UNIVERSITY OF CALIFORNIA, BERKELEY

CLARENCE CORY AND A HISTORY OF EARLY ELECTRICAL ENGINEERING AT U.C. BERKELEY

A PAPER SUBMITTED TO PROFESSOR CATHRYN CARSON OF THE HISTORY DEPARTMENT IN COMPLETION OF HISTORY 199

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Introduction

While The Department of Electrical Engineering and Computer Science (EECS) at U.C. Berkeley is today internationally renowned for excellence in the most advanced technologies, its rich historical legacy has not yet received proportional attention. Standing behind today's advanced semiconductor, signal processing and integrated circuit research, electrical engineering at Berkeley has been developing for 114 years since its inception by Clarence L. Cory in 1892. This paper aims to stimulate interest in the department's history and recognize the foundation upon which it was laid. Even in its early years, electrical engineering at Berkeley had an active and dynamic history that changed as quickly as the technology behind it. In response to California's growing need for electricity at the turn of the century, Cory established electrical engineering into Berkeley's curriculum and simultaneously founded the university's first electronics laboratory. When the engineering colleges were reorganized in 1903, Cory became Dean of the Mechanical and Electrical Engineering Department. Under Cory's leadership, Berkeley electrical engineering pioneered high voltage power transmission technologies through the late 1910s, enabling cities like San Francisco and Los Angeles to access hydroelectric power from the Sierra Nevadas. However in the 1920s, as the field of electrical engineering began to expand towards radio and consumer electronics, the Mechanical and Electrical Engineering Department faced the challenges of both finding a new direction for electrical engineering research while also sharing resources between the two now more disparate disciplines composing it. Before becoming an autonomous department in 1930, electrical engineering struggled externally to define its role and place within the University and internally to define its area of technical expertise.

Section 1:

California's Need for Electrical Engineering

Electrical engineering at Berkeley arose from the advent of practical electrical technologies around the 1880s. As physicists began to harness the power of the electricity, they created a myriad of new technologies. In 1876 Bell and Gray invented the telephone; five years later, in 1881, Edison introduced the incandescent light bulb, and in 1887 the first electric street cars were established in the United States. The demand for electrical technologies was strong immediately following their creation, especially in California, where San Francisco was the home to the first electric street lighting in the country. California also developed the largest electric street car network in the world in Los Angeles.[1]

At the same time as California began to utilize these new technologies, Berkeley launched its first course devoted to electrical technologies. In 1889-1890, the Physics department introduced a class that focused on the more pragmatic side of electricity and magnetism: 'Physics V' entitled 'Electrical Measurements.' The course description in the University Register is brief and only states that lesson would be based on Ayrton's Practical Electricity book and would include a lab session.[2] The fact that the course was centered on lessons from a textbook suggests that it was not intended to provide innovation but rather general competence. Further, the Register states that this class was optional in the first three years of its inception. In 1892-1893, the 'Electrical

Measurements' course was changed to teach "the theory and absolute measurement of Electricity and Magnetism" according to the University Register for that year. But theory and measurement were not what California needed to keep apace with the electrification of the state.

The physicist's interest in electricity was more abstract than that of street cars and light bulbs. "It is a well known fact that alternating currents do not follow Ohm's Law and that nobody knows what law they do follow," wrote the American engineer George Prescott in 1888.[3] Alternating current, which drove many of the new technologies, was governed by a challenging set of differential equations that required a heavy knowledge of mathematics. While physicists strove to elucidate the universal principles and laws behind alternating currents and other electrical phenomenon, such a complete knowledge was not required to create more reliable lights and more powerful streetcars. The electrical engineer Charles Steinmetz summarized his frustration with physics when he wrote in 1893 that "Maxwellian Theory does not exist in practice, but merely haunts as a phantom transformer in text-books and mathematical treatises."[4] An engineering approach towards electricity was much more relevant as it could produce the immediate results desired by the State instead of intangible theories.[i]

Only one college at Berkeley stood out as the clear choice for the introduction of electrical engineering in 1892: the history and purpose of the College of Mechanic Arts provided an ideal context for this new field. The college was founded as part of the University of California at Berkeley in 1868 as stipulated in the provisions of its land

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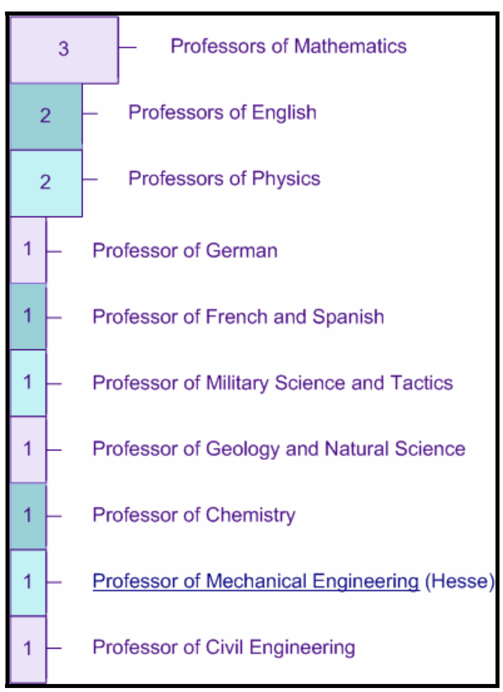
[i] Steve Finacom, a member of the Editorial Board of the *Chronicle of the University of California*, notes that a similar development took place with the introduction of field of optometry at Berkeley. Optometry was first a part of the Physics department as it was considered an application of the discipline. Optometry remained within Physics from 1921 through 1940, when a separate Department of Optometry was established, followed in 1941 by the current School of Optometry. (Stadtman 1967, 76)

grant charter. The College of Mechanic Arts offered a multifaceted curriculum which, while providing students with a grounding in mining, steam, and machine technologies, also emphasized a background in German, metallurgy, geology, political economy, and Civil Engineering. The heterogeneity of the department was underscored by the faculty composing it. Although faculty varied with time, the University Register of 1886-1887 presents a typical composition as seen in Figure 1 below. While such a varied faculty may appear rather arbitrary, it was well suited to the needs of electrical engineering. The differential equations of alternating currents required a mathematician, the novel properties of electricity a physicist, the design of lighting bulbs a chemist, and the synthesis and creation of new technologies an engineer. Having a professor of German was also useful as much of the pioneering work in electrical engineering was being conducted in Germany. Thus the College of Mechanic Arts provided a good balance of professors needed to teach and investigate electrical engineering.

Figure 1: Breakdown by Specialty of Faculty in 1886-1887 in the College of Mechanic Arts as presented in the University Register on page 73 of that year's volume.



Further, the College of Mechanic Arts also provided a mission of practical service and research to California that matched well with electrical engineering. Research in the College of Mechanic Arts was led by Dean Frederick G. Hesse and directly supported California's early mining industry. Hesse undertook one of the university's first efforts at scientific research with a project to determine the efficiency of different bucket shapes utilized on a water wheel. The mining industry also sought the department's help in improving efficiency of the flat vane, and Hesse immediately improved the design according to College of Mechanic Arts Professor Joseph N. LeConte.[5] Further, the University Register of 1881-1882 indicates that graduating seniors in the College were required to write research papers on topics also relevant to industry[6]. A sample of these theses include, A Hydraulic pumping system as applied to mines, "A proposed system of centrifugal pumps for mines", and "A design of discussion of a hydrostatic press". Further, the College was also responsible for the University's power plant, where it maintained a boiler, steam engine, and gas engine. Junior and senior students would help maintain and run these machines as part of their training in shop practice. Another senior thesis from 1881-1882 reflecting the College of Mechanics' work on campus was "A proposed Water Wheel for the furnishing of power to run a Lathe on University Grounds." Thus the College of Mechanic Arts' history of producing engineering research relevant to California industries made it a good venue to locate electrical engineering, which was now expected to produce similar results. Further, the goals of electrical engineering were parallel to those of the College of Mechanic Arts in supplying power to California's industries, be they mining, lighting, or street railways.

Figure 2: A View of The College of Mechanic Arts Building circa 1900 as accessed from the EECS Website[7]

However the problem of supplying electricity to the California's cities contained one significant challenge that the College of Mechanic Arts was not prepared to deal with. The main source of electricity in the 1890s was from hydroelectric plants. These plants would employ the energy of a moving river to turn powerful dynamos which in turn produced electricity. However, California's major cities such as San Francisco or Los Angeles were not located along major rivers, and the nearest hydroelectric plants were located hundreds of miles away in the Sierra Nevada Mountains. In 1890 there were few power transmission technologies and their range was low making it difficult to meet the cities' demand for electricity. The "most spectacular transmission line to date" in 1891 was only 175 kilometers long and located in Germany writes the historian Robert Kline[8]. Thus California found itself in the paradoxical position that forced it to pioneer long distance power transmission technologies. While the College of Mechanic Arts was well suited to establishing an electrical engineering program, it had no experience in this complex yet significant electrical engineering problem.

