CHEMICAL ENGINEERING PERSPECTIVES

Cornell's Fourth Decade of Chemical Engineering Education /2
Charles C. Winding, Director of the School of Chemical Engineering, discusses chemical engineering education, past and present, at Cornell: its origins in chemistry, the five-year professional degree program, changing areas of concentration, and curriculum development.

Research Directions in Chemical Engineering /12
Innovative research in chemical engineering is occurring at the interfaces of chemical engineering: chemistry, engineering, and biology. Professor Ferdinand Rodriguez of the School of Chemical Engineering explores the promising areas and determinants of research and the resultant orientation of today's chemical engineering faculty.

Vantage /25
Through the appointment of Mr. Donald B. Gordon as director of industrial liaison, the College of Engineering is accelerating its efforts to increase the interplay between industry and the classroom.

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Chemical engineers must be competent chemists and also competent engineers, besides having specialized training in the practical application of both kinds of knowledge to the design and construction of chemical manufacturing plants.” Such was the belief of the father of chemical engineering at Cornell, Professor Fred H. Rhodes (Ph.D., 1914), when the first chemical engineering students were graduated from Cornell in 1933.

Although many chemists were engaged in what today would be known as chemical engineering, they were almost exclusively confined to the chemical industry—in plant operations and design—and considered themselves industrial chemists. It was they who taught the industrial or applied chemistry courses offered in many of this country’s early chemistry departments. Chemical engineering education at Cornell, then, as elsewhere in the United States, had its origins in chemistry rather than in engineering.

Actually, the concept of “industrial chemistry” first arose at Cornell in 1870 when Chester Wing was appointed “professor of chemistry applied to manufactures.” The “course in chemistry” (“curriculum” in today’s terminology) offered by the University in that era was “designed to prepare not only teachers and analytical chemists but also technical chemists in manufactories and mines.”

It wasn’t until World War I, however, when United States chemical imports from Germany were cut off, that universities began to feel the impetus for strengthening their programs in industrial chemistry. Before this time, the manufacture of chemicals in the United States was regarded as an art based on the chemist’s laboratory preparation methods.

In 1910, Cornell’s College of Arts and Sciences introduced a four-year program in chemistry leading to the professional Bachelor of Chemistry degree. Professor Rhodes gave courses in industrial chemistry within the University’s Department of Chemistry from 1920 to 1932; he also developed a basic unit operations laboratory in the basement of the Baker Laboratory of Chemistry.
THE FIVE-YEAR PLAN

The growth of the United States chemical industry in the 1920s enhanced the value of education in applied chemistry. In response, Cornell in 1931 approved a plan whereby graduates with its Bachelor of Chemistry degree could undertake a fifth year of study in engineering, receiving the degree of Chemical Engineer. This initial pattern, devised by Professor Rhodes, was dictated partly by the exigencies of the times. Little money was available to establish an independent faculty group in chemical engineering or to house a new school within the College of Engineering.

Three students received their degrees in this four-plus-one chemical engineering program in 1933, and this curricular pattern was continued until 1938 when the School of Chemical Engineering was established within the College of Engineering. Freshmen were then admitted directly to the School, whose five-year program led to a Bachelor of Chemical Engineering degree. Since the principle of a five-year program was well established by this time, there was little difficulty in selling the merits of
the new program. Applications came in at a high rate, and large freshman classes were admitted to the newly established School from 1939 to 1941.

Up until the 1960s the School of Chemical Engineering’s freshman enrollment varied between 100 and 160 students, with the number of graduates ranging between 25 and 55 each year. Then there was a development affecting all engineering programs at Cornell: all entering engineering freshmen were admitted to a Division of Basic Engineering Studies. They could not elect an engineering field as a specialty until the beginning of their sophomore year. (Before this, a candidate was admitted to one of the four established engineering schools—Chemical, Civil, Electrical, or Mechanical—or the Department of Engineering Physics.) It is difficult to determine how chemical engineering enrollments were affected by this shift; too many other factors were operative to isolate the effect of any one. The number of students entering their junior year in the chemical engineering program nevertheless reached a peak of sixty-two in 1961 and thereafter fell slowly to stabilize between forty and fifty a year, where it has remained for the past several years.

**IMpact of Graduate Education**

During the late 1950s and early 1960s the increased interest of undergraduates in graduate study affected the traditionally practice-oriented five-year Bachelor’s degree program. While many graduate-level courses in chemical engineering were included in the fifth year, Cornell graduates who sought advanced degrees at other universities rarely received any graduate credit for them. To alleviate this situation and to enable some of the best undergraduates to obtain their doctorates in a shorter period of time, the School of Chemical Engineering introduced a predoctoral honors program in 1961. Through it, promising fourth-year students were permitted to enroll in Cornell’s Graduate School during their fifth year. Such candidates received the usual B.Ch.E. degree at the end of their fifth year, but at the same time they were credited with a year of graduate residence. The num-
"Major contributions by chemical engineers will likely be in catalysis, reaction kinetics, separation processes, and applied chemistry."

ber admitted to this program each year ranged from four to ten.

THE NEW STRUCTURE: B.S. AND M.ENG.

Then, in 1964, the College of Engineering introduced a new professional engineering degree structure: a four-year undergraduate program led to an undesignated Bachelor of Science degree, which could be followed by a fifth year of graduate study leading to a Master of Engineering degree, designated by field. Since its inception, the Master of Engineering program in chemical engineering has been directed exclusively to those students who are interested in the practice of their profession. Study during the junior, senior, and fifth years is integrated as a unit. Thus, students interested in research and teaching can begin work toward the Ph.D. at the end of their fourth year while those interested in practice can continue in the Master of Engineering program. Students interested in business, law, medicine, or other professional fields can leave chemical engineering at this point.
Since 1932, all three degree patterns in chemical engineering have required five years for a professional chemical engineering degree. The aim of the faculty, beginning with Professor Rhodes, has been to provide students with an education that will enable them to handle complex problems in development, design, production, and management in the process industries. Because of this strong practice-oriented tradition, many Cornell graduates have played important roles in the development and growth of the chemically based process industries.

As the operations of these industries have become progressively more complex, a greater emphasis has been placed on basic fundamentals in chemical engineering curricula. Through a revision of basic courses, the modernization of laboratories and experimental projects, and a thorough exposure of students to design, economics, and optimization, we are making a major effort to enrich our programs.

AREAS OF CONCENTRATION

We expect that advances in selected aspects of applied physics (e.g., transport phenomena) will be of continuing interest to all engineers and are therefore continuing to concentrate on flow stability and mass transfer studies. Major contributions by chemical engineers will likely be in catalysis, reaction kinetics, separation processes, and applied chemistry. Each of these areas is being continually strengthened through the School's research programs, instructional courses, and projects.

It is our belief that advances in catalysis and improved reaction systems will have a greater effect on the future of the chemical process industries than will any other technical developments. Plans are underway to increase our research efforts in these fields.

In the School, interest in separation processes centers around desalination, crystallization, and the little-known separation techniques applicable to biochemicals, all fields with promising futures. And work at Cornell in applied chemistry continues to develop around relatively long-standing interests in biochemical engineering and polymeric materials.

