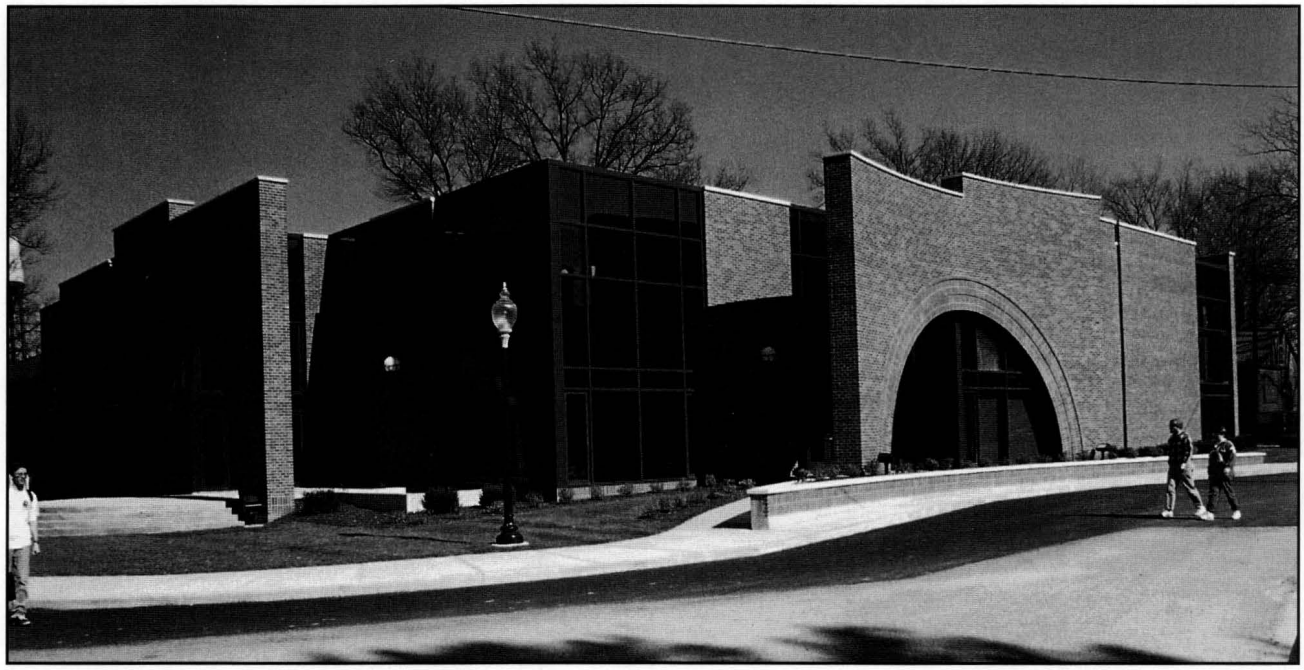


The Chemical Engineering Department at Rose-Hulman Institute of Technology.

Rose-Hulman Institute of Technology

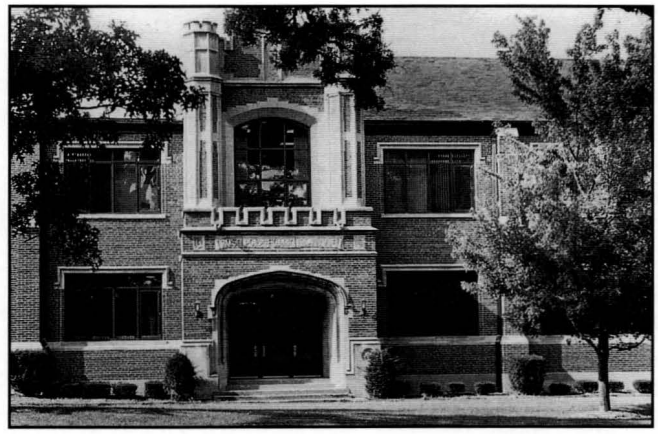
JERRY CASKEY, HOSSEIN HARIRI
Rose-Hulman Institute of Technology • Terre Haute, Indiana 47803

Rose-Hulman Institute of Technology is one of the few private colleges for undergraduate engineering, mathematics, and science in the United States. It has earned its reputation as one of the nation's leading independent colleges because of its educational philosophy focusing on small classes, dedicated faculty, and an innovative curriculum, all supported by modern educational facilities. The campus is located in a suburban area about five miles east of Terre Haute in west-central Indiana.