Section 2:

Cory's Arrival and the Early Years of Electrical Engineering at Berkeley

While in 1892 Dean Hesse desired for the College of Mechanics to adopt electrical engineering, he also recognized that he would have to hire an expert in the field to address the unique challenges. In 1892 Hesse selected Clarence Cory as the University's first professor in Mechanical and Electrical Engineering. Cory had graduated in 1889 from Purdue University, where he had received his bachelor's degree of mechanical engineering in electrical engineering. Upon graduation Cory was only 16 years old, making him one of the youngest to ever receive such a degree.[9] He subsequently attended Cornell University, where he earned his master's in Mechanical Engineering in 1891. However, only eight years earlier in 1883 Cornell had become the first school in the United Sates to offer courses in electrical engineering. Although Cory had received his master's degree in mechanical engineering, he had specialized in electrical engineering. Thus in 1892 Cory would have been one of the few individuals in the country who had actually studied electrical engineering in a U.S. university setting. Also, LeConte notes that he and Cory attended Cornell together and that he personally recommended Cory to Hesse for the position.

Figure 3: A photograph of Cory (right) in 1898, accessed from the EECS Website[10]

Hired as an Assistant Professor in the College of Mechanics[ii], Cory was asked to develop the College's electrical engineering program during a period of great growth. "It was an opportune time to take up electrical engineering in the United States," writes Kline about the field in 1890[11]. "While telegraphy was a mature industry, telephony, electric light and power were barely a decade old [and] the latter field was booming". The electronics industry was growing tremendously and the General Electric Company had just increased its employment to 6,000 up 2,000 from just the previous year. The first electric elevator had recently been installed by the Otis Brothers and over 5,500 electric street cars were in service across the country in 1891.

Cory immediately began teaching courses in electrical engineering that were offered as electives to seniors in the College of Mechanics. The 1893-1894 academic year was Cory's first at Berkeley and was also marked by the University's first class entitled

[ii] In 1892-1893 there were only 58 faculty members on the Berkeley campus. There were 18 full professors, nine associate professors, 10 assistant professors, and 21 instructors and lectures. Thus Cory's position of assistant professor may indicate the importance of his duties in establishing electrical engineering. (Stadtman 1967, 269)

‘Electrical Engineering’ which included a lecture, laboratory, and design component according the University Register for that year[12]. The design and laboratory component of the class is significant for it indicates that from the beginning, Cory sought to introduce innovation into electrical engineering at Berkeley. This ‘electrical engineering’ class was offered as an elective to senior students in the College of Mechanics, who could chose between it or the more traditional Mechanical Engineering and drafting classes. By the 1897-1898 academic year, this one ‘electrical engineering’ elective was replaced by five non-elective courses, according to the University Register[13]. These classes were grouped under the titles of ‘Electrical Engineering’ or ‘Electrical Machinery and Construction.’ The University Register shows that Cory alone taught these classes for the first years of their inception. Cory offered courses that had direct practical applications to California’s industry’s needs and the problem of transmitting hydroelectric power from the Sierra Nevada to the coastal cities. The course description of ‘Electrical Machinery and Construction 10a/b’ includes: “… applications to electric lighting and power distribution. The location and construction of electric lighting, telephone, telegraph, and power circuits and electric street railways.” Another course, ‘Electrical Engineering 11b,’ specifically dealt with “long distance power distribution … and other applications of electricity for industrial purposes.”[14] In these classes, Cory presented solutions to California’s two main problems: getting power to the cities and efficiently using that power for lighting, communications, and transportation. Thus we see that Cory kept electrical engineering very practical and tied to the state’s immediate needs. Cory’s five electrical engineering courses accounted for approximately 30 percent of the College of Mechanic’s offerings around 1900.[15]

As a new field, electrical engineering lacked long standing traditions or a professional culture, notes the historian Monte Calvert.[16] However, it soon found an identity in the corporate culture. Large electrical manufacturers like Westinghouse and General Electric became closely integrated with the educational system. "General Electric had direct control over the most prestigious avenue of postgraduate electrical engineering education in the United States [in 1900]," writes Kline[17]. The University Registers shows that the College of Mechanics chose not to compete with this system and offered few graduate classes. Instead Cory created a program that placed an emphasis on the fundamental principles of electrical engineering. A survey by the Society for the promotion of electrical engineering of 18 electrical engineering curricula in 1899 revealed that only four schools required a course in differential equations: MIT, The Armour Institute, Ohio State, and the University of California.[18]

At the same time that Cory was pioneering the undergraduate curriculum, he and Joseph LeConte were also establishing the new Electronics Laboratory that would serve as center for electrical engineering research. The University provided $63,000 to construct 41,600 square feet of floor space in the new Mechanics Building.

Figure 4: A View of the New Mechanics Building in 1912, Courtesy of Steve Finacom[19]

With its completion in 1894, Cory and LeConte installed a range of mechanical and electrical equipment. To provide power to the lab, they installed a 100 horsepower boiler that was fueled by coal. The main piece of electrical equipment was a 20 kilowatt, 120 volts direct current (DC) Edison bi-polar machine. Other experimental generators were powered by a 50 horsepower engine that received its energy in the form of steam from the central boiler. The laboratory also contained many other small DC and AC generators, measuring devices such as galvanometers, and a sixty-cell storage battery that discharged 25 amperes.[20] According to LeConte, "The installation of electrical equipment [in the lab] was surpassed by few universities of the country."[21] Running such a lab, especially with boilers and engines, necessitated the hiring of a plant engineer and fireman. Further, the senior class was also expected to assist with the laboratory's operations.

Cory immediately utilized the new laboratory to meet "the growing demand for electrical power in many of the Scientific Departments [of the University] such as Physics, Chemistry, and Mining,"[22] according to LeConte. He and Cory ran wires from their Electrical Laboratory to South Hall and the library to provide electricity for arc lamps. Their efforts also provided the University with its first ever lighting system and put a new meaning to its motto: "Fiat Lux." However, early arc lamps were unreliable; LeConte and Cory were often called upon to repair the system, even at night. "I remember one night when President Kellogg was giving his annual reception, three lamps went out of action at critical locations, so that we [Cory and I] in our dress suits climbed the poles and got them going while on our way to the reception," wrote LeConte in his proto-history.[23]

Cory's efforts to bring electricity from his lab to the campus served as a microcosm for the lab's true goal of bringing electricity from the Sierra Nevada to the cities. In a 1900 paper in the *Journal of Electricity, Power, and Gas* entitled "Regulation in Long Distance Transmission," Cory analyzed the 150 mile long high voltage line that brought power from the Mokelumne River to San Francisco. After calculating the lines' parameters, he made suggestions on the best ways to increase its efficiency.[24] Cory also studied alternating currents and published a paper in the same journal in 1899 entitled "Regulation of Alternating Currents," in which he explored the relationship between the power factor and demagnetizing current in alternators.[25] Graduates of Cory's program continued the lab's work. In his memoirs, Robert Sibley writes, for instance about, "Herbert A. Barre, '97, pioneer in long distance high voltage transmission of electric power" and "James B. Black, '12, who has carried agricultural electric power distribution to new heights by securing private investment of over a billion dollars, a world record achievement of this kind."[26] Cory's research program addressed the needs of California and improved the efficiency and range of long distance power transmission.

But power transmission was not the only factor that limited the electrification of California. Gas cost half as much as electricity in 1890 and continued to challenge electrical engineering technologies through the early twentieth century. Around 1900 electrical engineers were creating quiet and clean electric vehicles that could travel 100 miles between charges.[27] But the lack of charging stations and especially the advent of Ford's more economical gasoline powered Model T spelled the end of this technology. The high cost of electricity also limited its accessibility to the home, and in 1915 only 25 percent of Americans homes were electrified. Historian Kline writes, "There was too much capital investment in the older [gasoline based] system of steam engines, belt shafts and, pulleys,"[28] and the high cost of electricity did not encourage a rapid conversion. Thus while city utilities, electric railways, and large manufactures created a demand for and could afford electricity, many individuals could not.

