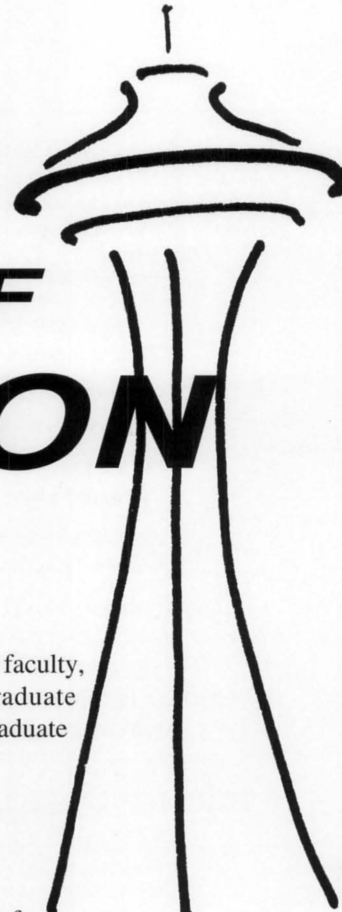

UNIVERSITY OF WASHINGTON

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It was too early to exchange pleasantries; the ringing phone could only mean that something was wrong—at best a wrong number, at worst, well, who knows? Thus awakened on Saturday morning in February, 1964, Albert "Les" Babb quickly ruled out the first possibility. The easily recognizable voice belonged to Dr. Belding Scribner, inventor of the arteriovenous shunt, and he was obviously distressed. Scribner related that the "Who-Shall-Live Committee" had just denied treatment to a 16-year-old high school honor student and "[her] only hope for survival would be to get intermittent dialysis therapy within the next four months!"

Babb, a chemical engineering professor at the University of Washington, knew full well the binding and irrevocable nature of the committee's decision and its consequences for the patient, the daughter of a friend of his. He had just overseen development of the "monster," a multipatient dialysis machine in use at the University of Washington hospital.

After Scribner's call, Babb's next course of action was clear; he must develop an in-home dialysis machine that could be used without medical supervision and he must do so within the next four months. Scribner and Babb quickly assembled a team of physicians and engineers, and the "Mini-I," the first in-home portable dialysis machine, made its lifesaving debut in June of that year. Commercial production of dialysis machines based on the Mini-I and its novel continuous proportioning dialysate system began the following year, and by 1969 the system was the predominant method of dialysis. Today it is the exclusive method.

The portable dialysis machine is one of the many treasured accomplishments of our Department of Chemical Engineering. Accredited by the AIChE in 1926 (only the second year in which accreditation was offered) the department has a long history leading up to its current position as a flourishing institution of research and teaching with 14 full-time faculty, 10 staff members, 60 graduate students, and 150 undergraduate students.

THE UNIVERSITY OF WASHINGTON AND SEATTLE

The 680-acre University of Washington (UW) campus blends woodlands, wetlands, landscaped verandas, and urban architecture into a setting of uncommon beauty. The main campus sits on a predominantly southward-facing, and sometimes steep, slope etched out by glaciers during the ice age. Two of the many visual highlights of the campus include the "Quad," with its breathtaking display of blooming Japanese Cherry trees each spring, and the Rainier Vista, the main promenade that makes a virtual connection between the campus and the 14,400-ft peak of Mt. Rainier a hundred miles to the southeast. Within this setting, 25,000 undergraduate students, 9,000 graduate and professional students, and 2,800 faculty carry out the pursuit of education and scholarship.

The campus is located just four miles northeast of downtown Seattle, where the University began as the Territorial University in 1861. It remained there until 1893, when it moved "as far away from the city as is reasonable" to its present location.

Seattle has prospered as a center of transportation—water, rail, air, and even bicycle. In *Cry of the Wolf,* Jack London describes Seattle's role as the starting point in the Alaskan-Yukon gold rush of 1898-99. It also became the western terminus of the Great Northern railroad from Minneapolis-St. Paul in 1893—under the ownership and control of the "empire builder," James J. Hill, it was the first transcontinental railroad built without government subsidy. Three statues stand on the UW campus today: one, naturally, is of

George Washington; another is of the composer Edward Grieg; and the third, J.J. Hill.

In 1916, lumberman William E. Boeing began building seaplanes to improve transportation throughout the vast Pacific Coastal waterways of the Northwest, and late in the 1920s, he formed a regional airline, both as a market for his planes and to deliver mail across the Cascade Mountains. In the early 50s it took "betting the company" to build the Boeing 707, the first successful commercial jet, establishing Boeing's place as the preeminent builder of commercial airliners. What about the airline? In 1934 the Roosevelt administration forced Boeing to divest itself of the airline—it is now United Airlines.

