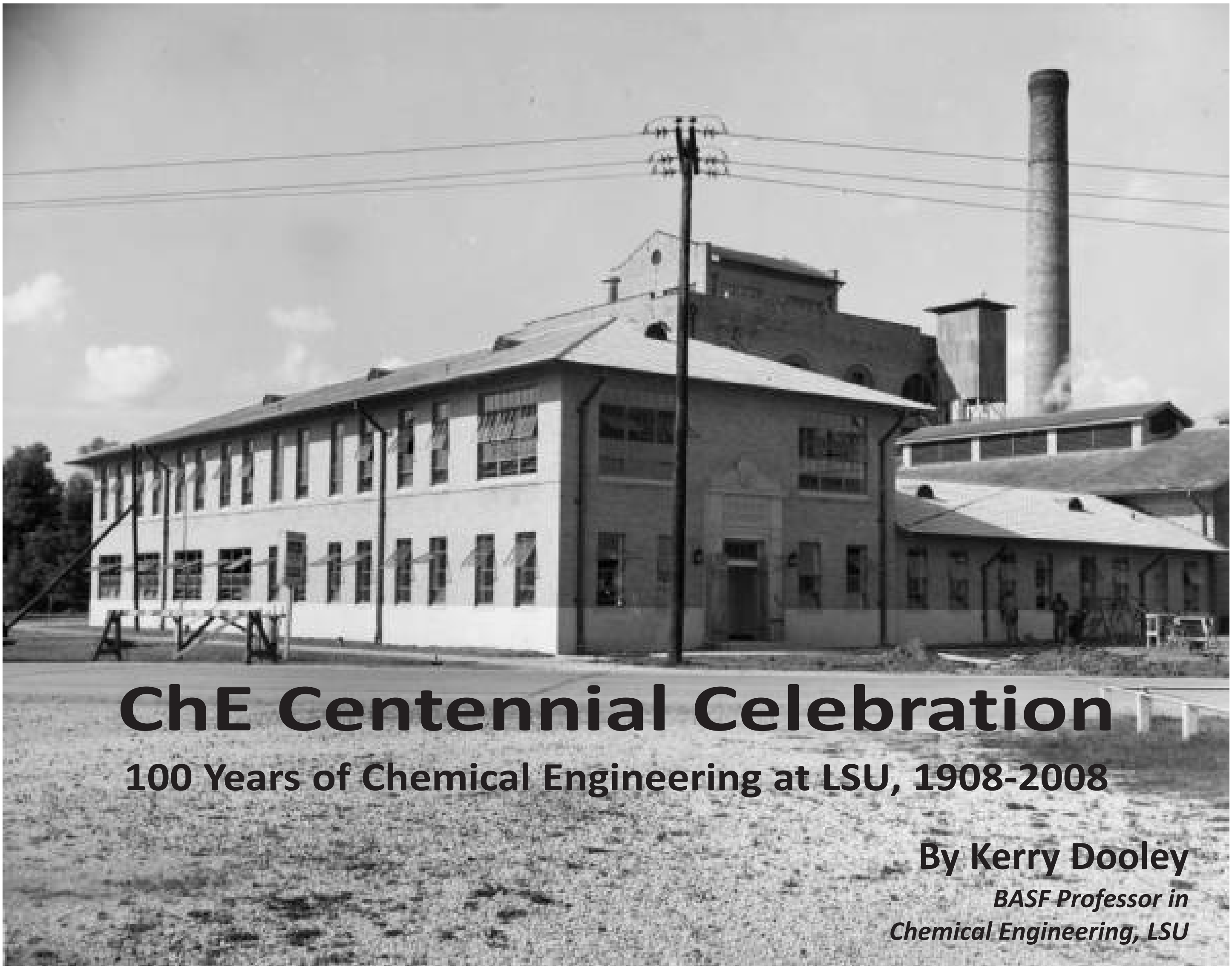
LOUISIANA STATE UNIVERSITY

CAIN DEPARTMENT OF CHEMICAL ENGINEERING



ChE Centennial Celebration

100 Years of Chemical Engineering at LSU, 1908-2008

By Kerry Dooley

BASF Professor in Chemical Engineering, LSU

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“The course … is designed to train the student in those fundamental principles which underlie all engineering problems, and at the same time give him an opportunity to obtain a specific chemical training…It is believed that wide fields are now to be found in Louisiana in sugar, gas, petroleum products, fertilizers, sulphuric acid, bricks and ceramics, alcohol, paper, cottonseed oil, soap-making and general chemicals. Some of these branches of industry are still in their infancy in this State, but few places offer greater natural advantages than does Louisiana…” – Charles Coates, LSU Catalog statement, 1920s.

Historical Highlights

Our origins are tied to the Audubon Sugar School, from which evolved both the Chemistry and Chemical Engineering (ChE) departments. While our friends in Chemistry may point out that the combined department's initial name was "Chemistry", we can point out that its first Chair, Charles Coates, consciously modeled much of its curriculum on the "unit operations" of the sugar industry, and nascent chemical engineering programs throughout the U.S., especially Cornell, MIT and Illinois [11]. Coates's initial sugar curriculum in "general science" (1893) was his own, although revisions in 1899 were partly in imitation of MIT's Practice School [11]; he claimed until his death that this original curriculum constituted the real start of ChE at LSU [12]. Therefore LSU ChE dates to the beginnings of chemical engineering as a recognized profession (MIT was first, in 1888), whether called a "Sugar School" or "Industrial Chemistry". Graduates of the school prior to 1908 did call it sugar or chemical engineering [13].

Figure 1. Charles Coates, father of Chemical Engineering and Chemistry at LSU, who wrote: "I believe we should offer, next year, graduate courses in Chemistry and Chemical Engineering…There is a demand, however, for men skilled as chemists, who have had considerable training both in electrical and mechanical engineering…We already have such a course in the Audubon Sugar School, modified to meet the peculiar demands of the sugar industry." (Report to President of LSU, 1907). With the support of Thomas Atkinson, the new Dean of Engineering at LSU, Coates initiated his new "Chemical Engineering" curriculum in 1908.