Cory understood the significance of this economic problem, and his colleagues noted that "he early recognized the responsibility and relation of power and light companies to the public and his outstanding engineering contributions were the solutions of problems involving true appraisal of public utility properties and equitable rates for power and light."[29] Believing that the best way to keep apace with the rapidly growing electrical industries and to understand their needs was to become an active participant, Cory spent 1901 on sabbatical in San Francisco forming his own engineering consulting company, 'Cory, Meredith, and Allen,' wrote fellow faculty.[30]

Between teaching, research, and consulting, Cory still found time for leisure. The Cory family house was located on College Avenue on a block then just southwest of the campus at the present site of the Calvin Lab.[31] According to Finacom, "The LeContes, Dean Christy of Mining, and Professor Slate of Physics lived on the same city block bordered by College, Piedmont, and Bancroft, putting Cory in close personal proximity to some of the leading faculty in fields related to his own."[32] Married to Mayme Pritchard Cory; they had one daughter, Marian Elizabeth Cory. In the memories of his colleagues, "Cory was a devoted lover of nature. Nearly every weekend found him tramping the hills of Marin County with a small group of close friends, and many of his summer vacations were spent with pack train in the High Sierra."[33] Exhibiting a more adventurous side, Cory and LeConte climbed many mountains in the Sierra Nevadas. In 1898, the two were the first to ascend the 13,163 ft peak of Red Slate Mountain in the Sherwin Range of the Sierra Nevada[34]. Such expeditions also had a pragmatic side and Cory and LeConte scouted new sites for hydroelectric plants which would later prove "valuable," according to fellow faculty[35]

Figure 5: A view of Red Slate Mountain's peak, first ascended by Cory and LeConte in 1898. [36]

Section 3:

Cory's Leadership of the Department of Mechanical and Electrical Engineering

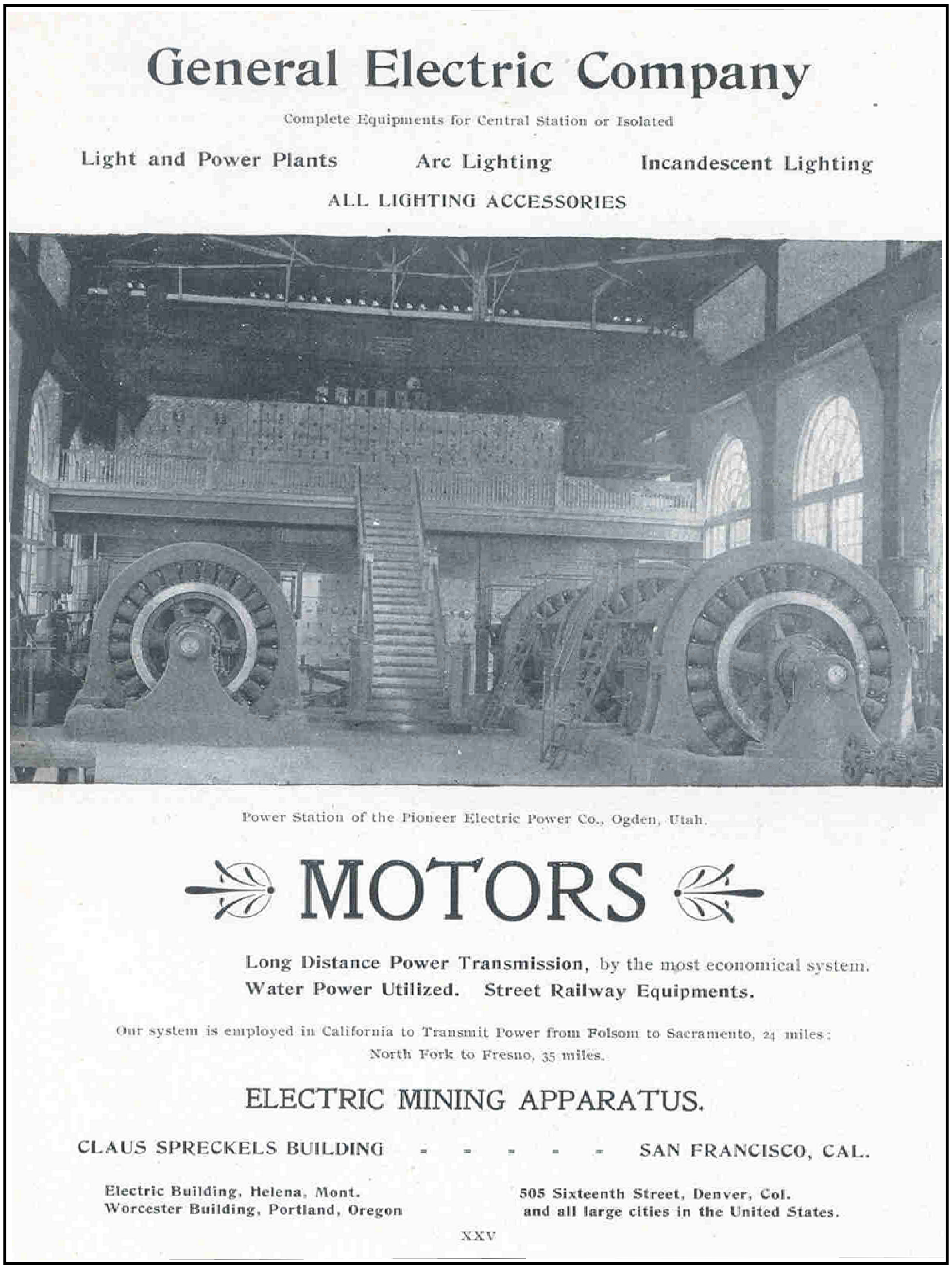
By 1900 the study of electrical engineering was rapidly evolving. The famous electrical engineer Steinmetz introduced the complex number representation in 1897 to greatly simplify the mathematics required to solve the differential equations associated with alternating currents. The rise of graphing techniques also replaced the need for exact solutions to challenging equations. Electrical engineers began their own research into the material properties and laws of motors, current, inductors and hysteresis that were more relevant and applicable to their problems than the work of physicists. Thus the multifaceted Department of Mechanics that had originally provided strong support for electrical engineering at Berkeley may longer have been as pragmatic or beneficial as it had been just 10 years before. Perhaps in response to these and other changes in the field, the University reorganized the College of Mechanics and created inside it the Department of Mechanical and Electrical Engineering in 1903[iii].

To lead the College of Mechanics and the new Department of Mechanical and Electrical Engineering, Hesse chose Cory as his replacement as Dean in 1901. The department that Cory took over did not feature the diverse faculty of the old College of Mechanics and only included professors, instructors, or assistants with engineering backgrounds, as evidenced in the University Register of 1903-1904[37]. Although the name of the department might have seemed to imply equality between electrical and mechanical engineering, the department employed more faculty and offered more courses in mechanical engineering. Although it initially may seem odd to have both mechanical and electrical together in one department, it was a wise move as the two fields remained closely allied in 1900. The massive hydroelectric plants that produced the electricity were mechanical engineering feats with large rotating turbines and hydraulic machinery as seen in Figure 6 on the next page. While electrical engineers innovated transmission of that electricity to the cities, they worked with closely mechanical engineers to create new motors for electric railways, transformers to step up and down voltage, and other practical electromechanical technologies. Cory himself, as we saw, was trained as

[iii] The reorganization of the College of Mechanics appears to correspond with University President Benjamin Ide Wheeler's success in securing new income from the State in 1901. This period in the University's history has been characterized as an "era of growth" in which many departments exanded, according to the historian Stadtman . (Stadtman 1967, ch13)

mechanical engineer and worked on projects that drew equally upon both sides of his engineering knowledge.

Figure 6: An image of a hydroelectric plant, taken from an advertisement in the 1899 *Blue and Gold Year Book*, underscoring the need for collaboration between mechanical and electrical engineering.



As Dean of the department, Cory found himself thrust into a new administrative role. Serving on the Student Affairs Committee, or Discipline Committee, "his sympathetic cooperation with and energetic support of the student organizations founded after the introduction of student self-government by President Wheeler, serve as bench marks in the history of faculty-student relations at the University of California," noted colleagues[38]. Cory also received all inquires from companies and other universities interested in hiring students from the Department of Mechanical and Electrical Engineering. California Polytechnic wrote to Cory in 1915 asking if he knew of a qualified "lighting engineer for the city of San Luis Obispo,"[39] while Harvard inquired into anyone interested "in undertaking computation of a new set of logarithms", and the University of Colorado for a young engineering graduate qualified as an instructor in mechanical drawing and descriptive geometry. Cory replied personally to most of these requests. Serving as the primary contact between the university and industry, his opinion was valued by companies such as General Electric, which always sought Cory's recommendation in their hiring of students.