The newest chapter in transportation involves the bicycle. A vast network of bicycle trails threads through Seattle and neighboring areas, with the most prominent being the 17-mile Burke-Gilman trail, which runs through the campus along the right-of-way of an abandoned railroad. Chemical engineering students, staff, and faculty all use the trail for commuting, not just by bicycle but also by skateboard, roller blades, roller skis, and, of course, by foot!

Rainier Vista, the main promenade of the campus, with the tower of the Administration Building, Drumheller Fountain, and Mt. Rainier in the background. *(Photo by Davis Freeman)*

THE CHEMICAL ENGINEERING DEPARTMENT

Chemical engineering began in 1904 as a discipline within the chemistry department. Its first BS degree was granted in 1907, and one of its first PhDs went to Waldo L. Semon in 1924 —Semon, now installed in the Inventor's Hall of Fame, first synthesized polyvinyl chloride; among his many other inventions, bubble gum remains the favorite of his grandchildren.

Henry K. Benson began teaching in 1905, specializing in industrial and physical chemistry and placing special emphasis on continuous (as opposed to batch) processing. At the end of World War I, he became Executive Officer of the new Department of Chemistry and Chemical Engineering. Subsequently, Prof. Beuschlein was hired to take on chemical engineering matters as Benson's responsibilities were set mostly by the much larger chemistry program.

Throughout the next two decades, chemical engineering continued in the hands of Benson and Beuschlein, and then in 1947 two relative newcomers, R. Wells Moulton, a PhD graduate of UW, and Joseph L. McCarthy, a former UW student with a PhD from McGill, took the reins: Moulton took over Beuschlein's responsibilities of running the chemical engineering program, while McCarthy worked on cleaning up the polluted effluents of the local pulp mills.

In 1953, the Department of Chemical Engineering became established as a separate department within the College of Engineering, but remained physically with the Department of Chemistry in Bagley Hall. Moulton became chairman of the new department and oversaw a period of dynamic growth. He encouraged Les Babb to pursue the new field of nuclear engineering and brought Babb and Scribner together for their collaboration leading to the Monster and Mini-I dialysis machines. Chemistry, chemical engineering, and the nuclear engineering group all expanded rapidly within Bagley Hall, and the time eventually came when additional space was needed. In 1967 chemical and nuclear engineering (with Babb as its chair) moved into their new home, Benson Hall—named after the founder of chemical engineering at UW.

Charles Sleicher became the next chairman in 1977 and continued the tradition of growth started by Moulton, establishing a center for surface science in 1983. The department's investment in new faculty also returned high dividends in the form of four PYI awards among a faculty of twelve. Sleicher remained chairman until 1989 when Bruce Finlayson became only the fourth chairman in the department's long history.

Benson Hall sits amid a diverse collection of natural and

Eric Stuve

Mary Levin

Above: Flanked by twin 20,000 volt coupling devices, graduate student Tim Pinkerton adjusts tip alignment in the field ion microscope. At Right: One of the twenty-five Japanese Cherry trees in full bloom in the Quad.

architectural beauty. It has 20,000 square feet of research laboratory space and 5,300 square feet of teaching laboratories, including the laboratories of unit operations, computer and process control, colloid and surface science, and electrochemistry. Supporting facilities include a well-equipped machine shop, electronics shop, and a computer network of 75 Macintosh-based machines and three Vaxes.

UNDERGRADUATE INSTRUCTION

Over the past twenty years, an average of 62 BS degrees have been granted yearly by the department. Recent enrollment has been quite stable, with 57 BS degrees granted last year, of which 40% went to women. Participation of women in the program has increased from an average of 30% over the last five years to 48% for the most recently admitted class. The department maintains an active scholarship program, and approximately 20% of each undergraduate class receives either full or partial support of their education through chemical engineering scholarships.

Undergraduate students from UW enter the department at the end of their sophomore year, while students transferring from one of the community colleges or state-wide four-year universities enter at the beginning of their junior year. Typically, about 40% of each class is made up of transfer students. The average entering grade-point average is 3.43, with 30% of students having a GPA of 3.7 or higher.

Once in the department, students take the canonical mass and energy balance course. Process simulation with Aspen is an integral part of all required undergraduate courses, and Babb has the formidable task of introducing sophomores and juniors to Aspen. Many students have had little experience with spreadsheet programs and computer communications protocols, so Babb also undertakes to redress these deficiencies.

