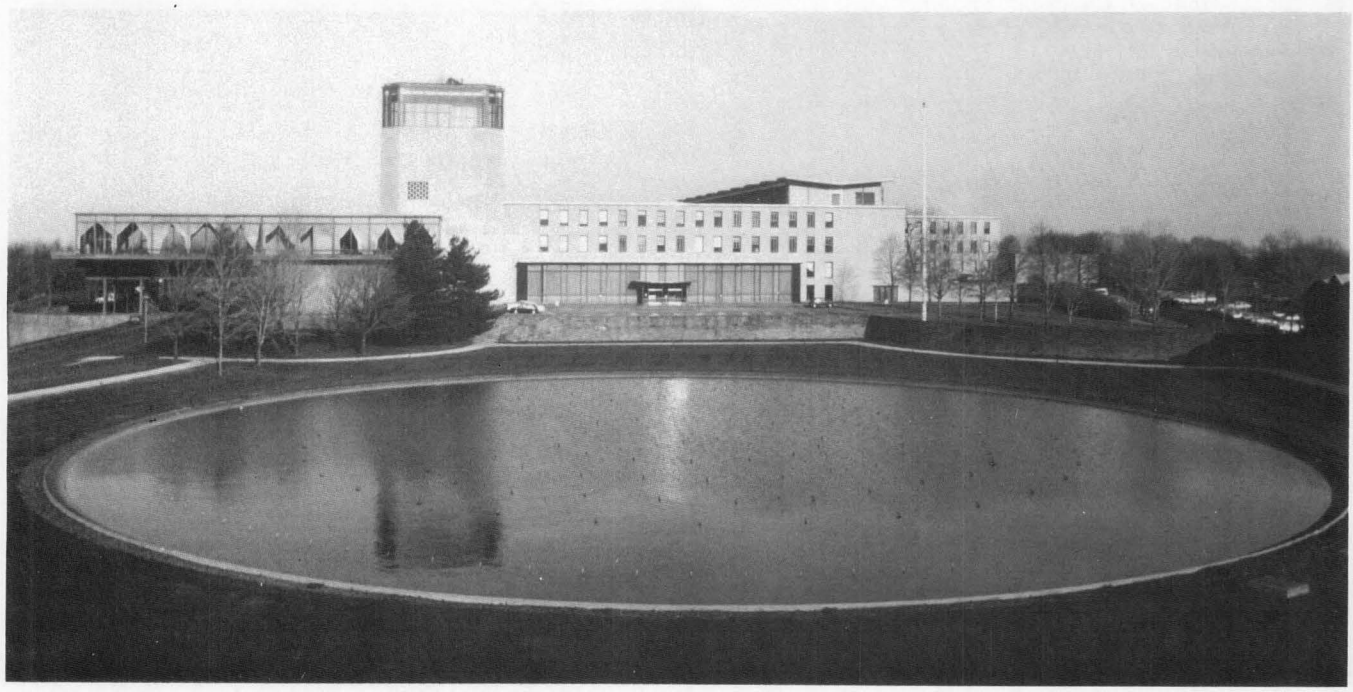
ChE department



New home of Chemical Engineering Department at Mountaintop Campus.

LEHIGH UNIVERSITY

HUGO S. CARAM, JOHN C. CHEN
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THE CHEMICAL engineering program at Lehigh started in 1907 and followed the growth of Lehigh University from a small undergraduate school to its current research university status. The department has been characterized by a creative and personalized approach to undergraduate education, complemented by steady growth of its graduate and research activities. It is currently among the larger chemical engineering departments in the U.S., with 22 faculty members, approximately 150 undergraduate students, 95 resident graduate students, and 30 part-time graduate students. In the past three years the department has graduated an average of forty BS, twenty-five MS, and fourteen PhD students per year.

Founded in 1865, Lehigh University is an independent, co-educational institution dedicated to the advancement of knowledge in a wide range of disciplines. The University takes pride in its highly competitive curricula in science and technology, the arts and humanities, and business and economics. Current enrollment is approximately 4,300 undergraduate and 2,000 graduate students. The Chemical Engineering Department has the largest graduate program of any single department at the University and accounts for approximately one out of every five PhD degrees granted by Lehigh.