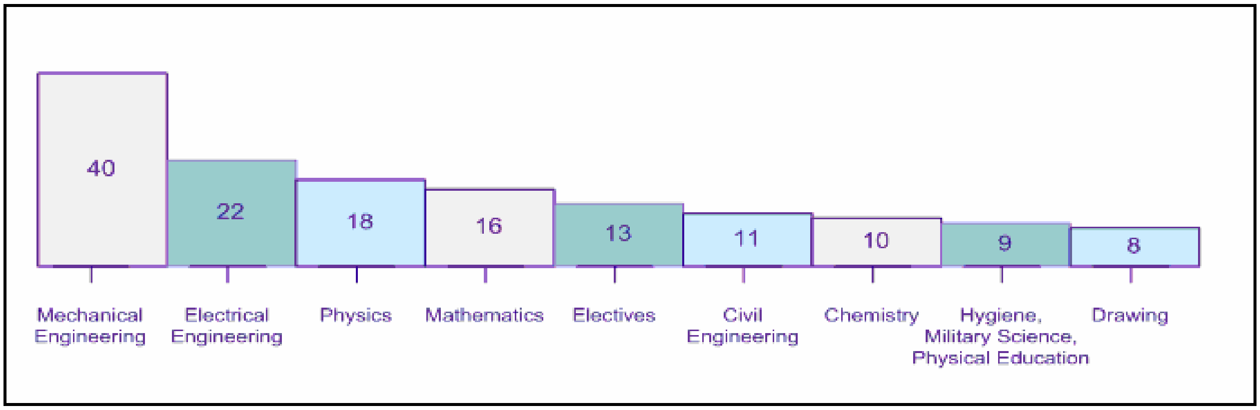
But such duties began to take their toll on Cory as he was able to devote less time to his research, teaching and consulting. In January of 1909, Cory wrote an "absolutely confidential" letter to MIT complaining of his position at Berkeley. "I cannot say that I have enjoyed being the chairman [of the Student Affairs Committee] … and while I have been glad to assist the University in connection with the building and operation of its plant, yet I often felt that the Professor of Greek was very lucky as compared with myself, since, though he might have troubles, they were certainly less numerous than mine,"[40] expressed Cory. He continued, "I have thought only with pleasure of becoming a member of your department, and, while I should always hope to do my share of faculty committee work, I am certain that to be relieved of the work involved upon a Dean of a department or College and also the responsibility connected with the extension and operation of a university power plant would consummate my secret hope for a number of years." Cory was clearly dissatisfied with being the Dean of the Department of Mechanical and Electrical Engineering, but he did not leave Berkeley and would continue in that role for another 21 years. Not enough relevant documents have been found to answer the question of why Cory chose to stay and a whole gamut of speculations is possible. In his letter, Cory stipulated that MIT should match his salary, provide him with interesting work, and allow him to continue his consulting firm. As the historian John W. Servos explains in his article "The Industrial Relations of Science: Chemical Engineering at MIT, 1900-1939", many MIT professors were involved with consulting at the time. Thus either MIT could not match Cory's Berkeley salary or was unable to offer him more interesting work. Regardless of the reasons, the incident provides a rare glimpse into Cory's personal opinions and underscores that he preferred academic duties over administrative.

Cory kept his research apace with the rapid changes in electrical engineering technologies through the 1910s. As long distance power transmission became a realizable goal, research switched from creating new electrical technologies to improving those already in existence. In 1915 Cory wrote to Cornell University to obtain information regarding sending two alternating currents through the same conductor by varying frequency as he believed such would "produce the maximum economy in copper for any given total loss in transmission." [41] The fact that electrical engineers had the time to study these important yet minor problems reflects a new confidence and security in their methods of high voltage power transmission. When Cory was asked about the most significant research undertaken by the laboratory in 1916, he responded that “the most important research work … had to do with the possible dispersion of fog with the use of very high-voltage, high-frequency discharge.”[42] Fog, endemic to San Francisco, was another minor problem in transmission as it caused a slight loss in efficiency due to current leakage.

Research that made high voltage transmission more efficient also made electricity cheaper, and by 1915 the public began to see its potential. An article of the *Ladies Home Journal* published that year entitled “You Will Think This a Dream” described a near future where electricity would “cook all meals, heat and cool temperature-controlled homes, run industry and propel all forms of transportation.”[43] Prominent electrical engineers like Steinmetz supported such utopian visions, claiming that “the means for all these things are here now.”[44] Combined with the standardization of outlets and plugs in 1915, sales of household electronic items doubled from $24 million in 1915 to nearly $48 million in 1916. These new demands for even more electricity kept Cory and other electrical engineers striving to further increase efficiency and lower costs.

While advancing research, Cory did not neglect his teaching duties and continued to update the curriculum. However, he believed that a strong foundation in mathematics and science was the best training for an electrical engineer. “Owing largely to Cory’s influence, curriculum requirements in mathematics, physics, and mechanics were raised to higher levels,”[45] writes Robert Seidel in an informal survey of the program.

Figure 7: The 147 Units Required for Electrical Engineering in 1916 according to a letter sent from a faculty member in request to a inquiry from the University of Arizona in that same year[46].



The undergraduate program in electrical engineering for 1916 is presented above in Figure 7 where each semester unit corresponds to one hour of instruction and two hours of student preparation. Mechanical engineering, drawing, and civil engineering together composed 40 percent of the curriculum, indicating that the electrical engineering was still heavily tied to these above fields. However, the stability that the electrical engineering program had finally found was soon to be shaken.

The advent of World War I and the Unites States' entry in 1917 quickly changed the Department of Mechanical and Electrical Engineering from an important research and teaching institute into what Cory aptly titled a "versatile war laboratory." By November of 1917, the draft took many engineering students from the classroom and into the trenches. Worried that the "next draft will take all engineering students 21 and over … and practically close every single engineering college in the country," the Case School of Applied Sciences sent a letter to Cory and the President of the University, asking them to sign a petition to the Secretary of War.[47] Although we do not know whether Cory or the

President signed the petition, it would have been irrelevant for electrical engineering at Berkeley, as Cory himself soon left to serve as a consultant and assistant director of The Nitrate and Powder Plants in West Virginia which produced explosives. The production of nitrates involved large amounts of electricity and Cory thus was put in charge of power production.[48]

Just as the US Government virtually nationalized of the country's telegraph, railway, and agriculture industries through the War Industries Board, it also took control of the Department of Mechanical and Electrical Engineering.[iv] The government established a Radio School and Shipping Board School at Berkeley that made use of the department's labs and faculty. One of the newly hired junior professors, G.L. Greeves, provided all necessary instruction to the Radio School's 240 men in radio transmission, elementary telegraphy, telephony, circuit work, and code practice.[49] It seems surprising that a junior faculty member was put in charge of such a task, but there was no one else in the department qualified to teach the subject. The incident foreshadowed the growing importance of radio in electrical engineering as well as the department's lack of resources devoted to it.

[iv] University President Wheeler received the approval of the Regents in his request "to offer the war department such use of the grounds, buildings, and equipment at Berkeley and Davis as may accord with the plans and needs of the department in the training of troops." (Stadtman 1976, ch13)

Section 4:

New Research Directions for Department of Mechanical and Electrical Engineering and the Initial Response to Radio

The Department of Mechanical and Electrical Engineering quickly returned to normal with the conclusion of the war as Cory and the engineering students returned to Berkeley, replacing the Radio and Shipping Board Schools. Cory was pleased for the department to inherit much of the machinery, including three new steam engines, a steam turbine, a steam boiler, various internal combustion engines, as well as a 14,400 square foot wooden Mechanics Annex building that these schools left behind. Yet instead of using these resources to formally establish radio at Berkeley and build upon the work done during the war, Cory utilized them to "make possible investigation and research work directly related to important power problems."[50]

However, as Berkeley, other universities, and industry all continued to investigate power transmission they began to notice diminishing returns. By the 1920s, high voltage power transmission was a well studied problem and field was forced to turn in new directions as the electrical industry entered a post-war slump in 1922. The General Electric Company wrote to Cory in that year expressing that "we have reduced their forces extensively and are running below output."[51] Instead of recruiting students for their hydroelectric or power transmission divisions, they asked Cory to recommend graduating seniors possessing a knowledge of fractional motors, small transformers, small generators, battery charging equipment and farm lighting equipment. Supplying electricity no longer concerned General Electric as much as finding applications for its consumption. As electricity became more plentiful and affordable to the average consumer in the 1920s, electrical engineering found itself catering no longer to the large private utilities and street railways but rather to individuals desiring innovative ways to use this new source of energy. By 1920, over half of all urban residences had electricity and more importantly, the capital investments in the older steam engine, belt shafts, and pulley technologies were finally no longer economical. In addition to homes, factories quickly began to electrify and created a further demand for practical applications of electrical engineering.

