Chemical Engineering at
Columbia University

CARL C. GRYTE,
with contributions from
LENORA BABB AND
EDWARD F. LEONARD
Columbia University
New York, NY 13699-5705

CELEBRATING 100 YEARS

Columbia Chemical Engineering is quintessentially New York, a central part of a university whose legal name is Columbia University in the City of New York. It is a university united to its city perhaps more than any other urban university in the United States. In 2005 Columbia Chemical Engineering celebrated its 100th anniversary, but it is rooted even farther back into the chemical, financial, and public works history of its home city; the special characteristics of contemporary chemical engineering at Columbia trace far into the department's, the city's, and the country's past.

A STORIED HISTORY

Columbia's engineering school was founded in 1864, initially named the School of Mines. It originated out of science departments that had participated in the 19th-century struggle in much of the Western World to reconcile philosophical and practical views of science.

In 1896, separate schools of engineering, chemistry, and architecture were set off from the School of Mines, resulting, finally, in Columbia's first curriculum in chemical engineering being offered by the School of Chemistry in the fall of 1905 (having been approved the preceding February).

A towering figure at Columbia and in New York at the time was **Charles Frederick Chandler**, a Bostonian whose pivotal education in chemistry was, notwithstanding his origins, in Germany. There he met some of Europe's leading scientists, including Wöhler, Liebig, von Humboldt, and Pasteur—all of whom had progressed from a purely philosophical to a decidedly practical bent. On his return with a doctorate from Göttingen, Chandler joined Columbia, where he taught for 46 years.

Professor Chandler actually campaigned for 14 years before 1905 for a program that would produce what we could now only call chemical engineers. He was strongly resisted by professors who saw chemistry as pure science, beautiful in its own right and with deep philosophical meaning. Such battles raged in many universities and account for the earliest realization of chemical engineering as a distinct discipline being born in technological institutions such as MIT.

INFLUENCES FAR AND NEAR

New York in 1905 was one of the high-thinking, intellectual centers of the young United States. It was an international business center where agents of European—especially German—chemical firms issued and oversaw limited licenses to operate processes developed in Europe. In reaction, strong incentives existed for establishing an American capacity to develop and improve chemical processes, even before this became a desperate priority when the first World War broke out.

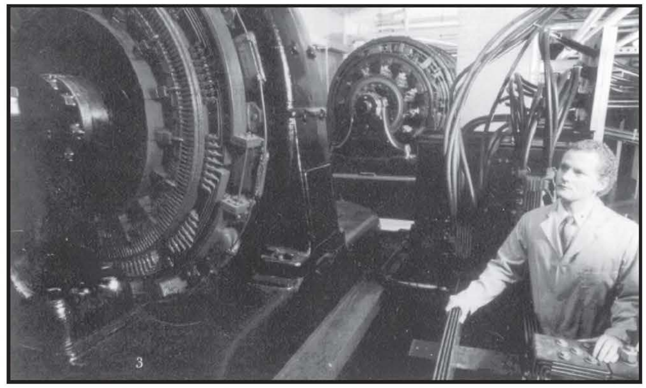
Professor Chandler was close friends with **Nicholas Murray Butler**—Columbia's president from 1902 until 1949. Both men consulted and were on good terms with the New York business community centered on Wall Street. Columbia's role in international business and politics was then, and remains today, preeminent, affecting every department of the university. These connections, and Professor Chandler's popularity as a teacher deeply involved in his subject, impelled the Columbia program to flourish.

In 2005 Columbia Chemical Engineering celebrated its 100th anniversary, but it is rooted even farther back into the chemical, financial, and public works history of its home city.

New York City after the Civil War was also a dirty, overcrowded, unhealthy, and unsafe place. In addition to his extensive involvement with the chemical industry, Professor Chandler played a central role in the public health of New Yorkers, dealing officially for the city with "the adulteration of milk, kerosene accidents, gas-factory nuisances, and general sanitation," as well as an issue that persists today—lead in drinking water. Professor Chandler was also very concerned with the chemical education of physicians and pharmacists and presented lectures to those professions regularly. We at Columbia like to think of him as our first biomedically oriented chemical engineer.