GENERAL EDUCATIONAL OBJECTIVES

To prepare students for careers in chemical engineering, whether in research or in practice, the faculty of the School of Chemical Engineering has affirmed two major objectives:

The preparation of highly talented students for leadership in the practice of the chemical engineering profession through a design-oriented professional program

The expansion of coherent, vital research efforts for the continuing enrichment of the chemical engineering program

The first of these objectives is, of course, the concern of the Master of Engineering degree program. If professional degree programs are to be an important element in chemical engineering education in the future, consideration should be given to their upgrading to meet the demands of advanced industrial design. Generally, Ph.D. programs do not adequately meet these, nor should they. In short, to provide parallel research- and design-
oriented programs in chemical engineering seems the most desirable and feasible of future objectives of the School of Chemical Engineering at Cornell.

Research in chemical engineering need not oppose the objectives of the professional program. The predoctoral honors program offers an attractive opportunity for Cornell students who wish to prepare for teaching and research.

CHANGING CURRICULA

Table 1 and Figure 1, presenting chemical engineering curricula in 1946, 1956, and 1968 (all five-year programs), show the changes and trends in the School's curriculum content. The most obvious trend has been the significant reduction over this twenty-two year period in the time devoted to chemistry; most of this reduction has come in laboratory work rather than in course content. Drawing and mechanical engineering courses, as such, have disappeared from the curriculum. A significant increase in the number of elective hours is evident, as is a modest increase in chemical engineering courses.
Overall, the number of credit hours required for graduation has dropped from 190 to 174.

As for the chemical engineering courses themselves, work in unit operations has given way to work in equilibria, staged operations, rate processes, and thermodynamics. New requirements have been added in reaction kinetics and in process control, and the time devoted to design has been substantially increased.

ALUMNI EDUCATION AND EMPLOYMENT

About 37 percent of those who were graduated from the Cornell chemical engineering program during the 1950s and early 1960s continued their education in graduate schools. A survey just completed, covering the period 1942 to 1965, revealed that 38 percent of all graduates of five-year programs obtained an advanced degree; the distribution is as follows:

<table>
<thead>
<tr>
<th>Degree</th>
<th>Field</th>
<th>Percent</th>
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</thead>
<tbody>
<tr>
<td>Master's</td>
<td>Chemical Engineering</td>
<td>20</td>
</tr>
<tr>
<td>Master's</td>
<td>Science</td>
<td>6</td>
</tr>
<tr>
<td>Master's</td>
<td>Business</td>
<td>27</td>
</tr>
<tr>
<td>Master's</td>
<td>Other</td>
<td>4</td>
</tr>
<tr>
<td>Ph.D.</td>
<td>Chemical Engineering</td>
<td>24</td>
</tr>
<tr>
<td>Ph.D.</td>
<td>Chemistry</td>
<td>5</td>
</tr>
<tr>
<td>Ph.D.</td>
<td>Other Science</td>
<td>2</td>
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<tr>
<td></td>
<td>Law</td>
<td>8</td>
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<td>Medicine</td>
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A review of the four-year Bachelor of Science degree program for 1965 to 1967 showed that 85 percent of the graduates continued in advanced degree programs; over one-half entered the Master of Engineering program, and approximately one-fourth entered M.S. or Ph.D. programs.

CORNELL CHEMICAL ENGINEERING HIGHLIGHTS

1910 A four-year professional degree program in chemistry (Bachelor of Chemistry) is offered by the Department of Chemistry in the College of Arts and Sciences.

1920 Professor F. H. Rhodes begins his long association with chemical engineering education at Cornell by teaching industrial chemistry courses in the Department of Chemistry.

1931 A fifth year of study, leading to the degree, Chemical Engineer, is offered to graduates of the Bachelor of Chemistry program.

1938 The School of Chemical Engineering is established within the College of Engineering with Professor F. H. Rhodes as its director. A five-year degree program, under the jurisdiction of the School, now leads to the degree, Bachelor of Chemical Engineering. Freshmen are admitted directly to the School of Chemical Engineering.

1957 Director F. H. Rhodes retires; Professor C. C. Winding is named director of the School.

1961 All Cornell engineering freshmen are admitted to a common underclass division, Basic Engineering Studies.

The School of Chemical Engineering introduces a pre-doctoral honors program wherein top fourth year students are enrolled in the University Graduate School during their fifth year.

1964 The College of Engineering introduces a new undergraduate-graduate degree structure. All candidates receive a Bachelor of Science degree at the end of four years, then may apply for either a one-year professional degree program, the Master of Engineering (Chemical), or a M.S. or Ph.D. degree through a research-oriented program.
As might be expected, the new Selective Service System regulations regarding graduate students caused a decrease in the percentage of graduates with the B.S. entering the Master of Engineering program in the fall of 1968. The figure was reduced from 85 percent going on to further education to 65 percent, with half of these entering the Master of Engineering program. Estimates for 1969 indicate that similar figures will obtain unless changes in the Selective Service regulations occur before the June commencement.

A comparison of figures for practicing Cornell chemical engineering alumni with figures for professional chemical engineers throughout the nation shows a much higher percentage of Cornell graduates serving in administrative and staff, sales and sales service, and plant operations positions than the national average (see Table 2). All of the Cornell data are based on the kind of work performed rather than on the department in which one works; that is, engineers concerned with economic analysis in a research department, for example, are classified as staff and not
as research engineers.

Over the years Cornell has educated more than 1,200 chemical engineers. While the five-year professional program grew out of a unique situation in the early 1930s, Cornell alumni as a group have experienced remarkable success in both industry and education, their average salary being well above the national average (approximately the upper decile of published salaries for chemical engineers in the chemical and petroleum industries).

The new pattern of an undesignated Bachelor’s degree followed by two distinct graduate paths—one professional and the other research-oriented—provides broad opportunities for the School of Chemical Engineering to emphasize professional engineering in its broadest sense.

Charles C. Winding, Herbert Fisk Johnson Professor of Industrial Chemistry and director of the School of Chemical Engineering since 1957, joined the Cornell faculty in 1935. He has played a major role in the education of all but a handful of the 1,200 Cornell chemical engineering graduates and in the development of the School.

Professor Winding's special interest has been in polymers, an area in which he has coauthored two texts, Plastics: Theory and Practice with R. Leonard Hasche in 1947 and Polymeric Materials with Gordon D. Hiatt in 1961. Both were published by McGraw-Hill Book Company. He has been a member of the education committee of the Society of Plastics Engineers since 1951, serving as its chairman from 1960 to 1963.

A native of Minnesota, Professor Winding earned the Bachelor of Chemical Engineering and the Ph.D. degrees in 1931 and 1935, respectively, from the University of Minnesota. He has been a consultant to the Tide Water Associated Oil Company, the Rubber Reserve Company, Rome Cable Corporation, B. F. Goodrich Company, and the Cowles Chemical Company, where he was a member of the board of directors for nine years.