The Sugar School functioned mainly as a lab course, on a quarter system. Students conducted experiments in fluid flow, filtration, heat transfer, crystallization, evaporation, extraction, size reduction, etc. for more than 24 hours per week! This lab focus persisted in the pre-WWI ChE curriculum [14]. Analytical chemistry of sugar was a large component. There was also ethics training. The fourth and fifth years were partly devoted to field work at sugar factories. International students were common – the school drew from East Asia, Europe, the Caribbean and Mexico [15].

But at the same time other industries (oil refining, paper, chemicals) were developing in Louisiana; Coates recognized this and pushed for a more general engineering curriculum independent of both the Sugar School and Chemistry [16]. It would combine elements of industrial chemistry with mechanical and electrical engineering and physics. This was a bold (and probably tiring) move in that the pre-WWI enrollment in the Sugar School was on a par with that of the entire College of Engineering [14, 17, 18]; in 1912 the Sugar School had 28 out of nearly 150 seniors for LSU as a whole [18].

Many initial students were transfers from the Sugar School. But Coates's decision to make ChE a five year curriculum [19] dampened enrollment relative to the other engineering programs. There were few graduates until the 1920s, by which time it was a four-year curriculum again, and had shed several of its purely "sugar" elements to adopt a more general "unit operations" flavor [20, 21], with classes in Chemical Factory Equipment (6 hours, later changed to Unit Operations) and Engineering Chemistry Lab (18 hours), both taught by Paul Horton, who started at LSU in 1919. By the late 1920s the number of ChE students in some years exceeded Chemistry, and began to approach that of the Sugar School [20].

In 1925 Chemistry and Chemical Engineering relocated from the old to new campus, from Irion Hall (approximately 22,000 square feet, [22]) to the building (75,000 square feet at the time) later named for Charles Coates [23]. Many courses (e.g., all of thermodynamics) were taught in the Engineering Building (now Atkinson Hall) by mechanical or electrical engineers. The sugar mill was begun in the location next to the current ChE buildings (now the LSU cogeneration facility). Around this time graduate classes, especially for ChE's, appeared. These included classes such as Advanced Technical Analysis, focused on "control of sugar factories, paper and pulp mills and industrial problems" [24]. Previous graduate classes were targeted for both chemists and ChE's [20]. The departments were beginning to diverge.

Coates kept ChE and Chemistry together until near his retirement in 1937. He moved ChE to a new College of Pure and Applied Sciences (with himself as dean) in 1931. Part of his reasoning was that he envisioned the combination as the key piece to his "Industrial Research Institute" at LSU, marketing both contract research by faculty and graduate fellowships to companies. He waived all intellectual property rights and agreed to keep the work confidential for some period of time [16]. Initially successful in attracting broad industrial interest, the continuing depression shrank the institute by 1937, and it died during WWII for lack of personnel. It did fund graduate work for several early theses, including that of Gipson Carter, a ChE [25] and LSU's first Ph.D. (1935). The idea has been resurrected in the college many times since.

The Department was re-incorporated into the College of Engineering in 1937, primarily for accreditation purposes [23]. There were no problems with accreditation – aside from the courses listed above, Fluid Flow and Heat Transfer had already entered the curriculum, with Plant Design starting about this time; there were 149 hours total [26, 27]. The first ECPD (now ABET) accreditation was received in 1939, the third department in the south to be accredited; we have remained continuously accredited since that time [28]. There was some grumbling about the administrative move, because it reduced the pool of graduate students, and because engineering was considered less research-oriented at the time [23]. The new ChE/Sugar School building was completed during this period (1933) and the larger working mill completed by 1938. These buildings are shown on the title page.

In the postwar period the department expanded the breadth of the faculty and its offerings. Notable among these efforts were programs in water technology and in management, both beginning in the late 1940s [29-32], and a combined petroleum/chemical engineering degree [33, 34]. ChE's were allowed to substitute 9 hours of business administration classes for certain ChE classes [31]. But there was considerable tinkering, with requirements changing almost yearly. A separate Process Control class (at the graduate level) first appears in 1945, taught by Arthur Keller [29]. The Water Technology program ultimately was cancelled due to personnel losses, but not the environmental efforts in ChE, which switched more to research under the pulp and paper industry-sponsored National Council for Stream Improvement program [35], and later the EPA-funded Hazardous Waste and Hazardous Substances Research Centers.

After standardization in the late 1950s, the curriculum became one familiar to most practicing chemical engineers of today; the problems for such courses as Unit Operations, Heat and Mass Transfer, and Thermodynamics are familiar but surprisingly detailed [36]. Jesse Coates had a 40 page solution to a problem on how to design a steam cracker for propane – he may have been fortunate to predate the student course evaluation age. There was also less focus on specific industries by this time, by design; the faculty proclaimed: "The undergraduate curriculum in chemical engineering must be concerned primarily with fundamentals, and ... there is no specialization in any particular industry" [37]. This shift in emphasis was attuned to the national reforms in ChE education of the period, especially the emphasis on unified subjects such as Transport Phenomena and Reactor Design.

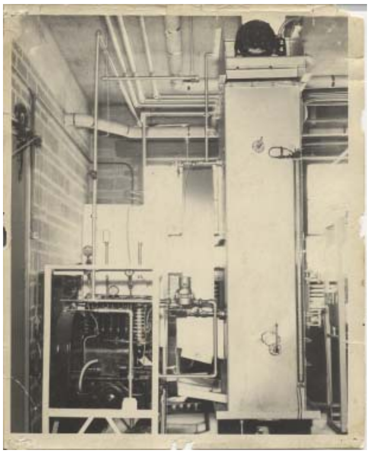

Figure 2. This refrigeration-dehumidification experiment appears to have been one of the first installed by Jesse Coates in the ChE building / Sugar School, along with an evaporator and two distillation columns. The building was targeted by the state for sugar experimentation only, but with help from ChE's first federal grant, Jesse Coates began equipping undergraduate labs in the same location they are today [23]. The labs served as a model for other departments such as Texas and Wisconsin.

