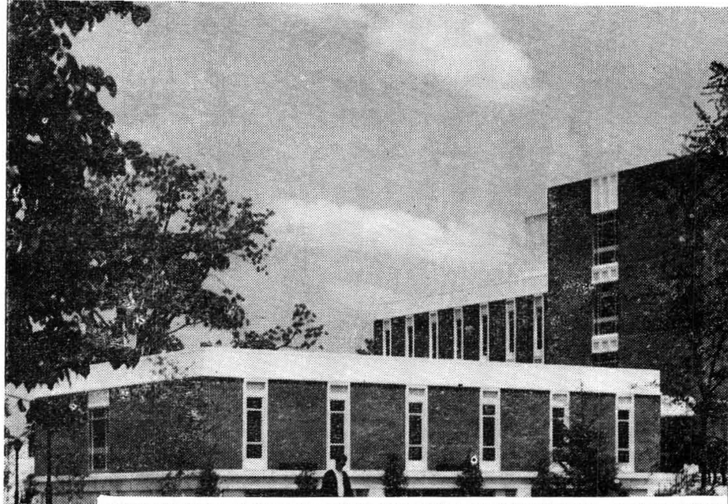
DELAWARE



ChE department

JACK A. GERSTER*
University of Delaware
Newark, Del. 19711

The Department of Chemical Engineering at the University of Delaware offers a wide variety of services consistent with the demands of the technical community, both local and world-wide. Local needs are important, because northern Delaware is a large chemical manufacturing and research center; beyond the state line to the north and east lies the even larger chemical and oil refining industrial complex which borders the Delaware River from above Philadelphia to below Wilmington for more than 30 miles. The university, located 12 miles west of Wilmington and the river in the town of Newark, offers a small college-town atmosphere for its students, yet, is only a half-hour's drive from either the Chambers Works, duPont's largest manufacturing plant, or from Getty Oil's 100,000 barrel a day oil refinery. It is never a problem explaining to Delaware high school students what a chemical engineer is, the kind of work he does, or where he might be employed.

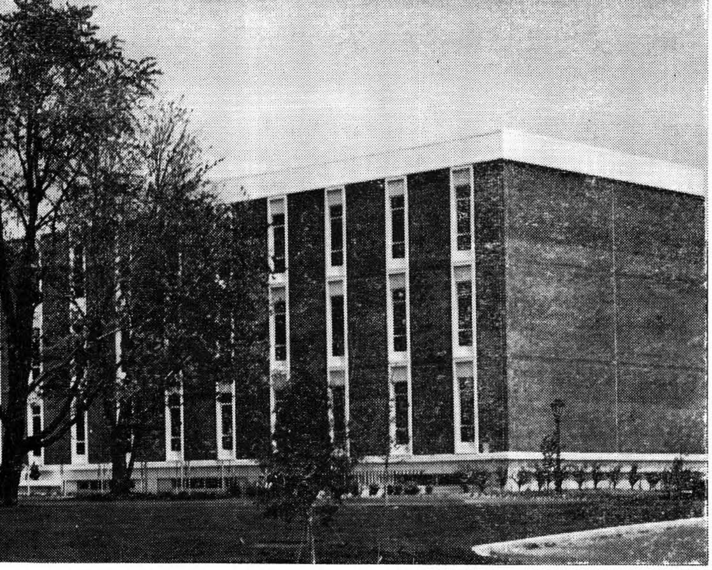
Delaware is nevertheless, a small state having only 3 counties and a population of just over one-half million; University of Delaware, with its 8,000 undergraduate and 2,000 graduate students, is the only institution of higher learning in the state offering training in most of the professional areas, including engineering. Originally a state university, Delaware is now a state-related agency receiving income both from the State legislature and from its endownment, the latter being fairly substantial.

Although some chemical engineering training was available at Delaware prior to World War II, it was not until 1946 that the number of undergraduate students became significant and graduate work was offered in depth. The first PhD degree was awarded in 1948. The department chairman at that time was Allan P. Colburn, an outstanding chemical engineer whose reputation in heat and mass transfer was first developed while working under Olaf Hougen at Wisconsin and later under T. H. Chilton at the duPont Experimental Station. (Colburn's career was presented in detail in the previous issue of this journal.) Colburn's spark-plug personality and driving enthusiasm attracted a small nucleus of outstanding faculty. In 1946 this group included O. P. Bergelin, whose research on shell-side coefficients and shell-and-tube exchangers remains as the classic basis for design of such equipment.

