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THE FULLNESS OF TIME[1]

PERSONAL EXPERIENCE FROM A HALF CENTURY IN ENGINEERING EDUCATION

By Dr. ARTHUR M. GREENE, JR.

DEAN, SCHOOL OF ENGINEERING, PRINCETON UNIVERSITY

The eighth decade of the nineteenth century marked the beginning of the electric light and power industry, following the introduction of the incandescent lamp of Edison in 1878 and of the electric motor in 1873 at the Vienna Exposition.

The Jablochkoff candle had been used for street lighting from 1877 and many were employed throughout Europe. Its limitations prevented extensive use and other arc lamps were developed. This lamp, suitable for street lighting, was not adaptable for residences and offices.

The principle of the electric motor was known to Faraday in the early part of the century, and Siemens had suggested the use of the dynamo machine as a motor in 1867. However, it was not until a chance connection of a generator of Fontaine and Breguet to a power line from another of their machines at the Vienna Exposition that the fact that motors are generators operated from an electric supply was fully realized. From that time on the electric motor became an element of power transmission.

The field of electric light and power was extended into all parts of the world, and in this eighth decade the technical press was filled with notices of organizations of power companies and with invitations for bids to furnish equipment.

The power plants of 1888 were limited as much by the facilities of manufacture and erection and by the demands for service as by the engineering knowledge of that day. The Edison Electric Company of Philadelphia built its plant near the center of the district

[1] Address delivered at the annual spring meeting of the Rensselaer chapter of the Society of Sigma Xi, Troy, N. Y.

devoted to shopping, banking and the practice of law. The cost of copper was the controlling factor which located this plant on expensive ground, at a distance from transportation facilities and where no condensing water was available. The effectiveness and convenience of the electric light and the electric motor made such plants, expensive in construction and operation, commercially possible.

The necessity of high potential for utilization of energy at any distance from the power station was recognized and the alternating current system for this purpose was suggested by Gailard and Gibbs in 1883, using Ruhmkorff coils, the secondaries of which could be sectionalized to give any desired voltage. From this suggestion the transformer was developed and the final steps were the inventions and uses of polyphase currents by Ferraris and by Nikola Tesla in 1888 and the rotating field motor of Debrowalsky in 1891.

The street cars were drawn by horses and the automobile was not in evidence. Edison had worked on electric traction in the early eighties, but it was in 1888 that Frank Sprague installed the first real city system in Richmond, Virginia.

The gas engine of this period was not reliable in small sizes, and although Lenoir had used the jump spark for ignition in his successful engine of 1861, the gas engines of my college days used a hot tube for this purpose. The compression of the explosive mixture into a heated, closed tube fired the charge. The heat was applied near the end of the tube and timing of ignition was fixed by selecting the proper length tube from a supply of different lengths.

The hydraulic turbines of this time were small, three hundred horsepower being a large unit capacity. The theory of such machines had been studied by Weisbach, Bodmer, Francis and many others since the early Fourneyron turbines of 1827, but in this country at least most of the development was by trial and error, using the testing flume (1872) of Emerson at Holyoke, Mass., to determine the improvement produced by changes in design.

The use of the telephone had increased so that by 1890 there were several hundred thousand subscribers. In 1887 the pole line on West Street, New York, had twenty-five cross arms and the aerial lines on lower Broadway appeared as a collection of spider webs. The underground cable was being installed at this time although only fifty pairs of wire were used in one cable. Long distance telephony was a cherished hope, to be carried to Chicago in 1892.

Steel and iron were used extensively at this time with the Bessemer patent expiring in 1890. The great production of later decades had not been reached, and it was not until 1892 that the first trainload of Mesabi ore entered Duluth.

Petroleum had been found in the Appalachian field, in California and Indiana, and in 1889 the great mid-continent field was first drilled. Indeed, the output at this time was so limited that the possibility of fuel oil in any great quantities was denied by the chief chemist of the Pennsylvania Railroad, Dr. Dudley.

The office buildings of this date were of moderate height, tall buildings being those of ten and twelve stories. Steel frames were used, but reinforced concrete had not been introduced to any great extent.

Into this state of engineering I had my introduction to the profession at preparatory school age in the Central Manual Training School of Philadelphia. My father was attracted by this new type of high school which had just been introduced into America. Philadelphia was one of the early cities to adopt the new method and I was a member of its second class to graduate in 1889. The educational philosophy of the school was to train the hand while developing the mind and although the curriculum was in a formative stage, it was well planned. In addition to preparing some city boys for positions in manufacturing, a number of my classmates went on to college and have become teachers of philosophy, chemistry, English and engineering. In their chosen fields they have won distinction.

