ChE department

CHE AT ARIZONA STATE UNIVERSITY

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A familiar sight to all ASU students is Palm Walk, above, one of the main walkways on campus, while the Engineering Center offices and classrooms shown below are Chemical Engineering territory.

The institution known today as Arizona State University began in 1886 as a small teacher's college with thirty-three students. Following World War II, large enrollment increases and an accompanying program expansion resulted in its change from a state college to Arizona State University in 1958. Today, with over 43,000 students, ASU is the fifth largest university in the United States. The main campus is located in Tempe, Arizona, on the eastern edge of Phoenix. As a leading public university in a populous urban setting (Phoenix is the ninth largest city in the U.S., with a metropolitan area population of over 2,300,000), a large part of its mission focuses on problems associated with the area's changes from a desert to a metropolitan center. The growth of the university, as measured by enrollment and the quality of research, has paralleled the growth of Phoenix as a major electronics center.

The College of Engineering was established in 1956, and chemical engineering followed in 1958 when **Castle O. Reiser** was hired to build a chemical engineering program. **Sam Craig** came in 1960, **Gene Sater** in 1962, and **Neil Berman** in 1964; with these four faculty, the group was large enough to obtain formal accreditation of the program in 1966. The first graduate class began in 1964, the AIChE student chapter was chartered in 1967, and the first PhD student was Marshall Gurian.

Bill Dorson, who has a strong interest in biomedical engineering, came to ASU in 1966 and initiated an interdisciplinary program at the BSE level in that discipline. **Jim Kuester** became the sixth faculty member in 1969, and **Eric Guilbeau,** another chemical engineer with a biomedical research interest, joined the faculty in 1977. **Imre Zwiebel** arrived on campus as Chair in 1979, and during his tenure the bio program saw steady growth in terms of both faculty and students—in 1988, with Eric Guilbeau directing the program, ASU began offering BSE, MS, and PhD degrees in bioengineering.

In 1986 the materials science program moved from the Mechanical and Aerospace Engineering Department to chemical and bioengineering, creating the present Department of Chemical, Bio, and Materials Science Engineering (CBME). The name is lengthy, but it reflects a natural and synergistic combination based on the overlapping interests of the faculty in those three areas.

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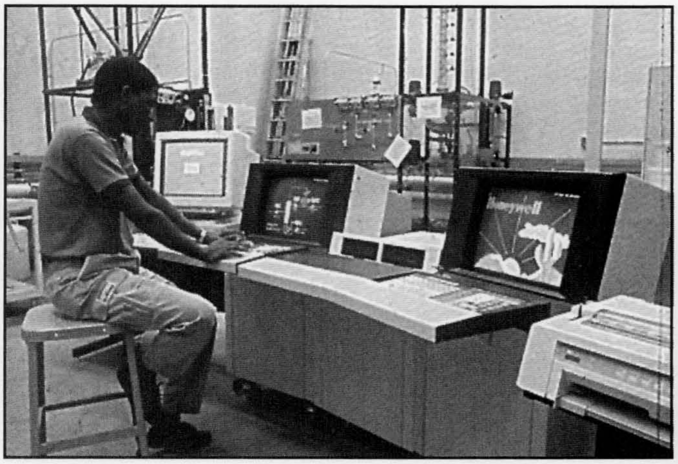


One of our students working in the Honeywell Automatic Control Lab at ASUand its distillation column control with the TDC 3000 system.

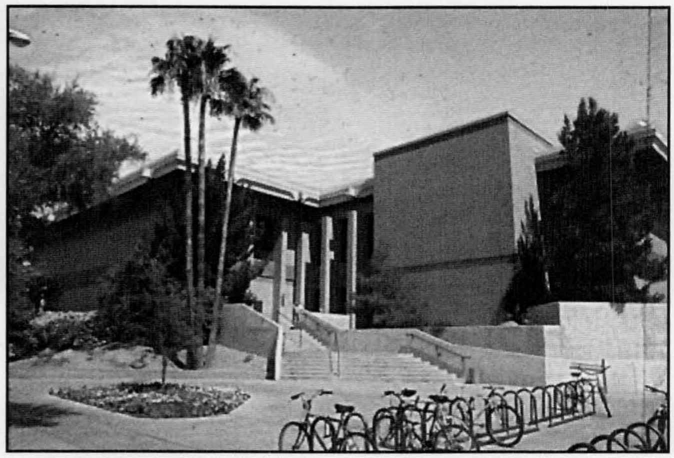
Joe Henry, Jr., became Chair of the department in 1988. He stepped down last fall, and **James Mayer** (who is also Director of the university's Center for Solid State Science) has assumed the role of Interim Chair. The chemical engineering program has thirteen faculty, 230 undergraduate students, and 50 graduate students who make up about one-half of the CBME department totals.

