University of Missouri Chemical Engineering
1903 to 2013
A History from the Beginning

by
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Preface

When Professor Deng asked would I write a history of Chemical Engineering at the University of Missouri I agreed with the understanding that I am not an Historian and it will get personal. I have lived half of the Chemical Engineering Department history and it is nearly impossible to "filter out" personal feelings and understanding of those times. The successful Nuclear Engineering Graduate Program was formed as an initiative of the Chemical Engineering Department. The graduate degree productivity of that program is included. There are gaps in the data that time would not allow me to fill (it may not exist) but the record available speaks to success.

I decided to write this history in four parts:

1. There is the time from 1839 when the University of Missouri was formed to 1903 when the Chemical Engineering Department was approved. This provides the political, intellectual, financial, and public opinion "seed bed" where the ChE program was expected to grow. This section ends at the academic year 1959-60, a span to 121 years.
2. The development of chemical engineering as a profession using the textbooks and the changes in those writings over the 110 years.
3. The faculty members at the beginning of each decade starting with academic year 1960-61 to 2000-2001. A description of some of the research and an index of productivity – the number of BS, MS and PhD degrees earned during the decade. The Chemical Engineering Department faculty worked to form the Nuclear Engineering Graduate Program in that first decade with collaboration continuing.
4. Future directions chemical engineering might "grow." There are some indicators pointing to tasks that need to be addressed during the next couple decades.

Part 1: The First 120 Years

The history of chemical engineering at the University of Missouri begins with an investment made by President Thomas Jefferson. He executed the Louisiana Purchase obtaining a huge block of land (~ 825,000 square miles) extending west from the Mississippi River, North to British Territory (Canada), along that border to the Oregon and Spanish Territories. This region contained rich farmland and natural resources.

Missouri became a state in this territory on August 10, 1821, and Jefferson City its third and final capital in 1826.

St. Louis College was opened in 1818 as the oldest private college west of the Mississippi River (There are older Mission Churches in the Spanish Territories). The Jesuit Order added Priests and it was established as a school to train Priests for service in this new territory. A charter for that school was issued by the State of Missouri in 1832. Today this has become St. Louis University.

The pioneer legislature established the University of Missouri in 1839. They then sought a central location along the Missouri River that would be equally accessible to citizens from all corners of the state. The location would be determined by a "lottery" where the county that submitted the highest bid in cash and/or land pledged to the university would be the site of the University. The legislature assumed these lottery funds plus the funds from the sale of two townships granted to the state when it was admitted to the Union "for the use of a seminary of learning" would support the University for many years.

Boone County was second in population to St. Louis in 1840 with 13,560 citizens and it won the bid for the University. Columbia (the County Seat) incorporated in 1821 was selected as the site for the University (population ~ 700 with about one third slaves). There was considerable bickering and negotiations before a bid of $74,494 was let for construction of the University Academic Building. There was a "bumpy period" of faculty appointments with the first Commencement on November 28, 1843. Robert L. Todd and Robert B. Todd were to receive the degree Bachelor of Arts. They had to wait for their certificates because the 1942 legislature forgot to authorize the Board of Curators to award degrees!

Continuing the account, Viles' history runs for about 250 pages under the title *The Old University*. This section reads like a tragic novel with some people insisting the University become a Harvard or Yale - teaching clergy, lawyers, classical languages, etc. A minority were concerned with practical courses. There were halting attempts to raise private money to supplement meager funds made available by legislative appropriation.

The 1849 University Catalog includes the course, "Civil Engineering with the Use of Instruments." William Barr and Thomas Field were listed as "Civil Engineering Graduates of the Class of 1856." This established Civil Engineering as the first engineering course offered by the University of Missouri.

The Civil War Period An event called the Civil War (April 1861 to May 1965) changed the cadence of the history of the University. Missouri was listed as a Union State, but was on the border between North and South. The border between north and south was broad and not a straight line in Missouri and fighting between counties/communities described in Missouri Civil War History books tell the brutal nature of the conflict. Classes haltingly continued while the Academic building on campus was used as a barracks for Union Troops. The end of the war did not heal the anger – the killings and destruction did not produce an easy transition to discussions of support for the University.

An “attention getter” called the Morrill or Land-Grant Act of 1862 did draw legislator’s attention. Congress granted each state 30,000 acres of federal land for each senator and representative in Congress – 300,000 acres for Missouri. The Missouri legislators accepted this grant in 1863 and their acceptance legislation stated that the Land Grant Act provided an endowment for “Agriculture and Mechanic Arts.” The angry cry to close the Columbia campus and rebuild on another site was muted by this award but it took until 1870 to pull the “wrinkles” out of the political discussions and allow a legislative decision to proceed. For the Columbia campus, this may be a more important date than the University founding date 1839!

In 1868 a department of military engineering was established. There was a shortage of officers ready to train new officers and recruits for the Union Army before the Civil War. A provision was written into the Morrill Act of 1862 that included support for training in military engineering. Federal funding for a military officer (retired) to teach on campus caused some friction – these officers salaries were higher the university faculty salaries.

It was 1870 when the General Assembly approved the formation of a College of Agriculture and Mechanic Arts. This action was consistent with the General Assembly wording in the legislation accepting Morrill Land Grant in 1863. In 1877, the School of Engineering was identified as separate from Agriculture but the School of Engineering remained in the College of Agriculture.

The Rolla School of Mines and Metallurgy The 1870 General Assembly yielded to political pressure from the mineral district in southeast Missouri when they agreed the University would have a School of Mines and Metallurgy, location undesignated. This was the first school in the Mechanic Arts category under the Morrill Act so it would share in the Morrill Act endowment. The political balance rested with the southeast Missouri counties so by agreement the University’s School of Mines and Metallurgy would be located at Rolla in the southeast mineral district.

A course in Electrical Engineering was offered by the University Physics Department in 1882. Thomas Edison donated an electric dynamo to the University in 1882 with a demonstration of incandescent lighting on campus in 1884. The Department of Electrical Engineering was established in 1885. This was followed by the formation of the Department of Mechanical Engineering in 1891.

The Great Academic Hall Fire On January 9, 1892 a fire completely destroyed the Academic Building. Following the fire, there was another attempt to move the university from Columbia. On March 15 the House of Representatives voted on a resolution to move the University with the location and the vote as follows: Columbia 67 ballots, Sedalia 69, and Clinton 1. A constitutional majority of 71 was required for passage and it also required approval by the Senate. Two days later, the Senate voted 18 to 12 to rebuild in Columbia. A bill to appropriate $250,000 passed the House on March 19 and the Senate on March 24, the Governor signed the bill that day. A couple of provisions in the bill: 1. Columbia had to place $50,000 in the building account and 2. An adequate water supply for the University would be provided without delay or expense to the State. By March 1, 1893, six buildings had been constructed at a total cost of $204,651 (no equipment provided) allowing classes to be held. (Stephens, pg 331-2)

The next Legislature approved $250,000 to erect a new Hall. The building was completed in time for June Commencement in1895. The six columns that remained after the Academic Hall fire still adorn the middle of Francis Quadrangle and remain the "picture icon" of the Columbia Campus. Ironically, the Boone County Court House also burned leaving six columns one half-mile north on 8th Street earning it the title of "Avenue of the Columns."

The College of Engineering moved into its own building in 1893 but remained under the College of Agriculture administration. The Department of Chemical Engineering was established in 1903 classes originally conducted by the staff of the Chemistry Department, Professor Herman Schlundt, Chairman. In 1906 the College of Engineering was separated from the College of Agriculture.