Colburn also hired J. A. Gerster and R. L. Pigford for Delaware's teaching staff during this period. Gerster assisted Colburn in his research on nonideal solutions, extractive distillation, and tray efficiencies for a brief period, then took over this assignment when Colburn was moved up into higher administrative positions at Delaware in 1947 when Pigford was brought in as Department Chairman.

THE "COLBURN YEARS" at Delaware provided an educational philosophy which has been carefully followed, updated, and amplified during the next 19 years while Pigford directed the fortunes of the department; the same philosophy remains in effect today. **Colburn, in spite of**

***After the receipt of this article, CEE learned that Prof. Gerster died January 20, 1969 in Newark, Delaware. Dr. Gerster received his BE, MS, and PhD in chemical engineering from Ohio State University. In 1962 he was named winner of the Professional Progress Award of the American Institute of Chemical Engineers "for important contributions to research, especially in distillation and to chemical engineering education." CEE joins the profession in mourning the loss of this outstanding Chemical Engineer.**



his great theoretical knowledge and background, was nevertheless primarily an engineer, and insisted that chemical engineering research have practical value**; the practical value could be eventual rather than immediate, but it had to be there in order to merit his interest. This requirement by no means eliminated the need to apply fundamental science or basic mathematics to correlate or explain a result, in Colubrn's opinion. For example, he successfully used the best available two-phase flow theory for correlating condensing film coefficients for the case of turbulent vapor flowing downward in cooled vertical tubes. On the other hand, complex problems not amenable to full theoretical treatment still received Colburn's attention, provided they were of practical interest; he searched for the unique and characterizing experiments necessary to define and predict the desired result, and was usually able to develop recommendations for use in design regardless of the complexity of the situation.

Colburn and Pigford set high standards in their course teaching. At the graduate level, two-semester sequences were made available in each of the basic chemical engineering subjects such as thermodynamics, kinetics, fluid mechanics, and transport processes. Usually most of the important topics of the subject were taught during the first semester, including both basic principles and applications. This permitted the master's students, who usually took only the first semester courses, to be fully trained in a wide variety of subjects. In the second semester of these courses, more specialized topics were covered: an example would be the teaching of fluidization and two-phase flow in the second semester of the graduate fluid mechanics course. Applications of fluidization and two phase theory would be included. The second semester courses always included study of current literature so that by the end of the two-term sequence, the student became familiar with knowledge of the subject updated to the present time. Graduate courses remain structured in this manner today, as the value of the procedure has been proven many times.

All of the basic graduate courses devote some time to the solution of short, practical problems which most often have a design flavor, but may also be directed toward characterizing a particular piece of operating equipment or process, or may illustrate the workings of a strictly research-type apparatus. Although the graduate course in design synthesis is not taken by a majority of the graduate students, inclusion of design-type problems in the regular courses meets much of the need for preparing masters' students for industry and PhD students for their qualifying examinations.

A successful innovation is graduate teaching developed over the past several years is the use of "term teaching." In this approach several professors—usually three—have joint responsibility for a given course. Each contributes lectures on topics related to his own expertise but in a manner that is related to what the others are doing and to the basic subject matter as well. This practice has been particularly successful in the second semester of the two-term courses described above.

