ChE department

Clemson University

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Clemson University, the land-grant institution of South Carolina, is the realization of a long-held dream of its founder, Thomas Green Clemson. A Pennsylvania native, Clemson developed a profitable career as a young consulting and mining engineer in Paris, Philadelphia, and Washington. In 1838 he married the daughter of South Carolina statesman John C. Calhoun, and over the next fifty years he developed an abiding love for upstate South Carolina and an intense interest in the application of scientific principles to improve agriculture. Clemson managed Calhoun's Fort Hill plantation, wrote and published extensively on agricultural chemistry, and eventually served as U.S. Superintendent of Agricultural Affairs. He bought Fort Hill in 1866 after Calhoun's death and spent the last years of his life developing plans to create a "high seminary of learning to benefit the agricultural and mechanical arts." Outliving his wife and children,Clemson left the bulk of his estate to South Carolina upon his death in 1888, with specific instructions in his will leading to the establishment

The Clemson Chemical Engineering Class of 1999 . . .

and evidence of a midnight prank when students rearranged the letters on Earle Hall to indicate that Clemson has the hottest chemical engineering program in the country.

of Clemson College on the Fort Hill site. The Calhoun mansion remains in the center of campus today—a historic landmark to Clemson's vision. The small town that borders the campus also bears his name.

Chemical engineering was first introduced as a course of study at Clemson in 1917. At that time there was no chemical engineering department or faculty, and the core of the curriculum was drawn from courses in mathematics, physics, chemistry, and mechanical engineering. In the spring of 1923, four students completed the prescribed course of study and became Clemson's first chemical engineering graduates. The Department of Chemical Engineering was formally established in 1946, and the undergraduate program has been accredited by ABET since 1959. The Master of Science program was begun in 1960, and the Doctor of Philosophy program was added in 1962. In 1965 the department awarded the first PhD in engineering in the State of South Carolina.

FACILITIES AND FACULTY

Earle Hall was donated to the University by the Olin Charitable Trust in 1958 specifically to house chemical engineering. The 50,000-square-foot facility contains four classrooms, an auditorium, a library, a student lounge, a seminar room, a shop, a 9,000-square-foot unit operations lab, several dedicated research labs, and faculty, graduate student and administrative offices,

Over the past forty years, Earle Hall has undergone many renovations, the most recent being the conversion of the old auditorium into a modern, 68-seat seminar and teaching facility, complete with multimedia projection equipment and a network connection at each seat. As the department has matured, it has benefited enormously from the generous support of alumni and corporate benefactors. Several research labs have been refurbished in recent years to accommodate growing programs and new faculty additions, and the Dow Chemical Company Unit Operations Lab is currently undergoing additional equipment upgrades and modifications.

The faculty of the department is also undergoing a transition, with four new additions in the last few years, all with youthful exuberance and excellent credentials. David Bruce and Mike Kilbey joined the deprtment in 1995, Scott Husson arrived in 1998, and Graham Harrison will be on board in August 1999, after completing a post-doc at the University of Melbourne. The faculty now totals twelve tenured and tenure-track faculty members involved full time in the teaching and research programs of the department (see Table 1). Another new colleague, currently in industry, will also join the faculty later this year. In addition, Y. T. Shah is Senior Vice Provost and Chief Research Officer of the University, Steve Melsheimer is Associate Dean for Undergraduate Studies in the College of Engineering and Science, and Bill Beckwith is Director of the General Engineering Program. Professor Emeritus Joe Mullins also remains active in the support of numerous teaching and research activities of the department.

