Chemical Engineering at . . .

Tuskegee University

Tamara Floyd-Smith, Shamim Begum, Nader Vahdat, Qinghua Peter He, Kyung Kwon, Jonathan Mbah, and Allen Smith
Tuskegee University • Tuskegee, AL 36088

Tuskegee University, a private, but state-related, historically black college/university (HBCU) located in Tuskegee, AL, was founded in 1881 as a school for teachers (normal school). The school was formed by a legislative act by the state of Alabama with a $2,000 appropriation. During his tenure of 34 years, Booker T. Washington, the first president and a former slave, advanced the university from 30 students and one classroom near Butler Chapel AME Zion Church to a campus of 1,500 students, 40 majors, 100 buildings, 200 faculty members, and a $2M endowment by 1915. He also led Tuskegee University in gaining independence from the state in 1892.

Luther H. Foster Hall: Home of the Department of Chemical Engineering.

The germination of the College of Engineering can be traced to the second Morrill Act of 1890. The first Morrill Act of 1862 gave northern universities land from the federal government that could be sold for support of industrial colleges for professions like agriculture and engineering, but states that had seceded were not allowed to participate. After southern states rejoined the union, they were allowed to participate

in the land grant program. States, such as Alabama, that considered race for admissions, were required to designate a separate institution for African American students. Among other things, the 1890 Morrill Act gave land grant status to the designated institutions that educated African Americans in segregated states. Tuskegee University achieved land grant status in 1899.

Soon after the 1890 Morrill Act, in 1896, Tuskegee hired George Washington Carver, one of the most famous individuals associated with Tuskegee University, to lead its agricultural department. Carver, a renowned inventor, made lasting contributions in the area of agriculture. Also, after the 1890 Morrill Act in 1893, Robert R. Taylor, the first African American student to attend the Massachusetts Institute of Technology and the first academically trained African American architect, began to award certificates in architecture at Tuskegee University. Then, in 1903, Taylor began to serve as an administrator for Tuskegee's Division of Mechanical Industries. The 20th century brought additional attention to the Tuskegee community for the egregious Tuskegee Syphilis Study and the celebrated Tuskegee Airmen, who served during World War II and were the first African American pilots in the United States military.

Booker T. Washington: Founding President of Tuskegee University.

Although the College of Engineering began to germinate in the 1890s with the Morrill Act, the electrical engineering department was not initiated until 1948 with the mechanical engineering department following soon after in the early 1950s. Then, the chemical engineering program at Tuskegee University was initiated in 1977 as a program in the Department of Mechanical Engineering. Dr. Ira Dillon was appointed as the coordinator for the program. He was the only chemical engineering faculty member teaching courses for the program. The program started with a handful of students and grew steadily. In 1981, three more faculty members were hired and the Chemical Engineering Program became a separate department in the College of Engineering. The same year, the program applied for ABET accreditation. The department was visited in 1982 by ABET evaluators and was granted accreditation. In 1985, Tuskegee Institute was renamed Tuskegee University.

Currently, the chemical engineering department is located within the College of Engineering which includes undergraduate departments in aerospace science engineering, chemical engineering, electrical engineering, and mechanical engineering as well as a graduate-only department in materials science and engineering and the ROTC programs. The chemical, mechanical, and electrical engineering programs are housed in Luther H. Foster Hall, named after the fourth president of Tuskegee University who served during the time that the building was constructed.

