems with scheduling due to conflicts with other courses.

been a lack of continuity in lab maintenance and supervision because of the quarterly change in personnel responsible for any given lab. Our summer program at the University College London has helped to reduce the load. Each summer, 15-20 students spend 5 weeks at UCL and the program includes lab experiences that will satisfy requirements for two or three of the five required labs at Georgia Tech.

The "Open Lab Concept" represents our attempt to deal with current problems. The labs will be staffed by teaching assistants and will be open from 1:00 p.m. to 6:00 p.m., five days a week. The teaching assistants will report to a Laboratory Coordinator who will be a member of the faculty, although perhaps not in a tenure-track position. The responsibilities of the teaching assistants will include: scheduling of experiments, maintaining supplies, maintaining order, reporting maintenance needs to faculty and/or staff, referring students to appropriate faculty members as required, enforcing safety and housekeeping requirements, and security. The teaching assistants will not be responsible for the technical nature of the experiments or for grading the reports. With the help of the teaching assistants, groups of three or four students will schedule the dates and times for their experiments at the beginning of the quarter and will be responsible for completing the experiments as scheduled. The faculty will approve the schedule to insure that the correct number and types of experiments are chosen. Each faculty member will be assigned responsibility for one or two experiments in an area of his interest for a duration of two to three years. For these experiments, the faculty will instruct teaching assistants and students as required, coordinate maintenance and grade reports.

One faculty member will be assigned to each lab course, such as Transport Phenomena I, each quarter as a course coordinator. He will determine the final grade by tabulating the grades received on each report from the faculty member responsible for the experiment. The course coordinator will approve each group's schedule as mentioned above. In determining their schedule, the student groups will choose from a list of experiments with the requirement that at least one experiment be done from each of several areas. This system will insure that the students will interact with several faculty members during a lab course.

We are currently searching for a non-tenure-track staff member. The person in this position will serve as the laboratory coordinator, be in charge of the machine shop and electronics lab, be responsible for lab equipment maintenance and will possibly get involved in purchasing and safety. Hence this person will be in an excellent position to give the continuity to lab upkeep which has been lacking in the past.

SUMMARY: R. Neal Houze

Many techniques can be used to cope with and provide quality educational experiences for the current large numbers of chemical engineering students. The techniques employed by our institutions are attempts to use our ingenuity and our concern for our students to improve their experiences. There are many challenges facing us in the foreseeable future. We have met challenges in the past, and we will continue to do so. The real challenge is to help our students develop into mature, knowledgeable professionals. We are all involved and responsible to meet this challenge. □

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EXPERIENCES IN A SENIOR CHEMICAL ENGINEERING MATERIALS COURSE*

JOHN P. O'CONNELL
TIMOTHY J. ANDERSON
University of Florida
Gainesville, Florida 32611

WHEN CLASSES STARTED at the University of Florida on September 5, 1966, the senior author had precisely two days to prepare for his inaugural teaching assignment: Materials Science for Chemical Engineers. Since he had never had such a course, nor settled his family in Gainesville, and the scheduled meetings started the first day at 7:30 AM, even a week's substitution by a colleague could not prevent the rest of the 13 week trimester from being a struggle to just keep ahead of the students. Fortunately (?), most of them were seniors with senior-itis (the course was one of the requirements usually postponed to the last term) and they did not really care as long as their grades were adequate to graduate. It was found that many of the "basic" concepts of the text were understood by the students, so higher level content could be covered at a faster rate. This made it pleasant, but harder, for the instructor.

Thus began the evolution of a successful course which we have retained in chemical engineering, manpower permitting, despite an alternate sophomore-junior course available in our excellent Materials Science and Engineering Department. Its success in comprehensive coverage at a solid professional level hinges on two factors; direct integration of concepts learned in prior chemistry and engineering courses, and considerable interaction of the students and teacher using visual aids. The result is an experience in reflection about natural phenomena and how descriptive use of thermodynamics, kinetics, transport phenomena, interfacial behavior and molecular theory can make sense out of what may have happened, and/or what probably would happen, to a sample under changing environmental conditions of temperature, concentration, mechanical forces and electromagnetic fields. The objective is to prepare the student to explain with proper language, to himself and others, how such generalized methodology can qualitatively, and perhaps quantitatively, unify the diverse behavior observed in systems containing solids and to cope with new developments.

Since ChE practice generally involves fluids in reactions and separations there is little emphasis on the solid state. Yet we believe a strong case can be presented for incorporating materials engineering on a permanent basis into the ChE curriculum.

WHY A CHEMICAL ENGINEER'S MATERIALS COURSE?

The chemical engineering profession has been expanding in breadth and depth, and the practicing chemical engineer is now required to be knowledgeable in many more diverse facets of engineering science. Because only two to three years are devoted to study in professional courses, we must be as efficient as possible in assimilation of knowledge and development of understanding. Since chemical engineering practice generally involves fluids in reactions and separations, there is little emphasis on the solid state. Yet, we believe a strong case can be presented for incorporating materials engineering on a permanent basis into the chemical engineering curriculum. First, the nature of solids makes them vital to the chemical industries as containers for the fluids. Pipes, reactors, distillation towers, tanks, etc., are all essential to chemical processing. Also, polymer processing has emerged as a major economic

*Presented at the 1979 ASEE meeting, Baton Rouge LA.

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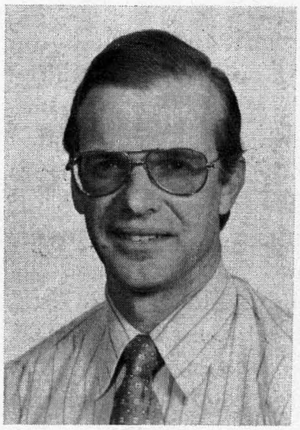
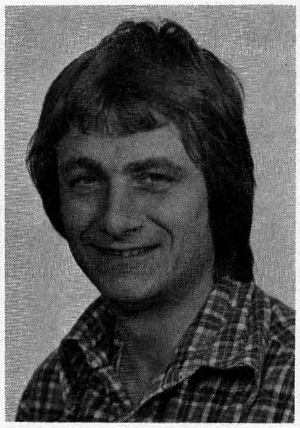




John P. O'Connell is a Professor of Chemical Engineering at the University of Florida. He received his education at Pomona College (A.B. 1961), M.I.T. (B.S. 1961, M.S. 1962) and the University of California, Berkeley (PhD 1967). His area of research interest include thermodynamic and transport properties of fluids, phase and reaction equilibria, and interfacial behavior and microstructures of surfactant solutions. **(L)**

Tim Anderson is an Assistant Professor at the University of Florida in the department of ChE. He received his B.S. (1973) in ChE from Iowa State University and M.S. (1975) and PhD (1979) from the University of California, Berkeley in ChE. He is interested in the chemical engineering problems associated with semiconductor processing. **(R)**

factor in the industry, though it often receives little or no attention in professional education. Further, a growing proportion of the chemical feedstocks are in the solid phase as are, for example, coal, ores and wood. In addition, the solutions to many of today's technological problems in energy and pollution, where chemical engineers are essential, pivot on an understanding of solid state properties and materials handling. These are illustrated by needs such as the development of a viable fusion container, an economical photovoltaic solar cell, a reliable reactor vessel for coal gasification and an understanding of fundamental catalysis. Finally, our strongest argument for the inclusion of a materials course in a chemical engineering program can be found by examining the end result of the educational process—the functions the practicing engineer performs after graduation. Increasingly, our chemical engineering graduates are placed into interdisciplinary, solids-related activities that include polymer processing, semi-conductor technology, biomedical applications and research in interfacial science. While we cannot offer study in the depth of the historically spawned disciplines such as nuclear, environmental, polymer and metallurgical engineering, materials is a fundamental engineering science finding intense application in today's engineering practice and it needs to be treated at a sophisticated and integrative level for practical professional use. For our purposes, it should not just be a survey of catalogued behavior, memorized structures and phenomena.

An important question involves the department in which the course is taken. Though a materials science department is well qualified to present such a course, the authors believe certain advantages exist in presenting the course within the chemical engineering department to isolated chemical engineering seniors. Assuming qualified instructors are available, an internal course at the senior level allows them to integrate previously studied fundamental chemical engineering sciences. In this respect the format presents the student with the opportunity to "put it all together." In particular, this synergistic effect brings in the chemical engineer's strong background in the chemistry and physics of equilibria and rate processes coupled with chemical processing knowledge. Differences found in the formulation, notation and application of various engineering sciences are usually confusing to the student though actual behavior is independent of our description. A chemical engineering instructor can translate the commonly used formulations to familiar terms and bridge these concepts to the

Though a materials science department is well qualified to present such a course, the authors believe certain advantages exist in presenting the course within the chemical engineering department to isolated chemical engineering seniors.

students' basic background. For example, the concept of the Fermi energy of electrons would be foreign to most chemical engineering students, while the "chemical potential" of electrons has more meaning. In addition, an understanding of materials problems found in industry are not easily divorced from knowledge of the chemical process involved. The junior author had the opportunity to investigate the continued failure of trays in a palm oil distillation column. Without knowledge of the distillation process, the problem could not have been solved efficiently. Only chemical engineers can quickly appreciate the nature of such relations. We find that other, more subtle, benefits are also realized. Established student-instructor familiarity and commonality of objectives, direct departmental control over content, intensity and scheduling, more accurate assessment of class background and ability are all found. It can be argued that there should be student interaction with other engineering departments, but we feel there are more merits to an internal course. We do invite several guest lectures from other departments to augment our presentations.

COURSE CONTENT AND STYLE

THE SENIOR LEVEL MATERIALS course currently offered by the Department of Chemical Engineering at the University of Florida constitutes three lectures and one recitation section per week for three units of credit. Listed in Table 1 is a summary of most of the topics which have been presented in the lectures over the years. The inaugural two weeks supplement and review the student's understanding of the relevant chemistry and physics. Included is a review of quantum mechanics and chemical bonding, intermolecular forces, polymer synthesis and chain conformation, and melting phenomena. These topics have all been introduced to the student in previous courses, but, as usual, reminders are valuable. Then we introduce supplemental solid state physics and chemistry topics such as crystallography, defect structure, microstructure, nucleation and growth, all of which are natural extensions of the chemical engineer's background. For example, the chemistry of imperfections is easily understood when point defects are treated as chemical species, allowing the student to apply understood chemical kinetic and thermodynamic concepts. The remainder of the course is organized to address many questions of the "what?, how? and because" format. First, the question of what does a material do under various forces is posed. The primary forces approached are mechanical, electrical, chemical and thermal, while secondary emphasis is given to magnetic, optical and surface properties. In presenting the material, exact calculation of numbers and listing of comprehensive property values is not stressed as this is not fundamental information which is likely to be applicable to materials of twenty years in the future. The students need little more experience with calculations, and reference/textbooks serve this purpose well in any case. The utilization of the facts are only illustrations of the general response of materials. The type of information discussed is order of magnitude and direction, and a classification of materials is used which depends on the relative magnitude of response. We want to generate an overview of the range of material properties so the student can compare all materials and place their potential applications in perspective.

