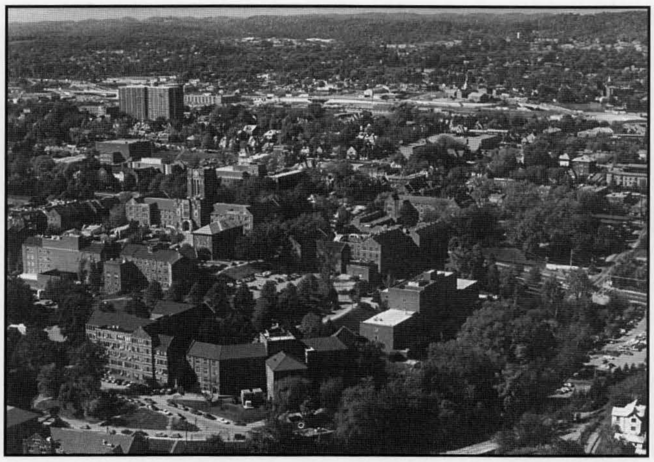
ChE department

Chemical Engineering at . . .

THE UNIVERSITY OF TENNESSEE

FRED E. WEBER, JOHN P. PRADOS
The University of Tennessee • Knoxville, TN 37996-2200

The University of Tennessee is located in Knoxville near the headwaters of the Tennessee River and roughly in the center of the Great Valley of East Tennessee. The main range of the Appalachian Mountains lies forty miles to the southeast, with the Cumberland Plateau about the same distance to the northwest. Within an hour's drive are six Tennessee Valley Authority lakes and the Great Smoky Mountains National Park. The Knoxville metropolitan area has a population over 600,000, but enjoys a pleasant, generally uncrowded atmosphere, consistently ranking among the nation's top ten metropolitan areas in surveys on quality of life. East Tennessee has a four-season climate, ranging from summer temperatures in the 90s to winter temperatures cold enough for snow skiing in nearby mountain resorts.



Aerial view of the University of Tennessee campus.

HISTORY AND MISSION

Founded in 1794 as Blount College, the first non-sectarian college west of the Appalachians, The University of Tennessee today is the state's largest university and Land-Grant institution with about 17,000 undergraduates, 7,500 graduate and professional students, and a faculty of more than 1,600. Bachelor's degrees are offered in over 150 fields, master's degrees in 85, and doctoral degrees in 52.

Although a program called "chemical engineering" appeared in the university catalog as early as 1905, true chemical engineering courses were not offered until 1934, first in the Department of Chemistry and two years later in a separate Department of Chemical Engineering. The first chemical engineering faculty member was Robert M. Boarts, a PhD graduate of the University of Michigan and student of the legendary W.L. Badger. The Master's program was begun in 1935 and the PhD program in 1949 as the first doctoral program in engineering offered by any institution in Tennessee.

The undergraduate program in chemical engineering received its initial accreditation from the Engineers' Council for Professional Development (now known as ABET) in 1939, making it one of the first four chemical engineering programs in the South to receive accreditation. (Programs at Georgia Tech and Virginia Tech were accredited in 1938, while those at Tennessee and Louisiana State were accredited in 1939.) The program has been continuously accredited since that time. The department has had only five heads in its 58-year history: Robert M. Boarts (1936-1960); Homer F. Johnson (1960-1984); Joseph J. Perona (1984-1990); John W. Prados (1990-1993); and Charles F. Moore (1993-present).

The undergraduate program in chemical engineering received its initial accreditation from the Engineers' Council for Professional Development (now known as ABET) in 1939, making it one of the first four chemical engineering programs in the South to receive accreditation. (Programs at Georgia Tech and Virginia Tech were accredited in 1938, while those at Tennessee and Louisiana State were accredited in 1939.) The program has been continuously accredited since that time.

