THESIS

on

THE EVOLUTION OF THE PHILOSOPHY OF ENGINEERING EDUCATION

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THE EVOLUTION OF THE PHILOSOPHY OF ENGINEERING EDUCATION.

INTRODUCTION.

Education is a subject of universal interest. Volumes have been written regarding education in its different phases, its problems, its methods. A fair share of this material has been devoted to engineering education. In all the mass of published material, however, there seems to be no one article the purpose of which was to trace the development or evolution of the ideas regarding engineering education, from early times to the present.

The purpose of this study is to supply that deficiency in-so-far as possible. In reviewing the literature of engineering education, the objective has been to ascertain the philosophy back of this type of education and the views or attitudes toward it held by people of prominence; to determine whether these views have changed from time to time; and to observe the trends of such changes as may have occurred. Extraneous material has been introduced when it seemed desirable as a background for a better understanding of the subject.

It has seemed that such a study, even though the treatment might be inadequate, must tend to reduce misunderstanding and to clarify thoughtful consideration of the problems of engineering education.

For the purpose of this paper, consideration has been limited to the engineering schools of the United States, and to the professional type of training leading to a de-
gree in engineering. Doctor Wickenden, in his "Comparative Study of Engineering Education in the United States and in Europe", (1:2) says, "The term engineering education is loosely used in America and has no direct equivalent in the more precise terminology of continental Europe." He further states that, "The continental systems may be divided into three quite distinct categories of technical education, commonly called 'higher', 'middle', and 'lower'. Our terms 'professional' and 'vocational' fit the first and last reasonably well, and it is convenient to borrow the term 'middle' for the intermediate category, which is less widely recognized in America." In spite of the looseness of the term there should be no difficulty arising from the use of the nomenclature commonly accepted in America.

There have been made at different times, studies or investigations of engineering education with a view to its improvement. Certain of these studies are of considerable interest, viz., that of 1849 by Professor B. F. Greene, that of 1892 by Mr. A. M. Wellington, that reported in 1918 by Professor Charles R. Mann, that by the Society for the Promotion of Engineering Education 1923-29, and the one by the United States Bureau of Education which has just been completed. The reports of these different studies or investigations have been invaluable in the preparation of this study and quotations from them have been freely used. They could not be ignored by anyone who hoped to discuss
the changes in the philosophy of engineering education.

In 1849, Professor B. F. Greene, of Renssalaer Polytechnic Institute, went to Europe to investigate the status of engineering education there. The report of this study was instrumental in causing a major revision of the curriculum at Renssalaer, the new one being modelled along the lines of those of the French technical schools. This curriculum has served as a foundation for all subsequent engineering curricula.

In 1892, Mr. A. M. Wellington made a survey of the engineering schools of the United States for the Engineering News. This survey was reported in the Engineering News during the years 1892 and 1893. There was a series of forty-one weekly articles devoted to the subject, followed by a series of seven articles devoted to "The Ideal Engineering School". Mr. Wellington intended to republish these articles in book form, but toward the end of the series evidence was presented to show that the information furnished by the schools, upon which his discussion was based, contained numerous errors. He decided not to publish the book. There is no evidence to show that Mr. Wellington's report caused any major modification of the engineering courses, although it did arouse much interest.

In 1907, the Society for the Promotion of Engineering Education invited the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American
Institute of Electrical Engineers, and the American Chemical Society, to join the Society for the Promotion of Engineering Education in appointing delegates to a "Joint Committee on Engineering Education" to examine into all the branches of engineering education, including engineering research, graduate professional courses, undergraduate engineering instruction, and the proper relations of engineering schools to secondary industrial schools, or foremen's schools, and to formulate a report or reports upon the appropriate scope of engineering education and the degree of co-operation and unity that may be advantageously arranged between the various engineering schools. In 1908, the Carnegie Foundation for the Advancement of Teaching and the General Education Board were invited to appoint delegates. It was found impracticable to carry on the work without additional funds, so the Carnegie Foundation was urged to undertake the work on a comprehensive scale. This request was granted and Professor Charles R. Mann was selected to make the investigation and report.

This report, "A Study of Engineering Education", by Charles Riborg Mann, was published in 1918 as Bulletin #11 of the Carnegie Foundation for the Advancement of Teaching. The report takes up first the existing conditions in engineering education, and follows with a historical review of the early development, the aims and curricula, the struggle for resources and recognition, the development of
the curriculum, methods of administration, student elimination, and types of instruction offered. Part two of the report is devoted to the problems of engineering education, admissions, the time schedule, content of courses, testing and grading, and shop-work. There follow suggested solutions regarding the curriculum, specialization, engineering teachers, and the professional engineer. There can be no doubt that this investigation and its report served to stimulate interest in the field of engineering education and to arouse a spirit of enquiry among engineering educators. Professor Mann received much commendation for his method of dealing with this difficult problem. There was some disappointment that the report was inconclusive, and some disagreement with the conclusions drawn.

The most comprehensive study directed to the improvement of engineering education was proposed in 1922 and undertaken in 1923 by the Society for the Promotion of Engineering Education. Schools, engineering societies, industry, governmental agencies, and individuals cooperated. Doctor William E. Wickenden was Director of the Investigation and Mr. H. P. Hammond was Associate Director. Partial reports have been published from time to time in the Journal of Engineering Education, and as bulletins of the Investigation of Engineering Education. More recently, the first volume of the final report was published. The second, and final, volume has not yet been released. This
has been a monumental work going into all phases of the subject. Practically all engineering schools in the United States have been visited, and in addition the Director made two trips to Europe for the purposes of study and comparison. It is too soon to appraise the value of this study, but engineering educators in general agree that it has been invaluable as a record of what has been done and as a stimulus to improvement.

A new study of the status of engineering education was made by the United States Bureau of Education at the request of the Society for the Promotion of Engineering Education, to determine the progress that had been made in the five year period since the survey conducted by the Society was completed. The report of this survey was issued as a supplement to the Journal of Engineering for March 1931. (15) In January 1930 questionnaires were sent to the institutions which took part in the investigation conducted by the Society for the Promotion of Engineering Education. The blanks were sent out by the Office of Education, Department of Interior, Washington, D. C. The report, which consists of a compilation of the answers to the questionnaire, is divided into three parts; the first of which deals with problems of enrollment, the second with standards of education, and the third with problems of administration. Statistics are presented graphically and in tabular form in the first and third parts of the report,
but the major portion of the report consists of a reproduction of the answers made by the institutions, 145 in number, to the questions on the blank. No conclusions are drawn. Study of these answers shows that numerous experiments are under way in various institutions which may prove beneficial to the individual schools or to engineering education in general, but there has been no general change in teaching methods or curricular requirements. The answers generally commend highly the summer schools for engineering teachers. They also indicate a tendency to select more carefully from among entering students those who may pursue engineering courses and to give more attention to their orientation. More attention is also being given to personnel work. The report shows general progress but no startling innovations.

HISTORICAL DEVELOPMENT OF ENGINEERING EDUCATION.