From there, the students take traditional courses in transport processes (fluid mechanics, heat transfer, and mass transfer), reactor design, and process control. Homework problems and class projects include work in design and statistics. Students also take two quarters of unit operations laboratory where they receive their first exposure to independent problem formulation, working in groups, taking and statistically analyzing data, and preparing convincing written and oral reports. All experiments are open-ended, with only minimal guidance from instructors; students are allowed, and even encouraged, to learn from each other.

Process design is covered in two courses in the last two quarters of the senior year. The first course introduces students to engineering economics and gives them a first crack at a "conceptual design" of an entire process in about three weeks. This design is done on Aspen and reawakens students to the systems approach to engineering design—for many a rude awakening, indeed. In the capstone course, students work in groups of four to design an entire chemical process both at the conceptual stage, where equipment specifications float, and at the application stage, where optimization proceeds with fixed equipment parameters. Students then submit phone-book size reports detailing their designs and rationale.

A number of elective options are available to students along the way. The department offers "specialty options" in which students focus at least 9 credits of their advanced chemistry and engineering science electives into a particular

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Graduate student Theresa Jurgens-Kowal examines sample alignment in the X-ray photoelectron spectrometer.

area: biotechnology; polymers, composites, colloids, and interfaces; electronic materials; computers applied to chemical engineering; environmental engineering; and nuclear chemical engineering. About 40% of students perform undergraduate research projects both to prepare for entry into the job market and for graduate school.

At graduation time, the most important problem looming for students is finding a job. To help increase their employment prospects, the department encourages students to take co-ops during their studies and offers a two-track curriculum so that, with careful planning, students can take a six month co-op without lengthening their time to degree. Currently, about 19% of students take co-ops.

The current employment situation looks good, especially because of the increase in semiconductor manufacturing in the Northwest. No single type of job is preeminent; students find employment in small local companies, waste remediation at the Hanford Nuclear Reservation, semiconductor manufacturing, and of course, the oil and chemical process industries.

GRADUATE INSTRUCTION AND RESEARCH

The department has about sixty graduate students, all engaged in research activities. During the past five years the department has graduated an average of 10-11 PhDs each year, making it fourteenth in annual production of PhD chemical engineers. Entering graduate students take courses in applied mathematics, thermodynamics, fluid mechanics, heat transfer, and reaction kinetics during their first two quarters.

Students earn entry into the PhD program upon successful completion of a Preliminary Exam that embodies the goal of teaching students to "learn how to learn" by assessing their abilities in three areas: a knowledge-base of chemical engineering fundamentals, critical and analytical thinking skills, and research performance itself. Fundamentals of chemical engineering are probed in an oral examination, and critical and analytical skills are assessed through a written and oral critique of a current research paper assigned to the student by the faculty. Once these two parts have been successfully completed (at the end of the second quarter), students then choose a research advisor and begin their thesis research in earnest. About six months later, students take the last part of the Preliminary Exam, in which they present and defend their research to date and field related questions from the faculty.

CHEMICAL ENGINEERING RESEARCH

The nature of research spans the full spectrum from molecular-level fundamental research to applied research for end-use products. Some major research successes of the department include the home kidney dialysis machine (Babb) mentioned at the beginning of this article, textbooks on numerical mathematics for chemical engineering (Finlayson), polymer composites for airplane manufacture (Seferis), design of a Seattle Metro sewer project (1993) that has saved local taxpayers about $10 million (Ricker), and development of a biocompatible, plasma deposited polymer (Ratner).

Research in the department has grown according to a strategy of developing strength in a number of critical research areas. Today, the department offers a variety of research programs in surface science, biotechnology, environmental studies, computers and process control, and materials (polymers and thin films). These five topics represent the subject matter of eighteen research groups, yet research methodologies can be broadly categorized (with a few exceptions) into three groups. Seven research groups engage in some form of surface science, six in biotechnology, and four in computer methods. Perhaps the most distinctive exception is the work on industrial teaming, which has been implemented in the Boeing 777 program.

The relatively large proportion of surface science work is perhaps surprising for a chemical engineering department. **John Berg** began the department's modern surface science era by studying liquid interfacial and colloidal phenomena. Today, Berg offers an industrial short course on surface and colloidal science with about 45 participants each year. Berg's current research focuses on improved absorbents and de-inking of papers.

In 1983 a $500,000 grant from the Shell Companies Foundation established a state-of-the-art surface analysis center based on X-ray photoelectron spectroscopy. **Buddy Ratner** combined this center with operating funds from the NIH and began to study surfaces of biological interest, especially the biocompatibility of polymers used in implants. Shortly thereafter, **Eric Stuve** started his program of electrochemical surface science that incorporates both solid/liquid and solid/gas surface science, including a system that does both. This work focuses on fundamentals of electrochemistry and mechanisms of fuel cell reactions.