The computer revolution was also taking place in engineering education and LSU was a leader. ChE immediately made use of LSU's new (1960) IBM 650, even in undergraduate classes [35]. It was soon replaced by two state-of-the-art IBM mainframes [38]. Cecil Smith helped inaugurate the Department of Computer Science and served as its chair from 1972-77 [28, 38]. By the late 1960s both the College of Engineering and ChE were running their own large computers [8].

The graduate program was re-energized in the late 1950s to early 1960s. There were traditional M.S. and Ph.D. programs and an evening M.S. program to serve the needs of industry – the evening classes continue to this day. There were even some off-site classes in Lake Charles, and faculty made the commute [35] – truly distance learning. The program requirements were loose (there were no specific course requirements even in the 1970s) and ChE students often worked for co-advisors outside the department [39]. With the burgeoning research programs, new facilities were needed and the department itself took the lead in obtaining a new building, winning a National Science Foundation grant ($350 million) in 1967, matched two-for-one by the state [38]. Around the same time an extensive modernization program for the "old" building was also begun [40], resulting in its current appearance.

There was general retrenchment in programmatic and research developments at LSU in the 1970s, caused by both skyrocketing enrollments and fiscal problems [41]. Whereas the department had previously expanded offerings, there was now a narrower focus on the chemical and petrochemical industries. Sugar engineering was severed from ChE and eventually (1986) from engineering. Some technical options were eliminated. This situation persisted until recently, when concentrations (biochemical, materials, and environmental) were re-introduced to the curriculum and a new infusion of faculty re-established some of the breadth lost previously.

Figure 3. Cecil Smith (L) and Paul Murrill in pre-laptop days. Murrill's leadership of a process control revolution in the department helped catapult him from Instructor (1962) to Chancellor of LSU (1974), with stops as ChE Department Head (1967) and Provost (1969) [10]. In 1980 he left LSU to take an executive position in industry.

In the modern era, the department has consistently been ranked (among U.S. ChE departments) in the top 20% in undergraduate enrollment and the top 30% in external funding.

The Students

The first three B.S. graduates (in 1913) were Isidore Colon and Francisco Lopez of Puerto Rico and Robert Holmes of Massachusetts [42]. There was a lot of dropping in and out of the Sugar School, ChE and Chemistry in those days, often occasioned by money problems – the lab fee per class was $5 [13, 14]. The first graduates from Louisiana (1914) were Cyrus Helm and Glenn Ledbetter [14], both of whom stayed for graduate school [43]. However, the trend of nearly majority non-Louisiana (including international) students continued through the 1920s [20, 22, 24]. Other notable early graduates included later faculty Roger Richardson, Arthur Keller and Jesse Coates, major donors such as Ike East and Roy Paul Daniels, and LSU's first Indian and Chinese graduate students (Ramchandra Padhye and Chennan Shen, [20]).

The early graduate (M.S.) students were listed as Chemistry, Engineering [44]. Before WWI, these made up a high percentage of LSU's total - 4 out of 13 in 1911 ; 8 in 1913 [19, 42]. Most of them wanted to become part of the booming sugar industry and they assisted running both the Sugar School and the ChE program [16].

ChE became more homogeneous with the advent of the depression. The international student pool dried up, and most of the students were Louisianians, all male, all white. This continued even to the late 1960s [36, 38], with only one woman graduate prior to WWII [27]. But enrollment grew steadily, with 96 undergraduates (sophomore-senior) by 1933 and 121 by 1941 [26, 27]. ChE had 14 B.S. graduates in 1934, compared to only 16 for all the sciences at LSU, excluding pre-med. Lab fees mostly disappeared, and there were opportunities for poorer students to work on campus – e.g., Bernard Pressburg's (later LSU professor) first job was in the University gardens [16, 35]. Other significant graduates of this era included Ike East (International Paper), Arthur

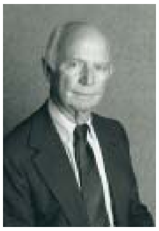

Figure 4. Gordon Cain, 1998. Cain served as vice president of the Chemical and Plastics Division of Conoco, president of Petro-Tex Chemical Company, and founder of the Sterling Group. The $10 MM plus Cain endowment of ChE provided for graduate assistantships, faculty startup funds, undergraduate lab modernization and five $2 MM chairs. On December 16, 1998 the LSU Department of Chemical Engineering was officially renamed the Gordon A. and Mary Cain Department of Chemical Engineering.

Keller (LSU ChE professor), Junius Sapp (Crown Zellerbach) and Gordon Cain (pictured left).

Little can be said about the WWII years, because almost all ChE students entered the service in 1942 (Bernard Pressburg was in the army also, and two other professors left on war assignments). By the later part of the war, Jesse Coates was teaching all the classes to the few students who remained [23]. Those who left during the war had returned by 1946, and LSU ChE participated fully in the postwar boom in engineering enrollment by returning GIs, with 242 undergraduates by 1946 [45].

A boom in graduate enrollment in the late 1950s to early 1970s resulted in a corresponding increase in ChE faculty worldwide with LSU pedigrees. By 1970 there were five department chairs or deans and 23 other faculty in the U.S. alone; 57 total have served or are serving over the entire history [46, 47]. The late 1960s also marked the end of the almost monolithic student body. Aside from an increasing presence of international students in the graduate program, the numbers of women increased (to approximately 20-25% of the undergraduates by the late 1970s, and higher since), and the first black students appeared with the advent of desegregation at LSU (James Hamilton may have been the first, graduating in 1973). Wayne Bolden became the first African-American M.S. (1984) and Ph.D. (1986). Our emphasis on the sugar industry also helped attract a large (more than 50) student influx fleeing Cuba in the early 1960s. Many of these students obtained advanced degrees with one (Armando Corripio) joining the faculty in 1970.

Figure 5. Susan Hadlock (L) and Bredow Bell (R) in the computer lab (1978), with hybrid computer in background. By this time analogs were obsolete, but the department still maintained its own digital super-minis through the early 1990s. Susan's father, Gene Hadlock, became an Instructor upon his retirement from Exxon in 1984, and patiently mentored students in Senior Lab until his death in 2003.