It is not feasible to give a detailed history of the development of engineering and of engineering education. It is profitable, however, to glance over the past in order to obtain a better understanding of the present. History gives a perspective in which events are shown in their true significance. In delving into history there is always a question as to where to begin. Particularly is this true with respect to engineering education. Engineering was practiced before the Pyramids. There has been education since the first child sat on its mother's knees. Engineering ed-
ucation as we know it today, however, is a comparatively recent development.

For the purpose of chronological discussion the history of engineering education may be divided into five periods or epochs, viz.,

1 1800 to 1862
2 1862 to 1918
3 1918 to 1930
4 1930 to ----

The first period, extending from the beginning of time to the opening of the nineteenth century, might well be called the prehistoric or antediluvian age of engineering education.

During this period, practically all engineering work done was under the auspices of the governments. The military service required men who could plan and build bridges and roads, take care of water supply and sanitation, transport the necessary food and supplies, invent and construct the various machines of war, or erect barriers and maintain them during a siege. These were truly engineering problems. The Great Wall of China, and the Roman Roads and Aqueducts were inspired by military necessity. The remarkable state of preservation in which they are found today gives us cause to marvel at the ability of some of our ancient engineers.
Some of the rulers caused to be erected great monuments to commemorate victories or to perpetuate their names. These edifices too, required the services of engineers of no mean skill. Even with the equipment available today it would tax the ingenuity of engineers to duplicate the Great Pyramid. Knowing how meager was the equipment available at the time of its construction we can but marvel at the expenditure of time and labor required.

The education of the men who actually constructed these engineering works was probably typical of their times. Their technical training was probably acquired through the apprenticeship system. Of technical schools where such training might be acquired there were none until late in the period. Of all countries, in 1750, "France alone had a recognized profession of engineers and a school for their recruitment and training, created within the hands of the profession itself. In 1800 the engineering profession was first emerging in England and could scarcely be said to exist in the United States. There was then no school of applied science in the English-speaking world. Germany was a scattered group of agricultural states, possessing two small mining academies and a feeble school for surveyors and builders. At this period France had two flourishing schools of application for civilian engineers and two others for military functions; she had created the most notable scientific school of the period to assure the re-
cruitment and intellectual culture of a Corps d'élite of engineers and had engaged her most illustrious scientists in their training; she had created the first great museum of science and engineering; and she had formed in embryo the original group of schools of mechanic arts". (1:21)

Again quoting from Doctor Wickenden's "Comparative Study of Engineering Education", "Perronnet may be called the father of modern civil, (civilian) engineering and was certainly the father of engineering education. When summoned to Paris in 1747 to become chief engineer of bridges and highways he was charged 'with the direction and supervision of surveyors and designers of plans and maps of the roads and highways of the realm and of all those who are appointed and nominated to said work; and to instruct the said designers in the sciences and practices needful to fulfilling with competency the different occupations relating to the said bridges and highways.' Perronnet's commission was the germ of the first engineering school.

While the school began to function in 1747 the name Ecole des Ponts et Chaussées was not officially bestowed nor the institution legally regularized until 1775. The school retains most of its original characteristics to this day." (1:9 & 10)

The second period, between the years 1800 and 1862, roughly coinciding with the so-called machine age or the period of the industrial revolution, might be called the
dawn age of engineering education. It was during this period that the forces were taking form which resulted in the development of our modern engineering schools. It is not possible in a brief discussion of this period to describe in detail, or even to enumerate, the various inventions and developments which revolutionized our civilization and changed our ways of thinking, nor is it necessary. The material development of humanity is pertinent to this discussion only in-so-far as it may explain the changes which have occurred in education, and the attitude of the public toward engineering education.

Many of the principles of mechanics were known long before the Christian Era. In fact, Hero demonstrated a steam engine as a toy about 250 B. C. It was not until the latter part of the eighteenth century, however, that Watt put steam to work for humanity.

In the year 1800 there were no street lights; the sperm candle was the standard source of illumination. At George Washington's Inaugural Ball two thousand candles furnished the illumination and the brilliance of the lighting called forth much comment. A proposal to light the streets at night was opposed vehemently, as evidenced by the following list of objections published in a New England Paper in 1816. The objections were upon five different grounds; (1) Theological, - Artificial lighting is an attempt to interfere with the Divine plan of the world which called for dark
during night time; (2) Medical, - Emanations of illuminating gas are injurious. Lighted streets will incline people to remain late out doors thus leading to increase of ailments by cold; (3) Moral, - The fear of darkness will vanish and drunkenness and depravity increase; (4) Police, - Horses will be frightened and thieves emboldened; (5) People, - If streets are illuminated every night such constant illumination will rob festive occasions of their charm.

Communities of that day were isolated and self-contained entities. They produced their own raw materials and transformed them into finished products within their own boundaries. They raised their flax, spun their yarn, wove their materials, and tailored their own clothing. The diet of the average family was limited to food produced within a relatively short distance. Horse drawn vehicles or canal boats sufficed for transportation. Communication was carried on by personal messenger. Paul Revere made his famous ride because that was the most rapid means of spreading his news.

In chapter four of "The American Spirit in Education" Professor Mann recounts some of the incidents in the early history of the railroad. The following extracts are pertinent to this discussion; - "The problem of the railroad in America was solved by first adapting the track to the country and then adapting the engine to the track. This
solution divided the responsibility between the civil and the mechanical engineer. It has been a powerful incentive to the development of the technique of road and engine building and to the growth of the professions of civil and mechanical engineering." (5:31)

"Many of the civil engineers who built the railroads were trained in field work on canals. Prior to 1840, Renssalaer had graduated 151 men. Of the first thousand cadets at West Point, 150 became engineers, many of whom were prominent in early railroad work. On the other hand, those who built the locomotives had no formal technical training. ---- Although the main principles of American locomotive practice were determined by 1846, three important mechanical inventions since then have added much to the comfort and safety of travel. These are the Pullman car (1864); the Westinghouse air-brake (1869); and the Hall automatic block signal (1871). Since these were all the work of men who had no formal technical schooling, it is clear that transportation by machines -- the engineering achievement that lies at the basis of our whole industrial fabric -- was accomplished before engineering schools had really begun to train men for the work.

The difficulties that the early builders of railroads had to overcome were not limited to the scaling of mountains and the building of tracks and locomotives. They have had to educate the educators. Thus in 1829 the
guardians of education in the persons of the school board at Lancaster, Ohio, seriously considered the propriety of using the schoolhouse for the discussion of such a question as whether the railroad was practical or not. They said: 'You are welcome to use the schoolhouse to debate all proper questions in, but such things as railroads are impossibilities and rank infidelity. There is nothing in the Word of God about them. If God had designed that His intelligent creatures should travel at the frightful speed of fifteen miles an hour, by steam, He would have clearly foretold it through His holy prophets. It is a device of Satan to lead immortal souls down to Hell.' (5:31 & 32)

The development of educational facilities is not, as a rule, ahead of the demand, but follows as a consequence of a felt need. The English Grammar School was developed because there was need for a wider dissemination of elementary education. The American High School was the outgrowth of a philosophy which advocated equal opportunities for all people. A better general education was required to enable the people to understand the problems of citizenship.