Higher Education Begins It was in 1896 a Graduate Department was established. Summer school had been offered for public school teachers and the program expanded into graduate school programs. Students in the Graduate Department were candidates for the Master's degree and would take some courses and submit a thesis, the results of an original investigation. The PhD candidate was expected to study for three years beyond the Bachelor's Degree, attain high proficiency in a selected branch of learning and show high proficiency in at least one other discipline. The results of this work would be reported in a dissertation. It took a couple more years to settle on a Dean for the Graduate Department.

World War I The period leading to World War I contains "banter" between the University Administration and the General Assembly over funding. The war on Germany was declared in 1917 so there had to be accommodation. Faculty members and students entered government service or became soldiers disrupting academic schedules. This saved some salary money but it decreased tuition money. In spite of a tight budget and hardship on the University personnel the institution did continue to operate, offer classes and stay within budget.

The ROTC program was not finishing enough junior officers for the expanding army. In 1918 a program called the Student Army Training Corps trained enlisted United States Army personnel for effective military service and secondly they could continue with their education. This option was available to men ages 18 to 45. An attraction of the program was that it offered continued college education, clothing (uniforms), meals, and thirty dollars per month. The University fraternity and rooming houses became barracks – conversion of the campus into a military base. There were several other military training programs at the University. Serving the military and maintaining the normal university functions of regular classes was a "muddling through" process that faculty were hoping would end soon.

The 1918 Spanish Flu The last few months of World War I saw a worldwide spread of an epidemic of Spanish influenza. On October 1, 1918 there were seventy cases among the students. The University and town essentially shut down for a month. Many students and Faculty members died as the epidemic ran its course. The illness returned in November and classes were called ending the fall term on December 6.

There followed a few years of relative calm and expected recovery after the war. With the exception of agriculture, times were good in Missouri but prosperity didn't yield much additional support for the University, so not much progress for the University. The Great Depression added pain. Since there had been little growth in the 1920s, cuts had to be made in essential programs, faculty were dismissed where possible and if you were lucky enough to stay on you took a salary cut. Not a good time!

Chemical Engineering Deans Dr. F. Ellis Johnson, a chemical engineer was appointed Dean of Engineering in 1935. He served until the spring of 1938 when he resigned to take the position of Dean at the University of Wisconsin. In October 1938 Dr. Harry Curtis was appointed Dean of the College of Engineering and Professor of Chemical Engineering. Curtis brought experience as Chief Chemical Engineer of the TVA. He had served on the faculties of Colorado, Northwestern and Yale Universities. He was a member of the Editorial Board of McGraw-Hill, Inc., a major book publisher of chemical engineering technology. This appointment gave the University a shot of national visibility.

The chemical engineering department offered 17 courses for undergraduate and graduate students. The faculty consisted of Dean Harry Curtis, Associate Professor James Lorah, Assistant Professors Ralph Luebbers and D. J. Porter. This was a traditional program covering equipment and processes designed for use in chemical production.

World War II The celebration of the University Centennial in1939 was damped by the German invasion of Poland in September plunging Europe into World War II. Here we are a couple decades beyond World War I and it looks like we're going to be involved a second time. The German Ally Japan struck Pearl Harbor on December 7, 1941. From that day forward it was "game on." Full mobilization followed and the University was again a training base for military personnel.

The largest trainee group was the Army Specialized Training Program established on June 14, 1943. Training included basic or advanced engineering, per-medical or medical units, area and language units. The largest enrollment was about 1,500 and most were withdrawn by April 1944. The number of students on campus before the war peaked in the first semester 1938-39 at 5,212. There were about 1,500 in 1943, a major fraction were women. The G. I. Bill-of-Rights was passed in June 1944 and enrollments grew quickly after the surrender documents were signed to 11,452 in 1945-1946 .

Emancipation Proclamation Revisited During the first year of President Middlebush's (1935-1954) tenure a problem arose in states with a large black population (count Missouri in this group). In the constitution adopted after the Civil War, Missouri set the policy of providing "separate but equal" schools for white and black students. The state supported Lincoln University in Jefferson City as the "equal university" for black students. In the winter of 1935-36, four academically qualified graduates from Lincoln University applied for permission to enter the University School of Law, the College of Engineering, the School of Medicine and the School of Journalism. Admission was denied but this dragged on through the courts until the U. S. Supreme Court decision in 1950 "Brown versus the Board of Education of Topeka" determined applications from all qualified students had equal rights to admission. The University of Missouri Admissions Office deleted the blank for "race" on the application for admission form. Problem solved-but attitudes lingered.

Athletics often solves problems involving student participation. Frank Broyles was brought in to coach football after legendary football coach Don Faurot became athletic director in 1957. Broyles coached football one year and moved to the University of Arkansas, but he did give scholarships to two black football players, the first in Missouri's football history. Slowly black athletes were included in other sports and they are now common in athletic teams and most academic programs.

The history of chemical engineering education at the University of Missouri follows the development of chemical engineering practice as it has evolved over time. Chemical engineering tended to be an "intellectual orphan" when compared to the other engineering disciplines. Managing the chemical changes required to produce a desired chemical product (fuels from petroleum, margarine from soy beans, polymer packaging, etc.) is the chemical engineer's task. The public generally understand roads, bridges, dams, etc. (civil engineering), machines, diesel engines, railroad locomotives, (mechanical engineering), electric power distribution lines, telephones, radios, etc. (electrical engineering). It took awhile for chemical engineering to stake out its intellectual territory.

Tracking the Growth of Chemical Engineering Technology

I have chosen to use the evolutionary changes in the textbooks we've used to teach chemical engineers to track changes as the profession grew. Most of the early developments in mathematics, chemistry and physics occurred in Europe and one would expect chemical engineering would have started there.

Chemical manufacturing that became the domain of chemical engineering started with batch processes. The history of the German dye industry is an example. Today batch processing is still used to produce pharmaceuticals. One of the oldest batch processes converts grain or fruit to beverage alcohol. Today in the hills of Kentucky or West Virginia you can buy "Corn," a clear liquid sold in pint or quart mason jars with no tax stamp attached.

As we moved into the mid to late 1800s, demands for large quantities of selected chemicals demonstrated the inefficiency of batch processing. Ammonia that provided fixed nitrogen for fertilizer is an example. Fritz Haber, a German physical chemist was able to produce a few drops of liquid ammonia from hydrogen and nitrogen on his laboratory bench. Carl Bosch, an industrial chemist developed the high-pressure equipment to continuously produce ammonia. Each won a Noble Prizes for their work on the ammonia process. Modifications of this technology are used today. The fixed nitrogen in ammonia produced fertilizer by the ton and certainly was important for the production of explosives for German War efforts.

A second example is the classic Fischer-Tropsch process. Franz Fischer and Hans Tropsch developed the process in 1925 to convert carbon monoxide and hydrogen gas (synthesis gas produced from coal by the water gas reaction) to produce lubricants and liquid fuels. The Germans had little access to petroleum during World War II so this is one of the processes they used to produce liquid fuels. In 1946 one of these plants was moved from Germany to the U. S. Bureau of Mines site at Louisiana, Missouri. I visited this plant on my Iowa State College senior plant trip in 1952. This is the process the South Africans have modified and that is the heart of their SASOL coal to liquid conversion process.

The chemical engineers at the Massachusetts Institute of Technology (MIT) noticed that flow diagrams for continuous production of different chemicals contained common elements or steps: Heat exchangers, pumps, distillation columns, etc. So why not learn how each of these steps works? Then the process for producing a desired chemical product can be assembled by connecting the unit operations together to produce the desired product.

The professors at MIT developed this idea when they wrote the first (?) chemical engineering textbook: Walker: W. H., W. K. Lewis and W. H. McAdams, *Principles of Chemical Engineering*, McGraw-Hill Book Company, Inc., New York, NY, 1923. The concept of connecting “units” together to perform the series of steps required in a chemical plant is a key educational contribution of this textbook and useful for the practicing engineer.

