ChE department

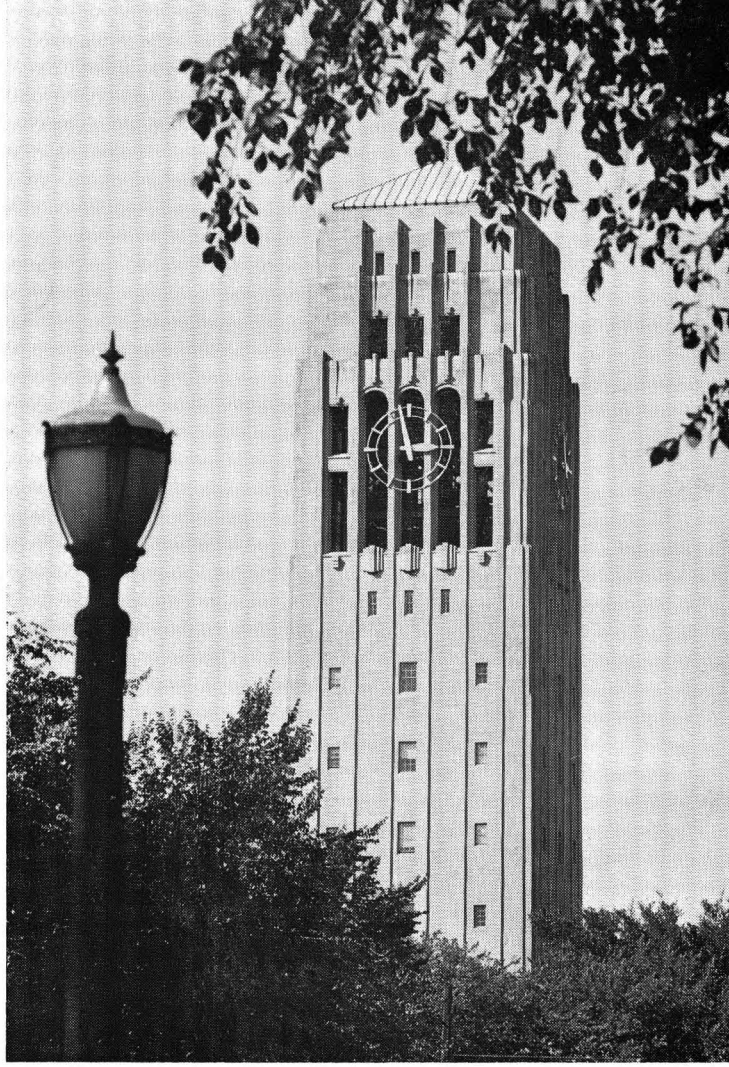
MICHIGAN

This paper was submitted by the Chemical Engineering Faculty, The University of Michigan, J. O. Wilkes, Chairman.

Considerable changes have occurred in our department during the past decade. Most significantly, about half of our present faculty have been appointed within that period. Thus, although we have strong roots in the past, our composition and outlook has, we hope, kept well abreast of the times. Also, in 1971, after a liaison of 36 years, the combined Chemical and Metallurgical Engineering department separated into two: Chemical Engineering, and Materials & Metallurgical Engineering. This separation has proved beneficial, giving us a renewed sense of identity and purpose. Allowing for joint appointments, etc., our faculty (Table 2) has a net full-time count of 17. Current enrollments are: undergraduates, 170; graduates, 55. Degrees awarded during the past year were: 50 B.S.E.; 16 M.S.E.; and 6 Ph.D.

The number and diversity of backgrounds of our faculty allow us to offer a wide range of viable programs at all levels. We also participate to a considerable extent in teaching courses outside the department, to freshmen and other engineering students. Although many of our offices and classrooms are still in the East Engineering building on the main Ann Arbor campus, most of our laboratories and research facilities are housed two miles away, in the relatively new G. G. Brown building at North Campus. Adjacent to the latter, construction of a Water Resources building is about to start, and we are looking forward to the additional facilities it will provide for our microbiological and other biologically oriented laboratories.

A program in chemical engineering has now existed at the University of Michigan for 75 years. The history of the first 60 years has been documented by Katz‡, chairman from 1951-61, and who has since been succeeded as chairman by Churchill (1961-66), Van Vlack (1966-70), Balzhiser (1970-71) and Wilkes (1971-).