So long as higher education was reserved for the Ministry, even when it was expanded to include the professions of Law and Medicine, the classics could well serve as a foundation for special training. When science was removed from the exclusive control of the philosopher and applied for the benefit of mankind a different type of higher ed-
ucation was required.

The need was recognized and voiced by forward looking men long before facilities were provided for the acquire-
ment of such an education. In 1693 William Penn wrote:
"The World ---- ought to be the Subject of the Education
of our Youth, who, at Twenty, when they should be fit for
Business, know little or nothing of it. We are in Pain to
make them Scholars but not Men! To talk, rather than to
know, which is true Canting; ---- to know Grammar and
Rhetorick, and a strange Tongue or two, that it is ten to
one may never be useful to them; Leaving their natural
Genius to Mechanical and Physical, or natural Knowledge un-
cultivated and neglected; which would be of exceeding Use
and Pleasure to them through the whole course of their
life." (5:16)

"At the time (1693) ---- the only occupations open to
graduates of the college were those of minister, teacher,
and gentleman. The great majority of the people, includ-
ing physicians and lawyers, learned their trades by the ap-
prenticeship system. Therefore, the responsibility for
their education was divided between the schoolmaster and
the master of apprentices. The schoolmaster was 'to teach
all such children as may resort to him to write and reade'
and be 'able to instruct youth so farr as they may be fit-
ed for the university.' The master of apprentices was to
train them 'in some honest lawful calling, labor or em-
ployment, either in husbandry or some other trade profitable for themselves and the Commonwealth'. (5:17)

Benjamin Franklin has been called "The Prophet of American Education", and in his papers on the English Academy he outlines a type of education which developed into our modern engineering schools. "The history of commerce, of the invention of arts, rise of manufacture, progress of trade, change of its seats, with the reasons and causes, may also be made interesting to youth, and will be useful to all. And this, with the accounts of the prodigious force and effect of engines and machines used in war will naturally introduce a desire to be instructed in mechanics, and to be informed of the principles of that art by which weak men perform such wonders, labor is saved, and manufactures expedited." (5:12)

It has been shown that at the beginning of the Nineteenth Century there was in America no engineering profession and of course, no school for the training of engineers. The men responsible for our revolutionary inventions were self trained or trained through the apprenticeship system. "The Erie Canal was executed by three American Judges -- James Geddes, Benjamin Wright, and Charles Brodhead -- who had had no formal technical training. They felt their way along, working out each problem as it came with energy and determination. What they did not understand, they conquered by diligent study, unwearied
zeal, and sound common sense. By the constant exercise of these qualities they laid the foundations of the profession of Civil Engineering in the United States." (5:24 & 25)

Renssalaer Polytechnic Institute was established in 1824 to supply the demand for a type of education for which facilities were lacking. It was planned along the lines of the Fellenberg School at Hofwyl, Switzerland, which in turn sought to follow the methods of Pestalozzi. A course in civil engineering was added in 1829 and for twenty-three years Renssalaer and West Point were the only two scientific schools in the country.

Steven Van Renssalaer’s own statement of the purposes of his school follows:— "I have established a school at the north end of Troy ---- for the purpose of instructing persons who may choose to apply themselves in the application of science to the common purposes of life. My principal object is to qualify teachers for instructing the sons and daughters of farmers and mechanics ---- in the application of experimental chemistry, philosophy, and natural history to agriculture, domestic economy, the arts, and manufactures. From the trials which have been made by persons in my employment ---- I am inclined to believe that competent instructors may be produced in the school at Troy, who will be highly useful to the community in the diffusion of a very useful kind of knowledge, with its application to the business of living." (5:26)
The slowly increasing demand for a different type of education, one which would better fit men to cope with the problems of industry, was met at first by privately supported schools. Renssalaer Polytechnic, Lawrence Scientific School, Sheffield Scientific School, Massachusetts Institute of Technology were all privately endowed institutions. The first State supported school of practical arts was opened in Michigan in 1857. The "Michigan idea", that manual labor is educative when it is inseparably connected with the acquisition of knowledge, has served as inspiration for many of the later schools.

In 1853, Professor Jonathan B. Turner published a pamphlet entitled "An Industrial University for the People", in which the new philosophy of education was well expressed. The following quotations will serve to illustrate the ideas back of engineering education at that time. "Mere learning, book knowledge, has been considered the great end of education, and all such systems of culture direct the mind too much toward books, and too little toward facts. The pupil is taught to think of letters and words rather than of things and events. ---- A real grammar school boy of such schools, can brave no other idea than that God made the world out of the nine Parts of speech, and in English, at least spelled it all wrong ----. This method does not produce mind but merely learning -- not intellect but scholarship -- not thinkers, but plausible and so-
phistical debaters; schoolmen (as of old) who can prove either side of any proposition, but not real men who can discharge the hard side of every single duty. —— The most natural and effectual mental discipline possible for any man, arises from setting him to earnest and constant thought about the things he daily does, sees, and handles, and all their connected relations, and interests. The final object to be attained, with the industrial class, is to make them Thinking Laborers: while of the professional class we should desire to make Laborious Thinkers." (5:44 & 45)

Professor Turner also differentiated the professional and industrial classes. "All civilized society is, necessarily, divided into two distinct cooperative, not antagonistic classes:— a small class, whose proper business it is to teach the true principles of religion, law, medicine, science, art and literature; and a much larger class who are engaged in some form of labor in agriculture, commerce, and the arts. For the sake of convenience we will designate the former the professional, and the latter the industrial class. —— What do the Industrial Classes want? —— They want, and they ought to have, the same facilities for understanding the true philosophy —— the science and the art of their several pursuits, (their life-business) and of efficiently applying existing knowledge thereto and widening its domain, which the professional classes have long enjoyed in their pursuits. —— So far
forth as discipline of mind is concerned, all know that the greater part of it is procured in all these professions, not at their several schools, however excellent and appropriate in themselves, but by continued habits of reading, thought and reflection, in connection with their several professional pursuits in after life; and if not so acquired, it is never, in fact, acquired at all. --- Why are there more recondite and profound principles of pure mathematics immediately connected with the sailing of a ship, or the moulding and driving of a plow, or an axe, or a jack-plane than with all three of the so-called, learned professions together, if it be not intended that those engaged in these pursuits should derive mental culture as well as bodily sustenence and strength from these instruments of their art and toil?" (6:59)

The demand for educational facilities for the training of those who were to go into agriculture and the industries finally became imperative. State legislatures and Congress were besieged with requests for the establishment of such schools. To Justin S. Morrill belongs the credit for securing the legislative enactments which resulted in the establishment of our land grant colleges whose object was "Without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to agriculture and the mechanic arts --- in order to promote the liberal and
practical education of the industrial classes in the several pursuits and professions of life." (5:46) Mr. Morrill was not an educational expert but a practical politician. Through his efforts financial support was provided for educational facilities in accordance with the ideas of Professor Turner and other far sighted educators.

