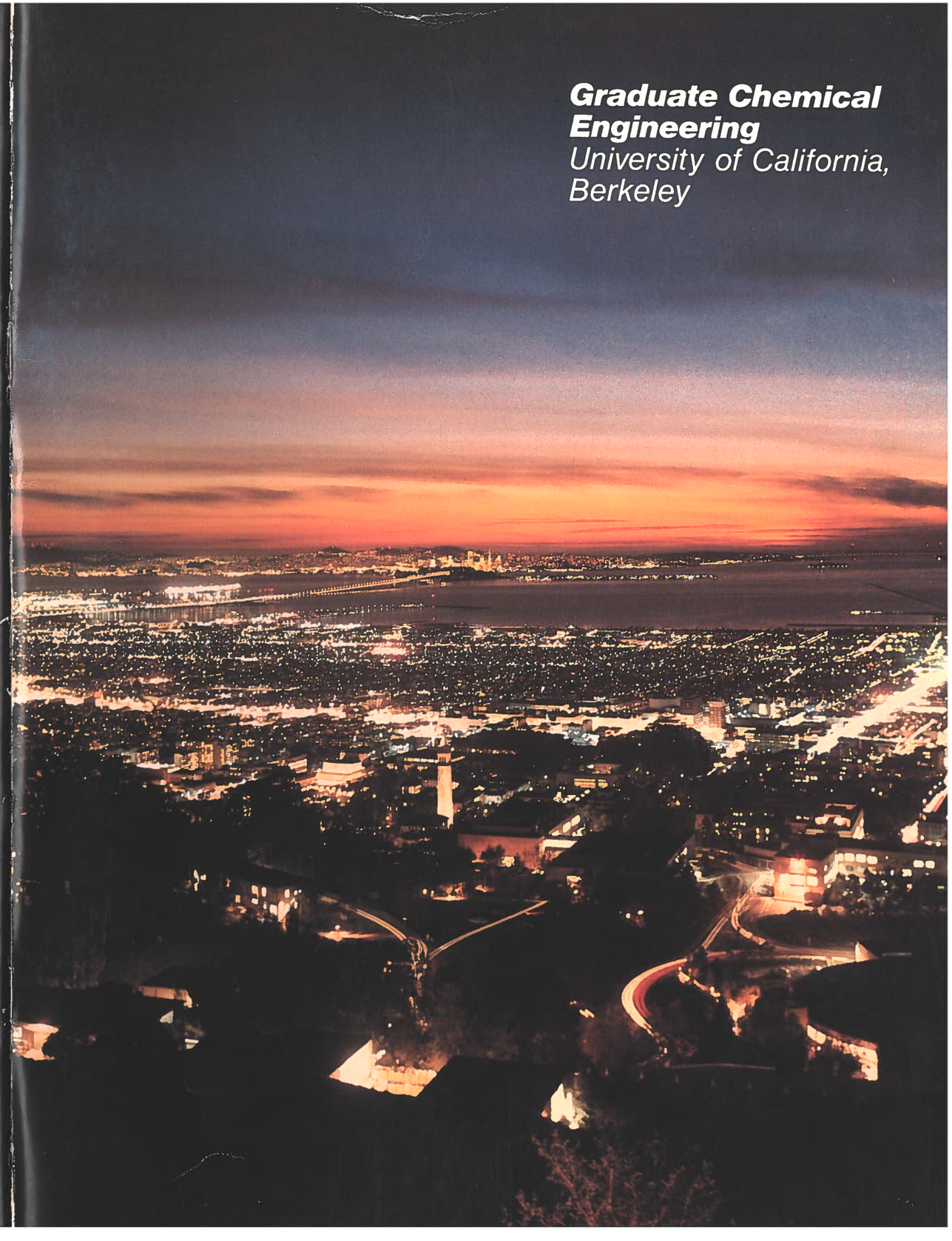
Graduate Chemical Engineering

University of California, Berkeley



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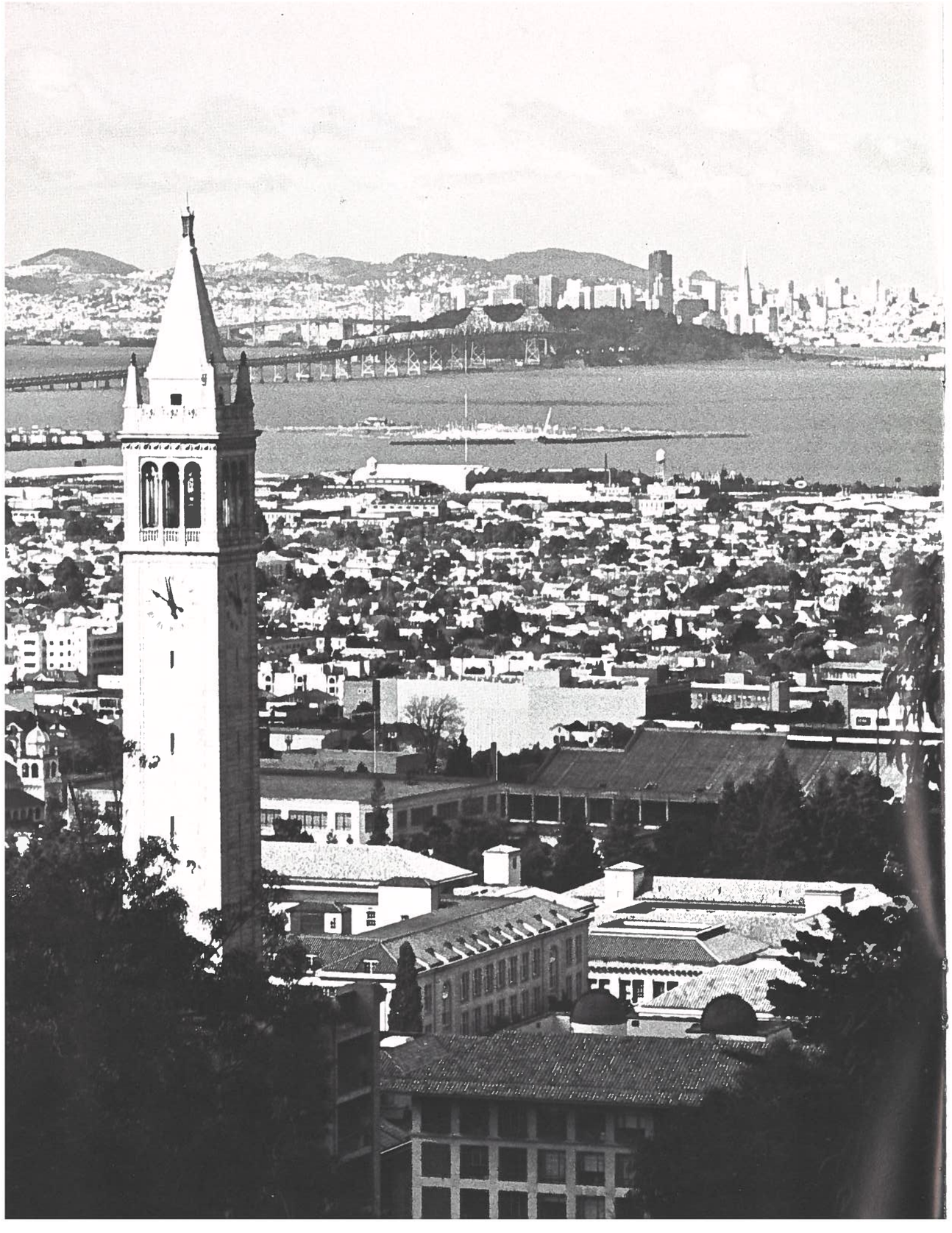


The University

Berkeley is the original campus of the University of California. Its official charter was granted by the legislature in 1868, when it was created from the 10 faculty and 40 students of a small college in Oakland. By 1873 it had expanded to 20 faculty and 189 students and had moved a few miles north to its permanent home on the slopes of the Berkeley hills, where it now occupies 1232 acres of rolling, wooded parklands overlooking San Francisco Bay. The statewide University has grown to a total enrollment of 130,000 students with 6,000 faculty on nine major campuses. The campus at Berkeley now enrolls 31,000 of the total and heavily emphasizes graduate work; 9,000 of the students here are in the graduate program.

From its small beginning, Berkeley has grown to become one of the major centers of scholarship in the world. It offers students an unrivaled breadth and depth of inquiry with its distinguished faculty and its 300 degree programs. The faculty includes 11 Nobel Laureates, 88 members of the National Academy of Sciences, and 46 members of the National Academy of Engineering. Twenty-six Berkeley departments are rated among the three best such departments in the nation, and the latest national survey, completed in 1982, again ranks Berkeley as the strongest graduate institution in the country. The quality of the student body, drawn from every portion of the United States and from almost every country of the world, complements the stature of the faculty and contributes significantly to the outstanding achievements of the campus.

The Department

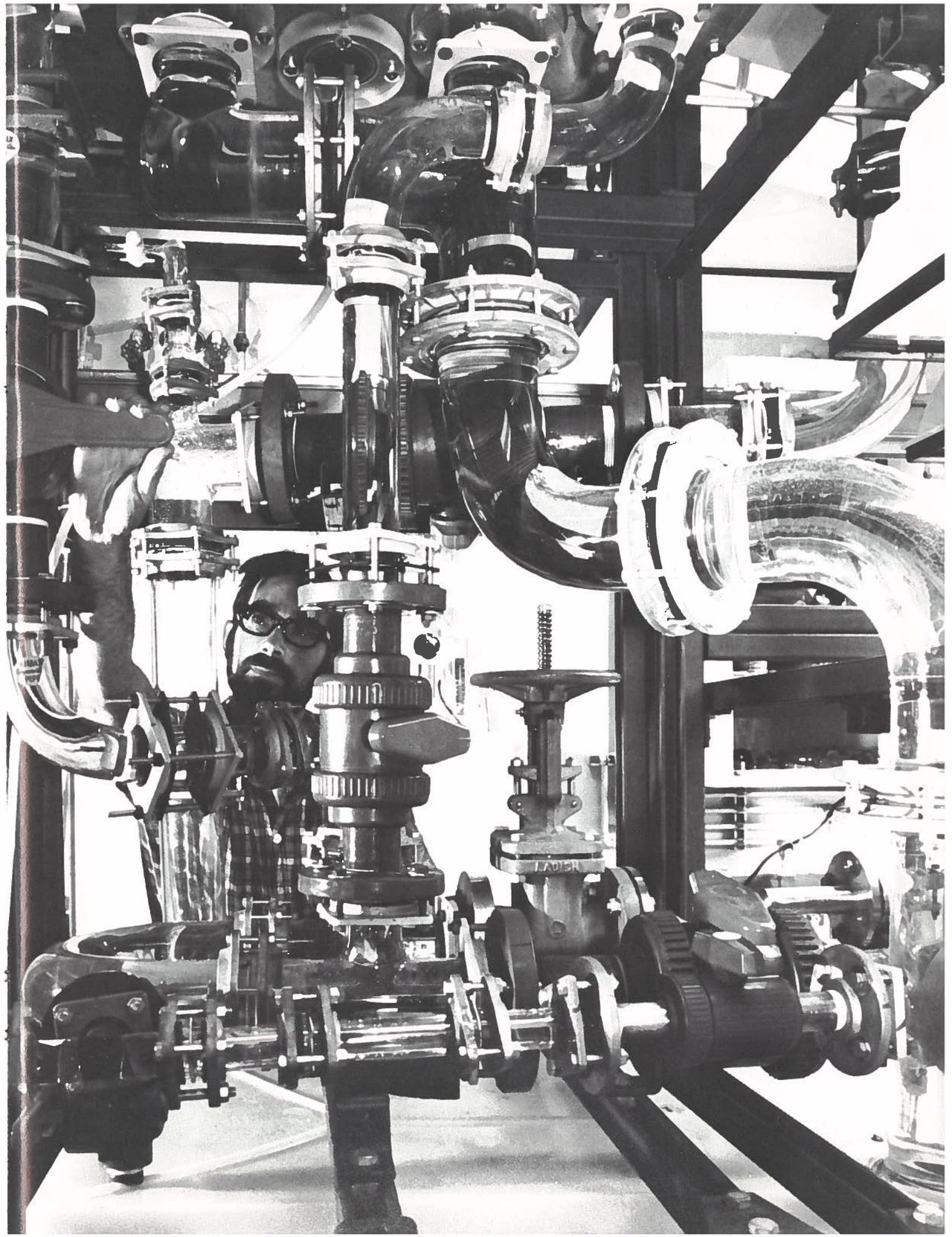
The Chemical Engineering Department at Berkeley was begun only in 1946; today approximately 120 seniors graduate annually. A graduate student group of about 150 is in residence, of whom roughly 25 percent are M.S. candidates and 75 percent are Ph.D. candidates.

Distinctive features characterize Berkeley's Chemical Engineering Department. One is the close affiliation with the Chemistry Department. The Departments of Chemical Engineering and Chemistry make up the College of Chemistry at Berkeley, one of few such college structures in the world. In addition to ready collaboration with the chemistry group, many advantages accrue from this relatively small administrative structure, the College library, joint shops and stores, and other facilities.

Also, Berkeley's Chemical Engineering Department is able to devote a larger share of its effort and resources to the graduate program than is possible at most schools. As a result, both the M.S. program and the Ph.D. program receive the careful attention and full support of the Department. Both degrees require research and the completion of a thesis, and to a great extent graduate education is built around the individual tutorial instruction that accompanies the joint student-faculty research projects.

The graduate program is intended, on the one hand, to give the student extensive competence and understanding through the courses and seminars available within the Department and in the other scientific and engineering departments of the campus. Berkeley presents an unparalleled array of opportunities for expansion of a student's knowledge. On the other hand, the program is designed to instill in students the ability to develop knowledge and insight in whatever specialized area they may enter through the unique learning process provided by the research project.

Research projects span the field of chemical engineering from basic scientific problems to process synthesis and development. As will be apparent from the research interests of the faculty, the field of chemical engineering is thoroughly covered in the projects underway at any particular time. However, the Department has for many years also been devoted to the extension of chemical engineering into new areas of technology. For example, the electrochemical engineering effort at Berkeley is the largest in the nation. Other areas include biochemical engineering, food science, plasma processing, processing of solid state electronic materials, and the application of chemical engineering to semiconductor device manufacturing. The pursuit of such novel and forward-looking areas is an important aspect of the program.



Faculty of the Department of Chemical Engineering

Alexis T. Bell, Professor and Chairman, S.B. 1964, Sc.D. 1967, Massachusetts Institute of Technology

Harvey W. Blanch, Professor, B.Sc. 1968, University of Sydney; Ph.D. 1971, University of New South Wales

E. Morse Blue, Lecturer, B.S. 1934, University of California, Berkeley; M.S. 1937, Massachusetts Institute of Technology; employed at Chevron Research Company (retired)

LeRoy A. Bromley, Professor (Emeritus), B.S. 1941, University of California, Berkeley; M.S. 1943, Illinois Institute of Technology; Ph.D. 1948, University of California, Berkeley

Elton J. Cairns, Professor, B.S. 1955, Michigan Technological University; Ph.D. 1959, University of California, Berkeley

Morton M. Denn, Professor, B.S.E. 1961, Princeton University; Ph.D. 1964, University of Minnesota

Alan S. Foss, Professor, B.S. 1952, Worcester Polytechnic Institute; M.Ch.E. 1954, Ph.D. 1957, University of Delaware

Simon L. Goren, Professor, B.S. 1958, D.E.S. 1962, Johns Hopkins University

David B. Graves, Assistant Professor, B.S. 1978, M.S. 1981, University of Arizona; Ph.D. 1985, University of Minnesota

Edward A. Grens, II, Professor, B.S. 1953, M.S. 1960, Ph.D. 1963, University of California, Berkeley

Donald N. Hanson, Professor, B.S. 1940, University of Illinois; M.S. 1941, Ph.D. 1943, University of Wisconsin

Heinz Heinemann, Lecturer, Ph.D. 1937, University of Basel; employed at Lawrence Berkeley Laboratory

Dennis W. Hess, Professor, B.S. 1968, Albright College; M.S. 1970, Ph.D. 1973, Lehigh University

C. Judson King, Professor and Dean of the College of Chemistry, B.E. 1956, Yale University; S.M. 1958, Sc.D. 1960, Massachusetts Institute of Technology

Scott Lynn, Professor, B.S. 1950, M.S. 1951, Ph.D. 1954, California Institute of Technology

David N. Lyon, Professor (Emeritus), B.A. 1940, M.A. 1942, University of Missouri; Ph.D., 1948, University of California, Berkeley

James N. Michaels, Assistant Professor, B.S. 1976, M.S. 1977, University of California, Berkeley; Diploma 1978;, Imperial College of Science and Technology, London, Sc.D. 1982, Massachusetts Institute of Technology

Rolf H. Muller, Lecturer, M.S. 1953, Ph.D. 1956, Swiss Federal Institute of Technology; Employed at Lawrence Berkeley Laboratory

John S. Newman, Professor, B.S. 1960, Northwestern University; M.S. 1962, Ph.D., 1963, University of California, Berkeley

Eugene E. Petersen, Professor, B.S. 1949, M.S. 1950, University of Washington; Ph.D. 1953, Pennsylvania State University

John M. Prausnitz, Professor, B.Ch.E. 1950, Cornell University; M.S. 1951, University of Rochester; Ph.D. 1955, Princeton University

David E. Quady, Lecturer, B.S. 1963, M.S. 1964, Ph.D. 1968, University of Wisconsin; employed at Chevron Resources Company

Clayton J. Radke, Professor, B.S. 1966, University of Washington; Ph.D., 1971, University of California, Berkeley

Jeffery A. Reimer, Assistant Professor, B.S. 1976, University of California, Santa Barbara; Ph.D. 1980, California Institute of Technology

David S. Soong, Associate Professor, B.S. 1973, National Taiwan University; M.S. 1977, Ph.D. 1978, University of California, Berkeley

Ralda M. Sullivan, Lecturer, B.A. 1952, Stanford University; M.A. 1968, Ph.D. 1975, University of California, Berkeley

Doros N. Theodorou, Assistant Professor, Diploma 1981, National Technical University of Athens; M.S. 1983, Ph.D. 1985, Massachusetts Institute of Technology

Charles W. Tobias, Professor, Dipl. Eng. 1942, Ph.D. 1946, University of Technical Sciences, Budapest

J. Frank Valle-Riestra, Lecturer, B.S. 1948, M.S. 1949, California Institute of Technology; employed at Dow Chemical Company

Fred H. Vorhis, Lecturer, B.S. 1966, M.S. 1968, Cornell University

Charles R. Wilke, Professor, B.S. 1940, University of Dayton; M.S. 1942, Washington State University; Ph.D. 1944, University of Wisconsin

Michael C. Williams, Professor , B.S. 1959, M.S. 1960, Ph.D. 1964, University of Wisconsin

Alexis T. Bell, Chairman, Department of Chemical Engineering

Graduate Courses

Graduate courses offered by the Department of Chemical Engineering are listed below. The numbers in parentheses indicate the unit credit for each course.