About this time chemistry professors at the University of California were studying the behavior of pure chemicals, mixtures and chemical reactions. Their work produced an important textbook: Lewis, G. N. and M. Randall, *Thermodynamics and the Free Energy of Chemical Substances,* McGraw-Hill Book Company, Inc., New York, NY, 1923. Clearly, this book formed the basis for many chemical engineering thermodynamics texts that followed.

Physical properties data, mathematical tables, chemical process information, etc. were collected into a handbook in 1934. The latest edition is: Perry, John H., Editor-in-Chief, *Chemical Engineers’ Handbook, Seventh Edition,* McGraw-Hill Book Company, Inc., New York, NY, 1997. That First Edition had over 2,600 pages. It will be interesting to see how future editions will look when (probably if?) we go “paperless” using electronic/searchable files. This will almost certainly happen.

The textbook I used while studying for my BS degree: Badger, W. L. and W. L. McCabe, *Elements of Chemical Engineering, Second Edition*, McGraw-Hill Book Company, Inc., New York, NY, 1936. This is a recasting of the seminal MIT book *Principles of Chemical Engineering* using the unit operations division of the text material. The authors/coauthors changed but this title and publisher survived may years.

The technical material described in these first four books needed to be expanded to cover chemical plant design. When you have picked a product and decided (or are deciding) how and where to build the plant, you have entered the domain of plant design. The cost of construction, chemical feed stocks, pay the plant operators, financing, what will the product sell for, etc. are questions that must be answered by an engineer working for a chemical company. Vilbrandt, F. C., *Chemical Engineering Plant Design*, McGraw-Hill Book Company, Inc., New York, NY, 1942, was an early textbook I used as a student at Iowa State College in 1952.

It was time to update the engineering science we used in our courses. Three books authored by University of Wisconsin faculty were written to fill this gap. Hougen, O. A. and K. M. Watson, *Chemical Process Principles*, John Wiley & Sons, Inc. New York, NY:

Part One: *Material and Energy Balances, 1943.*
Part Two: *Thermodynamics, 1947*.
Part Three: *Kinetics and Catalysis, 1947*.

Professor Hougen was Chairman of the ChE department and Watson brought industrial experience when he joined the Wisconsin faculty from the Pure Oil Company.

The undergraduate thermodynamics textbook at Purdue University when I entered graduate school in 1955 was: Smith, J. M., *Introduction to Chemical Engineering Thermodynamics*, McGraw-Hill Book Company, Inc., New York, NY, 1949. During fall semester 1955, H. C. VanNess coauthored the second addition published in 1959. The book was widely adopted and by adding coauthors extended to the sixth edition. (Editoral note: J. M. Smith was my dissertation supervisor, Professor Van Ness taught graduate thermo and introduced us to the draft copy of parts of the second edition. I completed the PhD requirements in January 1959, the date the second edition was published).

In 1959 there was movement underway in chemical engineering to put the empirical information used to support the unit operations on a more scientific basis. My introduction to this physics and chemistry was contained in a book from the Theoretical Chemistry Department at the University of Wisconsin: Hirschefelder,J. O., C. F. Curtiss and R. B. Bird, *Molecular Theory of Gases and Liquids,* John Wiley & Sons, Inc. New York, NY, 1954. Not an easy read. It was an introduction to R. B. Bird a key player advancing chemical engineering science.

The explosion over Hiroshima and Nagasaki, Japan near the end of WWII was the world's introduction to the massive power of nuclear fission. The "mushroom clouds" became the terrifying signature of the "top secret" nuclear energy development. Admiral Rickover assembled a technical group to build small nuclear reactors to power submarines. The electric power industry scientists and engineers that built those reactors and the submarines saw potential to use nuclear reactors to produce commercial electricity. This portion of nuclear technology was declassified and domestic nuclear power was headed to commercialization.

Chemical engineers were important contributors to nuclear science and to nuclear power development. The textbook: Benedict, M., T. H. Pigford and H. W. Levi, *Nuclear Chemical Engineering, Second Edition*, McGraw-Hill Book Company, Inc., New York, NY, 1981, (First Edition, 1957) is an example. There are currently 104 nuclear power plants in the U. S. producing about 19% of our electricity. It has been about 30 years since the last nuclear power plant was built here but there is "stirring" with approval for construction of nuclear power plants in southeast U. S. where there is a shortage of electricity. U. S. firms have continued to build nuclear power plants for international customers.

The chemical process design textbooks continued to be upgraded. Peters, M. S. and K. D. Timmeraus, *Plant Design and Economics for Chemical Engineers, Fourth Edition,* McGraw-Hill Book Company, Inc., New York, NY, 2003 (First Edition 1958). This latest edition uses chemical process simulator programs for process design calculations. See more about computer programs later.

It was Olaf Hougen, Chairman of Chemical Engineering at the University of Wisconsin who brought R. B. Bird, a physical chemist at Cornel University back to the Chemical Engineering Department at Wisconsin. In conversation with Professor Bird, he described his assignment - to write a textbook for engineers that would put the empirical unit operations of chemical engineering on a sound scientific basis. He noted that physics departments were focused on particle physics, quantum and statistical mechanics, and had stopped teaching classical physics. Engineers needed classical physics to solve problems involving flow of mass, momentum and energy. The result was the seminal textbook: Bird, R. B., W. E. Stewart and E. N. Lightfoot, *Transport Phenomena,* John Wiley & Sons, Inc., New York, NY, 1960. This book has been translated into many languages and has been internationally recognized as transforming how chemical engineering technology is formulated, taught and practiced.

Shortly after I left Purdue, two professors published an update of their chemical engineering unit operations text. Their second edition was revised using the transport phenomena forms: Bennett, C. O, and J. E. Myers, *Momentum, Heat, and Mass Transfer, Second Edition,* McGraw-Hill Book Company, Inc., New York, NY 1974. (Their first Edition, 1962)

With the move to digital computer/process simulators we find when a chemical reactor is included in the process steps, pay attention. There are times when computer simulation codes for reactors cannot meet the conditions of the chemical reactor for your process. Specific code must be written into the process simulator to make it work. There are books that are helpful when this is a problem. The first: Carberry, James J., *Chemical and*

Catalytic Reaction Engineering, McGraw-Hill Book Company, Inc., New York, NY 1976.
A second book: Amundson, N. R., *Chemical Reactor Theory, A Review*, Prentiss Hall, Englewood Cliffs, NJ, 1977. Dr. Neal Amundson was chairman of the ChE Department at the University of Minnesota for several years. He made advanced mathematics the core of ChE education and his research at Minnesota provided mentoring for many outstanding graduate students. They have been leaders in academic research.

Fluid mechanics has always been a concern for chemical engineers. Newtonian fluids are described by the Navier-Stokes equation that defies analytical solution but provides the mathematical structure that we use to represent fluid flow systems. Processing polymeric (non-Newtonian) fluids has become common and these problems are more challenging. Chemical engineers encounter wide range of these fluids when working with plastics manufacture, lubricant performance, paint application, foodstuff processing, biological fluids, etc. Progress on these problems are treated in two volumes:
Bird, R. B., R. C. Armstrong and Olaf Hassager, *Dynamics of Polymeric Liquids, Volume 1*, *Fluid Mechanics, Second Edition* and
Bird, R. B., C. F. Curtiss, R. C. Armstrong and Olaf Hassager, *Dynamics of Polymeric Liquids, Volume 2, Kinetic Theory, Second Edition*, John Wiley & Sons, New York, NY, 1987. Professor Bird and collaborators provide an introduction to the methods for measuring behavior and the theory (expect a challenge here) that describes the non-Newtonian fluid behavior.

