Chemical Engineering at . . .

South Dakota School of Mines and Technology

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The year was 1921, and the South Dakota Board of Regents (SDBOR) authorized a degree program in chemical engineering at the South Dakota School of Mines—a new field that had been birthed from applied chemistry a few decades earlier. A vision had emerged to bring this growing field to the Great Plains. Dr. **Andrew Karsten** (1922–1960), the first professor of chemical engineering at the South Dakota School of Mines (as the institution was named at this time), single-handedly brought the school's chemical engineering program into existence. Dr. Karsten would then shape and sustain the department for the next 20 years, along with chemistry colleagues Drs. **G.G. Osterhof** and **G.W. Bond**.

Where it all began: The Chemistry and Chemical Engineering Building, photographed shortly after its completion in 1957.

In 1935 several Master of Science (M.S.) programs were authorized by the SDBOR, including one in chemical engineering. During the early years, the Department of Chemical Engineering was the sole source of M.S. graduates on campus, establishing a culture of graduate education in the program. In 1943 South Dakota School of Mines was renamed the South Dakota School of Mines and Technology (SDSM&T) to signify this institution's expansion from its mining heritage to a broad array of engineering and science offerings. Dr. **Warren E. Wilson**, the fifth President of SDSM&T (serving in the role from 1948 to 1953), urged the chemical engineering program to become accredited, and this prompted the hiring of **R.L. Sandvig**, who would lead the department in the decades to come. A new Chemistry and Chemical Engineering building designed by chemistry and chemical engineering faculty Osterhof and **R. Heckman** (1953–1977), respectively, was dedicated in 1957. It included a state-of-the-art chemical engineering unit operations laboratory—a crowning achievement for Karsten. In classic pioneering fashion the laboratory was designed and fabricated by chemical engineering students with the help of their mechanical engineering colleagues. The unit operations laboratory would become a popular Parents' Day visitation spot in the years to come. Accreditation was achieved and the department has enjoyed accreditation status ever since.

During the '70s, faculty to join the department (with their years of service in parenthesis) included **L.G. Bauer** (1973–2002), **W.A. Klemm** (1975–1990), and **J.M. Munro** (1977–2005). In addition, the biology program was integrated into the department structure, which planted the seeds for the development of the biochemical engineering emphasis within the chemical engineering program. Faculty members **Sookie Bang** (1985–present) and **Kent Fish** (1969–1995) were brought onto the team. With the retirement of Sandvig in the late '80s came the close of an era that saw Karsten, Sandvig, and Heckman provide continuity and bold, visionary leadership over nearly seven decades, 1922 to 1987.

Leading the way: (Left to right) Russell F. Heckman, early faculty and one of the building's designers; Andrew Karsten, the first ChE professor at the school and a key player in the department's creation; and Robert L. Sandvig, integral to the accreditation of the department and its chair for many pivotal years.

The '90s saw a renaissance of the chemical engineering curriculum at SDSM&T. Bauer, **D.J. Dixon** (1993–present), Munro, **J.A. Puszynski** (1991–present) and **R.M. Winter** (1988–present) pursued the development of the next generation of the curriculum determined to provide SDSM&T chemical engineering graduates with a modern, industrially relevant education, including an emphasis on design and controls. Soon after, our Industrial Advisory Board agreed that the time was ripe for the chemical engineering program to develop a biochemical engineering emphasis. In this regard, the chemical engineering and biology team found Cargill, Inc., to be particularly interested in developing a unique undergraduate curriculum that would produce graduates with a practical knowledge of bioprocesses at the Bachelor of Science level. Over the next several years faculty **P. Gilcrease** (2002–present), **T. Menkhaus** (2005–present), and **R. Sani** (2006–present) developed this biochemical engineering emphasis, which integrates topics relevant to bioprocessing across the ChE curriculum, and also immerses the students in hands-on, open-ended biochemical engineering laboratory experiences. With the arrival of Dr. **Ruch** (2003-2008), the 10th president of SDSM&T, came a restructuring of the university that resulted in the formal creation of the Department of Chemical and Biological Engineering. The growth and vigor seen over the last 15 years would be the springboard for the request and approval of the Ph.D. degree in chemical and biological engineering (CBE) and the hiring of faculty **K. Benjamin** (2007–present) and **R. Shende** (2008–present), with a third faculty member yet to be hired. Over the last 20 years research has become an indispensible vehicle for education and infrastructure development. The core areas of research broadly include biochemical engineering, energy, and nano- and macro-materials.