The curriculum of this school prepared men for college as well as industry, not by the means of electives or different schedules but by a single curriculum which was offered to all. There was need for such a city high school to fit the graduates for gainful employment in positions created by the developments which were taking place in engineering and in manufacture, if further formal education was not possible.

I entered the Towne Scientific School of the college department of the University of Pennsylvania in 1889. The courses of this school led to a B.S. degree in four years with some specialization after the sophomore year, to be followed by a graduate year for the technical degree.

At the end of the sophomore year the student had to elect a field of specialization from the following: chemistry, metallurgy and mining, civil engineering, dynamical engineering and architecture, and in the junior year the real engineering work began.

It was at the end of my sophomore year that the university inaugurated four-year courses in engineering to meet the demand for such throughout the country. Most of the engineering schools were offering these and the number of applicants for admission to Pennsylvania was small because of the attraction of the shorter curricula elsewhere. The university offered at first three undergraduate courses leading to the degrees of B.S. in C.E., B.S. in M.E. and B.S. in E.E.

The chemical engineering course was established in 1895.

On the completion of my undergraduate course, definite changes were taking place in the engineering world, as indicated by the direct-connected engine generator units of the World Columbian Exposition, Chicago, 1893, the electrical illumination and the intermural electric railroad of the exposition, by the three short transmission lines in France at Gyannax, Domène and Paris of 1890, and by the Frankfort-Lauffen line of one hundred and six miles, the Rome-Tivoli line of eighteen miles, the three-mile line at Telluride, Colorado, and the twelve-mile line from Willamette to Portland, Oregon, of 1891.

Two operating steam turbines were exhibited at the Chicago Exposition—one a 300 K W de Laval unit, and the other a 50 K W unit of Parsons. A still unit of 500 K W was exhibited by Parsons, who had built units up to 150 K W for the Newcastle and District Lighting System of Great Britain.

My summer job in 1893, before returning for the graduate year, was on the power house of the Peoples Traction Company, which was installing the first of their street railway electrifications of part of the city of Philadelphia. This year, 1893, marks also the first hydraulic turbines installed in power house No. 1 at Niagara Falls.

Following my graduate work I taught at the Drexel Institute for a year and then returned to the university as an instructor in mechanical engineering, teaching from year to year the courses of the mechanical engineering schedule.

Before going to the University of Missouri in 1902, I aided in planning the mechanical engineering laboratory for the University of Pennsylvania, which was erected in 1905, but on entering upon my new position in the Middle West a mechanical laboratory had to be equipped and a course had to be planned to meet the needs of that period, as the previous curriculum had been largely based on the mechanic arts rather than upon engineering.

Three courses were offered at Missouri in 1902: civil, mechanical and electrical, and these were altered from year to year to meet the engineering requirements of the period 1902 to 1907 and to fit the preparation of students coming from the approved high schools of the state of Missouri.

In 1907 the requirements for admission to engineering were fifteen Carnegie units, of which three were required in English, three in mathematics, one in science and two in a foreign language. The students from accredited high schools were admitted without examination on the presentation of proper credentials.

It was while administering the courses at Missouri, as junior dean of the school, that I received a telegram in the spring of 1907 from P. Cricketts asking me if I could see him at the university on a certain day but with no further information. I did not know P. Cricketts, but on asking one of my associates if he knew such a person, he at once said that it must be P. C. Ricketts, who had received a million dollars from Mrs. Russell Sage with which to inaugurate a course in mechanical engineering at the Rensselaer Polytechnic Institute. He suggested that President Ricketts probably desired to talk with me about mechanical engineering. He came to Columbia and we had a frank discussion regarding engineering education, including the value of Rankine's books and allied subjects, and he left us on the late night train for the north.

After some weeks I was asked to meet a number of the faculty and trustees at a dinner at the home of Director Ricketts and I visited the buildings of the institute, which at that time consisted of the Carnegie Building, the Walker Laboratory, the Proudfit Building, the Rankine House, the Warren House, the old chemical laboratory on Eighth Street, the old gymnasium at the head of Broadway and the library, museum and administration offices in the Alumni Building on Second Street. This visit resulted in my call to Rensselaer that spring.