Here is an historical aside on digital computers in engineering. In 1959 a Burroughs 205 was the digital computer on the University of Missouri campus. It was programmed in binary (+ or – followed by eleven 0s or 1s) that were “keyed” into memory or onto a “punched tape” produced using a teletype typewriter (Western Union equipment used to produce telegrams before and during WW II). That tape was read into memory. The computer output was produced on punched tape (or read from the computer council one word at a time) and interpreted with the Teletype typewriter. At that time cumbersome – Yes! Options available – none!

In the early 1960s, IBM offered their model 1620 digital computer. The operating system replaced binary code with an octal word length. Computer code was typed onto IBM punch cards using the FORTRAN language. Output was produced with a line printer or to punched cards. This worked as a teaching tool but the computer memory was small so processing large numbers of punch cards proved cumbersome to use for programs required for research problems.

The computer memory was much larger in the IBM 7000 series. While on sabbatical leave at the University of Maryland (1965-66) they had just installed an IBM 7080. An IBM punched card program was presented and read into the computer at the computer room desk. The printed output was available at that desk in eight hours! By writing computer code in subroutines, the segments could be submitted in one file, run and debugged in one submission. This was tedious by today’s standards but we did lots of computing in the 1960s.

The big central computer was the model – they were expensive! A terminal in our office with a wire to the computer made a "line editor" possible. When you hit "submit" on this terminal your request entered the central computer "service request queue." There would often be a service delay during busy hours. Lots of user service requests – ten-second delays were common. So they stepped up and installed a "full-page" editor. Computer use increased and delays increased – better just got worse.

Computer memory chips made computers smaller (maybe not cheaper) so enter the age of the PC (personal computer). The application computer codes are now on my desk! I am typing on a laptop that outperforms any of the central computer programs available in the 1980s. The ability to control experiments, collect and process data, communicate with international collaborators is really remarkable! Thankfully, now the India ink drafting pens that I used to make drawings on linen and the slide rule that did calculations with are museum pieces in my desk drawer.

A chemical engineering student taking a senior design course now might use a newer addition of a textbook like: Seider, W. D., J. D. Seader and D. R. Lewin, *Process Design Principles: Synthesis, Analysis and Evaluation*, John Wiley & Sons, Inc., New York, NY, 1999. There are four process simulators listed on page 29 and numerous computer aids for the chemical engineering student. A special issue of the ASPEN process simulator for students is used extensively in this book. ASPEN used in industrial settings can be customized and proprietary data added to the data set. Comment: Herb Britt, MU ChE PhD 1974 (now retired) was a principal developer of ASPEN.

When an engineer is "plowing new ground" in process development or basic research new mathematical problems keep showing up. The following resource can be helpful: Wolfram, Stephen, *Mathematica: A System for Doing Mathematics by Computer, Second Edition*, Addison-Wesley Publishing Company, Inc.1991 (First Edition1988). If your research problem can be described by coupled first or second order partial differential equations, this computer application is a good tool to produce answers and provide excellent graphical presentation of the results.

Members of the MU Chemical Engineering Department members have been active in nuclear science and technology over 80 years. Nuclear fission energy to electricity is an international option that should be kept open. Reprocessing the spent nuclear fuel from these nuclear reactors to recover fuel values and secure radioactive fission product wastes for disposal must be included in the long-term nuclear energy option. The following text is an introduction to the discussion of this aspect of the future for nuclear energy: Nash, K. L. and G. J. Lumetta, Editors, *Advanced Separation Techniques for Nuclear Fuel Reprocessing and Radioactive Waste Treatment,* Woodhead Publishing Limited, Cambridge, UK. 2011.

There are many books available that are not included in this list. Make your own list that includes 50 years of publication dates and you will see the progression of chemical engineering science and technology. You will see this is an impressive record authored our most celebrated colleagues

Faculty and Accomplishments 1960-2010

The task of the Chemical Engineering faculty is to teach undergraduate and graduate students and to supervise the research of each graduate student. There are academic administrative assignments assumed (assigned?) to individual faculty members that are not included in the Faculty Productivity Index chosen here – the number of bachelors, masters and doctoral degrees earned by the students during each decade.

The faculty members are listed on the first year of each decade. A ten-year span will not account for faculty that leave for another position or retire during the decade. Faculty members who retire with Emeritus status are listed – some remain active part time, others "stay home" or move out of town.

Chemical Engineering Faculty Academic year 1960-61

Professor:	G. H. Beyer, Chairman
	J. R. Lorah
	R. H. Luebbers
Assoc. Prof.	L. E. M. DeChazal
	A. H. Emmons, Director Nuclear Reactor Facility (Feb. 1960)
Asst. Prof.	T. S. Storvick

Dr. G. H. Beyer came to the ChE Department from Iowa State College. He taught my first chemical engineering course in 1950. As students we knew he did research at the Ames Metals Laboratory in a building attached to the Chemistry Building. There was a locked door at the end of a hallway guarded by a uniformed officer with a holstered side arm. Q-Clearance (top secret) was required for admission to the Metals Lab.

Later I learned that Dr. Frank Spedding who was chief scientist at the Metals Laboratory in the 1950s led the scientists an students working to prepare and characterize pure rare earth metals. This was the laboratory that prepared the pure uranium slugs that were used in the graphite pile in the first controlled fission experiment at Stag Field, University of Chicago in 1942.

Dr. Lorah joined the faculty in the late 1920s and worked with Dr. Schlundt preparing pure radium metal, some of it used by Marie Currie in her laboratory in France. Dr. Lorah described some of his experiences working with those radioactive metals. The good experience prompted him to offer radiation detection/measurements in the laboratory course for ChE undergraduate students.

Professor DeChazal spent a sabbatical year at the United Kingdom nuclear facility at Harwell. This represents his continued interest in things nuclear building on the first courses in Nuclear Fuels and Nuclear Engineering approved in 1955.

In 1958 the General Assembly approved $1.25 million to build a nuclear reactor at the University Campus. Dean H. O. Croft recruited Dr. A. H. Emmons to be Director of the Nuclear Reactor Project. Dean Croft placed him in the Chemical Engineering Department until he got the project underway.

Dr. Emmons proceeded quickly to design a nuclear reactor that would provide a source of neutrons for multiples tasks. Neutron beams would be available for neutron scattering to study the structure of solids, sample radiation to produce radioisotopes for medical diagnosis and treatment, neutron activation to determine composition of material samples, etc. The design generated interest to win Federal and private funding of $3.5 million for the reactor and supporting laboratories. The construction was completed and reactor went “critical” in September 1966 with Dr. Glenn Seaborg delivering the Dedicatory Lecture.

The University of Missouri System came into being in 1963. The 125 miles west to Kansas City and East to St. Louis made it difficult (both geographical and politically) for the Columbia campus to serve those major cities. The decision was made to expand the University to four campuses: University of Missouri Columbia (UMC), Kansas City (UMKC), Rolla (UMR) and St. Louis (UMSL) with the Central Administration office of the system President located in Columbia.

This restructuring provided an opportunity for the faculty on the Rolla Campus to obtain funds for an undergraduate nuclear engineering program and to a purchase a nuclear training reactor. The Columbia faculty then decided their nuclear engineering effort should be a Graduate Program sponsored by the Chemical Engineering Faculty. This arrangement in 1964 and has proved successful

Faculty Productivity from 1960 to 1969
Degrees Earned: BS 225, MS 35, PhD 14

Nuclear Engineering Graduate Program approved in 1964
Degrees Earned: MS 7

The success of the departmental teaching and research funding made it possible to recruit faculty. Both the chemical and nuclear engineering faculty numbers grew in the 1960-1969.