His memberships include Tau Beta Pi, Sigma Xi, Phi Lambda Upsilon, the American Chemical Society, the American Institute of Chemical Engineers, and the American Society for Engineering Education. He is also a fellow of the American Institute of Chemists.
Opportunities for innovative research are often best seen at the interfaces of a given field where new tools, new attitudes, and new problems are most evident. Chemical engineering research today has three important interfaces: engineering, chemistry, and biology.

It should not be inferred from the use of the word interface that the work of the chemical engineer is immiscible with that of practitioners of other disciplines, for chemical engineers have always worked in the adjacent areas of chemistry and engineering. Over the past half-dozen years, the number of chemists who have been added to chemical engineering faculties bears witness to a counter-movement too. Perhaps Professor Giulio Natta of Milan best stated the special training and attitude of the chemical engineer when, upon receiving the Nobel Prize in Chemistry in 1963, he said, "I had the good fortune to become a chemical engineer. In this way I combined the dedication of a pure chemist with the practical logic of an engineer."

All of the physics-oriented branches of the engineering profession (e.g., mechanical, civil, and electrical) may be included in the engineering interface. During the 1950s, chemical engineering departments increased their emphasis on the physical-mathematical aspects of transport phenomena, an emphasis which encouraged the merging of chemical engineering research with the broader area of general engineering studies. More recently, research efforts have accelerated in the more chemistry-oriented areas. However, this development complements, rather than displaces, the engineering aspects of chemical engineering.

Looking to the future, it seems likely that government sponsorship and student concern for social relevance will encourage increased activity in the chemical engineering–biology interface as well.

THE CHEMISTRY INTERFACE

To create a desired product from available reactants, rapidly and in pure form, has been the dream of chemical engineers. Because of this, the kinetics of chemical reactions has provided one
major area for chemical engineering research for many years. Only within the past decade have significant advances been made in the study of catalysis. It seems now, however, that prospects are good for an era of catalyst design.

Although inorganic chemists have learned much about the structure and reactions of metals and oxides, today the simple reactions of oxidation, hydrogenation, and isomerization on the noble metals have been correlated only in generalized form. But as the chemistry of the inorganic species is unraveled, more effort will be spent by chemical engineers on industrial catalyst design; for even when reaction thermodynamics would normally yield undesirable products, an “engineered” catalyst could establish equilibrium for desired products much more rapidly than for undesired ones. For example, there is currently no efficient catalyst that will induce a rapid production of ammonia at room temperature. If one could be designed it might be as valuable as the philosopher’s stone.

*Polymer* chemistry is one area in which chemists have acquired a substantial amount of basic knowledge. Because a major fraction of the chemical industry is concerned with polymers (plastics, fibers, castings, rubber, and adhesives), it has become natural for chemical engineers to undertake research in both the synthesis and application of these materials.

The general study of polymers spills into the adjacent areas of kinetics, biology, and fluid mechanics. Polymerization, the formation of polymers from small molecules, was revolutionized by the discoveries of Ziegler and Natta in the 1950s. For the first time, ordered, stereospecific structures were made, not by recourse to enzymes or optically active catalysts, but through the use of complex precipitates of aluminum alkyls and transition metal halides. One dramatic consequence of this work was the production of stereoregular polyisoprenes identical to the naturally occurring materials, rubber and gutta percha. While the goal of tailor-made materials is still some distance from being attained, the prospects for success grow stronger daily.

The study of fundamental polymer properties that affect fabrication processes and product performance has largely fallen within the province of the chemical engineer. Although a description of the flow and deformation of polymers becomes part of that branch of mechanics termed *rheology*, the underlying chemical-structural relationship of properties of molecular architecture demands a sound background in physical-organic chemistry which is not normally a part of the educational background of researchers in theoretical and applied mechanics.

Some aspects of polymer engineering are truly in their infancy. Despite the fact that most polymers are studied as *pure* entities, almost all polymers are used as parts of systems with complex interactions. An example is the ordinary automobile tire in which a partly bound, dispersed phase, carbon black, is essential to the performance of the cross-linked, plasticized polymer, which, in turn, must be bound to the fabric of the tire cord as well as to the metal beading. The ability to predict the glass transition temperature of the *pure* polymer, in
itself a proud accomplishment of polymer science, is woefully inadequate for the prediction of the usefulness of the finished "mixed" product.

Other polymer systems which are not completely understood, but of great importance, are those where a water-soluble polymer forms a complex with another molecular species. As a simple case one can take the complex of iodine with poly(vinyl pyrrolidone), wherein the antiseptic behavior of the iodine is preserved but the oral toxicity is markedly reduced. The physiological applications of such complexes to the problems of drug-release, detoxification, and chemical therapy in general are obvious.

CORNELL POLYMER RESEARCH

At Cornell, we have worked on a particular problem of a chemical-physical-biological nature which illustrates the usefulness of the chemical engineering approach. This is the problem of growing crystals (usually inorganic) in a gelatinous, aqueous matrix. The growth of inorganic crystals in aqueous gels is analogous to the chemical-biological mechanism for the formation of bones, teeth, and animal and plant shells and also for the precipitation of minerals in some rocks. Often, a composite structure with unusually high strength-to-weight ratios results. It is conceivable that a thorough understanding of the crystal growth process under these circumstances could lead to the development of materials for prosthetic applications, such as compatible bone replacements and tooth fillings.

Teeth and bones grow by crystallization in gels resembling the gelatin desserts that are familiar to us. What gives structure and form to these gels are strands of the protein collagen and similar polymers. A gel's rigidity is known to be a complex function of pH, temperature, salt or sugar concentration, and time. A covalently cross-linked, non-ionic polymer network is much less likely to be influenced by these variables. Since these factors should be studied separately for their effect on crystal growth, this class of polymer allows us to determine how...
each variable affects (a) crystal growth and (b) gel structure.

In recent work, partially supported by the National Science Foundation, Professor Cocks and I, together with a group of graduate students, have been studying gels based on poly(ethylene oxide). This polymer, with the repeating unit (—CH₂CH₂O—) is commercially available in high molecular weight form. Early in our work, we found that when a dilute aqueous solution of this polymer is exposed to gamma radiation, a strong gel is formed which is quite rugged. For example, it can be frozen and thawed or dried out and reconstituted with little change in the appearance of the gel.

Through an experimental procedure (see Figure 1) we have been able to analyze the effect of this gamma radiation on the gelling process. We have found that when a dilute aqueous solution of this polymer is exposed to gamma radiation, a strong gel is formed which is quite rugged. For example, it can be frozen and thawed or dried out and reconstituted with little change in the appearance of the gel.

Through an experimental procedure (see Figure 1) we have been able to analyze the effect of this gamma radiation on the gelling process. We have found that crosslinks are produced in the polymer (—CH₂CH₂O—) in direct proportion to radiation dosage up to a certain plateau which is a function of concentration and molecular weight. From studies by other workers we know that each crosslink is formed by a free-radical attack on the main polymer chain, with the loss of hydrogen.

By using electron microscopy techniques, we were able to study the gel structure as a function of gamma radiation. The first crosslinks of the polymer in the gel serve to localize the Brownian segmental motion of the polymer chains. Each successive crosslink increases the probability that the next crosslink will occur between polymer chains in a smaller volume. At the plateau modulus, further crosslinking takes place within the walls. Pictures taken of gels made with doses much lower than the plateau dose do not show a well-defined cellular structure.

