

*Chemical Engineering at . . .**The Pennsylvania State University*

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The Chemical Engineering Department at The Pennsylvania State University (commonly known as Penn State) is located in State College, PA, an area colloquially known as “Happy Valley.” The drive into Penn State is beautiful, passing through the hills of the Allegheny Mountains and through multiple state parks and forests. For many visitors, that trip ends at Beaver Stadium, the second largest stadium in the western hemisphere and home to the Penn State football team. For others, the draw might well be Penn State’s Breazeale Nuclear Reactor, the longest continuously operating university research reactor in the world. However, for most of the past 60 years, visitors interested in chemical engineering would arrive at Fenske Laboratory, the long-time home for the department named after Merrell Fenske (who is also the namesake for the “Fenske equation” used to calculate the minimum number of theoretical plates in a distillation column). But not anymore. In Spring 2019 the department moved into a brand new, state-of-the-art, 195,000 square foot facility (shown in Figure 1) specifically designed to accommodate our undergraduate and graduate programs. The department graduated 223 BS chemical engineers in 2017-2018, ranking first among all degree-granting institutions in the US<sup>[1]</sup> and 22 graduate students received their PhD degrees,<sup>[2]</sup> the largest number ever produced by the department in a single academic year.

**THE UNIVERSITY**

Penn State was founded in 1855 as the Farmers’ High School of Pennsylvania<sup>[3]</sup> – the name was chosen to allay fears from the local farming community that this new college would focus on what was viewed as the “impractical” curricula of traditional schools of higher education. The college was originally located on 200 acres of land in Centre County, chosen in large part because of its proximity to the geographic center of the state. The university now owns more than 22,000 acres (> 90 million m<sup>2</sup>) across the entire state.



*Figure 1. Photo of the new Chemical and Biomedical Engineering Building.*

The school’s name was changed to the Agricultural College of Pennsylvania in 1862 and then to the Pennsylvania State College in 1874; it became Pennsylvania’s sole land-grant college in 1863 with the passage of the Morrill Act.<sup>[3]</sup> The school was renamed as The Pennsylvania State University in 1953 under the presidency of Milton S. Eisenhower (brother of then US President Dwight D. Eisenhower), reflecting the tremendous growth in research and doctoral programs that occurred during the first half of the 20th century.<sup>[3]</sup>

Penn State is part of the *Commonwealth System of Higher Education*,<sup>[4]</sup> a legal designation that confers “state-related” status on four institutions of higher education in Pennsylvania: The Pennsylvania State University, the University of Pittsburgh, Temple University, and Lincoln University. These schools are separate entities, each with its own charter and governed by its own board of trustees. They all receive annual appropriations from the state, primarily to support the education of Pennsylvania residents. This particular public-private hybrid model is unique to Pennsylvania. Penn State’s current state appropriation is around \$320 million, which is less than 5% of the university’s total annual operating budget of \$7 billion.

Today, the university has 24 campuses across the state of Pennsylvania (shown in Figure 2), offering more than 275 baccalaureate degree programs with more than 100,000 students and 17,000 faculty and staff.<sup>[3]</sup> This includes the Penn State College of Medicine, adjacent to the Penn State Health Milton S. Hershey Medical Center in Hershey, PA, which became part of Penn State through a \$50 million gift from the Hershey Trust Company in 1967. The Pennsylvania College of Technology in Williamsport, PA became part of Penn State in 1989, and the Dickinson School of Law in Carlisle, PA merged with Penn State in 2000. Penn State has a single president and a single University Faculty Senate that has legislative authority on education-related matters across all 24 campuses.

The Department of Chemical Engineering is located on the University Park (main) campus in State College, PA, home to around 40,000 undergraduates and an additional 6,000 graduate students. Undergraduates can start their educations at any of the campuses, but they must relocate to University Park to take the required chemical engineering courses. Approximately 20% of our current undergraduates begin their studies at one of the branch campuses.

## HISTORY OF CHEMICAL ENGINEERING AT PENN STATE

The study of chemical engineering at Penn State began as an offshoot of the Department of Chemistry.<sup>[5]</sup> The first BS degree in Chemistry was given to William H. Walker in 1890, shown in Figure 3. Walker is widely recognized as the father of chemical engineering for his efforts to establish the School of Chemical Engineering Practice at MIT in 1917 and his co-authorship of the first chemical engineering textbook, *Principles of Chemical Engineering*, in 1924. Walker retained close ties to Penn State throughout his career, serving for a number years on the Board of Trustees for what was then the Pennsylvania State College.