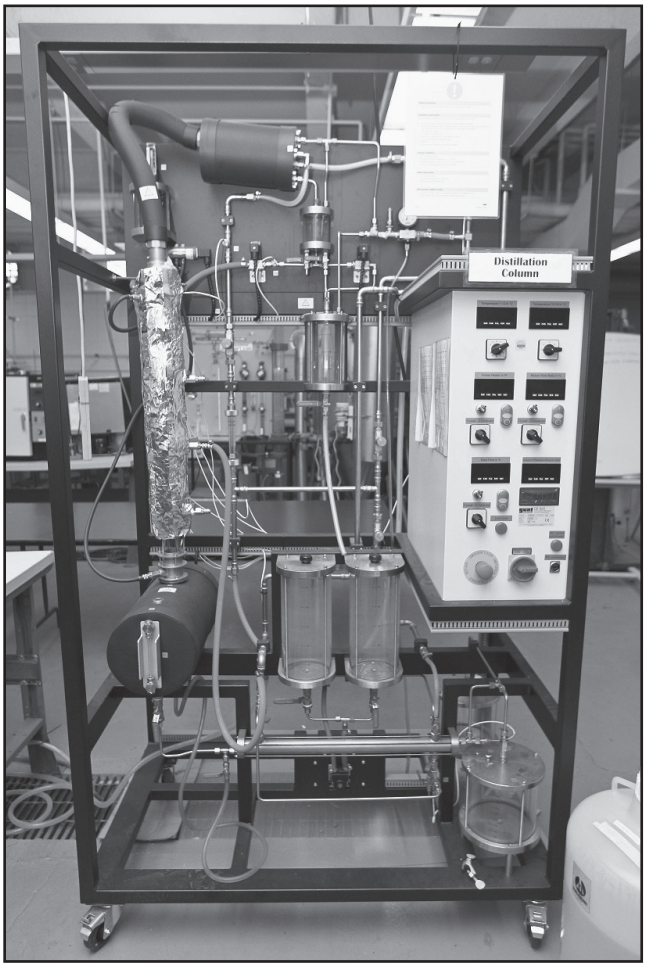
UNDERGRADUATE PROGRAM

The current enrollment in the chemical engineering department is approximately 130 students. The curriculum of the undergraduate program provides a strong emphasis on fundamental science, mathematics, and engineering science. The upper-level curriculum is structured on basic knowledge and applications of transport processes, thermodynamics, chemical reaction processes, process control, and computer-aided design. The undergraduate curriculum of the chemical engineering department is revised regularly to meet the requirements of the employers of its graduates. In addition, the undergraduate curriculum is designed to ensure achievement of the student outcomes assigned by the ABET.

Within the last decade, two significant curriculum changes occurred which include the addition of an introductory course to the curriculum and the formal development of a general education curriculum for the entire university. Beginning Fall 2005, an Introduction to Chemical Engineering (CENG 0110) course was added to the curriculum because, prior to the course, the department was not scheduled to instruct chemical engineering students until sophomore year when they were expected to take Material and Energy Balances (CENG 0210). CENG 0110 introduces students to the field and faculty members during freshman year and, based on anecdotal evidence, aids in retention. Also, in 2008, a formalized general education curriculum was introduced for all undergraduate programs at Tuskegee University. The purpose of the general education program is to enable students to build a solid foundation in the humanities, behavioral science, and life and physical sciences. The impact of this curriculum was that the number of credits for the humanities and the social science courses increased from 15 to 17 for the chemical engineering department.

Currently, the curriculum includes essential math, science, and engineering courses needed to ensure that students acquire

the necessary technical knowledge and skills for a practicing chemical engineer or graduate student. All students take an ethics course (CENG 390) that teaches them ethical standards. Engineering design is emphasized during the senior year in a required two-course sequence, Chemical Engineering Plant Design (CENG 0470) and Capstone Design (CENG 0490). Process development, safety, hazard control, process design, economic analysis, and optimization are covered in CENG 0470. Students use the concepts learned from courses such as material and energy balances, fluid mechanics, heat and mass transfer, and reaction engineering to design a complete chemical process. In the Capstone Design course, students are divided into teams of two or three and each team receives a project that requires a full design of a process to produce a product or control environmental contaminants. Students meet once per week to present their report on the team's progress. Each team has a faculty advisor with whom they meet weekly. Additionally, students prepare weekly written reports and give weekly oral presentations to the entire chemical engineering faculty.



A Distillation Unit in the Unit Operations II Laboratory (CENG 0420).

In addition to core content, the curriculum addresses lifelong learning, teamwork, multidisciplinary activities, and tools for chemical engineering practice. The concept of lifelong learning is discussed in several courses such as Plant Design and Capstone Design. Students in these courses are required to conduct comprehensive literature surveys and are encouraged to attend workshops. In several courses such as Unit Operations Lab I (CENG 0320), Unit Operations Lab II (CENG 0420), Process Control and Instrumentation Lab (CENG 0440), and Senior Design (CENG 0490), students are required to work in teams. CENG 320 is designed with experiments in fluid mechanics and heat transfer and offered jointly with mechanical engineering students to form multidisciplinary teams. Simulation and computational tools such as Excel, MATLAB®, and ASPEN Plus® are used extensively in thermodynamics, reaction engineering, transport processes, process control, and senior plant design courses. In summary, the curriculum provides a solid foundation in mathematics, basic sciences, and engineering, and exposes students to extensive design experiences, safety, and ethics.