The college's 1998 freshman class had a combined SAT average of 1350, with half of the students having achieved 700 or better on the math portion of the standardized test. More than 90% of the students at Rose-Hulman graduated in the top fifth of their high school class. Fall enrollment in 1998 was 1,749 students.

Undergraduate degrees are awarded in applied optics, chemical engineering, chemistry, civil engineering, computer engineering, computer science, electrical engineering, economics, mathematics, mechanical engineering, and physics. Master's degrees can be earned in biomedical, chemical, civil, electrical, environmental, and mechanical engineering as well as in applied optics and engineering management.

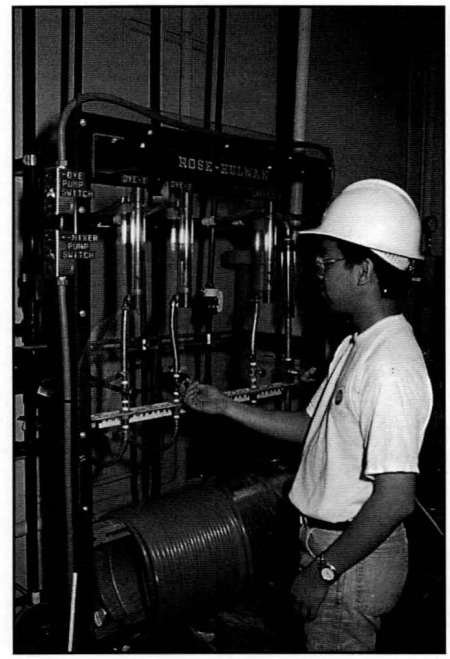
There is also an engineering management graduate program designed to help engineers who want to enhance



The college's 1998 freshman class had a combined SAT average of 1350, with half of the students having achieved 700 or better on the math portion of the standardized test. More than 90% of the students at Rose-Hulman graduated in the top fifth of their high school class.

their management skills for use in technology-based businesses.

Rose-Hulman prides itself on offering outstanding personal attention to the needs of its students, which is illustrated by our 12-to-1 student-to-faculty ratio. Rose-Hulman has been honored in the prestigious Hesburgh Award competition that recognizes a select group of colleges for exceptional efforts to improve undergraduate education.

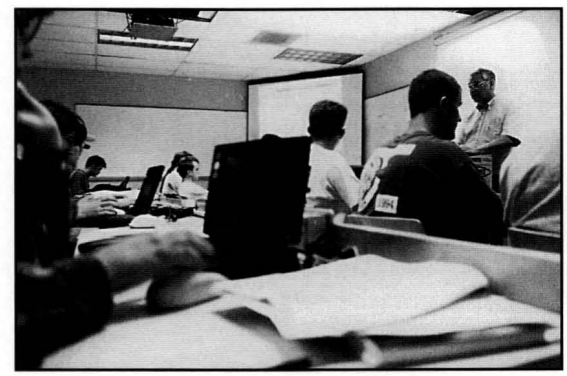


Faculty have been innovators in the use of computer-aided instruction and in developing ways to improve the freshman curriculum. In 1995, the Institute was among the first colleges to require all new students to purchase laptop computers.

Special programs offer Rose-Hulman faculty and students an opportunity to work as teams and to use the latest technology to help business and industry create new products, processes, and services. The Technology and Entrepreneurial Development program is creating a model for project-based engineering and science education. The program increases the number of students and faculty involved in industry-sponsored, projects-based programs and creates new laboratories for product and process development.

Rose-Hulman offers a unique commitment to the humanities within an engineering, mathematics, and science curriculum. Students can earn a minor in East Asian Studies, and they are offered language courses in Spanish, German, and Japanese.

During the 1998-99 academic year, Rose-Hulman is celebrating the 125th anniversary of its founding. The college was known as Rose Polytechnic Institute from the time it was founded in 1874 until 1971, when the name was changed to Rose-Hulman Institute of Technology in recognition of more than 100 years of support by the Hulman family. In the fall of 1995, Rose-Hulman became a coeducational campus, ending its 121-year history as an all-male institution.