The implications of this gel structure for crystal growth center on the rather open, apparently connected cells which allow for much freer diffusion and nucleation than is imaginable in the more evenly dispersed picture. Using time-lapse photography, actual microphotographic studies of crystals growing in these gels reveal large-scale movements of the small crystals. While we cannot correlate or predict such movements, we can begin to develop some

Figure 1: Pictured here is the torsion pendulum used to judge the effectiveness of radiation in producing crosslinks. An oscillating arm is held in proper alignment by an air-lubricated bearing. In a cone-plate geometry the gel acts alternately to store energy and to convert it to kinetic energy. The amplitude of successive oscillations is transformed to an electrical signal and recorded on an oscillograph by a Proximeter, which does not come in contact with the moving part of the apparatus. From the geometry of the sample, the moment of inertia of the moving system, and the frequency of oscillations, it is possible to calculate a dynamic modulus, $G'$, which is equal to the number of network chains per unit volume, $N$, times the factor $RT$, where $R$ is the gas constant and $T$ the absolute temperature. (Diagram courtesy of Journal of Applied Polymer Science, 12: 2417, 1968.)

1. When water contains about 20 percent sucrose, no large crystals are formed. Here a polymer gel in sucrose solution has been freeze-etched. The polymer is segregated into membrane-like structures which form the walls of cells.

2. Using the technique of freeze-etching, followed by replication and shadowing, we can see the microstructure of a brittle poly (ethylene oxide) gel (left). Ice crystals with no polymer are visible since impurities segregate at the crystal boundaries (right). The gel was made from a solution containing 1 percent of a polymer of $2.5 \times 10^5$ molecular weight.
underlying reasons for the phenomenon and in turn derive a better understanding of the crystallization process in gels.

THE ENGINEERING INTERFACE

The development of computer techniques and applied mathematics and their application to chemical engineering systems have profoundly affected the directions of chemical engineering research. Process control and optimization represent two of the areas of general interest. In fact, a comparison of theses listed in Chemical Engineering Progress in 1957 and 1967 shows that none were written in the control and optimization fields in 1957 while in 1967 there were thirty-eight (over 10 percent of the total chemical engineering theses listed).

It seems that the ultimate goal of research in control and optimization for the chemical engineer is not merely fully automated plants but also the automated design of plants. And closed-loop computer control of a production facility, although not yet implemented on a large scale, seems certain to become so in the future as labor and production costs and the availability and reliability of computers increase.

Indeed, the application of mathematical methods of optimization to the design of production facilities, as distinguished from the mere selection or testing of available modules, would represent a giant step beyond present production control. But neither the computers nor the mathematical tools of the 1960s have proved robust enough to tackle the design of an integrated process on more than a superficial basis.

Another area which has been advanced by the application of mathematical methods is stability analysis. We can take as an example the prediction of drop sizes made by injecting one fluid into a second. Essentially, the problem is one of predicting the stability of a jet in viscous flow (see Figure 2). Under the direction of Professor G. F. Scheele, a general solution to this problem has been obtained which covers many variations in fluid viscosity. It has been found, in fact, that many previous analyses were but special cases of the general relationship established. Industrial processes where jet stability is important include spray drying, aeration, and all mass transfer operations where perforated plates are used. Other kinds of stability, such as laminar-turbulent transitions in pipe flow in situations with heat transfer, chemical reaction, or viscoelastic fluids, present further opportunities for study.

Membrane diffusion processes provide a fourth area of interest to chemical engineers for two reasons: they apply to desalination and to biomedical problems. In the first place, desalination (especially of brackish waters in which salt content is lower than in sea water) can be carried out by selective flow of water through a membrane under pressure with concurrent salt rejection. This process is called reverse osmosis since the pressure which causes flow from the salt solution side to the pure water side of the membrane must exceed the osmotic pressure before any flow can occur. When brackish water is subjected to pressures of about 300 psi, water can be forced through a cellulose acetate membrane at rates up to 40 gal per ft²·day, with removal of 95
Figure 2: This high-speed movie sequence shows breakup of a liquid heptane jet into drops when injected into water through a 1/8-inch diameter nozzle. The injection velocity is 25 centimeters per second. The time interval between photographs is .0029 second.

Lower right: The simulation of a hydraulically propelled moving bed used for washing ice crystals is conducted during this student’s research in the general area of desalination.

percent of the ionic impurities.

It is of interest that cellulose acetate remains unique among membrane materials in its combination of water flow and salt rejection. Although newer methods of fabrication have made stronger, more reliable membranes, the entire picture could be drastically changed by a new material with two or three times the flow rate of cellulose acetate and the same salt rejection capability.

Whether or not this or any other desalination process can ever operate economically enough to permit irrigation of arid regions remains doubtful. Reverse osmosis is by no means the only important method of desalination. In fact, the direct-contact freezing process pioneered by Cornell’s Professor H. F. Wiegandt is a much more attractive process for the desalination of seawater.

The further development of membranes and membrane processes, however, scarcely seems to have reached the limits even of today’s technology.

In the second place, biomedical engineering has a direct stake in the development of membranes for the artificial kidney. Beyond this work lies the possibility of complementing or replacing other body processes, such as blood oxygenation.

Although the desalination and biomedical areas are not the only ones of interest to chemical engineers, they are the popular areas for university research efforts because government money is directly available for the work. Moreover, there is a strong moral motivation for research on projects which have such direct human benefit.

THE BIOLOGY INTERFACE

The availability of government sponsorship and the criterion of humane objectives are channeling increasing amounts of chemical engineering research efforts into the general area of the life sciences. In the biomedical field, research in membranes for artificial organs has already been noted at the engineering interface. In addition to the artificial organ work, a host of synthetic problems involving implants, transplants, and prosthesis provide opportunities for research by the chemical
engineer. With his background in chemistry he is better suited than other engineers to work on these and related projects. One can see that if such research areas continue to grow, biology might well be introduced into the undergraduate chemical engineering curriculum.

The area of *biochemical engineering* embraces the study of those chemical processes carried out by living organisms. Continuous fermentation is an example. It has been demonstrated for some products in the food and pharmaceutical industries. At present, most large-scale production of antibiotics, yeasts, beer, and wine is still carried out in batchwise fashion.

Research into continuous operations has always been a favorite subject for chemical engineers. Dealing with living systems presents many complications not encountered in simpler organic reactions. Instead of catalyst poisoning, with consequent decrease in productivity, a living system may show genetic mutations in long, continuous operation which have a more subtle effect on product quality.
The development of computer techniques and applied mathematics and their application to chemical engineering systems have profoundly affected the directions of chemical engineering research.

Among the many possibilities for contributions by chemical engineers, protein production from low-grade hydrocarbon sources offers a balanced humanitarian and technological objective. One can scarcely imagine a more urgent worldwide need than that for food. In addition to the millions who subsist today on inadequate diets there are those millions yet unborn who will double the world's population in less than half a century. Although many of the problems of food distribution are social and political, the scientific and economic production of food by industrial fermentation is amenable to study by chemical engineers.