BUILDING THE PROGRAM

Records show the first chemical engineering curriculum at Columbia laid out four solid years of unremitting "chemistry, engineering, metallurgy, mathematics, mechanics, physics, and mineralology," having presumed prior preparation in "algebra, geometry, plane trigonometry, chemistry, physics, freehand drawing, English literature, composition and grammar, American and English history, French, and German."



An early view of the large electrical generators at Columbia ChE's now-closed Heat Transfer Research Facility. For more than 50 years the laboratory tested electrically heated models of nuclear fuel-rod assemblies. Practically every configuration used in the Western World's boiling-water nuclear reactors was tested at this facility. Tests were run late at night to reduce dimming of lights in Manhattan.

Professor A.W. Hixson, who joined the faculty in 1922 and later became the preeminent department historian of Columbia, put forth the claim that despite the preexistence of other programs entitled chemical engineering, Columbia's was "the first well-balanced and completely integrated curriculum in chemical engineering to be established in America." In what is arguably a less disputable first, only five years after its 1905 founding Columbia admitted students to study for the degree "doctor of philosophy in chemical engineering."

Professor Chandler's handpicked colleague and later successor, **Milton C. Whitaker**, also became a leading figure in chemical engineering education. He was recognized with two honorary degrees and was an early president of AIChE.

Engendered by these early innovators, Columbia Chemical Engineering's current specializations all have origins and histories that reach back to the department's founding.

Polymer Surfaces

In the earliest years, polymers were mostly natural and the coursework was concerned with materials such as cellulose, gutta percha, and rubber. The esters of cellulose were already in wide use, however, and as the department was being founded **Leo Baekeland** was inventing the phenol-formaldehyde resin that was to bear his name. Indeed, Baekeland was an honorary professor in the department, an advisor to Columbia's President Butler, and an overseer of the chemical engineering program nearly until his death in 1944.

Left, Columbia's Unit Ops Lab, circa 1929, with students dressed "properly" for lab work in those days. Columbia's department was one of the earliest proponents of the unit operations concept and such laboratories evolved continuously along these lines through the first half of the 20th century. Above, Professor Elmer Gaden and family. Gaden was named "Father of Biochemical Engineering" by **Chemical Engineering News** ***in 1971; this photo appeared on the magazine's cover.***

With the nation's drive for independence from European technology, major emphasis was placed on process and plant design. A steady stream of doctoral theses based on process and plant design flowed out of the department from 1915 through the beginning of the second World War. While these dissertations covered a wide range of processes, many were concerned with raw materials for synthetic substances.

In 1939, **James M. Church** arrived at Columbia and for more than 20 years ran an undergraduate unit processes laboratory in which students conducted carefully scaled-down versions of industrial, mostly organic, processes. The real resurgence of interest in polymers began in the mid-'60s, however, with the hiring of **George Odian** in 1966 and **Harry Gregor** in 1967. They were joined by **Carl Gryte** in 1972 and **Christopher Durning** in 1983. The trend continued when **Ben O'Shaughnessy**, a condensed-matter physicist, joined the faculty in 1988, followed by **Rasti Levicky** in 1998, and **Jeffrey Koberstein** in 2000. The lasting theme of this resurgence has been an interest in polymer surfaces in an exceptionally wide range of applications.

Electrochemical Engineering

Electrochemistry and electrochemical engineering have had a similarly long run through the department's history. For a long time the ability to generate electricity from the potential energy of water far outweighed the ability to transmit electricity over long distances. In that era, a major center of electrochemical manufacturing evolved at Niagara Falls, N.Y.

The first professor of electrochemical engineering, **Samuel A. Tucker**, was appointed in 1910 and rapidly built up what historian Hixson has called the most complete electrochemical laboratory in the country. The strength of a great university was brought to bear on this enterprise through the influence of Columbia's Department of Physics, with its interests in electricity.

In 1922, **Colin G. Fink** joined the department to begin a long and distinguished career in electrochemical engineering. Professor Fink was a 1903 Columbia graduate who subsequently received his Ph.D. in chemistry (from the University of Leipzig) in 1907. Fink's personal research accomplishments were extraordinary, including—during earlier employment with General Electric—the process for drawing tungsten wire that was essential to light-bulb manufacture, as well as the development of chromium plating. He became the executive secretary of the Electrochemical Society, revitalized it, and negotiated a home for it on the Columbia campus.