THE FACULTY AND STAFF IN PROFILE

The faculty of the CBE department at SDSM&T is composed of chemical engineers, biochemical engineers, biologists, and microbiologists, by training. Among the nine faculty members, seven have had industrial experience, allowing our department to provide an applied dimension to our teaching and research, in addition to engineering and scientific fundamentals.

Professor and Chair David Dixon has a long history at SDSM&T. He is an alumnus of the department, having received both his B.S. and M.S. degrees in chemical engineering from the school. He obtained his Ph.D. in chemical engineering from the University of Texas at Austin. Dixon joined the faculty at SDSM&T in 1993 and has served as chair of the CBE department since 2006. His teaching interests include thermodynamics and numerical methods, and his research interests center on supercritical fluids, polymers, and environmental and biochemical engineering. Recently, he has also been appointed site director for the new National Science Foundation Industry/University Cooperative Research Center (NSF I/UCRC), the Center for BioEnergy Research and Development.

Professor Robb Winter arrived in the CBE department in 1988. He obtained his Ph.D. in chemical engineering from the University of Utah. Winter's research centers on understanding how molecular-level chemical phenomena, particularly at interfaces, influence bulk materials properties for composite and thin film systems. The research is largely experimental, and is aided by use of an interfacial force microscope—one of few available in the country. Winter was also instrumental in the creation of the Composites and Polymer Engineering Laboratory (CAPE) on campus. In addition to research,

The faculty of the Department of Chemical and Biological Engineering, from left to right, front row: Rajesh Shende, Sookie Bang, Pat Gilcrease, Rajesh Sani, and Robb Winter; back row: Dave Dixon, Jan Puszynski, Ken Benjamin, and Todd Menkhaus.

Winter has helped shape the educational environment in the department by creating the polymer/materials emphasis for students within the undergraduate ChE curriculum, and by helping bring National Science Foundation (NSF) Research Experience for Undergraduates (REU) and Research Experience for Teachers (RET) sites to the SDSM&T campus.

Professor **Jan Puszynski** joined the CBE department in 1991. He obtained his Ph.D. in chemical engineering from the Institute of Chemical Technology in Prague. Puszynski's research foci include heterogeneous (gas-solid) combustion, nanoenergetic powders, densification of nanocomposites, and ceramic synthesis. His research spans experimental investigations as well as mathematical modeling and simulation. Puszynski has played integral roles in both undergraduate and graduate education in the CBE department and on the SDSM&T campus. He led the incorporation of Aspen software across the undergraduate curriculum, and has helped in the formation of two Ph.D. programs on campus, in nanoscience and nanoengineering and in chemical and biological engineering.

Sookie Bang, professor of biology in the CBE department, has been at SDSM&T since 1985. She holds a Ph.D. in microbiology from the University of California, Davis. Bang's research interests are focused on environmental/molecular microbiology and biotechnology, with current emphasis on deep underground geomicrobiology and the use of extremophiles for biomass degradation. Her teaching interests include general and molecular biology and industrial microbiology. Bang has been consistently devoted to introducing undergraduates to the research environment, as evidenced by the fact that she has had NSF/REU recipients nearly continuously from 1995-2008, many from disciplines outside biology.

Associate Professor Patrick Gilcrease has been a member of the SDSM&T CBE faculty since 2002. He obtained his Ph.D. in chemical engineering from Colorado State University. His research activities include biomethane production from coal, biomass pretreatment, fermentation, and biocatalysis of solid substrates. Gilcrease's teaching activities complement his research well, as he has been the lead force behind the development of biochemical engineering curriculum and laboratories within the CBE department. He also serves as advisor of the AIChE student chapter, which was just selected as an Outstanding AIChE Chapter for 2007–2008.