UNDERGRADUATE STUDIES

Over the last decade the senior chemical engineering class at Clemson has averaged forty-five students per year, and our recent graduates have taken jobs with over 100 different companies. About

TABLE 1
Faculty

Charles H. Barron Jr. (DSc, University of Virginia, 1963)
Polymer reaction engineering, analysis of the effects of physical interactions on molecular weight distribution; information systems for design database development

David A. Bruce (PhD, Georgia Institute of Technology, 1994)
Catalyst development for the petrochemical and pharmaceutical industries and for pollution abatement, chiral zeolites, solid superacids, supported metal complexes

Dan D. Edie (PhD, Univ. of Virginia, 1972) Dow Chemical Professor
Director of the Center for Advanced Engineering Fibers and Films
Polymer processing, formation and characterization of high performance fibers and composite materials, mathematical modeling, rheology

Charles H. Gooding (PhD, North Carolina State University, 1979)
Department Chair
Mass transfer, particularly application and modeling of membrane separation technologies

James M. Haile (PhD, University of Florida, 1976)
Molecular dynamics and thermodynamics, the use of computer simulation techniques to determine thermodynamic and transport properties in fluids

Graham M. Harrison (PhD, Univ. of California, Santa Barbara, 1997)
Non-Newtonian fluid mechanics, optical and mechanical techniques for experimental characterization of polymers, molecular-based constitutive equations

Douglas E. Hirt (PhD, Princeton University, 1989)
Polymer films: extrusion, additive diffusion, interfacial phenomena, mass transfer modeling, polymer thermodymanics

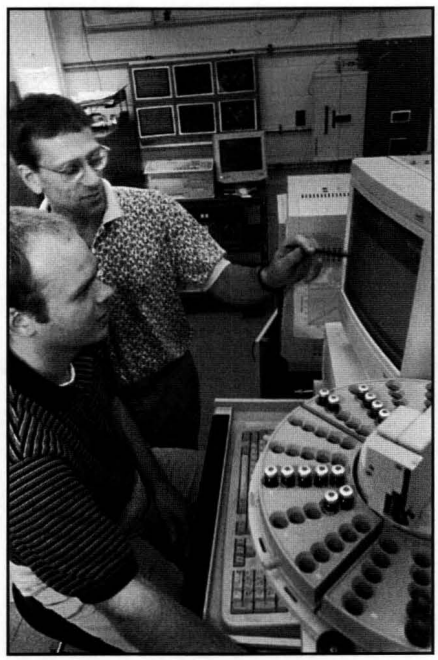
Scott Husson (PhD, University of California, Berkeley, 1998)
Bioseparations, reversible complexation in adsorption and extraction, environmentally benign processing

S. Michael Kilbey II (PhD, University of Minnesota, 1996)
Equilibrium and dynamic behavior of molecularly thin films, interface modification using amphiphilic molecules and electrically conductive polymers, surface forces measurements

Amod A. Ogale (PhD, University of Delaware, 1986)
Polymer processing; composite formation, characterization, micromechanics and modeling; stereolithography and rapid prototyping

Richard W. Rice (PhD, Yale University, 1972)
Kinetics and catalysis, heterogeneous catalysis in petrochemical and related reactions, catalyst characterization, environmentally related catalysis

Mark C. Thies (PhD, University of Delaware, 1985)
Thermodynamics and supercritical fluids, separation processes, materials processing, phase behavior of complex mixtures, environmental applications



Above: Experiments in Dr. Thies' lab are designed to produce phase equilibrium data, usually at high temperatures and pressures.

Left: Professors Husson and Thies discuss an on-line analytical scheme.

10 to 15% of our BS graduates elect to continue their engineering education by pursuing graduate study, and one or two each year choose law school or medical school to further their education. To ensure that students with such diverse interests and career aspirations are well prepared, the Bachelor of Science program in chemical engineering at Clemson emphasizes broad, fundamental principles in science and engineering rather than narrow specializations. Over half of Clemson's chemical engineering undergraduates also gain valuable experience, career insight, and financial assistance by participating in the Cooperative Education Program, which requires at least three semester-long work periods in industry.

