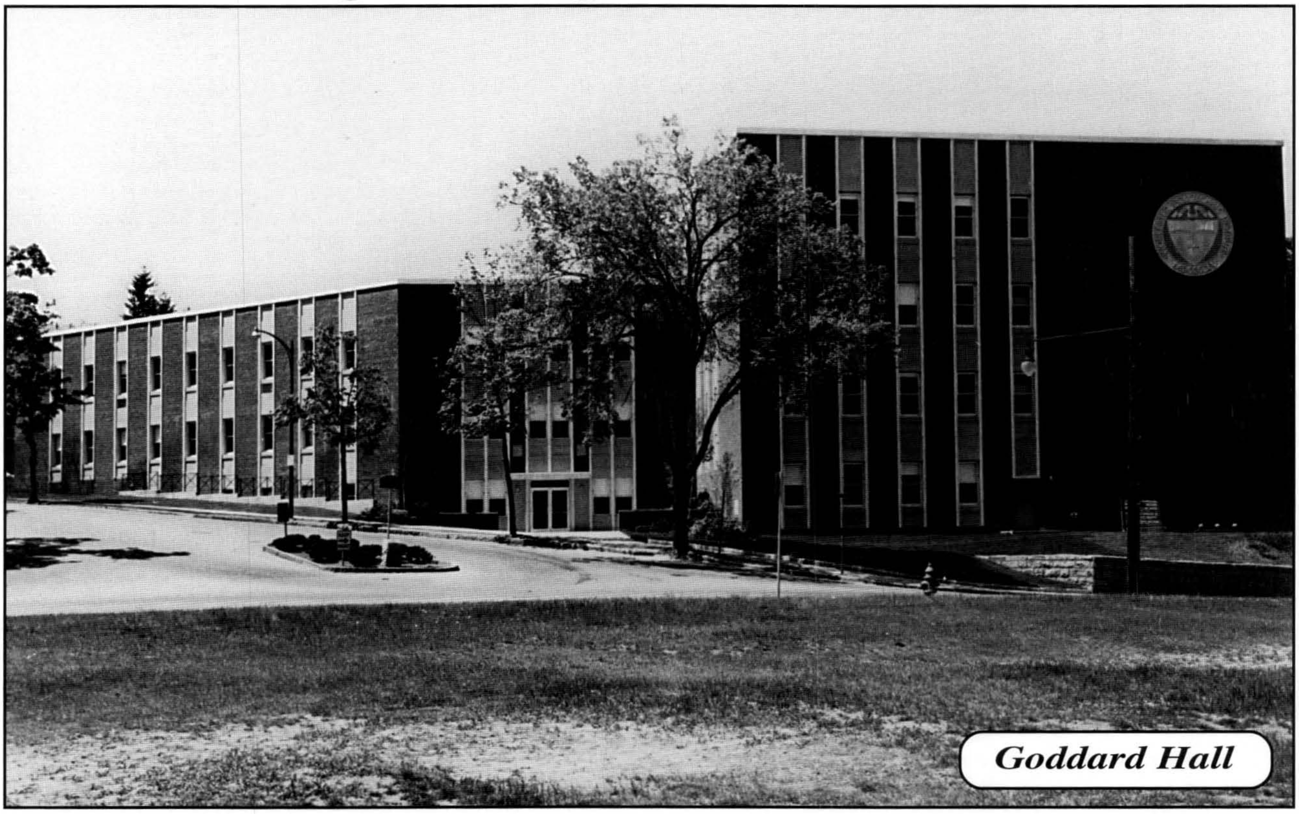
Chemical Engineering at...



Worcester Polytechnic Institute

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Worcester (pronounced "Wustah"), Massachusetts, is situated on seven of the gently rolling hills of the Massachusetts Piedmont. It is about forty-five miles due west of Boston, all uphill. It is considered to be in the Great Midwest, far too distant for most proper Bostonians to venture, except on those weekends when many pass it by on their way to the West (*i.e.,* the Berkshires). When a Bostonian is asked, "What is the best route to San Francisco?" the invariable answer is "Through Worcester."