Lehigh University's educational philosophy is based on the premise that preparation for successful living must combine the acquisition of knowledge and skills necessary to the profession with the development of humanistic values and ethics that enrich personal life. Thus, the University's emphasis for a liberal education combines the professional with the cultural, the practical with the ideal, and the functional with the esthetic.

The University is located in the city of Bethlehem, in the Lehigh Valley of eastern Pennsylvania. The

area, with a population of half a million, supports a significant cultural life of its own as well as offering easy access to the metropolitan environments of New York and Philadelphia, and to the outdoor recreational opportunities of the Pocono Mountains, the Delaware River Basin, and the New Jersey Shore.

The University is situated on three adjoining campuses covering 1,500 acres of South Mountain and the neighboring valleys. The Chemical Engineering Department is now based in the Tower Building of the new Mountaintop Campus, a beautiful 700 acre site along the summit of South Mountain.

THE WAY WE WERE

Chemical engineering at Lehigh University started as a program in the Department of Chemistry, and the first chemical engineering degree was awarded in 1907. By the early 1930's, some twenty to thirty Bachelor degrees and three to four Masters degrees were being awarded each year in chemical engineering. Distinguished faculty of the 1940's included Darrell Mack, Vincent Uhl, and Harvey Neville. 1952 marked the beginning of the "new" program at Lehigh. In that year chemical engineering was formally recognized as an independent academic department, and Leonard A. Wenzel and Alan S. Foust joined the faculty, the latter to serve as its first chairman. In short order, Curtis W. Clump, Bryce Anderson, and Louis Maus also joined the department and together with Foust and Wenzel began building the modern department of today. That effort included writing of the classic textbook *Principles of Unit Operations*. In 1962, Leonard Wenzel became chairman and oversaw the move of the department to the new Whitaker Laboratory Building in 1965. By the time Len left the chairmanship in 1983, the department had won a place among the well-regarded chemical engineering programs in the country, graduating some sixty BS, twenty-eight MS, and two PhD's per year. John C. Chen assumed the chairmanship in 1983 and, with the current faculty, has continued to pursue enhanced quality in both the educational and research programs of the department.

RECENT INITIATIVES

Along with the entire profession, our department has undergone intense self-scrutiny and clarification of objectives in the past six years. This was triggered by a realization that today chemical engineering is challenged by rapid technical developments, a great variety of products and applications, emphasis on higher value-added products, concerns with quality and safety, and intense competitiveness in development and production. Our response as an academic department was to

- **Affirm the importance of fundamentals in science, mathematics, and engineering basics for both undergraduate and graduate curricula**
- **Nurture and develop students' "intellectual nimbleness," the ability to define problems, apply critical faculties, optimize solutions, integrate knowledge from multiple disciplines and work effectively in interpersonal relationships**
- **Develop the very best research capabilities of international stature *in a few selected areas* of chemical engineering.**

In pursuit of the above goals, the following initiatives were taken.

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Undergraduate curriculum • A better-integrated curriculum has been instituted which more efficiently covers the fundamentals of chemistry, physics, natural sciences, mathematics, and engineering science, with room for a substantial amount of elective options.

Laboratory Instruction • The old "unit operations laboratory" had lost favor in the 60's and 70's for many departments across the country. The importance of hands-on laboratory experience in an engineering context was reaffirmed, and we have just completed a four-year development effort, at a cost of over $1 million, to enhance both the physical facilities and the instructional content of our undergraduate process engineering laboratories. The fifteen new experiments provide students with experience in both classical technology (heat and mass transfer, thermodynamics, distillation, *etc.*) as well as some of the advanced technologies (membrane separation, digital process control, bioengineering, *etc.*).

Undergraduate Research • With sponsorship by an educational foundation and a dozen companies, a new program called Opportunity for Student Innovation (OSI) was started in 1987. Teams of senior students work with faculty advisors and industrial men-

tors on research projects that arise from real needs of the industrial companies. This attempt to foster the students' critical faculty for problem definition and solution has generated enthusiastic interest and active participation by students, faculty, and industrial partners.

