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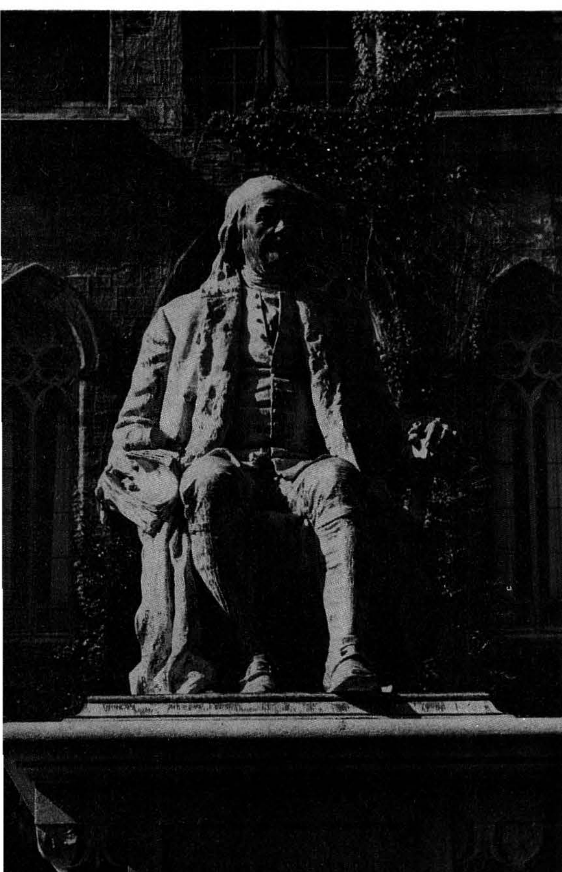
Benjamin Franklin founded the University of Pennsylvania in 1740. Initially, most of the Ivy League schools had a formal or informal association with a religious denomination, and Penn was to be known as a Quaker school. The Quaker love for things practical left a strong imprint on the university. Penn offered one of the earliest courses in chemistry (from 1769), had one of the first departments of engineering (founded in 1855), and the second-oldest program in chemical engineering (actually the oldest in *continuous* operation, since 1893). Today, two-thirds of the population on the Penn campus consists of graduate and professional students, and the numerous professional schools—engineering, medicine, and the Wharton school of business among them—are a vital and prestigious part of the university.

The pre-eminence of chemical engineering and chemistry at Penn is not surprising if one remembers that, since the late 1700's, Philadelphia has been a center of the American chemical industry. Indeed, the American Chemical Society was founded here (in 1876), as were the American Association for the Advancement of Science (in 1847) and the AIChE itself (in 1907). Appropriately, the Center for the History of Chemistry and Chemical Engineering (co-sponsored by the ACS and the AIChE) is located on the Penn campus and run by the university. This unique collection, with its old textbooks, manuscripts, and many portraits is a delight for visiting chemical engineers and chemists.

The Penn campus is situated in West Philadelphia, only one mile from "Center City," as the downtown area is known in Philly. It is a surprisingly beautiful urban campus, with modern sculptures poised against ivy-covered collegiate gothic walls. On campus one can enjoy tree-lined walks, the pleasant lawn of the Quad,



Benjamin Franklin, 1706-1790

Founder of the University of Pennsylvania. Printer, engineer, statesman. Engineering education at Penn derives directly from his "Proposals Relating to the Education of Youth in Pennsylvania" (1749):

"As to their Studies, it would be well if they could be taught every Thing that is useful and every Thing that is ornamental: But Art is long and their Time is short. It is therefore propos'd that they learn those Things that are likely to be most useful and most ornamental. Regard being had to the several Professions for which they are intended."