Given this perception, which has always been the situation, Worcester has developed very independently from Boston. There is surprisingly little interaction, *e.g.,* between WPI and MIT or Harvard.

In addition to WPI, Worcester boasts of having the University of Massachusetts Medical School, Clark University, College of the Holy Cross, Assumption College, Anna Maria College, Becker Junior College, Worcester State College, and Quinsigamond Community College. In short, education is the major industry in this city of less than two hundred thousand. Worcester has a sizeable BioTechnology Park and was home to the Worcester Foundation for Experimental Biology (where the "Pill" was invented). These, together with the research proceeding at the medical school and the other colleges, combine to make Worcester's bio research a major industry. There are also major computer companies in Worcester and the nearby areas (*e.g.,* DEC, EMC, Allegro), as well as a myriad of smaller high-tech companies whose manpower needs draw on the local colleges and universities.

The Blackstone River Valley, in and around Worcester, is considered to be the birthplace of the Industrial Revolution. Worcester still has some of the heavy industry it was once known for, including abrasives (Norton) and heavy forgings (Wyman-Gordon). But much of this low-tech industry has moved away, mainly to the South. At one time there were major wire mills (including US Steel), textile operations, and plastic processors.

Worcester's isolation from Boston has resulted in cultural facilities that developed far beyond the level one might expect for the city's size. These include both the spectacular Worcester Art Museum and Mechanic's Hall (opened in 1857), one of the most acoustically perfect and beautiful concert halls in the nation (the name reflects Worcester's industrial beginnings). The theatre and music seasons provide the best of internationally and nationally known performers and orchestras for concerts, recitals, operas, and theatre. Worcester is quite culturally independent of Boston.

> ***"Students must be taught not only how to create technology, but also to assess and manage the social and human consequences of that technology." That approach is known as "The WPI Plan."***

1865—WPI IS FOUNDED

Going back in time to the nineteenth century, it was well-recognized that local industry needed a local source of trained engineers to work in the burgeoning light and heavy manufacturing industry that was successfully operating in Worcester. A local philanthropist, John Boynton, established an endowment of one hundred thousand dollars on May 1, 1865, to establish "The Worcester Free Institute." Thus was established the third oldest technological college in the USA (following RPI and MIT).

"The aim of this school shall ever be the instruction of youth (*boys* of Worcester County) in those branches of education best adapted to train the young for practical life; and especially that such as are intending to be mechanics, or manufacturers, or farmers, may attain the principles of science applicable to their pursuits."

Mr. Boynton's gift was quickly supplemented by a gift of one hundred and ten thousand dollars by Stephen Salisbury of Worcester. The new Institution was chartered by the legislature of Massachusetts and opened to receive its first students on May 12, 1868, as the "Free Institute of Industrial Science of Worcester, Massachusetts." Farmers seem to have been neglected in the list of courses offered: Mechanical Engineering, Civil Engineering and Topography, Architecture, Drawing and Design, Chemistry, and English, French, and German.

The first catalog stated that "Certain [of the above] studies are common to all of these Departments, for it is the aim of the school to give as complete a general education as possible, and to point out the true relation of theory and practice." This statement is, in effect, from the very beginning, the essence of the WPI education. The motto of WPI —Lehr und Kunst (Science and Technology)—states the school's intent to provide engineers and chemists to industry who have not only practical capabilities but also an understanding of the fundamental principles they will need to advance knowledge. It is noteworthy that such a philosophy was new to technical education, which heretofore had been almost universally theoretical and which left the new graduate short on practical skills. To accomplish these goals, the first catalog pointed out the need for practicums. Drafting and design, shop training, and laboratories were required, so that the graduate would be able to enter his profession directly, not as an apprentice who had to learn to apply his theoretical background to practice.

Speeches made at the time (1869) also fixed the goals of the school. Chester S. Lyman of Yale stated, "I see not simply a new institution, but a new class of institutions." Charles O. Thompson, the first Professor of Chemistry and Principal, noted, "It is not the boy we are training, but the giant he is to become." Mr. Thompson also said at that time, "We cannot receive any women without undertaking to instruct all competent women who apply. This we have not room for now. It is our purpose to throw the school open to youth of both sexes as soon as we can." (This finally happened, but it took one hundred years until the first female student graced the halls of WPI.)