Top Photograph: *A view of the Rose-Hulman campus.*
Center Photograph: *Tubular flow reactor in the unit ops lab high-bay area (senior student, Thu Vu Pham).*
Bottom Photograph: *Classroom scene showing students using laptop computers.*

CHEMICAL ENGINEERING AT ROSE-HULMAN

It has been reported that the nation's first four-year curriculum in chemical engineering was announced by M.I.T. in 1888.[1] But, "Professor Hammond presented a paper on 'Promotion of Engineering Education in the Past Forty Years' at the fortieth anniversary meeting of the Society for the Promotion of Engineering Education. In this paper, Professor Hammond stated that after searching the early records and catalogues, it did seem that Rose Polytechnic had actually had the first chemical engineering graduate in the United States."[2] Walter Brown Wiley entered Rose Polytechnic in September 1885 and graduated from the Chemical Department in 1889.[3] "Mr. Wiley is the first graduate in the chemical course from the Rose Polytechnic Institute and has been engaged in a special line of work in connection with fuel engineering, especially to improve the quality of coke and the investigation of coking coals."[3]

Rose-Hulman prides itself on offering outstanding personal attention to the needs of its students, which is illustrated by our 12-to-1 student-to-faculty ratio. . . . We will continue to maintain a strong teaching commitment and to give personal attention to students.

The Chemical Engineering Department is the third largest department at Rose-Hulman, with approximately 250 students at the present time.

According to Dr. Warren Bowden, there were sixteen to eighteen undergraduates per class and three graduate students when he joined the department in 1956. The laboratory provided basic experiments in the areas of filtration, evaporation, distillation, and heat transfer. The equipment was old, rusty, and in marginal working order, which made it difficult for students to obtain meaningful data from their experiments. The courses were demanding. Textbooks such as Brown's *Unit Operations* and Weber and Meisner's *Thermodynamics for Chemical Engineers* were used. The students included some extremely talented individuals. For example, the class of 1957 included Ernest Davidson, Glen Miles, and Toby Eubank: Davidson has had a very successful career as a professor of chemistry; Glen Miles obtained a ScD at MIT and had a successful career in industry; and Toby Eubank received a PhD at Northwestern and has been a professor of chemical engineering at Texas A&M University for many years. These students did not get sheepskin diplomas since Rose Poly switched to paper diplomas in the late 1920s.

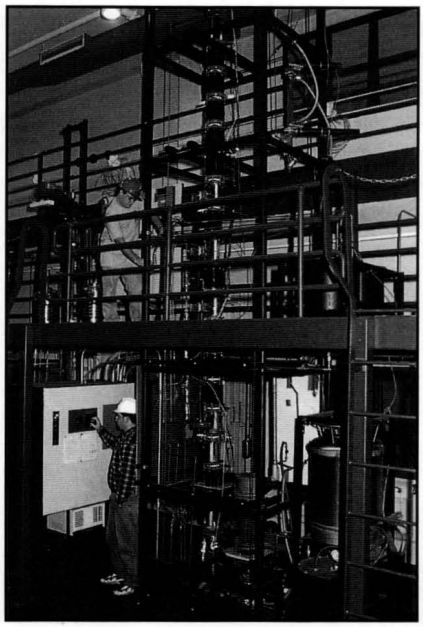
The department went through a period of low student enrollment during the early and mid '60s. Then, in 1966, Dr. Sam C. Hite, Chairman of Chemical Engineering at the University of Kentucky, went to lunch with a recruiter for Commercial Solvents, located in Terre Haute, and was told that chemical engineering was about to be discontinued at Rose. He learned that the chairman had already left, and only two professors (Warren Bowden and Tony Blake) remained. Sam was interested, so he applied for and was made chairman of the Department. He immediately began a drive to increase the faculty from two to eight, the BS ChE degrees from 16 to over 70 per year, and to aggressively find money for new equipment and facilities. The plan began with the recruiting of Dr. Noel E. Moore from Kentucky. Noel later followed Sam as chairman at Rose-Hulman and served as chair until 1997, when he stepped down to prepare for his retirement in 1998. Hossein Hariri is the current chairman of the Department.