THE UNDERGRADUATE PROGRAM

Our undergraduate curriculum is outlined in Table 1. The relation between the basic sciences and their application to a wide variety of engineering problems is emphasized. Digital-computer techniques are integrated within the courses at an early stage of the program, and we are building a disk-file library of documented computer programs that can be used throughout the curriculum, in areas such as optimization, design, material balances, and laboratory data processing.

Some areas of specialization available in the regular chemical engineering program are: *biochemical* engineering, *polymer* engineering, *petroleum* engineering, *electrochemical* engineering, *materials* engineering, *environmental* engineering, *control* engineering, and *computers and systems* engineering. There is a particularly strong interest in the biochemical option. Courses in the chemical engineering of water and air pollution control are also very popular among the students.

‡D. L. Katz, "Development of Chemical Engineering at the University of Michigan," **Chem. Eng. Progr. Symposium Series**, Vol. 55, No. 26, pp. 9-15 (1959).

TABLE 1—Course of Study for the B.S. Degree in Chemical Engineering

Core Subjects Common to All Eng. Programs	Credits
Mathematics	16
Physics	8
Chemistry	4
Digital Computing	2
English (Freshman)	6
English (Advanced)	6
Humanities & Social Sciences	12
	54
Professional and Advanced Subjects	
Advanced Chemistry	20
Material Balances and Engineering Thermodynamics (includes laboratory)	7
Rate Processes (includes laboratory)	7
Separations Processes	3
Chemical Engineering Laboratory	3
Properties of Liquids, Solids, Gases, and Surfaces	3
Engineering Materials in Design	3
Process Design	3
Senior ChE Elective	3
	52
Electives	
Course in mechanics of solids and a course in electrical circuits	8
Free electives	14
TOTAL	128

THE TEACHING OF CHEMICAL ENGINEERING

The department continues to develop and implement new procedures and packages in undergraduate instruction. A recent survey by Woods‡ places our introductory course in material and energy balances in a unique position relative to companion institutions. Using material adapted from the University of Pennsylvania, process simulation and the use of computer accounting are stressed by Professors Carnahan and Kadlec. The rate processes are begun via a problem booklet compiled by Professor Tek, reinforced with printed notes developed by Professor Wilkes.

Another successful effort in teaching innovation is the use of programmed learning and guided design in our course in chemical kinetics and reactor design. Professor Fogler's programmed text (see below) has been used to great advantage with this technique. The instructor usually lectures via closed-ended (convergent) problems, and also collaborates with the students as they work

‡D. R. Woods, "Material and Energy Balance Courses," Symposium at 65th National AIChE Meeting, New York, 1972.

There is a particularly strong interest in the undergraduate biochemical option.

on open-ended (divergent) projects lasting several weeks. Representative projects include: design of a catalytic afterburner, solid-waste reactors, hollow fiber artificial kidney with encapsulated enzymes, and the fermentation kinetics in wine making.

CEE readers have seen our view of modeling instruction in the Fall 1972 issue, which is but one of several courses intended to bridge the gap between graduate and undergraduate work. In addition, our approach to materials problems involves two courses: one in properties, based on thermodynamics and rate operations, and a second aimed at structural and equipment problems. These are not sacred, however, for our biologically oriented students take microbiology and biochemical technology instead.

The familiar unit operations laboratory also has a twist. In common with other schools, we offer this lab on a 40 hour per week schedule during a 3-week period following our winter trimester. Professors Williams and Hand have spearheaded this operation.

In collaboration with others, we have recently written the following books for use in our courses:

Balzhiser, Samuels, and Eliassen, *Chemical Engineering Thermodynamics*, Prentice-Hall, 1972.

Carnahan, Luther, and Wilkes, *Applied Numerical Methods*, Wiley, 1969.

Carnahan and Wilkes, *Digital Computing and Numerical Methods*, Wiley, 1973.

Fogler, *The Elements of Chemical Kinetics and Reactor Calculations*, Prentice-Hall (in press).

Sliepcevich, Powers, and Ewbank, *Foundations of Thermodynamic Analysis*, McGraw-Hill, 1971.

THE GRADUATE PROGRAM

Although the chemical engineer with a B.S. degree can clearly be successful professionally, we look upon graduate study not as simply a continuation of undergraduate work, but as an opportunity to accomplish several new objectives. The Master's degree is also viewed as having its own special character and not as a way-stop in a doctoral program. We expect that many students will have the M.S. as their educational goal and we do not discriminate between M.S. and Ph.D. aspirants for our first-year fellowships. Also, we conduct a popular M.S. extension program in Midland, Michigan.