230. Theoretical Methods in Chemical Engineering. (3). Mathematical formulations and solution of problems drawn from the fields of heat and mass transfer, fluid mechanics, and reaction kinetics employing vector calculus, ordinary differential equations, Laplace transforms, and partial differential equations. Numerical methods for interpolation, data fitting, integration, and solving differential equations.

232. Computational Methods in Chemical Engineering. (3). Introduction to modern computational methods for treatment of problems not amenable to analytic solutions. Application of numerical techniques to chemical engineering calculations with emphasis on computer methods.

240. Phase Equilibria with Applications of Statistical Mechanics. (3). Molecular thermodynamics of multicomponent systems with applications to separation operations. Equilibrium properties of pure and mixed fluids. Principles of statistical mechanics with emphasis on configurational properties of fluids. Introduction to theories for gases, liquids, polymers and their mixtures, and adsorbed fluids, with applications to separation operations.

244. Applied Chemical Kinetics and Reaction Analysis. (3). Collision theory and transition-state calculations, chain reactions and free-radical mechanisms, adsorption phenomena. Langmuir-Hinshelwood kinetics, description of selected systems of industrial importance. Interaction of chemical and physical rate processes in governing the apparent behavior of chemically reactive systems.

245. Catalysis. (3). Adsorption and kinetics of surface reactions; catalyst preparation and characterization; poisoning, selectivity, and empirical activity patterns in catalysis; surface chemistry, catalytic mechanisms and modern experimental techniques in catalytic research; descriptive examples of industrial catalytic systems.

246. Principles of Electrochemical Engineering. (3). Electrode processes in electrolysis and in galvanic cells. Charge and mass transfer in ionic media. Criteria of scale-up.

248. Applied Surface and Colloid Chemistry. (3). Principles of surface and colloid chemistry with current applications; surface thermodynamics, wetting, adsorption from solution, disperse systems, association colloids, interacting electrical double layers and colloid stability, kinetics of coagulation, and electrokinetics.

249. Biochemical Engineering. (3). Application of chemical engineering principles to the processing of biological and biochemical materials. Design of systems for cultivation of microorganisms and for the separation and purification of biological products.

250. Process Fluid Mechanics. (3). An advanced-level first course in fluid mechanics, with emphasis on topics relevant to problems of the processing industries. Development of basic conservation equations, constitutive equations for Newtonian and elementary non-Newtonian fluids; exact solutions; ordering and approximation; applications at low and high Reynolds numbers, including convective mass and heat transfer.

251. Mass Transfer and Separation Processes. (3). Methods for separating homogenous mixtures. Computational approaches for binary and multi-component separations, carried out in simple continuous and batch contactors, and in staged and countercurrent equipment. Diffusion and interphase mass transfer. Effects of high flux and simultaneous reaction. Patterns of change and energy consumption in separation processes. Selection of separation techniques.

256. Advanced Transport Phenomena. (3). Formulation and rigorous analysis of the laws governing the transport of momentum, heat, and mass, with special emphasis on chemical engineering applications. Detailed investigation of laminar flows.

257. Polymer Rheology and Melt Processing. (3). Rheological properties of polymers. Continuum and molecular models. Analysis of flow processes including extrusion, calendering, fiber spinning, wire coating, and mixing.

258. Polymerization Reaction Engineering. (3). Polymerization mechanisms and kinetics. Principles of polymerization reactor design including reactor dynamics, optimization, and control.

260. Optimization in Chemical Process Design. (3). Applications of linear and nonlinear mathematical programming to problems of optimum design and operation of chemical processes.

261. Process Simulation. (3). Introduction to simulation by digital computer programs of chemical processes operating in the steady state. Emphasis on decomposition of recycle systems. Practice in simulation of simple units and processes.

262. Computer Control of Chemical Processes. (3). Synthesis and implementation of digital control systems for complex systems. Control configurations, process modeling and identification, multivariable and adaptive controls. Applications to distillation, combustion, heat exchange, and flow reactors.

263. Chemical Process Economics and Project Evaluation. (3). Methods used by the chemical and petroleum industry to evaluate the commercial worth of processes using accepted economic, marketing, and managerial factors. Practice is offered through the medium of unstructured and open-ended projects involving group participation and individual efforts.

265. Design and Engineering of Integrated Chemical Process Systems. (3). Consideration of specific, realistic cases involving the synthesis, evaluation, selection, and optimization of processing alternatives. Qualitative and quantitative studies. Criteria for engineering judgment and economic evaluation.

295. Special Topics in Chemical Engineering. Current and advanced study in chemical engineering, primarily for advanced graduate students.

- 295B. Studies in Electrochemical, Hydrodynamic, and Interfacial Phenomena. (2).
- 295C. Advanced Topics in Transport Phenomena. (2).
- 295E. Special Topics in Electrochemical Energy Conversion. (2).
- 295K. Chemistry of Extraction Processes. (2).

296. Special Study for Graduate Students in Chemical Engineering. (1-6). Special laboratory and theoretical studies. May be repeated for credit. Must be taken on satisfactory/unsatisfactory basis only.

298. Seminar in Chemical Engineering. (1). Lectures, reports, and discussions on current research in chemical engineering. Sections are operated independently and directed toward different topics. May be repeated for credit. Must be taken on satisfactory/unsatisfactory basis only.

299. Research in Chemical Engineering. (1-12). Research. May be repeated for credit. Must be taken on satisfactory/unsatisfactory basis only.

Professional Courses

300. Professional Preparation: Supervised Teaching of Chemical Engineering. (2). Discussion, problem review and development, guidance of large scale laboratory experiments, course development, supervised practice teaching. May be repeated for credit. Must be taken on satisfactory/unsatisfactory basis only.

602. Individual Studies for Graduate Students. (1-8). Individual study in consultation with the major field adviser for qualified students to prepare themselves for the various examinations required of candidates for the Ph.D. May not be used for unit or residence requirements for the doctoral degree. May be repeated for credit. Must be taken on satisfactory/unsatisfactory basis only.

Specialized undergraduate courses in the Department are also available to graduate students and many courses, both graduate and undergraduate, are available in the various departments of the University. A small fraction of such courses is listed below.

Chemical Engineering:
- 170. Introduction to Biochemical Engineering.
- 171. Transport Phenomena.
- 172. Dynamics and Control of Chemical Processes.
- 173. Particulate Systems.
- 176. Principles of Electrochemical Processes.
- 178. Polymer Science and Technology.
- 179. Process Technology of Solid-State Materials Devices

Chemistry:
- 104. Inorganic Chemistry.
- 113. Advanced Organic Chemistry.
- 204AB. Advanced Topics in Inorganic Chemistry.
- 210AB. Physical Organic Chemistry.
- 220AB. Thermodynamics and Statistical Mechanics.

Physics:
- 141AB. Solid State Physics.
- 142. Introduction to Plasma Physics.
- 180. Physics of Energy Conservation and Use.
- 240AB. Quantum Theory of Solids.

Mathematics:
- 220AB. Applied Mathematics for Physical Sciences and Engineering.
- 228AB. Numerical Solution of Differntial Equations.

Engineering:
- 153. Introduction to Bioengineering.
- 160. Energy and Power

Civil Engineering:
- 212. Water Quality Engineering
- 216. Industrial Water and Wastewater Treatment.
- 218ABC. Air Pollution.
- 221. Finite Element Methods.

Electrical Engineering and Computer Sciences:
- 131. Semiconductor Electronics.
- 137. Electron and Ion Beams and Plasmas.
- 222. Nonlinear Control.
- 231. Solid-State Devices.

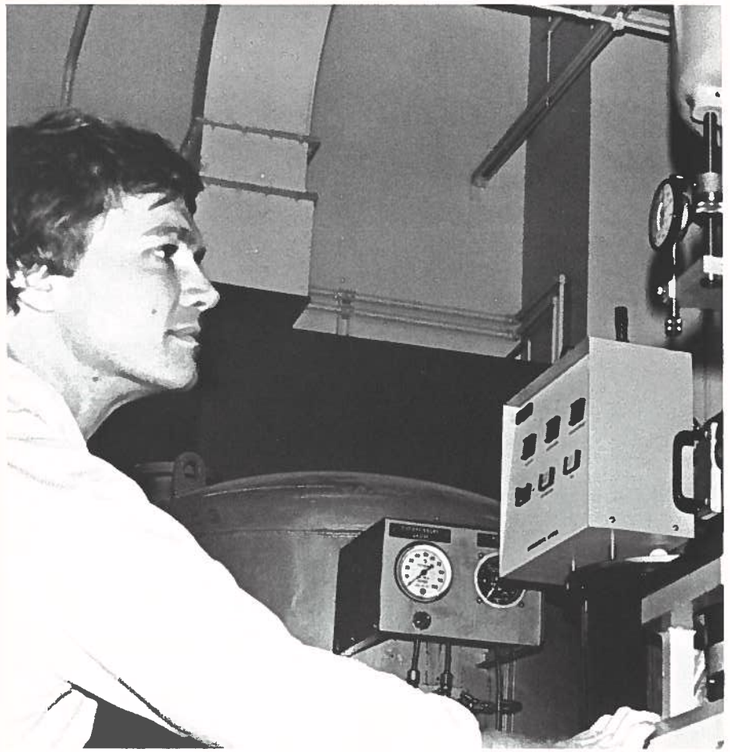
Material Science and Mineral Engineering:
- 112. Corrosion.
- 203. Numerical Methods for Analyzing Fluid Flow in Soil and Rock Systems.
- 224. Solar Energy Materials.

Mechanical Engineering:
- 247. Subsurface Reservoir Characterization.
- 256. Combustion.
- 290G. Kinetic Theory of Rarefied Gases.

Nuclear Engineering:
- 124. Nuclear Chemical Engineering.
- 266. Two Phase Flow and Heat Transfer.

Geology and Geophysics:
- 231. Equilibrium, Mass Transfer, and Kinetics in Geochemical Processes.
- 402. Electron Microscopy and X-Ray Diffraction.

Master of Science Degree



The master's degree program places equal emphasis on advanced course work and on research. A research project and thesis are required of all candidates in order to provide to each student the opportunity for growth and maturity in independent professional activity.

Completion of a minimum of 20 semester units is required by the Graduate Division. At least 14 units must be in letter-graded courses, which must include a minimum of 9 units in graduate level (200) series chemical engineering courses offered by the department; the remaining units may be chosen from the wide variety of courses available in the science, engineering, and business departments of the campus.

Unit credit is also given for graduate research (ChE 299), seminars (ChE 298), and special studies (ChE 296). These courses are graded satisfactory/ unsatisfactory, and are used to make up the remainder of the 20 total units required.

The specific courses taken in the master's program are selected in consultations between students and their academic advisers. Students are encouraged both to broaden their knowledge and to pursue particular specialized interests through their choice of courses.

Selection of a research topic is made early in the first semester after students have discussed prospective research projects with faculty members whose research areas are of special interest to them. The length of time spent in completion of the program varies, depending principally on the schedules which the students set for themselves in their research. The Graduate Division requires at least two semesters in residence. Many students complete their programs in fifteen months. The average residence time is twenty months.

Doctor of Philosophy Degree

The Ph.D. program is designed to ensure breadth of knowledge and, more importantly, to discover and develop talents for original, productive, and creative work in chemical engineering.

Breadth of knowledge is achieved through advanced course work, both in areas central to chemcial engineering and in areas outside the field. Emphasis on the latter is in recognition that practicing chemical engineers draw increasingly on information from other disciplines. The course requirement, therefore, consists of a 15-unit program in chemical engineering and a 9-unit sequence in an outside specialty, making a total of 24 letter-graded units, at least 18 of which must be at the 200-series level. These graded units should be viewed as a basic course requirement; the student is strongly encouraged to pursue additional courses of specific relevance to the thesis research and to explore other areas of technical, professional, or personal interest. In general, graduate courses taken as part of an M.S. program at Berkeley or another school can be counted.

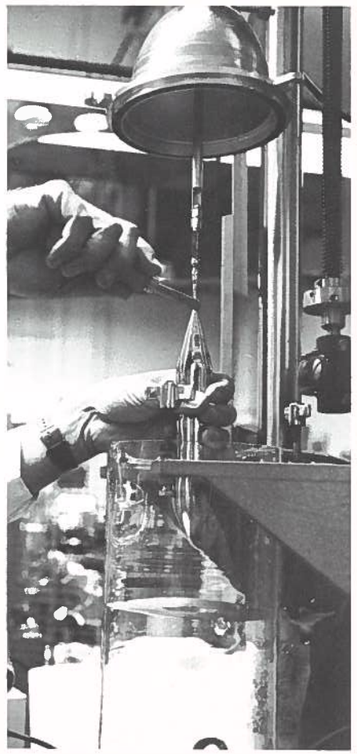
To develop the creative talents of the student, a paramount emphasis in the Ph.D. program is placed on intensive thesis research, a project on which the student works closely with one or more members of the faculty. Students are expected to consult extensively with faculty members regarding the research project early in their first semester. The choice of a research project takes place in the first semester, and students begin their research at that time. As part of the preparation for the qualifying examination the student is expected to make substantial progress on the research project during the first year, particularly in mastering the background knowledge necessary and developing a carefully constructed plan for execution of the project. In addition, students concentrate on course work during the first year.

Two departmental examinations are required. An oral preliminary examination, at the end of the first semester, ensures adequate knowledge of fundamental undergraduate course material. Deficiencies found in the preliminary examination are remedied by appropriate courses.

The second examination, the oral qualifying examination, consists of two parts taken at the same time. The main part is a formal presentation of the student's research program, including review of the most relevant literature, accomplishments to date, and a future plan. The other part requires the student to propose and describe an original research problem, which, if it were carried out, would be expected to make a significant contribution to chemical engineering knowledge. The student is expected to demonstrate mastery of the fundamentals, a general proficiency in the research area, and the ability to identify and attack in a preliminary way an unsolved problem in areas of interest to chemical engineers. The qualifying examination must be taken before the end of the third semester in residence.

In addition, the department requires that each Ph.D. graduate student assist in the instructional program of the department as a teaching assistant during two semesters, normally during one semester in each of the second and third years. The department regards such experience as highly valuable for all graduate students and especially for those Ph.D. graduates of the department who plan to enter teaching as a career.

Following passage of the examinations, students spend most of their time on their Ph.D. research projects. Completion of the Ph.D. degree occurs with the filing of the student's dissertation. The time for completion of the Ph.D. is highly variable, from three to five years, averaging four and one-half years. Students are strongly discouraged from spending more than five years in residence.



Graduate Admissions

Formal admission to the graduate programs of the University is granted by the Graduate Division in consultation with and on the recommendation of the department. Admission to graduate school generally requires evidence of superior performance in the last two years of undergraduate studies. In addition, the department requires submission of test scores for the aptitude portion of the Graduate Record Examination (GRE); the advanced test is not required. Letters of recommendation from professors or colleagues familiar with the applicant's academic and professional aptitudes are also required, and admission is based on the weight of evidence from all sources.

Most students applying for the graduate program will have completed a typical undergraduate program in chemical engineering. However, students are admitted with undergraduate degrees in other related disciplines. Such students are normally admitted to the M.S. program, and the necessary background courses in chemical engineering are taken as part of the program for the first year. A portion of the background material can be credited toward fulfillment of the M.S. degree. Students who so desire may be admitted to the Ph.D. program after a satisfactory demonstration of their aptitude for chemical engineering studies.

Students are accepted to begin their graduate program in both the fall and spring semesters. For admission to the fall semester, applications should be submitted by the late fall of the preceding year, and applications should be submitted for spring admission in the summer of the preceding year.

Processing of admissions is done principally through the department. Completed applications, transcripts, and letters of recommendations should be sent directly to:

Department of Chemical Engineering
Graduate Office
University of California, Berkeley
Berkeley, CA 94720

Material sent to the Graduate Division will be forwarded to the department but will be delayed. The department welcomes applications and is happy to respond to any inquiries regarding the graduate program. Many questions can be answered through a telephone call to the Graduate Secretary of the department, Mrs. Kay Ekman, at (415) 642-1533. Visits are also encouraged and provide the best opportunity to become acquainted with the faculty, students, and research underway in the department. Prospective students who plan to be in the Bay Area are invited to stop by.

Financial Support

Support of students during their graduate work is available in the form of research assistantships, teaching assistantships, and fellowships. Prospective students are automatically considered for all means of support on receipt of their application for admission. Essentially all students admitted are provided with financial support throughout the year, including the summer if the student remains in the department during that peirod.

Research assistantships provide the major financial aid for students in the department, and they are given to support students directly in the conduct of their thesis research. No auxiliary work or research work unrelated to the thesis is required to obtain such support. Master's degree students are usually supported completely through research assistantships. Ph.D. students are supported through a combination of teaching assistantships and research assistantships. Teaching assistantships are used as the means of appointment during the two semesters in the second and third year in which the student is fulfilling the departmental requirement of two semesters of teaching experience. During the remaining periods of their programs, Ph.D. students are also supported through research assistantships. Both types of assistantships provide the same stipend.

Withholding tax is normally removed from the stipend provided under assistantships. However, the present ruling of the IRS agrees with the department's position that the research assistantship is essentially a fellowship, thus allowing students to obtain a rebate of all taxes withheld under the research assistantship. By filing a simple form, withholding can even be avoided.

Fellowships are available both through the University and through the department. University Fellowships are awarded through a campus-wide competition from funds available to the Graduate Division. Decision on the awarding of University Fellowships are made by the Graduate Division, but the department again processes the applications and applies for University Fellowships for all highly qualified applicants who have requested admission. Stipends under such fellowships are normally low, but they are supplemented by partial assistantships to a level above the normal assistantship. Students are also urged to investigate all possible outside sources of fellowship support or other means of support. The National Science Foundation and the Hertz Foundation have proved to be excellent sources.