The passing of the first Morrill Act in 1862, marks the end of the second epoch in engineering education. This type of education had been recognized as worthy of national support on a large scale. It was some years before engineers were graduated in sufficient numbers to have any material effect on the life of our nation, but the seed had been sown, the interval was devoted to germination and growth. Up to 1870 the engineering schools had graduated less than 900 students. Only about one in nine practicing engineers was a college graduate. Today a comparatively small percentage of practicing engineers do not have at least one degree.

The third period in the history of engineering education, that between 1863 and 1918, was marked by a rapid growth and development of the agencies for training of this kind, and a reluctant acceptance of this training as a coordinate branch of education. The number of engineering schools in the United States increased from 4 in 1860 to 17 in 1870, to 85 in 1880, and to 126 in 1918.

Paralleling the rapid growth of engineering and of
the facilities for engineering training occurred a division of engineering into its major branches and a corresponding differentiation of engineering curricula. The first engineering degrees granted in the United States were to four members of the class of 1835 of Renssalaer Polytechnic. They were in Civil Engineering. Mining Engineering and Mechanical Engineering were differentiated as the field of applied science began to broaden and the demand for men trained in those fields began to increase. Electricity did not play an important part in the life of the people until the late seventies. The American Society of Civil Engineers was established in 1852, The American Institute of Mining Engineers in 1872, The American Society of Mechanical Engineers in 1883, and the American Institute of Electrical Engineers in 1884.

The later years of this epoch, from 1900 to 1918 witnessed the establishment of a large number of diversified courses in engineering. Civil Engineering was too broad a term, there must be courses in Municipal and Sanitary Engineering, Bridge Engineering, Highway Engineering, Structural Engineering, etc. The Mechanical Engineer must become a Steam or Gas Engineer, or an Industrial Engineer. The Electrical Engineer must specialize in Hydro-electric Power or Illumination, or Telephone Engineering. There were not only Railway Engineers, but Railway Electrical, Railway Mechanical, Railway Civil, or Railway Signal Engineers.
Chemical Engineering was recognized as was Marine Engineering, and later Automotive engineering, Radio Engineering, and Aeronautical Engineering. It was the age of the specialist.

The congestion of engineering curricula, as a result of these specialized courses superimposed upon the fundamental science so essential to an engineering training, was one of the factors responsible for the "Study of Engineering Education" by Professor Charles R. Mann. This is shown by the following quotation from the prefatory remarks by President Pritchett in Bulletin #11 of the Carnegie Foundation for the Advancement of Teaching. "The point of view from which the study was undertaken was the following: Fifty years ago, when the engineering schools of the United States were inaugurated, they began their work upon a definite teaching plan and one that had at least pedagogic consistency. The course was four years. The first two were spent mainly in the fundamental sciences -- chemistry, physics, mathematics, and mechanics; the last two years mainly in the applications of these sciences to theoretical and practical problems. In the half century that has passed this course of study has been overlaid with a great number of special studies intended to enable the student to deal with the constantly growing applications of science to the industries. While the original teaching plan remains as the basis of the four year engineering curriculum, the courses given in most schools have been great-
ly modified in the effort to teach special subjects. As a result, the load upon the student has become continually heavier and bears unequally in different places and in different parts of the course." (3; V)

By the end of this third period or epoch, engineers had attained success, in that there was a recognized profession of engineering, and a recognition of the engineering type of education as a coordinate branch of education had become quite general. It was not until 1916 that "the Federal Government, for the first time in its history, formally recognized the engineering profession in the organization of the Naval Consulting Board, the Council of National Defense, and the National Research Council. The establishment of the Engineering Foundation, the United Engineering Societies, and the Engineering Council, and the recent appointment of one man as secretary of them all, indicates the progress that is being made toward the conception that there is really but one profession of engineering, in spite of its apparent division into the several well known branches." (3; 107)

During the year 1918 the engineering schools were called upon to give a short course of training, two months in duration, to over one hundred thousand men. During this two months it was expected that men without previous training in a specialty should be given a certain skill along some special line. The results were astounding.
In many cases the skill at the end of the training period was as great as that acquired only after years of effort in the normal course of events. The men turned out were not engineers, nor were they highly skilled technicians, but they were capable of taking a minor position in a skilled trade. The armistice aborted an even more comprehensive experiment in education, the Student Army Training Corps. These movements, however, together with the rehabilitation vocational training and the Reserve Officers Training Corps, established after the War served to focus upon education, and especially upon vocational and engineering training, the attention of large numbers of our boys and young men. The increase in the enrollment in engineering schools during the immediately succeeding years was phenomenal. The engineering enrollment has continued to increase, although at a less rapid rate than immediately after the War.

The contemporary period, 1918 to date, has emphasized to the world the increasing importance of the engineer to civilization. The problems of production on a large scale he has solved to a great extent. There are comparatively few commodities which cannot be supplied in any desired quantity in a comparatively short time if the need warrants the expense. Transportation is peculiarly an engineering function. There are few things which cannot be moved from one place to another at speeds un-
dreamed of but a few years ago. There are undoubtedly problems in transportation and in the distribution of transporting equipment which remain to be solved, but no one need doubt the ability of the engineer to solve them. The material prosperity of the United States has been attributed largely to the great use of mechanical power. The American workman has on the average fifty horsepower to help him with his work. No other workman in the world averages one tenth as much assistance. Is it any wonder, then, that our workmen produce more per man, receive higher wages, are accustomed to more luxuries, and have more leisure in which to enjoy them?

Much is heard about the "Good old days", and the "Simple Life", but few would choose to give up the benefits of the present in order to go back to those days. The engineers, more than any other class are responsible for the change. The revolution has not been confined to industry and transportation; our homes have been invaded and our lives made over. It is difficult for most young people of today to imagine a home without a telephone, electric light, a furnace, running water, an automobile, etc., none of which would be available except for the engineer. Our night life would be sadly restricted without motion pictures and the radio. If we list some of the less universal, yet common luxuries such as washing machines, electric iron, dishwashers, vacuum cleaners, electric
stoves, refrigerating machines, portable motors, etc., it is seen that even the housewife needs education of a different kind than was available a century ago. She leads a different life and speaks a different language, a language whose vocabulary is largely composed of terms introduced by applied science. A silk purse has been made out of a sow's ear.

There remain many major sociological and political problems to be solved and it is not unlikely that the engineer will assist in their solution. Problems are his daily routine and in many cases he is in position to have first hand information regarding those problems of politics or welfare. He is used to handling men. Statistics show that seventy per cent of the engineering graduates ultimately get into positions which are predominantly executive. It was not accident that an engineer was elected to the presidency.