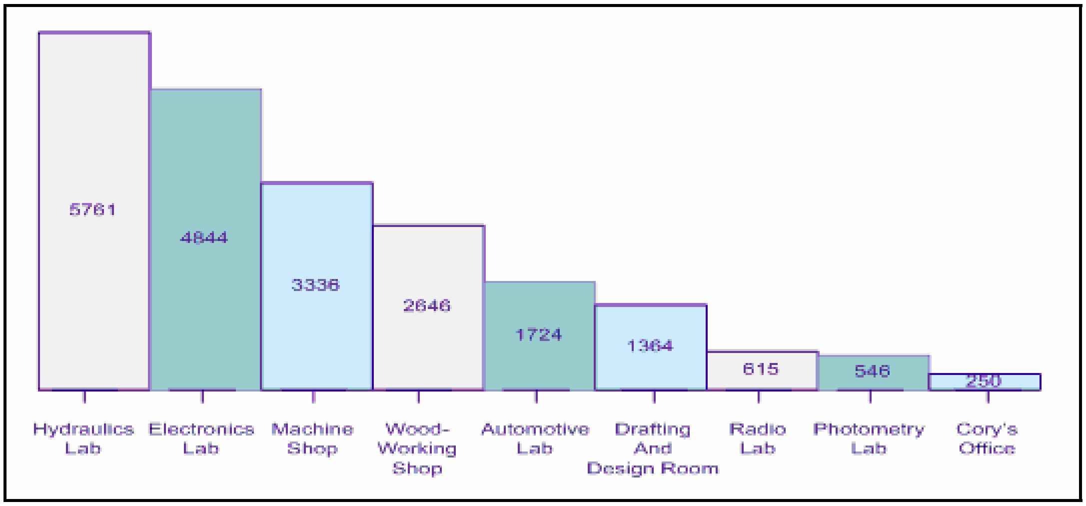
Cory seems to have anticipated this shift, for Berkeley electrical engineering quickly assumed research roles in this new direction. Berkeley's electrical engineering labs became responsible to the State Highway Department in 1919 for work in testing automobile headlights. The product of this research was detailed candle power and adjustment tables that quantified the requirements for reliable and safe headlights. According to Cory, "not only the design and efficiency, but also the cost of manufacturing [headlights] has been materially reduced.[52] While automobile headlights may not have been as inspiring as the lofty power lines that stretched from the mountains to the sea, headlights were only a small part in a new more broad research plan that included everything from airplane engines to shipbuilding. The poster in Figure 8, from the General Electric Company, found in the 1921 edition of Berkeley's *Blue and Gold Year Book*, gives a good impression of what was considered a relevant topic in electrical engineering for the early 1920s. From the hydroelectric plant at the top of the illustration to the car at the bottom, General Electric depicted relevant applications of electrical engineering technology. Most of these technologies, such as the ship, locomotive, textile factory, and vacuum cleaner, were applications of electrical technologies that would have been of interest to newly empowered consumers or companies.

Figure 8: Advertisement by General Electric on Page 619 of the 1921 *Blue and Gold Year Book*

With electro-mechanic technologies in high demand, the Department of Mechanical and Electrical Engineering appeared to have a perfect foundation further innovation. Cory was excited by what he considered "the two most noteworthy developments of perfecting the automobile and transportation through the air."[53] Thus neither Cory nor the department had significant interest in the nascent field of radio, which must have appeared as mere distraction compared to the advanced electro-mechanic technologies of the 1920s. This lack of interest in radio is best exemplified in a series of personal letters between Cory and the General Electric Company. In 1924 the General Electric Company farsightedly wrote to Cory explaining that "right at this time we are especially striving to inspire interest in radio."[54] To recruit students into their radio department, General Electric offered immediate lab positions bypassing the company's 'Student Engineering Courses' usually required of new college recruits. Further, General Electric promised to allow students hired into the radio department the ability to easily switch to more traditional positions in the company after nine months if they were dissatisfied for any reason. Yet despite these benefits, Cory could only recommend one student in the entire graduating class who might be both interested and qualified. In the recommendation for this student, Mr. Mayers, Cory was forced to admit that Mr. Mayers had not completed a single class in radio but instead was "enthusiastic" about the topic. Why was there so little interest in field of radio among Berkeley electrical engineers?

As L.A. Geddes writes in his history of Purdue's electrical engineering department, "following WWI, Purdue and other schools of electrical engineering found that they had two kinds of students, '60-cycle students' and 'odd-ball-students.' From before the war until the mid-1930s, electrical engineering continued to be dominated by the problems associated with 60-cycle power generation, distribution, and utilization. However, the future was to belong to the odd-ball engineers who had an interest in things that could be done with vacuum tubes such as radio."[55] But the future Geddes refers to was not in the early 1920s when neither Cory nor Berkeley's electrical engineering students viewed radio as a topic worthy of serious study. In the 1920s, the focus of electrical engineering was on more tangible electro-mechanical devices desired by both industry and consumer. Further, the union of the mechanical and electrical engineering in a single department further retarded the growth of radio at Berkeley, as such a topic would not promote harmony between the two fields. Electrical engineering grew allied to and in support of mechanical engineering and thus Cory promoted research and study in electrical topics with integral applications to mechanics. Indeed, Cory himself was educated as a mechanical engineer and mechanics composed over 50 percent of the faculty in the department in 1923-1924 according to the University Register for that year[56]. Radio failed to fit well as a research topic as it was a purely electrical technology that was largely independent of mechanical engineering. Evidence of the scare resources allocated to radio research may be seen in Figure 9 below, which presents the floor space division in the Mechanics Building in 1924.

Figure 9: Lab Space Allocation in Square Feet in the Mechanics Building in 1924 as Presented in a Survey of the Physical Needs of the Campus for that year[57].

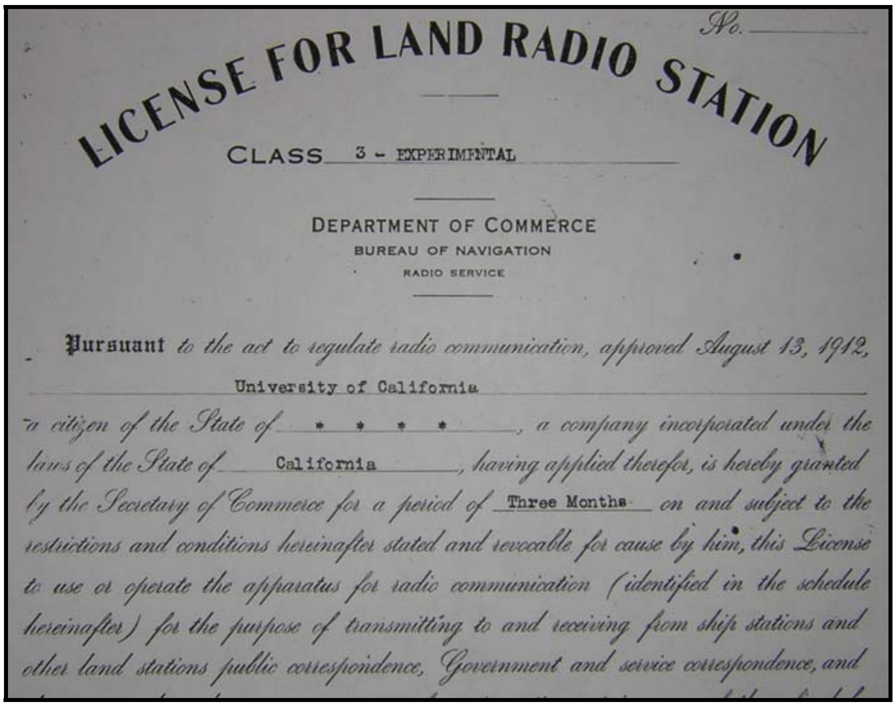


The above figure shows that the size of the radio lab was only two and one half times larger than Cory's own office and approximately eight times smaller than the Electronics Lab, where projects like headlight testing and high voltage transmission characteristics were carried out. The small lab space allocated for radio research may indicate the low priority or emphasis that Cory and the department placed upon it. A further important point revealed from Figure 9 is the smaller total square footage allocated for electrical engineering research as compared to that of mechanical engineering research with such facilities as the Hydraulics Lab, Machine Shop, and Wood Working Labs. Mechanical engineering was clearly the dominant component of the Department of Mechanical and Electrical Engineering. Thus researching a purely electrical topic void of mechanics would have been a challenge.