TABLE 1

Summary of Lecture Topics

CHEMISTRY AND PHYSICS OF SOLID MATERIALS
Bonding
Structure and Packing
Microstructure and Processing
Point, Line and Interfacial Defects
Atomic Probes
Molecular Engineering

RESPONSE OF SOLIDS TO ELECTRICAL FIELDS
Conductivity, Semiconductivity, and Super Conductivity
Dielectrics

RESPONSE OF SOLIDS TO MAGNETIC FIELDS
Dia-, Ferro-, and Paramagnetic Materials

RESPONSE OF SOLIDS TO ELECTROMAGNETIC RADIATION
Optical Properties
Radiation Damage

RESPONSE OF SOLIDS TO TEMPERATURE
Thermal Properties

RESPONSE OF SOLIDS TO SURFACE FORCES
Surface and Interfacial Phenomena

RESPONSE OF SOLIDS TO MECHANICAL FORCE
Mechanical Tests and Elastic Properties
Plasticity and Flow
Strength and Fracture

RESPONSE OF SOLIDS TO CHEMICAL FORCES
Chemical Gradients
Nucleation and Crystallization
Interaction with Reactive Materials
Transformations
Phase Diagrams and Processing
Electrochemistry and Corrosion Control

SELECTED TOPICS
Ceramics and Glasses
Composites
Biological Molecules and Materials

Having established the general behavior of materials to environmental stresses, attention is turned to examining how it is that different classes and samples respond differently to this stress. The behavior is explained in terms of molecular and atomic forces, structural arrangement of the atoms and molecules, and, where appropriate, microstructure. Very little emphasis is placed on detailed mathematical calculations and use of only simple models is made to describe primary effects. Such an approach is intended to allow the student to formulate a coherent view of solid state behavior that is comfortable for the student and to cultivate engineering judgment about the significance of various effects. For example, in discussing transition temperatures in solids the lecture shows the various types of transitions (structural) rearrangements in the solid, melting, sublimation, glass transition, etc.) and associated phenomena (i.e., hysteresis, supercooling, limited rates). We discuss the influence of strength and angle dependence of attractive interparticle forces, size and packing (repulsive forces), flexibility of molecules on equilibrium and kinetic phenomena. This is correlated with the observed behavior in the different classes of materials (metals, ionic crystals, simple organics, polymers, etc.) which are covered in some detail. The effect of chemical composition upon the glass, melting or decomposition temperature of polymers, for example, was treated according to the 5 broad classes of molecular arrangement. For polymers that contain chains with perfectly repeating units and are characterized by their ability to crystallize, order of magnitude and ranges of transition temperatures are presented along with the relationships between the temperatures (e.g., $T_g/T_m \sim .5\text{-}.67$). Next, a discussion of the reason for a high or low transition temperature is presented (chain stiffness e.g., polyethers vs alkyls; strength of intermolecular forces, e.g., polyamides vs alkyls, etc.) Similar treatment is given to the remaining 4 classes of polymers.

INTERACTION WITH STUDENTS

ILLUSTRATIVE EXAMPLES familiar to the student are used to reinforce the concepts. Besides the usual diagrams and lists, in-class demonstrations and samples are used in as many cases as possible. The demonstrations include molecular and glued ping-pong ball models for structures, stretched and fractured tensile samples with actual data, the "nylon-pulling" experiment for synthesis, an operating solar cell for radiation effects, a geode and mining and cave minerals for solidification and wetting phenomena, corroded pipes for treatment of corrosion, etc., and many plastic, metal and ceramic items found in the home that students touch, bounce, pull, and rearrange.

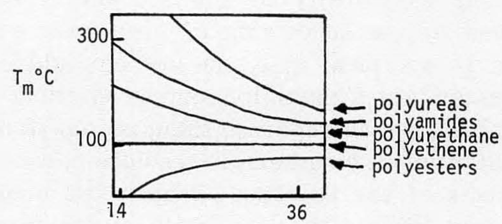
They have been sufficiently "turned on" that they bring new ones back from trips and vacations. The familiar examples and demonstrations vary the pace and promote student interest and retention in the lectures.

The most intense interaction involves recitation sections. The class is divided into small groups (10 to 15) for weekly meetings. The overwhelming majority of time is spent in an instructor question-student answer session. The instructor, having a prepared list of questions directs a question to an individual student with the response being graded. A typical list of questions that would accompany the previous lecture example of transition temperature is given in Table 2. Samples are

TABLE 2

Typical Recitation Questions Concerning Transition Temperatures in Materials

1. Why do we iron clothes with steam?
2. Estimate the glass and melting transition temperatures of polyethylene terephthalate. (Give structure).
3. Explain the following behavior.

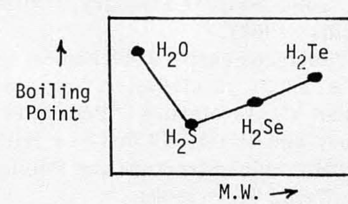


Number of Chain Atoms in Repeating Unit

4. Is a silicon or carbon based polymer a better heat resistant material?
5. Why is nylon so sensitive to water?
6. Describe the variation of the melting and glass temperature as ethylene terephthalate is added to polyethylene adipate. Give structures.
7. Explain the following table.

Substance	M.W.	Dipole Moment	Boiling Point, °C
n-pentane	72	0	36
ethyl ether	74	1.18	35
n-butyl alcohol	74	1.63	118
n-butyl aldehyde	72	2.72	76

8. Which would you expect to have a higher melting temperature: n-butane or isobutane? Why?
9. Explain the following graph.



10. Why does n-octane melt at —57°C and tetramethyl butane at 100°C?
11. Explain why T_iC melts at 3410°K.
12. If a drop of water is immersed in an immiscible oil, the water can remain as a liquid at a temperature well below 0°C. Explain.

The demonstrations include molecular and glued ping-pong ball models for structures, stretched and fractured tensile samples with actual data, the "nylon-pulling" experiment for synthesis, an operating solar cell for radiation effects, a geode and mining and cave minerals for solidification and wetting phenomena, corroded pipes for treatment of corrosion, etc., and many plastic, metal and ceramic items . . .

also used when appropriate. The questions are designed to require the student to apply and extend the previous lecture material. Student feedback on the success of these sessions indicated this was the most positive aspect of the course. The success and viability of such a format can be attributed to several factors. We find the students are generally motivated to be prepared for recitation by both the grading policy and the "embarrassment" factor if they were unable to answer. In addition, the small size, informal nature and specific questioning bring out contributions from all present. The curiosity of the student is easily awakened by the succession of discussion which follows. In a typical case, the student addressed produces at best a partially correct solution. The instructor can then rephrase the question so as to lead that student, or others, to a solution, examine the defects of the response or open the original question to the entire class. Such dialogue often occupies 5-10 minutes per question and in many instances generates new questions from the students for the instructor to guide the class to the answer. In addition to significant practice in oral expression by the students, the extemporaneous format of the recitation provides the instructor with subtle, but valuable, feedback about the success of the lectures and a gauge on the learning processes of the students. Student evaluations show that this is the most positive aspect of the course. However, it might not be possible for all instructors or all situations.

TABLE 3

Textbooks and Supplemental Reading Used in Past Courses

J. Wulff, et al., "Structure and Properties of Materials," Wiley, N.Y. Vol. I, II, III, IV (1965).

M. Kaufman, "Giant Molecules," Doubleday, Garden City (1968).

T. Alfrey and E. F. Gurnee, "Organic Polymers," Prentice Hall, 1967.

K. L. Watson, "Materials in Chemical Perspective," Halsted, New York (1975).

N. B. Hannay, "Solid State Chemistry," Prentice Hall, Englewood Cliffs (1967).

ARC Westwood, "Surface Sensitive Mechanical Properties," Ind. Eng. Chem. *56*(9), 15 (1964).

A. X. Schmidt and C. A. Marlies, "Principles of High-Polymer Theory and Practice," McGraw-Hill (1948).

F. W. Billmeyer, "Molecular Structure and Polymer Properties," J. Paint Tech., 41, 3(1969).

K. Kammermeyer, "Biomaterials," Chem. Tech., 719 (1971).

L. L. Hench, "Structure and Properties of Glass-Ceramics," Univ. of Fla. Technical Paper Series, #377, *21* (6), 2(1967).

A. S. Grove, "Mass Transfer in Semiconductor Technology," Ind. Eng. Chem., *58*(7), 49 (1966).

Home problems are assigned weekly, graded and kept at a minimal amount. In general they reflect the philosophy of the course in stressing qualitative understanding and elucidation of concepts. Examinations generally number two midterms and a final. Again, they are always phrased in a fashion which requires essay type answers to questions as: Here's a common observation—how come? What would another sample do? How would you cause a different effect? How would you make a specimen with given properties? Thus homework and exams are not a regurgitation of material or "find the number" type but require the student to be creative and communicative with the tools recently acquired. We believe such practice in written expression to be important for seniors though it admittedly requires more time from the teacher in developing and grading.

Also required in the course is a term paper covering a topic chosen by the student. Tutorially-oriented initial references from Science, Scientific American, Annual Reviews, etc., are offered to the student in over one hundred topics. The paper should be about five pages and should stress effective communication of understanding for the chosen topic. Since it is impossible to cover the entire spectrum of materials science (an entire curriculum in itself) in a single course, the term paper presents an opportunity for the student to apply the concepts learned and to seek and comprehend a more detailed analysis of a particular topic. This reinforces the utility of the course as well as requiring practice in library use and concise expression. Again, instructor time is required for appropriate feedback to the students.

One continuing problem of the course has been finding a textbook that presents a consistent

Continued on page 148.

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ChE lecture

MOLECULAR THEORY OF FLUID MICROSTRUCTURES

H. TED DAVIS
University of Minnesota
Minneapolis, MN 55455

MANY OF THE CURRENT courses on the statistical thermodynamics are restricted to bulk phase phenomena. However, interfacial and colloidal phenomena are involved in important ways in engineering processes and products. Associated with and perhaps even determinant of interfacial and colloidal properties are what we call fluid microstructures. A fluid microstructure is a region in a fluid in which densities and/or compositions vary appreciably over distances of the order of magnitude of the range of molecular forces. Examples of fluid microstructure include fluid-fluid interfaces, fluid-solid interfaces, multiphase contact regions, thin films, drops and bubbles, micelles, microemulsions, liquid crystals, lipid bilayers, vesicles, emollients, foams, spinodally developing density variations, and gels.

H. Ted Davis received his B.S. from Furman Univ. (1959) and his Ph.D. from the Univ. of Chicago (1962). He joined the ChE department at the University of Minnesota in 1963 and is the author of over 100 publications in scientific and engineering journals and edited books. His research interests include statistical mechanics of equilibrium and transport processes, experimental and theoretical investigation of the physico-chemical processes in flow in porous media as related to petroleum recovery, interfacial and colloid science, mathematical modelling of transport, reaction and mechanical properties of disordered media, liquid electronics, and heat and water movement in food systems. Professor Davis recently became head of the Department of Chemical Engineering and Materials Science.

Fluid microstructures are ubiquitous in the products and uses of products of the emollient, detergent, coating, and processed foods industries. Foams, bubbles, drops, films (membranes), gels, and microporous solids are frequently involved in separation and reaction processes of the chemical industry as well as pollution control and water treatment industry, and the natural processes of biological systems. Capillarity, wettability, and multiphase flow in porous media are controlled to a great extent by fluid microstructures—multiphase flow phenomena in porous media are involved in natural and induced ground water movement, solution mineral leaching, petroleum recovery, processes, and wood fiber treatment and manufacturing processes. Emulsion polymerization is a well established industrial process now. Micellar or microemulsion reaction processes are under investigation for their ultimate practical utility. And liquid crystals are commonplace as watch dials and thermometers. The importance of bilayers in cellular structure, and the organizational and transport processes of living matter is thoroughly established although incompletely understood. Vesicles are under active investigation as potential vessels for drug delivery to specific sites in living organisms. The foods industry is also researching vesicle behavior for future application.