DIVERSITY

ASU recognizes the importance of actively encouraging the education of underrepresented minority students. The College of Engineering and Applied Sciences provides special advising services and courses intended to ease the transition of minority students into university life. In addition, tutoring sessions and minority professional organizations have chapters on campus. **Tony Garcia** is a Co-Project Director of an NSF-funded Southern Rocky Mountain Alliance for Minority Participation which sponsors a special series of academic and support activities including undergraduate research programs.

THE UNDERGRADUATE PROGRAM

The undergraduate engineering programs at ASU were traditionally based on a strong engineering science core, but in 1992, the chemical engineering faculty decided that the curriculum should include more technical electives so that students could better prepare themselves for careers in the emerging technologies. At about the same time, a decision was made at the college level to reduce the total credits required for BSE degrees to 132. An integrated core, based on the underlying conservation laws, has been adopted—



COB—home of the undergraduate laboratories at ASU.

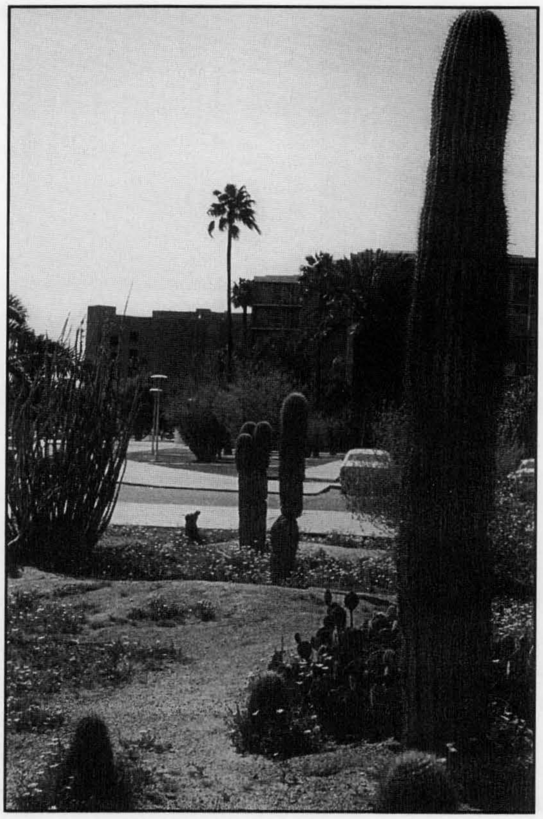
patterned after the sequence of courses developed at Texas A&M University. **Lynn Bellamy** and **Greg Raupp** were the leaders in teaching these courses and using cooperative learning and TQM principles in the classroom. By teaching the engineering sciences in this more efficient integrated format, the number of elective courses was increased, even though the total program hours were reduced.

The current curriculum consists of 132 semester hours (math, 19 hours; chemistry, 18 hours; physics, 8 hours; English and general studies, 19 hours; engineering core, 19 hours; chemical engineering, 31 hours; and technical electives, 18 hours). Traditional chemical engineering courses in thermodynamics, fluids, heat and mass transfer, reactor design, and process control are followed by two design courses at the senior level.

The undergraduate program has a heavy laboratory component. **Bob Torrest** has developed a transport lab (fluids and heat transfer) that has been highlighted by accreditation visitors as being truly exceptional. Before leaving ASU for a position with Setpoint, Inc., **Lew Bezanson** led in arranging a cooperative venture with Honeywell that made available a six-console TDC 3000 distributed-control system. This system has been integrated into the undergraduate process control course, resulting in a state-of-the-art platform not normally available in a university, and **Dan Rivera** was added to the faculty in 1990 to serve as its Director. A "unit operations" lab (with experiments ranging from measuring the rate of oxide growth on silicon wafers to determining tray efficiencies in a 20-tray distillation column) rounds out the three-lab sequence; **Jim Beckman** was the main contributor to the development of this lab.