The best remembered annual event of the 1970s onward was the spring crawfish boil, which also served as an awards ceremony. Before campus regulations intervened (eliminating both the boiling and the beer kegs), the work was done in-house, using the steam-jacketed kettle in the undergraduate labs – which could boil a 150 pound batch. Many students and some faculty played significant roles [48, 49].

Our department has produced many distinguished engineers in its modern (post-1955) era, in industry, government and academia. Even a long list would leave out many important names, but would certainly include Robert Anding, Clarence Eidt and Al Lopez of Esso/Exxon, Roy Gerard of Shell, Otha Roddey of Parsons, Bim Gautreaux (also an Instructor in 1956-57) and George Daniels of Ethyl/Albemarle, Nai-Yuen Chen of Mobil, Murray Rosenthal of Oak Ridge National Labs, Thibaut Brian of Air Products, Joseph "Guy" Thibodaux of NASA, Ed Schmitt of Georgia Gulf, Rene Sagebien of Hovensa, Rene Latiolais and Ronald Cambre of Freeport McMoRan, and in academia Ronald Rousseau (Georgia Tech), Ray Bailey (Tulane), Charlie Moore (Tennessee), Jack Hopper (Lamar) and James Kelly (University of Virginia). Gautreaux, Brian, and Chen were elected to the National Academy of Engineering.

Figure 6. ChE's eat crawfish even in their barrel yard; Ed McLaughlin (L) presents the Coates Award to David Clary at the 1980 crawfish boil, with Jesse Coates (2nd from left) himself in attendance. The award is given to a graduating senior exhibiting outstanding professional, campus, and community activities. Clary is now Vice-President , Chief Sustainability Officer for Albemarle.

Figure 7. The student AIChE chapter has over the years organized many events, including plant trips, the annual trek to the Student Regional meetings, and participation at AIChE Annual meetings. This group from 2007 is shown with their award-winning entry in the chemical car competition.

Faculty and Staff

The early history of the program was dominated by three towering personalities – Charles Coates, his son Jesse, and Paul Horton. Charles's record at LSU is well known – he greatly expanded the Audubon Sugar School, founded both Chemistry and Chemical Engineering, was instrumental in founding the Graduate School, and later served as a dean. He was also the first LSU football (co)-coach. The picture shown of him does not do him justice, as he was well known for a steady stream of corny jokes and inexhaustible energy and kindness in helping students [50, 51]. Coates was ideally suited for the LSU job in that he had done post-doctoral work in both Chemistry and Mining Engineering (at Heidelberg and Freiberg, respectively) [16]. Paul Horton taught an amazing variety of courses in the post-WWI years [22], firmly established the program's tradition of graduate research, and served as the first chairman of the separate (from Chemistry) department, starting in 1936 [50].

Charles Coates's only pre-WWI assistants other than graduate students and instructors (who seem to have come and gone rather quickly) were Allan Odell and Raoul Menville. Menville's specialty was analytical chemistry (he authored a textbook in the subject) and he is remembered as an outstanding teacher [23, 36], for example covering the new area of catalysis [21]. Horton's first ChE course was similar to a heat and mass balances class, but coupled with industrial and analytical chemistry [20, 21]. As Coates took on more administrative responsibility and concentrated on the upper-level sugar technology courses, Horton took over most of the ChE curriculum. Coates, Menville and Horton held joint appointments in Chemistry and Engineering [14, 22].

Figure 8. Paul Horton, ca. 1955. Contemporary testimony paints Horton as the classic hard-nosed but fair engineering professor. In his first year as an assistant professor (1920-21), he taught 5½ different classes and several labs.

Charles Coates's son, Jesse joined the faculty in 1936, relieving the burden on Paul Horton – Menville had switched to the Chemistry program exclusively. Arthur Keller began as an instructor in the early 1930s, later becoming a professor prior to WWII. Bernard Pressburg became a professor upon completion of his Ph.D. work at LSU in 1941 [52].

Almost all the WWII and early post-WWII era faculty had some industrial experience, as did Jesse Coates, who worked at four industrial jobs prior to obtaining his Ph.D. [23]. Bernard Pressburg worked for Dixie Pine Products, Frank Groves for Texas Instruments, James Cordiner for Kaiser, Dale von Rosenberg for Esso, Adrian Johnson for IBM and Union Carbide, and Clayton Callihan for Dow. Adrian taught the first LSU computer course – to faculty – in 1960 and took over the graduate process control course for some time [53].

The staff also grew rapidly in the postwar period. A fully functional machine shop was established (see next section). Administrative staff were also added, Helen Chisolm and Alma Oliver in the 1950s, Hazel LaCoste in the early 1960s [35], and later Jan Easely, Jimmie Keebler and Darla Dao. Hazel became an institution and in many ways ran the department until her retirement in 1982.

Jesse Coates seems to have been the first ChE at LSU to take a sabbatical (1963), which he used to visit all the European powerhouses in the field [36]. During the trip, he met Edward McLaughlin of Imperial College, University of London, whom he convinced to come to LSU on a temporary basis [23]. Ed then returned permanently in 1970, becoming department chair in 1979 and dean from 1987-1996 [10]. He is remembered for an explosion in faculty hiring, the commencement of major fund-raising activities in both the department and College of Engineering, and as somewhat of a character.

Figure 9. Clayton Callihan (R) with graduate student Satyajit Verma, late 1970s. While Jesse Coates ("Mister Thermo") was an unforgettable teacher [8], Clayton was unforgettable, period. With his boundless energy, many interests (botany, inventions, shrimp farming, among others) and crazy clogs and shirts, he probably figures in more stories than any faculty member in ChE. But Clayton was both an effective teacher of process design and skilled in human relations within the department.