PRACTICAL CHEMISTRY— THE BEGINNING OF CHEMICAL ENGINEERING

There was, of course, no such thing as "Chemical Engineering" in 1868. Industrial chemists and mechanical engineers met industry's needs in the chemical technology area. The founders not only felt that it was important for engineers to have an understanding of chemistry, but also that it was important for chemists to have engineering skills. Besides a spectrum of courses in theoretical and applied chemistry, chemistry majors had extensive laboratories in chemistry, focusing heavily on analysis and physical chemical measurements. But they also took the drafting workshops, machine shops, and metallurgy and forging workshops required of the mechanical engineering students. A new building was opened in 1887 (Salisbury Laboratories) to house facilities for chemistry that ultimately evolved into elaborate unit operations experimentation. It was purported to provide the chemistry students "with even more air to contaminate."

Proceeding to the catalog of 1898, laboratory and workshop capabilities and facilities had advanced considerably, allowing a philosophy of education in which engineering students produced the parts for, and actually built, complex machines. The next step was for the students to actually produce commercially valuable products, and to understand the costs involved in their manufacture and sale. (The revenues obtained from the sale of student-produced products, such as drafting tables, were applied to the costs of education!)

The Chemistry Department had not only General, Analytical, and Organic laboratories, but also very practical Industrial, Sanitary, and Gas Laboratories. These were complemented by chemistry-major courses in General Chemistry, Qualitative Analysis, Quantitative Analysis, Advanced Inorganic and Theoretical Chemistry, Organic Chemistry, Industrial Chemistry, and Thesis. The Chemistry Department also offered Mineralogy (for all students except electrical engineers), Metallurgy (for all students), Sanitary Chemistry (for chemists and civil engineers), and Gas Analysis (for all students except civil engineers).

Seniors received sixty lectures describing the most important chemical manufacturing processes. Visits were made to manufacturing enterprises, and large equipment for grinding, mixing, pressing, filtering, drying, etc., was studied, both at the company's and in Salisbury's laboratory "for study of chemical processes on a large scale."

▲ *Dr. Robert Goddard's early experiments on rockets were done during World War I in the WPI Magnetic Laboratory, pictured above, which was isolated from other campus buildings.*

The catalog states "The principal work in the laboratory is not the preparation of pure chemicals, but rather, the study of practical methods of working up the waste products of various manufacturing industries, which are in reality the student research projects."

The very practical chemistry degree (without, of course, actually bearing the name "chemical engineering") offered in 1898 corresponded very much to the chemical engineering programs at most schools even sixty years later.

DR. ROBERT H. GODDARD—THE FATHER OF MODERN ROCKETRY

On January 6, 1917, Dr. Robert H. Goddard (WPI class of 1908, and Assistant Professor of Physics at the local Clark College) was provided a $5,000 grant through the Smithsonian Institution to further his pioneering work on rockets. He arranged to work together with WPI staff, and the Magnetic Laboratory at WPI was rewired to enable testing of the devices he had made in Clark's Machine Shop. The military potential of his research was immediately recognized, and by January of 1918, he was also working with funds provided by the US Signal Corps. Because of spy paranoia during World War I, it was necessary to hire watchmen; the staff of the Magnetic Laboratory working on the Testing Project grew to about ten. Shots were heard from the small building for about four months, frightening the neighbors on a regular basis. A good deal of public curiosity resulted, and

***Dr. Robert Goddard is shown at his liquid-fueled rocket-launch site in Auburn, Massachusetts (1926)* ▶**

the Signal Corps decided to move the project to Mount Wilson Observatory shops at Pasadena, California, and subsequently to Aberdeen Proving Ground, Maryland. After the armistice was signed, funding for the Project ended abruptly, but the efforts had produced a prototype of the "bazooka" World War II anti-tank weapon.