In an address at a recent annual meeting of the American Society of Mechanical Engineers, Lawrence W. Wallace, Executive Secretary of the American Engineering Council, stated that, "Men of science are assuming a dominant position in American life. By supplementing with broad humanistic and scholarly interests the technical genius responsible for the 'Machine Age', they are becoming a controlling force in culture and in politics no less than in commerce and industry, in finance, in education, and in national defense." (7; 11) He made this statement on the
basis of a survey conducted by himself in association with Joshua Eyre Hannum of "Engineers in American Life". The sample for analysis was taken from "Who's who in America", 1928-29 in order to avoid the implication of partiality.

The statistics show that of the 28,805 notable living men and women of the United States, men of science comprise 30.4 per cent, lawyers 15.2 per cent, and physicians and surgeons 7.3 per cent.

"The 2858 engineers and architects named received 1417 academic degrees in branches of learning other than science, as well as 2497 scientific degrees. They are members of 1138 associations, conferences, boards, and commissions, half of which are non-technical, they hold 4785 official positions in 3928 organizations, of which 2993 are industrial and commercial companies. They occupy the position of president in 1128 industrial and commercial organizations, 72 engineering firms, 68 banks and trust companies, and 23 colleges and universities.

Among these 2858 engineers and architects there are, or have been, 10 governors, 13 members of Congress, 2 members of the Cabinet, and the President of the United States. Five hundred and eighty-eight of these men hold 905 memberships in Phi Beta Kappa, Phi Kappa Phi, Sigma Xi, and Tau Beta Pi."

"The findings show that engineers and architects are versatile, not narrow; internationally, not provincially,
minded; leaders, not followers; scholarly, not unlearned; cultured, not rude; humane, not cruel; lovers, not haters of mankind. --- The charge that engineers are overspecialized and narrow in their interests is refuted by the diversified classification of the organizations to which they belong and the activities in which they are engaged."

The fifth period of engineering education, the future, remains. What the future will bring forth we may not know. We may only speculate, those speculations, however will be postponed until after certain special problems have been considered.

SPECIAL PROBLEMS

Time does not permit a full discussion of all the special problems in engineering education which would be of interest. Certain ones, however, are of such importance that they should not be overlooked. These problems may be grouped under three general headings; problems of teaching personnel, those pertaining to the curriculum, and those of administration.

No discussion leading to improvement in engineering education can be complete which does not consider the teaching personnel of our engineering schools. In his series of articles on the "Ideal Engineering School", Mr. Wellington seems to agree with the criticism, prevalent
at that time, that the engineering schools were too academic and not sufficiently practical. He attributes this "To the fact that their courses are laid out by men who are not themselves engineers and who copy too closely the precedents of the older 'learned' professors in which they have been trained." (2; 1893, 565)

It was inevitable that the teachers in our earliest engineering schools should be men who had received their training in schools devoted mainly to literary studies. As time passed and more engineers were graduated, the necessity became less obvious. Mr. Wellington deplores the fact that even at the time of his investigation there were few members of the engineering school faculties who had had long practice in engineering, (fifteen years for a graduate or twenty years for a non-graduate), a condition which did not exist in law schools or medical schools. He answered his own criticism to a certain extent, however, when he stated that the qualities which lead to eminence in a physician or lawyer are the qualities which enable him to convey his information to a class; while those which lead to eminence in an engineer are not necessarily the qualifications of a successful teacher.

The chapter devoted to this subject in Professor Mann's report, paints a picture in rather drab colors. He finds that engineering teachers are too academic, their salaries are too low, there is too much inbreeding, too
much routine work, indifference to problems of education, promotion is too often dependent upon research leading to a Ph.D. instead of improvement in teaching. (3; 101 - 105)

The report of the Investigation of Engineering Education by the Society for the Promotion of Engineering Education is more reassuring. Doctor Wickenden considers the deficiencies mentioned by Professor Mann but feels that some of them have been removed. After analyzing the statistics he states that "The general situation as regards teaching personnel, in-so-far as it is disclosed by the data collected, is on the whole an encouraging one. The teachers of engineering subjects are certainly doing their work energetically and conscientiously; they are obviously thoroughly alive to the fact that they have important problems before them and are earnestly and actively seeking their solution. This in itself is an evidence of vitality which indicates that the time is ripe for an advance to a higher level of achievement." (4; 273 - 317) He recognizes the fact that teaching loads are often excessive, also that the compensation of engineering teachers is inadequate, and makes recommendations leading to improvement.

A movement which offers much promise for the future is the establishment of Summer Schools for Engineering Teachers, by the Society for the Promotion of Engineering Education. The first two of these schools were held in 1927. Each summer since has seen one or more of them in session.
Each school has emphasized particularly the teaching of one subject, or a coordinated group of subjects. A study of the programs of these sessions, however, reveals the fact that not only was the subject material or content studied, but also, teaching methods, educational psychology, and the historical and cultural aspects of the subjects. The enthusiastic manner in which these schools have been received augurs well for the future of the teaching personnel of the engineering schools.

The courses of study in the early American engineering schools were very similar. That of Renssalaer Polytechnic was strongly influenced by the French schools of engineering, the French schools being far in advance of those of any other nation at that time. Other early schools were largely influenced in their curriculum planning by the example of Renssalaer. An examination of them shows that the early part was devoted to the mastery of fundamental principles, the latter part to the application of these principles to concrete problems. This plan is still in general use in engineering schools today.

The percentage of the student's time devoted to fundamental science and humanistic subjects as compared with that devoted to professional subjects has shown more variation. There are two reasons which may account for this in earlier American schools. First, the teachers in those early engineering schools, of necessity, received their
training in the classical schools. They were therefore imbued with the importance of fundamental science and the humanities as the backbone of education. Second, there was a dearth of material on applied science and engineering subjects. These two factors gradually ceased to have weight, and a third factor entered, viz., the enormous development of applied science with the accompanying development of specialization. Additional technical subjects were added to the curricula and to make room for them the time devoted to fundamental science and humanistic subjects was cut. Foreign languages received the most drastic cut in time, being eliminated as a requirement in many schools, but even the time devoted to mathematics has been decreased. Probably this is due to better preparation in mathematics in the secondary schools. However, the eliminations did not equal the additions, with the result that the curricula in all branches of engineering education became overcrowded.

This shift in time may be shown by the figures for 1867 and for 1914 as presented in Professor Mann's study for the Carnegie Foundation. He shows that in 1867, at the University of Illinois and Massachusetts Institute of Technology, the student devoted, on an average, 59% of his time to the fundamentals and the humanities, and 41% to professional subjects. In 1914, on the other hand, the average for all engineering schools was 48% and 52% respect-
There is evidence that the peak of this movement was reached about 1914 or 1915. In a paper "Evolutionary Trends in Engineering Curricula", in the Journal of Engineering Education for June, 1926, Doctor Wickenden presents diagrams showing a definite, though not large, decrease in 1923 as compared with 1915 in the percentage of time devoted to professional subjects. (8; 658)

The decrease in the proportion of time spent on professional subjects may be attributed in part, at least, to the reaction from the high degree of specialization prevalent during the early part of the present century. The crowded condition of the engineering curricula became so marked that the impossibility of giving highly specialized courses in all branches of applied science was obvious. The concensus of opinion at the present time seems to be that the four year undergraduate courses in engineering should be devoted to securing for the student a broad general foundation upon which the superstructure of specialization may be erected. The foundation should be strong in mathematics and fundamental science. The application of mathematics and science to the types of problems which engineers are called upon to solve must be stressed. The economic and humanistic sides of the problems must not be overlooked, nor the problems of expression. Inasmuch as analytic and synthetic reasoning is an outstanding characteristic of the highest type of engineer, every effort
should be made to inculcate the habit of thinking things through. Division of the curriculum in accordance with the major divisions of engineering practice is not a disadvantage, but further specialization should be left for graduate work. The curriculum in each branch of engineering should be integrated.