Students are encouraged to select technical electives from areas of emphasis such as environmental, biochemical, or semiconductor materials processing in order to build on the chemical engineering base while developing depth in some area.

ASU is a consortium participant in an NSF-funded Engineering Education Grant to extend the integrated curriculum to the freshman level. A pilot program will be in effect this coming fall when freshmen are enrolled as a block in calculus, physics, English, and a freshman engineering course with the intent of integrating the subject matter across these four courses. Chemistry was excluded from the program because of the different levels of freshman chemistry required of engineering students. Chemical engineering faculty will play an active role in the development of and instruction in this program.



Typical ASU desert landscaping, with Palo Verde dormitory in the background.

THE GRADUATE PROGRAM

Traditional MS and PhD degrees are offered in chemical engineering. The MS degree requires 21-24 hours of course work and 9 or 6 hours of thesis. Currently, students must take four of the following courses: thermodynamics, reactor engineering, transport phenomena I and II, and applied math analysis. A proposal to relax this requirement to give students greater opportunity to specialize in a given area is in the process of being implemented. Specialized technical electives at the graduate level include courses in environmental and biochemical engineering, process control, solid state and electronic materials processing, and process engineering.

The PhD degree is research oriented and requires 84 semester hours, including research and dissertation. Students entering the program must pass a qualifying exam. The first part of the exam is based on undergraduate material (this part is waived for well-qualified candidates.), and the second half is the development of a research proposal on a topic outside of the student's intended research area. A comprehensive exam based on the dissertation prospectus is also required. Once this exam is completed, the student is expected to engage in scholarly, independent research leading to a successful dissertation defense.

DEPARTMENT RESEARCH

Research within the department began modestly in the late 1960s with work in materials processing, environmental dispersion, alternate energy sources, and biomedical engineering. The establishment of a strong research component evolved over time as faculty members with diversified interests were added to the faculty. Research funding in chemical engineering has varied between $500,000 and $1 million during the past three years and has come from a healthy mix of industrial and governmental sources. The university has just been designated a Research I University by the Carnegie Foundation, a significant accomplishment for an institution lacking a medical school and land grant college status.

Chemical engineering faculty play active roles in the Centers for Energy Systems Research, Computer Integrated Manufacturing Systems, and Solid State Electronics Research; **Tim Cale,** a member of the chemical engineering faculty, is Interim Director of the latter. While the emphasis of the Centers is on graduate research, they have also benefited undergraduate students by serving as hosts for undergraduate research and providing high-tech equipment that can also be used in the teaching labs.

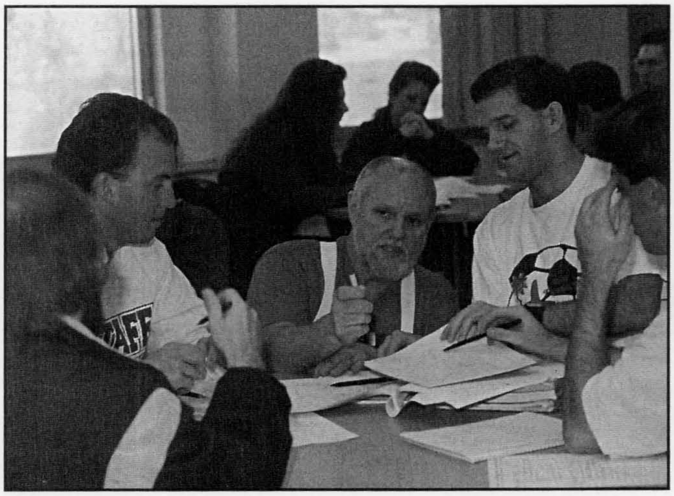
In addition to these Centers (based in the College of Engineering and Applied Sciences), chemical engineering faculty are contributing members of the University Cancer Research Institute and the Center for Solid State Science.