The Clemson chemical engineering faculty has placed a high priority on undergraduate instruction since the formative years of the department under the leadership of Charlie Littlejohn. Traditional methods are honed and applied conscientiously, and innovations are continuously being developed and tested to better reach today's students. For example, to improve the communication skills of students, Doug Hirt uses journal writing in most of his undergraduate classes. He and Charles Barron also developed the concept of evolving design projects several years ago with support from the NSF SUCCEED coalition. In the introductory sophomore chemical engineering course, a new process flow sheet is introduced each year, and student teams are formed to study and solve material and energy balance problems. The same flow sheet follows the students through the curriculum, with new aspects being investigated in each course, such as pump specification in fluid flow and heat exchanger layout in heat and mass transfer. In the first semester of the capstone design sequence the evolving design project culminates with an economic analysis.

Doug Hirt is a frequent speaker and author on the subject of both evolving design projects and effective writing assignments in engineering education. He was honored recently by the Chemical Engineering Division of the ASEE with the 1998 Ray W. Fahien Award, which recognizes outstanding teaching effectiveness and educational scholarship. Doug also chairs the Teaching Effectiveness Committee in the College of Engineering and Science. Jim Haile was also recognized in 1998 by ASEE's Chemical Engineering Division, winning the Corcoran Award for his series of papers, "Toward Technical Understanding," which appeared in the Summer 1997, Fall 1997, and Winter 1998 issues of *Chemical Engineering Education*. In these papers Jim investigated the fundamental question of what is meant by understanding of technical material. He is now immersed in the application phase of that quest as a teacher, investigating new ways to inspire, probe, and open the minds of undergraduates as they attempt to grasp the concepts of chemical engineering.

The commitment to teaching excellence is also in good hands with the most recent additions to the chemical engineering faculty. At the May, 1999, commencement exercises, Mike Kilbey received Clemson's top teaching honor for the year, the Alumni Master Teacher Award. It is rare for a professor in one of the university's smaller departments to receive this student-determined award; even more notable, Mike is the youngest recipient ever. Though they haven't yet received such singular awards, David Bruce and Scott Husson have also demonstrated their ability to establish excellent rapport with students at all levels and to guide them to understanding the intricacies of chemical engineering.

Undergraduate students who complete Clemson's chemical engineering program develop a sense of community and pride that is nurtured by small class sizes (usually 20 to 30

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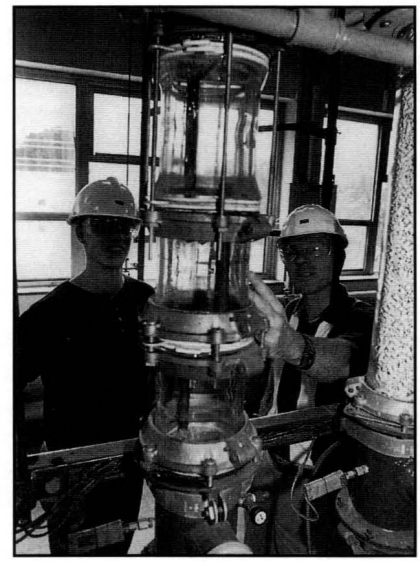
students), accessibility of the faculty, a heavy emphasis on team projects, and the professional and social activities of the AIChE student chapter. Enrichment opportunities include the Co-op Program and the Senior Departmental Honors Program through which academically qualified students can participate in research activities with the faculty and graduate students. The two-semester senior seminar series also serves to complement the classroom and laboratory experience and prepare students for entry into the profession. In the fall semester the seniors learn about career opportunities, resume preparation, interviewing, and early career success skills from a series of external speakers, including recent graduates of the department. In the spring they refine their speaking skills further and learn from each other about business aspects of the chemical industry, professional ethics, safety, the environment, and other topics researched and presented in 40-minute team seminars.



The undergraduate unit ops lab emphasizes planning and execution of experiments, analysis of results, technical communication, and teamwork.