LSU's troubles in the 1970s affected the faculty. There were disagreements over consulting, space and the role of contract research versus federal grants versus teaching in an era of stagnating engineering enrollments [10, 39, 46]. This resulted in some turnover in faculty; consequently, many long-term faculty were hired in the late 1970s through the early 1980s, including Art Sterling, Doug Harrison, Dave Wetzel, Geof Price, Carl Knopf, Danny Reible, Kerry Dooley, Martin Hjortsø, Lou Thibodeaux, Greg Griffin and Kalliat Valsaraj. Sterling, Harrison, Knopf and Valsaraj all later served as department chairs, and Harrison, Thibodeaux and Reible as heads of the Hazardous Waste or Hazardous Substances Research Centers. The new faculty of this time recall that the senior faculty were helpful in getting their feet off the ground with joint projects, and keeping their service loads light [48]. Teaching loads were another matter, as the department's total enrollment skyrocketed in the early 1980s.

Figure 10. Frank Groves teaching heat transfer in the 1960s. Frank introduced modern Reactor Design to LSU [23], and taught three generations of ChE's. Many remember him as their best teacher. He is still active in the department.

The faculty infusion paid off eventually, as LSU ChE climbed into the top 25 in research funding for ChE departments in the late 1980s, and then again in the late 1990s. The gender and color barriers of the faculty were also finally broken with the hiring of Margaret Cygan (1984), Rose Wesson (1991), Lisa Podlaha (1998) and Judy Wornat (2002).

The Department and Louisiana

Charles Eliot, President of Harvard, visited LSU in 1908 and in his speech to the assembled student body stated "…the American University, which is secular in origin, trains experts for professional and business careers" [15]. This sentiment resonated with the LSU engineering faculty of the time – its focus was almost entirely educational and service-oriented. Charles Coates himself was a tireless advocate for industrial development in the region [50], and traveled extensively to meet with businessmen and politicians, especially in the development of the Audubon Sugar Factory [16] on the new campus in the 1930s.

For example, Thomas Keaty [2] developed catalysts to convert pinene chloride to camphene, used to make artificial camphor – an early biorefining process. Gordon Cranfill and Joseph Heard ([3], yes, a joint thesis) investigated processing of liquid rosin from southern yellow pine – providing a design of the rosin plant in the thesis. There were many more in this practical bent.

The department's contributions to the Louisiana sugar industry cannot be overestimated. Students from the department's sugar factory lab course helped operate the mill, producing brown sugar and conducting research in crystallization, analytical methods, solids processing, utilization of bagasse, and evaporation [28, 35]. Sugar mills would submit problems that students worked on in the course. Many ChE faculty and instructors taught sugar technology-related courses over the years, among them Charles Coates, Raoul Menville, Arthur Keller, Carl Stewart, James Cordiner, John Seip and Joe Polack. LSU's first "worldwide" patent resulted from Paul Horton and Arthur Keller's "Horkel Depither" to help process bagasse into wallboard or animal litter [54]; the University's license was profitable in the late 1950s through the early 1960s.

Figure 11. William Richardson (M.S., 1932) testing compressive stability of a mineral aggregate / asphalt mix for the Louisiana Highway Chemical Testing Lab. LSU did not offer Ph.D. degrees until the early 1930s, and most of the early M.S. projects were tied to the sugar, naval stores, paper, oil refining, natural gas and asphalt industries [1-7]. All of this work was funded by Louisiana industries and tied to their improvement.

However, there were broad-based contributions to other Louisiana industries as well. James Kelly [56] determined the key process impurities that disrupted the crystallization of alumina trihydrate, with Arthur Keller. The project was notable for its early use of electron microscopy at LSU. Roy Gerard [57] studied the influence of velocity, surface roughness, and material on scaling rates for solutions used in the sulphur industry, with Bernard Pressburg. Other efforts were on a contract basis and never published as papers or theses but made their way into handbooks – for example, Jesse Coates's measurements of the thermodynamic and transport properties of basic plastics [58].

In the 1980s the department – primarily Armando Corripio – partnered with IBM on delivering training to practicing engineers in advanced control. It also engaged in contract distillation work with modest success, eventually converting the packed column to its largest undergraduate lab in the 1990s. Other notable extension/continuing education efforts included both Adrian Johnson and Corripio in distillation, and Doug Harrison, Art Sterling and Dave Wetzel in the professional engineer license review class. Jesse Coates himself was instrumental in the development of professional licensing of engineers in Louisiana, contributing to the exams and collaborating with engineers from around the country to standardize them. The assembled problems in his collected papers [36] may be the most extensive anywhere.

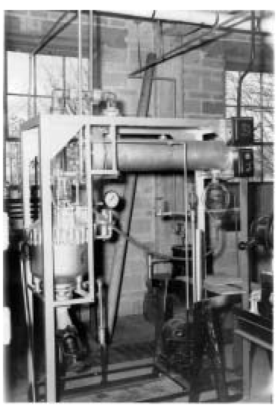

Figure 12. Notable among the early, applied studies was Paul McKim's [9] pilot plant (partly shown here) for the manufacture of terpinol hydrate and terpineol from sulfate turpentine. McKim (Ph.D., 1949, later Senior V-P of Texas Eastern) ran the plant (assembled by the ChE shop) with help from undergraduates. By this time the department's shop facilities (under Eugene Snyder, later L.M. Carpenter and Henry Sparrow, then Larry Veilleux) were among the best at LSU, a trend which has continued until this day.

Intellectual Contributions

The oldest (1926) identifiable ChE M.S. thesis at LSU is that of Grady Albritton on the effects of surfactants on sugar solutions [1]. The early theses were supervised by Paul Horton, sometimes in conjunction with a Chemistry colleague. Although application-oriented, some of the later industrially-supported projects produced notable work of utility to the research community – e.g., Gordon Hughmark's [59] study of gas holdup and pressure drop in vertical gas-liquid flow, with Bernard Pressburg.

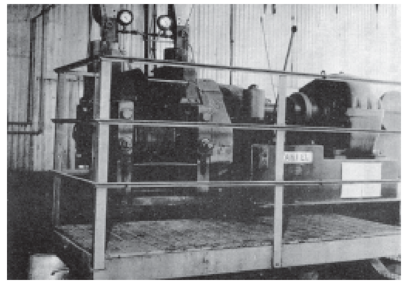

Figure 13. A three-roll mill for cane studies by John Seip as part of his Ph.D. (1963) research on how to relate factory and lab determinations of cane quality [55]. Seip later became Director of the Institute, which remained associated with Engineering until 1986.