Maintaining high quality in chemical engineering education over the years has been possible only because of the insistence in quality in the selection of faculty members. It is not possible to list all faculty in the department since 1946, but changes have been relatively few and stability has existed through the years. Currently, the faculty numbers thirteen: J. A. Gerster, (Ohio State) is Chairman; C. E. Birchenall (Princeton), A. B. Metzner (MIT), and J. H. Olson (Yale) are Professors: M. M. Denn (Minnesota), T. W. F. Russell (Delaware), and J. H. Schultz (Carnegie-Mellon), are Associate Professors; and B. H. Anshus (Berkeley), B. C. Gates (Washington), J. D. Eliassen (Minnesota), J. E. Katzer (MIT), M. R. Samuels (Michigan), and S. I. Sandler (Minnesota) are Assistant Professors. Further, the Dean of Engineering, E. W. Comings, is a chemical engineer by training and directs a graduate thesis from time to time. All of the faculty just mentioned have PhD degrees

Pigford . . . strongly required that both courses and research have engineering relevance.

and all have a strong, traditional chemical engineering background with abilities to teach a wide variety of courses (except for two of the professors in the Materials Science area, Birchenall and Schultz). Yet each has his own special interests, but, because of the breadth of background, each has the technical competence to change or add to his interests—as each has done in the past and will continue to do in the future as new developments occur. The faculty also maintains contact with industry by consulting work, by informal contacts with engineers from industry, by attending technical meetings, and by various kinds of committee work.

DISCUSSION OF DELAWARE'S chemical engineering faculty is not complete, however, without mentioning three long-term faculty members who are now teaching elsewhere: Robert L. Pigford, John R. Ferron, and David E. Lamb. Pigford influenced the growth and stature of the department during his period as chairman (1947-1966) more than anyone else. He implemented and improved upon Colburn's policies, and added many important innovations. **He strongly required that both courses and research have engineering relevance. Course problems or thesis work which were no more than mathematical exercises were not condoned. Yet, on the other hand, Pigford was a strong applied mathematician, and believed that students should both know and be able to apply mathematics in their studies;** he was one of the first to use computers in his research and strongly motivated the university to obtain its first computer. Pigford also innovated a short course in electronics for the department's PhD students, and introduced the requirement of an oral proposition for this same group. Development by the student of an oral proposition—which is a fully-documented research proposal not related to the thesis—provides training for the PhD student in conceiving and planning a research problem; such training is vital for anyone planning a career in research, yet often this phase of the student's own research is completed by the thesis advisor before the student enters the scene. (Today the oral proposition is presented by the student during the oral part of his PhD qualifying examination. The oral part is preceded by the written part of this examination, which is eight hours long and administered over a two-day period.)

Pigford was also the prime mover in promoting a new building for the department. Although the building was barely under construction when Pigford moved to the University of California at Berkeley in 1966, his contributions to the planning and in developing funding were very substantial.

John R. Ferron is the second former Delaware faculty member whose impact on the department merits attention. After a career at Delaware spanning the years 1958-1969, Ferron became, in September, 1969, Chairman of Department of Chemical Engineering at University of Rochester. Dr. David E. Lamb joined the Delaware Chemical Engineering Faculty in 1956. He became the first Chairman of the Department of Statistics and Computer Science at Delaware in 1965; he retains his interest in chemical engineering but no longer teaches in the department.

At this point the individual areas of interest and research specialties of the current faculty might be listed:

Dr. Gerster has interests in mass transfer, distillation, and applied thermodynamics; he has 45 published papers on vapor-liquid equilibrium, efficiency and performance of distillation towers, and tower control. He authors the "Distillation" section of Perry's Handbook, and in 1962 received the Professional Progress Award of AIChE. Dr. Metzner has over 50 papers to his credit, mainly in the areas of non-newtonian fluid mechanics and kinetics. His awards include: The Chemical Engineering Lectureship. ASEE, 1963; Colburn Award, AIChE, 1958, Wilmington Section Award, ACS, 1958; and U. N. Lacey Lectureship, Cal. Tech., 1968.