Fellowships are also available through the department from funds dedicated to this purpose by industry, and while a majority of funding for general assistantships comes from the federal government, industrial grants for support of research in the department are of great and growing importance. Donors of such funds include:

ACS Petroleum Research Fund
The Air Products Foundation
Alcoa Foundation
Allied Foundation
Amoco Foundation
Atlantic Richfield Company
Bechtel Foundation
Center for Biotechnology Research
Chevron Corporation
Chevron Research Company
The Clorox Company
CPC International
Dow Chemical U.S.A.
Dow Corning Corporation
The Camille and Henry Dreyfus Foundation
E.I. duPont de Nemours & Company
Eastman Kodak Company
Elf Technologies
Exxon Education Foundation
Exxon Research and Engineering Company
Fairchild Camera and Instrument Corporation
FMC Corporation
The General Electric Foundation
General Motors Research Laboratories
W.R. Grace & Company
International Business Machines Corporation
Marathon Oil Company
Measurex Corporation
Merck & Company
Mobil Research and Development Corporation
Optical Coating Laboratory
Owens-Corning Fiberglas Corporation
Procter & Gamble Company
Raychem Corporation
The Shell Companies Foundation
Sohio Petroleum Company
Stauffer Chemical Company
Texaco
Union Carbide Corporation
Union Oil Company of California
Universal Oil Products Foundation
Xerox Foundation

Facilities

C. Judson King (right)
Dean of the College of Chemistry

The College of Chemistry is housed in a cluster of four buildings arranged in a quadrangle so that all facilities are readily accessible. The Department of Chemical Engineering utilizes space principally in three of the buildings, Gilman Hall, Lewis Hall, and Hildebrand Hall, for its research and teaching.

The cluster includes a large branch library, devoted solely to chemistry and chemical engineering, which contains about 24,000 volumes and 450 journals. Branch libraries also exist for Physics, Mathematics, and the College of Engineering, all located within approximately 100 yards of the College of Chemistry,. The combined facilities of these branch libraries offer a superb collection for literature work, more than adequate for almost all projects, and backed up when necessary by the 6,500,000 volumes and 99,000 current serial publications of the main library, which is 200 yards away.

Chemical Engineering's proximity to the Department of Chemistry provides ready access to an array of modern chemical instruments. General facilities such as an Analytical Services Laboratory and a Mass Spectrometry Laboratory also offer routine analyses, normally within a day. Shop facilities and storerooms are all located within the college complex and provide an outstanding series of services. The main machine shop manufactures precision scientific machinery; two spectrometers built in the shop formed part of the Mariner Project which took the first infrared spectra of Mars. Essentially any experimental apparatus can be built in the ships. For minor projects, a well-equipped student shop is available. Completion of an informal short course in the operation of lathes, drill presses, mills, and other equipment, taken at convenient hours for the student, entitles one to a key to the shop.

Many dedicated microcomputers are in use by various research groups. In addition, the University Computer Center operates an IBM 3081 computer which can be readily accessed for interactive operation from CRT facilities in the Department complex. The Lawrence Berkeley Laboratory, operated by the University for the U.S. Department of Energy and situated in the hills immediately east of the College, provides two CDC 7600 computers which can also be run from terminals within the department. Computer time for essentially all research is provided at no cost.

The department also utilizes the facilities of the Lawrence Berkeley Laboratory. The laboratory conducts research in physics, chemistry, and a few related areas of engineering. Chemical engineering participates substantially in the work of three of the laboratory divisions, the Applied Science Division, the Materials and Molecular Research Division, and the Center for Advanced Materials, using laboratories located both in LBL and in the College of Chemistry.

Housing

Accommodations are available at the University and in the surrounding community through several sources.

University Village
University Village is a low-rent apartment development operated by the University primarily for married students. It is situated four miles from campus on eight acres and has 902 units, ranging from studio apartments to three-bedroom apartments. Child care services are available, and the complex is served by excellent public transportation.

Detailed information and applications can be obtained from the Housing Office, University of California, Berkeley, 2401 Bowditch Street, Berkeley, CA 94720.

International House
I-House, located very near the department, houses primarily graduate students; the group is deliberately kept at half American students and half foreign students. Room and board are provided and many group activities are available. For information, contact Office of Residence, International House, Berkeley, CA 94720.

Alpha Chi Sigma
Alpha Chi Sigma is a professional chemistry and chemical engineering fraternity. The Sigma chapter is located in Berkeley, a few minutes' walk from the department.

Local membership is made up principally of graduate students in chemistry and chemical engineering and is co-ed.

Room and board and several amenities such as a Steinway piano, cable TV, etc., are provided. Information and applications can be obtained from the House Manager, Alpha Chi Sigma, 2726 Virginia Street, Berkeley, CA 94720.

University Dormitories and University Co-ops
The University operates several residence halls on the campus which house approximately 3000 students. Seventy percent of the rooms are reserved for students new to the dormitories. Graduate students are eligible and room and board are provided. The University Students' Cooperative Association also owns and operates houses which accommodate 1400 students; each of these facilities is completely operated by the house members.

For information and applications, write to the Housing Office, University of California, Berkeley, 2401 Bowditch Street, Berkeley, CA 94720.

Private Apartments
The Housing Office maintains a large file of apartment listings in the surrounding community, and the majority of chemical engineering students live in quarters of this type, particularly after the first year. Accommodations in such facilities must be arranged in person, but the Housing Office has a staff of counselors to assist students in finding such housing.

San Francisco Bay Area

The San Francisco Bay Area and the other nearby areas of Northern California provide an unparalleled opportunity for cultural and recreational pursuits.

San Francisco is justly regarded as the most scenic city in the United States. Situated at the northern tip of the San Francisco peninsula, it is surrounded on three sides by the Pacific Ocean and San Francisco Bay. Its buildings and streets, located on a succession of steep hills, provide an unending series of exhilarating views in all parts of the city. The mountainous rural Marin peninsula lies just to the north across the Golden Gate Bridge, and the Berkeley-Oakland area lies on the eastern edge of the Bay, across the Bay Bridge. The Berkeley campus is situated directly east of the Golden Gate overlooking San Francisco and the major portion of the Bay. The cover of this publication shows a view from the campus hills.

The Bay Area provides an abundance of cultural events through its theater, symphonies, opera, ballet, jazz festivals, and other programs in the performing arts. Several excellent museums are situated in both the East Bay and San Francisco.

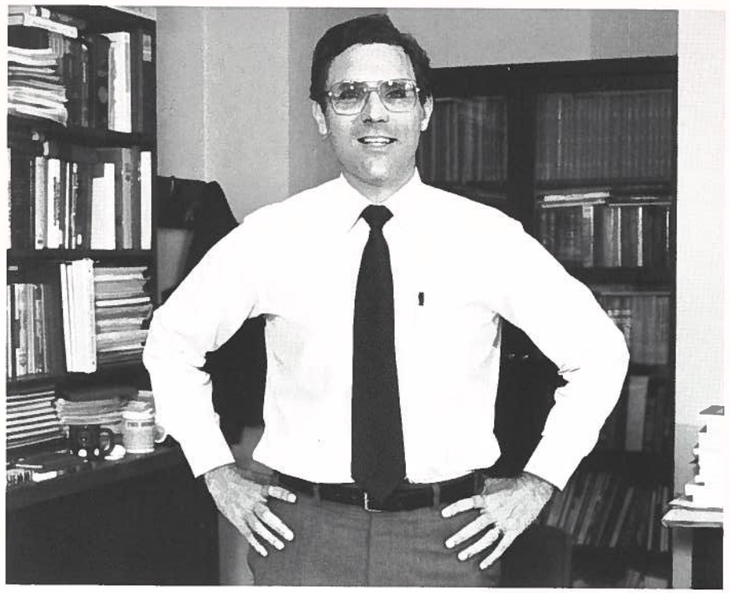
Essentially every cuisine can be enjoyed in the famous restaurants of San Francisco. The scenic Napa Valley, just one hour's drive from Berkeley to the north, produces the best wines of the United States; most wineries welcome visitors and provide free tasting rooms. Professional sports events of every kind abound in the area, and the mild climate provides a year-round opportunity for such outdoor sports as sailing, tennis, and golf. The normal daily maximum temperature in Berkeley is about 65°F. Because of the tempering action of the ocean, hot days are relatively rare in Berkeley, and snow creates headlines.

Northern California enjoys a wealth of opportunity for those interested in hiking, camping, skiing, or just sightseeing. A few hours to the south of the Bay Area along the coast are Monterey, Carmel, and the Big Sur area where the coast range reaches the ocean. To the north are the Mendocino coast, the redwoods, Lassen National Park, and Mount Shasta. In the Bay Area itself, Mount Diablo, Mount Tamalpais, Muir Woods, and the Point Reyes National Seashore provide many scenic facilities.

Two or three hours to the east of the Bay Area are the Sierra Nevada, whose foothills contain California's historic gold country. Further up, in the high Sierra, the Lake Tahoe area, Yosemite and Sequoia National Parks, and Kings Canyon offer unexcelled mountain hiking and camping in the summer. In winter, the many ski areas are easily reached from the Bay Area.

Faculty and Research

Alexis Bell



Alexis T. Bell, Professor, born 1942; S.B. Massachusetts Institute of Technology (1964); Sc.D. Massachusetts Institute of Technology (1967); Curtis W. McGraw Research Award of the American Society of Engineering Education (1981); Professional Progress Award of the American Institute of Chemical Engineers (1983); Donald L. Katz Lecturer, University of Michigan (1984); Paul H. Emmett Award in Fundamental Catalysis of the Catalysis Society (1985); Editor, Catalysis Reviews—Science and Engineering; Assistant Dean, College of Chemistry (1979–1981); Chairman, Department of Chemical Engineering (1981 to date); Faculty Senior Scientist, Materials and Molecular Research Division and Center for Advanced Materials, Lawrence Berkeley Laboratory.

My research interests are in the fields of heterogeneous catalysis and reaction engineering. One of the goals of my work on heterogeneous catalysis is to understand the relationships between catalyst composition and morphology and catalyst performance. Another goal is to develop the understanding of catalysis in terms of the elementary processes occurring on the catalyst surface. These investigations are being carried out using catalysts in the form of supported transition metals, bulk compounds, and zeolites. Measurements of reaction kinetics are complemented by information obtained from a variety of spectroscopic techniques. Recent studies in my group have dealt with the synthesis of hydrocarbons and oxygenated compounds from CO and H_2, the catalytic reduction of NO, and the hydrogenation and hydrogenolysis of coal. At present we are engaged in understanding the details of carbon formation and consumption during Fischer-Tropsch synthesis, the influence of metal-support interactions on methanol synthesis and NO reduction, and the influence of catalyst synthesis conditions on catalyst activity and selectivity.

Another topic of interest is understanding how catalyst synthesis influences the properties of metal, metal compound, and zeolite catalysts.

"^{13}C NMR Spectra of Carbonaceous Deposits on Silica-Supported Ruthenium Catalysts" (with T.M. Duncan and P. Winslow), *J. Chem. Phys. Lett.*, **102** (2,3), 163–167 (1983).

"Influence of Adsorption and Mass Transfer Effects on Temperature-Programmed Desorption from Porous Catalysts" (with Jeffery S. Rieck), *J. Catal.*, **85,** 143–153 (1984).

"Application of Transient Response Techniques for Quantitative Determination of Adsorbed Carbon Monoxide and Carbon Present on the Surface of a Ruthenium Catalyst during Fischer-Tropsch Synthesis" (with P. Winslow), *J. Catal.*, **86,** 158–172 (1984).

"Reduction of NO by H_2-CO Mixtures over Silica-Supported Rhodium: Infrared and Kinetic Studies" (with William C. Hecker), *J. Catal.*, **88,** 289 (1984).

"Characterization of the Preparation of Pd/SiO_2 and Pd/La_2O_3 by Laser Raman Spectroscopy" (with Shirley S. Chan), *J. Catal.*, **89,** 433 (1984).

"Effects of Metal-Support Interactions on the Hydrogenation of CO over Pd/SiO_2 and Pd/La_2O_3" (with Robert F. Hicks), *J. Catal.*, **90,** 205 (1984).

Harvey Blanch

Harvey W. Blanch, Professor, born 1947; B.Sc. (First Class Honors) University of Sydney (1968); Ph.D. University of New South Wales (1971); Post Doctoral Fellow, ETH, Switzerland (1971-1973). E.R. Squibb & Sons (1973-74); Faculty of Chemical Engineering, University of Delaware (1974-78); Faculty Senior Scientist, Applied Science Division, Lawrence Berkeley Laboratory.

Our current research program examines the cultivation of bacterial, yeast, mammalian, and plant cells. One major focus is the production of sugars from cellulosic materials by enzymatic hydrolysis, and the subsequent fermentation of these sugars to ethanol, for use as a liquid fuel. We are also examining the growth of hybridoma and mammalian cells to develop high cell density systems for monoclonal antibody and other biologically active materials production. Similar investigations are being carried out on plant and bacterial cell systems. Product recovery from fermentation systems is difficult, and approaches such as affinity chromatography and *in situ* solvent extraction are being examined both theoretically and experimentally to develop recovery systems of sufficient selectivity for the biological metabolities produced. Additional research focuses on mass transfer problems in biological systems.

"Sugars and Chemicals from Cellulose" (with C.R. Wilke), *Reviews in Chemical Engineering, N.R. Amundson and D. Luss, eds.*, **1,** 1 (1982).

"Lactic Acid Production by *Lactobacillus delbreuckii* in a Hollow Fiber Fermenter" (with B. Vick Roy and C.R. Wilke), *Biotechnology Letters*, **48** (8), 483 (1982).

"Water Recycle in Extractive Fermentation" (with T.K. Murphy and C.R. Wilke), *Process Biochemistry* **17**(6), 6, November/December (1982).

"Liquid Circulation Patterns and Their Effect on Gas Hold-Up and Axial Mixing in Bubble Columns," (with James F. Walter), *Chem. Eng. Commun.*, **19,** 243–262 (1983).

"Feed Component Inhibition in Ethanolic Fermentation by *S. cerevisiae," Biotechnol. Bioeng.*, **26,** 1155–1166 (1984).

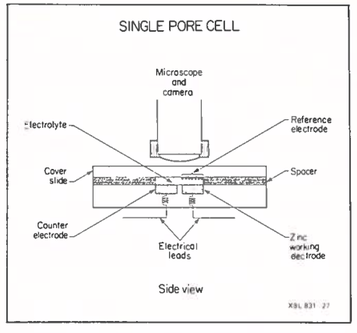
Elton Cairns

Elton J. Cairns, Professor, born 1932; B.S. Chemistry, Michigan Technological University (1955); B.S. Chemical Engineering, Michigan Technological University (1955); Ph.D. Chemical Engineering, University of California, Berkeley (1959); Francis Mills Turner Award (1963); IR-100 Award (1968); Croft Award (1979); Case Centennial Scholar Award (1981); Division Editor, Journal of The Electrochemical Society (1972 to present); Advisory Board, Advances in Electrochemistry and Electrochemical Engineering; National Battery Advisory Committee; Chairman, Physical Electrochemistry Division of The Electrochemical Society (Member, Board of Directors); Vice President of the International Society of Electrochemistry; ACS, AIChE, AIC (Fellow); Associate Director, Lawrence Berkeley Laboratory, and Head, Applied Science Division.

Electrochemical energy conversion is a complex and challenging field of research. Advances made here could make possible new energy systems that have impact on the lives of all of us.

My research is aimed toward the understanding of the complex phenomena that occur in electrochemical energy conversion systems such as secondary (rechargable) batteries and fuel cells. This understanding is then used to design and operate advanced electrochemical cells of very high performance. This research program employs computer-controlled electrochemical cell-testing techniques, scanning electron microscopy, surface x-ray analyses, other x-ray methods, photo-lithography, real-time photo-microscopy, advanced *in situ* spectroscopy of electrode surfaces, and mathematical modeling of electrodes and electrochemical systems.

Current topics of investigation include solid metal electrodes in aqueous electrolytes (e.g., Zn in KOH), single-pore microelectrodes, high-temperature cells with molten-salt or solid electrolytes, photothermal deflection spectroscopy, superacid electrolytes and mixed alkaline electrolytes for oxygen reduction, and photoelectrochemical cells.



Fuel Cells and Fuel Batteries (with H.A. Liebhafsky), John Wiley and Sons, New York, 1968.

"The Zinc Electrode" (with J. McBreen), *Advances in Electrochemistry and Electrochemical Engineering,* C.W. Tobias and H. Gerischer, eds., **11,** p. 273, John Wiley and Sons, New York, 1978.

"Secondary Batteries—New Batteries: High Temperature," *Comprehensive Treatise of Electrochemistry, J.O'M. Bockris, B.E. Conway, E. Yeager, and R. White, eds.,* **3,** p. 341, Plenum Press, New York, 1981.

"Rechargeable Molten Salt Cells," *Proceedings of the Third International Symposium on Molten Salts,* Mamantov, Blander, and Smith, eds., p. 138, The Electrochemical Society, Pennington, N.J., 1981.

"Electrochemical Energy Storage," *Energy and Chemistry,* R. Thompson, ed., p. 252. The Royal Society of Chemistry, London, 1981.

"Computer-Controlled Multiple-Channel System for Electrochemical Experiments" (with M.H. Katz, J.T. Nichols, F.R. McLarnon, and J.E. Katz), *Journal of Power Sources,* **10,** 149 (1983).

"Zinc Electrode Cycle-Life Performance in Alkaline Electrolytes Having Reduced Zinc Species Solubility" (with J.T. Nichols and F.R. McLarnon), *Chemical Engineering Communications,* **37** (1985).

Morton Denn

Morton M. Denn, Professor, born 1939; B.S.E. Princeton University (1961), Ph.D. University of Minnesota (1964); Postdoctoral Fellow, University of Delaware (1964-1965); Faculty, University of Delaware (1965-1981); Guggenheim Fellow (1971-1972); Fulbright Lecturer and Visiting Harry Pierce Professor, Technion, Israel (1979); Visiting Chevron Energy Professor, California Institute of Technology (1980); Visiting Professor, University of Melbourne (1985); Professional Progress Award, American Institute of Chemical Engineers (1977); William N. Lacey Lectureship, California Institute of Technology (1979); Peter C. Reilly Lectureship, University of Notre Dame (1980); William H. Walker Award, American Institute of Chemical Engineers (1984); Bicentennial Lectureship, Louisiana State University (1984); Editor, AIChE Journal; Editorial Board, Journal of Non-Newtonian Fluid Mechanics; Program Leader, Polymers and Polymer Composites, Center for Advanced Materials, LBL.

My research has generally been in two areas: polymer processing and chemical process analysis. We are currently investigating a variety of problems in polymer processing, ranging from the onset of flow instabilities in polymer liquid crystals and fiber orientation distribution in the molding of polymer composites to the dynamics of the fiber spinning process. The emphasis in all of this work is on the interactions between the material rheology and the processing geometry and conditions, with the goal of developing procedures for prediction of final properties. We use all of the tools necessary to enable us to achieve this goal: analysis, numerical computation, and experiment.