Penn State introduced a program in industrial chemistry in 1902. Many of the graduates of this program became leaders in the rapidly developing US chemical industry. This included



Figure 2. Map showing the location of the different Penn State campuses.<sup>[3]</sup>

W.A. Slater (1907), Vice President of Gulf Oil; R.W. Ostermayer (1917), President and Chairman of the Board of the Pennsylvania Industrial Chemical Company; M.W. Geiger (1921), President of Davidson Chemical Company (subsequently a division of W.R. Grace); W.C. Decker (1922), Chairman of the Board of Corning Glass; and S.F. Hinkle (1922), President and Chairman of the Board of the Hershey Chocolate Corporation.



*Figure 3. Photo of William H. Walker.*

Penn State's Chemical Engineering Department will soon be celebrating its official centennial; the first chemical engineering curriculum at Penn State was introduced in 1924<sup>[5]</sup> based on the concepts of unit operations that were described in the text by Walker, Lewis, and McAdams. The first class of 11 Chemical Engineering graduates received their degrees on June 15, 1925. In 1929, Merrell R. Fenske (shown in Figure 4) was recruited to Penn State from MIT. Fenske helped establish the *Petroleum Refining Laboratory* (PRL), with world-class facilities for distillation research. As many as 70 chemical engineers and chemists were employed in the PRL during World War II. The research conducted in the PRL established the technologies used for producing aviation fuels, hydraulic fluids, and lubricants, all of which were essential to the Allied war effort. The PRL was officially merged into the Department of Chemical Engineering in 1959, with Merrell Fenske appointed as the department head.<sup>[5]</sup> The department's research activities continued to focus on distillation, lubrication (tribology), and thermodynamics for much of its early development.



*Figure 4. Photo of Merrell R. Fenske.*

In addition to Fenske and Walker, several of the Fifty Chemical Engineers of the Foundation Era<sup>[6]</sup> (as chosen by the AIChE Centennial Celebration Committee) had direct ties to Penn State, including Edwin Gilliland (MS in 1931) and Max Peters (BS in 1942 and PhD in 1951). AIChE's list of the top 100 Chemical Engineers of the Modern Era<sup>[7]</sup> also included numerous Penn State alumni, such as William H. (Bill) Joyce, George Keller, John (Jack) McWhirter, and John Sinfelt.

## RESEARCH INITIATIVES

Penn State has seen a dramatic growth in its research portfolio over the past 50 years, with current annual research expenditures of more than \$1 billion. NSF's 2018 analysis of academic research expenditures ranked Penn State in the top 10 in 18 different disciplines, which is more top-ten programs than any other university in the US.<sup>[8]</sup> Penn State's expenditures in chemical engineering were ranked 8th. These rankings are a reflection of Penn State's strong commitment to interdisciplinary research, with many of these programs involving, or being led by, chemical engineering faculty. The Intercollege Research Program in Materials was established in 1958; the Penn State Materials Research Laboratory (a set of core facilities to support materials-related research) was formed in 1973. In 1992 the University created the Materials Research Institute (MRI), the first University-wide research institute supported directly through the Office of the Vice President for Research. Penn State has consistently ranked 1st in the US in the NSF rankings for total research expenditures in materials science.<sup>[3]</sup> The Life Sciences Consortium was established several years later; it was renamed as the Dorothy Roehr Huck and J. Lloyd Huck Institutes of the Life Sciences in 2002. The Institute of Energy and the Environment, the CyberScience Institute, the Social Science Research Institute, and the Rock Ethics Institute are newer additions. Together, these Institutes support an investment of over \$100 million in core facilities, provide dozens of seed grants for interdisciplinary research projects, and facilitate/co-fund new faculty hires in targeted strategic research areas.

The Chemical Engineering Department has effectively leveraged the institute structure at Penn State to develop world-class research programs in:

- Biotechnology and Synthetic Biology
- Energy and the Environment
- Interfaces and Surfaces
- Materials and Nanotechnology
- Separations and Transport
- Systems Engineering

Our faculty are highly collaborative, in many cases combining novel experimental approaches with state-of-the-art computational/theoretical analyses to solve complex problems and conduct groundbreaking research in truly diverse fields. Penn State ranked 7th among all US institutions for chemical engineering research publications, as reported by National Taiwan University in their latest annual ranking.<sup>[9]</sup> We hired eight new faculty in just the past two years, pushing our faculty head count to 33, the largest in our history.

In addition to typical single and multi-investigator grants, the department is home to a number of major research centers, including:

- NSF IUCRC *Membrane Science, Engineering, and Technology* (MAST) Center
- NSF NRT-DESE *Computational Materials Education and Training* (COMET) program
- ONR MURI Center for *Self-Assembled Organic Electronics* (SOE)
- NSF REU program in *Integration of Biology and Materials*

Our faculty are also actively involved in a wide range of research centers with homes across Penn State and the US, including the DOE-EFRC *Center for Lignocellulose Structure and Formation*, the DOE-EFRC *Center for Atomic-Level Catalyst Design*, the DOE-EFRC *Center for Performance and Design of Nuclear Waste Forms and Containers*, the DOE *Center for Bioenergy Innovation*, the DOE *Center for Advanced Bioenergy and Bioproducts Innovation*, the NSF-MRSEC *Center for Nanoscale Science*, and the NSF-IUCRC *Center for Atomically Thin Multifunctional Coatings* (among many others).