Dr. Goddard returned to the Worcester area to forge his place in history. On March 26, 1926, the first flight of a rocket using liquid fuel was recorded as having been made from Aunt Effie's Farm in neighboring Auburn. Testing of larger rockets followed in short order, making the neighbors and fire marshal nervous enough to have Goddard exiled to a far corner of Fort Devens, Massachusetts. By 1930, he was in Roswell, New Mexico, continuing his research.

There is no record of formal close collaboration between Robert Goddard and the WPI Chemistry Department, even though his work on liquid-oxygen-fueled rockets encompassed both chemical and chemical engineering principles, not the least of which were design and construction of pumps and cooling systems. WPI felt that it was important to recognize Dr. Goddard's great contributions by naming a new building after him. A grant from the Olin Foundation funded the construction of this new building for the combined Chemical Engineering and Chemistry Department (united under one Department Head in 1940). The new building, named Goddard Hall of Chemical Engineering and Chemistry, was dedicated in 1965. It replaced the old Salisbury Laboratories building.

CHEMICAL ENGINEERING

WPI's first course in "Chemical Engineering" was offered in the Chemistry Department in 1922.* It was a senior course taught by non-resident lecturer Barnett F. Dodge. In 1928, Thomas K. Sherwood was appointed as Assistant Professor of Chemical Engineering. He joined MIT three years later. By 1936, chemical engineering was established so firmly that the department changed its name to Chemical Engineering and Chemistry. Internal jousting resulted in splitting the combined department into two separate departments in 1938; the Department of Chemistry and the Department of Chemical Engineering. The departments merged again in 1940—and separated again, to go their separate ways (possibly forever) in 1967.

Once Goddard Hall was opened, the chemical engineering faculty, with Yankee frugality, moved the antique chemical engineering equipment from Salisbury to the state-of-the-art three-story Goddard Hall unit operations laboratory. An equipment grant allowed the department to purchase sophisticated new pilot-scale experimental units to supplement the old. A decision was also made to increase the chemical engineering faculty in the new building by fifty percent. Eventually, the new faculty, not burdened by the nostalgia of the senior faculty, threw out the old equipment.

The reason for increasing the size of the chemical engineering faculty was to implement research activities in the department, now that facilities were available. This was quite in accord with new policies that were developing across all of the departments of the Institute. Under the guidance of its gifted Dean of Faculty, M. Lawrence Price, WPI's courses had been completely revised in 1959 to keep up with the new technologies of the era, such as ultrasonics, aerospace, nuclear power, magneto hydrodynamics, cryogenics, etc. The problem became what to stop teaching to make way for the new technologies.

Along with existing technologies, both educational methods and the mechanical equipment in the laboratories were becoming obsolete. Concepts, rather than courses, were now important: *how* to learn, not *what* was learned, was the key point of departure from the past. The need for the type of practical training exemplified by the foundry and manufacturing in Washburn Laboratory had long passed. For example, Washburn was now converted to a 1-KW pool reactor nuclear facility, the only such facility in the Northeast dedicated to teaching (and, of course, research). The Physics Department had installed a Van der Graaf accelerator in its new building for research in nuclear magnetic resonance and X-ray diffraction. WPI's Alden Research Laboratories, located in nearby Holden, had become both nationally and internationally renowned as a center for hydraulic research and development. Forty truckloads of antiquated power equipment were removed from electrical engineering to make way for the new activities in microwaves, electronics, and computers. Civil engineering redirected itself to human problems of environment, safety, health, sanitation, and transportation.

The Chemical Engineering and Chemistry departments shared the new Goddard Hall, and the new facilities allowed research that had been started years before to blossom in both departments. Most notable in chemical engineering were the catalysis research of Professor Wilmer Kranich (the Department Head) and the combustion research of Professor C. William Shipman. Starting in 1965, new faculty were brought in with a departmental goal of establishing a critical research and teaching mass in the related and burgeoning areas of reaction study—catalysis, kinetics, transport, and zeolites. These included, in order of arrival over a three-year period: Imre Zwiebel (adsorption), Alvin Weiss (kinetics and catalysis), Yi Hua Ma (transport and diffusion), Leonard Sand (zeolite synthesis). They quickly aggrandized all available laboratory space and as much funding as could be found, and began to make WPI a well-known name in these areas of chemical engineering research. The Catalysis Society of New England was organized at WPI in 1967, and the Second International Conference on Molecular Sieve Zeo-