New Facilities • Having outgrown its home of twenty years in Whitaker Laboratory, the department was moved to the newly acquired Mountaintop Campus in the Summer of 1988. Offices, classrooms, seminar rooms, and laboratories are all integrated ir the 200,000 square feet Tower Building. An additional 10,000 square feet of engineering laboratory space is also available to chemical engineering in a neighboring pilot-plant building. For the first time in two decades, nearly all of the chemical engineering faculty and their research programs are located together at a single site. Campus-wide communications were also significantly enhanced by a fiber-optic computer network.

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RESEARCH

Research is the heart of our department's graduate activity. With the intention of concentrating in selected areas, the faculty has developed focused thrusts in bioprocessing, polymer science and engineering, process modeling and control, and multiphase processing. Approximately a quarter of the faculty members are involved in each of these four areas.

The research in bioprocessing is focused on the operations required for manufacture and isolation of biological products. Faculty and students are currently investigating the fundamental kinetics of microbial, enzyme, and mammalian cell systems, the design and scale up of bioreactors, the development of on-line instrumentation, and novel separation/purification schemes for recovery of biologically active species. These activities are coordinated through the BioProcessing Institute, directed by Janice A. Phillips, as a part of Lehigh University's Center for Molecular Biosciences and Biotechnology, directed by Arthur E. Humphrey.

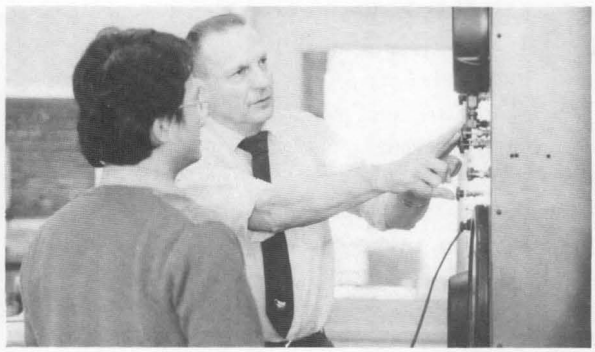
The polymer program at Lehigh is an interdisciplinary activity pursuing research in polymer colloids and polymer materials. The polymer colloids activity is promoted by the Emulsion Polymers Institute, co-directed by John Vanderhoff and Mohamed El-Aasser. Currently active projects pursue the preparation of special monosize polymer particles, the morphology of composite polymer particles, the kinetics, transport phenomena, and modeling of emulsion polymerization processes, the absorption of various molecules on surface of latex particles, and the phenomena of copolymerization and inverse emulsion polymerization. The research activity in polymer colloids is strongly supported by an industrial consortium of over fifty companies. Research on polymer materials has concentrated on multicomponent polymers. Specific projects have studied interpenetrating network composites, neutron scattering characterization techniques, block copolymers, and the engineering properties of polymeric materials.

Research in process modeling and control has the objective of using advanced computer science to develop novel approaches for dynamic modeling, simulation, and control of industrial chemical processes. Active projects include the modeling and control of batch reactors, the design of nonlinear and multivariable control structures, the design and control of energy-conserving distillation systems, the development of improved numerical integration methods, the use of artificial intelligence in process control, and the application of statistical control schemes. Activities in this area are organized in a Center for Process Modeling and Control, co-directed by Christos Georgakis and William Luyben, and are supported by an industrial consortium of a dozen companies.

While technical specializations are highly varied within the multi-phase processing research activity, the common theme is concern with interfacial phenomena as found in multiphase systems. Faculty interests reflect the wide range of industrial processes dependent upon multiphase processing technology. Active projects include the studies of plasma etching of semiconductor materials, heterogeneous catalysts for production of synthetic fuels, laser Raman spectroscopy to characterize surface oxides on substrates for improved catalysts, phase equilibria of multicomponent fluid mixtures, fluid mechanics of spouted beds and the flow of granular materials, fluid mechanics and heat transfer in both bubbling and circulating fluidized beds, and multicomponent evaporation and condensation. Much of the research is coordinated through the Institute of Thermo-Fluid Engineering, the Zettlemoyer Center for Surface Science, and the Energy Research Center.