The department currently has 26 tenure-line faculty (with two others to join in 2021), two faculty with joint appointments (one in *Energy & Mineral Engineering* and one in *Agricultural & Biological Engineering*), three full-time teaching faculty, and eleven faculty from across campus with courtesy appointments. Our faculty continue to receive international recognition for their work. In just the last year and half, we have had faculty recognized with the Warren K. Lewis Award (2020), the Lawrence K. Cecil Award (2020), the Biotechnology Progress Award for Excellence in Biological Engineering Publications (2020), and the Nanoscale Science and Engineering Forum Award (2019), all from AIChE; the International Metabolic Engineering Award (2020); the Arthur K. Doolittle Award from the ACS Polymeric Materials – Science and Engineering Division (2021); the ACS Separations Science & Technology Award (2020); the Langmuir Lectureship from ACS (2020); and the Alan S. Michaels Award for Innovation in Membrane Science and Technology from the North American Membrane Society (2020). In addition, our faculty serve as Editors of several major journals (e.g. *Industrial & Engineering Chemistry Research*, *Metabolic Engineering*, *Environmental Microbiology*, and *ACS Applied Polymer Materials*) and in leadership positions in multiple professional societies, including the current president of AIChE (Monty Alger).

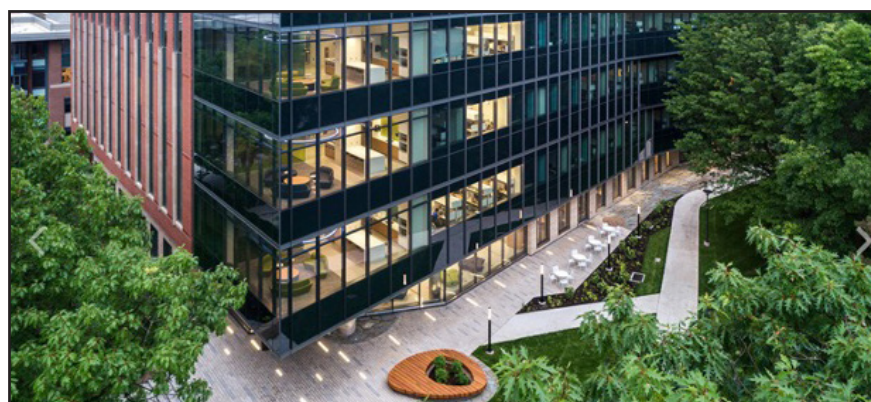
The department has seen a dramatic increase in the size of our graduate program over the past decade. In 2016 the graduate program was officially named in honor of John (Jack) and Jeannette

Dachille McWhirter, becoming the first named (and fully endowed) graduate program at Penn State (and one of the only such graduate programs in the US). Penn State had the 5<sup>th</sup> most PhD recipients in chemical engineering in 2018, as shown in Table 1.<sup>[2]</sup> We have a very active Graduate Student Association (GSA) that organizes our yearly Departmental Research Symposium as well as a range of networking opportunities and social events, including fall and spring picnics at

one of the parks near the Penn State campus. The GSA also plays a major role in the department’s efforts to recruit prospective students, serving as personal “hosts” for the visiting students during our Department’s Open House.

The department’s research efforts are poised to grow significantly in the coming years through the opportunities presented by our new state-of-the-art laboratory facility, shown in Figure 5. This 195,000 square foot facility is organized around laboratory “neighborhoods,” each providing space for between one and four faculty with complementary research interests. Shared infrastructure (e.g. autoclaves, cold rooms, and shared equipment) are located at the intersection of different neighborhoods. Each floor has conference rooms, a kitchen area, and collaborative space for graduate students

Institution	Number of PhD Recipients
MIT	33
Georgia Tech	33
U Delaware	28
U Minnesota	27
<b>Penn State</b>	<b>22</b>
Michigan	22
Purdue	22
UT Austin	22
Ohio State	20
Stanford	20

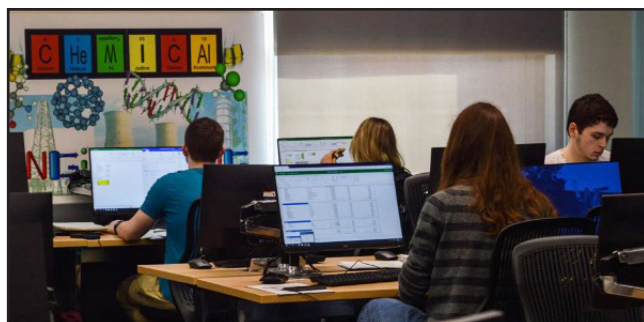


**Figure 5.** Photo of new Chemical and Biomedical Engineering Building.

and faculty to gather. The co-location of the Biomedical Engineering Department provides exciting new opportunities for collaborations in the life sciences.