The list of processes and systems in which fluid microstructures are consequential goes on and on and will not be produced here. What is relevant to this paper is the fact that in spite of the wide involvement of fluid microstructures in technological and natural processes and products and even though interfacial science is an old classical subject, the fundamental basis for understanding the behavior of fluid microstructures still forms an exciting and developing subject. Among the objects of current theoretical interest are the local density and stress (pressure) distributions associated with the fluid microstructures; interfacial tension and other stress moments; contact angle of three phase contact

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The theory illustrated here for a one component fluid is developed in the course for multicomponent fluids and for fluid-solid microstructures. Electrostatic effects are also included so that double-layer and electrostriction phenomena are accounted for. Meniscus shapes, disjoining pressures, and contact angles are investigated also.

lines; film tensions, stability, and disjoining pressure; and contact angle and meniscus shape. The course deals with the modern theory of such objects. In the remainder of this article we shall try to exhibit the spirit of the theory developed in the course introduced in a previous article.*

In an inhomogeneous system, the thermodynamic functions depend on the density distribution $n(\mathbf{r})$. For example, for the pair potential model, the average attractive energy is

$$\langle u_A^N \rangle = \frac{1}{2} \int \int n(\mathbf{r})\, n(\mathbf{r}')\, g(\mathbf{r},\mathbf{r}')\, u_A(|\mathbf{r}-\mathbf{r}'|)\, d^3r\, d^3r' . \tag{1}$$

To simplify the theory, we assume as in the VDW theory that g depends only on $|\mathbf{r}'-\mathbf{r}|$, expand $n(\mathbf{r}')$ about $\mathbf{r}$ in the integrand of Eq. (1), and truncate the series after third order in gradients of n to obtain

$$\langle u_A^N \rangle = \int [-n^2(\mathbf{r})a - \frac{n(\mathbf{r})c}{2} \nabla^2 n(\mathbf{r})] d^3r , \tag{2}$$

where ∇ is the gradient operator, a is the Van der Waals energy parameter, and

$$c \equiv -\frac{1}{3} \int s^2\, u_A(s)\, g(s)\, d^3s . \tag{3}$$

The so-called gradient theory represented by Eq. (2) yields quite good results for planar interfaces [2, 3, 4, 5]. In the rigorous developments [2], c depends on density and temperature, but the dependence is weak [4] and will be ignored here. The Helmholtz free energy of inhomogeneous fluid can be expressed in the form $F = \int f(\mathbf{r})\, d^3r$, where $f(\mathbf{r})$ is the Helmholtz free energy density at position $\mathbf{r}$ in the fluid. With arguments similar to those supporting the VDW theory of homogeneous fluid, Equation (3) leads to

$$F = \int [f_o(n) - \frac{n}{2} c \nabla^2 n]\, d^3r , \tag{4}$$

where $f_o(n)$ is the Helmholtz free energy density of homogeneous fluid. The chemical potential, determined from Eq. (4) as the change in F per unit material added by changing the fluid density locally at constant T and V, of inhomogeneous fluid is

$$\mu = \mu_o(n) - c \nabla^2 n . \tag{5}$$

$\mu_o(n)$ is the chemical potential of homogeneous fluid at density n.

At equilibrium μ is constant throughout the system so that Eq. (5) becomes a partial differential equation determining those fluid microstructures allowed at equilibrium. The factors in the equation determining the nature of a microstructure are the chemical potential of homogeneous fluid, $\mu_o(n)$, which dictates the existence of a particular microstructure, and the *influence parameter* c, which determines the length scale of the microstructure. The kind of microstructure predicted will depend on the temperature and chemical potential set and on the nature of any boundary conditions set. This will be illustrated now with some examples.

Consider a planar interface whose normal is in the x-direction and cross-sectional area is A. In one dimension the Laplacian $\nabla^2 n$ becomes simply the second derivative d^2n/dx^2 of density. Equation (5) can be rearranged by multiplication by dn/dx into an integrable form and then integrated to yield

$$\frac{1}{2} c \left[\frac{dn}{dx}\right]^2 = \omega(n) + K;$$

$$dx = -\sqrt{\frac{c}{2}}\, dn / \sqrt{\omega(n) + K} \tag{6}$$

where K is a constant of integration and

$$\omega(n) \equiv f_o(n) - n\,\mu \tag{7}$$

The boundary conditions of a planar interface are $n(x) \to n_l$ as $x \to -\infty$ and $n(x) \to n_g$ as $x \to \infty$, where n_l and n_g are the bulk phase liquid and vapor density, respectively. The boundary conditions are equivalent to the conditions of thermodynamic equilibrium:

$$\mu = \mu_o(n_g) = \mu_o(n_l) \ ;$$
$$-K = \omega(n_g) = \omega(n_l) = -P_N , \tag{8}$$

where P_N is the bulk phase pressure (which is also equal to the normal component of pressure, which is constant throughout the planar system).

---

*CEE, Fall 1979, page 198.

The surface tension γ of the interface, computed from the thermodynamic relation

$\gamma = (\partial F/\partial A)_{T,V,N}$,

is given by

$$\gamma = \int_{-\infty}^{\infty} c \left[\frac{dn}{dx}\right]^2 dx = \int_{n_g}^{n_l} [c\Delta\omega(n)]^{1/2} dn\,, \tag{9}$$

where the second formula is obtained by eliminating dx with the aid of Eq. (6). $\Delta\omega(n) = \omega(n) - \omega(n_l)$.

Equation (9) illustrates the fact that the broader an interface, i.e., the slower the density change across the interface, the smaller the tension. And, by referring to Fig. 1 in which the function $\Delta\omega(n)$ is shown as a function of n, one sees that low tensions occur as the temperature approaches the critical point and the free energy surface of homogeneous fluid flattens out between the minimal characteristic of phase equilibria.

For a planar system, gradient theory yields the following relationship between the transverse pressure P_T (measured with a transducer whose normal lies in the interfacial plane) and the normal pressure P_N (measured with a transducer whose surface lies in the interfacial plane):

$$P_T = \frac{1}{3} P_N + \frac{2}{3} P_o(n)\ . \tag{10}$$

$P_o(n)$ is the pressure of homogeneous fluid at density n. The tension can also be computed from

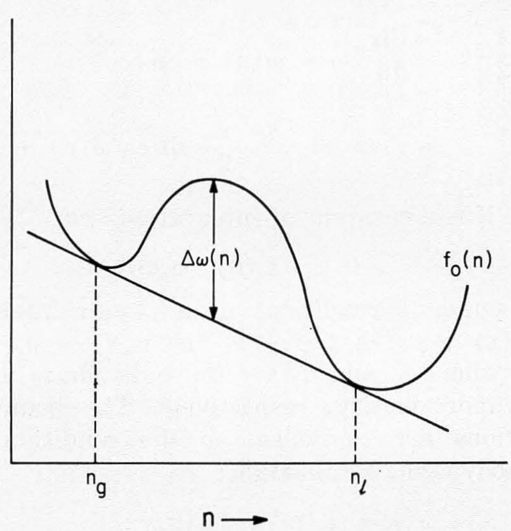

FIGURE 1. Illustration of tension determining function $\Delta\omega(n) = \omega(n) - \omega(n_l)$ of a one-component fluid. $f_o(n)$ is the Helmholtz free energy density of homogeneous fluid.

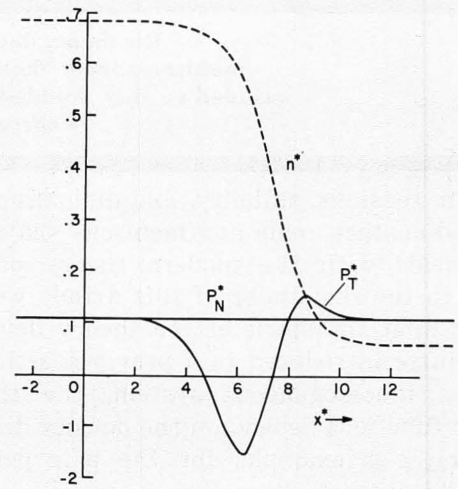

FIGURE 2. Profiles of density, normal pressure, and transverse pressure across a planar interface of a Van der Waals fluid at $T^* = 0.223$. $n^* \equiv nb$, $P^* \equiv Pb^2/a$, and $x^* = x\sqrt{a/c}$.

the formula

$$\gamma = \int_{-\infty}^{\infty} (P_N - P_T)\, dx\ . \tag{11}$$

In Fig. 2, the density profile and the pressure component profiles are shown for a planar interface of a VDW fluid. From the curves we observe that the interfacial zone is under tension (P_T actually negative) on the dense side of the interfacial zone and is under compression ($P_T > P_N$) on the dilute side of the zone. This behavior seems typical of low temperature fluids for which the pressure isotherm $P_o(n)$ goes through negative values in the Van der Waals loop. Experimentally, the magnitude of tension and the fact that it increases with decreasing temperature imply that P_T has to have a region of negative values at sufficiently low temperatures. Formula (10) brings out the fact that the values of $P_o(n)$ in the spinodal region are physically meaningful and contribute importantly to interfacial structure and tension.

Other fluid microstructures can be obtained by using different boundary conditions. For example, planar thin films result with the boundary conditions $dn/dx = 0$ at $x = 0$ and $n \to n_B$ as $x \to \pm\infty$. Liquid crystals result from periodic boundary conditions. Drops and bubbles are obtained by assuming n to depend only on the radial distance r from their centers. For this case

Continued on page 145.

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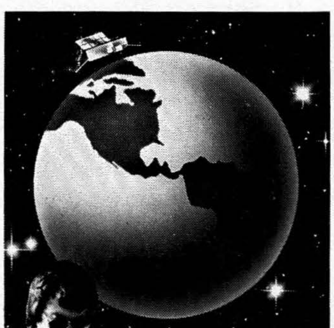

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ChE classroom

USING TROUBLE SHOOTING PROBLEMS*

Edited by
DONALD R. WOODS
McMaster University
Hamilton, Ontario, Canada

Trouble shooting problems are used as a learning experience in a wide variety of contexts. The format varies and several methods were described in the Spring 1980 issue of CEE. *Additional methods are discussed here.*

Sometimes a problem is presented as a computer simulation, sometimes as a situation described on a piece of paper. Students can gather information and solve a problem by sampling and performing experiments from a given set of possibilities, or the students can choose/ask questions. The emphasis can be on getting the answer or on the methodology used, or both. Some advantages and disadvantages of using trouble shooting problems are explored in the two installments and hints on how to troubleshoot are given.

TROUBLE-SHOOTING SYSTEMS AND EXPERIENCES AT NEW SOUTH WALES

IAN D. DOIG
University of New South Wales
Kensington, Australia

AT NEW SOUTH WALES two different modes are used in which the student interacts either with the computer or with an instructor.

COMPUTER BASED SYSTEMS

For the computer-student interactive programmes, the performance of a malfunctioning plant is simulated, and the student calls for a series of ad-hoc spot measurements until he can identify the cause and location of the fault. A student first studies a plant manual which contains a process flowsheet, details of all plant items (including the sizes and geometry of all lines, details of all valves, pumps, blowers including performance specifications), physical data for all components and streams, a list of over 100 possible causes (with location) of plant malfunction, and a set of normal values for the routine samples measurements of plant performance (input and output streams properties and flowrates plus a few intermediate measurements indicative of plant behaviour).

On logging in to the computer, the student is presented with a corresponding set of current routine measurements which differ significantly from the normal values and show that a fault exists. The student calls for additional samplings and measurements until his assembled information can be positively linked to one of the causes listed

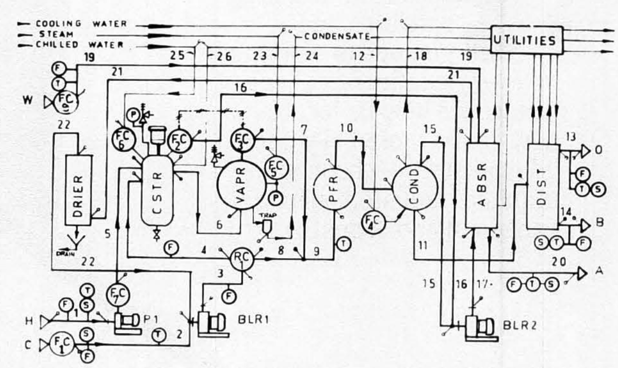

FIGURE 1. Flowsheet for revised Syschem Plant.

*This is the second installment of a two-part article. The first installment appeared in the Spring 1980 issue of *CEE*.