The principles involved in the planning of an engineering curriculum are well set forth in the following guide which was formulated by a committee appointed by President Wilbur of Stanford University to consider the question of organizing an engineering school. (9; 550)

"Basic Ideas for a Four-Year Undergraduate Curriculum in Engineering:"

1. The curriculum should be practicable.

2. The curriculum should include all fundamental principles that comprehensive engineering problems require for their solution.

3. The curriculum should include the application of fundamental principles to the solution of minor and major engineering problems.

4. The curriculum should include such studies as will, together with studies of high school and grammar school, give the student the widest experience among the different departments of knowledge to broaden his outlook, stimulate his interests, disclose the range of his aptitudes, and discover those lines of effort for which he is best fitted.

5. The curriculum should include the field, laboratory, and office technique of measuring, recording and combining the physical data of engineering problems, and the tech-
nique of giving effective expression, in office, field, and laboratory, to the solution of engineering problems.

6. The curriculum should call into play the initiative and the judgment of the student in the important matter of revising, from time to time as data from his experience accumulate the plans for his immediate and distant future.

Experience proves that a four-year curriculum cannot fully satisfy the six ideas described above, and we are forced to one or another of the following three alternatives:

A. Extend the curriculum to five or more years; or

B. Ignore entirely one or more of the six ideals, as may be necessary to confine the curriculum to four years; or

C. Plan a four-year curriculum which shall sacrifice partially each and every one of the six ideals.

Alternative A must be rejected, because it would be unfair to the engineering student to require more time for the A.B. degree in engineering than for the A.B. degree in other branches of learning.

Alternative B must be rejected, because every one of the six ideals is of high importance, and the ideal of highest does not overshadow the ideal of lowest importance to such an extent as to warrant entirely ignoring the latter in order to recognize to the full the former.

Alternative C is therefore to be adopted.

This committee therefore adopts the plan of making a
four-year curriculum which shall partially satisfy each of the six ideals set forth above.

Now arises the question: Shall all the ideals be sacrificed to the same extent, or shall some be sacrificed more and some less? The correct answer to this question is indicated by the four facts known from experience, as follows:

a. Fundamentals -- organized bodies of principles -- can be mastered with less cost of time and effort in school than in practice; indeed, can be mastered in practice only slowly and with great difficulty.

b. The application of principles to engineering problems can, after some training therein in school, be learned in practice about as readily as in school.

c. The myriad facts and customs of practice are learned rapidly and without conscious effort in practice, but only slowly and with great and tedious effort in school.

d. Real skill in technique of instruments and methods cannot be imparted in school, except to the unusual student.

The conclusions of this committee are in accord with those of others who have made a study of this subject.

Mr. Wellington, in his report, opposes bitterly the long period of vacation in the summer, a problem which concerns engineering in common with other types of schools. His suggested remedy, for Civil Engineering students, is field work in the summer time. This, he feels, would solve not only, the vacation problem, but also, would give helpful practical training in the line of the students' chosen
profession.

The status of shop work, field work, and laboratory work in the engineering curricula has varied from time to time. In the original curriculum at Renssalaer approximately one-third of the time was devoted to field work and to inspection trips, with some laboratory work. By 1865 field trips and inspection trips had been discontinued. At Massachusetts Institute of Technology there was no shopwork until 1877, nor was there much laboratory work before 1870. Professor Mann, in his report to the Carnegie Foundation, makes the following statement: "The use of the illustrated lecture in instruction in science was not new, but the organization of laboratories for undergraduate students in physics was a striking innovation, suggested by President Rogers and carried out by Professor E. C. Pickering in 1869.

The marvelous expansion of this method of laboratory work into all branches of science in all grades of schools, and the profound impress made by this expansion on the American school system are matters of common knowledge."

(3; 37 & 38)

Since 1900 there has been a definite diminution in the amount of time spent by the engineering student in shop courses, as is shown in the charts prepared by Doctor Wickenden and published in the Journal of Engineering Education for June, 1926. (8; 658) This is due, undoubtedly, to a change in viewpoint regarding the purposes of shop
courses. Whereas, during the latter part of the nineteenth century the acquirement of skill in the use of tools was considered a primary objective of shop courses; at the present time it is recognized "That acquirement of knowledge of the technique of shop operations, rather than the acquirement of skill or manual dexterity, is the primary objective." (4; 47)

Professor Mann's report advocates the cooperative plan of engineering education. The University of Cincinnati made the original experiment along this line. The plan was formulated by Dean Hermann Schneider in 1899 but it was not until 1906 that he was able to give it a trial. Proponents of this plan feel that it has many advantages over the more common type of engineering course. It is more economical for the university and also for the student. It also has educational advantages. The work in a commercial shop under conditions of industrial production is of greater variety, equipment is up-to-date and in good repair, there is contact with the human problems in industry and a recognition of the correlation between industry and academic work. Other schools have since organized cooperative courses upon much the same plan as that of the University of Cincinnati.

A comprehensive survey of the Cooperative Engineering Courses was made during the Investigation of Engineering Education, and is summarized in the Report, Vol. I. A
bibliography of selected references with a summary of their contents is appended. The following extracts from the concluding paragraph will indicate the opinion of the Board. "Cooperative engineering training has passed through an initial experimental period and is now firmly established in the general field of engineering education in the United States. It has been adopted and is working successfully in several of the strong institutions of the country. This fact alone, if there were no other, is proof that the plan has merit and deserves a recognized place in engineering education. On the other hand, few except the most ardent advocates of the system will probably hold that it should be adopted universally. ---- Neither all students nor all institutions, nor all types of engineering services, are best served by a single, uniform, standardized type of program. ---- The indications are that its particular function and peculiar merit is in training men for the operation of industrial enterprises." (4; 613 & 614)

Many of the problems of engineering education are so interrelated that it is difficult to segregate them for the purpose of discussion. The problem of elimination, for instance, is affected materially by the preliminary training of entering students and by the requirements for admission. Proper orientation of students is a factor and it is closely related to curricular requirements.

In the earlier days of engineering education the
secondary school system was comparatively undeveloped. Entrance to the technical schools was based upon examination, as in other colleges. It was customary to have a preparatory department in which deficiencies in entrance requirements might be removed. As the high school system developed, the entrance requirements of the colleges were raised. Two, three, and four years of high school training were made prerequisite for entrance. The preparatory departments gradually ceased to be necessary and were finally discontinued. The system of accrediting high schools and waiving the entrance examinations for graduates of accredited high schools became common. While affording many apparent advantages, and seeming to raise the standards of the colleges, the change was not entirely salutary.