A new level of research sophistication was introduced by the arrival of Jesse Coates from Michigan. Coates's early work was in heat transfer (for W.L. Badger, but heavily influenced by Warren McCabe); he did significant work at LSU in film condensation [60], the measurement of liquid thermal conductivities [61, 62], and heat transfer in plate towers [63], but also in fundamental thermodynamics of phase equilibria [64]. Coates's graduates also differed from many early LSU M.S. and Ph.D. students, in that most of them went on to industrial or academic research – Byron Sakiadis, Nai-Yuen Chen and Marcelian "Bim" Gautreaux to distinguished careers at DuPont, Mobil, and Ethyl, respectively. Coates was also well known for assisting the graduate students of other faculty.

Figure 14. The Department's greatest contribution to Louisiana is the practical training it has provided thousands of ChE's. In the last 10 years it has made capital improvements of more than $4 MM (in partnership with industrial donors) to modernize its undergraduate labs. Shown here is a polymerization reactor/separator experiment brought on-line in 2000. It was designed and assembled under the direction of Paul Rodriguez, who has made ours among the best Engineering shops in the nation.

Coates helped jump-start the process control research era at LSU (roughly early 1960s through the mid 1970s) with his mentorship of Paul Murrill, who studied transient response of distillation columns [65]. Murrill in turn mentored Cecil Smith (Ph.D., 1966) and Armando Corripio (Ph.D., 1970), and the combination made LSU a control powerhouse, at one time housing possibly the world's most sophisticated hybrid computer (a EAI 680 analog operated by a SDS Sigma 5 digital, [38]). They published both on general tuning principles and control of specific operations such as distillation and heat exchangers [66]. ChE was also instrumental in the founding of the Computer Center at LSU (1960), with Adrian

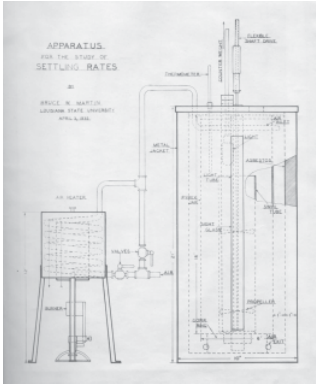

Figure 15. Diagram of two-phase slurry reactor studied by Martin for the causticizing process in paper mills; he called it a "settling apparatus", because rates were computed by measuring settling rates of the calcium carbonate product [7]. The project was funded by a paper company. This funding mode remained predominant in ChE until the early 1960s.

Johnson its first assistant director [53]. ChE needed all the computing power it could get; by 1968 Paul Murrill's group alone was using 30% of the total for LSU [38], primarily for defense research (Project Themis, the largest grant at that time in the college).

The 1960s through the mid 1970s were a golden age for research in ChE, because in addition to the process control efforts there were major contributions in catalysis, biochemical engineering and fluid mechanics. The catalysis efforts were stimulated by the arrival of Alex Voorhies from Esso Research and Engineering. Voorhies mentored an early study of the kinetics of metal/zeolite systems [67] and other projects on coking in zeolite catalysts. He is still remembered as a pioneer in this field. Clayton Callihan was ahead of his time in biochemical engineering, both in ideas (e.g., high protein foods from waste cellulose, [68]) and in collaborative effort (with biochemist V.R. Srinivasan and chemist Bill Daly), somewhat unusual for the times. Ralph Pike worked in fluid mixing from both experimental and numerical angles, developing models for 3-D flow fields [69]. There was some symbiosis – e.g., Harry Toups's work with Dave Greenberg on dynamic modeling of cell cycle kinetics in higher eukaryotes [70]. There also began the organization of research now familiar to faculty – e.g., lab allocations by faculty member [58], and continual grant writing.

However, some of these efforts were not sustainable due to retirements, departures, skyrocketing undergraduate enrollments and financial problems at LSU in the 1970s. By the early 1980s the large cadre of new faculty branched into different areas. Notable among the work of this later period were Mike Frenklach's combined experimental, empirical modeling and detailed modeling studies of combustion kinetics [71, 72], Ed McLaughlin's studies of high-pressure gas solubilities and solubilities of aromatic hydrocarbons in hydrogen-donor solvents [73], Geof Price's work on synthesis and characterization of metal/zeolite catalysts [74] and catalytic dehydrocyclization, Greg Griffin's on chemical vapor deposition of TiO_2 [75], Art Sterling's on urology and urodynamics [76], and Doug Harrison's on hydrogen production by combining steam reforming with carbon dioxide adsorption [77].

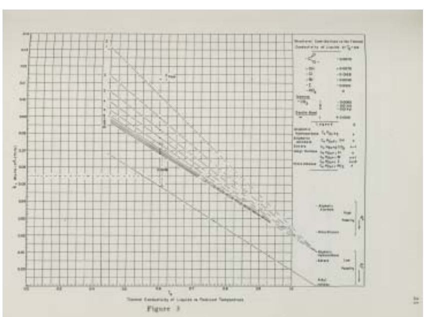

Figure 16. Plot of thermal conductivities of aliphatic liquids with corrections for polar groups on right, from work of Sakiadis and Coates [61]. The thermoconductometric apparatus designed by them required precise adjustments of spacers to better than 0.1 micron.

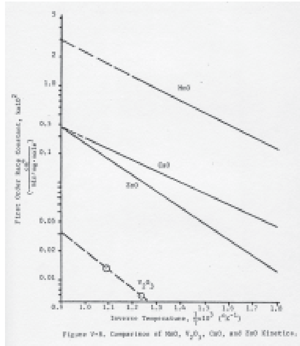

Figure 17. Plot of desulfurization kinetics with metal oxide sorbents from Phil Westmoreland's thesis [78], with Doug Harrison. Harrison conducted a long-running and successful program in the study of high-temperature sorbents. In total he mentored some 13 Ph.D. and 28 M.S. students, and is remembered by them as patient, thorough, and incisive.