Biker professors at a local rally. From left to right: Larry Ricker, Barbara Krieger-Brockett, Dan Schwartz, Brad Holt, Eric Stuve, Bruce Finlayson, and Lew Wedgewood. *(Photo by Eric Stuve.)*

The growth of both "wet" and "dry" surface science has been steady throughout the last ten years. In the former category, **Dan Schwartz** has established an electrochemical engineering program that, among other projects, has developed a method of Raman spectroscopy that images multicomponent electrodeposition of magnetic thin films in situ and in real time. Ratner has added scanning probe techniques (scanning tunneling microscopy and atomic force microscopy) for imaging biological surfaces under water. **Tom Horbett** studies the response of cells to polymer surfaces with respect to platelet activation and surface thrombogenicity by thermodynamic means (adsorption isotherms) and a new imaging system incorporating a mega-pixel, cooled CCD camera.

In the latter (dry) category, **Dave Castner** studies polymer-metal interactions with X-ray photoelectron spectroscopy and X-ray absorption methods, the latter at the National Synchrotron Light Source (Brookhaven). **Bill Rogers** uses a wide range of surface science techniques to study novel organometallic precursors for growth of boron nitride and aluminum nitride thin films.

With all of this surface science comes a thirst for instrumentation. For its major surface science equipment, the department has four X-ray photoelectron spectrometers, two secondary ion mass spectrometers (one of which is time-of-flight), three atomic resolution microscopes, and a field ion microscope. Nine ultrahigh vacuum chambers support this equipment, as well as other (minor) instruments such as mass spectrometers, electron diffraction optics, and Auger spectrometers.

The department also maintains strong research programs in biotechnology. Those with surface science components (Castner, Horbett, and Ratner) were mentioned above. Two programs involve research on bacteria. Mechanisms of protein production in the bacterium *E. Coli* and regulation of protein folding by chaperonins are studied by **François Baneyx**. Another class of bacteria, the methylotrophs, which feed on methane or chlorinated C_1 hydrocarbons, are examined with respect to their potential in bioremediation and other biocatalytic reactions by **Mary Lidstrom**.

Materials related research includes the surface science work of Schwartz and Rogers, mentioned above, as well as a strong emphasis on polymers. The Polymer Composites Laboratory of **Jim Seferis** examines the influence of processing methods on polymer performance. This work has been incorporated into the new Boeing 777, which is the first commercial airliner to incorporate polymers in structural components. **Graham Allan** works with natural polymers (wood fibers) to precipitate inorganic pigments inside the fiber. This increases the fiber's opacity to allow reduced fiber content in paper. The flow properties of macromolecules are studied both experimentally and numerically by **Lew Wedgewood.** This work combines traditional rheological measurements with numerical analysis and has led to a new vorticity theory for non-Newtonian fluids.

The department's program on environmental studies includes studies of the behavior of aerosols and solid particulates in the atmosphere, marine bioremediation, and reaction engineering. **Jim Davis** studies gas/solid and gas/droplet interactions and reactions with the aid of the dynamic electrobalance, a device capable of isolating and suspending single particles or droplets of micrometer size. Absorption (or release) of pollutant gases can be followed by light scattering, mass spectroscopy, and Raman spectroscopy. **Barbara Krieger-Brockett** examines thermal reactions (combustion) of solids and then uses statistical models to predict gas evolution rates during these reactions. She also

TABLE 1
Chemical Engineering Faculty, University of Washington

G. Graham Allan (Professor of Forest Resources): fiber and polymer science

Albert L. Babb (Professor Emeritus): reactor engineering, bioengineering
- Past chair, Committee on Future Nuclear Power Development (National Academy of Sciences)
- National Academy of Engineers

François Baneyx (Asst. Professor): biotechnology, protein technology, biochemical engineering
- NSF-CAREER award

John C. Berg (Rehnberg Professor): interfacial phenomena, surface and colloid science;
- Co-Editor in Chief, *Adv. Colloid & Interf. Sci.;* Editorial Board, *Langmuir, J. Colloid & Interf. Sci., Colloids & Surfaces, J. Adhesion Sci. & Tech.*
- UW Distinguished Teaching Award; Guggenheim Fellowship; Alpha Chi Sigma Award

David G. Castner (Research Assoc. Professor): polymer and metal-organic interfaces, catalytic materials
- Society for Biomaterials (chair, surf. charact. & modification group); American Vacuum Society (past local chapter chair, applied surface science division); Assoc. Editor, *Plasmas & Polymers*