My recent work on process analysis outside the polymers area has focused on coal gasification reactors. We have been using tools of mathematical modeling to study the operability regions of gasification reactors, and using the understanding gained from our modeling to explore new concepts in reactor operation. We are currently seeking to understand the gas-phase mechanics in the combustion zone of moving bed gasifiers.

"Fiber Spinning," *Computational Analysis of Polymer Processing,* J.R.A. Pearson and S. Richardson, eds., p. 179, Applied Science Publ. (Elsevier) 1983.

"Capillary and Slit Methods of Normal Stress Measurements" (with D.V. Boger), *J. Non-Newtonian Fluid Mech.,* **6,** 163 (1980).

"Computer Simulation of Steady Polymer Melt Spinning" (with D.K. Gagon), *Poly. Eng. and Science,* **21,** 844 (1981).

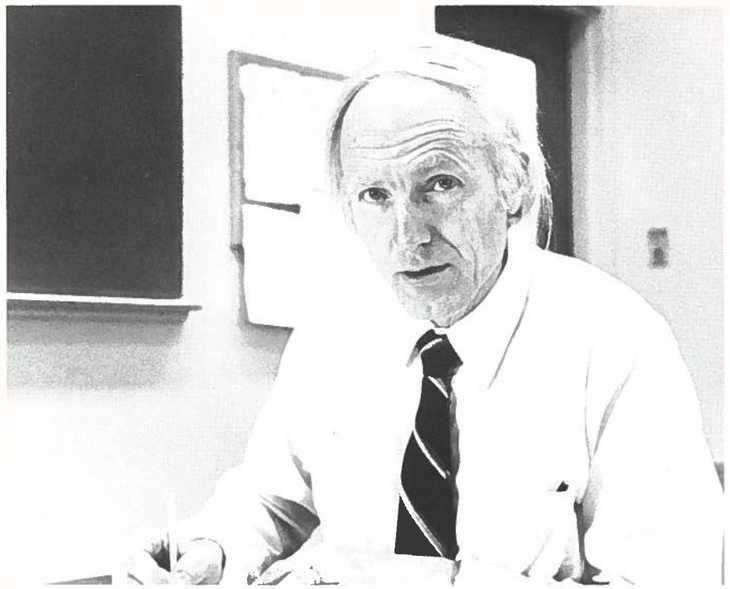
"Dynamic Simulation of Low Speed Melt Spinning" (with J.C. Chang and S. Kase), *Ind. Eng. Chem Fundamentals,* **21,** 13 (1982).

"Radial Effects in Moving Bed Coal Gasifiers" (with W.C. Yu and J. Wei), *Chem. Eng. Sci.,* **38,** 1467 (1983).

"Profile Development in Continuous Drawing of Viscoelastic Liquids" (with R. Keunings and M.J. Crochet), *Ind. Eng. Chem. Fundamentals,* **22,** 347 (1983).

"Constitutive Equations Based on the Transient Network Concept" (with J. Mewis), *J. Non-Newtonian Fluid Mech.,* **12,** 69 (1983).

Alan Foss



Alan S. Foss, Professor, born 1929; B.S. Worcester Polytechnic Institute (1952); M.Ch.E. and Ph.D., University of Delaware (1954, 1957). Research Engineer and Research Project Engineer, E.I. duPont de Nemours & Co. (1956-61). Chemical Engineering Department, University of California, Berkeley.

Research is in progress on various problems arising in the operation of industrial chemical processes. The studies center around maintenance of process stability and optimization of process operating objectives.

We presently have under study an autothermal fixed-bed catalytic reactor that tends toward instability when attempts are made to maximize production rate and when large disturbances afflict the reactor. Mathematical models are used to assess the relative stability of the reactor at any time and to provide information for skirting difficulties. These ideas are tested on an experimental laboratory reactor; a dedicated minicomputer system performs the diagnosis of the difficulties and the control calculations.

Interactive graphics and computing systems are under development to speed the synthesis of process control systems. Multiloop control systems are sketched directly on a video display and a data base concurrently established that defines the control linkages sketched. Such information can be output to on-line control computers or to control programs used with process simulations. The graphical mode of configuring the control systems expedites the rapid evaluation of alternative systems.

"Multi-Bed Catalytic Reactor Control Systems: Configuration Development and Experimental Testing" (with J.M. Silva and P.H. Wallman), *Ind. Engr. Chem. Fundam.*, **18** (4), 383-391 (1979).

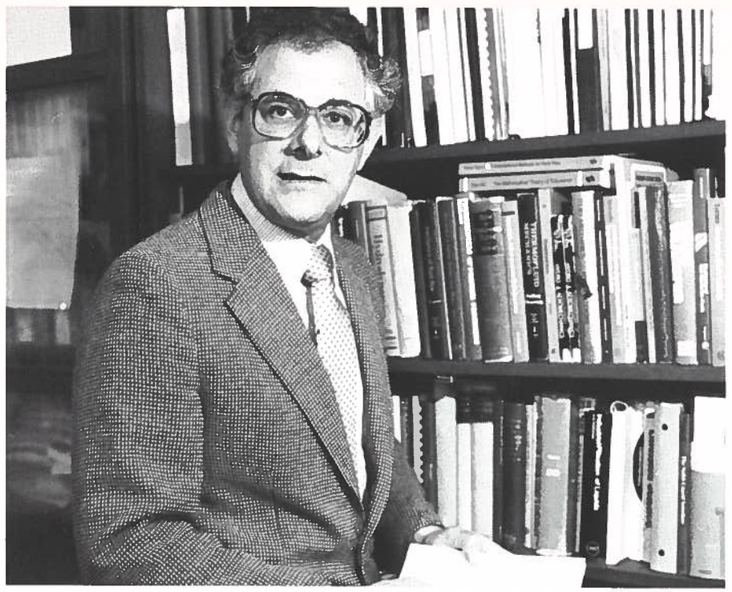
"Multi-variable Integral Controls for Fixed-Bed Reactors" (with P.H. Wallman and J.M. Silva), *Ind. Engr. Chem. Fundam.*, **18** (4), 392-399 (1979).

"Multi-variable Control System for Two-Bed Reactors by the Characteristic Locus Method" (with J.M. Edmunds and B. Kouvaritakis), *Ind. Engr. Chem. Fundam.*, **19** (1), 109-117 (1980).

"Experiences with Dynamic Estimators for Fixed-Bed Reactors" (with P.H. Wallman), *Ind. Engr. Chem. Fundam.*, **20** (3), 234-239 (1981).

"Rapid Set Point Attainment of a Reactor Feed Preheat System and Coordination with Reactor Control" (with A. Lappinga), *Proceedings 1984 Amer. Control. Conf., p. 1602.*

Simon Goren



Simon L. Goren, Professor, born 1936; B.S., The Johns Hopkins University (1958); D. Eng, The Johns Hopkins University (1961); Research Engineer, Esso Research and Engineering (1961-62); Assistant Professor (1962-67), Associate Professor (1967-71), and Professor (1971-present), University of California, Berkeley; Program Director, National Science Foundation (1977-78); President, Fine Particle Society (1981-83); Vice President, American Association for Aerosol Research (1982-present); Academic Adviser, International Fine Particle Research Institute (1982-83).

My research deals with formation, dynamics, and separation of particulate systems. This research requires a synthesis of fluid mechanics with physical chemistry. The first is needed to understand the motion of small particles in response to various forces, especially in the vicinity of collectors or other small particles. The second is needed to understand how interparticle forces and other responses depend on particle, fluid, and substrate properties. My approach is a mix of theory and experiment.

At present I am applying these principles to the following projects:

1. ***Smoldering Combustion.*** Billions of dollars are lost and thousands of people are killed or injured each year by fires which originate as slow smoldering of porous fuels. We are studying the smoldering process with emphasis on quantifying the mass generation rate and size distribution of the smoke which is produced.

2. ***Granular Bed Filtration.*** Electric power production using high temperature-high pressure gases generated by pressurized, fluidized bed combustion requires that these gases be cleaned of particulate matter to minimize erosion of the turbines. We are studying high speed gas filtration by granular beds as one technique for gas cleaning in harsh environments.

3. ***Particle-Surface Interactions.*** Impaction of particles onto surfaces occurs in granular bed filtration, pneumatic conveying, and other engineering applications. We are studying the physical processes that may follow particle contact with surfaces at high speeds. Among the phenomena studied are particle bounce, particle attrition, deposit resuspension, and electric charge transfer.

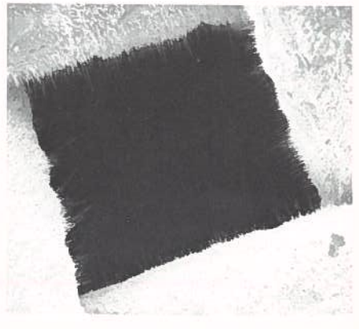
4. ***New Filtration Media.*** Filtration performance could be improved by the development of new filter media. We are growing metal oxide whiskers on wire screens and measuring the particle capture efficiency and pressure drop characteristics of these structures.

"Radionuclide Release from Severe Accidents at Nuclear Power Plants" (with 12 other authors), *Reviews of Modern Physics*, July 1985.

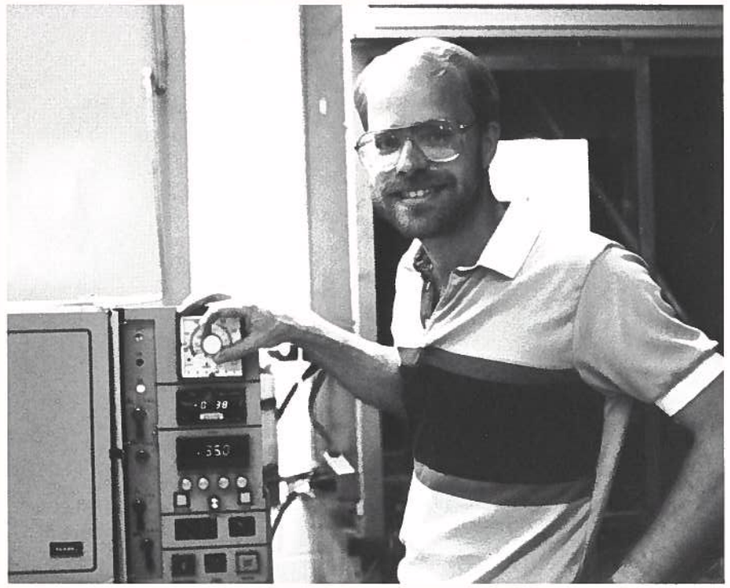
"Evaluation of Metal Oxide Whiskers Grown on Screens for Use as Aerosol Filtration Media" (With J.M. Brewer), *Aerosol Sci. and Tech.* **3,** 411 (1984).

"Aerosol Capture in Granular Beds in the Sedimentation and Diffusion Dominated Regimes" (with L.A. Mann), *Aerosol Sci. and Tech.*, **3,** 195 (1984).

"Aerosol Capture in Granular Beds in the Impaction Dominated Regime" (with T. D'Ottavaio), *Aerosol Sci. and Tech.*, **2,** 91 (1983).



David Graves



David B. Graves, Assistant Professor, born 1955; B.S. 1978, M.S. 1981, University of Arizona; Ph.D. 1985, University of Minnesota; Young Author Award of Electrochemical Society (1983); Member, American Institute of Chemical Engineers, Electrochemical Society, and American Physical Society.

My research interests focus on the fundamental physical and chemical phenomena occurring in low pressure plasma chemical reactors. The primary applications of this research are in thin film deposition and etching, which are key processes in the manufacture of microelectronic devices. Low pressure plasmas are weakly ionized gases with high-energy free electrons and cooler ionic and neutral species. This highly nonequilibrium system is capable of unusual and useful chemistry, but the system complexity makes process design, development and control very difficult. By uncovering the relationship between microscopic fundamentals and macroscopic observables, these intrinsically chemical engineering tasks are made much easier and the processes can be more widely applied.

We have used detailed balance equations to predict the physical structure of radio-frequency discharges. The use of large-scale scientific computers (super computers) has made this approach feasible and represents an important step forward in the modeling of gas discharges. Other approaches are the use of Monte Carlo (direct particle simulation) methods and Boltzmann equation (distribution function) methods. A key challenge here is to effectively exploit advances in computer hardware such as vector processing and multiple processors in implementing these approaches.

Of equal importance are experimental measurements. The recent application of relatively non-intrusive spectroscopic methods has considerably improved our ability to probe plasmas. From plasma-induced emission comes information about the electron density and energy distribution and electronically excited neutral states. From laser-based spectroscopic systems (e.g. laser-induced fluorescence and laser optogalvanic methods) have come information about the chemically important neutral species as well as ionic species and the electric field strengths in the discharge. Both plasma-induced emission and laser-induced fluorescence can be spatially and temporally resolved to reveal variations in plasma properties as a function of position in the discharge and time in the r.f. period.

Perhaps the key feature of this research is the close interaction between modeling predictions and experimental measurements. Both are essential for significant progress. This field is still in its infancy, and opportunities to create new chemical engineering abound.

"Flammability Characteristics and Structure of Pulverized Coal, Laminar Opposed Jet Diffusion Flame" (with J.O.L. Wendt), 19th Symposium (International) on Combustion, *The Combustion Institute,* pp. 1186–1196 (1982).

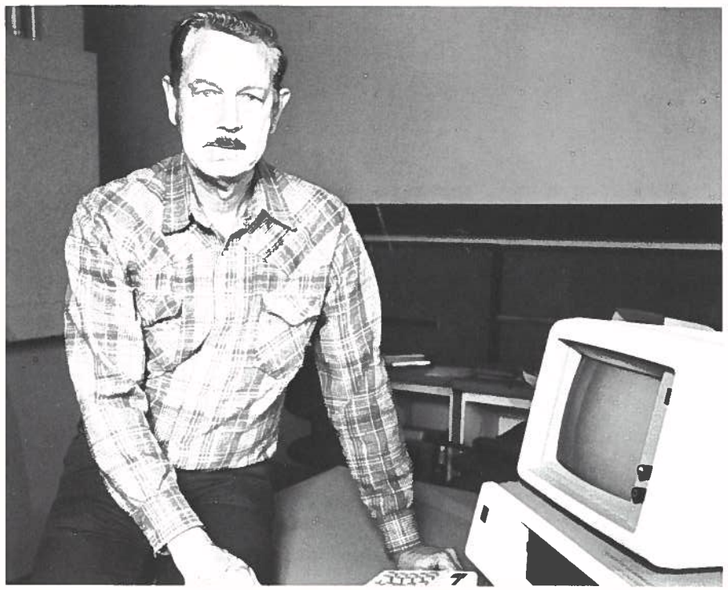
"Modeling and Analysis of Low Pressure CVD Reactor" (with K.F. Jensen), *J. Electrochem. Soc.,* **130** (9), 1950-1957 (1983).

"Chemical Vapor Deposition in Stagnation Point Flow" (with K.F. Jensen), *Chem. Eng. Sci.* (submitted)

"A New Reactor for Plasma-Enhanced CVD" (with K.F. Jensen), *AIChE,* Anaheim, May 1984.

"Modeling of Low Pressure Gas Discharge Reactors" (with K.F. Jensen), *AIChE,* San Francisco, November 1984.

Edward Grens



Edward A. Grens II, Professor, born 1931; B.S. (1953), M.S. (1960), Ph.D. (1963) Chemical Engineering, University of California, Berkeley. Guest Professor Technische Hogeschool, Eindhoven, The Netherlands (1967-68); Visiting Scientist, Lawrence Livermore Laboratory (1974-75); Associate Faculty Scientist, Applied Science Division, Lawrence Berkeley Laboratory.

The emphasis of my research at the present time is in two areas: the development of efficient methods for computer aided design and simulation of separation processes; and the investigation of transport processes involved in coal liquefaction and gasification.

Energy efficiency has become increasingly important in the chemical process industry, and this has led to heightened interest in processes, such as extraction and extractive distillation, that utilize a chemical agent to effect, or assist, separations. These processes depend on strongly nonideal phase-equilibrium phenomena, which cause severe difficulties in process design calculations. Traditional computation procedures often either fail to converge or require grossly excessive amounts of computer time. We are developing new calculational approaches that can greatly reduce required computation effort. They are based on use of simple approximations for component distribution functions, which are adaptively redefined to approach the true distributions as the calculation converges. We are also investigating modified iteration procedures that selectively relax constraints, until convergence is approached, in order to minimize the amount of computation required.

In the field of coal conversion we have been involved in studies of homogenous (fluid phase) catalysis to decompose the coal below its pyrolysis temperature, and of underground coal gasification. Conventional coal-liquefaction processes are based on pyrolysis as the initial step, and suffer from the non-selective nature of this thermal decomposition. Homogeneous catalysis seeks to break selectively certain bond types in the coal structure, and thus achieve reductions in both hydrogen consumption and char formation. Underground (or in-situ) coal gasification has the potential to exploit deep coal resources that cannot be economically mined. However, many problems remain to be solved before this approach will become really attractive. We are investigating heat and mass transfer to the gasification cavity walls, phenomena that control the efficiency of recovery of the coal resource.

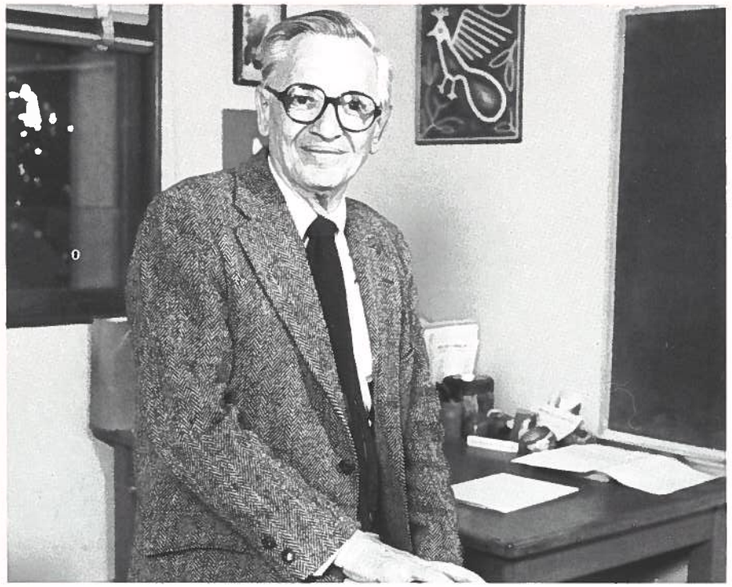
"Coal Liquefaction Catalysis by Zinc Chloride Melts in Combination with Organic Solvents" (with F. Hershkowitz, R.R. Holten, J.H. Shinn, and T. Vermeulen), *Ind. Eng. Chem. Proc. Des. and Dev.*, **19,** 396 (1980).