* *WPI had initiated an advanced one-year professional engineering program in Chemical Engineering in 1917. The first graduate that year was William Bartlett Jones (BS in Chemistry, 1916). The first BS in Chemical Engineering was granted in 1935.*

lites was held at WPI in 1971. The department quickly became recognized as a center for research excellence in the above listed fields, particularly for synthesis of zeolites and for catalytic studies that showed the relationship of acidity to silica-alumina ratio in zeolites. The 1973 energy crisis brought major funding in both energy and environmental areas. Professor Robert Thompson, hired in 1976, became Editor of the *Zeolites Journal* (now *Non Porous and Mesoporous Materials Journal*). International research collaborations on food synthesis in space for NASA established space research as a key activity of the department. Professor Albert Sacco, hired in 1977, became an astronaut and did microgravity zeolite synthesis research during space flight. Professors William Clark and David DiBiasio established biochemical engineering research in the department. Professors Anthony Dixon and William Moser were hired for their respective contributions to transport and catalysis studies.

Endless debates were held in 1968 faculty meetings on the question of admitting female students. There were heated discussions by a small vocal group at these meetings, both about inadequate lavatory facilities for women and about corruption of WPI's young men. Quite unilaterally, the Chemistry Department admitted a nun to the Master's program. The lady had the wit to locate lavatories (and laboratories); and her morals could not be questioned, so the ice was broken. Females now represent about fifty percent of the students in chemical engineering, and three of the current ten chemical engineering professors are women.

The Three-story Unit Operations Laboratory has large-sized modern equipment for student experimentation

THE WPI PLAN—AHEAD OF ITS TIME

An important change in the school's administration took place when Dean Price was joined by the new President of the Institute, Lt. General Harry P. Storke (Ret.). These two men recognized the general state of engineering education at the time. Strict lists of required courses with inflexible prerequisites were the norm in engineering-degree programs across the nation, the goal being the "weeding out" rather than the nurturing of students. But, simultaneously, technology was changing at an unheard-of pace, and there was no way for engineering students to learn everything. What was needed was a new approach to engineering education where the student learned to learn, to acquire skills, and to function, even if he or she faced technologies that were unheard of at the time of their undergraduate education. According to the WPI catalog, "Students must be taught not only how to create technology, but also to assess and manage the social and human consequences of that technology." The approach is known as "The WPI Plan." The first "Plan" students graduated in 1973.

The WPI-Plan undergraduate chemical engineering program now averages fifty graduates per year and is centered on three key projects that distill classroom experience into real-world projects. The vision of the WPI Plan is that the project experiences prepare students to manage team efforts and to communicate exceptionally well, both in oral and written reporting. The Major Qualifying Project is a senior-year chemical engineering study, either laboratory research or a design task (usually as a subset of an ongoing graduate research project). The Interactive Qualifying Project emphasizes the need to understand and to relate how chemical technology affects society and its institutions. There is now a great emphasis on global issues. The project work can be done either at WPI or at any of the seventeen global program sites located both in the United States and in foreign countries. All students also do a project called a "Sufficiency," based on a five-course self-selected coherent series of courses in the Humanities and Arts. The goal is to develop an in-depth understanding and appreciation of one of the cultural aspects of our society.

It seems amazing that this WPI chemical engineering curriculum has existed for three decades. ABET (Accreditation Board for Engineering and Technology) requirements had to shift to accommodate the innovations. The new ABET 2000 requirements actually contain many of the WPI educational elements.