Chemical engineers may also work in environmental, ecological, and biomedical fields. To prepare students for careers outside of traditional chemical engineering, undergraduate students choose from one of the four options in the program:

1. ***General Chemical Engineering:*** *Students can select 12 credit hours of their technical electives from a list provided by the department. The list includes advanced undergraduate science, mathematics, and engineering courses. Total degree hours are 131.*

2. ***Environmental Engineering Option:*** *Students take several courses in environmental science and engineering. Total degree hours are 131.*

3. ***Biochemical Engineering Option:*** *Students will acquire knowledge required for pharmaceutical and related industries by choosing this option. The curriculum includes courses in biology, biochemistry, biochemical engineering, and microbiology. Total degree hours are 131.*

4. ***Pre-med Option:*** *This option prepares students to enter medical school. The curriculum includes all the traditional prerequisites for admission to medical school. Total degree hours are 135.*

The chemical engineering department at Tuskegee University has a collaborative program with the Auburn University Pulp and Paper program for undergraduate students due to the importance of the pulp and paper industry in the southern region. Two courses (CHEN 3090 – Pulp and Paper Technology, and FOPR 4780 – Wood Chemistry) in the technical electives are accepted by Tuskegee University as transfer hours. Students have an opportunity to receive an academic scholarship through the Auburn Pulp and Paper Foundation (APPF) to cover all expenses for this program.

As extracurricular activities within the chemical engineering department, undergraduate students participate in the

Spring 2014 Tuskegee University AIChE Student Chapter Plant Tour to AkzoNobel Chemical Plant in Axis, AL.

American Institute of Chemical Engineers (AIChE) and Omega Chi Epsilon Chemical Engineering Honor Society. At the end of four years of study, the students will be awarded a Bachelor of Science degree in chemical engineering and, typically, attend graduate school or accept industrial positions. Among the top recruiting companies are oil companies (Chevron and ExxonMobil), consumer product companies (Procter and Gamble), and materials companies (3M).

GRADUATE PROGRAM

In Fall 2014 the department began offering a Master of Science Degree in chemical engineering structured to be completed within two years. The M.S. program consists of 24 course credits and six credits of research for a total of 30 credits. Core courses include two advanced mathematics courses, advanced thermodynamics, and advanced reaction engineering. The remaining 12 course credits are for elective courses that students and their advisors choose to support the research effort. These electives include graduate-level chemical engineering courses in numerical methods, process dynamics and control, wastewater treatment, separation processes, biochemical engineering, and special topics. Tuskegee University also offers an M.S. in mechanical engineering with advanced courses in heat transfer, fluid mechanics, and numerical analysis that chemical engineering students conducting research in those areas will find beneficial. Chemical engineering M.S. students may also take advantage of courses offered in the M.S. programs in the natural sciences, including courses in biostatistics, advanced environmental science, inorganic synthesis, instrumental analysis, organic chemistry, and chemical thermodynamics. Finally, Tuskegee University offers a Ph.D. in materials science and engineering that includes courses such as physics of materials, polymer physics, materials properties and characterization, and electronic materials processing for students conducting interdisciplinary research in the field of materials science and engineering.

FACULTY MEMBERS AND RESEARCH AREAS

Consistently, the Department of Chemical Engineering employs seven full-time, tenure-track faculty members. As

of Fall 2014, the chemical engineering department includes three full professors, one associate professor, and three assistant professors.