The production of microbial protein from waste chemicals such as acids and alcohols, for instance, might alleviate two pressing socioeconomic problems, food production and waste disposal. Studies on particular waste chemicals and basic work on some of the engineering problems are under way.

In illustration, a recurrent bottleneck in industrial biosynthesis is the harvesting of solid products from large quantities of liquid. Flocculation is one way

At Cornell, work in biochemical engineering centers on growth kinetics and product formation, process design optimization, the shearing effects of agitation, oxygen transfer, and microbial oxidations. Several projects involve the production of proteins from chemical waste streams.
of concentrating the desirable part of the system. At Cornell, flocculation of microorganisms is being studied by means of an optical system under the direction of Professor R. K. Finn. It has been found that the average amplitude of the light signal transmitted through a suspension of microorganisms is a direct measure of flocculation. Amplitude-time records give insight into the efficiency and the mechanism of flocculant action (see Figure 3).

RESEARCH DETERMINANTS

The social groups which affect the direction of chemical engineering research in universities today are industry, government, and university administrations. The criteria applied to research are money, prestige, and morality. Having thus grossly oversimplified the "system" in typical engineering fashion, we must admit some realistic limitations. After all, the professor himself must be contended with. In the tradition of academic freedom, the professor who has attained tenure often has some option, even if that option only means refusing to do research that he deems without merit. As a linear approximation, we might postulate that the rate at which research is done on any given subject, \( dR/d\theta \), will be a function of the rate at which money is supplied, \( \partial L/\partial \theta \), the prestige afforded the researcher, \( P \), and the humanitarian value of the work, \( H \). Then,

\[
dR/d\theta = a\Sigma (\partial L/\partial \theta)_i + b\Sigma P_i + c\Sigma H_i
\]

1 and 2: The equipment of the microscopy laboratory includes a variety of light microscopes, metallographs, a research model (JCM-7A) electron microscope (1), regular and ultra-microtomes, equipment for time-lapse cinemicrography, grinding and polishing equipment for metals, ceramics, or polymeric materials, and a vacuum evaporator (2).

3. A pulsed argon ion laser and related equipment for experimental work on microscopical or macroscopical holographic imaging and interferometry are also in use in the microscopy laboratory.

Figure 3: Each of these recorder tracings was made four minutes after a polyamine flocculant was added to a suspension of Pseudomonas fluorescens. Each amplitude-time diagram covers a period of three seconds. Initially, each resembled the zero-dose diagram. The signal from the photocell is in the microamp range.
and recently a trade journal issued a caveat against "enticing" students into chemical engineering via humanitarian motivation. Both of these instances demonstrate the insensitivity of some sectors of industry to the environmental-social responsibilities they must assume.

Although one can argue that campus activists are often misguided and anarchistic and that few engineers are comfortable in their company, one must admit they do serve to make all of us reexamine our motives. In short, then, in his research more than in his teaching, the professor has direct, personal control of a significant activity. It is left to him to determine the motive for his research.

THE TRADITION

Traditionally, the chemical engineer has been associated with the chemical process industries. In fact, the profession evolved from the fusion of the industrial chemist with the mechanical engineer in response to the needs of the chemical and oil industries. Hybrids are not always successful, and fanciful
Work at Cornell in process dynamics and control has been concentrated in the study of exothermic chemical reactions and distillation of materials to high purity. The objectives have been to develop more accurate theories or models, to verify these by experiment, and to present simplified transfer functions suitable for control system design.
TABLE 1
Chemical Engineering Education
(ASEE Reports)

<table>
<thead>
<tr>
<th></th>
<th>B.S. degrees granted (three-year total)</th>
<th>Ph.D. degrees granted (three-year total)</th>
<th>Professorial-Rank Faculty (average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1956-1959</td>
<td>12,703</td>
<td>618</td>
<td>697</td>
</tr>
<tr>
<td>1960-1963</td>
<td>12,191</td>
<td>919</td>
<td>890</td>
</tr>
<tr>
<td>1964-1967</td>
<td>12,900</td>
<td>1,449</td>
<td>1,200</td>
</tr>
</tbody>
</table>

stories of unsuccessful hybrids abound. There was a man who wanted to produce a novel game fish, the "abadile," by crossing an abalone with a crocodile. Instead of producing an abadile, he produced a "crocobalone."

The chemist-engineer has been a successful hybrid because the chemical process industries needed precisely his combination of talents. Few chemical engineers stray from these industries. Other hybrids, the biochemist-lawyer, the chemist-economist, the physician-engineer, the psychologist-engineer, and the physicist-engineer, all have useful roles to perform, but none of these has proved essential to a large commercial enterprise which, in turn, provides opportunities for as many chemical engineers as elect to enter it.

THE TEACHING-RESEARCH INTERFACE

Chemical engineering research is a reliable index of the trends which will occur in undergraduate chemical engineering education over the next two decades. Curricula, after all, are devised by faculties, and chemical engineering professors are increasingly involved in research. (See Table 1 for trend.)

Not only are new faculty in chemical engineering hired with the assumption that they will conduct research, but the research they undertake is often an extension of their own recent graduate interests. Relatively few new professors today fit the older picture of the engineering educator who was an experienced practitioner of industrial design and administration. The merits of this development are open to question, but its reality is not. It is to be expected that the curricula favored by these new men will be biased to produce raw material for their research interests. As an extreme case one can imagine a faculty in which many professors involved in biological problems get together and decide that the traditional undergraduate course in engineering thermodynamics should be replaced by a course in biology.

Current research is a mirror, then, in which we can see, however dimly, the future of the profession. It is a future filled with new opportunities for the
Ferdinand Rodriguez is an associate professor of chemical engineering at Cornell. He joined the faculty in 1958 after receiving his Doctor of Philosophy degree from the University; he earned the Bachelor of Science and Master of Science degrees in 1950 and 1954, respectively, from the Case Institute of Technology.

In 1966, the Cornell Society of Engineers awarded Professor Rodriguez its annual $1,000 Excellence in Teaching award. In addition to his undergraduate and graduate teaching and research responsibilities, Professor Rodriguez has taught courses in polymeric materials in the College of Engineering's continuing education program for practicing engineers.

During the past five years, Professor Rodriguez has published over twenty technical papers based on his research activities and has completed the manuscript of a textbook, Principles of Polymer Systems, which will be published by McGraw-Hill Book Company.

His industrial experience includes four years as a development engineer and director of new product development for the Ferro Chemical Corporation in Bedford, Ohio, from 1950 to 1954. During the academic year 1964-65 he was a research engineer with the Silicone Division of Union Carbide Corporation, for which he is currently a consultant.

Professor Rodriguez is a member of Sigma Xi, Tau Beta Pi, Alpha Chi Sigma, Phi Kappa Phi, the American Chemical Society, the American Institute of Chemical Engineers, the Society of Plastics Engineers, and the Society of Rheology.