In accordance with the University's overall mission as a Land-Grant institution, the department has the threefold mission to: (1) provide excellence in chemical engineering education at both the undergraduate and graduate levels; (2) provide a strong research program which fortifies the educational process and which advances engineering knowledge; and (3) serve industries in Tennessee and the nation by providing educational opportunities for practicing engineers, research services, and technical assistance.

FACULTY

The chemical engineering faculty includes thirteen full-time members and one regular, part-time member. Some course offerings and graduate student research direction are shared with the Materials Science and Engineering Department, which was a part of chemical engineering prior to 1984. Adjunct faculty members from Martin Marietta Energy Systems, the Eastman Chemical Company, and the Texas Instruments (now Siemens) Company provide a rich source of industrial expertise for teaching specialized graduate courses and directing graduate students' research. The faculty, in turn, are supported by a well-qualified secretarial and technical staff.

The full-time faculty include six "old timers" whose combined service at the University of Tennessee totals 146 years: Don Bogue, George Frazier, Joe Perona, John Prados, and Carl Thomas. Duane Bruns, Robert Counce, and Charlie Moore constitute a "mid-range" group of senior faculty, while Marion Hansen, Tse-Wei Wang, Paul Bienkowski, and Fred Weber are more recent arrivals. The newest addition is Peter Cummings, who joined the faculty in January of 1994 as a Distinguished Scientist and Professor with a joint appointment in the UT Chemical Engineering Department and the Chemical Technology Division of the Oak Ridge National Laboratory (ORNL). There are about a dozen such faculty currently at the University; their positions are supported by special funds provided by the State of Tennessee and the US Department of Energy.

According to Peter Cummings, "These are exciting times at the University of Tennessee. Construction is nearing completion on a 200,000-ft^2 science and engineering research building that will house only research laboratories and which will result in a dramatic increase in both the quantity and quality of research space available to the science and engineering departments. There is an increasingly high level of cooperation between the University of Tennessee and nearby Oak Ridge National Laboratory, the latter being an extraordinary resource of theoretical and experimental expertise with 4500 employees, half of whom are PhD engineers and scientists. The Chemical Technology Division, the division with which chemical engineering has the most direct connection, is one of its largest, embracing a wide range of basic and applied research in such areas as chemical processing, fluid mechanics, separations processes, molecular thermodynamics, and environmental engineering."

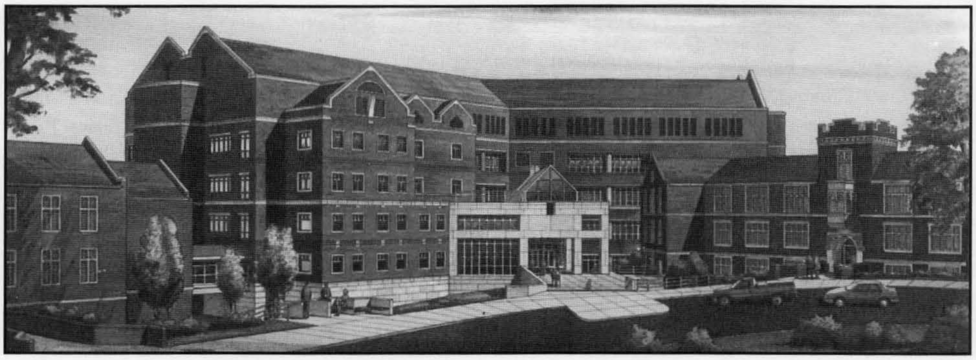
Some recent faculty activities that have attracted outside recognition include:

- Three Fellows of the AIChE: John Prados, Jack Watson, **Joseph Perona**
- A past president and Fellow of the ABET, along with a recipient of ABET's L.E. Grinter Award: **John Prados**
- A recent NATO Postdoctoral Fellow: **Marion Hansen**
- A recipient of a research grant for outstanding young engineering faculty from E.I. du Pont de Nemours and Company for work in pollution prevention: **Robert Counce**
- Recipient of a large, unrestricted grant by E.I. du Pont de Nemours and Company to support graduate education and research in chemical process control: **Charles Moore** and **Duane Bruns**
- One UT/ORNL distinguished Scientist: **Peter Cummings**
- A former director of the AIChE: **John Prados**
- A faculty member is on a one-year appointment as Senior Education Associate with the NSF Engineering Education and Centers Division: **John Prados**
- Chair of the Nuclear Engineering Division of AIChE: **Joseph Perona**

Perhaps more important than any of the preceding recognition is that six of the chemical engineering faculty have received multiple Outstanding Teacher awards.