Fink (who retired in 1950) was joined by **Henry B. Linford** in 1942. Linford, too, served as executive secretary of the Electrochemical Society, retiring in 1976. Joining late in Linford's tenure was **Huk Y. Cheh** (who retired in 2001 to become director of research for the Duracell Company). Cheh was honored in 1982 with the Ruben-Viele chair named in honor of Samuel Ruben—a protogé of physics professor Michael Pupin—who made important contributions to the electrochemistry of metals. Cheh was joined in 1991 by **Alan West**, a specialist in electroplating. West was joined in 2000 by **Scott Calabrese Barton**, specializing in fuel cells.

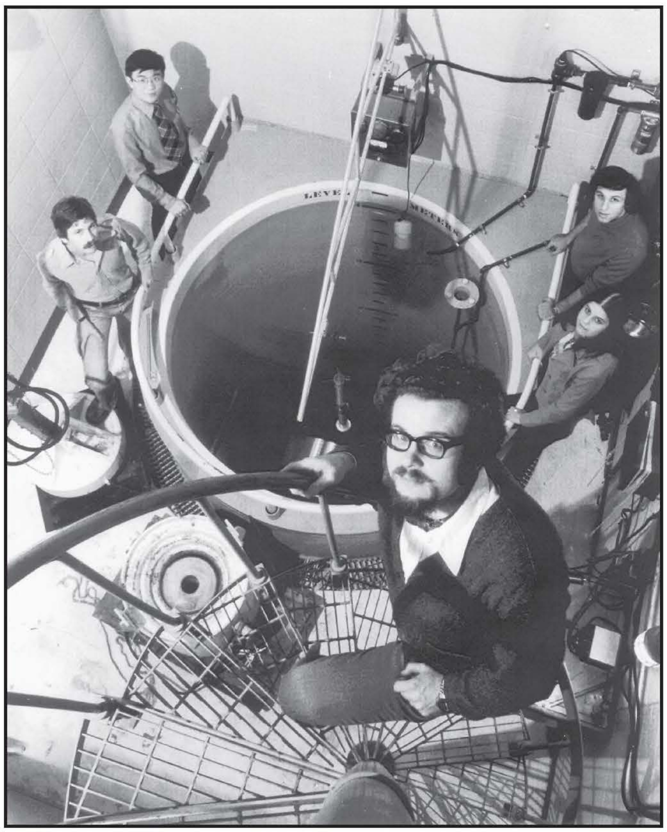
Bioengineering

Bioprocessing, biochemical engineering, and biomedical engineering have also long figured in the department's history. Professor Chandler's influential involvement with the healthcare community and public health has already been mentioned. Following in his footsteps was **D.D. Jackson**, who lead the department for 23 years, from 1917. Jackson was trained in chemistry, engineering, and biology, and had a major interest in biochemical processes (second only to his interest in processes for the production of heavy chemicals). Professor Jackson was succeeded by the aforementioned Professor Hixson—who had a major interest in yeast chemistry. Such chemistry was fundamental to much early bioprocessing.

The real prominence of Columbia in the area of bioprocessing, however, came with the rise of **Elmer L. Gaden** in the years immediately following World War II. The discovery of penicillin and its manufacture by fermentation, combined with the extensive demand for it during the war, had enormously accelerated interest in bioprocessing. Professor Gaden, an eminently practical man but also an ideologue, quickly grasped the significance of oxygen delivery in fermentations and developed, over many years, methods for measuring and increasing it. His students were soon continuing his efforts, both in other schools and in industry. **Juan Asenjo** and **Alex Seressiotis** followed Gaden, who left Columbia in 1974 to ultimately become a professor of chemical engineering at the University of Virginia.

Such was the influence of his work that, on the cover of its May 31, 1971, issue, *Chemical and Engineering News* declared Professor Gaden, "the father of biochemical engineering." But beyond Gaden's contribution to biochemical engineering was his early recognition of the development of biomedical engineering. Largely through his efforts, by 1965 Columbia had graduate and undergraduate programs in "bioengineering" with a decidedly medical orientation. The graduate program was run by an interdisciplinary committee, but the undergraduate program remained within chemical engineering until 1997, when a separate department of biomedical engineering was established.