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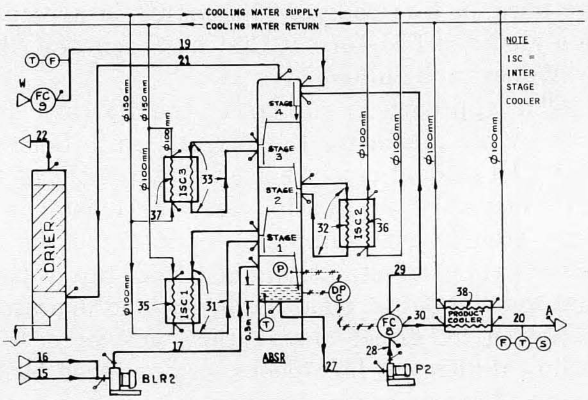
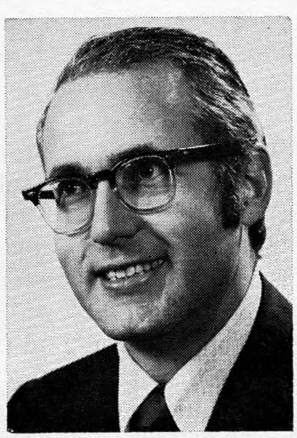


FIGURE 2. Flowsheet for ABSR (Acid Absorption Section).

in the plant manual. For each ad-hoc sampling and measurement ordered the student is charged a representative (but imaginary) expense; the student endeavours to successfully locate and identify the fault at a minimum 'cost' in national dollars. Other features of the system are that a randomly generated Gaussian distributed error is contained in all measured values reported and the student can be asked to resolve two simultaneous malfunctions (usually chosen to be noninteractive). Details of the system have been presented by Doig [5].

Three programmes are used. The first is a simplified version of Figure 1 developed initially by Pelloni and Rippin [6]. This uses a mass balance



D. R. Woods is a graduate of Queen's University and the University of Wisconsin (Ph.D.). For the past three years he has been attending all undergraduate lectures along with the students to try to discover what needs to be done to improve student's problem solving skills. His teaching and research interests are in process analysis, and synthesis communication skills, cost estimation, separations, surface phenomena and developing problem solving skills. He is the author of "Financial Decision-Making in the Process Industry." He received the Ontario Confederation of University Faculty Association award for Outstanding Contribution to University Teaching.

For the computer-student interactive programmes, the performance of a malfunctioning plant is simulated, and the student calls for a series of ad-hoc spot measurements until he can identify the cause and location of the fault.

simulation and requires an identification of the faulty unit only. The second is the plant illustrated in Figures 1 and 2 using simulated real models for all parts of the system (including valves, service and process piping) and mass, energy and pressure balancing; the third is a 20 plate multicomponent fractional distillation set.

Malfunctions used can be broadly categorised as either:

Type 1. Impurities: Leaking of oil or water into the process or impurity entering with feed.

Type 2. Leaks: Significant material imbalance indicating loss of fluid by leakage.

Type 3. Composition incorrect: Product (or other stream) composition significantly different from normal due to a maufunctioning of a reactor, separator or controller.

Type 4. Throughput incorrect: Product (or other stream) flowrate significantly different from normal due to a restriction, bypassing, or pump, blower or valve malfunctioning, or feed stream deficiency.

Type 5. Process producing correctly but inefficient: Defect within plant causing excessive pressure(s) or flowrate(s), or excessive use of steam or cooling water. Conversely, inadequacies in steam or cooling water system may be cause of inefficient abnormal operation. Alternatively, process correct but instrument(s) reading incorrectly.

In general, solution difficulty increases from type 1 to 5. Impurities and leaks are the easiest plant faults to locate and resolve.

Findings

The absence of a real process which would allow visual, audio, and olfactory observations is an obvious shortcoming: for example, students find the need to detect significant leaks by mass balancing faintly ridiculous. Many malfunctions in practice are unsteady, but only unsteady faults of long periodicity can presently be simulated and keep computer response times sensible for class exercises. Until recently, the programme went through the entire simulation for each student, and response time on time-share terminals has been much too slow. With current programmes, stream matrices corresponding to encoded malfunctions will be simulated, placed in a mass storage file and accessed using the random access option provided by the Extended Fortran Compiler.

Experience has shown the first programme (an extension of that initially developed by Pelloni and Rippin) is best suited for introducing first year students to chemical engineering while the two more sophisticated programmes are best suited to teaching at the fourth (final) year level.

INSTRUCTOR STUDENT INTERACTIVE EXERCISES

Trouble-shooting exercises developed by Woods [2] have been used as case studies in instructor-student or instructor-class situations since 1969. They have proved particularly valuable in presenting unsteady-state (usually liquid surging) problems typical of distillation, evaporation, steam trapping and venting processes and continue to provide a valuable adjunct to the computer interactive exercises. A particular benefit is that students become used to approaching pseudo-real problems in a methodical and imaginative manner.

Particular problems are:

1. **Number of students that can be handled in individual exercise by one instructor should not exceed five, or, where a whole class is tackling a common exercise, the number should not exceed ten.**
2. **Sketches used in presenting exercises must be brief for clarity and artificially avoid the distractions of a real plant situation.**
3. **To provide proper responses to student questions, the instructor needs real plant experience and a lively imagination. Few academics are inclined to simulate the practical situation to the extent required.**

TROUBLE-SHOOTING CASES AT McGILL UNIVERSITY

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At McGill we have presented a course that combines chemical reaction engineering and problem-solving skills. Trouble-shooting case problems are one of the types of problems that are used in this course. The course is presented in a modified PSI format that has been described by Weber and Fuller [7].

Judging from the . . . student papers, most (around 80%) of the students learn the process of trouble shooting reasonably well.

The approach is similar to the P4 card deck used by the McMaster Faculty of Health Sciences [8].* The student receives a brief statement of the background of a situation and the existence of some troublesome symptom. In addition, he receives a set of questions that is divided into subsets that may be put to plant engineers and operators, answered by direct observation, answered from technical files and handbooks, or answered by lab tests and experiments. The answers are printed on slips of paper that are stacked and stapled, printed side down, into file folders. The answer slips and question lists are coded so that the student can quickly locate the stack of answer strips that corresponds to any question. The student writes the reason that he wants the answer to a specific question and the code symbol of the question. He walks to the file folders (one set for every 6 or 8 students) and tears out a slip of paper from the stack that corresponds to his question. He returns with this slip of paper, studies the answer, makes any calculations that he wishes, draws his conclusions, and proceeds to the next question. A correct diagnosis that is obtained with a number of questions that is less than, or equal, to a given maximum is marked "pass"; all other outcomes are marked "fail" and result in a retest on a new problem.

The specifics of the problems are contained in the answers. By changing answers, the teacher can produce different problems, i.e. different causes, that use the same question set. When several sets of answers are used simultaneously, the student must be told which set to use. Calculation problems may be imbedded in a trouble-shooting problem by replacing an answer with data from which the desired answer may be calculated. It is also possible to give a cost and time delay for each answer. Limits on cost and time may then be substituted for a limit on the number of questions asked.

Two class meetings are devoted to a lecture on the strategy for solving this type of problem and an example. A student's paper gives a protocol of his process of problem solving. Students who have difficulty are given individual coaching using these protocols.

The student has access to three times the

*Described in Vol. XIV, No. 2, of *CEE*.

number of questions required, in principle, to solve the problem and he is permitted to ask 1.5 to 1.7 (depending on difficulty) times the minimum number of questions. The question set contains a modest number of imprecise, redundant, and irrelevant questions. Although the student does not pose the questions to be asked, he must be able to recognize questions that are likely to be helpful.

Judging from the protocols (student papers), most (around 80%) of the students learn the process of trouble-shooting reasonably well. Student acceptance of these exercises is excellent. In the most recent year, 17 of 18 students who responded to an anonymous questionnaire wanted the use of this type of problem to be continued.

TROUBLE-SHOOTING PROBLEMS AT THE UNIVERSITY OF CALIFORNIA, BERKELEY

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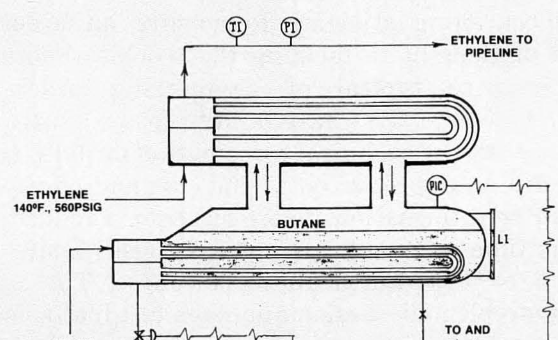
TROUBLE-SHOOTING PROBLEMS ARE used in Chemical Engineering at Berkeley as parts of a senior elective course and a course taken by most graduate students. The problems are mostly of the same nature as those developed by Woods at McMaster University [2], although we have created a number of additional problems based upon our own experience. The problems typically occupy about four hours of class time, with most of this being spent by the students working on problems individually. The student is given a problem statement and a blank solution sheet, on which he indicates what he wants to do and how much it will cost. Then there is a space for the result of the action to be filled in by the instructor (hereinafter called "oracle"). The student consults the oracle after each proposal.

We have found it most useful to preceed the trouble-shooting problems with a short lecture on appropriate strategies, including discussion and development of a systematic attack for an example problem. One aspect stressed is the importance of discerning whether or not the process ever worked, since that is useful for distinguishing between design errors and malfunctions. We have also found it helpful to present on the board a table

Trouble-shooting problems are used at Berkeley as parts of a senior elective course and a course taken by most graduate students.

FIGURE 3. Trouble Shooting Problem : Ethylene Product Vaporizer.



Our New Jersey petrochemical complex includes an ethylene plant which supplies 15,000 lb/hr of ethylene through a pipeline to various consumers. It is important that we maintain a steady flow of ethylene to these users, and as a result our plant contains a large storage sphere for liquid ethylene. The ethylene must be a vapor, however, when it enters the pipeline and must be at a temperature close to ground temperature in order to avoid thermal stresses. For these reasons we have installed an ethylene vaporizer (shown in the drawing) between the sphere and the pipeline. The ethylene is vaporized by condensing n-butane, which in turn is vaporized by steam. The cascade vaporization system is required so as to avoid undue thermal stresses across heat exchange surfaces.

Under normal operation, a small amount of ethylene (about 3500 lb/hr) is sent through the vaporizer, but the vaporizer is frequently called upon to provide more, or all, of the total ethylene supply. Before the vaporizer, the liquid ethylene is pumped up to 630 psig and metered through a flow control valve; the ethylene pressure in the vaporizer is roughly pipeline pressure (550 psig).

The butane pressure controller set point can correspond to anywhere from 70 to 125 psig. A set point of 100 psig has been used successfully at all ethylene flow rates during the past year, although the outlet ethylene temperature has been slow to recover following a change in ethylene flow rate.

In the last few months we have found it necessary to increase the PIC set point. Even so, we found yesterday when the ethylene unit came down that the vaporizer cannot handle the full-ethylene flow without tripping the low temperature shut off switch at the pipeline entry, which is set at 35°F. This situation will cost us $600 per hour plus inestimable customer good will if we stop flow, or else it may well necessitate expensive and time-consuming pipeline repair if we continue.

of costs for various services—pipefitter, analytical laboratory, etc. Most students are strongly impressed at the thought of assigning costs to the tests they propose. In grading problems we do not relate the grade directly to the money spent by the student in his solution, but instead grade qualitatively on a 0-1-2-3 basis determined in a reflective fashion upon reviewing all solutions together after class.

We have large numbers of students, typically thirty or more in a class. This is handled by having about one oracle per eight students, so that student proposals can be judged and quick responses given. We found it best when a particular problem is handled by a single oracle, since this promotes consistency and is less mind-addling to the oracles. We also use a procedure where different students start on different problems. This serves to equalize the load among oracles and greatly reduces the possibility that the "fault of the day" for a given problem will be leaked around the classroom. There is a particular sequence of problems, with different students starting at different points in the sequence. We find that as a rule students can complete two to four problems in an 80-minute class period.