Another successful effort in teaching innovation is the use of programmed learning and guided design in our course in chemical kinetics and reactor design.

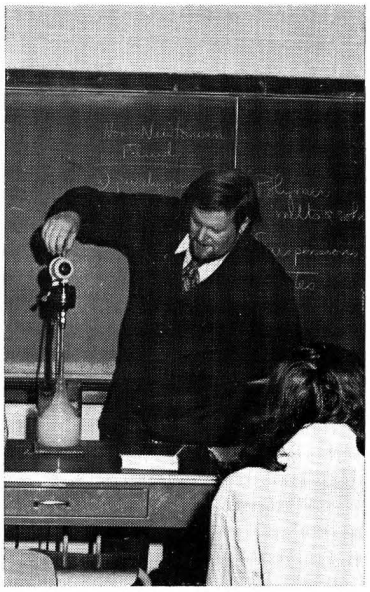
The objectives of the M.S. program are:

1. To build upon the B.S. in the specific fields of reactor design, separations, and process design,
2. To allow the student to study advanced topics of personal interest in areas such as bioengineering, computing, control, mathematical modeling and optimization, petroleum processing, and thermodynamics, etc.
3. To provide a foundation for possible subsequent doctoral work.

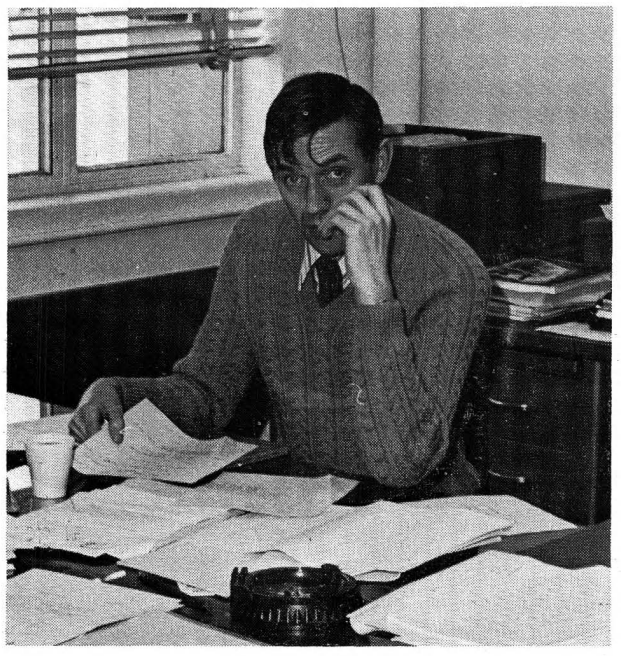
No thesis is needed, and the 30 credit-hour requirement can readily be met in 2½ terms (10 months).

The faculty research interests, and those of the students, are explored in a 1-hour Research Survey seminar, where students learn about the research viewpoints of the faculty and themselves carry out reviews in several areas. Individual students can optionally elect independent research toward M.S. credit and some, looking toward Ph.D. work, do this to initiate their entry into research. The regular graduate research seminar program throughout the year is now climaxed by a two-day visit to the department by the recipient of the Donald L. Katz Lectureship.

The written Ph.D. Qualifying Examination is given each term and those having any interest at all in the Ph.D. are urged to take it in their first term of graduate enrollment. The subject level is undergraduate, but the expected performance level is such that the student must have a good grasp of fundamentals and applications in order to do well. Once this examination is passed, a dissertation committee can be formed as soon as a suitable research topic is chosen, so that a Ph.D. program can be initiated even in the middle of M.S. study. Afterwards, the committee guides the academic and research programs of the student.



The Weissenberg effect is demonstrated by Jim Hand to his rate processes class.



Jim Wilkes, Chairman.