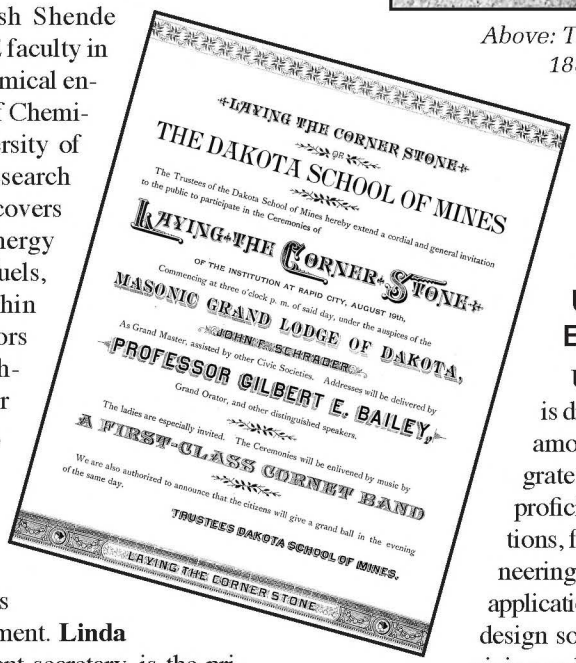
Assistant Professor Todd Menkhaus joined the CBE department in 2005. Prior to that, he completed his Ph.D. in

chemical engineering at Iowa State University. His major research area is bioseparations, and his teaching interests span separations and biochemical engineering as well as developing and delivering new bioseparations courses as part of the CBE curriculum. Menkhaus is active in integrating teaching and research, highlighted by his roles as acting director of the NSF RET program at SDSM&T and as advisor for the ChE Car Team.

Rajesh Sani is an assistant professor of biology within the CBE department. He joined the CBE department in 2006, and received his Ph.D. in environmental biotechnology from the Institute of Microbial Technology at Punjab University, Chandigarh, India. Sani's current research interests include thermophilic bioprocessing for bioenergy and biomediated transformations of metals and radionuclides. His teaching interests include microbiology, environmental engineering, and biochemical engineering.

Assistant Professor Ken Benjamin joined the CBE faculty in 2007. Prior to arriving at SDSM&T, he completed a postdoctoral rotation at SUNY-Buffalo and received his Ph.D. in chemical engineering from the University of Michigan. Benjamin's teaching interests include thermodynamics and process modeling. His current research areas involve molecular and mechanistic modeling, with a focus on catalytic reactions for biorefinery and bioenergy applications, and reactions and materials processing in environmentally benign, tunable solvents.

Assistant Professor Rajesh Shende became a member of the CBE faculty in 2008. He holds a Ph.D. in chemical engineering from the Institute of Chemical Technology at the University of Mumbai, India. Shende's research portfolio is very broad, and covers areas such as sustainable energy (including solar), alternative fuels, nanostructured materials, thin films and MEMS, and sensors and therapeutics. His teaching interests include reactor design, transport phenomena, and nanomaterials.