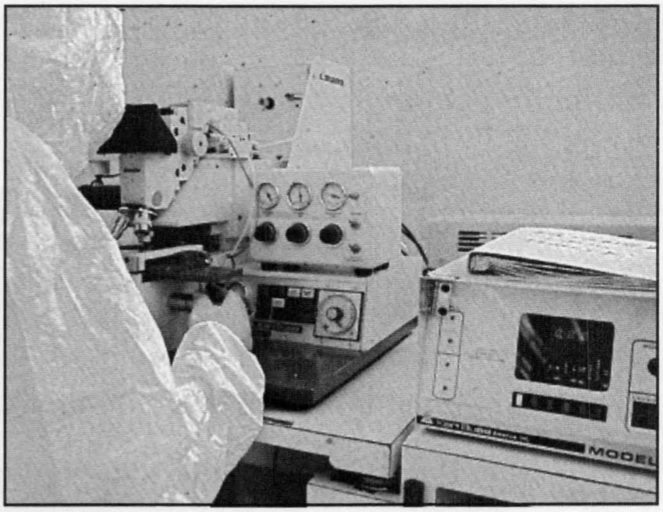
The department has prepared a more detailed description of its program and facilities on a HyperCard disk, which is available on request. We are also contributing material for the CD-ROM on department activities being prepared in conjunction with CACHE's Twentieth Jubilee at next fall's annual AIChE meeting.

► ***Environmental Research*** • **Neil Berman** is currently working on applications of numerical and physical modeling to dispersion calculations in complex terrain. This interdisciplinary research involves faculty and students from mechanical engineering and geography as well as from chemical engineering. A recent example of this research is the

Lynn Bellamy is shown below with some students, engaging in cooperative learning . . .

while the photograph at the right shows research being carried out in the Clean Room in ASU's Center for Solid State Electronics Research.





determination of the nocturnal windfield at the border between Arizona and Mexico during periods in the winter when the windflow is controlled by heating and cooling of the surface. A model of the surface representing a 12-kilometer square area centered on "ambos" Nogales (both U.S. and Mexican cities on the border have the same name) was constructed and used to determine the locations for the best field study when only a few sensors would be available. Other studies have used stratified salt solution to simulate the atmosphere above a long mountain.

Roni Burrows is leading a study on the use of ultra-thin films of organic semiconductors (phthalocyamines) as sensors for the measurement of hazardous gas molecules. Surface infrared spectroscopy, secondary ion mass spectrometry and Raman spectroscopy are being used to study the effects of Pc deposition methods. She is also developing a spectroscopic method for identifying and quantifying atmospheric dispersion onto leaves and other vegetation surfaces.

Jim Kuester has developed a process for converting renewable resources as well as liquid and solid wastes into various chemicals (primarily diesel and jet fuels) through indirect liquefaction. The current focus is on the use of agricultural residues, but studies have been done with scrap polymers, waste solvents, and municipal wastes. His research lab includes a pilot scale fluidized bed pyrolysis unit in series with a fluidized bed reactor to convert the pyrolysis products into liquid fuels.

Greg Raupp has been issued a patent based on a process for remediation of air streams contaminated with VOCs using a combination of UV light and a titanium catalyst. The process can also be adapted to ground water remediation by processing the VOC-laden air resulting when VOCs are air stripped from the water. The EPA is sponsoring a demonstration unit to be placed in the Phoenix area to treat water pumped from a chlorinated solvent contaminated aquifer.

Gene Sater has been investigating a process for recovering a chelating agent and a buffer that are present in a liquid used as a derusting agent by the military. The normal procedure to remove heavy metals from the resulting waste stream was to destroy the organics and then precipitate the metals as hydroxides or sulfides. Recovery and reuse of the organics would improve the economics of the cleaning process.

▶ *Surface Chemistry/Semiconductor Processing* • **Tim Cale** and **Greg Raupp** collaborate on an integrated experimental and theoretical research program aimed at improving the scientific basis for designing, optimizing, and controlling microelectronic device fabrication processes. Their modeling and experimental efforts at ASU, as well as their collaborations with a number of university and industrial groups, focus on developing the reaction kinetic and transport models appropriate for deposition and etch processes. EVOLVE, a 'topography simulation' package developed by Cale, uses these transport and kinetic models to predict how surfaces change during processing. Knowledge of topography is central to device manufacturing, and EVOLVE is being used in a number of companies. These efforts have led to an increased understanding of the role which chemistry plays in deposition and etch processes—particularly in: chemical vapor deposition of tungsten, tungsten silicide, aluminum, and silicon dioxide; plasma enhanced chemical vapor deposition of silicon dioxide; sputter deposition of aluminum alloys, titanium and titanium-tungsten films; and etching of titanium-tungsten-nitride and aluminum films. Cale is involved in collaborative research with faculty in HREM and engineers and scientists at Motorola and the national laboratories to study the evolution of film microstructure during process-

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ing, and to relate microstructure to the reliability of the final devices. Raupp is studying the epitaxial growth of HgCdTe through metal organic chemical vapor deposition.