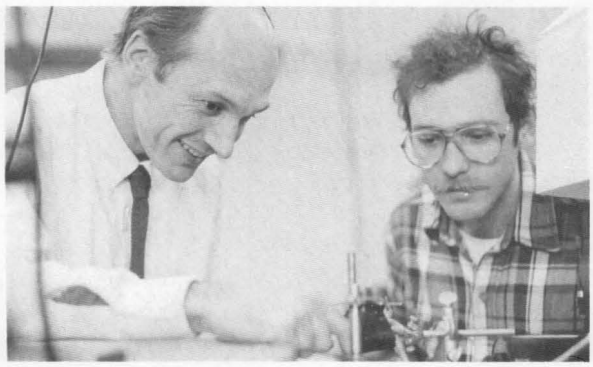
Due partly to the department's selective focus in

↑ *Professor John C. Chen Department Chairman.*

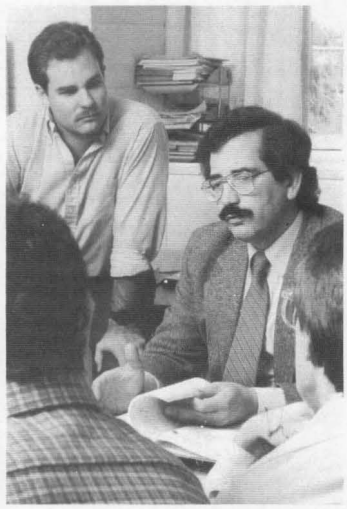


← *Professor Fred Stein and a graduate student measure VLE of fluid mixtures.*

↓ *Professor Christos Georgakis confers with a group of graduate students.*



→ *Professor Hugo S. Caram inspects the research apparatus of a graduate student.*



the above four research areas, we are enjoying a period of growth and effervescent enthusiasm. Since 1983, research funding has grown at an average annual rate of over 30%, resulting in a research budget of $3 million per year. The department's graduate educational program has seen a shift from the MS towards the PhD program. In a five-year span, the fraction of resident students studying for the doctoral degree has increased from 30% to 70%, and the average number of PhD degrees granted per year has increased from 4 to 14, ranking us, on this basis, among the top ten departments in the U.S.

THE FACULTY

In the spring of 1989 the department faculty consists of sixteen full-time faculty, three faculty with joint appointments (with other departments), two active emeritus professors, and one adjunct faculty. What follows is a brief introduction to each of our colleagues, in the chronological order of their joining the Lehigh staff.

First on the scene were **Leonard A. Wenzel** and **Curtis W. Clump,** who came from the University of Michigan and Carnegie Institute of Technology in 1951 and 1954, respectively. Along with **Alan Foust,** Curt and Len were instrumental in laying the foundation for our department of today. In addition to their own teaching and research efforts, each came to assume major administrative responsibilities. In 1962 Len became chairman of the department and held that position for twenty-one years. Curt took on the responsibilities of Associate Dean for Undergraduate Education in the College of Engineering over the period of 1975 to 1988. Both retired as distinguished emeritus professors but remain active in the department.

The sixties brought additional new blood, with two former Lehigh undergraduates joining the department. **William E. Schiesser** came in 1960, followed by **Fred P. Stein** in 1963. Bill (now the R.L McCann Professor) obtained his PhD at Princeton under the late Leon Lapidus and brought with him an interest in numerical analysis and computer methods that has continued unabated to this day. Fred came from graduate work at the University of Michigan and brought an abiding interest in thermodynamics. In addition to the substantial responsibility of being the associate chairman, Fred is now extending his work on thermodynamics into state equations for electrolytes, reactive solution theory, and the effects of thermodynamic data uncertainty on process design.