RECENT CHANGES AND DEVELOPMENTS

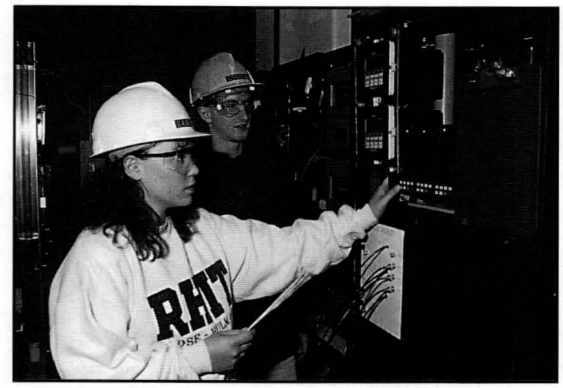
There have been evolutionary changes at Rose-Hulman and in its Chemical Engineering Department. Historically, the Institute has perceived a constant need to restructure and renew curricula and has sought the necessary equipment and encouraged faculty to develop new curricular materials based on the availability of additional resources. This cycle of discovery, initiation, acquisition, dissemination, and integration is one of the Institute's greatest strengths. The relatively small size of the Institute, the dedication of its faculty, and its outstanding student body make Rose-Hulman a recognized leader in curricular innovation in undergraduate engineering, science, and mathematics education.

Approximately one-quarter of the incoming freshmen participate in the Integrated First-Year Curriculum in Science Engineering and Mathematics. In a 12-credit "super course" during each quarter of the freshman year, students receive instruction in calculus, physics, chemistry, computer science, engineering graphics, and engineering design in a block-scheduled sequence of carefully coordinated activities that emphasize the interrelationships between the disciplines. Students receive a single grade for the course each quarter.

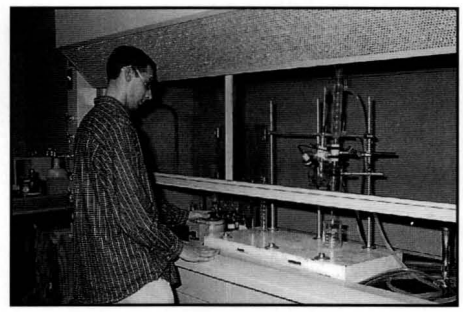
A central component of this course is an array of quarterly projects developed by teams comprised of three or four students. The following is a partial list of projects chosen by students in the spring quarter of the 1997-98 academic year: writing a program for Windows-based scheduling of final



◀ *Senior students Joe Lathey and Bill Morphew shown with the Corning Distillation Column in the Unit Operations Laboratory high-bay area.*



▲ *Seniors Amy Gainey and Jeremy Conner hard at work on a process control experiment in the Unit Operations Laboratory low-bay area.*



◀ *The Unit Operations Laboratory occupies a high- and a low-bay area as well as three separate rooms. Junior Craig Clark works with the Othmer Still Unit in one of the separate labs.*

exams; devising a method for determining the speed of a fast-moving object whose trajectory is not known; devising and carrying out an original experiment using a wind tunnel of the group's own design; investigating how variations of reactant ratio affect the properties of the plastic you create; synthesizing a ferrofluid and purifying it to improve performance. At the end of each quarter, students present their projects in a large poster session open to all faculty and students at the Institute.

One notable characteristic of Rose-Hulman is an interest in laboratory experiences for the students and a teaching emphasis leaning toward the practical side of the practical-theoretical spectrum. "If football teams were coached the way engineering students are educated, the players would all sit on the bench reading the play book," says Dr. Sam Hulbert, Rose-Hulman President.

Academic programs that implement our vision of student research and engineering design and discovery activities occur both in departmental courses and interdisciplinary activities. In the case of the engineering disciplines, such activities are generically known as "project work."

Project-based education was a key recommendation of the Task Force on Design and Research of the Commission on the Future of Rose-Hulman. The Commission is a national 410-member group of volunteers from business and industry. It developed 105 recommendations to help Rose-Hulman maintain its engineering and science educational leadership into the 21st century. In order to implement the recommendations of the Commission on the Future, the number of industry-based projects must be significantly increased, specifically those that benefit from multidisciplinary expertise applied to industrial projects. Some of these projects could be used as freshman design projects or as senior engineering-design projects, or as graduate thesis projects. It is our intent that each and every Rose-Hulman student should have a project-based experience.