Two basically different types of problems are shown in Figures 3 and 4. In Figure 3 any of many different malfunctions, operator errors, etc., can be at fault. In the double-boiler type of ethylene

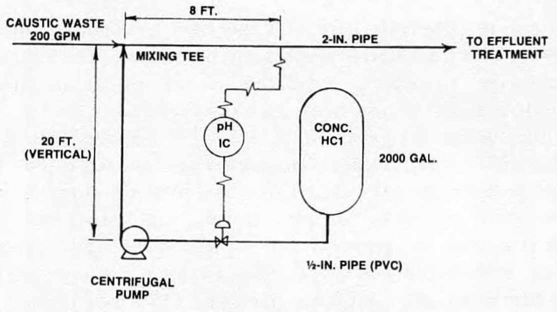


FIGURE 4: Trouble Shooting : the pH Control Unit.

Concentrated hydrochloric acid is being used to neutralize caustic wastes being fed to a newly-built effluent treatment plant. The volumetric flow of the wastes is approximately constant, but due to the nature of their source the concentration varies from 1 to 10 g/L equivalent NaOH. The average is about 5 g/L. Control is usually good, but at times it becomes erratic and occasionally the acid flow stops altogether. Turning off and restarting the acid feed control system usually serves to get the acid flow going again, but this mal-function threatens to shut down the entire plant.

You are given the job of finding the bug and getting rid of it.

vaporizer the flaws could include impurities in the shell, a low liquid-level in the shell, leaks in the header, a faulty temperature shut-off switch, etc. In the other type of problem (Figure 4) there is a basic design flaw. The student should recognize this from the symptoms and deduce the nature of the flaw; in the problem shown it is vapor-binding of the pump. For problems of the first type, the flaw is changed from year to year and from one class to another, but is kept the same within a class to reduce confusion for the oracle and help equality in judging the performances of different students on the same problem.

We have found no reason not to use the same problems repeatedly from year to year, often with the flaw changed. In this way we can use problems that have proven to work well through repeated experience.

TROUBLE-SHOOTING PROBLEMS AT THE UNIVERSITY OF WATERLOO

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EVOLUTION OF THE USE OF these problems at Waterloo since the publication of "Chemical Engineering Case Problems" [3] has been toward a conventional exercise designed to illustrate a procedure; in this case the solution of ill defined, open ended problems. Our objective continues to be encouraging students to acquire an orderly train of thought in tackling the trouble shooting problems so typical of engineering practice. Secondary objectives have been to foster a critical attitude toward technical information or data, and to instill an appreciation of the cost and effort of obtaining information. There has been a reduction of the time allotted from about 13 class hours to only 3 or 4 within a 13 week course. The case study-problem discussion approach originally used has given way to discussion of a problem solution, similar to the way a solution to a thermodynamics or fluid flow problem might be handled.

Time table pressures killed the original final term course which contained problem solving. An abbreviated treatment of problem solving has been incorporated into a seventh term lecture-problem course dealing with equipment and process design. Justification of this de-emphasis in the Waterloo curriculum is that trouble shooting is a skill quickly learned in industry. Since Waterloo engineering is entirely cooperative, many of our final

Evolution of the use of these problems at Waterloo since the publication of "Chemical Engineering Case Problems" has been toward a conventional exercise designed to illustrate a procedure; in this case the solution of ill defined, open ended problems.

year students will have faced open ended problems during their terms in the chemical industry.

Waterloo's equipment and process design course is offered twice each year and its teaching rotates among four faculty members, each of whom handles the mechanics of the course in a different way. Only two extremes in these mechanics will be discussed here.* In one, the course is offered as credit/no credit. In the trouble shooting portion (now just 1/8 of the course), solutions to two of the five or so trouble shooting problems distributed to students must be submitted. These are assessed as being satisfactory or unsatisfactory; if unsatisfactory, solutions must be resubmitted. A student must have a specified fraction of his solution acceptable for credit. In the other extreme, the course is given in a self-paced format in which four skill tests must be passed and the grade given is a mean of those achieved on these tests. Tests can be retaken in the usual self-paced manner, but an earlier test must be passed before proceeding to the next one. Tests are either drawn from the course problems or are quite similar to them. A short trouble shooting problem forms half of one of these tests.

Regardless of course mechanics, trouble shooting is handled in the classroom in about the same way. We employ about an hour long lecture to describe the morphology of problem solving and the procedures it leads to when applied to different types of problems, such as equipment failures, design, or economic decisions. The morphology we use is given in an earlier description of our use of case type problems [3] [4].

We generally give about five problem statements to our students and ask that they develop written solutions to two. In our self paced course solutions can be submitted by groups of students. They are examined and commented upon, but not graded. A detailed, annotated solution to a trouble shooting problem is distributed to students when their solutions are returned or at the time of the morphology lecture. Two one-hour lecture periods, at most, are used to discuss a solution to one of the problems the students submit. A student solution should be used as the basis for the discussion, but time pressures usually require producing a blackboard solution based largely on the instructor's solution, with students contributing by responding to questions. Unfortunately, it is seldom possible to use a case study procedure whereby the reasons for a suggestion or the purpose of a step in the analysis are discussed. Nonetheless, we try to show how each step in the trouble shooting solution relates to the solution morphology. Particular emphasis is given to the cost and time needed to gather information as the solution procedure develops.

Examples of problems used are given in our previous paper [3]. In the eight years that trouble shooting problems have been used, about one-third of them have been replaced. This casual rate of change can be explained by the non-competitive nature of our equipment and process design course. We encounter no passing on of problem solutions from class to class.

Unlike other uses of trouble shooting problems [1] [2], we do not employ student-instructor interaction to provide further information. Consequently, a solution to the "problem" cannot be achieved by our students. What we want as a "solution" is a strategy for solving a problem that might actually be encountered in an industrial environment. That is, we want the sequence of steps a student proposes to gather information, to undertake measurement and to order corrective action. As part of the development of his sequence, a student must justify each step in terms of its relevance to the information available, its chance of success and the cost and time needed for a measurement or gathering of information if unavailable. We have given an example of a satisfactory "solution" previously [3].

Student reaction to the trouble shooting problems has been neutral. We have encountered neither substantial belly-aching or wild enthusiasm. The problems seem to be accepted, like other course problems, as illustrations of a procedure and no more. Some students complain each year about the artificiality of the problems. This is understandable because we attempt to create an

*Further details of mechanics, problems used and material distributed to students can be obtained by writing to the author.

industrial atmosphere, but restrict the problem statements to one page. Statements, therefore, are sometimes awkward and problems often appear to be artificial. Furthermore, we tacitly assume a level of knowledge about equipment or processes which not all students have. As a result, the quality of the solutions submitted varies widely.

From an instructor's standpoint, the disadvantage of this brief treatment of problem solving is that we cannot develop adequate problem solving skills. At best we can only pass on the flavour of problem solving. We do give notice that orderly trouble shooting—problem solving procedures exist. We also illustrate how these procedures are applied. We believe that this is sufficient to justify trouble shooting in our curriculum. □

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BOOK REVIEW: Turbulent Mixing

Continued from page 112

reaction are not particularly emphasized. These subjects appear in a context of fluid mechanical or heat transfer analogs and as additions to analysis of fluid mechanical mixing in turbulent shear flows. As might be expected there are no discussions of laminar shear or mixing in periodic flows.

This volume can be recommended for discovering the state of research and for reading what workers in the area think about the topics presented. It tends to discourage a casual reader by showing great complexity, but at the same time it lays out a considerable portion of the problem for consideration by those who may not yet be lost in a maze of eddies. Of particular value are the experimental papers which give enough sampling of direct observation for a reader to ponder his own explanations and make his own uses of the information. Results from several types of novel experiments are presented, and these evoke interest not so much by the heuristic explanations given but by the nature of the experimental results. As with most proceedings the report is more valuable than the comment.

A review paper by the editor with an extensive bibliography and lists of references enhance the volume's purpose as a statement of position of a field of research and study. However, reading of this group of papers leaves the impression that mixing is not yet a discipline and that many of the approaches to quantitative understanding are giving diminishing returns for more effort. □

ChE book reviews

ELEMENTARY PRINCIPLES OF CHEMICAL PROCESSES

By R. M. Felder and R. W. Rousseau
John Wiley & Sons 1978, 576 pp, $21.95
Reviewed by John D. Stevens
Iowa State University

This textbook by R. M. Felder and R. W. Rousseau of North Carolina State University is aimed at traditional mass and energy balance courses and contains heavy emphasis on engineering techniques used to solve process-related problems. This book has already made considerable inroads on the market most recently dominated by Himmelblau's stoichiometry text.

The book is divided into fourteen chapters. Part 1 consists of the first four chapters which introduce basic concepts on units, variables and data representation. Some sections of this, particularly Chapter 4 on data representation and analysis, may be skipped depending on the students' background. Part 2 covers material balances and Part 3 covers energy balances. Part 4 (Chapters 12-14) consists of three case studies

Continued on page 146.

rec•og•ni•tion\ ˌrek-ig-ˈnish-ən, -əg-\

n **1 :** the action of recognizing; the state of being recognized; as **a :** ACKNOWLEDGMENT **2 :** special notice or attention.

rec•og•ni•tion\ as we see it\

1 : the primary motivation to do creative work for an outstanding company **2 :** ACKNOWLEDGMENT of the quality of that work; as **a :** self-satisfaction and pride **b :** respect from peers and associates **c :** opportunity for advancement **3 :** to recognize the challenge of the world today **4 :** to be recognized for doing something to meet those challenges tomorrow.

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Chemical Engineering Education (CE)—Spring-April, 1979
Printed in U.S.A.
D'ARCY-MacMANUS & MASIUS
8128—H6—4-5-79—225724

ChE classroom

WE CAN DO PROCESS SIMULATION: UCAN-II

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STUDENTS TRADITIONALLY introduced to chemical engineering through exercises in beginning subjects such as stoichiometry or related courses learn the intricacies of mass and energy balances, usually through steady-state approximations. However, these procedures generally do not reveal the true dynamic nature of process operation. Progressive educators have recognized the parochial nature of the steady-state approach to this subject matter. Moreover, dependence on analytical methods for solving significant differential equations, usually beyond the capabilities of sophomore students, severely limits the treatment of dynamic systems in beginning courses.

The availability of computers as a classroom tool has helped change this situation. Through simulation of basic mathematical models the beginning student can now be taught to visualize the dynamic behavior of process units, before detailed formal training in their analytical solution. Herewith the student develops a working facility for formulating, solving, and analyzing differential equations. The approach to mass and energy balances can now be made more realistic, as it is no longer restricted to the special case of steady-state behavior. The first course becomes an introduction to system design, through which the student is made aware of the optimization and control problem aspects of process equipment. [1]

In terms of classical engineering methodology, analog computer solution of differential equations enables the student to focus attention on forming and evaluating mathematical models, rather than on the details of solving them. Graphical computer output helps the student to visualize the dynamic behavior of process variables better than do tabulated results. Also, the ease of parameter adjustment and analysis helps to instill in the student the concept of parametric "cause and effect" relationships which forms the basis for a "design orientation." This approach, thus, becomes the foundation for more comprehensive study in advanced coursework. Specifically it has led to the hand-in-hand relationship between the course Process Simulation and the simulation language, UCAN-II, in chemical engineering at the University of Cincinnati.

. . . dependence on analytical methods for solving significant differential equations, usually beyond the capabilities of sophomore students, severely limits the treatment of dynamic systems in beginning courses.