"Efficient Use of Thermodynamic Models in Process Calculations," *Proceedings, 2nd International Conference on the Foundations of Computer-Aided Process Design* (FOCAPD-83), June 1983.

"Antimisting Action of Polymeric Additives in Jet Fuels" (with K.K. Chao, C.A. Child, and M.C. Williams), *AIChE J.*, **30,** 111 (1984).

"Wall Recession Rates in Cavity-Growth Modeling" (with C.B. Thorsness), Report UCRL-90729, Lawrence Livermore National Laboratory, August 1984.

Donald Hanson



Donald Hanson, Professor, born 1918; B.S. Chemical Engineering, University of Illinois (1940); M.S. and Ph.D. Chemical Engineering, University of Wisconsin (1941, 1943); Engineer, Shell Development Company, San Francisco (1944-46); Faculty Senior Scientist, Lawrence Livermore Laboratory (1952-54), Lawrence Berkeley Laboratory (1954-). Visiting Professor, University of the Philippines (1956-58), Distinguished Teaching Award, 1976.

My research program has been focused primarily on separation processes, accompanied by projects in other areas such as electrostatic precipitators, supercritical wet-air oxidation, and particulate systems. However, at present, essentially all of my research is in process evolution, and is shared with Professor Lynn. The joint effort to develop new, and particularly energy-efficient, processes has resulted in two principal projects. One project is addressed to the concentration of aqueous inorganic solutions with a minimum expenditure of energy by solvent extraction of water. This project is currently directed at concentration to the point of crystallization, and is a low-energy alternative to normal crystallization processes. The second project is synthesizing optimum distillation configurations and systems to separate aqueous mixtures which normally exhibit azeotropic behavior in distillation.

"Calculation of Distillation Columns at the Optimum Feed Plate Location" (with J. Newman), *I.E.C. Process Design and Development*, **16,** 223 (1977).

"Potential Distribution in a Corroding Pit" (with J. Newman and K. Vetter), *Electrochimica Acta*, **22,** 829 (1977).

"Vacuum Steam Stripping of Volatile, Sparingly Soluble Organic Compounds from Water Streams" (with E.A. Rasquin and S. Lynn), *I.E.C. Fundamentals*, **17,** 170 (1978)

"The Exact Calculation of Minimum Flows in Distillation Columns" (with M. Tavana), *I.E.C. Process Design and Development*, **18,** 154 (1979).

"Charge and Filtration of Solvent Refined Coal Suspensions" (with R.J. Steininger, II, and C.J. Radke), *I.E.C. Process Design and Development*, **18,** 708 (1979).

"Solvent Extraction of Phenols from Water" (with D.C. Greminger, G.P. Burns, S. Lynn, and C.J. King), *I.E.C. Process Design and Development*, **21,** 51 (1982).

"Predicting Relative Vapor Ratios for Organic Solvent Mixtures" (with E.C. Bishop, W. Popendorf, and J. Prausnitz), *Am. Ind. Hyg. Assoc. J.*, **43,** (9), 656 (1982).

Dennis Hess

Dennis W. Hess, Professor, born 1947; B.S. Chemistry, Albright College (1968); M.S. (1970) and Ph.D. Physical Chemistry, Lehigh University (1973); Member of the Research Staff, Fairchild Semiconductor (1973-1977); Member American Chemical Society, American Institute of Chemical Engineers, Electrochemical Society, Sigma Xi, Tau Beta Pi.

Our research efforts are in the areas of thin film science and technology. Thin (10A – 2 μm) films used in microelectronic and optical applications are of particular interest. We extensively use rf glow discharges (plasmas) to deposit inorganic and polymer film materials, and to etch patterns in films for electronic device fabrication.

Our studies take advantage of the high energy electrons in glow discharges. These electrons are capable of breaking chemical bonds via gas phase collisions, and thus can promote chemical reactions at low (<100°C) temperature. In deposition reactions, such capabilities allow the fabrication of unique film materials, which cannot be formed by other more standard deposition techniques. Fundamental relationships between plasma variables (rf power, rf frequency, pressure, etc.) and the resulting film composition and structure are determined. This knowledge permits specific properties (electrical, chemical, mechanical, and optical) to be "built into" film materials, so that films can be tailored for certain applications. Primarily, our work concentrates on transition metals (W, Mo) and their silicides that are used as metallization layers in integrated circuits, dielectric layers (SiO_2, Si_3N_4) for electronic devices, and on polymers poly(methyl methacrylate) and poly(vinylidene fluoride) used as resist materials and thin film sensors.

The etching studies in our laboratory involve glow discharges which generate gas phase chemical species capable of reacting with solid surfaces to form a volatile product. The emphasis is on film materials (Al, SiO_2, W) that are important in microelectronic device fabrication. Our interests lie in the fundamental understanding of rf glow discharges, and how etch rates and film pattern dimensions depend upon the chemistry and physics of the discharge.

"Phase Separation in Plasma-Deposited Polysiloxane Films" (with R. Szeto), *J. Polym. Sci.*, Letters Ed., **19,** 119 (1981).

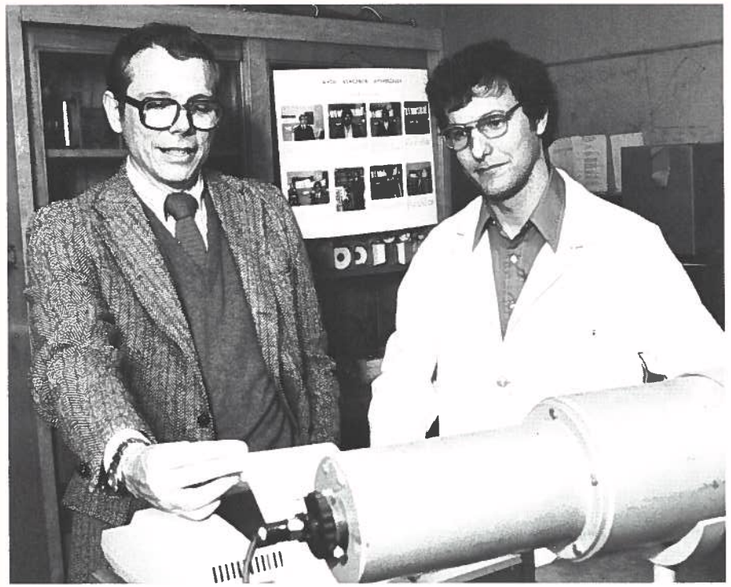
"Comparison of Aluminum Etch Rates in Carbon Tetrachloride and Boron Trichloride Plasmas" (with K. Tokunaga, F.C. Redeker, and D.A. Danner), *J. Electrochem. Soc.*, **128,** 851 (9181).

"Plasma Etch Chemistry of Aluminum and Aluminum Alloy Films," *Plasma Chem. and Plasma Proc.*, **2,** 141 (1982).

"Degradation of Poly (methyl methacrylate) in CF_4 and CF_4/O_2 Plasmas" (with B.J. Wu, D.S. Soong, and A.T. Bell), *J. Appl. Phys.*, **54,** 1725 (1983).

"Plasma-Enhanced Chemical Vapor Desposition of β-Tungsten, a Metastable Phase" (with C.C. Tang), *Appl. Phys. Lett.*, **45,** 633 (1984).

C. Judson King



C. Judson King, Professor, born 1934; B.E., Yale University (1956); S.M. (1958), ScD. (1960), Massachusetts Institute of Technology; Institute Lecturer (1973), Food, Pharmaceutical and Bioengineering Award (1975), and William H. Walker Award (1976), American Institute of Chemical Engineers; George Westinghouse Award, American Society for Engineering Education (1978); National Academy of Engineering (1981); Vice Chairman (1967-72) and Chairman (1972-81), Department of Chemical Engineering; Dean, College of Chemistry (1981–); Faculty Senior Scientist, Applied Science Division, Lawrence Berkeley Laboratory.

Separation problems pervade all areas of processing in the chemical and related industries. Research in our group has pursued novel methods of separation, as well as better understanding of fundamental mechanisms underlying separation processes.

In combined experimental and theoretical spray-drying research, we are investigating the mass-transfer mechanisms by which volatile trace organic substances are lost from aqueous solutions during spray drying. Such compounds constitute the flavor and aroma of common food liquids. We are examining the factors governing changes in size and shape of particles during spray drying—including shrivelling, expansion, and blow-out and blow-in holes. We are also studying mixing patterns and kinetics of degradation reactions in spray drying, and have developed and confirmed a simple model which interprets the mechanism of particle stickiness.

Several projects relate to the use of reversible chemical interactions to achieve separations. Applications are to removal of pollutants from water streams, to recovery of chemicals produced from biomass by fermentation-based processes, and to separations of polar organics from aqueous streams in general. Earlier work on the use of tertiary amines and phosphine oxides for extraction of acetic acid and phenols from water is being followed by studies of similar chemically interacting extractant systems for recovery of dicarboxylic acids, hydroxycarboxylic acids, and alcohols from aqueous solution.

Another project deals with processing of condensate waters formed in large volume during coal gasification. We have investigated extraction processes for phenols and hydantoins, and also an innovative approach for ammonia recovery wherein ammonia is extracted with a liquid cation exchanger, while acid gases are simultaneously stripped.

Yet another project deals with bulk adsorption for recovery of carboxylic acids, such as from fermentation broths. Here we are characterizing the important properties of carbons and polymeric sorbents for this application, and are using this knowledge to devise ways of creating improved adsorbents.

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"Equilibrium Distribution Coefficients for Extraction of Chlorinated Hydrocarbons and Aromatics from Water into Undecane" (with T.A. Barbari), *Environ. Sci. and Technol.*, **16,** 624 (1982).

"Acetic Acid Extraction," *Handbook of Solvent Extraction,* T.C. Lo, M.H.T. Baird, and C. Hanson, eds., Wiley-Interscience, New York, 1983.

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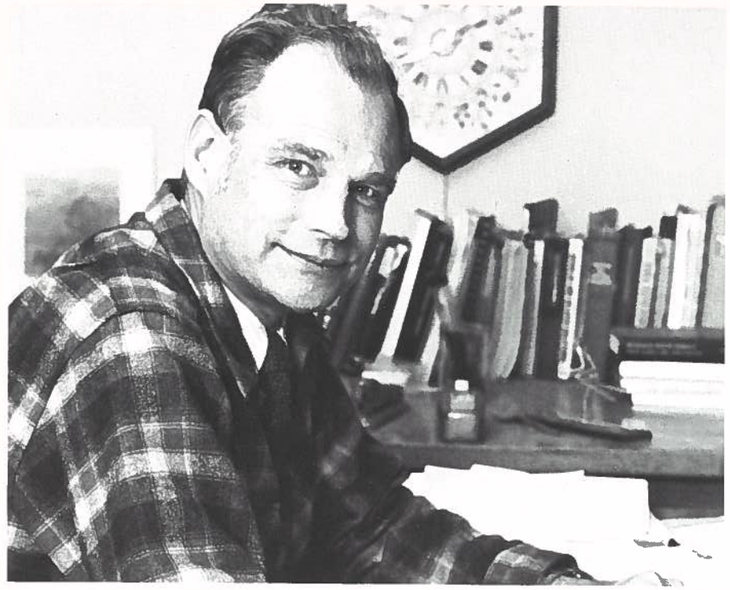
"Factors Influencing Solvent Selection for Extraction of Ethanol from Aqueous Solutions" (with C.L. Munson), *Ind. Eng. Chem. Process Des. and Devel.*, **23,** 109 (1984).

"Food Quality Factors in Spray Drying" (with T.G. Kieckbusch and C.G. Greenwald), in *Advances in Drying,* A.S. Mujundar, ed., **3,** 71-120, Hemisphere Publ. Co., New York, 1984.

"Solvent Extraction for Removal of Polar Organic Pollutants from Water" (with D.K. Joshi and J.J. Senetar), *Ind. Eng. Chem. Process Des. & Devel.*, **23,** 748 (1984).

"Loss of Volatile Trace Organics During Spray Drying" (with M.R. Etzel), *Ind. Eng. Chem. Process Des. and Devel.*, **23,** 705 (1984).

Scott Lynn



Scott Lynn, Professor, born 1928; B.S. (1950); M.S. (1951); Ph.D. (1954) California Institute of Technology; Technische Hogeschool, Delft, Netherlands (1953-54); Dow Chemical Co., Pittsburg, CA (1954-66); Fulbright Fellow, Technische Hogeschool, Delft (1973).

Process synthesis is required when a novel concept is to lead to a new chemical process. The novelty may arise from the nature of the raw material, the chemistry or engineering of the process, or the nature of the product. Much of my research has been done in collaboration with Prof. Donald Hanson. Projects include the separation of aqueous azeotropes, the production of concentrated sodium hydroxide from sodium carbonate, and the removal of sulfurous compounds from industrial gas streams.

"Vacuum Steam Stripping of Volatile, Sparingly Soluble Organic Compounds from Water Streams" (with E.A. Rasquin and D.N. Hanson), I&EC Fundamentals, **17,** 170 (1978).

"A New Power Cycle That Combines Power Generation with Energy Storage" (with J. Dayan and A. Foss), *Proceedings of the 13th Annual Intersociety Energy Conversion Engineering Conference,* San Diego, CA, August 20-25, 1978 **1,** 285 (1978).

"Do Man-Made Sources Affect the Sulfur Cycle of Northeastern States?" (with J. Shinn), *Env. Sci and Tech.*, **13,** 1062 (1978).

"Oxidative Removal of Hydrogen Sulfide from Gaseous Streams" (with B.J.L. Dubs), Patent: U.S. 4,278,646, July 14, 1981.

"Apparatus for the Small-Scale Manufacture of Chlorine and Sodium Hydroxide or Sodium Hypochlorite," Patent: U.S. 4,308,123, December 29, 1981.

"Method of Oxidizing a Polyvalent Metal," Patent: U.S. 4,330,478, May 18, 1982.

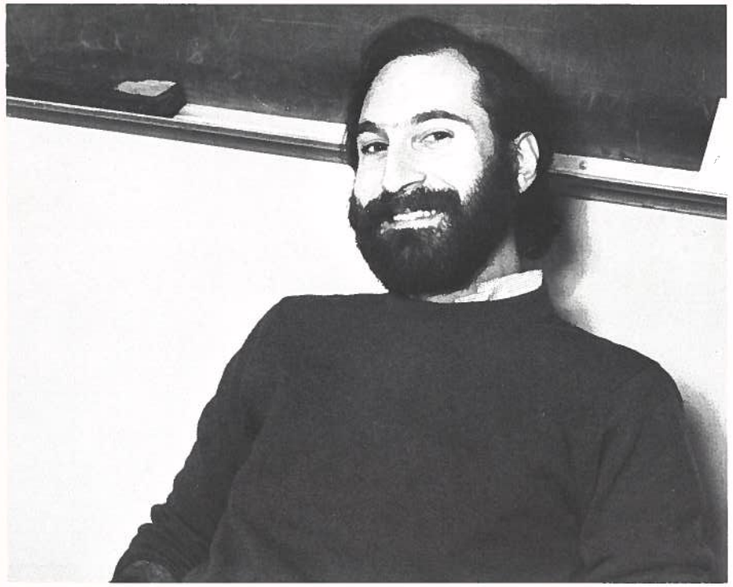
"Solvent Extraction of Phenols from Water" (with D.C. Greminger, C.P. Burns, D.N. Hanson, and C.J. King), *Ind. Eng. Chem. Proc. Des. Dev.*, **21,** 51-54 (1982).

"Effects of Metal Chelates on Wet Flue Gas Scrubbing Chemistry" (with S.G. Chang and D. Littlejohn), *Environ. Sci. and Tech.*, **17,** 649-653 (1983).

"Analysis and Design of a Viscous-Flow Cooler" (with C.F. Oldershaw), *Heat Transfer Eng.*, **5,** 85-92 (1984).

"Oxidative Absorption of H_2S and O_2 By Iron Chelate Solutions" (with D.W. Neumann), *AIChE Journal,* **30,** 62-69 (1984).

James Michaels



James N. Michaels, Assistant Professor; born 1955; B.S. University of California, Berkeley (1976); M.S. University of California, Berkeley (1977); D.I.C. (Chemistry) Imperial College of Science and Technology, University of London (1978); Sc.D. Massachusetts Institute of Technology (1983); member ACS, AIChE, AAAS, and Electrochemical Society.

My research group's interests are centered around investigations of novel catalytic and electrocatalytic systems. Two research efforts are currently in progress.

First, we are studying the electrochemical behavior of stabilized-zirconia electrolytic cells. These solid-state electrochemical systems find use as high-temperature oxygen sensors, fuel cells, and water electrolyzers. They also may be used to monitor and control *in situ* the surface coverage of oxygen on catalytic surfaces, and they offer the potential of being highly selective and controllable preparative reactors. We are interested primarily in determining the electrochemical, catalytic, and transport processes which dominate the electrode kinetics in these systems.

Second, we are studying the catalytic chemistry of a variety of transition metal compounds, including carbides, nitrides, borides, and silicides. Recently, a number of these compounds have been shown to exhibit catalytic activity representative of platinum, and we hope that this work will contribute to the development of inexpensive alternatives to noble-metal catalysts. Our project, which is part of an interdisciplinary effort in chemistry and chemical engineering, is a systematic study of the chemisorptive and catalytic activity of transition metal compounds for a number of probe adsorbents and reactions. Our goal in this project is to understand the relationship between the catalytic activity and selectivity of these materials and their bulk properties, such as stoichiometry, crystal structure, and electronic structure.

"On the Stability Limit of Surface Platinum Oxide and its Role in Oscillation Phenomena of Platinum-Catalyzed Oxidations" (with C.G. Vayenas), *Surf. Sci.*, **120,** L405 (1982).

"Kinetics of Vapor-Phase Electrochemical Oxidative Dehydrogenation of Ethylbenzene" (with C.G. Vayenas), *J. Catal.*, **85,** 477 (1984).

"Styrene Production from Ethylbenzene on Platinum in a Zirconia Electrochemical Reactor" (with C.G. Vayenas), *J. Electrochem. Soc.*, **131,** 2544 (1984).

Rolf Muller

Rolf H. Muller, Lecturer, born 1929; M.S. (1953); Ph.D. (1957) Swiss Federal Institute of Technology, Zurich, Switzerland; Plenary Lecturer, International Society of Electrochemistry, 1976; Invited Speaker, Gordon Research Conference for Electrochemistry, 1965, 1968, 1975, 1979; International Conference on Ellipsometry, 1968, 1975; member, Electrochemical Society, Optical Society of America, International Society of Electrochemistry, American Chemical Society, Swiss Chemical Society, American Association for the Advancement of Science; Staff Senior Scientist, Assistant Division Head, Materials and Molecular Research Division, Lawrence Berkeley Laboratory.