Above and opposite: The study of surface effects in vapor phase oxidation of butane is one of the subjects for kinetics research at Cornell. The yield of desired product and the rates of consecutive or parallel reactions have been major concerns in recent studies of partial oxidation and alkylation in the liquid phase. A laboratory for instruction in kinetics has been established through a grant from the National Science Foundation.
UNIVERSITY AND INDUSTRY INTERACT

For many years the College of Engineering at Cornell University has sought closer relations with industry to insure that its educational and research activities have some relevance to current and foreseeable industrial needs. Several programs have been specially developed to foster such relations.

In 1965 Congress passed the State Technical Services Act, enabling small business, commerce, and industry to benefit directly from recent advances in science and technology that have been made through federally sponsored programs. The Act grew out of a particular concern for small businesses, which frequently cannot support any significant amount of research and/or development activity.

The New York State Department of Commerce, administrator of the program, divided New York into seven areas, each assigned to a major institution for technical education. The Cornell College of Engineering began its participation in the program in 1966 when it became responsible for aiding small business in the Southern Tier region, including Allegany, Broome, Chemung, Chenango, Delaware, Otsego, Schuyler, Seneca, Steuben, Sullivan, Tioga, and Tompkins counties. For the small businesses in this region the Cornell State Technical Services Program (STSP) Office provides technical information, special instructional programs, and technical referral services.

To disseminate news of technological innovation, the College publishes the Southern Tier Technical Information Newsletter. A constant survey of the businesses in the Southern Tier region to discover their particular needs for technical information keeps the selected abstracts published in the Newsletter timely and pertinent. Further, in response to direct requests for specific information, the STSP Office conducts literature searches, prepares reading lists, and provides references to pertinent articles, publications, and technical films.

Special programs including short courses, workshops, and seminars are offered on the Cornell campus or at regional industrial centers. These programs may be on topics of general interest or may be prepared to meet the needs of a specific group of industries.

When presented with a specific industrial problem, the STSP referral service either provides direct assistance in solving the problem or, if the problem is of sufficient complexity, refers the com-

Donald B. Gordon, director of industrial liaison and coordinator of the State Technical Services Program, Southern Tier.
pany to competent consultants. The College of Engineering itself does not provide consultant services.

CLOSER TIES

The State Technical Services Program, then, is one means by which the College of Engineering establishes and maintains contact with local industries. Another group of industries plays a key role in the educational development of about 120 upperclass engineering students by participating in the Engineering Cooperative Program. This program enables student participants to spend alternate terms in school and in industry where they get a clearer insight into professional practices and see engineering "as it really is." (For more on this program, see Engineering: Cornell Quarterly, Vol. 2, No. 3, 1967.) These cooperative arrangements are monitored by the College of Engineering to ensure significant participation by the student in appropriate kinds and levels of engineering tasks.

More and more companies are now participating even more directly in College activities through the Design Projects Program. In this Program, interdisciplinary groups of seniors and graduate engineering students are given the opportunity to learn from industry about some representative technical problems and to try their skills in shaping solutions. The companies provide real technical problems and, often, funds and equipment. The students devise solutions and, sometimes, the required hardware. At the end of the term, they present their project results (for which they receive academic credit) to both faculty members and company representatives for critical appraisal. (See Engineering: Cornell Quarterly, Vol. 2, No. 2, 1967.)

Many engineering faculty members begin their university teaching careers with little or no industrial experience. It is imperative, therefore, that early in their careers they be given opportunities for direct contact with industry. This may be done through sabbatical leaves spent working in industry or through consulting work. This enrichment enables them to better prepare students for roles in the engineering profession, and should assist them in
directing their own research to make it more relevant to the needs of industry and society as a whole.

THE CORNELL INDUSTRIAL ASSOCIATES

Both industry and the university have a vested interest in the development of well-trained engineering graduates with sufficient motivation, depth of knowledge, and flexibility to keep abreast of their rapidly changing profession. The College of Engineering can better educate such students when it joins forces with industry to keep up with technological advances and the changing demands being made on the profession by industry and society.

To broaden the base of rapport with industry, the College of Engineering recently established the Office of Industrial Liaison. Through an associates program currently being organized by this Office, the College of Engineering seeks greater contact with certain industries with whom an association might be mutually profitable. These industries can provide their experienced talent and funds (whether undesignated or designated) for engineering education and research; the College in return can offer industry early access to College research findings, assistance in recruiting, and participation in seminars on campus or at individual companies. In addition, a limited number of interested company personnel may participate, tuition-free, in the College’s scheduled Continuing Education courses. Company personnel may also arrange for consultation with faculty members whose expertise can benefit their companies or arrange to use College facilities, when available, for meetings, conferences, or other company functions.

Industrial support might take the form of equipping a laboratory in the specific area of an industry’s strength or interest, establishing a permanent scholarship, providing fellowship funds, or lending a top engineer, on a short-term basis, to the College as a visiting professor.

Because no faculty can be expert in all technological fields, membership in the Cornell Industrial Associates will be restricted to those companies for whom current faculty proficiency can provide significant benefit.

1. A number of Master of Engineering degree candidates participate in design projects that are furnished and appraised by industry. Two students of mechanical engineering are shown here preparing the report they will present before their industrial sponsor.

2. In civil engineering, Master of Engineering candidates worked in teams of four to locate and design a fourth jet port for the metropolitan New York City area. Airline, local government, and transportation agency officials came to review the preliminary report. Critics and students are examining the proposed site on a map of the metropolitan area spread out on the floor of the Hollister Hall Lounge.

3. Reviewers from the Continental Can Company, Incorporated, discuss a mechanical engineering design project concerned with a “value analysis of a leak testing apparatus.”
Henry P. Goode, professor of industrial engineering and operations research, lectures to a group of IBM executives on the applications of probability, part of the Modern Engineering Concepts for Technical Managers program offered by the College of Engineering's Office of Continuing Education.

PROGRAM LEADERSHIP

Both the State Technical Services Program and the Office of Industrial Liaison are directed by Donald B. Gordon, a 1938 Cornell graduate in administrative engineering (civil), who also received an advanced degree in personnel and business administration from George Washington University. Mr. Gordon's experience in industry ranges from an early assignment in building dams, powerhouses, and power distribution lines for the Aluminum Company of America as an assistant project engineer on the Nantahala Dam and Power Project, to subsequent work for the National Steel Company in Detroit where he assisted in the design and production of 175,000 Quonset Huts for the Department of the Navy.

After reporting for duty as a second lieutenant in the Field Artillery early in 1942, he took part in four campaigns in Europe, was integrated into the Regular Army, and later participated in the occupation of Japan, the Korean War, and the war in Vietnam. He was also posted as an intelligence officer to observe the French-Indochina War. His last military assignment was as Chief of the Special Warfare and Civil Affairs Division of the Continental Army Command, Fort Monroe, Virginia. He was retired in 1967 as a result of injuries suffered in a parachute accident while training Special Forces personnel.