But the topic of radio was not completely ignored as Robert Seidel has suggested in his review of the department. Assistant Professor G.L. Greeves, who had headed the war Radio Board School, now led radio instruction and research at Berkeley. After much contemplation evidenced in correspondence between Greeves, the University President, Cory, and other faculty, in 1923, the Department of Mechanical and Electrical Engineering agreed to purchase a used radio set from the Extension Division for 800 dollars.[58] The purchase was motivated by Greeves' complaint that "under present conditions the [radio] laboratory is very poorly equipped and in general no more than one type of very simple experiment can be conducted at one time, and then only with considerable difficulty and undue loss of time."[59] A few months after Greeves took possession of the radio set, the Director of the Bureau of Standards in the Commerce Division of the U.S. Government wrote to Cory. In the letter, the Director, Mr. George K. Burgess, wrote, "In extending our work of transmitting standard frequency signals to cover the entire United States, it is desirable to establish a station on the Pacific Coast which would transmit. We would like to interest some school or college in this work as the precise measurements necessary would probably be made there more carefully there than anywhere else."[60] Cory quickly accepted the above proposal and in 1923 Berkeley was issued a class 3-experimental license for a land station, which may be seen below in Figure 10 on the next page

When the radio station was not being used for broadcasts, the Department of Mechanical and Electrical Engineering was authorized to conduct research and testing according to the provision of the above license. The products of such research have not yet been evidenced in any archival documents. However, whatever radio research was conducted was done without the aid of any journals; for only in the 1930s did an electrical engineering professor make a request to the library for a subscription to a radio research journal, *The General Radio Experimenter*.[61]

Figure 10: Top portion of the License for Land Radio issued to the Department of Mechanical and Electrical Engineering in 1923 found in the Radio Folder of Box 5 in the Records of the College of Engineering.



No. ______

LICENSE FOR LAND RADIO STATION

CLASS 3 - EXPERIMENTAL

DEPARTMENT OF COMMERCE
BUREAU OF NAVIGATION
RADIO SERVICE

Pursuant to the act to regulate radio communication, approved August 13, 1912, University of California a citizen of the State of * * * *, a company incorporated under the laws of the State of California, having applied therefor, is hereby granted by the Secretary of Commerce for a period of Three Months on and subject to the restrictions and conditions hereinafter stated and revocable for cause by him, this License to use or operate the apparatus for radio communication (identified in the schedule hereinafter) for the purpose of transmitting to and receiving from ship stations and other land stations public correspondence, Government and service correspondence, and

Greeves also led Berkeley's two radio courses, EE6A/B and EE115A/B. EE6A/B, 'Elements in Radio Communication,' was a popular class and had an enrollment of 63 students in 1922. Greeves' reported breakdown of students in the class by year and concentration is shown in Figure 11 below[62].

Figure 11: Breakdown of Students Enrolled in EE6A/B in 1922 by Year and Concentration as reported by Greeves in a letter that year.

	Sophmores	Juniors	Seniors	Total
Electrical Engineering	27	11	4	*42*
Mechanical Engineering	11	2	1	*14*
Chemistry	1	1	4	*6*
Letters and Sciences	0	1	0	*1*
Total	*35*	*15*	*9*	**63**

Figure 11 shows that radio was dominated by electrical engineers who composed approximately 66 percent of the class. But more significantly, younger students enrolled in larger numbers, perhaps indicating that younger generations of students were beginning to view radio as a more important topic. However, the students affinity towards radio may be called into question given the fact that the department's other radio class, EE115A/B, 'Advanced Radio Engineering,' was not offered in 1920/21 or 1921/22 due to a lack of interest and would subsequently be rarely offered.

While students may not have been drawn to radio at Berkeley, they were still attracted to the more traditional field of study offered Department of Mechanical and Electrical Engineering. While specific undergraduate enrollment in electrical engineering alone is unknown, the annual President's Reports do indicate total enrollment in the Department of Mechanical and Electrical Engineering was constant around 600 students.

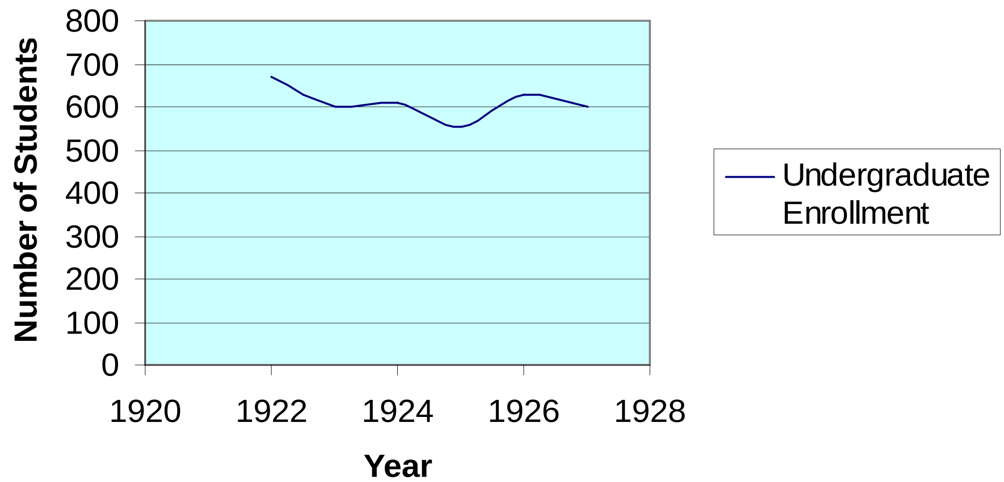
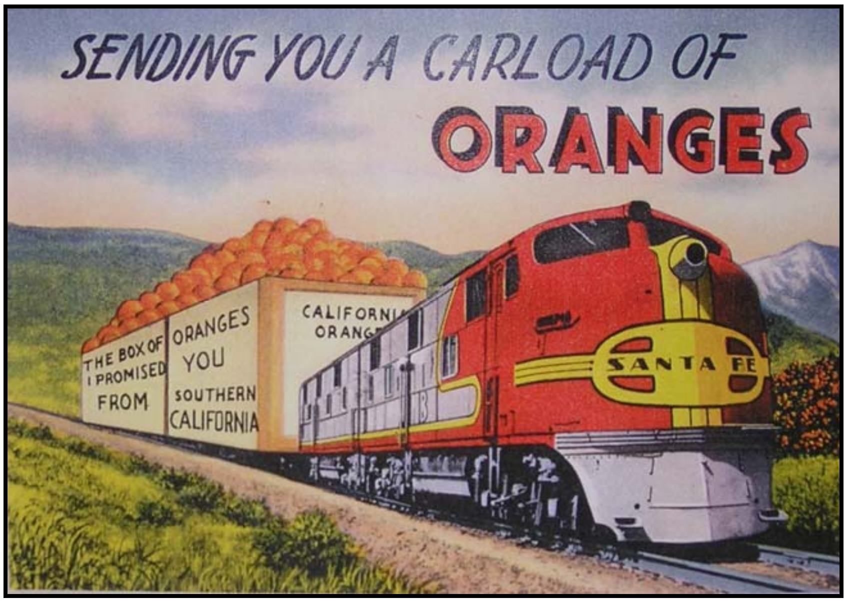


Figure 12: Undergraduate Enrollment in the Department of Mechanical and Electical Engineering versus Year. The data is from the department's annual President's Reports

However, Cory noted that "many students enter from junior colleges in California and other states and countries in order to complete their upper division work. As a result, the number of students enrolled in third and fourth year classes offered by the Department of Mechanical and Electrical Engineering exceeds the number of student in the College of Mechanics who take the required second year courses in Math, Physics, Electrical Engineering, and Shop Work."[63] This glut of students in third and fourth year courses was a problem, as the majority of upper division courses, especially in electrical engineering, were lab based. Undergraduate instruction took up so much lab space and time that the department was unable to significantly increase graduate student enrollment in the later 1920s simply due to lack of space. As Cory bluntly wrote to the President in 1928, "The floor space is adequate for the needs of undergraduates but not well adapted for graduate or faculty research work."[64]

Faced with this influx of students, Cory nevertheless managed to ensure that the Department of Mechanical and Electrical Engineering continued its research efforts. In maintaining the original purpose of the old College of Mechanics, Cory clearly encouraged investigations into topics relevant to industry. Cory's 1926 report to the President of the University was entitled "Services the Department of Mechanical and Electrical Engineering has rendered to organizations in California."[65] The report described 45 industry related projects conducted from 1923 through 1926. Of these 45 projects, approximately only one third were related to electrical engineering, reinforcing the hegemony of Mechanical Engineering in the department. The main research avenue of the electrical engineers at Berkeley remained in electro-mechanical technologies. The department conducted work, for instance, for the Pacific Fruit Express Company, the Southern Pacific Railroad, and the Santa Fe Railroad on electrical operated refrigeration plant. It also investigated lighting efficiency for the Bureau of Supplies in San Francisco and tested devices made by the General Electric Company, Westinghouse Electrical and Manufacturing, the Western Electric Company, the Pacific Telephone and Telegraph Company, and the American Telephone and Telegraph Company. Other investigation according the 1926 report were "electric power operated dry docks" and testing of "the new turbo-electric power generating plant installed at the U.S. mint in San Francisco." These research efforts of the department show that most electrical engineering was still done in conjunction with or applied to mechanical engineering projects. There is little evidence of research hoping to advance the field of electrical engineering itself instead of aiding applications to mechanical engineering as had been the case since the electrical engineering's inception at Berkeley. And again, the topic of radio was notably absent, indicating that Cory did not deem it of serious interest to industry. Nevertheless, electrical engineers in the early 1920s made significant contributions to the automobile, lighting, railroad and shipping industries.