Leslie H. Sperling and **William L. Luyben** came from Duke and Delaware, respectively, via Buckeye Cellulose Co. and Dupont, in 1967. The mechanical properties of polymers and composites are Les's core research interest. He applies his results to interpenetrating polymer networks, sound and vibration damp-

ening, and to novel adhesives and binders. This is explored at the molecular level with such techniques as neutron scattering. Bill brought process control to Lehigh. He has been extremely active in the analysis of distillation processes and has added to the sophisticated technology of what is currently the dominant separation technique in the chemical industry. Bill has written a well-recognized process control textbook and more recently, in collaboration with Len Wenzel, a sophomore text reflecting their personal philosophy on undergraduate teaching. Les has also just published a book on composites, reflecting the state of the art in this exciting field.

Marvin Charles had completed his PhD research in rheology at Brooklyn Polytechnic Institute when he came in 1970. He joined forces with Bob Coughlin, now at Connecticut, and developed what would be the initial roots of the biotechnology effort at Lehigh. While maintaining a New Yorker's attitude, Marvin worries, in his words, about "identifying problems inhibiting development and scale up of bioprocesses and solving them by understanding the basic biochemical and engineering concepts."

John C. Chen, our current department chairman, left a successful career at Brookhaven National Labs to join the Mechanical Engineering Department in 1970. John came to this department in 1980 as the Carl R. Anderson Professor of Chemical Engineering. His original interests in heat transfer, started at Michigan where he worked under S.W. Churchill, have cut a wide swath in radiation and multiphase processes. He has maintained a core activity in convective boiling, but heat transfer in circulating and bubbling fluidized beds and the cooling of electronic circuits are also a significant part of his current interests. John's research contributions have been recognized by both the AIChE and the ASME, with the Melville Medal and the Kern Award, respectively.

Mohamed S. El-Aasser studied under Stan Mason at McGill and came to Lehigh in 1970. Together with John Vanderhoff and Gary Poehlein, now at Georgia Tech, Mohamed was instrumental in the development of the Emulsion Polymers Institute and is currently its co-director. He is concerned with the formation, stability, and polymerization of mini-emulsions and the morphology of composite latex particles. With his co-workers, Mohamed was involved in the preparation of large monodisperse latex particles in the microgravity environment of the space shuttle. More recently he has become interested in the surface modification of latexes and their new intriguing applications in the biotech-biomed areas.

The late seventies brought **Hugo S. Caram** (1977), **Cesar A. Silebi** (1978), and **Andrew Klein** (1979). Hugo was the first Minnesota PhD (studied under Amundson) to join the department. With an initial interest in reactor analysis, he has now moved to study the flow of fluidized and granular media. Flow visualization and fiber optic probes are some of the tools in these systems. Cesar is the only Lehigh PhD on our faculty. He has expanded the work he started under developed and expanded the work he started under Anthony McHugh (now at the University of Illinois, Urbana) on the separation of colloidal particles using hydrodynamic chromatography and on the rheology and coagulation of colloidal suspensions. Cesar's basic research on separation and dispersion mechanisms has generated new analytical methods that are now used commercially. Andy, who did his doctoral work at North Carolina State, left research at GAF for Lehigh. Andy's research interests are in the morphology of emulsion polymers and scale up of mixing processes in colloidal systems. He is also involved in the study of membranes with reduced gas permeability.

Rapid changes took place in the eighties. **Arthur E. Humphrey** and **Janice A. Phillips** came in 1980 from the University of Pennsylvania. Art, a former student of Elmer Gaden at Columbia and Dean of Engineering at Penn, became Lehigh's provost. A member of the National Academy of Engineering, he pioneered the field of biochemical engineering with his well-known textbook, written with Aiba, being one of the first to link traditional fermentation technology with modern chemical engineering science. Having returned full time to the department as the T.L. Diamond Professor of Chemical Engineering, Art now leads the Center of Molecular Biology and Biotechnology. Art is interested in the "basics": fermentation modeling, monitoring and control, the new plasmid stability and plant cell culture; and in the "applied": waste water treatment and waste utilization. Students should be aware that graduate work with Art includes strenuous hiking about his mountain retreat in northern Pennsylvania. Janice, an avid runner and a former student of Art Humphrey at Penn, coordinates the graduate activities of the department and directs the Bioprocessing Institute. Her three key research areas are the use of Fourier Transform Infrared Spectroscopy for continuous monitoring of fermentations, the chemical engineering of mammalian cell technology, and enzyme engineering. The FTIR