Chemical Engineering Faculty Academic Year 1970-71

Professor:	G. W Preckshot, Chairman
	L. E. M. DeChazal
	J. R. Lorah
	R. H. Luebbers
	T. S. Storvick
Assoc. Prof.:	V-J Lee
	R. H. Luecke

	L. I. Stiel
	J. B. Sutherland
Asst. Prof.:	R. M. Angus
	J. L. Sutterby
	J. S. Winnick

Nuclear Engineering Program also expanded

Professor:	T. F. Parkinson, Chairman
	R. L. Carter
	L. E. M. DeChazal
	A. H. Emmons (Director Nuclear Reactor Facility)
	W. R. Kimel Dean College of Engineering
Assoc. Prof.:	T. J. Swierzawski Visiting
Asst. Prof.:	S. R. Bull
	P. K. Lee
	S. K. Loyalka
	C. F. Masters
	C. L Partan
	D. H. Timmons
	J. R. Vogt

The Chemical Engineering Department faculty doubled (from 6 to 12) in the 1960 to 1969 decade. The Nuclear Engineering Graduate Program attained approval and increased to 12 faculty members during the same interval. There was continued collaboration in teaching and research between the faculty and students in the two programs. Faculty members were able to obtain support for their research and graduate student stipends. The Nuclear Program had reached essentially a stand-alone-program status but there was beneficial collaboration between the Nuclear Engineering Program and the Chemical Engineering Department.

In mid 1960, the US Congress expressed concern that the Department of Defense wasn't spending much to support of graduate school education and research in science and technology. The DoD Project Themis initiative was born. The Chemical Engineering Department was awarded a contract titled, *Fluid and Transport Properties* funded at $763,500 for the period June 1,1967 to May 30, 1973.

The Project Themis award was an interdisciplinary program. Faculty and graduate students from chemistry, physics and engineering participated. Dr. Paul Schmidt, Professor of Physics, an expert on small angle x-ray scattering performed a nice experiment. He placed argon in a sample tube just below the critical temperature and at a pressure that would provide a liquid and vapor phase. As x-rays pass through the sample tube, the scattering angel changes when the x-ray beam passes from the liquid to the vapor phase as the x-ray beam is moved vertically. Gravity holds the liquid in the bottom of the sample tube.

By carefully controlling the temperature and pressure as scans were performed the liquid and vapor densities came closer together approaching the critical temperature. Dr. Schmidt showed with these data that an equation of state (in fact any mathematical function) extrapolated into the neighborhood of the critical point would be logarithmic singularity. Schmidt's data were among the first verifying this theoretical conjecture.

Dr. Lloyd Thomas, a physical chemist had a reputation for his measurements of the accommodation of gases adsorbed on solid surfaces. He worked with Chemistry Professor Robert Harris refining his experimental technique and the accuracy of his measurements. His measurements provide understanding the attachment energy of the gas atoms to solid surfaces. NASA scientists used Professor Thomas' early measurement for design of our first spacecraft operating at the very low pressure of outer space.

Dr. Richard Warder, Mechanical Engineering Professor performed shock tube experiments to study the charged particles present in hot gases. The combustion of fuel in the cylinder of a diesel engine in an example where these types of measurements are used to design engines with improved performance.

Dr. Jack Winnick, Chemical Engineering Professor, did two experiments using a high-speed centrifuge. He put very pure water in a short, clean capillary tube placed in the centrifuge rotor. When the centrifuge speeds up, the water at the middle of the capillary "feels" a negative pressure. This provides a measure of the "tensile strength" of a column of water, useful in water transport equipment design.

His second experiment placed a binary liquid mixture in a tube in the centrifuge. At high gravities, (high rotational seed) the mixture components may be made to separate. This enhanced gravity experiment identified the liquid mixture critical point where phase separation can be made to or ceases to occur. In chemical processing it is an advantage to know the composition where phase separation occurs.

A Friday Evening/Saturday symposium on critical phenomena with invited lectures was presented to regional faculty and students. Invitations were sent and about 200 attended. This program was excellent public relations for the science/technology programs at MU.

The Themis Project was a demonstration of the benefit of the "intellectual commons" that can exist on a university campus. If you know and talk to faculty members across discipline lines, the research programs of the institution participants benefit.

ChE Faculty Productivity for 1970 to 1979
Degrees Earned: BS 277, MS 61, PhD 28

Nuclear Engineering Program Faculty Productivity 1970 to 1979

	MS	PhD
Nuclear Engineering	65	15
Medical Physics	8	1

Total Degrees	73	16

There was considerable turnover among the faculty during the decade. There were two Chemical Engineering faculty members who chose retirement to Emeritus status.

Chemical Engineering Faculty Academic Year 1980-1981

Professor:	G. W Preckshot, Chairman
	L. E. M. DeChazal
	R. H. Luecke
	T. S. Storvick
Assoc. Prof.:	C. E. Dunlap
	W. Lee (visiting)
	T. R. Marrero
Asst. Prof.:	D. G. Retzloff
Emeritus	J. R. Lorah, R. H. Luebbers

The ChE faculty numbers reduced from 12 to 8 entering this decade. Several faculty members moved to industry, some to academic positions at other institutions. The faculty maintained their record of support for graduate students and research. There were no special research projects funded during this decade.

ChE Faculty Productivity for 1980 to 1989
Degrees Earned: BS 419, MS 68, PhD 34

The names of the Nuclear Engineering Faculty were not available. Clearly they were active because following are the degrees awarded.

Nuclear Engineering Program Faculty Productivity 1980 to 1989

	MS	PhD
Nuclear Engineering	63	26
Medical Physics	22	6
Health Physics	8	2
Total Degrees	93	34

Chemical Engineering Faculty Academic Year 1990-91

Professor:	D. S. Viswanath Chairman
	A. L. Hines (Dean, College of Engineering)
	S. L. Loyalka
	R. H. Luecke
	T. S. Storvick
	H. K. Yasuda
Assoc. Prof.:	R. K. Bajpai
	P. C. Chan

T. R. Marrero
R. G. Retzloff
Asst. Prof. N. H. Dural
Tushar Ghosh (Research Asst. Prof.)
Emeritus Prof: L. E. M. DeChazal, R. H. Luebbers,

Nuclear Engineering Program Faculty

Professor: J. F. Kunze (Chairman)
R. M. Bugger
R. A. Holmes
S. K. Loyalka (Curators Professor)
M. A. Prelas
W. H. Miller
Assoc. Prof.: P. K. Lee
Asst. Prof.: D. M. Alger
S. M Langhorst
R. V. Tompson (Research Prof.)

The number of faculty in Nuclear Engineering continued to increase. Their success attaining funding to support of graduate students and research has developed over two decades. Dean Hines requested and got approval to move the Nuclear Engineering Program from the Graduate School to the College of Engineering. They maintained experimental laboratories in the Engineering Building complex.

Professor Leucke has established himself as an authority on computer applications with emphasis on process control and chemical plant optimization. One of his PhD advisees, Dr. Herbert Britt (now retired) was a principal member of the technical staff for the ASPIN Process Simulator Company.

Professor H. K. Yasuda has become an internationally recognized authority on the application of plasma science and material treatment. With his students, he has demonstrated the use of plasma to clean surfaces and apply coatings. He is active consulting and writing on plasma applications.

Late in 1989 there was a Request for Proposal issued by the Rocketdyne Division of Rockwell International to perform laboratory bench scale experiments to demonstrate the chemical separation of the transuranic elements from fission products in spent nuclear fuel (street language – nuclear waste). Three University representatives: H. Marcus Price, Director Office of Sponsored Programs Administration; A. H. Hines, Dean of Engineering and Steve Morris, Interim Director of MURR went to California to discuss the scope of the project and evaluate whether the University of Missouri might submit a competitive proposal to perform the proposed experiments.