The graduate program has been much reviewed and changed in recent years. The Ph.D. Preliminary Examination is now the oral defense of a written research proposal, usually in the expected dissertation area. (Our previous "21-day problem" has now been incorporated into the required M.S. design course, taken by all Ph. D. candidates.) Also, set course requirements beyond the M.S. have been de-emphasized, thus allowing more freedom in planning a Ph.D. program. Graduate students have participated in all review committees concerning the graduate program. The two strongest influences on the graduate program have been the backgrounds of the new faculty joining the department, together with a shift in the interests of students towards computers, applications, and biological and environmental concerns. These have also altered the traditional concept of the

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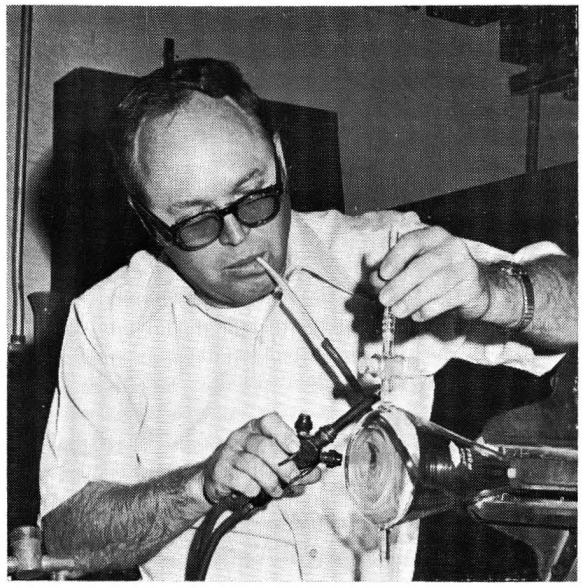
thesis, with dissertations being more frequently done in design algorithms, system modeling, and other current application areas.

RESEARCH ACTIVITIES

Our research interests are outlined in Table 2. Areas of expansion in the past decade include bioengineering, process dynamics, computer applications, pollution control, reservoir engineering, catalysis, sonochemistry, and polymer rheology. We illustrate by mentioning four representative, specific projects.

(1) **The Thermal Properties of Fluids Laboratory** has been dedicated for over 15 years to accurate calorimetric determinations. Currently three separate facilities are in operation. The



Glassblower Peter Severn is a member of our skilled and dedicated workshop staff.

TABLE 2.—Faculty and Fields of Specialization‡

Balzhiser, Richard E. Heat transfer and thermodynamics, liquid metal technology, use and reuse of energy and material resources.

Briggs, Dale E. Air and water pollution, computer control, heat transfer, adsorption, solvent refining of coal.

Carnahan, Brice. Digital computation, numerical mathematics, optimization, engineering and medical applications of digital computers.

Curl, Rane L. (Graduate Committee Chairman): Dispersions, pollution control, residence-time distributions, simultaneous mass transfer and chemical reaction, carbonate technology.

Donahue, Francis M. Electrochemistry; fuel cells, batteries, electroplating, corrosion and corrosion inhibition, electrosynthesis.

Folger, H. Scott. Kinetics and mass transfer in porous media, fluid mechanics, sonochemical engineering.

Goddard, Joe D. Fluid mechanics, rheology, mass and heat transfer.

Hand, James H. Molecular rheology, polymers, hydrodynamics, boiling heat transfer.

Kadlec, Robert H. (Undergraduate Program Advisor): Process dynamics and control, modeling and simulation, reactor engineering.

Katz, Donald L. (A. H. White University Professor of Chemical Engineering): Petroleum, natural gas, underground storage, information systems, engineering education projects.

Kempe, Lloyd L. Biochemical engineering (industrial microbiology). Food and pharmaceutical industries. Industrial waste and water treatment.

Martin, Joseph J. (Associate Director of the Institute of Science and Technology): Thermodynamics, energy conversion, properties and statistical thermodynamics, applied mathematics, radiation chemical processing.

‡**Parravano, Giuseppe.** Polymers and polymerization reactions; theoretical and experimental studies in heterogeneous catalysis and solid surfaces, thermodynamics and kinetics of solid-state reactions.

Powers, John E. Separation processes, experimental determination of thermodynamic properties.

Schultz, Jerome S. Biochemical engineering, production of pharmaceuticals by fermentation, gas absorption, transport phenomena in membranes, biomedical engineering.

‡**Sinnott, Maurice J.** (Associate Dean of the College): Physical metallurgy and materials, physical properties of fluids.

Tek, M. Rasin. Applied fluid mechanics, petroleum engineering, two-phase flow, underground storage of natural gas, mining from the ocean.

Wilkes, James O. (Chairman of the Department): Numerical methods, fluid mechanics, polymer processing, underground storage of natural gas, two-phase flow.

Williams, G. Brymer. Separation processes, vapor-liquid equilibrium, process design and analysis.

‡**Yeh, Gregory S. Y.** Polymers.

Young, Edwin H. Process design, process equipment design, heat transfer.