GRADUATE OPPORTUNITIES

The Department offers advanced study leading to the Master of Science and Doctor of Philosophy degrees. The MS degree requires completion of a research thesis and 24 semester credit hours of graduate-level courses. Four core courses are required: Advanced Transport Phenomena, Chemical Engineering Thermodynamics. Chemical Engineering Kinetics, and Separation Processes. Of the remaining twelve credit hours of technical electives, at least six must be in chemical engineering. For graduate students interested in polymers, transport phenomena, or process simulation, an exciting new series of interdisciplinary courses covering chemistry, flow behavior, transport phenomena and visual simulation of polymer flow and orientation is offered through Clemson's Center for Advanced Engineering Fibers and Films.

The MS Industrial Residency Program is a special arrangement involving Clemson University, a graduate student, and a sponsoring company. Typically an MSIRP student initiates a research project at the sponsoring company's site during the summer, completes the required 24 hours of course work in the following fall and spring semesters, and then returns to the company for another seven months of full-time research. This program is restricted to U.S. citizens. Graduate residency students are paid at the prevailing salary level for BS chemical engineers for the ten months on site, but the salary is distributed over the 19-month program. This arrangement results in a monthly stipend about 40% higher than normal graduate assistantships. The sponsoring company also pays tuition and fees, and the research is conducted under joint faculty and industrial supervision and produces a thesis or an equivalent formal report. The MSIRP is an excellent program for students who want to gain industrial experience while pursuing a graduate degree, whether their ultimate intent is to continue with the PhD or to enter industry full-time after earning an MS degree.

Students in Clemson's PhD program must complete at least 36 hours of approved course work beyond the BS, including the MS course requirements (or equivalent courses taken elsewhere) and at least 12 hours in fields other than chemical engineering. PhD students plan their course work with the approval of a research adviser and advisory committee to ensure general competence in chemical engineering, a comprehensive knowledge of the field of specialization, and a mastery of research methods. Each PhD student must pass a written comprehensive exam based on undergraduate and graduate course work, and an oral comprehensive exam, which consists of the presentation and defense of a formal research proposal. After a student's research is completed, the final requirement for the PhD is the oral defense of the dissertation.

RESEARCH AREAS

The research interests of the faculty are summarized in Table 1. Strong, multifaceted programs exist in materials science and engineering, particularly polymer studies, thermodynamics and sepa-

ration processes, and kinetics and catalysis. These programs encompass most of the traditional branches of chemical engineering as well as newer areas, such as advanced rheology, supercritical fluids, molecular simulation, and biotechnology. Research interests of the faculty range from purely theoretical topics to the analysis and improvement of full-scale industrial processes. Two Chemical Engineering faculty were recognized this year for their research accomplishments: Mark Thies received the McQueen Quattlebaum Faculty Achievement Award from the College of Engineering and Science, and Dan Edie received the Alumni Award for Outstanding Achievement in Research from Clemson University.

Research opportunities in the department increased exponentially in 1998 with the National Science Foundation's recognition of Clemson's Center for Advanced Engineering Fibers and Films (CAEFF) as a national Engineering Research Center. This signal event is expected to bring more than $100 million in research support to Clemson over the next ten years. "This award does more than establish us as a national research institution," said Thomas M. Keinath, Dean of Clemson's College of Engineering and Science. "It challenges Clemson to be a leader in the nation's revolution in engineering research and education. What we do in the coming years will have a profound effect on the fiber and film industry as well as the nation's next generation of engineers and scientists."

THE COLLEGE OF ENGINEERING AND SCIENCE

The Department of Chemical Engineering resides in Clemson's College of Engineering and Science (COES), the largest of the University's five colleges. Other engineering disciplines in the College include Civil, Electrical and Computer, Mechanical, Industrial, Ceramic and Materials, Biosystems (formerly Agricultural), and graduate-only programs in Bioengineering and Environmental Engineering and Science. A major reorganization of the University in 1995 also

The Center for Advanced Engineering Fibers and Films

The Center for Advanced Engineering Fibers and Films is a National Science Foundation Engineering Research Center that comprises a partnership between Clemson University and the Massachusetts Institute of Technology. The Center provides an integrated research and education environment for the systems-oriented study of fibers and films. It is the only NSF ERC in the nation to deal exclusively with fibers and films, an industry that accounts for 25% of the manufacturing segment of the U.S. gross domestic product. The industry's manufacturing base includes electronic components, fiber optic cables, synthetic fibers, multi-layer food-packaging films, and reinforced composites used in construction and aircraft. Products to be affected—in some cases, reinvented—as a result of Clemson research can be found in fields as diverse as biomedicine, transportation, communication, and construction.