## EDUCATIONAL PROGRAMS

The Penn State faculty have always had a deep commitment to educational excellence in our undergraduate program. Seven of our current faculty are past recipients of Penn State Outstanding Teaching Awards from the College of Engineering. Chemical Engineering faculty were awarded the Lawrence J. Perez Memorial Student Advocate Award for contributions to the welfare and enrichment of students for three consecutive years (2014, 2015, and 2016), each to a different faculty member – this is even more impressive when one considers that our Department has fewer than 10% of the total faculty in the College of Engineering.



**Figure 6.** Photo of students at work in the Chemical Engineering computer laboratory.

Our new building houses much of the department's teaching space, including a brand-new unit operations laboratory and a dedicated computational instruction lab (shown in Figure 6). The Dow Chemical Knowledge Commons provides space that is specifically designed to foster peer-to-peer interactions, student teams, and highly engaged learning.

Although our department resisted the trend to change its name, we were one of the first programs in the US to make a clear commitment to incorporate biological aspects of chemical engineering into the core curriculum for all undergraduates. Our comprehensive curriculum revision in 2005 led to the inclusion of required courses in *Molecular and Cell Biology* (taught through the Biochemistry and Molecular Biology Department) and *Introduction to Biomolecular Engineering* (taught by one of our tenure-track Chemical Engineering faculty). The latter course covers a wide range of applications demonstrating how chemical engineers use the biological sciences to solve important technological problems. More recently, we incorporated a new required three-credit course in *Chemical Process Safety*, providing our students

with broad exposure to both the technical and human aspects of safety in the chemical industry. More than 80% of our undergraduates participate in at least one formal experiential learning opportunity, including nearly 50% who are directly involved in undergraduate research and another 30% who participate in the college's cooperative education program. We consistently send more than two dozen students a year to top-ranked doctoral programs in chemical engineering, in addition to the occasional students who pursue advanced degrees in business, law, or medicine. Recent graduates of our BS program now hold tenure-line faculty positions in leading chemical engineering departments around the country including MIT, Michigan, Princeton, the University of Virginia, the University of Pittsburgh, and Colorado School of Mines, among others.

One of the unique components of our undergraduate program is the required *Professional Development Seminar*. This course includes material on intellectual property, professional networking, development of effective teams, entrepreneurship, process improvement using Six Sigma, and how to be successful in a first job. All of the topics are presented by department alumni – presenters include IP lawyers, CEOs, licensed Professional Engineers, Six Sigma Black Belts, and highly successful entrepreneurs. Our alumni are simply incredible. They travel across the country at their own expense for the opportunity to share their experiences and insights with our students – we actually have a waiting list of volunteers looking to do whatever they can to support the chemical engineering department at Penn State.

Given the department's strong emphasis on developing the next generation of chemical engineers, it is no surprise that we have always had a very active student chapter of the *American Institute of Chemical Engineers* – our chapter received the AIChE Outstanding Student Chapter Award in both 2017 and 2019; the officers are shown in Figure 7. One



**Figure 7.** Officers of the Penn State AIChE Student Chapter.

of the highlights of each fall is the weekly AIChE tailgate before home football games. These are typically hosted by an industry sponsor that provides free food and beverages for the students. Most company sponsors send one or two alumni back to campus to network with our students (and faculty) while also enjoying the Penn State football game along with the more than 100,000 fans who flock to Beaver Stadium each Saturday. The chapter is also active in THON, the largest student-run philanthropy in the world, helping to raise more than \$10 million each year to support children and families impacted by childhood cancer. These, and other less formal opportunities to connect and contribute, foster lifelong friendships and assure that Penn State educated chemical engineers continue to be effective, engaged participants in their workplaces, communities, and families.

## IN CLOSING

Chemical engineering at Penn State has had a truly illustrious first century – we have likely graduated more BS chemical engineers than any other US institution over that time period, many of whom have gone on to extraordinary careers in academia, industry, and public service. And we are poised to have an even better next hundred years. The University's commitment of new faculty lines, on top of the \$140 million that was provided for the construction of our new building and the endowment of the John R. and Jeanette Dachille McWhirter Graduate Program in Chemical Engineering, has provided a foundation for excellence that

our faculty, students, staff, and alumni are fully committed to fulfilling in the coming years.

## ACKNOWLEDGMENTS

The author would like to acknowledge helpful discussions with a number of the Penn State chemical engineering faculty, including Janna Maranas, Ron Danner, Mike Janik, Seong Kim, and Phil Savage.

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