Figure 13: Although the EMD E1 locomotive in the picture would not be built until 1937, the railways could only begin efficient transportation of fruits after the installation of electrically operated refrigeration plants as investigated by the department. The illustration is from the author's collection.[66]



Although Cory clearly encouraged research that paralleled industry goals, he was also very clear in drawing the line between the University and industry. In 1923, West and Company of Philadelphia offered the department the rights to hold and use the company's new hydraulic technology in the Mechanics Building with the understanding that the machinery would remain the property of West and Company. Supported by the President of the University, Cory gracefully yet forcefully replied that "the University should have complete control of the equipment in our laboratories. We are glad to co-operate with industry, but the University will not furnish to manufactures written statements of the performance of the apparatus [or permit product demonstrations]"[67].

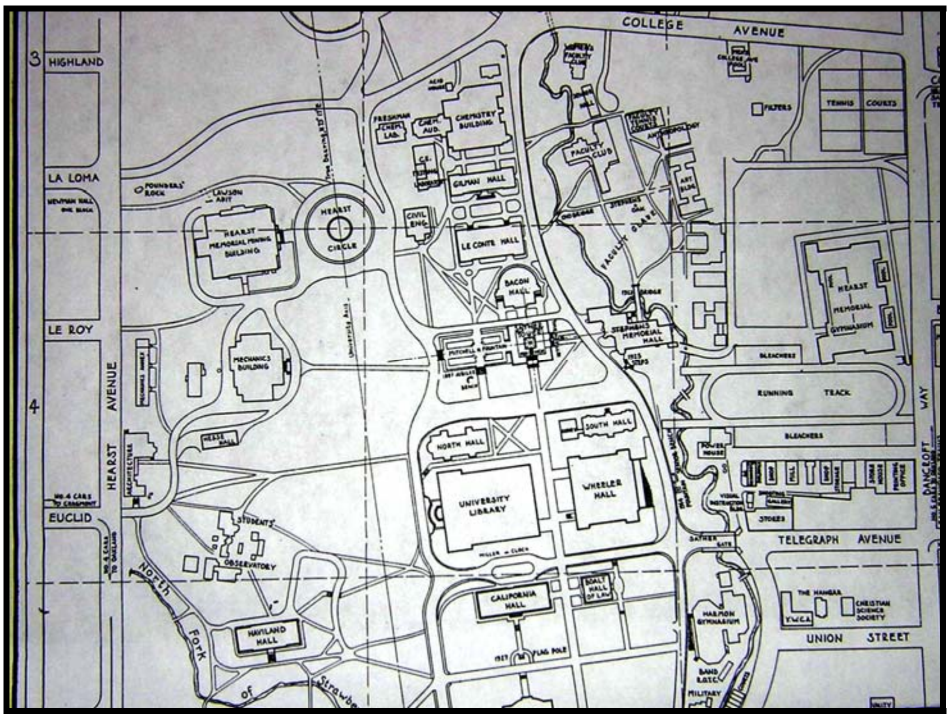
Cory clearly believed that the College's labs should remain autonomous and must not become dependent or controlled by industry, even if such a stance meant refusing to work with the newest technologies.

As the 1920s progressed, research clearly had become integral to electrical engineering at Berkeley. "Science is now advancing at a rate so rapid, that no industry can long ignore the importance of research and survive," wrote Cory to the *California Engineer* in the mid 1920s. However, a note of caution must be added about the word 'research' in the context of pre World War II electrical engineering. Professor David A. Hodges, an emeritus professor of the Electrical Engineering and Computer Science (EECS) department, who has written a short, later history of the department, explained that "before WWII, much Electrical Engineering research was empirical and involved compiling better tables from which an engineer could look up values and only after the war did the more scientific side of research emerge."[68] An example of such empirical research that Professor Hodges refers to may be found in the many editions of Reference Data for Radio Engineers[69] book, which he states many electrical engineers contributed to and relied upon.

To facilitate further research, Cory petitioned the Regents for construction of a new building for the Department of Mechanical and Electrical Engineering. In response, Hesse Hall was constructed in 1924 to provide space in which a new power, laboratory, motor and generator test room, and radio laboratory were established. With much of the bulky machinery now moved out of the Mechanics Building, more electrical engineering lab and classroom space became available.

The 1930 map of U.C. Berkeley in figure 14 indicates the positions of the Mechanics Building and Hesse Hall with respect to the rest of campus. These building may be seen on the middle left side of the map.

Figure 14: <u>Map of the Campus of the University of California, obtained from the Records of the College of Engineering</u> [70]



Section 5:

<u>Cory's Departure and the Separation of Mechanical and Electrical Engineering</u>

But Cory's research plan was cut short as change came suddenly to the Department of Mechanical and Electrical Engineering. In 1928 Cory was diagnosed with cerebral arteriosclerosis and his condition deteriorated rapidly. Faculty member Morrough O'Brien wrote that when he joined the department in 1928, Cory was "ill mentally, gone to pieces with age. The real director was Associate Dean Baldwin Woods in the president's office, who had to approve the budget."[71] Whether O'Brien was exaggerating Cory's condition or not, as cerebral arteriosclerosis does not necessarily correspond to mental illness, the fact remained that Cory was unable to take an active role in the department's decisions and leadership. Perhaps the disease had taken its toll on him even before 1928, as the archives begin to show fewer records of his activities past 1926 and Cory's name appears less frequently. With new faculty, practically Woods and Boelter, in control, the coexistence of both mechanical and electrical engineering in a single department came into question. While Cory represented an earlier generation of engineers who had watched electrical engineering find support in and grow from mechanical engineering, newer faculty seemed more inclined to notice the differences between the two fields. Without the leadership of Cory to hold them together, mechanical and electrical engineering immediately began to draw apart.

The undergraduate curriculum in Electrical Engineering was demanding, as the students had to fulfill many Mechanical Engineering requirements in addition to their Electrical Engineering classes. However, in 1928 the Department of Mechanical and Electrical Engineering overhauled the undergraduate curriculum. The Committee on the Correlation of Work in Electrical Engineering noted that "a study of the outline for electrical engineering courses indicates that most of the applications of the principles have been made to machinery, particularly of the rotating type."[72] In a conscious effort to separate electrical from mechanical engineering, the committee proposed new syllabi for electrical engineering classes that would focus on purely electrical engineering applications such radio and communication lines.

Innovations in technology further increased the separation between mechanical and electrical engineering. As Geddes has written in his history of Purdue's Electrical Engineering department, "The 1927 development of heater cathode vacuum tubes made radio receivers practical. Before the heater cathode tube, radio receivers were battery operated. With the new heater cathode tube, radio receivers could be operated from domestic power lines and radio reception was available at any time by the flick of a switch." Unlike Cory, those now in charge of the department chose not to hold back research in radio and instead allowed it autonomy in exploring this new vacuum tube technology. This combination of autonomy and technology created enormous growth for radio. According to the President's Report for 1927, ten of the department's 17 'investigations and experimental research' projects were electrical engineering-related with mechanical engineering projects in the minority. While this reversal may in part be ascribed to the improvements in vacuum tubes, such a difference in research from the 1926 President's Report may also be the result of a conscious change in department's focus. In allowing electrical engineering to become unfettered from mechanical, the department realized the full potential of the field and immediately allowed electrical engineering to pursue non mechanical related research. The department's research interests in 1928 included "radio receiver design and loudspeaker cabinet design," "audio frequency filter systems," and "audio amplifiers," according to the President's Report for that year.

With radio suddenly a valid research topic, electrical engineering students and faculty found themselves working with a significant yet purely electrical topic that had few correlations with Mechanical Engineering. To become proficient in radio and the nascent communications field, which would soon include television as well, an electrical engineer no longer required a strong background in mechanical engineering. While Cory himself had maintained a balance of both fields, he was no longer in control or in the majority. The first step in separating mechanical and electrical engineering had come via the 1928 Committee on the Correlation of Work in Electrical Engineering but the second would be far more drastic.

Immediately prior to Cory's official retirement, The Committee on the Reorganization of the Engineering Colleges was formed in early 1930. The committee voiced the view that "a separation [of Department of Mechanical and Electrical Engineering into separate Electrical Engineering and Mechanical Engineering departments] would not be difficult…. [and is] advocated on the basis of the difference of work in electrical and mechanical engineering…and had not a single member of either faculty opposed to the separation."[73] On March 31, 1930, the Academic Senate unanimously approved this separation and Electrical Engineering became its own separate department.