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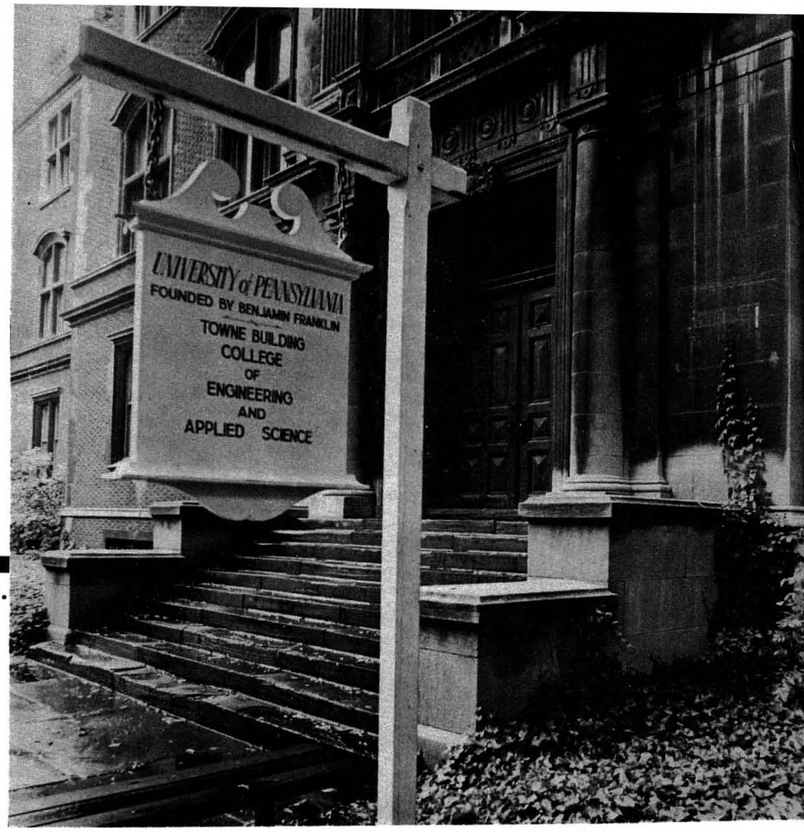

Towne Building, home of chemical engineering at Penn.

and even an unexpected small pond tucked away behind the biological/medical building complex. At the east end of campus, across the street from Franklin Field and the Palestra (where Ivy League championship football and basketball teams perform) is the Towne Building, in which the Department of Chemical Engineering is located along with most of the other engineering departments. When it was dedicated in 1906, it received considerable acclaim. The comment from *Engineering News* was, "It is with little doubt the finest, largest, and best-equipped structure devoted to instruction in engineering in the United States, if not the world." Although this venerable edifice does not pretend to those claims today, there yet remains a feeling of class and comfort in its marbled hallways.

It was in 1951 that chemical engineering was made completely independent of chemistry, and became what was then known as the School of Chemical Engineering. Two men had been primarily responsible for helping the department grow to that point, aided by an Army training program and a Manhattan Project subcontract during World War II: Norman Hixson and Melvin Molstad, who had arrived at Penn in 1938 and 1939, respectively. In 1955 they and their colleagues were joined by Arthur Humphrey, who would lead the department as chairman from 1962 until 1972. Art, later Dean of Engineering at Penn for a decade and now Provost at Lehigh University, played a most important role in shaping the department. Many of the current faculty were hired under Art's direction, setting the stage for the dramatic rise in prominence that chemical engineering at Penn has seen during the past two decades. In addition, Art was one of the first to foresee that biology would become a significant partner with chemical engineering. His vision allowed Penn to establish itself as a premier institution for education and research in biochemical and biomedical engineering well in advance of today's rush into biotechnology.