During Mr. Gordon's twenty-eight years in the Army, he rose to the rank of colonel, commanded tactical artillery units, worked in rocket and missile research and development, was the Army's representative to various defense contract corporations, and participated in planning the reorganization of the Army to incorporate the tactical mobility inherent in the helicopter. Mr. Gordon also served as military attaché to the United States Embassy in Vientiane, Laos.
Bruno A. Boley has been named to the Joseph P. Ripley Professorship in Engineering. His biography and a brief summary of Mr. Ripley's career follow as well as brief biographies of new and visiting faculty.

Among the twenty faculty members appointed to the College of Engineering in the fall, 1968–69, was Bruno A. Boley, former professor of civil engineering at Columbia University. Named to the Joseph P. Ripley Professorship in Engineering, Professor Boley also assumed the chairmanship of the College's Department of Theoretical and Applied Mechanics.

Professor Boley was born in Italy and educated in the United States, where he earned a Bachelor's degree in civil engineering from the City College of New York in 1943. His Master's and Doctor of Science degrees were both awarded by the Polytechnic Institute of Brooklyn, in 1945 and 1946, respectively, in the field of aeronautical engineering.

After receiving his doctorate, Professor Boley served for two years as assistant professor of aeronautical engineering and as assistant director of structural research at the Polytechnic Institute of Brooklyn. He then joined the Goodyear Aircraft Corporation and subsequently became associate professor of aeronautical engineering at the Ohio State University in 1950. In 1952, he was named professor of civil engineering at Columbia University, where he remained until joining the faculty at Cornell.

Professor Boley has been a consultant for the United States Steel Corporation; Sylvania Electric Products, Incorporated; McDonnell Douglas Corporation; the Princeton Astronomical Observatory; and the Atomic Power Development Associates. His research and teaching have spanned several disciplines. He is an authority on mechanics, about which he has edited one book and coauthored two others. One of these, Theory of Thermal Stresses, is considered authoritative in the field. Professor Boley is also a member of the editorial boards of the Journal of Solids and Structures and the Journal of Mechanical Engineering Education.

In addition to those avocations, Professor Boley is a fellow of the American Institute of Aeronautics and Astronautics, a director of the Society of Engineering Science, and a member of the American Society of Mechanical Engineers, the New York Academy of Sciences, and Sigma Xi. During the 1965–66 academic year, he held a National
Science Foundation Senior Postdoctoral Fellowship for teaching and research at the Instituto di Scienza delle Costruzioni of Milan, Italy.

The Joseph P. Ripley Professorship in Engineering, to which Professor Boley has been named, was endowed jointly by Mr. Ripley, chairman of the board of directors of Harriman Ripley and Company, investment bankers, and by the Ford Foundation. Mr. Ripley earned the degree of Mechanical Engineer from Cornell University in 1912. He was employed by the engineering firm, J. G. White and Company, in New York City following his graduation. In 1922, he joined the investment bankers, W. A. Harriman and Company, Incorporated, in New York City. He became president of Brown Harriman and Company, Incorporated, in 1934 and in 1958 was named chairman of its board of directors. The firm's name was changed to Harriman Ripley and Company, Incorporated, in 1939. Mr. Ripley served Cornell University as a trustee from 1944 until 1959, when he was named trustee emeritus.

- **Toby Berger**, assistant professor of electrical engineering, was awarded the B.E. degree *summa cum laude* from Yale University in 1962 and the M.S. and Ph.D. degrees from Harvard University in 1964 and 1966, respectively. He has served most recently as senior scientist at Raytheon Company in the field of analytic techniques, and his specializations include information theory and decision and estimation theory.

- **Louis J. Billera**, assistant professor of operations research and member of the Center for Applied Mathematics at Cornell, will rejoin the faculty after spending the spring and summer of 1969 at The Hebrew University of Jerusalem under the auspices of a National Science Foundation postdoctoral fellowship. Mr. Billera earned the B.S. degree from Rensselaer Polytechnic Institute in 1964 and the M.A. and Ph.D. degrees from City University of New York in 1967 and 1968, respectively. His interests are in the areas of game theory, combinatorial mathematics, and graph theory.

- **Mark Brown**, assistant professor of operations research, received the B.S. degree in 1964 from City College of New York and the M.S. and Ph.D. degrees in 1965 and 1968, respectively, from Stanford University. His particular interests are applied probability, stochastic processes, and time series analysis.

- **Robert Lee Constable**, assistant professor of computer science, received the B.A. degree from Princeton University in 1964. In 1965 and 1968 he was awarded the M.A. and Ph.D. degrees, respectively, from the University of Wisconsin. His thesis was titled "Extending and Refining Hierarchies of Computable Functions."

- **Renwick E. Curry** received his A.B. degree from Middlebury College in 1959 and his B.S. and M.S. degrees from the Massachusetts Institute of Technology simultaneously in 1962 through the honors course program there. He joins Cornell's faculty as assistant professor of electrical engineering. He was awarded the Engineer
of Aeronautics and Astronautics degree from M.I.T. in 1963 and the Ph.D. degree in 1968. His fields of study are modern control theory and estimation theory with aerospace applications. From 1963 to 1965, Mr. Curry worked for the Jet Propulsion Laboratory in Pasadena, California.

Constantine M. Dafermos comes to Cornell from Athens, Greece. He received the Diploma of Civil Engineering from the National Technical University in Athens in 1964 and the Ph.D. degree in 1967 from Johns Hopkins University, where he studied in the field of mechanics. During the academic year 1967–68 he was associated with Johns Hopkins as a postdoctoral fellow. He joins the faculty at Cornell as assistant professor of theoretical and applied mechanics and is a member of the Center for Applied Mathematics.

Paul S. Ho, assistant professor of materials science and engineering, received the B.S. degree in 1957 at the Chengkung University, in China, and the M.S. degree in 1959 at the National Tsinghua University there. He was awarded the Ph.D. degree from Rensselaer Polytechnic Institute in 1964. Mr. Ho has worked for Sprague Electric Company. His specialty is the elastic properties of crystals.

Allan I. Krauter, assistant professor of mechanical engineering (Department of Machine Design and Materials Processing), received the M.E. degree from Stevens Institute of Technology in 1963. He earned the M.S. and Ph.D. degrees at Stanford University in 1964 and 1968, respectively. Mr. Krauter's summer work experience has included Enjay Laboratories in Linden, New Jersey; Esso Research and Engineering Company in Florham Park, New Jersey; and Bell Telephone Laboratories in Murray Hill, New Jersey.

Arthur F. Kuckes, professor of applied physics and member of the Laboratory of Plasma Studies, received his B.S. degree in 1953 from the Massachusetts Institute of Technology; in 1959 he was awarded the Ph.D. degree from Harvard University. His previous work has been in the area of plasma physics at Princeton University from 1959 to 1966 and most recently at Culham Laboratory, England, from 1966 to 1968. A member of the American Physical Society, Professor Kuckes had held a Fulbright scholarship at the Georg August Universitat at Gottingen, Germany, and subsequently a National Science Foundation fellowship at Ecole Normale Superieure in Paris.

Howard L. Morgan, assistant professor of operations research and computer science, was awarded the B.S. degree in 1965 from City College of New York and the Ph.D. degree in 1968 from Cornell. His specialties are management information systems and information processing. He is vice president and director of Compuvisor, Incorporated, an Ithaca-based consulting firm.