STUDENTS

At present, the Chemical Engineering Department enrolls 230 undergraduate students, 49 full-time graduate students,



At left is the architect's rendering of the new research building that will be ready for occupancy in 1995,

and

below is the Dougherty Engineering Building, home of chemical engineering at Tennessee.

and 32 part-time graduate students who are employed full-time as engineers. After declining significantly in the mid-1980s, undergraduate chemical engineering enrollments are again beginning to increase, while graduate enrollments remain relatively stable; both are consistent with national trends. Approximately 32% of the undergraduate students are women, 13% are minority, and 5% are international. The corresponding percentages for the graduate students are 21% women, 2% minority, and 32% international. Over the past eight years the department has granted 197 bachelor's degrees, 52 Master's degrees, and 27 doctorates.

Chemical engineering undergraduates regularly fill leadership roles outside the department. Patty Wiegand, a 1992 graduate, was an All-American distance track star and captain of the varsity women's track team. Last year, Jerry Johnson, a junior co-op student, was president of the Tennessee Alpha Chapter of Tau Beta Pi. (It is worth noting that the Tau Beta Pi National Headquarters have been located at The University of Tennessee since 1907, with offices currently in the Dougherty Engineering Building along with chemical engineering.)

LABORATORY AND COMPUTER FACILITIES

A generous grant from the Eastman Chemical Company has been used to modernize the undergraduate chemical engineering laboratory with new equipment and instrumentation. Additional grants, primarily from the Siemens Company, are being used to modernize the chemical process control laboratory to provide undergraduate and graduate students with experience in a state-of-the-art industrial data-acquisition and control system.

Graduate students' experimental research is conducted in on-campus laboratories of the chemical engineering and materials science and engineering departments as well as at research facilities operated by the University at its Pellissippi Biotechnology Research Facility and by the Oak Ridge National Laboratory. At present, six chemical engineering graduate students are conducting research at the Pellissippi facility, and seven full-time graduate students, as well as several part-time students and six postdoctoral research scholars, all in chemical engineering, are conducting experimental research at the Oak Ridge National Laboratory.

On-campus opportunities for experimental research will be enhanced significantly in 1995 with the completion of a new, multidisciplinary Science and Engineering Research Building under construction adjacent to the present chemical engineering facilities in the Dougherty Engineering Building. Space and equipment in the new building will support research in the areas of bioprocess engineering, environmental and waste minimization studies, polymers and composites, and process control.

Both undergraduate and graduate students have access to mainframe computers operated by The University of Tennessee Computing Center and, under special conditions, to supercomputers accessed through the internet. The department operates two microcomputer laboratories, one primarily for undergraduates and one exclusively for graduate student use, along with a SUN SPARC-10 workstation. These laboratories presently contain a mixture of Apple Macintosh and MS/DOS personal computers, connected through a local area network to allow sharing of expensive peripherals and infrequently used programs; each computer contains a hard disk loaded with frequently used software. Faculty computers and those of the departmental clerical and technical staff are also connected through the network. A user-friendly electronic mail system has been implemented to simplify communication among faculty, students, and staff. The network has an interbridge connection to the University's ethernet, through which any personal computer can access mainframe computers and the internet.

The combined assets of The University of Tennessee and ORNL in massively parallel computers make it one of the richest computational environments in the U.S. Between them, the two institutions have two Intel Paragons, a Kendall Square KSR1, an Intel IPSC/860, a Masspar, and a Thinking Machines CM-5. The UTK/ORNL Joint Institute for Computational Science provides instruction on the efficient use of these machines.