Cory's reaction to the disbanding of the department that he had helped to create and lead for almost 30 years is unknown. He officially retired in 1931. A clear indication of the magnitude of change in electrical engineering over the 38 years of Cory's tenure at Berkeley is exemplified in a letter Cory received from Henry Ford's special representative inquiring whether he had "anything in the line of antique electrical equipment which might be gotten for a museum which is being built by Mr. Ford."[74] The equipment that Cory had used to found Berkeley's first electronics lab just 38 years ago was now prized by museums as radio raced electrical engineering into a new era.

While the technology that Cory pioneered may have been replaced, the work he conducted in founding electrical engineering at Berkeley, creating The Electronics Lab, and serving as Dean of the Department of Mechanical and Electrical Engineering for over 30 years was not forgotten or left unacknowledged. The generation of faculty that led after Cory's retirement, and death in 1937, sought to officially honor his achievements in 1950. Sibley wrote in 1952, that Cory "brought a marvelous spirit of enthusiasm to his work. So much so that the beautiful and wonderfully equipped new Electrical Engineering Building over back of the Mining Building has been christened in his memory--the Clarence Cory Building."[75]

Figure 15: An image of Cory Hall as it stands today, photographed by the author on May 20th , 2006.[v]

[v] Cory Hall was completed in 1950 at a then cost of $2,055,500, and paid for by State appropriation. The fifth floor is a later addition to the original structure. (Stadtman 1976, 54)

[1] Seidel 1974, 3.
[2] University Register, 1889-1890, 44.
[3] Kline 1992, 20.
[4] Kline 1992, 117.
[5] LeConte 1939, 8.
[6] University Register, 1880-1881, 60-61.
[7] *EECS History*, available from; http://www.eecs.berkeley.edu/department/history.shtml; Internet; accessed 1 February 2006.
[8] Kline 1992, 74.
[9] Completed Careers of Purdue Alumni, 1937.
[10] *EECS History*, available from; http://www.eecs.berkeley.edu/department/history.shtml; Internet; accessed 1 February 2006.
[11] Kline 1992, 26.
[12] University Register 1893-1894, 82.
[13] University Register 1897-1898, 193.
[14] University Register 1896-1897, 142.
[15] University Register, 1900-1901, 228.
[16] Quoted in Kline 1992, 27.
[17] Kline 1992, 173.
[18] Kline 1992, 41.
[19] Photograph courtesy of Steve Finacom. From a postcard in the *Album of Twenty-Five Views of University of California*. Souvenir Publishing Company, San Francisco.
[20] LeConte 1939, 15.
[21] *UC In Memoriam* 1937.
[22] LeConte 1939, 17.
[23] LeConte 1939, 18.
[24] Clarence L. Cory. "Regulation in Long-Distance Transmission," *Journal of Electricity, Power, and Gas*, no. 10 (1900): 6-13.
[25] Clarence L. Cory. "Regulation of Alternating Current Generators," *Journal of Electricity, Power, and Gas*, no. 8 (1899): 33-40.
[26] Sibley 1952, 124.
[27] Sulzberger
[28] Kline 1992, 126.
[29] *UC In Memoriam* 1937.
[30] *UC In Memoriam* 1937.
[31] Steve Finacom. Personal correspondence with author. Berkeley, Ca. 19 May 2006.
[32] Ibid.
[33] *UC In Memoriam* 1937.
[34] *Red Slate Mountain*. available from; http://www.absoluteastronomy.com/ref/red_slate_mountain; Internet; accessed 18 April 2006.
[35] Baldwin M. Woods, L. M. K. Boelter, George D. Louderback 1950.
[36] Wikipeadia. "Red Slate Mountain." available from; http://en.wikipedia.org/wiki/Red_Slate_Mountain; Internet; accessed 18 April 2006.
[37] University Register, 1903-1904, p246.
[38] *UC In Memoriam* 1937.
[39] Letter to Cory seeking a lighting engineer for the city of San Luis Obispo, 1915. Records of the College of Engineering, Bancroft Library, Box 1, California Polytechnic Folder, Berkeley.
[40] Letter to Professor Jackson of MIT from Cory, 9 January 1909. MIT Folder, Box 1, Records of the College of Engineering, Bancroft Library, Berkeley.
[41] Letter from Cory to Electrical Engineering faculty at Cornell, 1915. Cornell University Folder, Box 1, Records of the College of Engineering, Bancroft Library, Berkeley.
[42] Seidel 1974, 7.
[43] Cited in Kline 1992, 284.

[44] Ibid.
[45] Seidel 1974, 7.
[46] Letter from an unspecified faculty member in response to inquires by the University of Arizona, 1916. University of Arizona Folder, Box 1, Records of the College of Engineering, Bancroft Library, Berkeley.
[47] Letter to Cory and the President of the University in response to the draft for WW1, 24 November 1917. Case School of Applied Science Folder, Box 1, Records of the College of Engineering, Bancroft Library , Berkeley.
[48] *UC In Memoriam* 1937.
[49] Seidel 1974, 8.
[50] Seidel 1974, 9.
[51] Letter to Cory from GE in regard to a decrease in sales, 1922. GE Folder, Box 1, Records of the College of Engineering, Bancroft Library, Berkeley.
[52] President's Report of 1926 from the Department of Mechanical and Electrical Engineering, 1926 President's Reports Folder, Box 5, Records of the College of Engineering, Bancroft Library, Berkeley.
[53] Seidel 1974, 10.
[54] Letter to Cory from GE, 1922. GE Folder, Box 1, Record of the College of Engineering, Bancroft Library, Berkeley.
[55] Geddes 1998, 10.
[56] University Register 1923-1934, 185.
[57] Survey of the Physical Needs of the Campus, 1924. Aeronautics Folder, Box 2, Records of the College of Engineering, Bancroft Library, Berkeley.
[58] Letter in regards to purchase of radio equipment from the extension division, 1924. Radio Folder, Box 5, Records of the College of Engineering, Bancroft Library, Berkeley.
[59] Letter by Greeves complaining of the lack of resources allocated for radio, 1924. Radio Folder, Box 5, Records of the College of Engineering, Bancroft Library, Berkeley.
[60] Letter from George K. Burgess, Director of the Bureau of Standards, inquiring in regards to Berkeley's interest in radio, November 1923. Radio Folder, Box 5, Records of the College of Engineering, Bancroft Library, Berkeley.
[61] Letter from Professor L.F. Fuller asking for the library to subscribe to "The General Radio Experimenter," 1930. 'G' General Folder, Box 4, Records of the College of Engineering, Bancroft Library, Berkeley.
[62] Letter from Greeves in regard to his radio classes, 1922. Box 5, Radio Folder, Records of the College of Engineering, Bancroft Library, Berkeley.
[63] President's Report of 1926 from the Department of Mechanical and Electrical Engineering, 1926 President's Reports Folder, Box 5, Records of the College of Engineering, Bancroft Library, Berkeley.
[64] President's Report of 1928 from the Department of Mechanical and Electrical Engineering, 1928 President's Reports Folder, Box 5, Records of the College of Engineering, Bancroft Library, Berkeley.
[65] President's Report of 1926 from the Department of Mechanical and Electrical Engineering, 1926 President's Reports Folder, Box 5, Records of the College of Engineering, Bancroft Library, Berkeley.
[66] Image purchased from Just Imagine, Vintage Images. Santa Monica, California.
[67] Letter from Cory to West and Company in regards to the Allen Hydrautomatic, 1923. The Allen Hydrautomatic Folder. Box 4, Records of the College of Engineering, Bancroft Library, Berkeley.
[68] Professor David Hodges, interview by the author, Berkeley, California. 9 February 2006.
[69] Westman 1956.
[70] Section of a Map of Campus, 1930. 'R' General File, Box 5, Record of the College of Engineering, Bancroft Library, Berkeley.
[71] O'Brien 1988, 20.
[72] Notes from the Committee of Correlation of Work in EE, 1928. Committee of Correlation of Work in EE folder, Box 4, Records of the College of Engineering, Bancroft Library, Berkeley.

[73] Notes from a meeting of the committee for the reorganization of the engineering colleges, 10 March 1930. Minutes of the Reorganization of the Engineering Colleges, Box 4, Records of the College of Engineering, Bancroft Library, Berkeley.

[74] Letter From Jas W. Bishop to Cory in regards to acquiring material for Henry Ford's museum, February 1929. F-General Folder, Box 4, Records of the College of Engineering, Bancroft Library, Berkeley.

[75] Sibley 1952, 123.

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