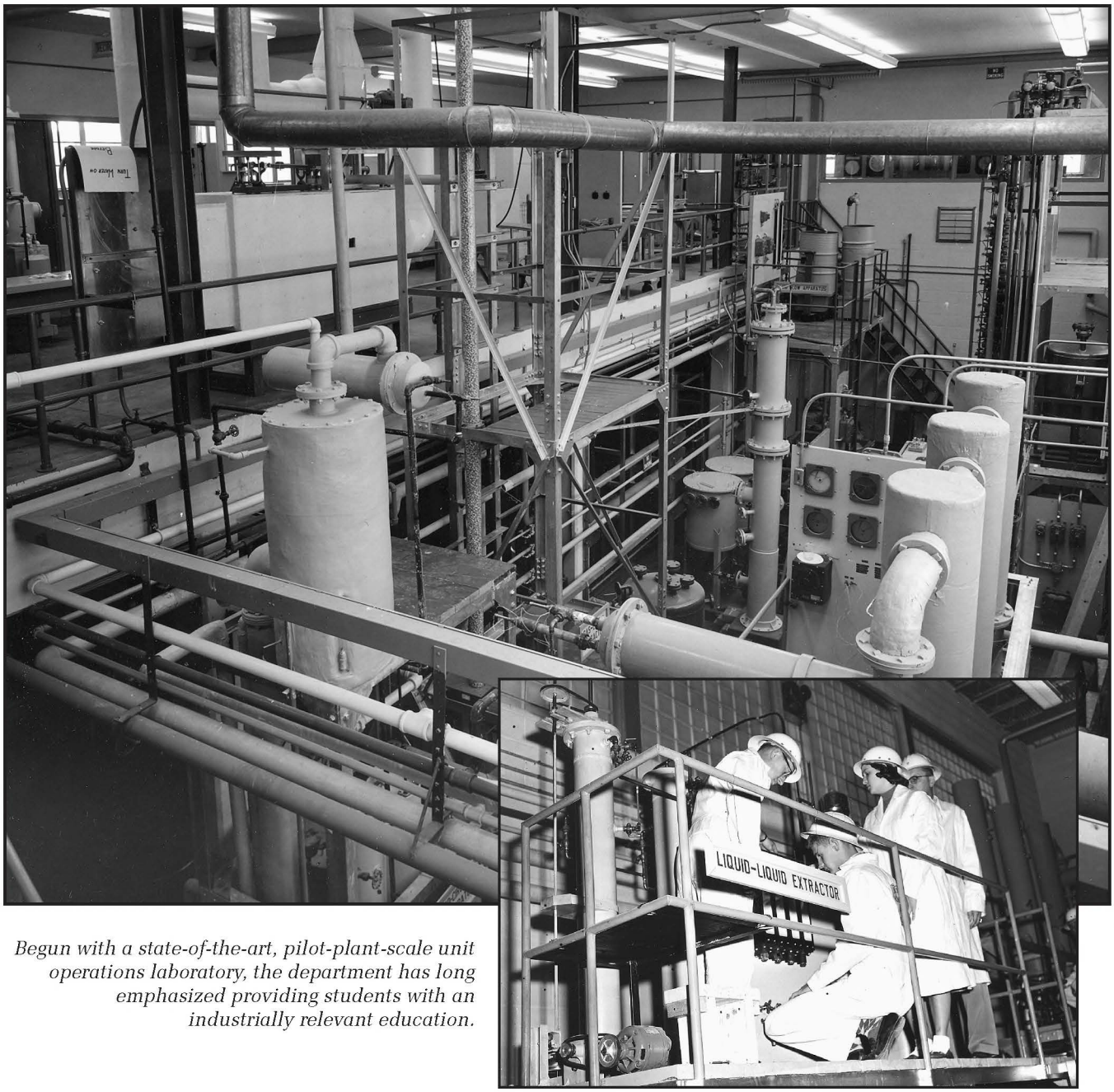

LAYING THE CORNER STONE
OF
THE DAKOTA SCHOOL OF MINES
The Trustees of the Dakota School of Mines hereby extend a cordial and general invitation to the public to participate in the Ceremonies of
LAYING THE CORNER STONE
OF THE INSTITUTION AT RAPID CITY, AUGUST 19th,
Commencing at three o'clock p. m. of said day, under the auspices of the
MASONIC GRAND LODGE OF DAKOTA,
JOHN F. SCHRADER,
As Grand Master, assisted by other Civic Societies. Addresses will be delivered by
PROFESSOR GILBERT E. BAILEY,
Grand Orator, and other distinguished speakers.
The ladies are especially invited. The Ceremonies will be enlivened by music by
A FIRST-CLASS CORNET BAND
We are also authorized to announce that the citizens will give a grand ball in the evening of the same day.
TRUSTEES DAKOTA SCHOOL OF MINES.
LAYING THE CORNER STONE

Above: The first building on campus, completed in 1886. Center: An early document outlines the school's inception.