The 1980s also saw the shift of much of the environmental effort at LSU to ChE. Some eight faculty were working on environmental projects throughout much of the 1980s and 1990s, and Lou Thibodeaux took over the EPA-funded Hazardous Waste Research Center in 1984. Projects funded by the center or directly from EPA ranged from Danny Reible's studies of contaminant transport in sediments [79] to Carl Knopf's work on supercritical fluid extraction of PAHs and other pollutants from contaminated waters and soils [80], to K.T. Valsaraj and Thibodeaux's study of micelle-water partitioning of hydrophobic organics [81]. The later work of the Hazardous Substances Research Center (a consortium on universities in the South, headed by Danny Reible) focused on bioavailability assessments of contaminated waters and sediments.

Textbooks are the chief intellectual contributions to the education of the next generation, and our faculty have authored 11 in wide use, including *Environmental Chemodynamics* by Lou Thibodeaux, *Optimization for Engineering Systems* by Ralph Pike, and *Principles and Practice of Automatic Process Control* by Armando Corripio (with Carlos Smith, Ph.D. 1972).

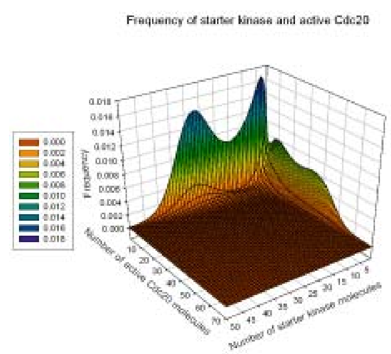

Figure 18. The profession underwent a paradigm shift to more molecularly-based research in the 1990s, and our department has participated fully. Shown here are results from Martin Hjortsø using the stochastic kinetics of the chemical oscillations driving the eukaryotic cell cycle to determine the distributions of cell properties in a population. The goal is to identify drugs and treatment regimes giving large differences in kill ratio between target (cancer) and healthy cells.