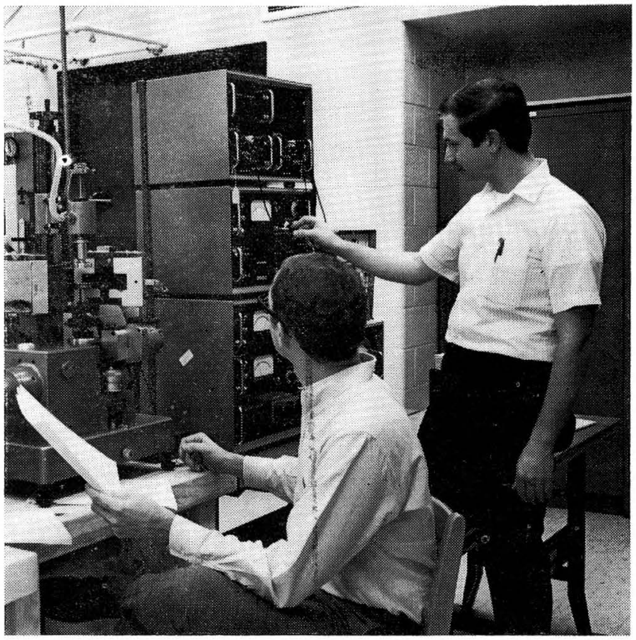
Dr. Birchenall is the author of the book, "Physical Metallurgy," and has published more than 70 paper, mainly on diffusion in metals and the mechanism of corrosion. Dr. Olson has published in the areas of catalysis and kinetics, mass transfer (particularly crystallization), turbulence, and automatic control. Dr. Russell is a well-known expert on two-phase flow in pipes, and in both pipeline and stirred tank reactors. Dr. Denn's new book, "Optimization by Variational Methods" has just appeared, and he has published 20 papers on optimization, automatic control, and non-newtonian fluid mechanics. Dr. Schultz uses x-ray diffraction and other techniques to characterize the crystallinity of polymers such as polyethylene in terms of their structure and treatment. Dr. Eliassen is interested in the fluid mechanics of liquid interfaces and in the related problem of emulsion polymerization. Dr. Samuels works in the computer solution of engineering problems and in the use of laser-Doppler flowmeter for flow-field determination. Dr. Sandler's field is statistical mechanics; his most recent paper is titled "Transport Properties of Partially Ionized Argon."

Both Dr. Gates and Dr. Katzer have interests in basic and applied catalysis; the former tends to emphasize gas

phase reactions, and the latter, liquid phase reactions. Dr. Anshus works in the area of fluid mechanics, particularly in flow stability.

The expanding size of Delaware's faculty — noted above to increase from 4 in 1946 to 13 in 1969, reflects the growth in numbers of undergraduate and graduate students over that period. As of September, 1969, there were 88 freshman chemical engineers and 43 seniors, nearly all of whom will probably graduate. **The number of undergraduate students have been increasing at the rate of 6 - 7% per year for the past six or seven years; this growth is unlike the national trend, which shows a nearly constant number of students being graduated each year in chemical engineering.** There is no definite explanation for this growth, but it is probably due to a combination of circumstances including Delaware's increasing reputation in the field and its rather favorable fee structure when compared with most of the competing private schools such as Lehigh, Carnegie-Mellon, Princeton, and MIT. At the graduate level, a peak of 65 full-time graduate students in residence was reached three years ago, but draft difficulties has reduced the figure to 49 for September, 1969. The average percentage of Asian and Indian students has remained constant over the past decade at about 6% of the total; this year, the number of English and Canadian students has been increased. Of the graduate students in residence, about half are PhD candidates. Delaware's PhD "production rate" (that is, the number which are graduated each year) has averaged nearly 10 for the past 5 years or so; only eight or nine schools in this country produce more than that.

DELAWARE'S UNDERGRADUATE curriculum is cast along traditional lines in many respects, but there are some features which are truly unique. For example, *freshmen are required to designate a preference for their major subject, and all of those choosing chemical engineering take a 2-credit course in engineering orientation taught by chemical engineer faculty.* The concept of what constitutes chemical engineering is taught by a simplified process design problem which involves the concepts of recycle, conversion and yield, cost factors, and net profit. Fortran programming is taught and used to solve the detailed calculations required in the design problem, and a plant trip is made to inspect the actual process under study. A second course for freshmen, taught by chemical engineering faculty,



Weissenberg Rheogoniometer for the Determination of Rheological Properties of Viscoelastic Materials.

may be elected in place of the 2-credit engineering graphics course. This second course is designated as a "chemical engineering seminar," and the class size is kept under 15. In this course students are guided into learning about and discussing a chosen chemical engineering topic such as, "Low Temperature Processes," "The Clam as a Chemical Engineering Operation," or "Plastic Flow Problems." In this course the close contatt with a senior faculty member cements the students' interest in chemical engineering at a time when he is mainly concerned with learning the fundamentals of mathematics, physics, and chemistry; it permits him to see in advance how these fundamentals are required and used in engineering practice.