The old Grammar Schools were frankly college preparatory schools. The present high schools were organized to perform the same function in a better way. As the American Ideal, of higher education for all young people developed, however, the objectives of the high school changed. Preparation for living rather than preparation for college became the dominant note. As the percentage of young people in the high schools increased the average intellectual capacity of the high school group decreased, resulting necessarily in a lowering of the high school standard of intellectual accomplishment. The engineering
schools in particular have felt the effect of this lower standard. In discussing the preparation of entering engineering students, Mr. H. P. Hammond, Associate Director of the Investigation of Engineering Education, made the following pertinent statement. "The serious aspect of the relationship of engineering education to the preparation which precedes it is not, however, so much the extent of the preparation as it is its general character and quality. Two strong tendencies in secondary education contribute to conditions which engineering colleges find to be seriously unsatisfactory. One is the widespread substitution of studies whose purpose is 'preparation for citizenship', including civics, other social sciences, and vocational subjects, for those involving more rigorous intellectual training. The other is a general softening of work all along the line. It is futile merely to inveigh against these conditions, yet they present a situation which must be considered, and dealt with if that is possible. There is serious danger that they may cause a general displacement of the curriculum downward." (10; 57) The following from the Report of the Investigation of Engineering Education, 1923-29, is confirmatory. "Our public secondary schools disclaim a predominantly intellectual purpose, and are preoccupied with exploratory processes and social guidance activities, intended to fit young people into spheres of life quite unlike those in which they were born
and reared. It is probably too much to ask that our preparatory education shall reach the levels of intellectual efficiency of the highly selective systems of Europe, but it seems clear that the present levels of achievement at the age of twenty or twenty-one could be reached at eighteen or nineteen by young persons of superior endowments without sacrifice of youthful vitality or zest. A study of European experience lends strong support to the conclusion that the most effective means to a broader scientific and humanistic education for engineers, which everyone agrees is needed, is through more effective secondary education and more selective admission, rather than delayed entrance into technical studies and pursuits." (4; 1003)

The question of selective admission to schools of collegiate rank has been given attention for some years. While the problem is of interest to many types of schools, the need of a satisfactory solution has probably been felt more keenly by engineering schools than by any other type. Chapter VIII of Professor Mann's report is devoted to the problem of admission. He strongly advocates the use of objective tests for the determination of engineering aptitude. In connection with this study Professor E. L. Thorndike made a special series of experiments with freshmen in engineering. A study of the college records of the students who took Professor Thorndike's tests indicated a definite prognostic value for the tests. Later experiments
and studies have corroborated this conclusion. A number of engineering schools are making use of similar tests of entering freshmen, and are using the ratings on the tests in their advisory work. The engineering schools, however, are reluctant to adopt such tests as the sole criterion upon which to judge the fitness for admission. In the appendix to Professor Mann’s report are given samples of these tests and a discussion of the results of Professor Thorndike’s experiment. (3; 117)

The high percentage of eliminations in engineering schools has long been a problem of concern to engineering educators. Statistics show that only about thirty-eight per cent of the students who matriculate in engineering courses, complete their courses. About twenty-eight per cent of the matriculants complete their courses in four years. (4; 26) This represents a higher rate of student mortality than is shown by any other division of collegiate work. A comprehensive study of this subject was made by the committees on Engineering Students and Graduates, and Admissions and Eliminations, of the Society for the Promotion of Engineering Education. This material was published as Bulletins #1 and #2 of the Investigation of Engineering Education, and reprinted in the Final Report. The following comparative figures are taken from this report. (4; 225)
<table>
<thead>
<tr>
<th>Type of school.</th>
<th># reporting.</th>
<th>Years.</th>
<th>Entrance requirements</th>
<th>% graduates to admissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medicine</td>
<td>7</td>
<td>1915-24</td>
<td>2 yrs. college</td>
<td>76.6</td>
</tr>
<tr>
<td>Dentistry</td>
<td>3</td>
<td>1917-24</td>
<td>1 yr. college</td>
<td>60.3</td>
</tr>
<tr>
<td>Law</td>
<td>4</td>
<td>1915-24</td>
<td>2 yrs. college</td>
<td>59.0</td>
</tr>
<tr>
<td>Bus. Ad.</td>
<td>1</td>
<td>1916-24</td>
<td>high school</td>
<td>61.7</td>
</tr>
<tr>
<td>Agriculture</td>
<td>5</td>
<td>1915-24</td>
<td>high school</td>
<td>54.6</td>
</tr>
<tr>
<td>Engineering</td>
<td>38</td>
<td>1914-24</td>
<td>high school</td>
<td>37.8</td>
</tr>
</tbody>
</table>

On pages 210 and 211 of this report are listed causes for this high percentage of eliminations. More discriminative selection of entering students, better orientation, and competent personnel supervision are remedies which promise results in the future.

Suggestions have been made that the unsatisfactory preparation of a large percentage of entering engineering students should be corrected by requiring one or two years of preparatory work in an Arts College before admitting them to the professional engineering course. This suggestion has been answered in the Report of the Investigation of Engineering Education. After a thorough study of the subject, the Director feels that the reasons against such a change far outweigh those in favor of it. "What the engineering student needs at the outset is not so much a widening of his intellectual horizons as a discipline in more intensive and directed methods of mental work: the broadening process is much more effective if distributed over the entire educational program. --- The actual results of a divided program, in which another type of college is made to serve as a vestibule to engineering, have
been seriously disappointing; it appears that the spark of enthusiasm for engineering is quenched more often than it is kindled and that more students are diverted from engineering through prejudicial influences than are directed to it through constructive educational guidance." (4; 125)

There is dawning a realization that scientific subjects are not, inherently, less cultural or less liberalizing than modern language, or art, or music. Harmony, for the professional music student may be as narrowly technical as hyperbolic functions for the engineer or anatomy for the surgeon. In a summary of opinions concerning engineering curricula, published as Bulletin #9 of the Investigation of Engineering Education, it is stated that "All subjects, if properly taught, have cultural value." also that "Cultural studies should be included to give balance to the curriculum and to provide the student with fields of interest outside of his scientific and technical subjects." (11; 406 & 407)

The Carnegie Foundation for the Advancement of Teaching is making an elaborate study of secondary and collegiate education in Pennsylvania: an important part is comprehensive examination in all fields of knowledge to measure content of students' minds; "in spite of fact that more than half college course for engineers was devoted to professional subjects and many more hours to fundamental sciences, seniors possessed breadth of knowledge suffi-
cient to score much higher in fields not their own than arts men." (12; 1102 - 3)

The remark has been made from time to time that too many engineers are being graduated. Few data are available to definitely prove or disprove this statement. Engineering educators in touch with the situation do not feel that the statement is true. When economic conditions are reasonably good, the graduates have little difficulty in obtaining jobs. In fact, in some schools situated near the industrial centers of the east, engineering seniors have had an average of seven jobs per man offered to them before commencement.