There was a remote site in Semi Valley in north Los Angeles where Atomics International, a manufacturer of nuclear fuel elements (Atomics International made the first fuel for the MURR reactor in 1965) owned a large tract of land where they had a nuclear fuel test facility. Rockwell International bought Atomics International and the open land was later chosen by Rocketdyne as a site to test big rocket engines. Rocketdyne/Rockwell (actually the Atomics International personnel) had signed a contract with the Japanese Electric Power Industries to perform the proposed experiments. Their Nuclear Regulatory Commission License to possess the radioactive materials to do those experiments was about to expire and it had to be renewed. There was serious local public opposition to this nuclear research with little economic incentive to Rocketdyne. Thus the corporate decision to forego relicensing and seek a subcontractor for the research project.

Our exploratory team brought back an outline of the proposed experimental work and a list of equipment available that would be shipped to Columbia. The proposed experimental program had much in common with the Argonne National Laboratory nuclear fuel-recycling module they were preparing to attach to Experimental Breeder Reactor II (EBR-II) in Idaho. The EBR-II was a liquid sodium cooled fast neutron flux reactor with metallic fuel elements. In the proposed fuel recycle module the spent fuel rods would be chopped and placed in a molten salt bath serving as an anode. The nuclear fuel values would be recovered electrochemically on a metal cathode, melted and cast into recycled fuel rods. The fission products, stripped of the long half-life actinides would be recovered from the salt for disposal and the salt recycled. The EBR-II program was terminated before this "closed fuel cycle" test was attempted.

So the proposed project was to demonstrate a safe, effective way to partition fuel values from fission products in domestic spent nuclear fuel. There were two objectives: remove essentially all of the uranium and actinides (Neptunium, Plutonium, Americium, etc.) the long half-life elements from the fission products. This recovers the fuel values for recycle to fuel fabrication for a reactor. The fission product stream, free of actinides, would require much shorter burial times. Commercially interesting products in the fission product stream could be recovered.

The title chosen for the project was Transuranic Management by Pyropartitioning Separation (TRUMP-S). This was like the Argonne program but with application to domestic electric power plant fuel. Since domestic spent fuel is in metal oxide pellets, the fuel must be reduced to metal. Since spent fuel is about 94% uranium, most of it would be recovered leaving some uranium rich in actinides and fission products. It is this mixture that was the object of the TRUMP-S research project.

There was space at MURR on the beam port level where the laboratory could be located. The MURR material license was amended to include small quantities of Neptunium, Plutonium (never simple!) and Americium, the transuranic elements to be removed from spent nuclear fuel. The MURR Health Physics office would take on that task for those working on the project.

A proposal to perform the experiments was submitted to Rocketdyne/Rockwell on January 12, 1990. On February 1, 1990, provisional approval was received by a letter of intent providing ~ $300,000 to build the laboratory with the expectation experiments would begin in August 1990. The first four-year contract was approved, completed successfully and a second four contract extending to a total eight-year funding of $5,400,000.

The research laboratory was designed as a negative pressure space with exhaust air passing through HEPA filters designed to contain any dust that might escape from the experimental space. The solvent for the separation experiments was molten lithium chloride/potassium chloride (LiCl/KCl) eutectic salt. Argon gas provided an inert atmosphere in the glove boxes for the experiments and the argon was circulated through units to remove oxygen, nitrogen, hydrogen and water vapor - all to less than five parts per million. The experimental chemicals were uranium chloride, the transuranic metal chlorides that were to be separated from rare earth chlorides representing the fission products compounded as "simulated spent fuel." All of these metal chlorides are very reactive and will form metal oxides, nitrides and hydrides that are insoluble in the LiCl/KCl solvent. These compounds mess up the experiment material balances and must be minimized since each experiment used just a few milligrams of reagent metals. This justified the cost to maintain nearly pure argon in the glove boxes.

Professor Paul Sharp, MU Chemistry Department served as a consultant during the eight years of the project. Chemists can offer advice that chemical engineers might pay for with "bad experience" so he was an important participant in the project.

It was essential to have a chemist manage the experiments in the glove boxes. Dr. Leon Krueger learned careful experimental technique with Dr. Lloyd Thomas (MU Chemistry Department) on his PhD dissertation. Accurate material balances were key to the success of each experiment performed. The radioactive waste from each experiment was also inventoried and packaged and removed from the glove boxes and stored. Those careful waste inventories from each experiment were more important at the end of the project than we realized. The details of packaging the radioactive waste for shipment to the New Mexico waste site was not known at the start of the project. The exact quantity of mixed radioactive metal placed in each waste shipment container could be certified by the exact experimental waste inventories.

The experimental samples in this research program were small. Dr. S. R. Koirtyohann, MU Professor of Chemistry had experience with Inductively Coupled Plasma Mass Spectrometer (ICP-MS) and helped us decide on this $400,000 plus instrument option to perform our analysis. The University Administration had just decided to move the Trace Substance Research Laboratory from Columbia to the Rolla Campus. This left Carol Nabelek, their ICP–MS chemist without an instrument – a job. She joined the project and "taught" the instrument to analyze samples containing heavy metals. This was new territory for this instrument. Calibration of this instrument to provide accurate analysis of samples from each experiment was very important to the success of the experimental program.

The electrochemical separation process requires free energy of formation data for the pure metals that compose the mixtures that are to be separated. The Gibbs free energy of formation for uranium trichloride was known so the first experiment was to measure the Gibbs free energy of uranium trichloride. The experimental procedure and apparatus performance was confirmed with this first test.

The computer program provided with the equipment from California did not perform well. Matthew McNally an MS student on the project wrote a new computer code in Microsoft Basic for the electrochemical reduction experiment. This program recorded the date and the time, the current and voltage at selected time intervals for the experimental metal chloride reduction, produced a magnetic file and printed output. The source code for this program was included in McNally's May 1992 MS thesis and served, with minor modifications, the final six years of the project.

The Japanese Electric Power Industry funded the project. The Central Research Institute of the Electric Power Industries (CRIEPI) is the research group responsible for nuclear power research in Japan and was a key participated in the project. Kawasaki Heavy Industries (KHI) is Japans major industrial equipment manufacturer also contributed oversight for the project. Scientists from CRIEPI and Rocketdyne were usually present in the laboratory during experimental runs and at times worked "hands on" in the glove boxes. Our contract called for a semiannual progress review. This arrangement provided independent verification for the sponsors that the data were obtained from the experiments scheduled for that six-month period. The contract included a "drop dead" clause that could end funding with failure reported at review time. No pressure to perform!

An assumption made at the start of the project was that all actinide metal chlorides would be confined to the +3 oxidation state. If true, this would have made the electrochemical separation process easier. Problems establishing the Gibbs free energy of formation for Americium (+3) Chloride were solved when it was demonstrated that Americium Chloride in LiCl/KCl molten salt is present as +2 and +3 ions. Electrochemical separation alone will not complete the separation of this long half-life actinide from the fission products. This suggested that we use a chemical reduction/extraction to make the actinide metal separation from the fission products.

The final experiments used a chemical reduction/extraction process. A simulated spent nuclear fuel mixture was prepared containing the chlorides of uranium and the three transuranic elements plus five or six of the most abundant rare earth fission product metal chlorides. These were all put into molten salt solution that was floated on a liquid metal. Cadmium metal was the first chosen, but it has a high vapor pressure and cadmium coated out on everything in the glove box. Bismuth was the final choice. It has a low vapor pressure and essentially nontoxic compared to cadmium.