Until recently, the only type of project work involving undergraduate students in a significant way has been coursework projects. They are projects done by a student or a student team, with the team managed solely by the students, as an academic exercise for academic credit. The faculty member is not part of the team. On the other hand, R&D projects are done by a team composed of undergraduate students in addition to faculty members.

The U.S. Department of Energy has awarded Rose-Hulman a $6.7 million grant to construct a 35,000 sq. ft. John T. Myers Center for Technological Research with Industry. This two-story facility will provide 7,500 sq. ft. of floor space dedicated to the W.M. Keck Foundation Laboratories for Research with Industry. An additional 10,000 sq. ft. will be dedicated to flexible laboratory space to support student research projects. Electronics and mechanical shops, a pre-

sentation room, conference room, and administrative offices will complete the facility.

As part of engineering design in the Chemical Engineering Department, undergraduate student project teams have worked on a number of industrially sponsored projects. One example is working in conjunction with Siemens Automotive to develop a non-pyrotechnic test to authenticate simulations and steady-state tests in plastic manifolds.

UNIT OPERATIONS LABORATORY

The Unit Operations Laboratory has a long history of being an integral part of the undergraduate chemical engineering program. This is in keeping with the conviction that students learn best by doing. In 1984, the Department moved into a new building that was constructed with funds donated by the Olin Foundation. The faculty designed the new facilities around the Unit Operations Laboratory, and some existing equipment was moved from the old laboratory, but for the most part new pilot-plant-size projects were built in the new laboratory. One piece of equipment that was brought over from the old laboratory (affectionately referred to as the "Dungeon") was the Sperry filter press. A forklift was rented for the move, but when it was time to connect the piping, it was discovered it had been set with the wrong end facing the supply tank. Not to be deterred, Professor Caskey promptly went to the football practice field (this was in August) and commandeered several hefty linemen and some steel bars. They hoisted the filter press, turned it 180 degrees, and returned to the football field. This type of family atmosphere continues to be one of the strengths of Rose-Hulman.

The laboratory has been continuously updated and now boasts over twenty different experimental modules for unit operations lab projects. These modules include distillation, gas absorption, liquid extraction, drying, filtration, microfiltration, membrane separations, mixing, heat exchangers of several types (including boiling and condensation), vapor-liquid equilibria, gas and liquid fluid flow, pumps, cooling towers, kinetics (including fermentation), process control, and other miscellaneous modules.

The laboratory has been operated as a project lab as opposed to a "cookbook" lab. In some cases, projects are assigned that require data to be taken for scale up. This has worked well with boiling heat transfer, cooling towers, filtration, drying, and membrane separations. Operating the laboratory in this fashion requires a large commitment from the faculty, and in any given quarter five of the eight full-time faculty are involved in the laboratory. Oral reports have also been an integral part of the laboratory. Each lab group of three gives three oral reports that are critiqued by other groups, and faculty are present at all oral reports to "grill" the group. This again requires a hefty commitment of time from the faculty. The reward comes when students call back after graduation and report they are able to hold their own when asked to report orally on a job assignment.

The mission of the Department is to provide a balanced education that will enable our students to practice as professionals in the dynamic industrial environment, to appreciate their responsibility to and respect for their colleagues, and to become life-long learners.

The Department also recognizes process control as an industrially important area that our students need to understand. The Camille Computer company has provided three laboratory/pilot-scale PC-based control systems that have been integrated with the lab projects. Our main Corning glass distillation column, ceramic cross-flow microfiltration unit, and process-control pilot plant unit are fully instrumented and are linked to the Camille systems. The systems have been designed to also operate in manual mode in the event of an unexpected sensor/transmitter fault or a "student-mediated event" that makes automatic control impossible. Foxboro 761 controllers are also a part of the process control pilot plant, allowing students to gain experience with remote local controllers as well as the PC-based systems.