At a conference on Electrical Engineering, at the annual meeting of the Society for the Promotion of Engineering Education, at Montreal in June, 1930, a paper was presented under the title "A Market Analysis of Electrical Engineering Graduates." The material for this paper was collected and prepared for a special report in "Sales Management" at the Harvard Graduate School of Business Administration. Questionnaires were sent to large employers of electrical engineering graduates and the returns were quite complete. Upon the basis of these returns an attempt was made to determine the relation between supply of and demand for electrical engineering graduates. The curves drawn for supply and demand are nearly parallel,
"And thus indicate a healthy and desirable condition -- sufficient openings for the capable college graduates and enough men to fill the vacancies in industry." (13; 425-432)

Comparisons are frequently made between the number of physicians or lawyers, and the number of engineers in their respective schools. No valid conclusions can be drawn from such comparisons. Conditions are absolutely different. When a doctor or a lawyer does a constructive piece of work, such as perfecting a cure for a certain disease, or clarifying a point in constitutional law, he has limited to a certain degree, the demand for all doctors or lawyers. On the contrary, when an engineer develops a method of utilizing a waste product, or a new application of power, he has increased the demand for engineers, Utopia, would demand no physicians or lawyers, but engineers would be in constant attendance.

The following quotation from an article by Colonel R. I. Rees is indicative of a feeling quite commonly found among engineers. "So the engineer's mastery of energy and material things must go on. He cannot pause nor shirk his responsibility, for through the character of his leadership, he has brought upon himself the responsibility for our present social order. He has brought about our industrial civilization and he must accept leadership which will keep for mankind the benefits which it gives and contribute to the suppression of the evils which have accom-
panied those benefits. While the world cannot demand, nor can the profession furnish, more than a reasonable proportion of executive leadership in industry, yet the engineer's analytical method of thinking and his passion for truth can and will have a great influence on all industrial leadership." (14; 7)

SUMMARY AND CONCLUSIONS

The literature of engineering education reveals, after careful study, a philosophy which has changed only in minor details during the past century. The fundamental ideas are: that nature and nature's laws constitute the best subjects for the education of our youth, that the study of these things together with the practical application of natural laws may provide an education comparable with any, that a knowledge of the materials and forces of nature is desirable for all and is imperative for those of our population, who are to earn their livings by using these materials and forces, that for a smaller, but nevertheless a significant group, those who are to direct large undertakings involving the use of the materials and forces of nature, and those who are to plan new applications of them, a much more rigorous training is necessary.

The ideas enunciated by William Penn and advocated by Benjamin Franklin, long before facilities were available for engineering training, blend by almost imperceptible
gradations into those of Johnathan B. Turner. His in turn are closely in accord with those of the modern engineering educator who believes that a rigorous training in fundamental science and its applications in a definite vocational field is not only equal to, but even superior to the older academic or classical training for a large proportion of college students. Indeed, engineers are prone to believe that this type of training is not less cultural than any other type, is equally broadening, and is a far better preparation for life in an industrial civilization than is any other collegiate curriculum.

Engineering curricula have been modified from time to time, in the attempt to accommodate them to the rapidly expanding fund of engineering knowledge. The emphasis laid upon different subjects has varied as pressure has been brought to bear by members of the profession, by educators in other lines, by changing conditions due to changes in the preparation of entering students, or by the demands of industry. However, throughout the history of engineering training, the different curricula have been planned with certain tenets in mind.

1. The curriculum must be a unified, coordinated whole.

2. No engineer can be a credit to his profession who does not have a thorough grounding in fundamental science and mathematics.

3. The habits of analyzing a situation into its component parts, of weighing those parts with re-
spect to each other and to the whole, and of synthesizing the components into the final solution, are essentially characteristic of engineers, and can best be trained by the solution of numerous problems in the application of fundamental science and mathematics to engineering situations.

4. Demonstration, and experimental verification of fundamental principles are valuable adjuncts.

5. Any educated man should be able to express his ideas either orally or in writing. Since an engineer may be called upon to present reports, it is imperative that he should be trained in expression.

6. An engineer should have knowledge of the methods and processes of industry, and of its human problems.

7. A knowledge of the ordinary principles of economics, and of commercial law is highly advantageous.

8. Free electives have a place in education but the foregoing statements lead to the conclusion that for engineering students, the advantages of a rigidly prescribed curriculum, with a few restricted electives, far outweigh its disadvantages.

Increasing care is given the recruitment and training of the teaching personnel. The Journal of Engineering Education is giving more space to methods of teaching and the psychology of learning. The former is a definitely favorable indication. The latter shows the desire of engineering educators to keep in step with their confreres in the schools of education and moreover calls attention to the contrast between American schools of higher education and those of Europe in regard to the point of emphasis. Whereas American schools stress teaching, the European schools pay more attention to learning. It may be necessary that
college teachers in America take a disproportionately large share of the responsibility for the general education of the college student because of his inadequate preparation. However, engineering educators are loath to assume too large a share of that responsibility, fearing that it will handicap the engineering graduate in later life.

The history and development of engineering education show a conservatism sufficient to prevent revolutionary changes, coupled, however, with openmindedness and an eager acceptance of modifications which have proven beneficial. Educational experiments have been under way almost continuously, though usually on a small scale, but the results have been made available to all. The one big experiment, that of establishing a system of education based upon a new philosophy, has had a century during which to demonstrate the value of that philosophy. Several different criteria suggest themselves by which its value may be judged. (1) The changed attitude of the general public toward engineering education, derided by the classicists and viewed askance by the general public during its early days, engineering training has taken a place among the most popular of undergraduate courses. (2) The success of engineering graduates in meeting the problems of life, the large number of engineers occupying executive positions in politics and commercial enterprises as well as in strictly engineering work gives evidence of the versatility of the engineer.
(3) The avidity with which engineering graduates are taken into industry, the 1930 Survey of Engineering Education shows figures from 47 institutions having 4282 senior engineering students who were offered 7697 positions, an average of 1.8 positions per man. (15; 60) If one may accept the validity of these criteria, one can only conclude that the philosophy back of that type of education is sound.

No system of training can be perfect. Engineering educators would be the first to deny that engineering education had reached its highest state of development. There is every reason for optimism, however, regarding the future of engineering education. The different surveys which have been made have shown a healthy condition. The fact, that since 1907 there has been almost continuous study of the field, instigated by engineering educators themselves, indicates a consciousness of the problems involved and an interest in their solution. A continuous inventory kept up to date provides a solid foundation upon which to build. With engineering educators alive to the situation, and with their analytical minds engaged in planning improvements in methods and facilities, there is reason to expect increased efficiency in engineering education and a consequent continued demand for engineering graduates, some to fill strictly engineering positions, and others to play equally important roles in world affairs.
Bibliography.

There is such a mass of material available on the subject of engineering education that only those articles have been listed from which quotations have been taken, or to which direct reference has been made.