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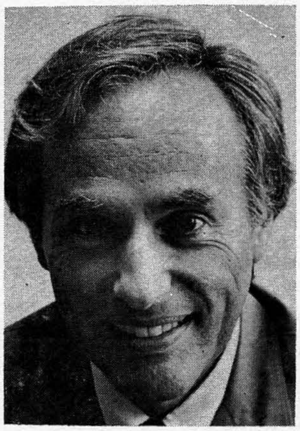
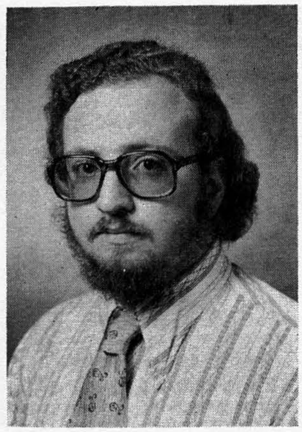
THE COURSE

PROCESS SIMULATION AS A course has evolved in a most unique fashion over the past several years. It is an elective taught annually to a limited enrollment selected from among chemical engineering juniors, seniors, and first year graduate students. The premier purpose of the course is to encourage students to expand their quantitive skills in systems analysis through the development and evaluation of process models. Adjunct to this objective is the review and introduction of pertinent mathematical techniques as necessary to accomplish this task.

Academically approached in tutorial fashion, which is unconventional (at least) for this department, the course, along with the language UCAN-II, has become popular among the "computer buffs" and the more mathematically oriented students in chemical engineering. After an initial period and several subsequent practice sessions to initiate the class to UCAN-II, as well as its implementation on the University Computer System, the course begins in earnest.

Problems are presented by the instructor to the group for discussion purposes at the first of two 90 minute meetings. At this time the problem receives a preliminary analysis by various student volunteers after queries are raised and answered by group members themselves, or by the instructor as a last resort.

Philip Hittner, who earned his BSChE at Drexel University and his MSChE at the University of Cincinnati, is a programmer/analyst with PEDCo. Environmental, Inc. of Cincinnati, Ohio. Refinements and additions to the U.C. Analog Simulator were the basis for his masters thesis. **(R)**

Dave Greenberg has been Professor and Head, Department of Chemical and Nuclear Engineering, University of Cincinnati since 1974. He has a BS from Carnegie Tech (CMU now), and MS from Johns Hopkins, and his Ph.D. from Louisiana State University. Prior to joining U. C. Dave spent the previous 14 years on the faculty of LSU, except for 1972-73 at which time he served as program manager in the Engineering Division of N.S.F. Dave's current research interests include computation, applied math, and laser applications in chemistry, biochemistry, and biomedicine. **(L)**

Often the problems are posed in a most general manner, and early in the course such "ill-defined" problems are somewhat unsettling to many students who are often critically tuned to the usually well delineated exercise and coordinated specific response found among the more conventional courses. This uneasiness is often amplified in the initial stages because the instructor does not provide further problem quantification but, rather, attempts to guide student thinking along fruitful channels to allow each to define for himself or herself the problem parameters. When students begin to realize that the "outside world" functions very often in such vague and "ill-defined" ways, the pain of discovery begins to ease immeasurably.

At this point there sometimes arises a fierce competition among students to determine whose solution satisfies the teacher's criteria. Subsequent class periods devoted to student solution presentations and critiques become quite spirited. More often than not the class becomes polarized with the graduates against the undergrads. In such cases the instructor becomes a referee. Enlightenment occurs when students comprehend that "real" problems are multi-faceted, the solution obtained is a function of the problem definition, and that there are often several "best" answers depending on the methodology and the tools used to obtain that solution.

UCAN-II

EACH TYPE OF SIMULATOR has advantages and disadvantages which is why examples of all levels are still in use today. UCAN has its heritage in LEANS, an acronym for the *LE*high *AN*along *S*imulator, which was developed by Morris and Schiesser in the 1960's at that institution. From a later version of that language, one of the authors (DBG) worked on an abridged version called LOUISA that was to be a hybrid debug language for the LSU hybrid computer system. LOUISA was never made fully functional and the project died when the author left the department. It has had a recent resurgence, however, as UCAN at the University of Cincinnati in 1976 and now UCAN-II in 1978. This illustrious history is briefly chronicled in Table I.

UCAN-II AS A TEACHING RESOURCE

UCAN-II IS A BLOCK-ORIENTED analog simulation program, as was its predecessors. Such digital programs have the advantage of requiring no amplitude or time scaling as do analog programs, and are easy to store and re-use. As an academic aid, a digital simulation language such as UCAN-II has a number of advantages over other methodologies. This is especially true in an engineering curriculum where it may be introduced as a problem solving tool in place of or before analog computers are normally introduced since digital programs, in general, require minimal user programming experience. In fact, one may learn to solve many problems with a digital simulator before he could effectively solve them in any other way.

When block oriented programs, as is UCAN-II, are general in nature they provide the user with a sense for the equation solution protocol that the computer actually follows. This is a valuable asset

TABLE 1: History

1965—LEANS (original)—Morris/Scheisser
1967—LEANS (Syracuse version)—Jelinek
Calcomp plotting added
1970—LOUISA (LSU LEANS update)—Jeffcoat/Greenberg hybrid interactive
1976—UCAN (LOUISA update)—Shields/Greenberg
expanded functional operation
1978—UCAN-II (UCAN update)—Hittner/Greenberg
added logic, improved plotting

TABLE II
UCAN-II Computing Elements

BASIC	MATH	LOGIC	PARALLEL LOGIC	SPECIAL FUNCTIONS
Constant	Summation	Relay	And	Arbitrary Function Generator
Ind. Variable	Multiplication	Bang-Bang	Not	Convergence
Integration	Division	Delay	Inclusive Or	Reset
Derivative	Exponentiation	Dead Space	Exclusive Or	User Defined Functions
	Nat. Log	Limiter		Master Block
	Power	Store		
	Trig Fns.	Abs. Val.		
	Arc Trig Fns.	± Clippers		
		Eng		

when the program is being used to teach the mathematics and simulation development, as opposed to being used strictly as a tool to study a particular system of interest. In terms of classical chemical engineering, the solution of differential equations via analog techniques helps the student to focus attention on the form and evaluation of mathematical models, vis-a-vis the details of solving the equations.

In addition to the standard computing elements derived from LEANS, UCAN-II has a number of unique features, some of which had been developed earlier as part of UCAN [8] and refined in UCAN-II. Among these features are the "Reset" block, which permits the solution of two-point boundary value problems, a "convergence" block to force the breaking of implicit function loops, and user-defined blocks which allow the user to define special non-analytic functions via FORTRAN subroutines. New to UCAN-II is a pre-processing "master-block" option which identifies a MACRO, a group of various blocks called a "master" set. This is used for computational redundancies or other special programming purposes. Mathematic blocks, logic blocks, and other special blocks give UCAN-II considerable flexibility for simulating dynamic systems. Moreover, new Boolean operator blocks make it possible to implement logically-controlled switching operations in a simulation. See Table II.

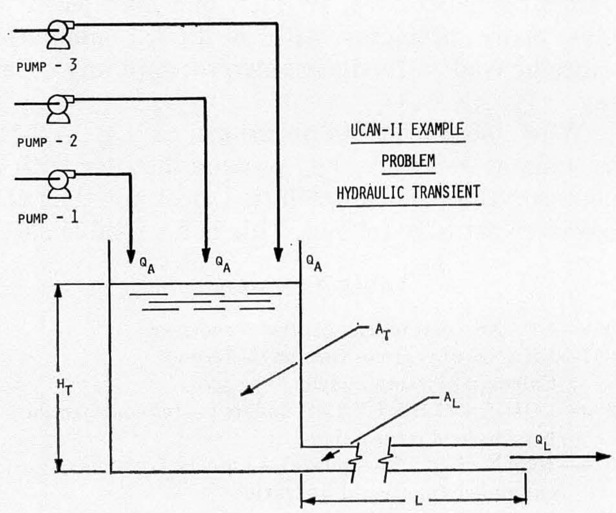


FIGURE 1.

USING UCAN-II

To solve a problem with UCAN-II, one must first derive the equations that model the process exactly as he would before solving the problem analytically. This includes specifying boundary conditions and all numeric constants, as well as converting all variables into consistent units. Consider as an example the problem presented below. After the mathematical description of the problem has been developed a block diagram is prepared, showing all mathematical and logical operations that must be performed, as well as the order and flow of information. Using this block diagram, a program listing is made which identifies the UCAN-II blocks to be called and the inputs to each. From the listing a computer card deck is assembled along with the appropriate JCL (Job Control Language) cards and, as required, additional data cards. This deck is run as a typical batch submission.*

PROGRAMMING EXAMPLE: HYDRAULIC TRANSIENTS

The following example of a UCAN-II problem solution has been abstracted from a report by a senior [12] in Process Simulation, Spring, 1979. It is a modification of a problem taken from a recently used text [7] in the process simulation course.

*Interested readers may obtain the UCAN II Programming Manual and information on the program by contacting the author.

A certain plant has been operating for five years. A project to expand capacity has been submitted and approved. The scope of the work calls for installation of new process equipment and alteration of some of the existing facilities. One of the engineers at the plant has requested an analog study of the "tank and pipeline" process described below.

Figure 1 shows the process schematically. Waste liquid is pumped from the production area by two existing pumps into a tank. From the tank, the liquid flows by gravity through a long line which discharges into the nearby river. The pumps operate in accordance with the buildup of waste liquid in the production area and are not controlled by conditions in the tank.

Under steady-state conditions, inflow equals outflow, and the height of the liquid in the tank remains constant. The mathematical relationships governing this process are:

MASS BALANCE

$$(\rho A_T)\frac{dH_T}{dT} = (\rho N)Q_A = (\rho)Q_L$$

FORCE BALANCE

$$\frac{(L)}{A_L G_C}\frac{dQ_L}{dT} - \frac{G}{G_C}H_T = H_P$$

PARAMETERS		VARIABLES	
A_T	= 470 FT.^{2}	N	= NO. OF PUMPS
A_L	= 12.6 FT.^{2}	H_T	= HT. OF LIQUID
L	= 665 FT.	Q_L	= OUTFLOW
H	= 9.5 FT.	H_P	= FLUID HEAD

The UCAN-II block diagram is shown in Figure 2.

The scope of the work calls for the addition of one more pump, identical to the two existing pumps, to handle the increased effluent from the expanded facilities. The engineer who proposed the analog study was afraid that the tank might overflow shortly after the third pump turned on. At first he encountered some resistance, based on the argument that the above equation gives a value of H_P less than the height of the tank for a Q_L equal to the maximum pumping rate (three pumps running). The engineer pointed out that the head might build up to overflowing before the mass of water in the outlet line could accelerate to the final discharge rate. Inspection of the existing installation showed that every time the second pump turned on, the liquid level surged up considerably higher than the final steady-state level for two pumps. The level then oscillated up and down for a considerable period of time before settling down to its steady-state height. The engineer's proposal to study the dynamic behavior of the tank and pipeline through analog simulation was approved.

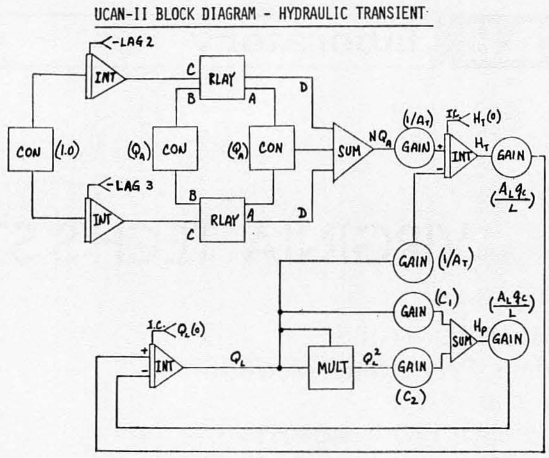


FIGURE 2.

The UCAN-II solution block diagram is given in Figure 2. Typical computer output is available both in tabular and graphical form. Figure 3 provides the optimal solution to the problem in terms

Continued on page 148.