WHO'S HERE NOW

It might be most interesting to look at the faculty in chronological order of joining the department at Pennsylvania in order to trace the growth of our program through the past 25 years. **Mitch Litt** is our elder statesman in terms of service, having come to Penn in 1961. Mitch, of course, was a pioneer in the application of chemical engineering principles to biomedical problems, and is well-known for his research in the area of biorheology. At the present time he devotes most of his energies to the bioengineering program, serving as chairman of that department. **Bill Forsman** has maintained an active research program in both theoretical and experimental polymer science since arriving in 1964. Among his current interests are light and neutron scattering techniques, composite materials based on graphite intercalation, and the rheological behavior of biological polymers. A constant in Bill's work is the application of graph-theory concepts to the prediction of polymer structures and properties. **Alan Myers** has provided high quality teaching and research in thermodynamics and separations processes (especially adsorption) during his more than twenty years here. In addition to his major research interests, he has been instrumental in making the personal computer an integral part of many of our courses. His consistently excellent teaching has been recognized by a School of Engineering award. A textbook he co-authored with Warren

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Penn's biochemical engineering program was established well in advance of today's rush into the field.

Seider, *Introduction to Chemical Engineering Calculations*, is used in many material and energy balance courses around the country. Alan has also served a term as department chairman, as has **Dan Perlmutter.** Dan came to Penn in 1964 from the Illinois faculty, bringing a prolific and scholarly research program in chemical reaction engineering. He has made important contributions in the mathematical analysis of reactor stability, and has been a pioneer in the study of the effects of pore structure on the kinetics of gas/solid reactions. Dan has lately turned his attention to the kinetics of inorganic chemical reactions, especially with application to the processing of novel materials such as the β″-aluminas. He is also the author of two well-known books, *Chemical Process Control* and *Stability of Chemical Reactors*.

Warren Seider, currently a director of AIChE, arrived in 1967 with an interest in the application of computers to chemical process modeling and design. Warren is well known for his early and continuing involvement in CACHE, and for his role in the diffusion of the FLOWTRAN computer-aided design language. He is primarily responsible for the superb undergraduate design courses here, and for the departmental computer facilities. In the past few years, the emphasis of his work has been in the area of numerical analysis of the dynamics of complex chemical systems. Warren's mentor, **Stuart Churchill**, came to Penn in 1967 after many illustrious years at Michigan. One of our three members of the National Academy of Engineering, Stuart has served as advisor to a number of individuals presently on chemical engineering faculties around the world. He maintains a high level of activity in both research and teaching, as well as in professional affairs. He is a popular favorite among students for his entertaining and instructive anecdotes, as well as for his service as advisor to our very active AIChE undergraduate chapter. His major current research interests are combustion and natural convection, continuing his long-standing investigation of transport and kinetic rate processes. A series of volumes under the title of *The Practical Use of Theory in Fluid Flow* continues to emerge from Stuart's facile pen, to join his earlier text called *Introduction to Rate Processes*.

Two of the major figures in our highly-respected biochemical/biomedical program were next to arrive on the scene. **David Graves** brought his experimental wizardry to Penn in 1970, and has since generated a number of innovative research projects. In addition, he runs our undergraduate laboratory course and teaches an unusual graduate course in instrumentation, featuring microprocessor interfacing. His primary research interests at this point in time center on novel biochemical separations processes. Two exciting current developments include the exploitation of magnetically-stabilized fluidized bed technology for continuous protein separation, and use of affinity techniques for separation of cell populations. Because of his experimental creativity, David has been a part of a number of productive collaborative efforts. Some of these have been with **John Quinn**, our second member of NAE. John's addition to Penn in 1971 from Illinois was another significant step in the growth of our program. His research remains focused on the fundamental understanding of transport processes, with special emphasis on membrane and interfacial phenomena. This has led to the recent development of a number of novel concepts in John's laboratory, such as the membrane bioreactor and a non-invasive blood gas biosensor. At the same time, John is another member of our faculty who has been recognized as an outstanding teacher by the Engineering School. We have also had the benefit of his leadership as department chairman during the past five years.