References

1. Albritton, G.G., A study of the effects of colloidal gums on the surface tension of sugar solutions. 1926, Louisiana State University: Baton Rouge.
2. Keaty, T.S., The decomposition of bornyl chloride. 1928, Louisiana State University: Baton Rouge.
3. Cranfill, G.R.H., Joseph R. , Investigation of liquid rosin from southern yellow pine, Louisiana State University: Baton Rouge.
4. Gosselin, C., A study of the gum formation in sulfuric acid-treated cracked gasoline. 1930, Louisiana State University: Baton Rouge.
5. Richardson, W.S., Investigation of cold laid bituminous mixtures. 1932, Louisiana State University: Baton Rouge.
6. Gill, C.E., A study of the development and application of a new system of gas odorization. 1934, Louisiana State University: Baton Rouge.
7. Martin, B.W., A study of some of the variables affecting the causticizing process in a sulfate paper mill. 1935, Louisiana State University: Baton Rouge.
8. Bryant, P., personal communication, K. Dooley, Editor. 2008.
9. McKim, P.A., Terpinol hydrate and terpineol from sulfate turpentine. 1949, Louisiana State University: Baton Rouge.
10. Frost, D.R., The LSU College of Engineering: Volume II. Growth and Maturity. 2000, Baton Rouge: Louisiana State University.
11. Coates, C., An Experiment in the Education of Chemical Engineers: The Twenty-Fifth Anniversary of the Audubon Sugar School. Industrial and Engineering Chemistry, 1917. 9: p. 379.
12. Coates, C., Ind. Eng. Chem., 1917: p. 379.
13. Freeland, E., Tales of a Sugar Tramp. 1954, New Orleans: Pelican. 6-23.
14. LSU Catalog, 1913-14. 1914, Baton Rouge: LSU Press.
15. LSU Alumnus. 1908, LSU Press: Baton Rouge.
16. Coates, C., Coates Collected Papers, LLMVC, Editor. 1881-1973, LSU Libraries: Baton Rouge.
17. LSU Quarterly, 1911-12, 1912. 6-7.
18. LSU Catalog, 1911-12. 1912, Baton Rouge: LSU Press.
19. LSU Catalog, 1910-11. 1911, Baton Rouge: LSU Press.
20. LSU Catalog, 1926-27. 1927, Baton Rouge: LSU Press.
21. Coates, V., Coates Collected Papers, LLMVC, Editor. 1881-1973, LSU Library: Baton Rouge.
22. LSU Catalog, 1920-21. 1921, Baton Rouge: LSU Press.
23. Traynham, J., Jesse Coates Oral Interview, LLMVC, Editor. 1993, LSU Library: Baton Rouge.
24. LSU Catalog, 1929-30. 1930, Baton Rouge: LSU Press.
25. Carter, G., A survey of the status of Ramie in Louisiana. 1935, Louisiana State University: Baton Rouge.
26. LSU Catalog, 1933-34. 1934, Baton Rouge: LSU Press.
27. LSU Catalog, 1941-42. 1942, Baton Rouge: LSU Press.
28. Sterling, A.M. and D.P. Harrison, Chemical Engineering at LSU. Chem. Eng. Ed. 13: p. 54-59.
29. LSU Catalog, 1945-46. 1946, Baton Rouge: LSU Press.
30. LSU Catalog, 1947-48. 1948, Baton Rouge: LSU Press.
31. LSU Catalog, 1949-50. 1950, Baton Rouge: LSU Press.
32. LSU Catalog, 1951-53. 1953, Baton Rouge: LSU Press.
33. LSU Catalog, 1961-63. 1963, Baton Rouge: LSU Press.
34. LSU Catalog, 1963-65. 1965, Baton Rouge: LSU Press.
35. Groves, F., personal communication, K. Dooley, Editor. 2008.
36. Coates, J., Coates Collected Papers, LLMVC, Editor. 1881-1973, LSU Libraries: Baton Rouge.
37. LSU Catalog, 1959-61. 1961, Baton Rouge: LSU Press.
38. Murrill, P., personal communication, K. Dooley, Editor. 2008.
39. Polack, J., ChE Faculty Meeting Minutes, Aug. 31, 1973. 1973.
40. Murrill, P., Tentative Order of Priority List of Repair and Renovation Work Needed in the Chemical Engineering Building. 1967, LSU.
41. Murrill, P., Memo to Faculty, Aug. 27, 1973. 1973, LSU, Provost's Office.
42. LSU Catalog, 1912-13. 1913, Baton Rouge: LSU Press.
43. LSU Catalog, 1914-15. 1915, Baton Rouge: LSU Press.
44. LSU Catalog, 1915-16. 1916, Baton Rouge: LSU Press.
45. LSU Catalog, 1946-47. 1947, Baton Rouge: LSU Press.
46. Coates, J., Report to the Faculty, Nov. 20, 1970. 1970, ChE Dept., LSU.
47. Thibodeaux, L.J. Chemical Engineering Professors from LSU - An Essay of a Peculiar Event. 2008 [cited August 5, 2008]; Available from: http://www.che.lsu.edu/centennial/ac_group/index.htm.
48. Price, G., personal communication, K. Dooley, Editor. 2008.
49. Mentzer, B., personal communication, K. Dooley, Editor. 2008.
50. Frost, D.R., The LSU College of Engineering: Volume II. Growth and Maturity. 2000, Louisiana State University. p. Ch. 2-3.
51. American Contemporaries Series, Charles Edward Coates, Jr. Industrial and Engineering Chemistry, 1931.
52. Cordiner, J.B. and J. Coates, Louisiana State University: Development and History. Chemical Engineering Education, 1991. Winter 1990: p. 2-5, 33.
53. Johnson, A., personal communication, K. Dooley, Editor. 2008.
54. Keller, A.G., The mechanical depithing of sugarcane bagasse. The Sugar Journal, 1957. Dec. 1957.
55. Seip, J.J., A Method of Determining Sugar Cane Quality in Louisiana. 1963, Louisiana State University: Baton Rouge.
56. Kelly, J., A study of the influences of Bayer process impurities on the crystallization of alumina trihydrate. 1962, Louisiana State University: Baton Rouge.
57. Gerard, R.D., Fundamentals of Scale Adhesion. 1958, Louisiana State University: Baton Rouge.
58. Coates, J., Coates Collected Papers, LLMVC, Editor. 1881-1973, LSU Library: Baton Rouge. p. Boxes 1, 3, 11-14.
59. Hughmark, G.A., Holdup and Pressure Drop with Gas-Liquid Flow in a Vertical Pipe. 1959, Louisiana State University: Baton Rouge.
60. Todd, J.B., An apparatus for measuring film coefficients of heat transfer of condensing vapors. 1950, Louisiana State University: Baton Rouge.
61. Sakiadis, B.C., Studies of Thermal Conductivity of Liquids. 1955, Louisiana State University: Baton Rouge.
62. Chen, N.-Y., A study of the molecular structure and thermal conductivity of some organic liquids. 1954, Louisiana State University: Baton Rouge.
63. Gautreaux, M.F., Direct Contact Heat Transfer in a Baffle-Plate Tower. 1958, Louisiana State University: Baton Rouge.
64. Gautreaux, M.F. and J. Coates, Activity coefficients at infinite dilution. AIChE Journal, 1955. 1: p. 496-500.
65. Murrill, P.W., The Transient Response of a Distillation Column to Liquid Rate Perturbations. 1963, Louisiana State University: Baton Rouge.
66. Lopez, A.M., et al., Tuning controllers with error-integral criteria. Instrumentation Technology, 1967. 14: p. 57.
67. Bryant, P.A., Hydroisomerization of n-pentane over a zeolite catalyst. 1966, Louisiana State University: Baton Rouge.
68. Dunlap, C.E., Proteins From Waste Cellulose by Chemical-Microbial Processing. 1969, Louisiana State University: Baton Rouge.
69. DeSouza, A., Fluid Dynamics and Flow Patterns in Stirred Tanks with a Turbine Impeller. 1969, Louisiana State University: Baton Rouge.
70. Toups, H.J., A Dynamic Model of the Kinetics of the Cell Cycle in Higher Eukaryotes. 1973, Louisiana State University: Baton Rouge.
71. Clary, D.W., Soot Formation During Pyrolysis of Aromatic Hydrocarbons. 1985, Louisiana State University: Baton Rouge.
72. Bornside, D.E., Ignition in Methane-Additive Mixtures. 1983, Louisiana State University: Baton Rouge.
73. Choi, P.B., Solubility Studies in Pure and Mixed Solvents. 1982, Louisiana State University: Baton Rouge.
74. Price, G.L. and V. Kanazirev, Ga2O3/HZSM-5 propane aromatization catalysts - formation of active-centers via solid-state reaction. Journal of Catalysis, 1990. 126: p. 267-278.
75. Siefereng, K.L. and G.L. Griffin, Kinetics of low-pressure chemical vapor-deposition of TiO2 from titanium tetraisopropoxide. Journal of the Electrochemical Society, 1990. 137: p. 814-818.
76. Schafer, W., et al., Good Urodynamic Practices: Uroflowmetry, Filling Cystometry, and Pressure-Flow Studies. Neurology and Urodynamics, 2002. 21: p. 261-274.
77. Balasubramanian, B., et al., Hydrogen from Methane in a Single-Step Process. Chemical Engineering Science, 1999. 54: p. 3543-3552.
78. Westmoreland, P.R., Desulfurization of Gasified Coal: Evaluation of Candidate High Temperature Sulfur Acceptors. 1974, Louisiana State University: Baton Rouge.
79. Savant-Malhiet, S.A., Modelling of passive contaminant transport in river sediments 1988, Louisiana State University: Baton Rouge.
80. Brady, B.O., Supercritical extraction of soils contaminated with hazardous organics 1985, Louisiana State University: Baton Rouge.
81. Valsaraj, K.T. and L.J. Thibodeaux, Relationships between micelle water and octanol water partition constants for hydrophobic organics of environmental interest. Water Research, 1989. 23: p. 183-189.