There are two additional members of the CBE department whose contributions are integral to the success and dynamics of our environment. **Linda Embrock**, the CBE department secretary, is the primary contact within the department for all of our students and visitors, and her tireless work ensures that our department functions productively. Also, **Ivan Filipov** (M.S. chemical engineering; Bourgas Professor, Assen Zlatarov University) is the CBE department instrumentation and laboratory specialist. Many students, both undergraduate and graduate, owe their enjoyable and productive laboratory experiences in large part to Filipov's continued efforts.

UNDERGRADUATE EDUCATION: BY DESIGN AND BY CHOICE

Undergraduate ChE education at SDSM&T is driven by several principles and themes, chief among them being computer applications, integrated design, and choice. To develop a desired proficiency with computers and computer applications, freshmen students take Introduction to Engineering Modeling—a course focusing on computer applications relevant to chemical engineers, including design software for creating process flowsheets and piping and instrumentation diagrams, programming in Microsoft Excel and Visual Basic, as well as the proper use of specialized mathematical and engineering software such as MathCad, Polymath, and AspenPlus and AspenProperties. To emphasize the importance of process design and simulation to our undergraduate students, we have integrated the use of



Begun with a state-of-the-art, pilot-plant-scale unit operations laboratory, the department has long emphasized providing students with an industrially relevant education.

AspenPlus simulation software in nearly every ChE undergraduate course.[1-3] This feature has helped our graduates serve more effectively as practicing process engineers.

An additionally large component in our undergraduate education is the Integrated Design Project philosophy. In addition to the aforementioned integration of AspenPlus simulation software throughout the curriculum, the Integrated Design Project philosophy has one other main objective—the development of design projects that emphasize the strong linkage and interdependency of the individual ChE courses. This philosophy is a modified continuation of the original Integrated Design Project,[1] which guided students through a three-year design project. We are currently revisiting this concept to consider how to most effectively implement such a "long-term" cohesive design project.

One last feature of our practical, design-based curriculum is the requirement that students take two process control courses. The first is taken during the junior year, and is a combination lecture/lab course that focuses more of the practical aspects of process control. The second course is taken during the senior year, and emphasizes the mathematics behind control theory. The solid foundation in controls provided by these courses complements the training our students receive in process design, and positions them well to function effectively in industry.

The emphasis on design is likewise carried through our laboratory courses. The Materials, Automation, Processing, and Simulation Laboratory (M.A.P.S), funded by the Dow Corning Foundation, exists to help teach design skills through the laboratory environment and experience. Conventional chemical engineering laboratory courses and projects involve conducting a "cookbook" experiment and performing subsequent engineering calculations to determine a parameter, or an optimal set of operating conditions. In the M.A.P.S. paradigm, however, students are asked to design a process to meet strict operating specifications using the methods learned in lecture classes, then build or assemble the equipment to meet their design, and finally to test their design by operating the process, taking relevant measurements, and conducting a critical review and comparison. Example M.A.P.S. laboratories include heat exchangers and heat exchanger networks, gas absorption,[4] piping networks, and tank-level control. Also, it should be mentioned that this open-ended approach to laboratory experiments is employed in all department laboratory classes. Other unique characteristics of the ChE laboratory courses includes the total number required for the B.S. degree (6—spread out from the freshman through the senior year), the availability of pilot-scale equipment for experiments (and the need to modify equipment for experiments), and the integration of automated process control into many laboratory experiments.[5]

The last component of our educational philosophy is that of choice. Students in our program can add specialization to their degree, by selecting curriculum options that emphasize materials/polymers, environmental engineering, or biochemical engineering. (It is worth noting that the ChE department is the founding member, and plays a continued, integral part, of the environmental engineering degree program on our campus.) Students in the materials/polymer concentration take advantage of SDSM&T's Composite and Polymer Engineering Laboratory (CAPE), a 9,500-plus-square-foot facility that houses state-of-the-art equipment for cutting-edge research and development of polymer and composite processing, prototyping, and tooling. For those concentrating on biochemical engineering, the Cargill Biochemical Engineering Laboratory (established with generous support from Cargill, Inc.) provides students access to state-of-the-art bioprocessing equipment at the bench and pilot scale, such as fermentors, centrifuges, and chromatography for analysis and purification. In addition, all ChE majors are required to take a microbiology course, and topics particularly relevant to bioprocessing (such as stirred tank design and the use of plate and frame heat exchangers) have been integrated into a number of core ChE courses.