The mid-1970's saw the addition of **Liz Dussan** and **Eduardo Glandt** to our faculty, bringing fresh blood and new ideas. Liz is a recognized authority in fluid mechanics and interfacial phenomena, having produced a number of major results in these areas. She has played a key role in the development of our graduate program, serving as its chairman for the past few years. A specific instance of improvement is the increased emphasis on applied mathematics she has brought to our curriculum. More generally, her scholarship and enthusiasm have been instrumental in setting its tone and in creating an atmosphere of interest in and concern for each student as an individual. With Liz on a leave of absence at the present time, Eduardo now bears the primary leadership of the graduate program. He also directs a very active research group in thermodynamics and statistical mechanics. Much of their current work is focused on statistical modeling of disordered systems. Heterogeneous media are of such a pervasive occurrence in chemical engineering that Eduardo and his students often find themselves interacting with many of the other research groups in the department. Eduardo has also been recognized for his teaching efforts, both by the School of Engineering and through a university-wide award.

We come next to the three youngest members of our department. **Doug Lauffenburger** arrived in 1979, bringing an unusual perspective on the application of chemical engineering ideas to biology and medicine. His investigation of fundamental cell behavioral phenomena has become a central aspect of our unique approach to biotechnology. Fusing the traditionally disparate fields of biochemical and biomedical engineering, we term our approach "molecular/cellular bioengineering" when pressed. Doug has also been in charge of graduate student recruitment for the past five years with great success, being that rare individual who truly enjoys this task. **Ray Gorte** has been here since 1981, building a strong research program in catalysis and surface science. The effects of support/metal interactions on reaction kinetics have been the major subject of his careful and clever experiments, undertaken in the best-equipped laboratories in the department. Ray has quickly become known as an excellent teacher, and is now chairman of our undergraduate program. In this position he has instituted a number of changes in our curriculum, incorporating more advanced fundamentals and new fields of application. **Lyle Ungar** has added both depth and breadth to the theoretical side of our department since his arrival in 1984, with a strong research and teaching program in application of advanced applied mathematical methods to areas rather new to chemical engineers. One of these areas is the processing of materials for the electronics industry, with understanding of transport phenomena involved in crystal growth and rapid solidification examples of major importance. Another is the development of expert systems for chemical process design and control. In addition, Lyle's expertise in modern numerical methods is bringing him into collaborative efforts with a number of faculty.

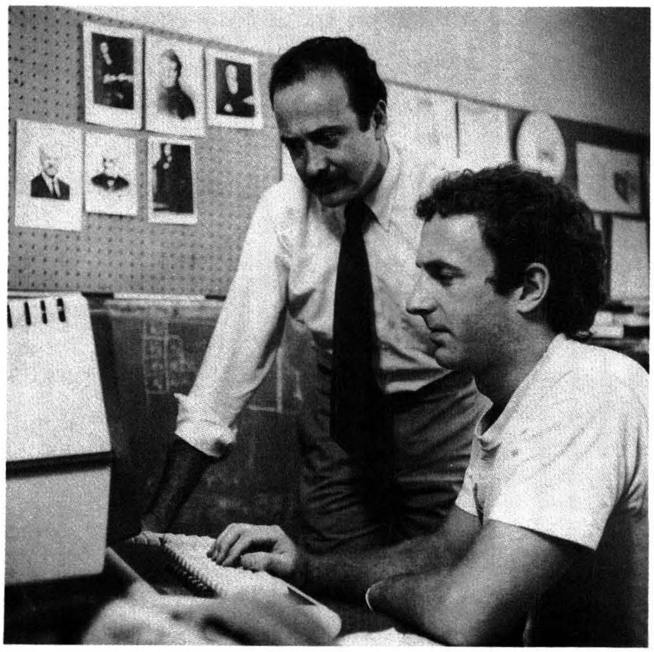
Finally, we are extremely pleased to have recently added two senior faculty to our number. **Greg Farrington** has a primary appointment in the Department of Materials Science, of which he is currently chairman. However, his excellent research and teaching in the field of electrochemistry is becoming an ever more important part of our program. Greg is one of the pioneers in the development and understanding of

Doug Lauffenburger conducts a research program on molecular and cellular bioengineering.

ionic materials, such as the novel ß″-aluminas, and is actively engaged in studies of ionic transport phenomena in these materials. Greg is also investigating analogous effects in zeolitic materials. Mention of zeolites is one of many ways to lead into a proud introduction of our newest faculty member, **Paul Weisz**. Paul, of course, has had an exceptionally distinguished career in research at Mobil, leading to membership in the NAE in addition to numerous honors and awards. He is continuing to pursue his many and varied interests with us, including the application of zeolites for biochemical reactions and separation processes, and the investigation of the role of diffusion and reaction in living systems. Having Paul here provides us with an unparalleled intellectual stimulus that we look forward to continuing for many years.