Many faculty members contributed to the bioengineering program, which was seen as a broad effort to focus the tools and methods of chemical engineering on biological and medical problems. These influential individuals included **Jordan Spencer, Harry Gregor, Frank Castellana, Mary Anne Farrell-Epstein**, Huk Cheh, and **Rakesh Jain**. No faculty member was more involved in this effort than **Edward Leonard**, however, who has worked on problems related to artificial organs since 1956—two years before he joined the Columbia faculty.



Professor Carl Gryte (on staircase) with Isao Noda (top left) and other doctoral students installing the Cobalt-60 radiation source used in polymer research (about 1971).

In more recent times, the department has initiated a program in *genomic engineering*, the first of its kind in the country. **Professor Jingyue Ju** is the director of sequencing in the Columbia Genome Center, while Professors Ju, Levicky, **Banta**, and Leonard are all involved in research that relates to the modeling and manipulation of gene expression.

SHAPED BY WORLD EVENTS

Thus, the three areas of current concentration in the department have extensive histories. The full story, however, is necessarily a bit more complicated. Two great wars stamped the department indelibly.

World War I matured chemical engineering throughout the country. Europe, most notably Germany, no longer served as the fountainhead of chemical engineering—professors were no longer "finished" in European universities—and the American chemical industry moved rapidly toward reliance on chemical engineers wholly formed in the United States. This shift lead inexorably to the dominance that American chemical engineering now possesses.

World War II had more specific effects. Columbia was the home of the Manhattan Project. While the project later moved to other universities and to the national laboratories, its beginnings were at Columbia, and no other university was as much affected. Chemical engineers participated, especially in the early conceptualization of the gaseous diffusion process for the separation of uranium isotopes. While the detailed story remains to be told, **Professor Thomas Drew** was pivotal in these efforts. He remained at Columbia until 1965.

Another legacy of the Manhattan Project was Columbia's Heat Transfer Research Laboratory. This laboratory, founded in 1951, served as the major research and testing facility for thermal-hydraulic design of nuclear reactors until its closure in 2003. In major tests it could consume 13 mW of electrical energy, which had to be accessed out of peak usage times yet could *still* dim lights on the west side of Manhattan during tests! The first director was **Professor Charles F. Bonilla**. Later directors included a number of chemical engineering professors, notably Huk Y. Cheh in the laboratory's later years.

The current faculty. Seated: Scott Banta, Rasti Levicky, Nina Shapley, Jingyue Ju, Jeff Koberstein. Standing: Edward Leonard, Alan West (chair), Ben O'Shaughnessy, Scott Calabrese Barton. Not pictured: Carl Gryte.

THE BIG PICTURE

Throughout the history of chemical engineering at Columbia there has been a steady concern with the "core" of chemical engineering. Notwithstanding the historical specialties emphasized above, Columbia Chemical Engineering has always been a broad endeavor, not a boutique dedicated to select applications. The more than 50 individuals who have held professorial positions—too many to mention here—have represented almost every area of research: process design and development; energy conversion; particular unit operations such as distillation, heat transfer, fluid mechanics, solids separations, extraction, and most of the rest, as well as kinetics and reactor design; process control and optimization; and oil and gas recovery.

Columbia Chemical Engineering today has 10 faculty, currently chaired by Alan West. Table 1 lists their interests. ❒

TABLE 1

Eminent Faculty in Columbia's Three Principal Areas (current faculty in bold)

Electrochemical Engineering

1911	1922	1942	1970	1984	1991	2000
Samuel Tucker	Colin Fink	Henry B. Linford	Huk Yuk Cheh	Ulrich Stimming	**Alan West**	**Scott Calabrese Barton**

Biomedical Engineering

1866	1946	1958	1977	1983	1988	2000	2001	2004
Charles Chandler	Elmer Gaden, "Father of Biochemical Engineering"	**Edward Leonard**	Rakesh Jain	Juan Asenjo	Alex Seressiotis	**Jingyue Ju**	**Nina Shapley**	**Scott Banta**

Polymer Engineering

1914	1917	1939	1966	1967	1972	1983	1988	1998	2000
Leo Baekeland, inventor of Bakelite, the first important thermosetting resin	D.D. Jackson	James Church	George Odian	Harry P. Gregor	**Carl Gryte**	**Chris Durning**	**Ben O'Shaughnessy**	**Rasti Levicky**	**Jeff Koberstein**