Sophomore students take a two-semester sequence of a unified chemical engineering subject which includes not only the traditional material and energy balances of various chemical processes, but also training in "chemical engineering analysis." This latter subject includes practice in setting up differential equations—expressing mathematically all kinds of physical situations. In addition to the modelling, procedures for solving differential equations are covered. The mathematical procedures are taught (by chemical engineering faculty) mainly in the Spring Semester, after the student has finished three terms of calculus; a separate course in differential equations is no longer a part of the curriculum. The analysis training provides the proper background for transport processes and thermodynamics, both taugh as 2-semester courses in the junior year.

The chemical engineering senior year includes six trips to nearby chemical manufacturing plants. Seniors are required to take a full year of senior projects and a Spring Semester course in design. The value to the student of carrying out an individual research project is so great that the faculty is willing to spend the time and money involved on the individual instruction which is required. The type of the research performed is not too sophisticated and the equipment is necessarily simple, but the student's sense of responsibility and judgment is sharpened, and he learns to appreciate the many factors involved in solving a problem on his own. In a weekly projects conference period, students learn about statistical design of experiments and report on their research progress.

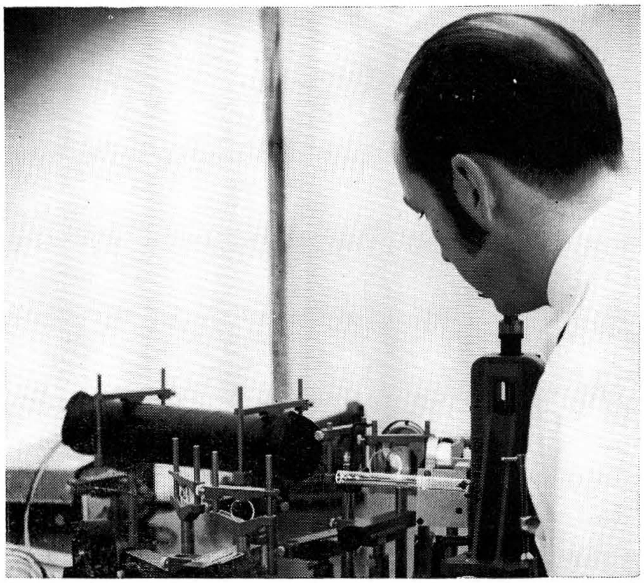
The senior design course has had many desirable improvements in the past several years. The duPont Company has assisted in the teaching of design by making avaliable a senior design engineer to handle the class for a six-week period during which one or more "case studies" or real design problems are solved under his guidance. For the last two years a Monsanto design problem—made available through Washington University (St. Louis)—has been used very successfully. DuPont has also agreed to prepare a case study for use by this class, and arrangements for this have already been completed. A regular faculty member has responsibility for the design course, and works jointly with the industrial representative. **The university-industry collaboration has produced a highly successful design experience for the seniors, requiring them to integrate most of their previous course experience to produce the needed process design.**

Seniors also choose two technical electives in their final year. These are commonly chosen from three senior-level courses offered by the department or from a listing of courses in the Departments of Chemistry, Physics, Mathematics, or Computer Science, or in the other engineering deartments which includes Materials Science. The departmental courses, which are more popular than the others with the students, are process dynamics and automatic control (a one-semester course) and a two semester sequence in characterization and processing of polymers. Some universities offer more technical electives in their curricula, but it is believed that only two technical electives can be accomodated in a sound four-year bachelor's program which includes all the necessary technical fundamentals: a year of organic and of physical chemistry; single semester courses in mechanics, electrical engineering, and materials science beyond the basic mathematics, physics, and chemistry; and the necessary chemical engineering courses described above.