The purpose of this research is to advance the understanding of thin films and boundary layers at electrochemical interfaces. New optical techniques are developed and used for the observation of solid surfaces in liquid media. Thin films are responsible for the chemical properties of most metals in liquid and gaseous environments and often represent the dominant resistance in metal deposition and dissolution reactions. The transformation of surface layers occurs in the charge and discharge of many batteries. A unique, fast self-compensating spectroscopic ellipsometer, which is computer-controlled, is used to investigate the mechanisms by which electrochemical surface layers are formed. Ellipsometer measurements are interpreted by use of multi-dimensional optimization routines for deriving multilayer film structures from time-dependent and spectral-scanning measurements. Simultaneous light-scattering measurements are used for the characterization of particulate deposits and surface roughness. Specimens are transferred to ultra-high vacuum, where ellipsometry can be combined with Auger spectroscopy and ion etching techniques, for the independent investigation of composition and structure profiles of complex films. Topics presently under study include formation of anodic films, the effect of adsorbed surface active materials on the nucleation and growth of metal deposits, and the composition, structure and conductivity of protective films formed on alkali metals in nonaqueous solutions.

Mass-transport boundary layers which control the chemical environment in which electrode processes take place and limit the specific rate at which most technical electrochemical processes can be conducted are investigated by optical interferometry. This technique makes concentration variations near electrode surfaces visible, and allows investigation of different means of accelerating mass transport. Present studies of new means to accelerate electrochemical mass transport concern the effect of small flow obstacles near electrode surfaces and the use of suspended solid particles in the electrolyte (with C.W. Tobias).

Thin electrolyte films provide the reaction environment for gas electrodes. The factors responsible for the formation of electrolyte films on metal surfaces are being investigated by use of optical thin-film interference techniques.

High-rate electrolytic dissolution and deposition of metals is investigated in collaboration with Professor C.W. Tobias. Questions of interest include the prediction and control of shape and surface finish.

"Interferometric Study of Combined Forced and Natural Convection" (with F.R. McLarnon and C.W. Tobias), *J. Electrochem. Soc.*, **129,** 2201-2206 (1982).

"Macroscopic Optical Model for the Ellipsometry of an Underpotential Deposit: Lead on Copper and Silver" (with J.C. Farmer), *Surf. Sci.*, **135,** 521-531 (1983).

"Anodic Films," *AIChE Symp. Ser.*, R. Alkire and D.T. Chin, eds., **79,** 211-217 (1983).

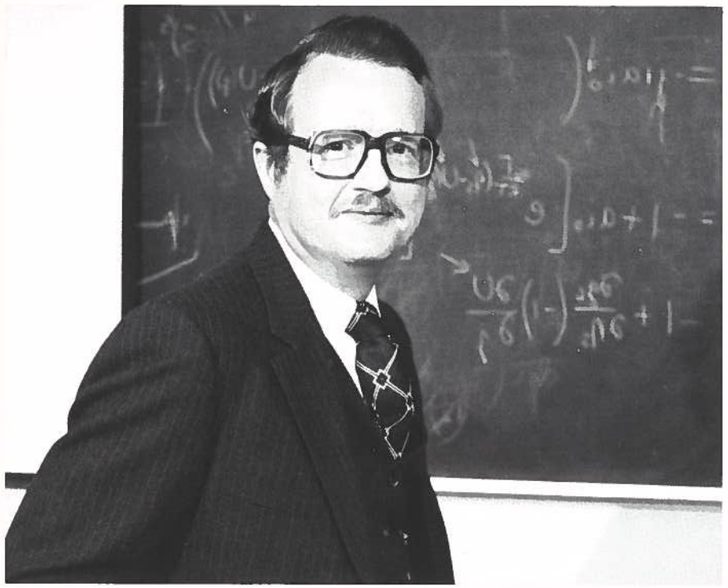
"Fast Self-Compensating Spectral-Scanning Ellipsometer" (with J.C. Farmer), *Rev. Sci. Instrum.*, **55,** 371-374 (1984).

"Ellipsometric Studies of Surface Layers on Lithium" (with F. Schwager and Y. Geronov), *J. Electrochem. Soc.*, **132,** 285-289 (1985).

"Nucleation of Pb Electrodeposits on Ag and Cu" (with J.C. Farmer), *J. Electrochem. Soc.*, **132,** 39-45 (1985).

"Effect of Rhodamine-B on Pb Electrodeposition on Ag and Cu" (with J.C. Farmer), *J. Electrochem. Soc.*, **132,** 313-319 (1985).

John Newman



John Newman, Professor, born 1938; B.S. Northwestern University (1960); M.S. University of California, Berkeley (1962); Ph.D. University of California, Berkeley (1963); Young Author's Prize of the Electrochemical Society (1966, 1969); David C. Grahame Award of the Electrochemical Society (1985); Member, Electrochemical Society, American Institute of Chemical Engineers; Associate Faculty Scientist, Materials and Molecular Research Division, Lawrence Berkeley Laboratory.

Research in my group includes the investigation of fluid flow and electrochemical transport, measurement of transport properties in molten salt solutions, analysis of mass-transfer rates and current distribution, design of practical electrochemical systems, and investigation of corrosion processes.

One of the projects underway is the development of a mathematical model to study the behavior of the Li-Si, FeS_2 storage battery during relaxation and charging.

Another mathematical model is being developed to predict the behavior of thin-gap channel flow cells, which are used for electro-organic synthesis and energy storage.

Several programs with an experimental emphasis are also underway. For example, the method of restricted diffusion is being used to determine differential diffusion coefficients in sodium polysulfide melts.

Another experimental program is the study of the passivation process and the corrosion behavior of iron and zinc in aqueous acidic media using AC impedance techniques on rotating-disk and rotating-hemishpere electrodes. AC impedance techniques are also being applied to a flow-through porous electrode with a soluble redox couple.

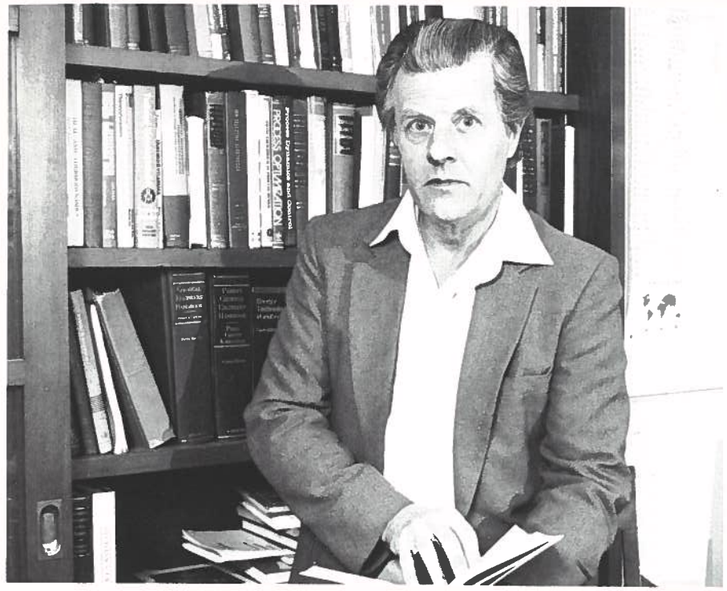
"Impedance Model for a Concentrated Solution" (with B. Tribollet), *J. Electrochemical Soc.*, **131,** 2780-2785 (1984).

"A General Energy Balance for Battery Systems" (with D. Bernardi and E. Pawlikowski), *J. Electrochemical Soc.*, **132,** 5-12 (1985).

"The Asymmetric Graetz Problem in Channel Flow" (with V. Edwards), *Int. J. Heat and Mass Transfer,* **28,** 503-505 (1985).

"Mathematical Modeling of Liquid-Junction Photovoltaic Cells. Part I. Governing Equations; Part II. Effect of System Parameters on Current-Potential Curves; Part III. Optimization of Cell Configurations" (with M.E. Orazem), *J. Electrochemical Soc.*, **131,** 2569-2589 (1984).

Eugene Petersen



Eugene E. Petersen, Professor, born 1924, B.S. (1949), M.S. (1950), University of Washington; Ph.D. (1953), Pennsylvania State University; Solvay Professor, Universite Libre de Bruxelles (1966); American Academy of Sciences Exchange Scientist, Novosibirsk, UUS 1976. Member American Chemical Society, American Institute of Chemical Engineers, California Catalysis Society.

My research activity is in the field of heterogenous catalysis and is mainly concerned with three project areas. The first is a study of the deactivation characteristics of bimetallic supported catalysts, in particular the platinum-rhenium-alumina naphtha reforming catalyst. This is an important industrial catalyst that has almost entirely replaced the platinum-alumina catalyst because of its greatly enhanced lifetime under commercial operating conditons. Our major goal has been to learn the detailed mechanism whereby the presence of rhenium is able to stabilize this catalyst and thereby permit operation for extended periods. At present we have strong evidence that a rhenium bimetallic cluster that makes the effective size of the platinum islands smaller and leads to reduced fouling rates.

A second research area is concerned with the distribution of active components of supported catalyst under various impregnation conditions. The goal of this work is to understand the process in sufficient detail that active materials can be distributed according to a predetermined specification. The work is a fundamental study of surface equilibria and ionic mass transfer. Using these results, the dynamics of impregnation can be modelled.

The long-term goal of a third research area is to develop a hydro-desulfurization catalyst that will maintain its activity in the presence of feedstocks having large trace concentration of organometallic compounds. Almost all of the previous work in this area has been obtained using pilot plant integral reactors and commercial feedstock. Our approach is to use a model reaction system that will permit more fundamental understanding of the details of these complex reaction systems. Detailed rate information on model reactants such as vanadyl and titanyl porphyrins and dibenzothiophene is being used to model the deactivation of the hydrodesulfurization activity and the hydrodemetallation activity in a differential recycle reactor leading to an estimate of the lifetime of the catalyst under specified operating conditons. By changing the pore structure of the catalyst being modelled we can design pore size distributions of a desired catalyst that will operate longer and maintain high desulfurization activity. We would then make a catalyst with a pore structure corresponding to the designed catalyst.

"On the Use of Asymptotic Solutions to Predict the Performance of Fouled Catalyst Pellets," *Chem. Eng. Sci.*, **37,** 669-675 (1982).

"Surface Area Measurement of Platinum/Rhenium/Alumina. 1. Stoichiometry of Hydrogen-Oxygen Chemisorptions and Titrations" (with Bruce H. Isaacs), *J. Catal.*, **85,** 1-7 (1984).

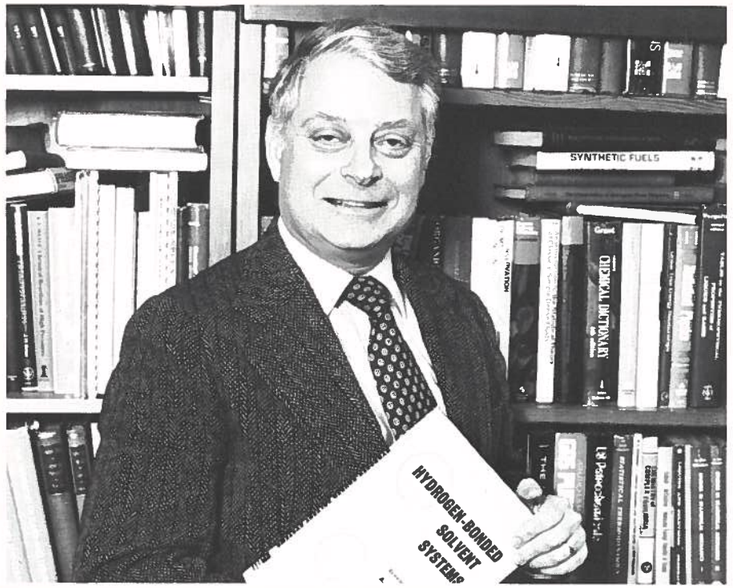
"Surface Area Measurement of Platinum/Rhenium/Alumina. II. Effects of Catalyst Pretreatment" (with Bruce H. Isaacs), *J. Catal.*, **85,** 815 (1984).

"Fundamental Deactivation Data from Laboratory Reactors" (with M.A. Pacheco), *Chemical and Catalytic Reactor Modeling,* 363-374 (1984).

"On a General Correlation for Catalyst Fouling" (with M.A. Pacheco), *J. Catal.*, **86,** 75-83 (1984).

"On the Development of a Catalyst Fouling Model" (with M.A. Pacheco), *J. Catal.*, **88,** 400-408 (1984).

John Prausnitz



John M. Prausnitz, Professor, born 1928. BChE, Cornell University, (1950); M.S., University of Rochester (1951); Ph.D., Princeton University, (1955); Dr. Ing. h.c., Univ. of L'Aquila (1983); Member of the National Academy of Sciences and the National Academy of Engineering. Guggenheim Fellow (1962, 1973); Miller Research Professor (1965, 1978); Faculty Research Lecturer (1981); Humboldt Senior Scientist (1976); GN Lewis Memorial Lecturer (1978). AIChE (Colburn Award 1962); Walker Award (1967); ACS (Murphree Award 1979); Fellow, Wissenschaftskolleg zu Berlin (1985); Fellow of AAAS. Faculty Senior Scientist, Materials and Molecular Research Division, Lawrence Berkeley Laboratory.

Efficient and economic design of chemical processes requires quantitative data for thermodynamic properties of mixtures, especially vapor-liquid and liquid-liquid equilibria. Since the number of possible important mixtures is extremely large, and since the possibly important conditions of temperature, pressure and composition can vary tremendously, it is not possible to obtain all desired data experimentally.

Our research effort is directed at physico-chemical interpretation, generalization and correlation of limited experimental data to provide reliable estimates of thermodynamic properties as required for process design. These limited data are, in part, obtained from the literature and, in part, from our own laboratory. Generalization and correlation are achieved through molecular-thermodynamic models.

The nature of our research requires familiarity with several areas: First, one must be closely acquainted with modern process technology and chemical-plant design to understand the thermodynamic-data needs of the process engineer. Second, one must have in-depth understanding of that part of physical chemistry which is concerned with intermolecular forces and statistical thermodynamics. Finally, one must be able to "translate" the *science* of molecular physics into the *engineering* of process design, using the language of computers.

In recent years we have worked on a variety of phase-equilibrium problems; some of these remain under active investigation. A few examples:

1. High-pressure vapor-liquid equilibria for natural-gas/brine systems (Production of gas from very deep aquifer deposits)

2. Characterization and thermodynamic properties of heavy fossil fuels, including coal-derived liquids (Alternate energy sources)

3. Multicomponent adsorption of organic solutes from dilute aqueous solutions (Water-pollution abatement)

4. Phase equilibria in complex multicomponent mixtures using continuous thermodynamics (Enhanced oil recovery with compressed nitrogen or carbon dioxide)

5. Supercritical fluid extraction (Development of a selective separation process with high energy efficiency)

6. Fundamental studies on the properties of very dilute and/or strongly nonideal fluid mixtures (Development of the theory of solutions for modeling "unusual" mixtures)

7. Phase equilibria in multicomponent aqueous solutions of volatile electrolytes (Water-pollution and acid-rain abatement)

8. Phase equilibria in aqueous dextran-polyethylene glycol solutions for separation of protein mixtures (Extraction for biotechnology)

"Molecular Thermodynamics for Chemical Process Design," *Science*, **205** (24), 759 (1979).

Computer Calculations for Multicomponent Vapor-Liquid and Liquid-Liquid Equilibria (with E. Grens, T. Anderson, C. Eckert, R. Hsieh, and J. O'Connell), Prentice-Hall, Englewood Cliffs, NJ, 1980.

"Phase Equilibria for Complex Fluid Mixtures; *Fluid Phase Equilibria*, **14,** 1-18 (1983).

"High-Pressure Phase Equilibria for the Water/Methane System" (with E.R. Larsen), *AIChE Journal*, **30,** 5, 732-738 (1984).

"Phase Equilibria for Mixtures Containing Very Many Components. Development and Application of Continuous Thermodynamics for Chemical Process Design" (with R.L Cotterman and R. Bender), *I & EC Proc., Des. & Dev.*, **24,** 1, 194-203 (1985).

"Adsorption of Weak Organic Electrolytes from Dilute Aqueous Solution onto Activated Carbon. Part I: Single-Solute Systems; Part II: Multisolute Systems" (with G. Mueller and C.J. Radke), *J. of Colloid and Interface Science*, **103,** 2, 466-491 (1985).

Clayton Radke

Clayton J. Radke, Professor, born 1944; B.S., Chemical Engineering, University of Washington (1966); Ph.D. Chemical Engineering, University of California, Berkeley (1971); NSF Overseas Postdoctoral Fellow, Chemistry, University of Bristol, Bristol, England (1972-3); Assistant Professor, Chemical Engineering, Pennsylvania State University (1973-6); Member AIChE, ACS, SPE.

Our work focuses on combining the principles of surface and colloid chemistry and engineering toward systems where phase-boundaries dominate overall behavior. We employ the tools of molecular theory along with transport phenomena and reaction engineering to provide quantitative descriptions.

Current research topics include polymer, emulsion, and foam flow in porous media, equilibrium and nonequilibrium modeling of underground oil displacement, ionic diffusion in clay gels, kinetic mechanisms and chromatography of mineral dissolution, catalyst impregnation kinetics, stability and rheology of concentrated suspensions, and hydrodynamics, electrokinetics, and diffusion in narrow, track-etched pores. In all cases experiments and theory are combined to establish the underlying principles.

For example, we are studying the mechanisms by which aqueous alkali dissolves silica. Using surface titrations, BET-surface area measurements, and SEM, we establish that the rate of silica dissolution is directly proportional to the number of hydrolyzed surface groups. The reaction is first order at low pH and shifts to zero order at high pH as all surface groups eventually dissociate. Given the dissolution kinetics we solve the mathematics of an ion-exchanging and reacting chemical pulse. This problem has relevance in enhanced oil recovery and is described in the fifth and tenth references below.

"Molecular Orientation of Aqueous Surfactants on a Hydrophobic Surface" (with P.D. Bisio, J.G. Cartledge, and W.H. Keesom), *J. Coll. Int. Sci.*, **78** (1), 225 (1980).

"Dynamic Interfacial Tension Minima in Finite Systems" (with E. Rubin), *Chem. Eng. Sci.*, **35**, 1129 (1980).

"A Chemical Theory for Linear Alkaline Flooding" (with E.F. deZabala, J.M. Vislocky, and E. Rubin), *SPEJ*, **22,** 245 (1982).

"Migration of Alkaline Pulses in Reservoir Sands" (with A.L. Bunge), *SPEJ*, **22,** 998 (1982).