COURSE PROJECTS

In addition to the lab projects, most elective courses also feature projects. For example, the environmental unit operations course has a project where the students make drinking water from raw sewage, using the operations of sedimentation, granular filtration, activated carbon adsorption, deionization, and microfiltration. The students conduct tests to determine the water's purity after each unit operation. This hands-on project reinforces the subjects studied in class. The students are invited to make coffee or hot chocolate from the final water—the ultimate test if they believe the process really works. In the polymer engineering course, students choose a plastic product and analyze it by one or more of the techniques studied in class. During the part of the course where polymer processing is studied,

groups experimentally measure the amount of a characterized polyethylene from an extruder and compare the amount extruded to the amount predicted by the equations studied in class.

A number of required courses also have projects associated with them. Our first contact with students enrolled in chemical engineering is in the freshman year in a course titled "Introduction to Design." The objectives of this course are twofold: to give the students a better understanding of chemical engineering and what chemical engineers do, and to give the students insight into the reason for, and the importance of, subsequent courses in the curriculum. To accomplish these objectives, the students are given a process patent along with relevant design data and are asked to do a preliminary design and economic analysis for a plant using the process. The students work in groups of three, with the professor serving as their supervisor/consultant. The students do the necessary material and energy balances, size selected items of equipment, determine the equipment cost and the total capital investment required, and determine the total product cost and the return on investment. Obviously, the process must not be complex, and close supervision and guidance is required. While the students feel that a lot is demanded of them in the course, they also feel that it is worthwhile and accomplishes its objectives.

In the sophomore year, students take a two-quarter sequence in material and energy balances. The capstone of this sequence is a case-study project done in teams of three completing a material and energy balance over a process supplied to each team. Students are given assistance through information on the course web page. They learn engineering methods in solving a case-study problem and are able to improve their computer skills as well as their skill in writing reports.[4]

Our materials engineering course has for some years required student teams to participate in a poster presentation, and the teams now have the option to develop a web page on some aspect of materials. Projects are also a requirement in the air pollution control course. The most ambitious project in this course was the work of a group that exposed pregnant rats to varying doses of sulfur dioxide and then examined the offspring for evidence of damage to internal organs.

CURRICULAR INTEGRATION

Rose-Hulman has placed increasing emphasis on curricular integration. As mentioned previously, about 25% of the freshmen take a program that emphasizes interrelationships between disciplines. The mechanical and electrical engineering departments have continued this trend into the sophomore year, emphasizing the common principles of conservation—conservation of charge, energy, mass, and momentum.

The chemical engineering department restructured the sophomore material and energy balance sequence to include this same emphasis. The restructured courses will be offered in the fall of 1999 and are titled "Conservation Principles and Balances" and "Basic Chemical Process Calculations." The first course includes an introduction to engineering calculations, application of numerical techniques, concepts of systems, conservation, and accounting of extensive properties (mass, energy, charge, linear, and angular momentum) as a common framework for engineering analysis and modeling. The second course offers the application of conservation of mass and energy in analysis of chemical engineering processes including recycle, bypass, and multi-stream processes as well as methodologies used by practicing chemical engineers. The use of computer software, especially spreadsheets, is highly integrated into the course.

The Department has also developed another tool to emphasize the interrelationships of the sophomore-, junior-, and senior-required chemical engineering courses. This is a CD-ROM developed by Professor Caskey using a saturate gas plant from Marathon's refinery in Robinson, Illinois. Modules have been made for material and energy balances, fluid mechanics, heat transfer, thermodynamics, mass transfer, and process design. This CD-ROM provides a resource for linking subjects regardless of the textbook or teaching method used in any particular course. A student can perform a material balance of a multicomponent absorption column in material balances (in the sophomore year), complete a vapor/liquid calculation on the same column in thermodynamics (in the junior year), find heat loss from the column in heat transfer (in the junior year), and calculate the number of stages required in mass transfer (in the senior year). Students can use this tool to get a sense of how courses are interconnected.

THE FUTURE

The Department faculty roster went through a change last year when three new faces replaced faculty members who were retiring. Mentoring and passing on the experience and tradition of the Department to the new faculty members are now important tasks that lie ahead. We will continue to maintain a strong teaching commitment and to give personal attention to students. The mission of the Department is to provide a balanced education that will enable our students to practice as professionals in the dynamic industrial environment, to appreciate their responsibility to and respect for their colleagues, and to become life-long learners.

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