RESEARCH AREAS AND SUPPORT

In recent years the chemical engineering faculty have attempted to focus their research in a few limited areas to allow better mutual support and interaction with the University's interdisciplinary research centers. Current research is concentrated in the following four principal areas:

Bioprocess Engineering • Four faculty members are currently working in this area, with much of the work conducted in collaboration with the Department of Botany, the Center for Environmental Biotechnology, and the Oak Ridge National Laboratory. Active research areas include the development of reactor systems for biodegradation of toxic organics, modeling and analysis on *in-situ* remediation processes, and the application of bioluminescent sensors to measurement of reaction rates in bioreactors.

Polymers and Composites • Four faculty members have active research in this area, with much of the work conducted in collaboration with the Department of Materials Science and Engineering and the Center for Materials Processing. Work is currently in progress in the rheology of polymers, modeling of tubular film blowing, multivariable control of a fiber spinning process, modeling of polymer crystallization in pipe extrusion, and in-line monitoring of polymeric processes.

Process Control • Three faculty members are collaborating with the Measurement and Control Engineering Center in this area. Research is currently being done in plant-wide process control system design and analysis, the use of neural networks for system process monitoring and control, sensor development and data acquisition and control for polymer processing operations, and the monitoring, modeling, and control of bioprocesses such as biowastewater treatment plants and fermentation processes.

Pollution Prevention and Separations Technology • Seven faculty members are currently active in this area, with much of the work conducted in collaboration with the Energy, Environment, and Resources Center, the Environmental Engineering Program, and the Oak Ridge National Laboratory. Areas of research include the development and evaluation of non-halogenated solvent cleaning technologies, the development of tools to aid in performance of life cycle assessments, supercritical extraction techniques, and air stripping of volatile organic compounds from ground water.

SPECIAL STUDENT OPPORTUNITIES

All full-time chemical engineering graduate students conduct research under the direction of one or more faculty members as a part of their MS or PhD degree requirements. In addition, undergraduate students with strong academic records may elect to conduct a senior research project with a faculty member for academic credit. Several such projects are conducted each year, some as individual efforts and some as small-group projects.

On-campus opportunities for experimental research will be enhanced significantly in 1995 with the completion of a new, multidisciplinary Science and Engineering Research Building under construction adjacent to the present chemical engineering facilities in the Dougherty Engineering Building. Space and equipment in the new building will support research in the areas of bioprocess engineering, environmental and waste minimization studies, polymers and composites, and process control.

The University operates a long-standing Engineering Cooperative (Co-op) Program in which students alternate semesters of academic study with semesters of work related to their career goals. The program is open to all students in the College of Engineering who are making satisfactory progress toward their degrees, and 25-30% of the chemical engineering undergraduates participate.

In addition to Co-op and undergraduate research experiences, a limited number of seniors may be invited to participate in an industrial internship for academic credit. In this internship, small groups of students under the direction of a faculty member are introduced to an actual industrial problem and are given the opportunity to develop a proposed solution. Most of the work is conducted on-campus, and at the end of the semester the students make a formal presentation of their proposed solution to the engineers who posed the original problem. In a number of instances, these solutions have been implemented in the industrial setting or have led to further studies that ultimately yielded a satisfactory solution. Currently, these internships are conducted with cooperation and support by the Eastman Chemical Company in the area of chemical process control under the direction of Charlie Moore, and by the du Pont Company in the area of industrial pollution prevention under the direction of Pete Counce.

The undergraduate curriculum allows some flexibility for specialization through the inclusion of four technical electives. Three 3-hour technical elective courses may be selected from a wide variety of advanced engineering, science, mathematics, or business courses, and the fourth 3-hour elective is taken in advanced chemistry or other advanced science (*e.g.,* microbiology, materials science). Possible areas of specialization include biotechnology, process control, industrial pollution prevention, and polymer engineering; a designated faculty member in each area can advise students on proper elective selection. Other areas of emphasis can also be developed in consultation with a faculty advisor.