Through CAEFF, faculty who are recognized for their expertise in key areas of engineering and science are partnering with fiber and film manufacturers to study polymeric fibers and films. These interdisciplinary teams are providing the knowledge base necessary to advance technology in engineering fibers and films and supporting an educational program to produce highly qualified professionals to lead this vital materials industry into the 21st century. Much of the work involves faculty members from the Chemical Engineering Department. In addition to Dan Edie, who directs CAEFF, Mark Thies, Amod Ogale, Doug Hirt, Mike Kilbey, David Bruce, and Graham Harrison are key participants. Dr. Hirt leads one of the Center's three major research thrusts. Drs. Thies, Ogale, and Kilbey head three of the Center's eight primary research topics.

Center facilities include its centralized research/teaching testbed, comprised of integrative fiber and film processing laboratories, on-line measurement instrumentation, a molecular modeling laboratory, and a virtual reality laboratory. Center researchers have access to an impressive battery of sophisticated instruments including FTIR, IR, UV, Raman and mass spectrometers; gas, liquid, gel permeation, and supercritical fluid chromatographs; thermal analysis instruments; x-ray analysis instruments, Instron capillary as well as Rheometrics and Haake rotational rheometers; and a central microscope facility. The Center also has several devices for the preparation of fiber and film precursors, small- and pilot-scale fiber and film extrusion equipment, compression and injection molding equipment for the fabrication of composites, and instruments for the physical testing of fiber, film and composite samples.

In CAEFF, chemical engineering undergraduate and graduate students join interdisciplinary research teams that are developing advanced process models capable of predicting final fiber and film properties. This work focusses on integrating molecular information into continuum models. To verify those models, CAEFF faculty, students, and industry partners are conducting an extensive experimental program for precursors ranging from conventional polymers, such as nylon and polyester, to liquid crystalline materials. The models are ultimately converted to 3-D visual process simulations. The goal is to create a new class of virtual process models that would allow fiber and film producers to develop new and improved products rapidly and efficiently. By designing materials at the molecular level, CAEFF is pioneering engineering technology for the 21st century.

In addition to undergraduate and graduate research programs, CAEFF provides short courses for industrial personnel, sponsors conferences and workshops, and pre-college outreach programs to attract younger students to engineering and science disciplines.

The National Science Foundation has committed $12 million in support for the Center in its first five years, with the total NSF funding anticipated at more than $20 million. In addition, the State of South Carolina and the University have committed $1 million per year, and industrial partners have already pledged more than $1 million per year to support the Center's research and education programs. Partnering industries include 3M, Allied Signal, Arteva Specialties, BP Amoco, Celanese Acetate, Collins and Aikman, Cryovac Division of Sealed Air Corp., Dow Chemical, DuPont, Kemet, Raytheon STX, MSNW, N.H. Andreas, and Shell Chemical.

For more information on CAEFF, visit the Center web site at

www.clemson.edu/caeff

brought the Departments of Chemistry, Computer Science, Geological Sciences, Mathematical Sciences, and Physics and Astronomy into the college as well as the School of Textiles, Fibers, and Polymer Science. Clemson also offers a comprehensive General Engineering program designed exclusively for freshman engineering students and students who transfer from one of the state's two-year institutions. This course of study provides a solid grounding in the fundamentals of engineering while the student explores the many options available in the engineering field. Upon completion of the freshman curriculum, students select their specific engineering major.