E. James Davis (Professor): colloid and aerosol physics and chemistry, electrokinetics, light scattering
- Regional Editor, *Colloid & Polymer Sci.;* Assoc. Editor, *Aerosol Sci. & Tech.;* Editorial Board, *J. Aerosol Sci., J. Colloid & Interf. Sci.;* American Association for Aerosol Research (past treasurer, vice president)
- Sinclair Award

Bruce A. Finlayson (Rehnberg Professor and Chair): modeling of chemical engineering problems
- CACHE (past trustee); AIChE (past director, CAST division chair); National Research Council; Editorial Board, *Intl. J. Num. Methods in Fluids, Num. Heat Transfer, Num. Methods Part. Diff. Eqns., Chem. Engr. Educ.*
- Walker Award; AIChE Fellow; National Academy of Engineers

Bradley R. Holt (Assoc. Professor): process design and control
- NSF-PYI Award

Thomas A. Horbett (Professor of Bioengineering): proteins at interfaces, biomaterials, drug delivery
- Clemson Award

Barbara B. Krieger-Brockett (Assoc. Professor): reaction engineering

Mary E. Lidstrom (Jungers Professor): biomolecular engineering, metabolic engineering
- American Academy of Microbiology; Editorial Board, *J. Bacteriol., FEMS Microbiol. Rev., FEMS Microbiol. Ecol.*
- NSF Faculty Award for Women

Buddy D. Ratner (Professor of Bioengineering): biomedical polymer surfaces and interfaces
- Editor, *Plasmas & Polymers;* Assoc. Editor, *J. Biomed. Matls. Res.;* Editorial Board, *Surface Sci. Spectra, J. Biomatls. Sci., Biomaterials, Biomed. Matls.*
- Clemson Award; Perkin Elmer Award

N. Lawrence Ricker (Professor): process control and optimization

J.W. Rogers, Jr. (Professor): surface chemistry and engineering, applications to thin film deposition
- American Vacuum Society (past national program chair, publications committee chair); Editorial Board, *J. Vacuum Sci. & Tech. B*
- Battelle Professorship

Daniel T. Schwartz (Asst. Professor): electrochemical engineering
- Electrochemical Society (chapter chair)
- DOE Jr. Faculty Award; NSF-PYI Award; UW Outstanding Faculty Achievement

James C. Seferis (Boeing/Steiner Professor): polymers and their composites, manufacturing, teaming
- Past chair, Gordon Conference
- NSF-PYI Award; Humboldt Prize; National Academy of Athens; Metler Award

Eric M. Stuve (Professor): electrochemical surface science
- American Vacuum Society (past chapter chair, past director, trustee); Co-chair, Gordon Conference
- Humboldt Fellowship; NSF-PYI Award

Lewis E. Wedgewood (Asst. Professor): computational fluid mechanics, macromolecular fluid flow,

Teaching Faculty

Kermit Garlid (Professor Emeritus): past Chair of Nuclear Engineering

William J. Heideger (Professor Emeritus): Director of Engineering Advising Center

Gene L. Woodruff (Professor): Dean Emeritus of the Graduate School

uses statistical methods to chart and predict the effects of marine bioremediation in Puget Sound in collaboration with the Department of Oceanography.

The computer-intensive research programs include those of Finlayson, Holt, and Ricker. **Bruce Finlayson** continues to apply computer methods to solution of chemical engineering problems, work that has grown out of his three textbooks on the subject. Current work includes a model for blood solutes passing through the heart and skeletal muscles and a model for the swallowing process with the ultimate aim of improving the condition of the millions of people with swallowing problems. **Brad Holt** studies the use of nonlinear control algorithms and neural networks to implement robust controllers, and **Larry Ricker** uses model predictive control to develop algorithms for complex continuous and batch processes. The Metro sewer project previously mentioned consisted of a program to manage twenty-three flow controllers in the existing sewer system to handle storm water runoff without polluting local bodies of water.

FACULTY

The department is fortunate to have a faculty deeply committed to all aspects of academic life: teaching, research, and administration. A goodly number of major awards have been bestowed on the faculty, including two positions in the National Academy of Engineering (Babb, Finlayson) and five NSF young investigator awards (Seferis, Holt, Stuve, Schwartz, Baneyx). The department also has a strong commitment to service; many faculty hold major positions on editorial boards or within professional societies. Table 1 lists the departmental faculty along with their research interests, major awards, and service appointments.

ACKNOWLEDGMENTS

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