Sidney Oldberg, professor of mechanical systems and design, received the M.E. degree from Cornell in 1929. Since that time he has obtained thirty-three patents on his technical developments and held significant positions in industry: from 1935 to 1945 he was supervisor of the Aircraft Powerplant Laboratories for Chrysler Engineering Laboratories; from 1952 to 1965, director of the research center of Eaton Yale and Towne, Incorporated; and from 1965 to 1968, director of research and development for that firm. Professor Oldberg is a member of the Society of Automotive Engineers.

Edward Ott, assistant professor of electrical engineering, comes to Cornell from Cambridge University in England where he has been a National Science Foundation postdoctoral fellow in the Department of Applied Mathematics and Theoretical Physics. He received his B.E.E. degree in 1963 from Cooper Union and his M.S. and Ph.D. degrees in 1965 and 1967 from the Polytechnic Institute of Brooklyn. His specialty is electromagnetic theory.

Michael Rubinoitich, assistant professor of operations research, was born in Israel, where he received the B.Sc. degree from Technion–Israel Institute of Technology in 1964. He was awarded the Ph.D. degree from Cornell University in 1968. His areas of special study are applied probability and stochastic processes.

Alan C. Shaw, assistant professor of computer science, is a Canadian who joins the faculty of Cornell after earning the B.A.Sc. degree from the University of Toronto in 1959 and the M.S. and Ph.D. degrees in 1962 and 1968 from Stanford University. His specializations are programming languages and computer graphics. Mr. Shaw has worked as a systems engineer for International Business Machines Corporation and as a research associate at the Stanford Linear Accelerator Center.
Shaler Stidham, Jr., assistant professor of operations research and environmental systems engineering, comes to Cornell from Stanford University. He received his B.A. in 1963 from Harvard University, his M.S. in 1964 from Case Institute of Technology, and his Ph.D. in 1968 from Stanford University. His special interests are queuing theory, logistics, and transportation systems.

George Szentirmai, associate professor of electrical engineering, earned the Diploma in Electrical Engineering in 1951 and the Candidate of the Technical Sciences in 1955, both from Technical University of Budapest. He was awarded the Ph.D. degree from the Polytechnic Institute of Brooklyn in 1963 and has worked for Bell Telephone Laboratories, Incorporated, at Murray Hill and Holmdel, New Jersey, since 1959. Professor Szentirmai has taught at the Polytechnic Institute of Brooklyn and the Technical University of Budapest. His professional interests are network theory and electromagnetic theory and the application of computers.

Kenneth E. Torrance, assistant professor of thermal engineering, received the B.S. degree in 1961, the M.S. degree in 1964, and the Ph.D. degree in 1966, all from the University of Minnesota. He was employed as a research associate at the National Bureau of Standards, Washington, D.C., from 1966 to 1968.

Robert A. Wagner, assistant professor of computer science, received the B.S. degree from the Massachusetts Institute of Technology in 1962 and the Ph.D. degree from Carnegie-Mellon University in 1968. He worked as a systems programmer for the Rand Corporation in Santa Monica, California, from 1962 to 1965.

David M. Watt, Jr., assistant professor of chemical engineering, was awarded the B.S.E. degree magna cum laude from Princeton University in 1964 and the Ph.D. degree from the University of California at Berkeley in 1968. His summer work experience has been with Procter and Gamble Company, Monsanto Company, and Dow Corning Company. His professional interests include combustion and catalysis.

Philip G. Ashmore, visiting professor of chemical engineering (first term), came to Cornell from England, where he is professor of physical chemistry at the University of Manchester and the University of Manchester Institute of Science and Technology.

Paul Baron, visiting associate professor of environmental systems engineering, received the Diploma of Engineering and the Ph.D. degree from the Karlsruhe Technical University in his native Germany.

The following are visiting faculty at Cornell for the academic year 1968–69.

Philip H. Calderbank, Mary Shep- herd B. Upson Visiting Professor (second term), is professor in chemical engineering at the University of Edinburgh, Scotland.

Hilliard B. Huntington, visiting professor of materials science and engineering, is chairman of the Department of Physics at Rensselaer Polytechnic Institute.

Ivan Kuščer, visiting professor of applied physics (first term) and of aerospace engineering (second term), is professor of physics at the University of Ljubljana in Yugoslavia.

Brian Le Lievre, visiting assistant professor of geotechnical engineering, comes to Cornell from Ontario, Canada, where he is assistant professor of civil engineering at the University of Waterloo.

Benjamin J. Leon, visiting professor of electrical engineering, is professor of electrical engineering at Purdue University.

Marcel F. Neuts, visiting professor of operations research, is professor of operations research at Purdue University.

Paul E. Schleusener, visiting professor of agricultural engineering, is employed as a research management specialist in agricultural engineering for the United States Department of Agriculture.

George Terzidis, visiting assistant professor in water resources engineering, has taught at the University of California at Davis.

Steven A. Thau, visiting associate professor of theoretical and applied mechanics, has been an assistant professor in that field at the Illinois Institute of Technology.
The following publications and conference papers by faculty members and graduate students of the Cornell College of Engineering were published or presented during February, March, and April 1968. The names of Cornell personnel are in italics.

**AEROSPACE ENGINEERING**


**AGRICULTURAL ENGINEERING**


**CHEMICAL ENGINEERING**


**CIVIL ENGINEERING**


COMPUTER SCIENCE


ELECTRICAL ENGINEERING


Engineer Physics


Industrial Engineering and Operations Research


MATERIALS SCIENCE AND ENGINEERING


MECHANICAL ENGINEERING


THEORETICAL AND APPLIED MECHANICS


The following publications and conference papers by faculty members and graduate students of the Cornell College of Engineering were published or presented during May, June, and July 1968. The names of Cornell personnel are in italics.

**AEROSPACE ENGINEERING**


**AGRICULTURAL ENGINEERING**


**CHEMICAL ENGINEERING**


**CIVIL ENGINEERING**


**COMPUTER SCIENCE**


ELECTRICAL ENGINEERING


Ott, E., and Shmoys, J., "Transient Radiation in a Plane Stratified Dispersive Medium I: Half-Space Configura-


ENGINEERING PHYSICS


INDUSTRIAL ENGINEERING AND OPERATIONS RESEARCH


MATERIALS SCIENCE AND ENGINEERING


Editor's Note: This issue is the first of Volume 4. The last issue, published in January 1969, was the only one in Volume 3. Over the three-year period of publication, we have fallen behind two issues; this is primarily the result of the turnover in our small staff. The editorial associates of Engineering: Cornell Quarterly are usually wives of graduate students whose period of service is limited by their stay in Ithaca.

This issue and the next one will carry six-month records of faculty publications to bring that section up to date.

At this point, the editor wishes to express his continuing appreciation to the editorial associates who have served the publication with distinction, the Office of University Publications for its handling of the production of the magazine, and Connecticut Printers, Incorporated, for the excellence of their printing craftsmanship.


MECHANICAL ENGINEERING


THEORETICAL AND APPLIED MECHANICS