The initial measured negative voltage of this mixture will be high. When lithium metal is added to the salt, it will reduce the least electro negative metal in the salt. The reduced metal forms an amalgam with the bismuth and the salt solution voltage becomes slightly more neagitve. Titrating with lithium metal continues to just below the reduction voltage of the least electronegative rare earth metal salts. At this point, all the uranium and actinide metal chlorides will be reduced. Decant the bismuth alloy from the salt and the nuclear fuel components have been separated from the rare earth fission products that remain in the salt.

The bismuth alloy is placed under clean molten LiCl/KCl and becomes the anode in an electrochemical cell. The uranium and actinides metals can be electrochemically plated to an inert metal cathode to complete the separation and recovery.

This eight-year program demonstrated at a bench scale that the separation of nuclear fuel components from fission products is possible. The fission products will essentially free of the nuclear fuel metals. The final test will be, can this procedure be scaled to commercial size? Someone else will get to take this step.

It took two years to complete packaging the nuclear waste from the eight years of experiments. It took another two years to get approval to ship to the New Mexico waste storage. I was told this was the first shipment of mixed actinide waste from a nongovernment laboratory across multiple state lines

ChE Faculty Productivity for 1990 to 1999
Degrees Earned: BS 346, MS 56, PhD 31

Nuclear Engineering Program Faculty Productivity 1990 to 1999

	MS	PhD
Nuclear Engineering	43	12
Medical Physics	39	9
Health Physics	36	6
Total Degrees	118	27

Chemical Engineering Faculty Academic Year 2000-2001

Professor:	Sunggyu Lee Chairman
	R. K Bajai
	T. R. Marrero
	S. K. Loyalka (Curators Professor)
	H. K Yasuda
Assoc. Prof:	P. C. Chan
	P. Darcy
	W. A. Jacoby
	S. J. Lombardo
	D. G. Retzloff
Asst. Prof.:	Q. Yu (Research)
Emeritus:	L. E. M deChazal, R. H. Luebbers, G. W. Preckshot, T. S. Storvick,

D. S. Viswanath

Nuclear Engineering

Professor:	W. Miller (Chairman)
	S. K. Loyalka
	M. Prelas
	W. Volkert (Curators Professor)
	Director Radiopharmaceutical Science Institute
Assoc Prof.:	T. Ghosh
	R. Tompson
Asst. Prof:	S. Langhorst, Radiation Safety
Emeritus:	R. Brugger, R. Carter, A. Emmons, W. Kimel and J. Kunze

There were administrative changes on the Columbia Campus. The Nuclear Engineering Program was renamed the Nuclear Science and Engineering Institute (NSEI) authorized by letter from Chancellor Richard Wallace. In 2004, Dr. James Thompson, Dean of Engineering requested that administration of NSEI be returned to the Graduate School. Two additional faculty members without an academic home were added to (NSEI). Dr. Volkert serving as "nominal" chair and Dr. Langhorst a specialist in radiation safety.

The Nuclear Engineering faculty members continued their successful research work. The Chronicle of Higher Education issue, November 16, 2007 published a Universities Faculty Productivity Index. NSEI ranked No. 1 in the U. S. based on per faculty research funding, publications and graduate degrees awarded. They were cited additional times in the top ten for faculty productivity.

The Chemical Engineering Department worked to develop an Undergraduate Research Program that students have found challenging and interesting. This often has students working with students from other disciplines, an opportunity to learn to work together and see how discipline technologies overlap or compliment each other.

Professor Pinhero received a Nuclear Regulatory Commission Faculty Development Program Grant. Pinhero will serve as mentor to Assistant Professor Matthew Bernards and Anthony Pace, a graduate student, studying the feasibility of building a small, portable, thorium-powered nuclear reactor to produce heat and/or electricity. For example, such a unit could provide an alternative power source in a disaster stricken area (think Joplin, MO!)

Professor Bernards is also working in the biological engineering area. Is it possible to replicate the binding properties in bone tissue without using a polymer? Nature regenerates bone tissue using a protein and a mineral structural component. The task is to make a bone-like material that can be substituted into an injured bone "signaling" the natural physical and chemical cues to produce healing. This is challenge with some real up-side potential.

Associate Professor William "Bill" Jacoby was recruited into the Chemical Engineering Department and later transferred to Biological Engineering. In collaboration with Professor Marc Deshusses of Duke University, Jacoby has been tasked to demonstrate the use of supercritical water oxidation to treat sewage. Clean water and sewage treatment are critical problems in third world countries – small communities need small-scale sewage treatment plants and this is where this research application is targeted.

Faculty Productivity for 1980 to 1989
Degrees Earned: BS 341, MS & PhD record not available

Nuclear Engineering Program Faculty Productivity 2000 to 2009

	MS	PhD
Nuclear Engineering	32	16
Medical Physics	44	7
Health Physics	14	6
Total Degrees	90	29

The Chemical Engineering Department productivity since the Department was authorized in 1903 to 2010: BS 2336, MS 393 and PhD 125.

The Nuclear Engineering Graduate Program productivity since the program was approved in 1964 to 2010: MS 381 and PhD 106.

The next decade of Chemical Engineering is now in the hands of the 2012-2013 Faculty

Professor:	Boalin Deng (Chairman)
	J. Gahl
	T. R. Marrero
	P. Pinhero
	G. Suppes
Assoc. Prof:	P. C. Chan
	W. A. Jacoby
	D. G. Retzloff
Asst. Prof.	S. Baker
	M. Bernards
Teaching Fac.	M. Meyers
Emeritus:	R. Bajpai, R. H. Luecke, T. S. Storvick, D. S. Viswanath, H. Yasuda

Nuclear Science & Engineering Institute

Professor	T. Ghosh
	S. K. Loyalka (Curators Professor)
	M. Prelas
	R. Tompson

These are the faculty members who will lead Chemical and Nuclear Engineering in the 2010 to 2019 decade and beyond.

4. Future Directions for Chemical Engineering

The history of the University and the 110 years of Chemical Engineering are prolog passing through the present into the future. The visions of the future becomes “murky” as you extend the timeline, but it is useful “to squint” and attempt to see the intellectual track Chemical Engineering at MU might take during the next decade or two. Let me share a vision.

Teaching the undergraduate students today requires accommodation to communication technology. Your students will be connected to their social network – maybe distracted from the discussion topic today. Books and Library are less (maybe totally un-) important since electronic media (Google, Yahoo, etc,) is available to fill gaps in information ChE students might have. In fact, there are available access to “electronic courses” that offer bachelors degrees. MIT offers technical courses, so is it reasonable to envision a total, off campus undergraduate degree program? If so, why build huge apartment complexes to house students across the street from the Campus? Why not stay home in Lebanon Missouri, for example, and study the course material and take examinations at home? It looks as though the students, the university faculty and administration and the local real estate folks “see” a different academic future.

Graduate education is different. It is possible to propose an MS thesis problem or even a PhD Dissertation problem that would not require any measurements in a physical laboratory. Mathematicians do it, but they often find a powerful computer useful. For chemical engineering graduate students there will need to be investment in laboratories. Our history shows the importance of financial support from Federal Government grants, contracts with industrial firms, but successful only when there is the infrastructure provided by the University. This model may not change much in the near future so what the University can provide usually allows the graduate school program to succeed.

Experience has shown that well qualified graduate students are very important to the success of a graduate program. A well prepared incoming graduate student views their research topic with “new eyes” that lead to solutions that can “teach” a major professor much about the problem. The graduate faculty must be allowed to select the students they enroll in the graduate program for this relationship to succeed.