Roni Burrows is investigating the effect of the treatment of gallium arsenide surfaces with sulfur-containing media in order to improve the electronic properties of these surfaces. She is using real-time surface spectroscopy, HREM, and ion-beam analysis to study the basic surface chemistry of the processes. She is also studying the effects of chemicals, either contaminants or those intentionally introduced, on semiconductor surfaces.

► ***Biochemical Engineering*** • **Tony Garcia** is developing a novel method for bioseparations involving metal affinity chromatography using Ag(I) and Pt(II) as metal supports in the separation of sulfur containing amino acids and biopolymers. He is also using scanning tunneling (STM) and scanning force (SFM) microscopy in the study of how cell morphology and surface chemistry influence immunomodulation.

Imre Zwiebel has used his background in adsorptive separation processes to study the adsorption of proteins onto various substrates. Using STM, he is looking for specific bonding points of collagen on a variety of substrates for answers to biocompatibility, wound healing, and tissue replacement.

Joe Henry, Jr., is currently focusing on biochemical separations with emphasis on the resolution of protein mixtures. He has recently developed a process which permits the use of affinity-specific ligands for highly selective protein separations in a continuous process mode.

► ***Process Engineering and Control*** • **Dan Rivera** is using his expertise in system identification to develop control-relevant algorithms resulting in improvements in all facets of the identification problem (experimental design, model structure definition, parameter estimation, and model validation). The highly fluctuating economic conditions faced by industry place importance on another of Rivera's research areas—the development of control systems that are robust to changing plant conditions, yet easily implemented in distributed control systems. A third research topic is the development of a "user-friendly" CAD package to allow the BS-level engineer to use sophisticated control technology.

Jim Kuester has a second research focus in the area of microwave heating of fluidized beds. This form of heating has the advantages that the reactor walls are relatively cool and that process streams or solids are heated rapidly. Microwave heating has potential applications in semiconductor materials processing, catalyst preparation, and thermochemical conversions. He has integrated a microwave generator and a pilot-scale fluidized bed and has performed initial experiments in the areas of catalyst preparation and polysilicon production from silane.

Bob Torrest is continuing his study of gas-liquid flow through porous media in a wide variety of applications. He is also looking at *in situ,* controlled precipitation of a plugging agent in porous media necessary for profile control in oil reservoirs and the suspension flow of aqueous polymer solutions which give the high viscosity necessary to minimize settling of the suspended particles.

Jim Beckman collaborates with a local company on the development of a non-freon air conditioner. The uniqueness of the unit is based on a patented highly efficient energy transfer process. He is also investigating the incorporation of the idea into distillation column and desalination equipment design.

► ***Engineering Education*** • **Lynn Bellamy** has taken the initiative in introducing Cooperative Education, TQM, and Teaming to the engineering faculty, as well as working with elementary schools, high schools, and community colleges to implement the principles in their environments. As part of the NSF-funded Integrated Curriculum team, Bellamy is continuing his work in developing a pilot freshman curriculum.

THE FUTURE

During the past spring semester, faculty in the three programs within the department met to develop a *Vision* statement of the department's future. The main outcome was recognition of the fact that we are in an unparalleled environment arising from our unique combination of disciplines and our setting in an expanding major metropolitan and manufacturing center. The population growth and the continuing movement of high-tech industries into the Southwest will result in increasing enrollments and opportunities to coordinate research and teaching activities with industrial partners. Having the three programs (chemical, bio, and materials) under one administrative umbrella has already resulted in cooperative efforts in graduate research. We believe that we can also build on this synergism in the classroom at both the undergraduate and graduate level.

The chemical engineering faculty intend to continuously improve our program by building on our closeness with the bio and the materials science programs, while at the same time maintaining our identity as a chemical engineering program. In summary, the future of chemical engineering at ASU is as bright as the Arizona sunshine. ❒