"Pulse Chromatography of Adsorbing and Reacting Chemicals" (with A.L. Bunge), *AIChE Sym, Series*, **78,** 218 (1982).

"Linear Oil Displacement by the Emulsion Entrapment Process" (with D. Schmidt and H. Soo), *SPEJ*, **24,** 351 (1984).

"The Flow Mechanism of Dilute, Stable Emulsions in Porous Media" (with H. Soo), *I. and E.C. Fund*, **21,** 342 (1984).

"Velocity Effects in Emulsion Flow Through Porous Media" (with H. Soo), *J. Coll. Int. Sci.*, **102,** 462 (1984).

"Spillover of the Diffuse Double Layer on Montmorillonite Particles" (with R.B. Secor), *J. Coll. Int. Sci.*, **103,** 237 (1985).

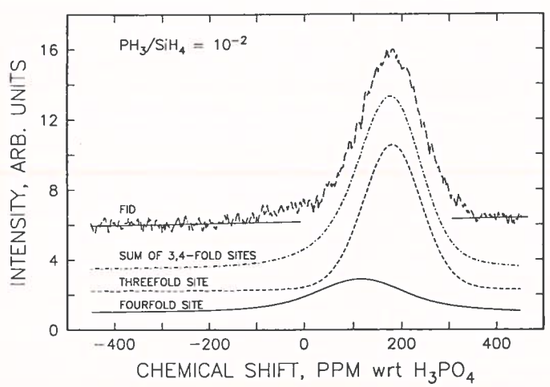
"Dissolution and Condensation Kinetics of Silica in Alkaline Solution" (with S.D. Thornton), SPE 13601, 1985 California Regional SPE Meeting, March 27-29, 1985.

Jeffrey Reimer

Jeffrey A. Reimer, Assistant Professor, born 1954; B.S. University of California, Santa Barbara (1976); Ph.D. California Insitutue of Technology (1980); Post-Doctoral Fellow IBM T.J. Watson Research Center, New York (1980-1982); Associate Faculty Scientist, Center for Advanced Materials, Lawrence Berkeley Laboratory; Presidential Young Investigator, 1985; Member, American Association for the Advancement of Science, American Chemical Society, American Institute of Chemical Engineers, American Physical Society.

Our research group studies the geometric and electronic structure of a variety of disordered materials. This effort includes discerning the relationship between structure, defect states, reaction chemistry, and electro-optical properties. The materials we are presently studying are amphorous and polycrystalline semiconductors, novel transition metal compound catalysts, and liquid crystalline polymers. Each of these materials has current and/or potential application in a number of industries. Furthermore, these materials are scientifically interesting and pose fundamental challenges to traditional concepts in solid state physics.

Our current research activities include both preparation and characterization of electronically active thin films, interfaces, and surfaces. For preparation of these materials we use a variety of techniques including plasma chemistry, homogeneous chemical vapor deposition, and temperature programmed reduction. Understanding and modeling these processes involves the fundamentals of reaction engineering, transport processes, and the physics of ionized gases. Typical characterization techniques include Fourier transform infra-red spectroscopy, x-ray crystallography, electron spin resonance, IR-VIS-UV spectroscopy, electrical conductivity, and nuclear magnetic resonance spectroscropy. Presently, we are heavily involved in the extension of solid-state NMR techniques to study both the geometric and electronic structure of these novel materials. Specifically, multiple quantum and optically detected resonance techniques show great promise as advanced structural probes.



"Local Bonding Configuration of Phosphorous in Doped and Compensated Amorphous Hydrogenated Silicon" (with T.M. Duncan), *Physical Review B15*, **27,** 4895 (1983).

"Growth and Defect Chemistry of Amorphous Hydrogenated Silicon" (with B.A. Scott and P.A. Longeway), *Journal of Applied Physics*, **54,** 6853 (1983).

"Low Spin Density Amorphous Hydrogenated Germanium Prepared by Homogeneous Chemical Vapor Deposition" (with B.A. Scott, D.J. Wolford, and J. Nijs), *Applied Physics Letters*, **46,** 369 (1985).

"The Characterization of Alkyl Intermediates on Silica-Supported Ruthenium with ^{13}C Nuclear Magnetic Resonance Spectroscopy" (with T.M. Duncan, P. Winslow, and A.T. Bell), *Journal of Catalysis*, 1985.

David Soong

David S. Soong, Associate Professor, born 1951; B.S. (1973), Chemistry, National Taiwan University; M.S. (1977), Ph.D. (1978), Chemical Engineering, University of California, Berkeley; Dreyfus Scholar (1984); Member of ACS, AIChE, SPE, Society of Rheology and Sigma Xi; Associate Faculty Scientist, Center for Advanced Materials, Lawrence Berkeley Laboratory.

Recent research activities in my laboratory have spanned a range of topics, including polymer rheology, processing and polymerization reaction engineering. The current focus and future direction lie in polymers applications in microelectronics and microsensors. The goal is to achieve a molecular-level understanding of major issues governing the use of polymers in these areas.

Several photolithographic processes, such as wafer spincoating and resist dissolution have been studied, both experimentally and through mathematical modeling. The next phase is to understand plasma-polymer interactions, as dry etching processes have emerged as a dominant industry trend. Polymers are also used to encapsulate integrated circuits. Stringent requirements are placed on such packaging applications, e.g., good moisture barrier property, high thermal conductivity, matched thermal expansion with the substrate, and strong interfacial adhesion. Research is underway in all these aspects. Molecular composites comprising liquid-crystal and amorphous polymers are candidates. Other polymer-containing mixtures are being studied for their potential use in optical data storage and electromagnetic interference shielding. The former relies on molecular orientation, while the latter exploits the high conductivity of embedded metal fibers. Laser-induced chemical and morphological changes, birefringence, and simultaneous measurement of time-dependent dielectric properties and stresses are examples of current efforts.

Microsensors made of polymer-coated optical fibers have generated a number of projects. Dynamic light scattering is employed to study molecular diffusion in polymers; pulsed FTNMR, Scanning Electron Microscopy, and modeling based on spinodal decomposition are pursued in an attempt to understand the dependence of thin film morphology on casting conditions; protein-synthetic polymer interactions are investigated by fluorescence.

Degradation of Poly(methyl methacrylate) in CF_4 and CF_4/O_2 Plasmas (with B.J. Wu, D.W. Hess, and A.T. Bell), *J. Appl. Phys.*, **54,** 1725 (1983).

"*In Situ* Measurement of Resist Dissolution with a Psi-Meter" (with W.W. Flack, J.S. Papanu, D.W. Hess, and A.T. Bell), *J. Electrochem. Soc.*, **131,** 2200 (1984).

"Measurement of Fast Transient and Steady State Responses of Viscoelastic Fluids with a Sliding Cylinder Rheometer Executing Coaxial Displacements" (with A.T. Tsai), *J. Rheol.*, **29,** 1 (1985).

"Free Radical Polymerization of Methyl Methacrylate in Tubular Reactors" (with P.E. Baillagou), *Polym. Eng. Sci.*, **25,** 212 (1985).

"Free Radical Polymerization of Methyl Methacrylate at High Temperatures" (with P.E. Baillagou), *Polym, Eng. Sci.*, **25,** 232 (1985).

Doros Theodorou

Doros N. Theodorou, Assistant Professor, Diploma 1981, National Technical University of Athens; M.S. 1983, Massachusetts Institute of Technology; Ph.D. 1985, Massachusetts Institute of Technology; Member of AIChE, ACS, Sigma X:, Technical Chamber of Greece.

My primary research objective is to gain a better fundamental understanding of the properties of materials useful in engineering applications, and to establish reliable methods for the quantitative prediction of these properties on the basis of chemical structure.

Polymers constitute a major area of interest. Some of the phenomena we are currently investigating are: the response of amorphous polymers to mechanical deformation; glass transition and the relaxation behaviour of polymeric glasses; molecular motion of macromolecular chains in the bulk; and the diffusion of low-molecular weight penetrants through polymers.

We seek to learn more about these phenomena by a combination of theoretical and experimental work. On the theoretical level, powerful computer simulation techniques (molecular dynamics, Monte Carlo, energy minimization) and the principles of statistical mechanics are used to construct detailed atomistic models of poloymeric systems. On the basis of these models we are able to predict macroscopic properties with no adjustable parameters, and to elucidate the microscopic mechanism of the phenomena investigated. Our experimental work involves synthesis of well-characterized polymer samples, determination of macroscopic properties, and direct quantitative measurements of molecular structure and motion by x-ray, neutron and light scattering.

Zeolites are another category of materials that attracts our interest. The ability to differentiate between molecular species in terms of size and shape imparts to them a unique potential for separation and catalytic applications. To exploit this potential fully we are trying to develop a better fundamental understanding of transport and reaction in their intracrystalline cavities.

"Diffusion and Reaction in Blocked and High Occupancy Zeolite Catalysts" (with J. Wei), *J. Catal.*, **83,** 205-224 (1983).

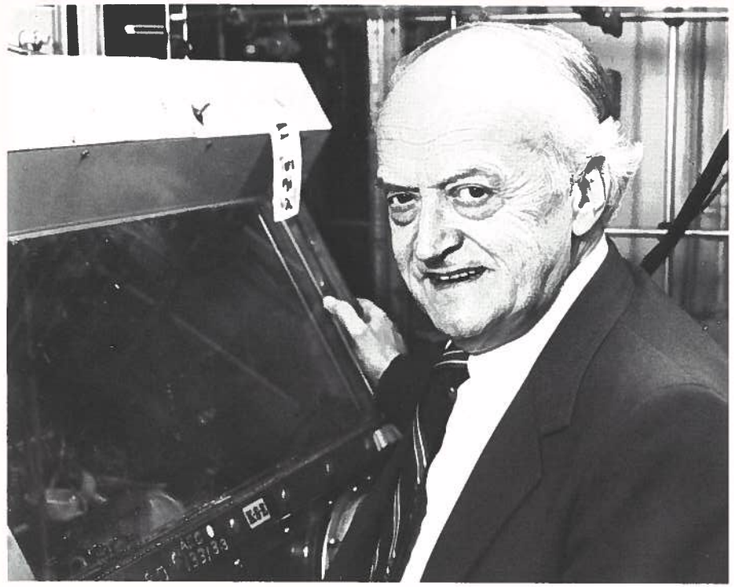
"Molecular Structure of a Vinyl Polymer Glass" (with U.W. Suter), *Polym. Prepr., Am. Chem. Soc., Div. Polym, Chem.* **25**(1), 180 (1984).

"Geometrical Considerations in Model Systems with Periodic Boundaries" (with U.W. Suter), *J. Chem. Phys.*, **82,** 955-966 (1985).

"The Shape of Unperturbed Linear Polymers; Polypropylene" (with U.W. Suter), *Macromolecules*, **18,** in press (1985).

"The Detailed Molecular Structure of a Vinyl Polymer Glass" (with U.W. Suter), *Macromolecules*, **18,** in press (1985).

Charles Tobias



Charles Tobias, Professor, born 1920; Diploma of Chemical Engineering (1942) and Ph.D. (1946), University of Technical Sciences, Budapest; Miller Research Professor, University of California, Berkeley; Acheson Award, The Electrochemical Society (1972); India-United States Exchange Scientist, NSF (1973); BASF, Renowned Scientist Lecture (1975); Centennial Scholar, Case Western Reserve University (1980); Henry B. Linford Award for Distinguished Teaching, The Electrochemical Society (1982); Alpha Chi Sigma Award of the AIChE (1983); National Academy of Engineering (1983); Chairman of the Department of Chemical Engineering (1967-72); Acting Dean, College of Chemistry (1978); Divisional Editor, Journal of the Electrochemical Society (1954-); Advisory Editorial Board: Journal of Applied Electrochemistry, London (1971-); Chairman, Committee on Battery Materials Technology, NAS/NRC (1979-81); The Electrochemical Society (Honorary Member), President (1970-71); American Institute of Chemical Engineers; Bunsen Gesellschaft; American Society for Engineering Education; American Chemical Society; Sigma Xi; Fellow of the AAAS (1965); Registered Professional Engineer, Calif.; International Society for Electrochemistry, President (1977-78).

Mass Transport in Electrolysis: The combined influences of cell geometry, electrode potential, and hydrodynamic conditions on limiting rates of electrolysis and on current distribution are evaluated. Emphasis is placed on high rate processes, such as anodic shaping (ECM), and electroforming.

Gas-Electrolyte-Electrode Interfaces: Supersaturation, nucleation, bubble growth, coalescence, and detachment from the electrode surface are characterized on various metallic substrates for hydrogen and oxygen evolution in aqueous electrolytes. The behaviour of bubble streams in free and forced convection and their influence on ohmic resistance are elucidated.

Surface Morphology of Metals Undergoing Electrodeposition/ Dissolution: The role of hydrodynamic flow, and of electric field on the macrocrystallization of metals in electrodeposition, and the contours obtained following anodic dissolution, are evaluated by various electrochemical and optical techniques. Theoretical models are developed for the simulation of advancing and receding profiles.

Non-Aqueous Ionizing Media: These are investigated for potential use at ambient temperatures for electrosynthesis and for galvanic cells. Of primary interest are the transport properties in aprotic solvents and the thermodynamic and kinetic parameters of electrode couples that are unstable in aqueous media.

"Periodic Phenomena during Anodic Dissolution of Copper at High Current Densities" (with J.F. Cooper and R.H. Muller), *J. Electrochem. Soc.*, **127**, 1733-1744 (1980).

"The Anodic Evolution of Ozone" (with P.C. Foller), *J. Electrochem. Soc.*, **129**, 506-515 (1982).

"Finite Difference Calculation of Current Distributions at Polarized Electrodes" (with G.A. Prentice), *AIChE Journal*, **28**, 3, 486-492 (May 1982).

"Resistance of a Planar Array of Spheres: Gas Bubbles on an Electrode" (with P.J. Sides), *J. Electrochem. Soc.*, **129**, 2715-2720 (December 1982).

"Transport Processes in Narrow (Capillary) Channels" (with R.E. Acosta and R.H. Müller), *AIChE Journal*, **31,** 273 (1985).

"A Mathematical Model for the Periodic Electrodeposition of Multicomponent Alloys" (with M.W. Verbrugge), *J. Electrochem. Soc.*, **132,** 1298 (1985).

Charles Wilke

Charles R. Wilke, Professor, born 1917; B.S., University of Dayton (1940); M.S., Washington State University (1942); Ph.D., University of Wisconsin (1944); Union Oil Company of California (1944-45); Washington State University, Instructor (1945-46); University of California, Berkeley, Instructor-Professor (1946-present); Chairman, Division of Chemical Engineering (1953-56), Department of Chemical Engineering (1956-63); Assistant to the Chancellor, Academic Affairs (1967-69); Faculty Senior Scientist, Lawrence Berkeley Laboratory; American Institute of Chemical Engineers, Alan P. Colburn Award (1951), Institute Lecturer (1955), Director (1960-62), William H. Walker Award (1965), Fellow (1970); President of California State Board of Registration for Professional Engineers (1967-69); American Chemical Society; American Society for Engineering Education, Chairman, Chemical Engineering Division (1960-61), Chemical Engineering Lectures Award (1958); American Society for Microbiology; Society for Applied Bacteriology; Reilley Lecturer, Notre Dame University (1966); Elected to the National Academy of Engineering (1975); Distinguished Service Citation Award, University of Wisconsin (1976); Distinguished Alumnus Award, University of Dayton (1984); Professional Progress Award, Northern California Section AIChE (1984).

Recent research has been concerned with the enzymatic and acid hydrolysis of cellulose to sugars with subsequent conversion of hydrolysis products to ethanol and other fermentation products. Kinetic modelling of enzymatic and microbial processes is under development to provide a basis for equipment design. High productivity microbial processes are being investigated employing cell recycle, vacuum and hollow fiber membrane reactors to attain dense cell cultures. Efforts are under way to develop high efficiency reactor systems for plant and mammalian cell growth in submerged culture. Studies of affinity chromatography are in progress for the recovery of complex organic molecules from dilute aqueous solutions.

"Distillery Effluent Treatment and By-Product Recovery (with B.L. Maiorella and H.W. Blanch), *Process Biochemistry*, **18**(4) (1983).

"Economic Evaluation of Alternative Ethanol Fermentation Processes" (with B.L. Maiorella and H.W. Blanch), *Biotechnol. Bioeng.*, **26,** 1003-1025 (1984).

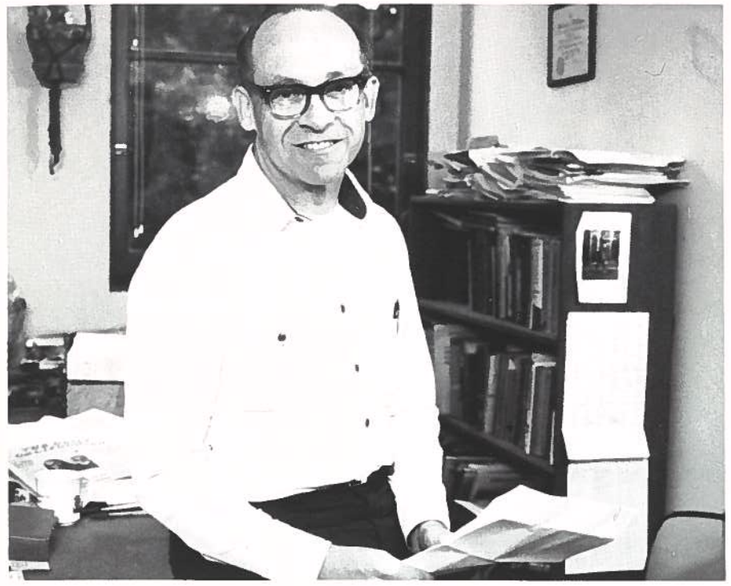
"Enhanced Cellulase Production in Fed-Batch Culture of *Trichoderma Reesei* C30" (with N.A. Hendy and H.W. Blanch), *Enzy. Microb. Technol.*, **6,** February 1984.

"Feed Component Inhibition in Ethanolic Fermentation by *Saccharomyces cerevisiae*," (with B.L. Maiorella and H.W. Blanch), *Biotechnol.* **26,** 1155-1166 (1984).

"Kinetics of the Enzymatic Hydrolysis of Cellulose" (with S. Wald and H.W. Blanch), *Biotechnol. Bioeng.* **26,** 221-230 (1984).

"*In Situ* recovery of Fermentation Products" (with S.R. Roffler and H.W. Blanch), *Trends in Biotechnol.*, **2,** 129-36, Sept./Oct. 1984.