Nader Vahdat, P.E., (Ph.D. University of Manchester) is a chemical engineering professor and department head at Tuskegee University. He joined Tuskegee in 1981, and was appointed as the department head in 1986. His research focuses on the application of membranes and adsorption processes to solve different engineering problems. His group has studied permeation of multicomponent mixtures through elastomeric materials that are used in the protective clothing industry. Another application is development of models to predict transport properties (such as diffusion coefficient) of chemicals through membranes from the properties of polymers and chemicals with application in membrane separation processes. Recently, his group has worked on the application of membranes and adsorption processes to capture CO_2 from flue gas at power plants. The existing technology for removing CO_2 from flue gas is 70 years old. The process uses chemical absorption as a method for CO_2 recovery from flue gas. This is an energy-intensive process and therefore very expensive for power plants. A new technology that achieves a more cost-efficient separation of CO_2 is needed in order to convince power plants to incorporate CO_2 capture modules in their processes. Membrane separation and adsorption processes could help fill this need. Development of new membranes with high permeability and selectivity for CO_2 and adsorbents with high capacity for CO_2 could produce very economical methods for CO_2 capture.

Kyung C. Kwon, P.E., (Ph.D. Colorado School of Mines) is a professor of chemical engineering who joined the department in 1982. His research interests are in the area of structured catalysts developed for biofuel production and biofuel upgrades. Structured catalysts as an alternative to pellet catalysts are formulated by impregnating structured catalyst supports with various promising catalytically active metals. The slug flow regime of a fluid consisting of a liquid phase and a vapor phase within narrow channels of a structured catalyst offers exceptionally high mass transfer characteristics at low-pressure drop. The high mass transfer rate is based on two key features: a) a very thin liquid film that separates the vapor phase (bubbles) from a solid catalyst surface wetted with liquid reaction mixtures and b) a rapid circulation of the liquid phase within liquid slugs trapped between two bubbles. This ensures continuous refreshment of the liquid phase in contact with both the solid catalyst surface and the vapor phase. A relatively uniform distribution of the liquid phase and the vapor phase throughout all of the channels of the structured catalyst is achieved. Drastic separation of a hydrophilic phase from a hydrophobic phase in oxygen-rich liquid reaction mixtures and that of a vapor phase from a liquid phase can be reduced in structured catalyst reactors in comparison with flow reactors packed with pellet catalysts. These hydrodynamic advantages of structured flow reactors developed in Tuskegee University over a flow reactor packed with pellet catalysts will have potential impacts on the design of reactors for oxygen-rich biofuel production as well as upgrades such as isomerization, hydrogenation, and

Left, a Spring 2014 photo of the full-time faculty members (L to R): Kyung Kwon, Q. Peter He, Tamara Floyd-Smith, Nader Vahdat (chair), Nosa Egiebor (now professor of ChE at The University of Mississippi), Jonathan Mbah, and Shamim Begum. Above, Allen Smith, the newest assistant professor.

hydrocracking. Structured catalysts with multi-layers of various catalytic metals shift equilibrium conversion of reversible reactions favorable to increased yields of desired products without drastic change in reaction operation conditions and maximize desired products in consecutive reactions.

Tamara M. Floyd-Smith, P.E., (Ph.D. Massachusetts Institute of Technology), who considers herself a native of Alabama, received her B.S. in chemical engineering from Tuskegee University in 1996. Then, she earned an M.S. in chemical engineering practice in 1998 and completed requirements for a Ph.D. in chemical engineering in 2001, both from the Massachusetts Institute of Technology. After working in an industrial research position for two years, she returned to Tuskegee University as an assistant professor of chemical engineering in 2003. Currently, she holds the titles of professor of chemical engineering, adjunct professor of materials science and engineering, and 3M Scholar.

Her core research area is microfluidics, which is fluid flow through small channels where at least one dimension is less than 1 mm. She uses microfluidics as a tool to address problems in mass and heat transfer in order to synthesize novel particles and films as well as enable applications in biosensing and thermal management. Prior to implementation of the M.S. degree in chemical engineering, she supervised M.S. degrees in chemistry and mechanical engineering and also currently supervises Ph.D. students in the area of materials science and engineering. In addition to traditional scientific research, she is also actively engaged in engineering education research.