STUDENT AWARDS AND RECOGNITIONS

Students in the SDSM&T chemical engineering program have participated in many opportunities to enrich their formal engineering education. They maintain an active student chapter of the American Institute of Chemical Engineers (AIChE) and a ChE Car Competition team—a multi-disciplinary team including environmental, metallurgical, mechanical, and electrical engineering, and computer science, students. At regional and national AIChE meetings, SDSM&T ChE students participate and compete with peer ChE students from other universities in such activities as research paper presentations, process designs, and the ChE Car Competition. As noted previously, the AIChE Student Chapter was designated one of 15 AIChE Outstanding Student Chapters for the 2007–2008 school year. ChE students have been recognized for outstanding academics by receiving national scholarships and fellowships from AIChE and Tau Beta Pi, the engineering honor society. During Summer 2007, **Travis Walker**, a ChE junior, was selected as the AIChE representative for the Washington Internships for Students of Engineering (WISE). In 2008, AIChE Student Chapter President **Ben Bangasser** was awarded the Dr. Harry West Student Paper Award from the AIChE Fuels and Petrochemicals Division. The ChE Car Team has competed in the regional AIChE Student Chapter Competitions every spring over the 10-year history of the competition. Additionally, they have qualified and participated as one of the top 31 teams in the national ChE Car Competition numerous times.

The steady and planned growth of the CBE research enterprise culminated in the formation of the Ph.D. program in chemical and biological engineering in 2007. The program currently supports 10 Ph.D. students, with the ultimate goal of growing to 20–25 students by 2010.

GRADUATE EDUCATION: A PROUD HISTORY AND NEW ENDEAVORS

Graduate education in chemical engineering has been part of the department since 1935, when the Master's program was added. In 1986, the Ph.D. program in materials engineering and science was formed on campus, which provided a natural mechanism for facilitating Ph.D. research for CBE faculty involved in polymer/materials research. Then, in 2005, the Ph.D. program in nanoscience and nanoengineering was started on campus, which augmented the existing department research in nanocomposites, nano-structured materials, and combustion synthesis of ceramic and intermetallic powders. During

Current research activity in the CBE department at SDSM&T covers a range of areas, including bioenergy, biofuels, polymers/nanocomposites, combustion synthesis of ceramic and intermetallic powders, biochemical engineering and bioseparations, bioremediation and extremophiles, nano-structured materials, catalysis and reaction engineering, and molecular modeling.

the past 10 years, the diversity of research in the department has grown considerably. The steady and planned growth of the CBE research enterprise culminated in the formation of the Ph.D. program in chemical and biological engineering in 2007. The program currently supports 10 Ph.D. students, with the ultimate goal of growing to 20-25 students by 2010. The SDSM&T CBE program is different in nature from what one finds most often in chemical and biological/biomolecular engineering (*i.e.*, CBE) departments across the country. Generally, CBE departments require Ph.D. students to take the core chemical engineering graduate courses for their degree, and provide elective courses in biology, microbiology, biotechnology, etc., to supplement the training of those students focusing on biological-related dissertations. In our CBE Ph.D. program, students are required to take both chemical engineering and biology/biological engineering graduate courses to fulfill their degree requirement. At a minimum, SDSM&T CBE Ph.D. students will take two courses from the following biological engineering topics: biochemical engineering, industrial microbiology and biotechnology, metabolic engineering, biocatalysis, bioseparations, and molecular biology. This structure ensures that the SDSM&T CBE Ph.D. graduate has the foundation and skill set to be proficient as both a chemical and biological engineer.