The University of Missouri is a deep hierarchical management structure. The state requires there be a layman or laywomen Board of Curators that pass on program changes, budgets, contracts, etc., in fact total oversight of the University for the General Assembly. The President of the University is responsible to this Board and with responsibility for all of the programs on the four campuses of the University. So we have hierarchical layers of administration that starts with the President and his Vice Presidents, overseeing the campus Chancellors and their vice Chancellors, checking on the Deans and associate deans of the colleges or schools, overseeing the Department Chairman and their cochairs: five administrative layers (ten layers if each proposal/idea also passes through the office of the vice- or associates- offices) before it reaches the professor and the students.

So how can this system be made to work? My experience has shown that Eric Ashby probably has it right: "A university is a society which cannot run except as an inverted hierarchy. The ideas well up from below. The money flows down from above." (Eric Ashby, *Adapting Universities to a Technological Society*, Jossey-Bass, Inc., Publishers, San Francisco, CA, 1974, pg. 59) This can only occur when the administrative model is supported by academic administration that avoids imposing an industrial management model where both ideas and money flow from the top down. Nearly everyone in the university administrative structure is a "layman" compared to the undergraduate and graduate students and the professor where chemical engineering teaching and research is done. When money is scarce the temptation to "manage" becomes overwhelming to those responsible for dividing resources (money, space and people) in the University.

The global physics community produced a significant advance this year. The positron super collider in Switzerland produced "particle tracks" identified as the Higgs Boson, predicted about 35 years ago. This particle completes the sub-nuclear particle list of massless particles in the Standard Model. The Higgs boson is the particle responsible for "turning on" the mass of the particles. Expect this discovery to encourage more research in particle physics. This should be available to chemical engineering research scientists.

We have been riding the tide of transition from empirical representation by the unit operations in chemical processing technology to the classical physics that describes momentum, heat and mass transfer. The new advances in physics suggest attention should move toward particle physics – quantum and statistical mechanics involving sub-nuclear particles. It is at this level we might learn more detail how physical and biological systems function.

One example, it is only recently we learned how chlorophyll uses a specific wavelength of sunlight to transfer an electron, almost instantaneously, to form the atoms that make up the molecules in plant tissue from carbon dioxide and water. This is a very old and very sophisticated natural process but a very slow process. For example, it takes all summer to grow corn to harvest. We humans can't wait – make it happen!

Suppose a photovoltaic solar panel could be designed to convert several of the electromagnetic wavelengths in sunlight to electricity. The size of these panels could be reduced. This might not reduce the cost of the panel but it would certainly reduce the panel area required to produce a kilowatt of electricity. Roof top units don't use additional real estate, but large solar panel arrays do. Anyone interested in this problem?

When you use solar panels to produce electricity there must be a way to store electricity (electrons) to use when the sun doesn't shine. There is demand for electricity at night, or 50% of the time on an annual basis when the sun just doesn't shine. The further north or south you go, the period of dark extends. If one uses batteries, improved designs can only come from understanding and by "bending" particle theory to do more than use reversible chemical reactions, the reversible metal/acid chemistry in rechargeable batteries. There is a "hero award" awaiting anyone solving this electron (electricity) storage problem.

Wind power suffers a similar problem, when the wind doesn't blow or it blows way too hard there is no power. Wind is solar energy by an indirect mode of collecting the solar energy. Wind farms tend to be spread out with energy loss problems during electricity collection and transmission to the point of use. About 40% of the U. S. population lives on a strip of land 50 miles inland from the ocean between Washington D. C. and Boston. Is it possible to make solar and wind serve this demand region? Part of it, yes, but how can that zero energy gap be filled?

Suggest small nuclear reactors and you will see some people shudder with a vision of a mushroom clouds over Hiroshima and Nagasaki dancing before their eyes. We do know that when a storm cuts off power for a week or two, the TV blinks off and the beer gets warm and the public is a little more receptive to a reliable power source. The nuclear option is available. The Japanese nuclear reactors survived the earthquake. It was the forty-foot wall of water that struck a few minutes later that "crushed" the reactor buildings, cut emergency power and laid waste to several reactors bunched together.

There are data accumulating every month indicting there is global climate change occurring. There are ice core data, ocean sediment data, geological "written in the rocks" data that show there have been five ~100,000 year climate cycles. It takes about 10,000 years at the end of an ice age to reach a maximum temperature when the atmosphere contains ~ 300 parts per million carbon dioxide. It takes about ~90,000 years for the temperature and the carbon dioxide content of the air to retreat. This year the carbon dioxide in the atmosphere reached has reached 400 ppm, well above the past 500,000-year maximums. Expect there will be a change in the natural climate change cycle. (See: A. E. Dessler, *Introduction to Modern Climate Change*, Cambridge University Press, New York, NY, 2012, pg. 30, or James Hanson, *Storms of My Grandchildren*, Bloomsbury, New York, NY, Paperback 2011, pg. 37, and *Natural Systems in Changing Climate, Special Section*, Science, vol. 341, August 2, 2013, pgs. 473-524).

The primary source of atmospheric carbon dioxide comes from burning fossil fuels; coal, natural gas and crude oil. These fuels are all sequestered carbon that is geologically stored solar energy produced over billions (?) of years from the organic materials that produced them. Massive mining and burning of fossil fuels has increased every year since the industrial revolution, the past 300 to 350 years. This is the first time humans will interfere with the natural climate cycle! Is there a task or two chemical engineers might work on to change the sources of energy we use? Is the default option is to "drill baby drill" and let the chips fall and take what we get. Robert Hanson says we then let our grandchildren pay and since I have a new great granddaughter, that's not my preferred option.

Chemical engineering has always been a good first degree for many advanced degree professions: Medicine, biochemistry, nuclear science and engineering, etc. Many options are open to those who can speak the languages of chemistry, physics, mathematics, economics, maybe a language in addition to English, and who are willing to work formulating problem statements and working on problem solutions. This is where the future of chemical engineering lies and it is open to those willing to try. It has been a great adventure for me.

T. S. Storvick Personal Career Notes

Chemical engineering in the academy has been a challenging and rewarding career for me. The career started with the Navy (1946-48), St. Olaf College (1948-50), Iowa State College (pre University) 1950-52 ChE BS, Research Engineer, FMC Corporation, Charleston, West Virginia, 1952-1955, Purdue University 1955-59 ChE PhD, University of Missouri Faculty from February 1959 to today.

Sabbatical Leaves

Sabbatical leaves are the "mother's milk" of an academic career. It provides time for renewal of mind and spirit. Leave town for a year; read, listen, discuss and formulate the plan for the next six years of your career. My choice has been to do more chemistry and physics. Here are the opportunities I was able to use.

1. September 1965 to August 1966. National Science Foundation Senior Faculty Fellowship for study at the Institute for Molecular Physics, University of Maryland, College Park, MD. Studied the kinetic theory of gases. Research applying intermolecular force models to describe thermodynamic and transport properties of gases.

2. September 1972 to August 1973. Norges Tekniske Høgskole, Trondheim, Norway. Awarded an NTNF Senior Scientist Fellowship. Studied solutions of the Boltzmann equation as a theoretical model for the properties of dilute gases near solid surfaces; in capillary tubes, porous media, etc.

3.September 1979 to June 1980. Chemical Engineering Department, Virginia Polytechnic Institute and State University, Blacksburg, VA. Studied the solution of the Boltzmann equation to describe the flow of gas mixtures in capillary tubes. Taught one undergraduate course: Transport Phenomena.

4. June 1987 to August 1988. The National Institute of Science and Technology. Boulder, CO. (This was the National Bureau of Standards Laboratory until January 1988) Half of my MU salary was funded by an Intergovernmental Personnel Transfer, U. S. Department of Interior reimbursing the University for half salary. Visiting Scientist with the Thermo Physical Properties Research Group. Studied the mathematical structure of equations of state to represent fluid properties of mixtures near and on the vapor-liquid critical region boundary. A second look at an old problem of interest to NIST scientists.

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