Q. Peter He (Ph.D. University of Texas, Austin) is an associate professor in the Department of Chemical Engineering at Tuskegee University. He obtained his B.S. degree in chemical engineering from Tsinghua University, Beijing, China, in 1996, and M.S. and Ph.D. degrees in chemical engineering in 2002 and 2005 from the University of Texas, Austin. The overarching theme of He's research is to apply systems engineering approaches to understand, predict, and control complex dynamic processes. In the renewable energy area, He's research focuses on the modeling and control of thermal (gasification) and biological (fermentation) conversion of lignocellulosic biomass into fuels and chemicals. Recently, He's group has expanded its research into the biological conversion of methane into valuable fuels and chemicals. In the cancer research area, He's group applies multivariate statistical methods and bioinformatics tools to high-dimensional (and often heterogeneous) cancer-omics and clinical data; tools employed include principal component analysis (PCA), Fisher discriminant analysis (FDA), support vector machines (SVM), and supervised/unsupervised clustering methods. In addition, He's group also conducts research in the general areas of process modeling, monitoring, optimization, and control, with special interests in the modeling and optimization of batch processes such as semiconductor manufacturing and pharmaceutical processes.

Shamim Ara Begum, P.E., (Ph.D. University of Nevada, Las Vegas) joined the chemical engineering department as an assistant professor in 2010. Begum's research focuses on physico-chemical treatment processes for water and wastewater. The goal of her research is to identify cost-effective bio-based adsorbents for the removal of heavy metals such as arsenic, chromium, mercury, and lead from water. Various parameters are optimized, and kinetics and removal mechanisms are studied to accomplish her research goal. In addition, she is interested in the development and characterization of nanomaterials obtained from bio-based adsorbents to remove various pollutants from aqueous systems and understand the surface chemistry involved with the removal process. Using the adsorbents, filtration units can be designed to treat contaminated water in full-scale water and wastewater treatment plants. Her research on wastewater deals with biological treatment for cyanide and nutrient removal from wastewater and aims to investigate the microbial population dynamics in the cyanide and nutrient removal system. Implications of this research apply to the design and operation of the unit operations required for the removal of cyanide and nutrient in the full-scale wastewater treatment plant.

Jonathan Mbah (Ph.D. University of South Florida) received his Ph.D. in chemical engineering in 2008 and taught and conducted research at the University of South Florida until 2010, before joining the Department of Chemical Engineering at Tuskegee University as an assistant professor. He is developing processes in the areas of electrochemical and photoelectrochemical synthesis as applied to energetic materials, carbon dioxide capture and conversion, hydrogen production, and fuel cells. Mbah is also interested in the synthetic chemistry of new and emerging energetic materials, as well as in new spectroscopic techniques and applications for trace and/or bulk energetic materials detection and identification.

Allen Joseph Smith (Ph.D. Auburn University) worked as a chemical engineer for 12 years with diverse process engineering and technical sales responsibilities including most aspects of the pulp and paper industry before returning to graduate school to complete his Ph.D. in chemical engineering in 2011. In Fall 2011, he joined the chemical engineering department at Tuskegee University as an adjunct professor and in Fall 2014 he joined the faculty as a full-time, tenure-track assistant professor.

His research interests center around three general topics: the pulp and paper industry, engineering education, and sustainability. Research interests in the paper industry involve separation of wood components in pulp bleaching for improved pulping efficiency and the advancement of the pulp mill biorefinery concept that would allow some additional flexibility of producing chemical products from the wood in addition to or instead of the traditional pulp

and current byproducts. Research in engineering education includes redesign of courses to include blended components and unification of curriculum to improve knowledge retention in the student and student retention in the program. Sustainability is a growing concern in society at large, but widespread implementation of sustainable practices in society depends on engineering of metrics of sustainability to identify appropriate actions to change and the technology to make the required changes. Part of the curriculum improvement will be to identify modifications to courses that would teach these metrics and methods to the students along with the other traditional engineering skills as modules within each course.

SUMMARY

The chemical engineering department is part of the rich 130-year history at Tuskegee University. With an almost 40-year history of educating undergraduate chemical engineers, the chemical engineering department expanded yet again in Fall 2014 to offer an M.S. degree in chemical engineering. The program has been ABET accredited since 1982 and prepares graduates for successful careers in industry and for furthering their education in graduate programs. With seven faculty members working in diverse research areas, the department looks forward to a productive 21st century continuing to educate students while having a global impact in engineering research. ❐

Top left, the main entrance to Tuskegee University and location of Margaret Murray Washington Hall.
Top right, Department of Chemical Engineering student and 2013 graduate Trena Sharpe at the annual Order of the Engineer ceremony held in the Luther H. Foster Hall Auditorium.
Bottom, the full Engineering Complex including General Daniel Chappie James Center and Luther H. Foster Hall.