UNDERGRADUATE PROGRAM

The aim of the undergraduate program in chemical engineering here at Penn is to prepare our students to be able to develop the technology of the future, rather than to train them as custodians of the technology of today. Thus, the emphasis in our core curriculum is on engineering science; that is, on basic phenomena in thermodynamics, kinetics, and transport phenomena rather than on chemical process operations. Since a solid education in science and the liberal arts is also expected at an Ivy League university, our core requirements must be reduced correspondingly. Of 41 course units necessary for graduation, only 20 are specifically required; the others must be drawn from basic sciences and mathematics, and from humanities and social sciences. As a result, our students receive an unusually well-rounded education which serves them well in business, law, or medical schools, which are all popular options. This flexibility also allows each student to tailor an individualized curriculum to satisfy any particular technical or scientific interests. A large fraction of our students go on to graduate school in chemical engineering, perhaps because of the emphasis on the fundamental engineering science perspective.



Computer simulations and other high-level computational studies are carried out on the department's VAX computer.

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The required core courses are

- **Sophomore year**—Material and Energy Balances, Thermodynamics
- **Junior year**—Fluid Mechanics, Advanced Physical Chemistry, Heat and Mass Transfer, Separations Processes
- **Senior year**—Reactor Analysis, Process Control, Chemical Engineering Laboratory, Process Design (two semesters)

In addition, there are elective courses in biochemical/biomedical engineering, polymers, and electrochemistry offered by our departmental faculty. The process design courses deserve special comment because of the attention to providing individualized design experiences. We take full advantage of our location in the Delaware Valley, with its concentration of chemical and pharmaceutical industries, and invite senior design engineers to participate in the design courses as consultants. Each group of three students is assigned to a different project, and meets weekly with a faculty advisor as well as with another industrial consultant. The resulting year-end reports give evidence of how the perspective of our seniors is enriched through these interactions which allow them to apply their knowledge of engineering fundamentals to applications of current interest. A number of our best students also choose to do independent research projects during their junior and/or senior years, which usually whets their appetite for graduate research.

GRADUATE PROGRAM

The central purpose of our graduate program is to educate students to become independent, creative researchers in chemical engineering. Every facet of our program is geared toward providing the personal interaction with accomplished scholars that is essential for development of scientific judgment and vision. To begin with, we maintain a low student/faculty ratio, with about sixty graduate students present among our faculty of fifteen. This allows small class sizes, as well as research groups large enough to be viable and productive but small enough to let an advisor work with each student individually. Post-doctoral research assistants are discouraged, for they interfere with direct involvement of the faculty advisor with the students.

In recent years, our graduate student population has become almost exclusively comprised of PhD candidates; less than 10% of our typical incoming class