Undergraduates develop their own programs of technical courses (with, of course, careful faculty guidance). There are no prerequisites for any courses. Failed courses disappear from the student's transcript; only successes are recorded. The student can go on to the next course, repeat the course, or forget about it. Apart from their projects, chemical engineering students are expected to complete twelve courses in mathematics and basic science, fifteen engineering science

TABLE 1
Faculty and Their Research

T.A. Camesano
Assistant Professor, PhD, Pennsylvania State University
Bioremediation; bacterial adhesion; atomic force microscopy; colloidal phenomena

W.M. Clark
Associate Professor, PhD, Rice University
Bioseparations; two-phase electrophoresis; aqueous two-phase extraction; membrane filtration; teaching methodologies

R. Datta
Professor and Department Head, PhD, California, Santa Barbara
Catalyst and reaction engineering; supported molten metal catalysts; catalytic microkinetics; fuels and chemicals from renewable resources; fuel cells and reformers; transport in porous media and membranes

D. DiBiasio
Associate Professor, PhD, Purdue University
Bioreactor engineering; magnetic resonance imaging of bioreactors, mammalian cell culture, hollow fiber reactors, immobilized cell reactors; teaching and learning methodologies

A.G. Dixon
Professor, PhD, University of Edinburgh
Reaction engineering; computational fluid dynamics for gas-solid catalytic reactors; dense and porous inorganic membrane reactors; zeolite membrane reactors; heat-transfer problems in fixed-bed membrane and microchannel reactors

Y.H. Ma
Professor, ScD, Massachusetts Institute of Technology
Inorganic membranes; palladium membranes for hydrogen separations; perovskite and perovskite-like membranes for air separation; zeolite membranes, membrane reactors; adsorbent development, adsorption and diffusion

K.M. McNamara
Assistant Professor, PhD, Massachusetts Institute of Technology
Chemical vapor deposition; CVD growth processes for semiconductors; impurity and defect incorporation; optical and electrical properties; materials for space applications; art and historical objects

W.R. Moser
Professor Emeritus, PhD, Massachusetts Institute of Technology

F.H. Ribeiro
Assistant Professor, PhD, Stanford University
Catalysis and surface science; heterogeneous catalysis; kinetics; model catalysts

R.W. Thompson
Professor, PhD, Iowa State University
Applied reactor design and particulate systems; zeolite crystallization; polymer degradation; water purification; film formation

R.E. Wagner
Professor Emeritus, PhD, Princeton University

A.H. Weiss
Professor Emeritus, PhD, University of Pennsylvania

B.E. Wyslouzil
Associate Professor, PhD, California Institute of Technology
Aerosol science; small-angle neutron scattering from aerosols; multicomponent aerosol formation; condensation in supersonic nozzles; aerosol transport in plant tissue reactors

and design courses, and six advanced chemistry courses. The well-rounded graduates of the Plan are qualified and sought after for industrial positions of responsibility, graduate schools, and professional schools. Many WPI graduates occupy key positions throughout the chemical industry.

CURRENT FACULTY AND GRADUATE RESEARCH

The WPI Chemical Engineering Department's graduate program averages about thirty-five graduate students, as well as about ten post-doctoral scientists and visiting professors. The department's ten professors and their fields of research are listed in Table 1. The department plans to grow to a total of thirteen faculty, with increasing emphasis on graduate study and research. Catalysis, zeolites, and reaction engineering continue to be the cornerstones of the department's research recognition, but other active research areas include fuel cells, materials science and technology, environmental studies, life sciences and bioengineering, space sciences and engineering, and computational modeling. The flavor of graduate research is highly international, and papers are presented at conferences throughout the world. Graduate study also involves a great stress on the student's research and great independence in course selection. Almost every project incorporates undergraduate participation, giving the graduate student experience in leadership.

CONCLUSION

There is no denying the dramatic changes that are occurring in chemical engineering technology. New instrumentation and concepts develop constantly. Most basic chemical and petroleum industry products are now commodities, resulting in limited growth in traditional industries. Although there is much debate on the future of the discipline, WPI's approach to chemical engineering of "Learning to Learn" accommodates present and future contributions of chemical engineers in new, as well as existing, technologies. The independence given the student in structuring his or her own program of courses, in managing and doing teamwork on projects, in oral and written reporting, guarantees future leaders in our discipline. The substantial exposure to humanities, other cultures, and international activities and commerce, produces well-rounded chemical engineers ready to function in today's world. Many schools have followed or are considering anew WPI's example in chemical engineering education. It is a future path of education for the discipline.

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