Students in their third and fourth years are urged to take junior and senior level cultural courses, (eight 3-credit courses are elected from history, philosophy, or literature) even although they do not have the necessary prerequisites. The advantage of being associated with more mature students in upper level course material more than counterbalances the disadvantages of not having the required prerequisite. To offset this disadvantage, engineers may take such cultural courses on a "pass or fail" basis.

In addition to the regular 4-year bachelor's degree in engineering, Delaware offers a 4-year degree in "Engineering Administration." The engineering administration degree is of course not accredited by ECPD; students entering the program are made aware that they will not be eligible for membership in AIChE and will not be admissable for graduate study in chemical engineering.

MANY SEMINARS ARE OFFERED, in addition to the regular graduate courses. These vary greatly in size and in the breadth of coverage. The main departmental seminar brings experts in a wide variety of fields to its weekly meetings—the speakers are mainly from industry or other universities (often from abroad). But three or four smaller seminars are also usually available—these are run by the permanent faculty on topics of limited scope, sometimes related to the research of the faculty member and his group of students, sometimes not. The department's visiting professor and distinguished scholar programs also bring additional educational advantages to the graduate program. Visiting professors are in residence for one or two semesters, usually in place of a permanent faculty member on sabbatical leave; distinguished scholars are brought to the campus for from 2 days to a week for a series of formal lectures and informal meetings with students.



Laser-Doppler flowmeter measures point velocities without disturbing the flow field.

Another important aspect of the graduate program is the research effort. The research of slightly more than one-half of the department's full-time graduate students is directly sponsored by contracts with NSF, NASA, the Department of Defense (through a Project THEMIS grant), the University of Delaware Research Foundation, and private industry. The other (smaller) half of the graduate student group has completely free choice of thesis topic because they are funded by NSF traineeships, NASA or NDEA fellowships, teaching assistantships, industrial fellowships, or from a special grant from the DuPont Company for promotion of research by new faculty.

It is probably apparent that a thesis is required of all graduate students. Terminal master's candidates perform a six-credit thesis; doctoral candidates may either get a master's degree first (with its required thesis) and then proceed with a related or completely different dissertation topic, or they may by-pass the master's degree and work directly on their doctoral requirements, including the dissertation. (In the latter case, permission to by-pass the master's degree is not given until after at least one semester of graduate study has been completed, but the student nevertheless picks a thesis topic—based upon his likely program—when he first arrives, as do all graduate students). The desirability of performing a master's thesis has been widely debated particularly in recent years, and many universities have dropped the master's thesis requirement. **But Delaware's chemical engineering faculty strongly and uniformly support the master's thesis as a necessary part of graduate training.**

Because of Delaware's location, there is a large demand for graduate course work in chemical engineering in the late afternoon and evening hours for those employed in the area. On the average, four or five such courses are offered each semester with enrollment in each course varying from 15 to 40. The courses in general are the same as those offered in the daytime to the resident graduate students, although the instructors are mostly industry persons with PhD degrees whose teaching abilities are well-known to the university.

RESEARCH AND TEACHING of chemical engineering at Delaware is made much more attractive than in former years because of the large, handsome new building which now houses the department. The structure, erected at a cost of 2.3 million dollars, contains 65,000 ft^2 of floor space. It was first occupied in May, 1968. The building was designed to serve future needs: it can accomodate a faculty of 22, a graduate student population of 120, and an undergraduate senior class of 70.

The building is divided into two parts, a classroom wing, and a laboratory and office wing. The classroom wing contains three 40-seat classrooms; two of these can be made into a single 80-seat room. In addition, there is a senior design room containing large area desk tops with file drawers underneath, and two smaller conference rooms for small seminars or laboratory computation groups. Beneath these classrooms, which are on the main floor, is the chemical engineering shop. The office and laboratory wing has 3 floors and a fully-utilized basement; the wing is 250 ft long by 50 ft wide. There are laboratories at each end of the building running across the entire width of the building. The laboratories on the upper three floors are mainly for research, although there is also a process dynamics laboratory, a photographic area, and a standards laboratory.

The basement floor contains the undergraduate teaching laboratories and the metallurgy laboratories. The basement of the building also contains a "Computation Laboratory" which contains a Wang electronsc desk calculator with four consoles; an IBM key punch; and several computer terminals.