The planning of the curricula for the two new courses in mechanical and electrical engineering was carried out in such a way that they would be comparable with the civil curriculum with its two studies in the morning and the scholastic amusements of Amos Eaton in the afternoon. From past experiences in engineering education, it was not difficult to arrange our work, as we had the civil schedule as a guide. This schedule was the result of many years of development by which the general requirements for a Rensselaer degree were fixed. The important part of our work was to arrange the freshman year of the new courses to care for the men entering in September, and then to begin the planning of the Sage Laboratory which would be needed in two years for the junior students of the new departments.

The matter of shop work was discussed very carefully. From my experience it was decided that the vast amount of repeated work with hand tools should be eliminated as the object was not to make skilled artisans. All exercises were planned to illustrate various shop methods and, as far as possible by their comparison, indicate the reason for certain shop procedure. These exercises were selected to indicate also the behavior of tools and of different engineering materials on which shop manipulation was required by actually handling them. Another purpose of the shop course was to bring the students into actual contact with these tools and materials of modern construction so that they would understand the requirements of manufacturing to be applied in engineering designs of the future. Shop work naturally fitted into four-week summer periods of two years, paralleling the two summer periods of surveying of the civil curriculum. It was also thought that by operating the shop on forty-four hours per week the tasks of the industrial worker might be realized in part by the students.

In the planning of these two new courses the only changes of the civil schedule of Division D (first year) were the elimination of topographical drawing and the shortening of the time for surveying, using these periods for elementary steam engineering.

As you may probably recall, all courses included French throughout Division D and the course in the English language during the first term Division C. A summer thesis was required at the end of each summer vacation.

The schedules for Division C (second year) followed the civil engineering patterns and included electricity, electrical laboratory and electrical measurements in place of surveying and surveying practice of the first term with machine drawing, kinematics, physical laboratory and electrical laboratory for perspective, shades and shadows, surveying and free-hand drawing of the civil course of the second term.

The studies of Division B (third year) of the two new courses were quite different from the civil curriculum as the only courses in common were rational mechanics, resistance of materials, structures and metallurgy.

The only common subjects of the three courses of Division A (senior year) were hydraulics of the first term and the graduating thesis. The remaining subjects were chosen for each curriculum to meet the requirements of that branch of engineering. The first E.E. and M.E. degrees were conferred at Rensselaer in June, 1911.

After fourteen years at Troy I was called to the deanship of a new school of engineering at Princeton University, which was inaugurated in 1921. During my fifteenth year at Troy I spent certain days at Princeton planning new schedules for the undergraduate course in civil engineering, which had been established in 1875, and for that in electrical engineering, which had been established as a graduate course in 1889, together with schedules in mechanical, chemical and geological engineering. Each of these four-year undergraduate courses led to the degree of B.S. in E.

This step had been taken by Princeton at the solicitation of the members of the Princeton Engineering Association and had been authorized by the trustees of the university on condition that the academic facilities of the university be used to the fullest extent.

Again, it was a problem of fitting courses into curricula of an institution with traditions and with established courses in arts and science and to use the civil course as a guide in placing as many applied technical subjects as possible into a fifth year of graduate work while retaining the fundamental engineering subjects. The retained courses were such that the student who could not return for the graduate year was prepared to continue study and development in the early days of his professional career.

The results of this study, as announced in the catalogue of 1922, provided for a common freshman year with English, a foreign language, analytic geometry and calculus, chemistry, engineering drawing and an orientation course, industrial development.

The sophomore year was practically common with electives in each term and a one-course difference in the second term between steam engineering and chemistry. The upperclass schedules contained few common courses, but there was a marked difference in the other required subjects. There was one academic elective each term.

The four graduate courses (civil, electrical, mechanical and chemical) were made up of applied engineering subjects, engineering economics, specifications and contract law being required in each.

All the schedules have received changes during sixteen years. These were made to equalize the work of each year and to meet changing conditions. At present the undergraduate studies are so divided that of the 144 credit hours of work required in the civil, electrical or mechanical courses, practically 30 per cent. may be treated as non-scientific or elective, 30 per cent. scientific and 40 per cent. engineering. The special departmental work of any one of these courses varies from 17 per cent. in electrical engineering to 23 per cent. in the mechanical course.

In the chemical engineering course 22 per cent. is non-scientific or elective, 46 per cent. scientific and 32 per cent. engineering, of which only one half is in chemical engineering.