work requires the use of statistical methods to extract information on concentration of the desired components against the noisy backdrop provided by the water spectrum. The mammalian cell work studies the environmental factors controlling the productivity of mammalian cell cultures. Janice is not only an active research scientist (PYI awardee), but also an excellent teacher, receiving the university's Robinson Award in 1983.

While **Matthew J. Reilly's** main activities are in the development of research programs at the university level, he actively participates in the teaching of undergraduate design courses and assists in the supervision of graduate students in process modeling. A student of Roger Schmitz at Illinois, and a former faculty member at Carnegie-Mellon, Matt occupied several positions with the National Academy of Engineering and the federal energy research program before coming to Lehigh in 1982.

Christos Georgakis, another Minnesota student (having studied with Aris-Amundson) joined the department in 1983. His research interests in process control synergized with Bill Luyben's and blossomed into an University-Industry NSF Research Center for Process Modeling and Control. For all of the industrial support, Christos' research remains thoroughly basic. He is interested in nonlinear and multivariable control and in the more exploratory tendency and expert control. Less traditional projects involve plant-wide control and statistical quality control in chemical processes.

Harvey G. Stenger studied under Charles Satterfield at MIT and joined Lehigh in 1984. Harvey's interests are in reaction engineering. He is working on a variety of heterogeneous reacting systems, including the processing of electronic materials, the use of layered catalysts for NOx and sulfur removal in combustion gases, and the modeling of food processes such as the semibatch alkalinization of cacao products. Harvey was given Lehigh's Robinson Award as the outstanding teacher in 1988 and currently chairs the department's Undergraduate Affairs Committee. Last, but not least, he contributes a solid batting average to the departmental softball team.

The last three years have seen the addition of **James T. Hsu** and **Israel E. Wachs.** Jim had extensive industrial experience in separations and catalysis and after doctoral work with Joshua Dranoff at Northwestern, came to Lehigh from Gulf Research and the NSF in 1986. His current research on bioseparations concentrates on the use of aqueous two-phase polymer systems, and on selective precipitation and chromatographic methods. More recently Jim has also become involved in vaccine technology. Israel brings into the department the tools of modern surface science. After PhD work under Robert Maddix at Stanford, he joined Exxon Research before coming to Lehigh in 1987. He has used, among other techniques, Raman spectra to elucidate the character of surface oxides on substrates that are finding increasing applications for metal oxide catalysts, ceramic materials, pigments, and electronic devices.

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Important contributions to the depatmental operations are made also by **Phillip A. Blythe** and **Eric P. Salathe,** who hold joint appointments in mechanical engineering and mathematics, respectively. Phillip works in diffusion and reaction and in the fluid mechanics of melts used in the production of semiconductor devices. Eric is interested in microcirculation and in biomechanics. We could not close this description without mentioning **William R. Hencke.** Bill was associate laboratory director at Texaco and his experience has been invaluable in the modernization of the Unit Operations Laboratory, the teaching of the professional development courses, and in the advising of both graduate and undergraduate students.

THE FUTURE

The only certainty about the future is that it will be challenging, both for our students and for our faculty. We feel that our emphasis on the fundamentals of education, combined with opportunities to experience applied engineering as well as innovative research, will be of long-lasting benefit to our students, both graduate and undergraduate. We think that the four areas of research selected for special attention by the faculty (polymers, biotechnology, multi-phase processing, and process modeling/control) are among the most significant and fertile in the broad spectrum of chemical engineering. Above all, we are convinced that the attention paid to engineering science will permit our department to respond to evolving technological challenges. As a department our collective objective is to give our students the very best possible education and to contribute significantly to the advancement of chemical engineering science and practice. □