OUTREACH

Over the years, outreach to both our local and global communities has been a continuous theme. The goal of drawing more women into chemical engineering was a major thrust begun in the '70s by Sandvig. This initiative, which received a majority of its funding from the Dow Corning Corporation and Dow Chemical, USA, was a great success, resulting in a steady and persistent increase of female students pursing a degree in chemical engineering at SDSM&T—from 2 percent to 35 percent. The '80s and '90s saw several interrelated activities to provide Native American middle and high school students and their teachers with insight to the opportunities that a chemical engineering degree can afford. Dow Chemical, USA, provided the majority of the funds for one initiative—the Dow Chemical Native American Studies Workshop for High School Teachers. The National Science Foundation All Nations – Alliance for Minority Participation program supported three initiatives, the Native American Summer Engineering Bridge program, the SDSM&T – Oglala Lakota College AISES Leadership initiative, and the Native American Summer Research Program. These programs were envisioned and developed to inform Native American students and teachers of opportunities in engineering and science in general. The result of these efforts has been a growing number of Native American students pursing engineering and science degrees at SDSM&T. In the '90s and '00s as the research efforts within the department grew, National Science Foundation support was sought and acquired to develop a Research Experience for Undergraduates (REU) site within the Department of Chemical and Biological Engineering. This site was successfully expanded to a sister international site at the Mongolian University of Science and Technology in Ulaanbaatar, Mongolia, where REU research assistants investigated topics in materials and environmental. To provide the regional K–12 community with opportunities to enhance their chemical engineering and science skills and knowledge, an NSF-funded Research Experience for Teachers (RET) site was established. It too was expanded internationally, to Pontifica Universidad Católica De Valparaíso in Valparaíso, Chile. Both efforts have been timely, with the recent realization of the importance of globalization and the development within the United States of a globally competent society.

DEPARTMENT RESEARCH

The research environment of the SDSM&T CBE department is vibrant and growing, and holds more promise with the recently formed Ph.D. program in chemical and biological engineering. Simultaneous with the new Ph.D. program was the creation of the Center for Bioprocessing Research and Development, a 2010 Research Center of the State of South Dakota. The focus of CBRD is on research that leads to new technologies for processing plant-derived lignocellulose materials into biomaterials such as ethanol and key building-block chemicals. In 2008, the department was awarded status as the lead site for a National Science Foundation Industrial/University Cooperative Research Center (NSF I/UCRC), formally titled the Center for BioEnergy Research and Development (<CBERD; http://bioenergynow.org>). Further, the biological-research component of our department has received an additional significant boost from another recently awarded

Envisioning future growth: The new addition to the Chemical and Biological Engineering/Chemistry building is scheduled to be completed in 2011.

NSF center—the Deep Underground Science and Engineering Laboratory (DUSEL)—to be located in Lead, South Dakota, approximately 50 miles from the SDSM&T campus. In the area of polymers and materials, department researchers take advantage of the school's Composite and Polymer Engineering Laboratory (CAPE), a 9,500-plus square-foot facility for advanced research and development of polymer and composite processing, prototyping, and tooling. Current research activity in the CBE department at SDSM&T covers a range of areas, including bioenergy, biofuels, polymers/nanocomposites, combustion synthesis of ceramic and intermetallic powders, biochemical engineering and bioseparations, bioremediation and extremophiles, nano-structured materials, catalysis and reaction engineering, and molecular modeling. Current funding in the department exceeds $1MM per year, with an average level of support of more than $200K/faculty.

THE FUTURE OF CHEMICAL ENGINEERING AT SDSM&T

The Department of Chemical and Biological Engineering at SDSM&T, coming from humble beginnings, has survived and thrived with the pioneer spirit so alive in the Great Plains. The Department of Chemical and Biological Engineering has entered the 21st Century with tremendous momentum and promise, with a vibrant curriculum, an emerging research program, and now on the horizon a new building to be completed in 2011. We are fortunate that the vision and tenacity of Drs. Karsten, Sandvig, Bond, and Osterhof has propelled us to where we are today, and we look forward to making continued contributions to chemical engineering research and education locally, nationally, and globally.

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