The department participates actively in the Engineering college program of videotaped, off-campus graduate instruction. Core and elective courses in the Master's program are offered on a regular cycle to students at off-campus sites, including Oak Ridge, The Kingsport University Center, and other chemical plants in Tennessee. Additional videotaped graduate courses will be offered as dictated by demand. When student demand is sufficient, graduate courses are also taught "live" at Oak Ridge and Kingsport. Students may complete MS degrees at these locations (and the PhD at Oak Ridge) without a period of full-time residence in Knoxville.

A CLOSING THOUGHT

Over the years, The University of Tennessee Chemical Engineering Department has enjoyed a happy combination of assets: faculty members with a wholeheared commitment to students in their roles as research directors, as graduate and undergraduate teachers, and as academic and career advisors; a highly trained technical support staff for both instrumentation/computers and mechanical systems, who provide invaluable support for experimental research and instruction laboratory development; and last but not least, a capable and caring secretarial staff whose motto is "how can I help you?" and not "go away and don't bother me!" Our chemical engineering graduates may soon grow hazy about the finer points of transport phenomena or the Second Law of Thermodynamics, but they will remember clearly how the departmental secretaries, Sancy Hail and Betty Frazier, created within a large and sometimes impersonal university a warm atmosphere of genuine care and concern for their welfare. ❒

ChE letter to the editor

Dear Sir:

This letter is motivated by the paper "Exothermic CSTRs—Just How Stable are the Multiple Steady States?" by Shacham, Brauner, and Cutlip, that appeared in the winter 1994 issue of *CEE.*

The authors argue that the upper steady state in an exothermic CSTR can be unstable; this is wrong and, as a matter of fact, it results from a misunderstanding of the mathematical stability concept.

Their conclusion stems from a linearized analysis of the problem which is not exact around that steady state; as they say in their paper, "...when it is integrated for a long enough time, the basic model will produce a limit cycle." As their basic model is, in reality, the nonlinearized model, we can believe that this is the correct answer to the problem; but, and this is the main mistake, a **limit cycle is a stable** periodic **solution,** as any standard textbook would teach them! Even if the oscillations were much larger than the ones observed in their Figure 6, where the "terrible oscillations" (which they incorrectly interpret as instabilities) are of the order of 0.1°R! Finally, one can say that one thing is the stability of the steady state, which can, in fact, be concluded from a plot with both the heats generated and removed (their Figure 1) and another is the nature of this stable steady state (limit cycle, in this case), which cannot be established from that plot.

Let's then restate that when three steady states result from the intersections of the lines of the heat generated and the heat removed, the upper and lower are stable (irrespective of the nature of these steady states), while the middle one is unstable.

Thank you very much for your attention.

José Miguel Loureiro, Associate Professor
Dept. de Engenharia Quimica •
Univ. do Porto
Rua dos Bragas •
4099 Porto Codex, Portugal

Response to Letter to the Editor

To the Editor:

The letter of Prof. Loureiro contains several misconceptions which are very important to correct. These misconceptions are:

1. *The results of a stability analysis for a linearized system are not valid for a nonlinear system.*
2. *A stable periodic solution is equivalent to a stable steady state.*
3. *The stability of a system can be deduced from a small initial response of the system to a disturbance.*

These misconceptions will be discussed separately.

▶ *Relationship between stability of the nonlinear and the linearized system.*

This relationship was established by the Liapunov theorem (see for example, reference 1). This theorem deals with the stability of a nonlinear system in the vicinity of a particular critical (steady state) point, and it states that "If the linearized solution is unstable, then the actual operation (as described by the nonlinear equations) will be unstable...." The meaning of Liapunov's theorem is that instability indicated by linear stability analysis is a sufficient condition for