‡Denotes joint appointment with Materials and Metallurgical Engineering Department.

About half of our present faculty have been appointed within the past decade.

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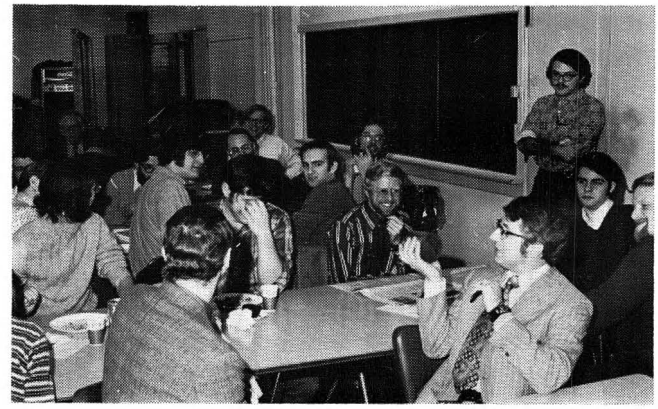
latest of these is a recycle-flow facility that has been built by graduate student Takaya Miyazaki in collaboration with Professor Powers, and is capable of operating from 110-650°K and at pressures up to 1000 atmospheres. A single calorimeter permits operation in the isobaric, isothermal, and isenthalpic modes, and is capable of measuring thermal properties typically within $\pm 0.1\%$

(2) **Modeling a Marsh Ecosystem.** Chemical engineering involvement in ecological problems in the past has tended to revolve around industrial waste treatment and improvement or modification of operations to eliminate waste. Recently Professor Kadlec has broken this imaginary boundary and is codirecting a project to evaluate wetlands as possible recipients of secondary sewage effluent. Wetlands generally have high growth rates, thus enabling them to immobilize large quantities of nutrients which otherwise might pollute streams and lakes. In addition, being "designed" for water or water-logged conditions, additional water may not adversely affect them.

One goal of this project is to develop an ecosystem simulation capability. Extending the concepts developed in programs like PACER and REMUS to biological systems will enable graduate student Peter Parker and others to predict ecological disasters or breakthroughs on the computer. By working closely with a group in the University's School of Natural Resources, this interdisciplinary effort is broadening the scope and application of standard chemical engineering analysis.

(3) **Biological Membrane Transport.** The challenge to understand the processes that are responsible for controlling molecular movements in living organisms has recently been accepted by chemical engineers. These problems of mass transport into cells and across various biological barriers such as capillary walls have been under investigation by cell biologists and physiologists since the turn of the century. Two of the phenomena that have surfaced as rather crucial to the understanding of biological transport processes are concerned with transport through molecular size pores and reaction-coupled carrier-mediated diffusion. The fundamentals of these membrane transport processes are being investigated by Professor Schultz and his students. Spin-offs of these studies are expected too. Some potential applications include membrane separation processes such as reverse osmosis, water purification, selective gas separations, and separation of ions by specific ionophoric carriers.

(4) **Thermal Auto-Emission Control Reactors.** The reduction of automotive exhaust pollutants is a major new area that requires an extension of traditional concepts of reactor design. The joint efforts of automotive and chemical engineers over the past several years have resulted in the development of design tools applicable to non-catalytic exhaust reactors. Professors Carnahan and Kadlec, in conjunction with several graduate students, have developed and tested design algorithms which are currently in use by Ford and General Motors. DuPont has reported that the use of these techniques has allowed them to redesign their reactor with a doubled effectiveness.



AIChE Student Chapter, oldest in the nation, holds a luncheon every week.

SERVICES TO THE PROFESSION

Individual members of our faculty have continued to play prominent roles in professional and governmental activities. Some of the more outstanding examples are:

Balzhiser: White House Fellow, 1967-68. Assistant Director, Office of Science and Technology, 1971-73.

Curl: President, National Speleological Society, 1970-.

Katz: President, AIChE, 1959; Chairman, National Academy of Sciences, U.S. Coast Guard Committee on Hazardous Materials, 1964-72; Member, National Academy of Engineers, 1968.

Martin: Chairman, Ch.E. Division of ASEE, 1963-64; Vice-President, ASEE, 1968-70; President, AIChE, 1971; President, Engineers Joint Council, 1971-.

Sinnott: Acting Deputy Director of ARPA, 1972.

Young: President, National Society of Professional Engineers, 1968-69; Fellow of ASME, 1972. □