South Carolina has been very successful in cultivating international investment in business and manufacturing, with more that 500 companies representing 27 countries now located in the state. Numerous international firms, including Michelin North America and BMW Manufacturing Corporation have both national headquarters and manufacturing plants in South Carolina. Clemson University has formed academic and business partnerships with many of these firms and the countries they represent, creating study-abroad programs that give engineering and science students a strong competitive advantage.

The Engineering Program for International Careers (EPIC) prepares engineering students to be more competitive in the international arena. Key features of this program include:

- *Foreign language courses, including a summer immersion program, to provide competency in French, German, Japanese or Spanish.*
- *An International Internship to provide experience living and working in a foreign culture.*
- *EPIC graduates receive a certificate to document completion of the program.*

The College of Engineering and Science is also committed to student support. The Programs for Education Enrichment and Retention (PEER) was begun to help underrepresented students in the College of Engineering and Science. PEER students are assigned in groups to a first-year PEER mentor, who is a junior, senior, or graduate minority student of the COES. The mentor meets with the PEER group regularly to share information. The PEER office also sponsors study halls, counseling, seminars, and social events. The Program for Educational Enrichment and Retention has helped make Clemson's graduation rate of African American engineering students the 5th highest in the nation.

As female enrollment in the COES has grown over the last two decades, the College responded with WISE (Women in Science and Engineering). An outgrowth of the PEER program, WISE encourages women to persist in preparing for and obtaining careers in science and engineering and to help them be successful in those careers. Academic assistance, including mentoring, advising, tutoring, and study groups, as well as a special resource library, is sponsored through the WISE office. Wise is definitely having an impact. Although women make up only 22% of the COES undergraduate student body (30% in chemical engineering), they won over 60% of the student awards presented this year.

Computers are essential to today's electronic modes and methods of communication as well as technical calculations. For the 1998-99 and 1999-00 school years, the College of Engineering and Science is hosting a Pilot Laptop Program for undergraduates at Clemson. Students can purchase high performance laptop computers at a discount. Special laptop courses are held in classrooms equipped with ethernet connections at every desk. Courses are being offered in English, math, chemistry, computer science, physics, history, and engineering.

CLEMSON UNIVERSITY TODAY

Thomas Green Clemson's dream has become the nucleus of agricultural, scientific, and technological advancement in South Carolina. Full-time enrollment at Clemson University is now approximately 16,300 including 3,700 graduate students. Clemson offers 73 undergraduate and 70 graduate areas of study in its five academic colleges. The University is accredited by the Southern Association of Colleges and Schools to award the bachelor's, master's, specialist and doctoral degrees, and appropriate curricula are accredited by various professional organizations and associations.

Nestled in the foothills of the Blue Ridge Mountains on the shores of Lake Hartwell, Clemson offers the amenities of a small, southern town while providing big-city opportunities. The local environs provide unlimited, year-round opportunities for outdoor recreation, including whitewater rafting on the Chattooga River and watching the Tigers play nearly every sport known to mankind. The University community provides and hosts numerous cultural events, and both Atlanta, Georgia, and Charlotte, North Carolina, are just two hours away via I-85. Clemson is 50 minutes from the regional GSP airport and only a half-hour from Greenville, South Carolina, which claims the greatest number of engineers per capita in the United States.

In its 110-year history, Clemson University has matured from a small agricultural college to a nationally recognized, comprehensive university. Achievements such as the National Science Foundation's designation of the Center for Advanced Engineering Fibers and Films as an NSF Engineering Research Center hold great promise for the future. With innovative faculty, curricula, facilities, and programs that respond to the needs of students, citizens, and industry, the Department of Chemical Engineering will continue to contribute toward Clemson University's goal of preparing students for 21st century careers.

Additional information about Clemson University, the Department of Chemical Engineering, and the Center for Advanced Engineering Fibers and Films may be found at http://www.clemson.edu ❐