Michael Williams



Michael C. Williams, Professor, born 1937; B.S. (1959), M.S. (1960), Ph.D. (1964) from University of Wisconsin-Madison. Postdoctoral Associate, University of Oregon (1964-65). Professor of Rheology, Universidad Nacional del Sur, Argentina (1970). Associate Faculty Scientist, Center for Advanced Materials, Lawrence Berkeley Laboratory. Member, Society of Rheology, AIChE, ACS, Amer. Soc. for Eng. Education, Society of Plastics Engineers.

Our work has involved the rheology of a wide spectrum of materials, including dilute polymer solutions, concentrated coal suspensions, blends of molten polymers, fluidized beds, blood, and block copolymers. Emphasis has been on the liquid state, but excursions into the relationship between microstructure and mechanical properties for the solid state have been made as well. Engineering applications of such work have also been diverse: aircraft fire safety, plastics melt processing, coal conversion processes, and life support systems.

Most extensive at the moment are efforts in the rheology of block copolymer melts and solutions. Our earlier work with the thermodynamics of microphase separation in such systems was helpful in defining microstructural factors needed to understand the rheology. These structured materials possess a yield stress even when the microphases are liquid, and fundamental studies of yielding phenomena are underway. Exceptional non-Newtonian viscosity is also seen and is being modelled with molecular and continuum theories. Transient flows, including large-amplitude oscillation, challenge our understanding of nonlinear rheology of all structured materials.

"Statistical Thermodynamics of ABA Block Copolymers, III" (with D.F. Leary), *J. Polym. Sci. (Phys.),* **12,** 265 (1974).

"Molecular Rheology of Polymer Solutions: Interpretation and Utility," *AIChE J.*, **21,** 1 (1975).

"Radial Flow of Viscoelastic Liquids. Part II" with M.C.H. Lee), *J. Non Newtonian Fluid Mech.*, **1,** 343 (1976)

"Solvation and Phase Separation of ABA Block Copolymers" (with E.R. Pico), *J. Applied Polym. Sci.*, **22,** 445 (1978).

"A Model for Triblock Copolymer Rheology" (with C.P. Henderson), *J. Polym. Sci.* (Letters), **17,** 255 (1979).

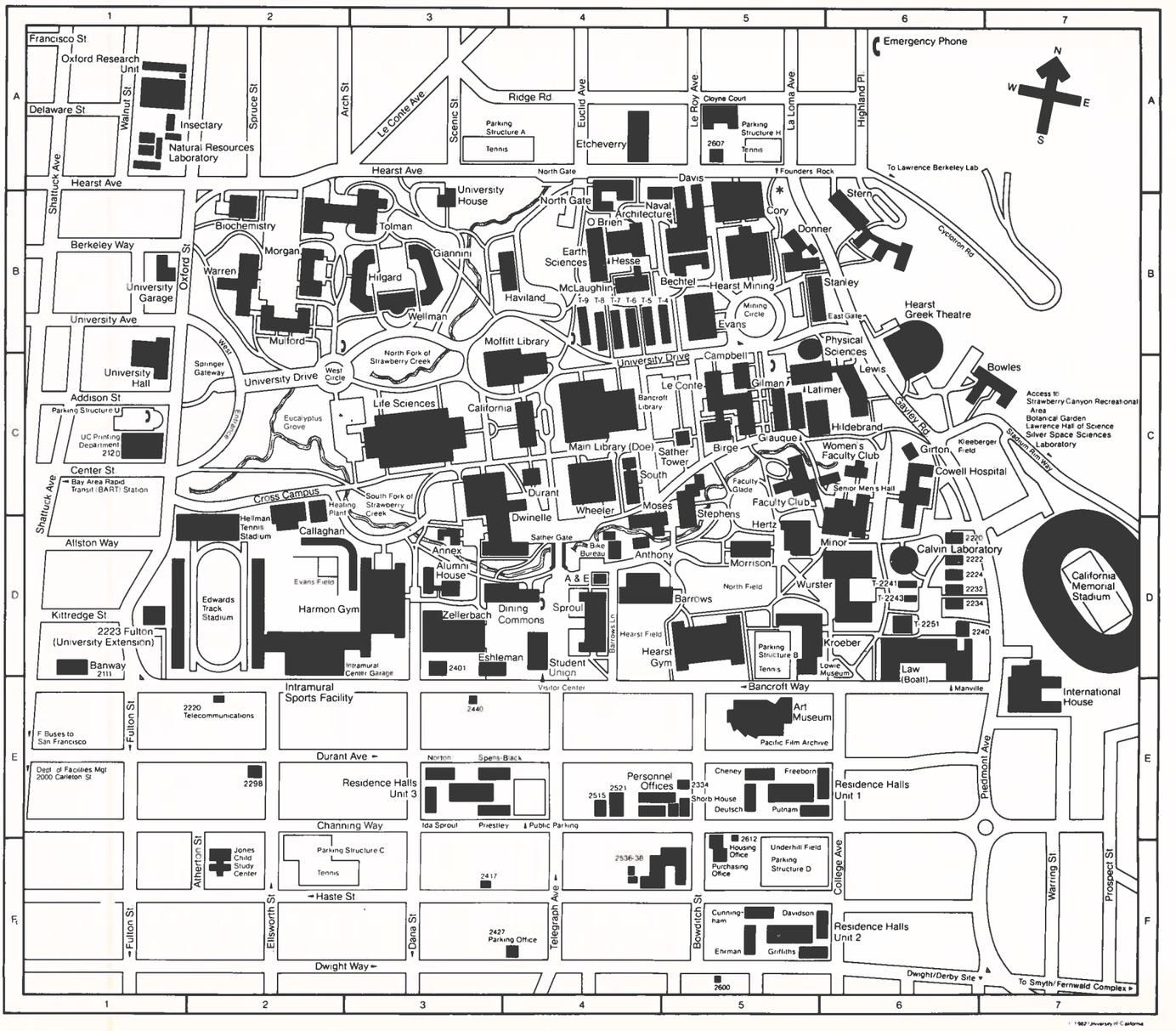
"Viscosity and Microstructure of Polyethylene-Poly(methyl methacrylate) Melt Blends" (with C. Martinez), *J. Rheol.*, **24,** 421 (1980).

"Transient and Steady Rheology of Polydisperse Entangled Melts" (with T.Y. Liu), *J. Polym. Sci.* (Phys.), **22,** 1561 (1984).

Modeling the Viscoelastic Behavior of SBS Block Copolymer Solids" (with J. Diamant), *Contemp. Topics Polym. Sci.*, **4,** 599 (1984).

"Viscosity of Suspensions Modeled with a Shear-Dependent Maximum Packing Fraction" (with C.R. Wildemuth), *Rheol. Acta.*, **23,** 627 (1984).

"Antimisting Action of Polymeric Additives in Jet Fuels" (with K.K. Chao, C.A. Child), *AIChE J.*, **30,** 111 (1984).



CAMPUS MAP

A & E (Architects & Engineers), D-4
Addison St., C-1
Allston Way, D-1
Alumni House, D-3
Anthony Hall, D-4
Arch St., A-2
Architects & Engineers (A & E), D-4
Art Museum, E-5
Bancroft Library, C-4
Bancroft Way, E-1
Barrows Hall, D-4
Barrows Lane, D-4
Bay Area Rapid Transit, C-1
Bechtel Engineering Center, B-5
Berkeley Way, B-1
Big C Trail, C-7
Bike Bureau, D-4
Biochemistry Bldg., B-2
Birge Hall, C-5
Boalt Hall, D-6
Botanical Garden, C-7
Bowditch St., E-5
Bowles Hall, C-7
Buses to San Francisco, E-1
California Hall, C-4
California Memorial Stadium, D-7
Callaghan Hall, C-2
Calvin Laboratory, D-6
Campanile (Sather Tower), C-5
Campbell Hall, C-5
Center St., C-1
College Ave., E-6
Cory Hall, B-5
Cowell Hospital, D-6
Cross Campus Rd., C-2
Cyclotron Rd., B-6
Dana St., E-3
Davis Hall, B-5
Delaware St., A-1
Dining Commons, D-3
Doe Library, C-4
Donner Lab, B-5
Durant Ave., E-1
Durant Hall, C-4
Durham Studio Theater (see Dwinelle Hall), D-4
Dwinelle Annex, D-3
Dwinelle Hall, D-4
Earth Sciences Bldg., B-4
East Gate, B-6
Edwards Field, D-2
Ellsworth St., E-2
Eshleman Hall, D-3
Etcheverry Hall, A-4
Eucalyptus Grove, C-2
Euclid Ave., A-4
Evans Field, D-2
Evans Hall, B-5
Faculty Club, C-5
Faculty Glade, C-5
Founders' Rock, A-5
Francisco St., A-1
Fulton St., E-1
Gayley Rd., C-6
Giannini Hall, B-3
Giauque Hall, C-5
Gilman Hall, C-5
Girton Hall, C-6
Harmon Gymnasium, D-3
Haviland Hall, B-3
Hearst Ave., A-4
Hearst Field, D-4
Hearst Greek Theatre, B-6
Hearst Gymnasium, D-5
Hearst Mining Bldg., B-5
Heating Plant, C-2
Hertz Hall, D-5
Hesse Hall, B-4
Highland Pl., A-6
Hildebrand Hall, C-6
Hilgard Hall, B-3
Housing Office, E-5
Insectary, A-1
International House, E-7
Intramural Sports Facility, D-2
Kittredge St., D-1
Kleeberger Field, C-7
Kroeber Hall, D-6
La Loma Ave., A-5
Latimer Hall, C-5
Law Bldg., D-6
Lawrence Berkeley Laboratory, A-6
Lawrence Hall of Science, C-7
Le Conte Ave., A-3
Le Conte Hall, C-5
Le Roy Ave., A-5
Lewis Hall, C-6
Library, C-3, C-4
Life Sciences Bldg., C-3
Lowie Museum of Anthropology, D-5
Ludwig's Fountain, D-4
Manville Hall, D-6
McLaughlin Hall, B-4
Mining Circle, B-5
Minor Hall, D-6
Moffitt Library, C-3
Morgan Hall, B-2
Morrison Hall, D-5
Moses Hall, B-2
Mulford Hall, B-2
Natural Resources Laboratory, A-1
Naval Architecture Bldg., B-4
North Field, D-5
North Gate, B-4
North Gate Hall, B-4
O'Brien Hall, B-4
Oxford Research Unit, A-1
Oxford St., A-2
Pacific Film Archive, E-5
Parking, A-3, A-5, C-1, D-5
Pelican Bldg., D-4
Personnel Offices, E-4
Physical Sciences Lecture Hall, B-5
Piedmont Ave., E-6
Placement Center (T-6), B-4
Ridge Rd., A-4
Sather Gate, D-4
Sather Tower, C-5
Scenic Ave., A-3
Senior Hall, C-6
Shattuck Ave., B-1
South Hall, C-4
Space Sciences Laboratory, C-7
Springer Gateway, C-2
Sproul Hall, D-4
Sproul Plaza, D-4
Spruce St., A-2
Stadium Rd., C-7
Stadiums, D-2, D-7
Stanley Hall, B-6
Stephens Hall, C-5
Stern Hall, B-6
Strawberry Canyon Recreational Area, C-7
Student Union, D-4
Telegraph Ave., E-4
Temporary Bldgs., T-4 through T-9, B-4; T-19, C-2; T-2241 and T-2243, D-6
Tennis Courts, D-2
Tolman Hall, B-3
Track Stadium, D-2
University Ave., B-1
University Extension, D-1
University Garage, B-1
University Hall, C-1
University House, B-3
Walnut St., A-1
Warren Hall, B-2
Wellman Hall, B-3
West Circle, C-2
West Entrance, C-2
Wheeler Hall, C-4
Women's Center (Bldg T-9), B-4
Women's Faculty Club, C-6
Wurster Hall, D-6
Zellerbach Hall, D-3
2401 Bancroft Way, D-3
2223 Fulton St., D-1
2607 Hearst St., A-5
2120 Oxford St., C-1
2220-40 Piedmont Ave., D-6

LBL ON-SITE SHUTTLE BUS ROUTES

LBL SHUTTLE BUS SCHEDULE

OFF-SITE SHUTTLE (Red Flag)

Route **65** – Cyclotron Road – Gayley – **Bancroft** – Oxford – Center – **Milvia** – Hearst – Cyclotron Road – 65 (see map for stops)

Bldg. 65	BART Station (Center & Shattuck)
6:30 a.m.	6:40 a.m.
6:40 a.m.	6:50 a.m.
•	•
every 10 min	every 10 min
•	•
(after 4:00 p.m. no service along Gayley & Bancroft Bus uses Hearst)	•
5:50 p.m.	6:00 p.m.
6:10 p.m.	6:20 p.m.
6:30 p.m.	6:40 p.m.
6:50 p.m.	7:00 p.m.

HILL SHUTTLE (Blue Flag)

Route **65** – 55 – 90 – 51 – 50/70 – 46 – 46A **27** – 25/26 – 42 – 77 – 72 – **62** – 72 – 48 – **6** – 29/54 – **65**

6:50 a.m. – 8:20 a.m. Direct Service from Bldg. **65**

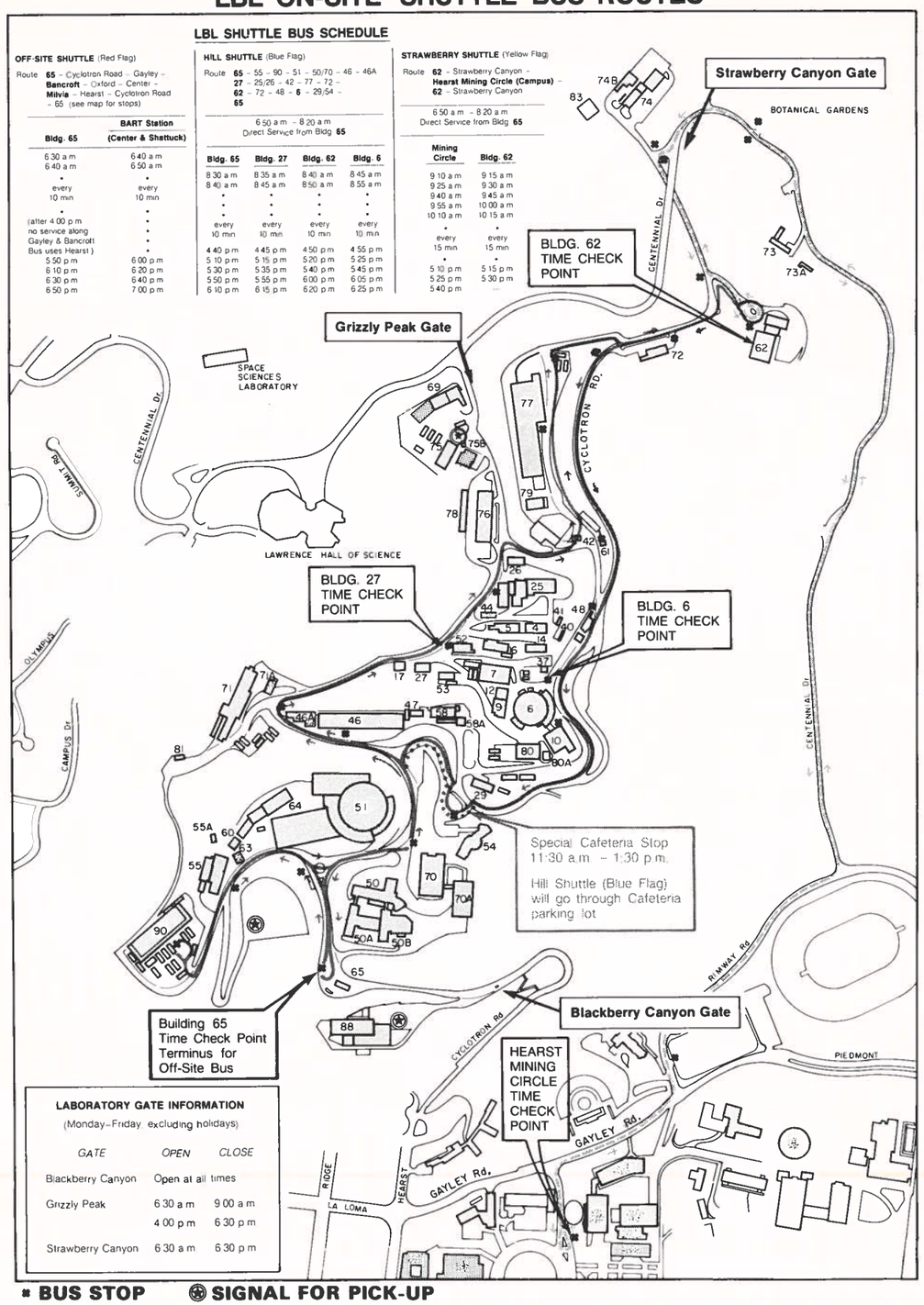
Bldg. 65	Bldg. 27	Bldg. 62	Bldg. 6
8:30 a.m.	8:35 a.m.	8:40 a.m.	8:45 a.m.
8:40 a.m.	8:45 a.m.	8:50 a.m.	8:55 a.m.
•	•	•	•
•	•	•	•
•	•	•	•
every 10 min	every 10 min	every 10 min	every 10 min
4:40 p.m.	4:45 p.m.	4:50 p.m.	4:55 p.m.
5:10 p.m.	5:15 p.m.	5:20 p.m.	5:25 p.m.
5:30 p.m.	5:35 p.m.	5:40 p.m.	5:45 p.m.
5:50 p.m.	5:55 p.m.	6:00 p.m.	6:05 p.m.
6:10 p.m.	6:15 p.m.	6:20 p.m.	6:25 p.m.

STRAWBERRY SHUTTLE (Yellow Flag)

Route **62** – Strawberry Canyon – **Hearst Mining Circle (Campus)** – **62** – Strawberry Canyon

6:50 a.m. – 8:20 a.m. Direct Service from Bldg. **65**

Mining Circle	Bldg. 62
9:10 a.m.	9:15 a.m.
9:25 a.m.	9:30 a.m.
9:40 a.m.	9:45 a.m.
9:55 a.m.	10:00 a.m.
10:10 a.m.	10:15 a.m.
•	•
every 15 min	every 15 min
•	•
5:10 p.m.	5:15 p.m.
5:25 p.m.	5:30 p.m.
5:40 p.m.	



LABORATORY GATE INFORMATION
(Monday–Friday excluding holidays)

GATE	OPEN	CLOSE
Blackberry Canyon	Open at all times	
Grizzly Peak	6:30 a.m.	9:00 a.m.
	4:00 p.m.	6:30 p.m.
Strawberry Canyon	6:30 a.m.	6:30 p.m.

*** BUS STOP** **SIGNAL FOR PICK-UP**

YELLOW FLAG ROUTE

BLUE FLAG ROUTE

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