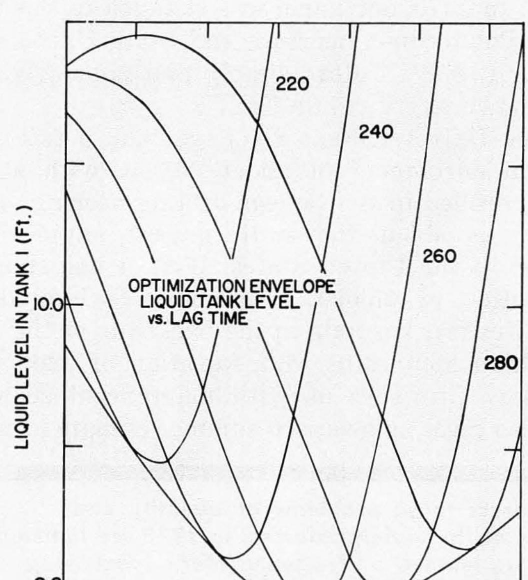


FIGURE 3.

ChE laboratory

VIRGINIA TECH'S STUDY-TRAVEL PROGRAM

GEORGE B. WILLS
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

WE WISH TO DESCRIBE our experiences with what we believe is a novel and highly effective Study-Travel Scholarship Program that we have developed for our rising seniors. In addition we would like to acquaint you with our university, since some of you may be uncertain of our geographical location, and many of you will be unsure of our official name.

BACKGROUND AND HISTORY

THE UNIVERSITY WAS FOUNDED in Blacksburg, Virginia in 1872 as Virginia's land grant university and at that time we were called the Virginia Agricultural and Mechanical College. Later we became the Virginia Polytechnic Institute or V.P.I. In 1970, our name was changed to the Virginia Polytechnic Institute and State University, or V.P.I. & S.U. More simply and popularly, we are known as "Virginia Tech".

The University has 8 colleges and a full-time student enrollment of about 20,000, with about 5400 enrolled in the College of Engineering. This makes us about the sixth largest engineering college in the United States. With a non-student population of 35,000, Blacksburg is located in southwestern Virginia in the backbone of the Appalachian Mountains. Our elevation of 2200 feet not only furnishes us with magnificent scenery but also gives us a superb summer climate of mild temperatures and low humidity.

To address these problems of quantity and quality of the undergraduates, in 1975 we initiated what we labeled a "Freshman Merit Scholarship Program." . . . this (Study-travel Program) evolved from this earlier scholarship program.

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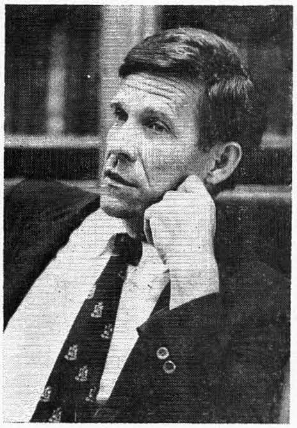


George B. Wills received a B.S. degree from M.I.T. in 1954 and a M.S. from the University of Wisconsin in 1955. After several years at the Mallinckrodt Chemical Works in St. Louis, Missouri, he returned to Wisconsin where he received a Ph.D. in 1962. He was then with the Phillips Petroleum Company in Bartlesville, Oklahoma, until joining the faculty of V.P.I. & S.U. in 1964. His research interests have been in mass transfer and heterogeneous catalysis. He is currently Professor of Chemical Engineering and Chairman of the Departmental Scholarship Committee.

Prior to 1937, Chemical Engineering was a part of our Chemistry Department. In 1937 we became an independent department with Dr. Frank Vilbrandt as the first Head. At the time of our founding the department was unique in the College of Engineering in having a graduate program to the Ph.D. level. The second Ph.D. awarded at the university was in Chemical Engineering, the first such degree being awarded in Chemistry. Since 1937 we have been a substantial department with graduating classes ranging from 25 to 90.

ORIGIN OF THE PROGRAM

WITH THIS INTRODUCTION we now turn our attention to the main subject of describing a study-travel scholarship program that has been developed for our rising seniors. This program evolved from an earlier scholarship program that we established at the freshman level six years ago. At that time our enrollments had reached an all-time low with the graduating class numbering only in the low twenties. Furthermore, there was a problem with the quality of students that we were attracting. For example, there was a sharp rise in the mortality rate in Physical Chemistry, particularly in the quarter devoted to quantum mechanics, and within the department we noted a disturbing loss in student aptitude and motivation. These low enrollments were of course a part of the national trend at that time, although perhaps we were somewhat harder hit than some other universities.

To address these dual problems of quantity and quality of the undergraduates, in 1975 we initiated what we labeled a "Freshman Merit Scholarship Program." Its purpose was to recruit outstanding high school seniors into our program. The awards were for full in-state tuition for the freshman year and these awards were made solely on the basis of academic merit. No statements of financial need were required and a simple written statement of interest in Chemical Engineering and enrollment in the engineering school were the only requirements for consideration. Selection of awardees was primarily on the basis of class rank and SAT scores, both of which we expected to be in the upper 10%. The program was financed solely by gifts from industrial sponsors and it was highly successful in addressing both the problems of low enrollments and of attracting a high quality student body. In the fourth year of our freshman program, the dean of engineering started a similar college-wide program. Our program was incorporated into the college-wide program and this released the funds that we had been using for freshman scholarships. We decided to divide the available funds into two parts: about half of the funds was to be used for merit scholarship awards at the sophomore level, and the remainder was to be used in a junior level scholarship program, with the nature of this junior level program at first undefined.

There was considerable discussion within the department as to how best use the funds that had become available. An obvious choice was simply to extend the merit scholarship awards into the junior year. However, there was also considerable sentiment for developing what we for a while termed an "opportunity award". Suggested alternatives were expense-paid trips to national AIChE meetings, special short courses which might be available only at off-campus sites, a "retreat" for students which would allow the faculty and invited guests to interact with the students in an informal atmosphere, and finally, a study-travel experience of some sort. We elected to try the latter proposal and the Dean agreed to help with the funding of an experimental program of this type. The thinking was that many of our fine students had traveled little and that a trip to Europe, coupled with some involvement with educators there, would be a valuable experience. The junior level was particularly suitable because of the structure of our Unit Operations Laboratory. It is a full-time course of five weeks duration taught during the summer. Since summer work opportunities for students are usually difficult to obtain for the remaining half of the summer, a study-travel award for the uncommitted part of the summer was not deemed a serious interference with plans for summer employment.

THE STUDY-TRAVEL PRIZE PROGRAM

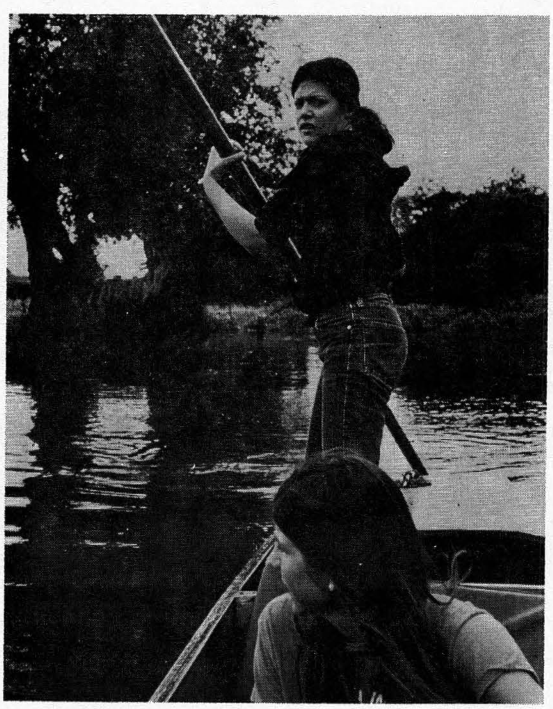
IN THE SUMMER OF 1978 we organized an experimental study-travel program. Those completing their junior year requirements by the end of summer school were invited to apply. We asked each applicant to submit a biographical sketch together with a short essay outlining how they would prepare for such a trip and what benefits they expected to gain from such an experience. We visited several universities in the United Kingdom, and after some negotiations we arranged for a group of six students to spend a little over a week at the University of Cambridge, to be followed by a week's stay at the University College of Swansea (a part of the University of Wales,

The Student Party of 1978 with Dr. David Harrison on the right.

The thinking was that many of our fine students had traveled little and that a trip to Europe, coupled with some involvement with educators there, would be a valuable experience.

located in Swansea, Wales.) At Cambridge, the students studied fluidization with Dr. David Harrison. They were housed in the dormitories of Pembroke College (one of the colleges making up Cambridge University) and their meals were also taken there. The academic work consisted of lectures, laboratory experiments, and the independent study of the pertinent literature.

Following the Cambridge visit, the group traveled to Swansea, Wales, where they spent a week studying metallurgical processes. This study culminated in a report which the group presented orally to faculty and students in residence. Their tutor at Swansea was Dean D. W. Hopkins, an authority on metallurgical processes. They also had extensive contacts with Professor J. P. Richardson and other members of the chemical engineering faculty. At Swansea, they and a Swansea graduate student were housed in an off-campus student house consisting of 8 bedrooms and its own kitchen, living room, etc. Their noon meals were taken at the university cafeteria and they prepared their own breakfast and dinner.



Punting on the River Cam at Cambridge.

After the visits to the universities, the group members were free to do as they liked for the remaining two weeks of their stay. Two traveled extensively in France, two toured Germany and Switzerland, and the remaining two spent two weeks hiking and backpacking in the British Isles.

The department paid all on-campus expenses as well as the transatlantic fares. In addition, we furnished each member of the group with a 30-day Britrail pass. The cost to the students for the two weeks on their own ranged from a low of \$200 to a high of \$800. Our costs were a little over \$6000, or about \$1000/student, and this was borne equally by the department and the Dean.

A point of interest might be the composition of this first group. It consisted of four women and two men. This is a fine tribute to the very able group of young women who were recruited in our freshman merit program in previous years, since their representation in the travel group greatly exceeds their representation in the class.

Following the return of the group to the campus, we received most laudatory reports from their tutors. For example, from Cambridge, "Let me say at once what a great pleasure it was to have them in Cambridge. . . The students were interested and competent, open and appreciative . . . ," and from Swansea, "It has been a great pleasure to have your six students with us . . . we were very pleased with the work which they did on the project . . . I would like to add that we enjoyed meeting your students socially . . ."

We of course interviewed the returning students and their reactions were clear: they felt that the experience was a superb one. One student wrote, "The education I received both inside and outside of the classroom is one I'll never forget and will always cherish." For some students it was the first time they had traveled independently with the responsibility for making all of the arrangements themselves. This was particularly true of the women. Several of the group had traveled but little, and for one it was the first time on an airplane. Later in the year the group gave a lecture-slide show for the student body and another presentation for aspirants to the continuation of the program. For those of us attending these presentations, the impact of the experience was evident.

CONTINUATION OF THE PROGRAM

IT WAS DECIDED TO continue the program for another year and this past summer another group of six students returned to the United Kingdom. They spent about a week at the University College of Swansea and another week at Imperial College in London. This year's group consisted of four men and two women. As before, two weeks were available for independent travel. At Swansea the group's tutor was again Dean Hopkins and this year's topic was an evaluation of competing zinc smelting processes. At Imperial College the group's tutor was Dr. Stephen Richardson (no relation to Professor Richardson at Swansea) and there they were concerned with a computer controlled set of adsorption-desorption columns.

We plan to continue the program again this year, keeping the group size at about five or six. This seems to be an ideal size. It is large enough so that the tutor can lecture without feeling foolish, and at the same time it is small enough to be invited into someone's home. The students are unchaperoned and no academic credit is given. This format obviously places a high level of responsibility upon the individual student and calls for initiative and good judgment on their parts.