In the geological engineering course, 30 per cent. of the 141 credit hours may be considered as non-scientific or elective, 49 per cent. scientific and 21 per cent. engineering.

Electives at Princeton extend through the complete list of academic departments, from art to psychology, and the elections vary from year to year.

After the arrangement of the courses of study for Princeton, the next problem was again to plan laboratory equipment, to enlarge the old and to create the new. As in my previous positions, I was fortunate in being associated with men of vision and understanding, and the laboratories have been fitted, regardless of those at other institutions, to suit the requirements of our courses as we understand them. It was once more my pleasure to move into a new building which represents the hopes and aspirations of a cooperative staff.

I have drawn a partial picture of the state of engineering as it existed when I was completing my manual training school preparation for engineering education and now, a half century after this, I ask you to hastily recall the things which you have enjoyed during the last twenty-four hours which were not dreamed of as possibilities in 1888.

We have seen the extension of the use of the automobile and of superheated, high-pressure steam; we have enjoyed the facilities of long-distance telephony, the radio and household refrigeration. The two thousand horse-power engine of the Columbian Exposition has been replaced by the one hundred and thirty thousand horsepower hydro-electric generators and the two hundred and sixty thousand horsepower steam turbo-electric units. Transmission systems have extended for hundreds of miles and electric networks have reached over several states. Electrical load dispatching has become as common a term as train dispatching. The small vacuum tubes used by Dr. Robb and Professor Williams in a limited way before installing the Rensselaer broadcasting station have been further developed and are now made for all sorts of services, for repeaters, for wireless and for power.

It is the development of these things, occurring at intervals during this half century, which has caused us to change some of our courses, but basically they start from those subjects in which I was trained at the beginning of the period and those subjects are still the alphabet from which we have formed and will continue to form at least the first parts of our new words.

I have used "the fullness of time" in my title because I believe that such things have come from the work of previous generations. The dreamer can think of a great prime mover, but how can he build it without the travelling crane and the massive machine tools at hand or to be built by the facilities available at the time of construction. The same may be said of the transportation of these parts and the possible facilities at the erecting site. Boulder Dam and the gigantic numerical coefficients before each common term describing it represents research and application of results but without the handling facilities for these enormous quantities and unit pieces it would be merely a dream of a Jules Verne.

I think of the gas engines on which my students worked at Pennsylvania and even at Troy and the troubles experienced by them in attempted operation. Then came the demands of transportation which made these engines reliable devices for the unskilled and even ignorant driver. With this development their use spread to the air, entrance into which had been denied to the planes of Leonardo and of Langley because of the lack of power.

We could enumerate devices common to-day which have become possible by developments in some other field and so in enjoying any one device we should try to recall the other developments which have made this one possible and the developers who have risked their futures on the outcome.

Our age, because of the numerous conveniences for all people, is more interdependent than any preceding civilization, and that fact should be kept in mind at the present time. The present-day leisure and the present-day facilities for enjoyment have come from an economic civilization in which freedom of action and personal gain have been driving forces. These have produced a plentiful supply of useful devices for the benefit of all. It is true that some few organizers have made stupendous fortunes which have been spent wisely for the benefit of the people or unwisely in unrighteous living, but by this system leisure and its possible utilization for the larger enjoyment of life have come to the average man, termed by some the forgotten man. Time and space for many have been contracted by communication and transportation. Our country has been reduced to the size of one of its smaller states when business requires the transmission of a letter or the visit of an executive. The comforts of our homes, our offices, our places of recreation have increased during this period. These have been brought about by the free enterprise of those who saw at the end a possible return and were willing to maintain laboratories and staffs of experts to produce devices to lighten burdens and increase enjoyment. The selfish motive, if one wishes to call it that, did bring about these beneficial results for the masses. Without it a dull picture of indifference and inefficiency appears to my mind's eye. History should be studied by those who would change the order of life.

The great increase in the number of institutions for engineering education which occurred in the seventh and eighth decades of the last century was in response to the needs of that time which came from the expansion in manufacturing and transportation following the Civil War. The continued increase in the enrolment of our engineering schools has been brought about by the demands for technically trained men to carry on in the expanding field of manufacture, communications and transportation, and it is the job for the younger men here to-night to change our applied courses of instruction to the needs of the future, remembering that the first steps of the ladder will remain the same as before until they can be shifted efficiently to the preparatory schools.