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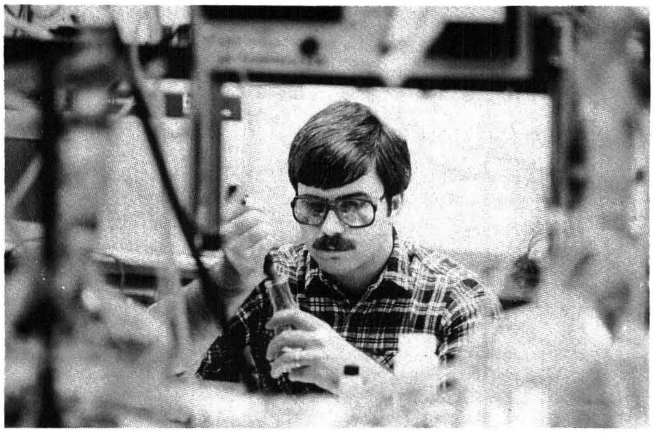
has a Master of Science degree as a goal. We require twelve courses of each PhD candidate, along with a research dissertation. Six of these courses are the core courses taken during the first year: thermodynamics, reactor analysis, and two semesters each of transport phenomena and applied mathematics. The latter sequence is unusual for its emphasis on theoretical rigor, but has become a popular feature of our program (see the Fall 1984 issue of *Chemical Engineering Education* for a description of this sequence). We insist on this set of courses for all our students, so that they will be equipped to apply advanced principles from the entire spectrum of chemical engineering science regardless of their areas of research specialization. We also use observations of their approach to and performance in these courses as input into the decision regarding PhD candidacy, along with results of a comprehensive written examination at the end of the first academic year. Research qualities are judged during the oral preliminary examination over a dissertation proposal, sometime after the second year.

In addition to the core courses, we offer a wide variety of elective graduate courses from year to year. Within the past couple of years, these have included the following

- **Statistical Mechanics (Glandt)**
- **Heterogeneous Catalysis (Gorte)**
- **Nonlinear Analysis in Applied Mathematics (Ungar)**
- **Mass Transfer (Quinn)**
- **Heat Transfer (Churchill)**
- **Analysis of Microbial Systems (Graves and Lauffenburger)**
- **Analysis of Physiological Systems (Lauffenburger)**
- **Numerical Methods (Seider)**
- **Polymers (Forsman)**
- **Instrumentation (Graves)**
- **Ionic Materials (Farrington)**

A collegial spirit of informal research collaboration is pervasive here, allowing students to benefit daily from the perspective of faculty and students from different research groups. For instance, it is common to see faculty and students participate in group meetings other than their own. Joint projects are not unusual. There are also an unexpectedly large number of joint projects with faculty from other departments, such as chemistry, biology, materials science, mechanical engineering, and medicine, consistent with Penn's "One University" concept. All this serves to broaden the scientific perspective of our students as they learn to pose and attack novel research problems.

A large measure of the quality of our program can be seen in the graduate students themselves. We bring in a class of only about twelve new students each fall, allowing an exceptional degree of selectivity for enthusiasm and commitment as well as intellectual ability. Our departmental graduate student association (ChEGA) is an active participant in policy formation for the graduate program, in addition to sponsoring academic, social, and athletic activities. The weekly noon-time student research seminars run by ChEGA are an enjoyable highlight. The students also play an extremely important part in our continuing recruitment of new students. Their enthusiasm for our program is a major reason for our success in attracting students of the highest caliber.



A fundamental understanding of transport processes is exploited in the generation of new separation technologies.

It is gratifying to see that our efforts to keep the students' education foremost is resulting in a continuing interest on their part to educate the chemical engineers of the future. Within the past five years, our PhD graduates have joined the ranks of chemical engineering faculty at a number of major institutions. Among these are included Julio Briano (Puerto Rico), Mark Burns (Massachusetts), Yee Chiew (Rutgers), Dan Hammer (Cornell), Patrick McMahon (Wisconsin), Jim O'Brien (Yale), Lisa Pfefferle (Yale), Janice Phillips (Lehigh), Al Post (Pittsburgh), George Prokopakis (Columbia), Don Ristroph (Louisiana State), Carol Steiner (CUNY), Bob Tranquillo (Minnesota), and Charles White (West Virginia). We trust that their experiences here will help them to serve as good models for the generations of students they will encounter in the future.

WHAT'S AHEAD

To be honest, we simply hope to continue the course that has led us to our present state: a commitment to excellence, with students the highest priority. Chemical engineering will continue to evolve, for it is, in John Quinn's words, "whatever chemical engineers do." We aim to be in the forefront of doing new and interesting things, doing them well, and educating students to carry on that tradition that is Penn Chemical Engineering. □