THE DEPARTMENT'S ASSESSMENT

WE FEEL THAT THE PROGRAM allows our students to penetrate the veneer of ordinary tourism and to interact in a meaningful way with teachers and students from a different culture. To be successful, a program such as this requires a group of highly capable students and we currently have these in unprecedented abundance. We are happy to be able to give recognition to these very fine students and we think that our funds are very wisely spent. □

ACKNOWLEDGMENTS

By way of acknowledgment, we wish to thank our industrial sponsors for their generous support. They have been enthusiastic in support of our use of a fraction of their awards for this program. The supporting firms have been: Diamond Shamrock, Du Pont, Mobil, Ethyl, Shell, Celanese, Exxon, Union Camp, and Union Carbide. Dean Paul Torgersen has generously supported the program from his discretionary funds. Dr. Henry McGee, the department head, has been an enthusiastic supporter of the program as has Dr. Peter Rony, a member of our departmental honorifics committee. Dr. Rony received an award of a somewhat similar type as an undergraduate at Caltech, and he has been an enthusiastic and valuable resource in the planning of our programs. Finally, we would recognize the very fine students who have received the awards. We have placed great confidence in them and they have acquitted themselves well.

MOLECULAR THEORY

Continued from page 128

$\nabla^2 n = \frac{d^2n}{dr^2} + \frac{2}{r}\frac{dn}{dr}$ and the boundary conditions for Eq. (5.5) are $\frac{dn}{dr} = 0$ at $r = 0$ and $n \rightarrow n_B$ as $r \rightarrow \infty$. In the limit of large drops and bubbles the pressure difference ΔP between inside and outside obeys the Young-Laplace equation $\Delta P = 2\,\gamma/R$, R being the drop radius. As the drops become smaller the above theory shows that this relationship fails, the pressure difference being greatly overestimated by the Young-Laplace equation.

The theory illustrated here for a one component fluid is developed in the course for multicomponent fluids and for fluid-solid microstructures. Electrostatic effects are also included so that double-layer and electrostriction phenomena are accounted for. Meniscus shapes, disjoining pressures, and contact angles are investigated also.

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In Memorium

Fred N. Peebles

Dean Peebles was born on April 4, 1920, in Paris, TN. His technical education started at Memphis Technical High School and advanced through bachelors, masters and Ph.D. degrees in ChE at the University of Tennessee. He served engineering education extraordinarily well as professor, department chairman and dean at the U. of Tennessee. During his career, he received numerous awards for his contributions to the University, the community and the engineering profession. He was a member of numerous professional and honorary societies and was the author of many scientific articles. His generosity of spirit infused his institutions' commitment to expanding dramatically the opportunities for minorities to enter the engineering profession. Loved by faculty and students alike, Fred gave unstintingly of himself in assuring their proper development and personal well-being.

ChE class and home problems

In the Spring 1980 issue of CEE, Professor Robert L. Kabel presented the "Prairie Dog Problem" and our student readers were encouraged to submit their solution to him at the ChE Department, Pennsylvania State University, University Park, PA 16802, by June 15th, 1980. This deadline for entries has now been extended to September 5th, 1980, and Professor Kabel's solution to the problem, will be published in the Fall 1980 issue of CEE. A complimentary subscription to CEE will be awarded to the best solution submitted in both graduate and undergraduate categories (please designate your student status on your entry.)

BOOK REVIEW: Chemical Processes

Continued from page 136

of industrial processes. The book contains almost 600 problems, including many computer problems, at the end of chapters. In general, the text content is similar to Himmelblau's.

The strength of this text is in the authors' use of clear, concise language and carefully chosen examples to convey concepts to the reader. This text is obviously written with students in mind. To aid in the students' learning, important points are italicized and "Test Yourself" questions are scattered throughout the reading material. Answers to all "Test Yourself" questions plus some homework problems are given in the Appendix. In Parts 1 and 2, SI units seem to be used in about one-half of the examples and homework problems. However, in Part 3 the emphasis on SI units increases. Conversion tables on the inside cover make conversion factors readily available. The physical property tables in the appendix are quite complete although in some problems the authors also force the student to become familiar with Perry's Handbook as an information resource. However, the psychrometric charts are a disappointment. They have been reduced to 4.5 x 6″ charts and are practically impossible to read. Most instructors will want to supply supplemental psychrometric charts.

Some instructors will also disapprove of the authors' decision to adopt the convention of positive work as that work done on a system by the surroundings. Thus, in the First Law the heat and work side of the energy equation becomes Q + W. While this convention has been adopted as an international standard, most current texts still use the opposite sign convention.

Nevertheless, this text appears to have many more positives than negatives. The case studies offer the opportunity of assigning term-long, comprehensive problems to help tie course concepts together. Alternatively, the instructor can choose to emphasize computer aspects and assign programming problems. The authors have gone to considerable lengths to help instructors use this text. The problem solution manual is almost error-free and includes four suggested course outlines for either a semester course or a two quarter sequence. Complete solutions to the case studies are supplied. The text is flexible enough to offer an instructor the opportunity to design an introductory stoichiometry course to suit that instructor's own objectives.

The bottom line is whether this text is accepted by students. In our initial experience we found the students' acceptance to be exceptional. Quite simply, the students find the text readable and easy to learn from. They find the problems understandable and worthwhile.

In summary, this text merits serious consideration by any instructor who teaches an introductory chemical engineering course. □

AIR POLLUTION—3RD EDITION VOL. IV—"ENGINEERING CONTROL OF AIR POLLUTION"

Edited by Arthur C. Stern
Academic Press, Inc., N.Y.
Reviewed by William Licht
University of Cincinnati

In 1970 Professor Arthur C. Stern was presented the Richard Beatty Mellon Award of the Air Pollution Control Association because (in part) he was "the man who wrote *the* book!" The reference was to the monumental "Air Pollution" already in its second edition (1968) of three volumes. Professor Stern conceived the grand detailed plan, wrote some sections himself, edited the many contributions written by others, and was the guiding spirit required to bring it to completion.

Now we have the third edition, expanded to five volumes of nearly a thousand pages each, but again organized and edited by Stern. The work attempts to deal with every aspect of air pollution and its control. It must run hard to attempt to keep up with the flood of technical literature of the last decade.

Volume III of the second edition dealt with: Sources of Air Pollution, Control Methods and Equipment, and Air Pollution Control (legislation and administration). Volume IV, under review here, is the corresponding part of the new edition with regard to the first two areas, but the subject of Air Quality Management has been moved to a separate Volume V. Each of the twenty one chapters is written by different authors, specialists in the topic of the chapter.

The first third of Volume IV deals with general control concepts and the principles of control devices as applied to stationary sources for the removal of particulate matter and gases. General principles of operation, description of equipment, and principles of selection and evaluation are given for mechanical collectors, filters, electrostatic precipitators, scrubbers (all kinds), mist eliminators, adsorption beds, and combustion processes.

The remainder of the Volume is devoted to specific categories of sources and their control: Fuels and combustion products of all kinds (including motor vehicles), agricultural and forest products, mineral and petroleum processing, the chemical industries, and metallurgical operations. Flow charts and process descriptions are given to indicate the source and amount of emissions and typical present methods of control.

The book is excellent for a general introduction or survey of any of the topics presented. For the in-depth knowledge needed in design work, more specialized references must be consulted, especially in regard to the theoretical aspects of the control equipment performance. The volume is handsomely printed and well-documented with original references. It is an inevitable risk in a work of this scope that the various chapters may be uneven in quality of writing and in being up to date. Professor Stern has succeeded in minimizing (although not eliminating) this risk. □

BIOPHYSICAL CHEMISTRY—PRINCIPLES, TECHNIQUES, AND APPLICATIONS

By Alan G. Marshall
(University of British Columbia)
Wiley & Sons, New York, 1978, 812 pages.
Reviewed by D. O. Cooney
Clarkson College

This book is a meticulous, thorough, and lucid exposition of biophysical chemistry. The clarity of presentation, the choice of examples and illustrations, and its precise (yet not stifling) attention to detail are all very strong features of this text. Moreover, along the way the scientific bases and applications of nearly every important modern type of biophysical measurement techniques are clearly presented (including affinity chromatography, laser light scattering, ultrasonic imaging, ion-selective electrodes, and many more). In addition, the same clear treatment is given to traditional subjects, such as the thermodynamics and chemistry of biological systems (electrochemical potentials, semipermeable membranes, macromolecular solubility, enzyme kinetics, pharmacokinetics, etc.). Techniques involving electrophoresis, sedimentation, polarography, radioactive tracers, and a wide array of spectroscopic and scattering phenomena (NMR; x-ray scattering; neutron diffraction; visible, UV, and IR spectroscopy; fluorescence, etc.) are explained, and interesting examples of their uses are presented.

The most novel and valuable feature of the book, however, is its arrangement into six major sections, in each of which processes or phenomena having the same types of mathematical bases are grouped. For example, one section treats all kinds of growth and decay processes, and another treats all processes based on probability (e.g., random walk processes like diffusion, radioactive counting methods). The advantage of this approach is that, once a basic type of mathematical model is presented, subsequent applications of the model to other processes having the same kind of physical basis consists simply of changing the names of the mathematical variables.

How useful this book might be to academic chemical engineers is another matter; however, for those having a biomedical or biochemical interest I would recommend this as a volume that might be valuable as a source of many ideas that could be injected here or there into a bio-related course. □

UCAN II

Continued from page 141

of the shortest timing sequence related to the safe maximum liquid level in the tank. It was prepared from an extensive series of UCAN-II runs in which the lag times for engaging pumps 2 and 3 were varied in systematic fashion.

SUMMARY

LEARNING TO USE A block-oriented simulation language such as UCAN-II may be achieved with practice and a brief initial period of instruction, supplemented by studying the USER'S GUIDE. Often students can begin solving problems of reasonable mathematical complexity the first day they encounter UCAN-II. In many ways UCAN-II is as easy to learn and use as a pocket calculator; only limited previous computer knowledge is necessary. Beyond the material in the manual, the user need only learn how to keypunch cards and submit his program, or how to use a remote terminal, and how to access the UCAN-II program.

Through computer simulation of basic mathematical models the sophomore or pre-junior student can learn to visualize the dynamic behavior of process equipment even before being taught the analytical solution of equations relating to the equipment. In introductory stoichiometry courses typical problems demonstrate the conservation of mass and energy, usually under steady-state conditions. These principles must be taught thoroughly as they form the basis of chemical engineering, but with a tool such as UCAN-II problems involving dynamic behavior may also be taught, and the approach to mass and energy balances can now be more reflective of "real-world" situations. Even before secondary level courses, such as process control, a student can gain an appreciation of the optimization and control aspects of process equipment. □

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ChE MATERIALS COURSE

Continued from page 124

picture with ours. As a result, several textbooks have been experimented with and they have been generously supplemented with outside reading (see Table 3). We have come to believe there is educational value in requiring that the student consult multiple sources for information. Students often considered the quantity of reading too extensive, but they usually adapted to reading at the proper level and became efficient.

CONCLUSION

IN RETROSPECT, WE BELIEVE the students have found this course to be a valuable integrative experience. While quite challenging, they can easily discern their own growth in understanding of the world around them and in effectively communicating the most important aspects of a situation. We think the success of the course can be principally attributed to the efficient coverage of considerable material at a professional level through use of the unique background of the chemical engineer and significant teacher/student interaction in oral and written considerations about real world phenomena and relationships. □

ACKNOWLEDGMENTS

Departmental Sponsors: The following 135 departments contributed to the support of **CHEMICAL ENGINEERING EDUCATION** in 1980.

University of Akron
University of Alabama
University of Alberta
Arizona State University
University of Arizona
University of Arkansas
Auburn University
Brigham Young University
University of British Columbia
Bucknell University
University of Calgary
California State Polytechnic
California Institute of Technology
University of California (Berkeley)
University of California (Davis)
University of California (Santa Barbara)
Carnegie-Mellon University
Case-Western Reserve University
University of Cincinnati
Clarkson College of Technology
Clemson University
Cleveland State University
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