RELATION OF CIVIL ENGINEERING TO INDUSTRY

FRANK P. McKIBBEN*

The planning, constructing, and maintenance of industrial works are so complicated that every branch of engineering must contribute its talents towards the successful production of the ensemble, in order that in the completed works articles needed to satisfy man's wants may be created thoroughly and economically by loyal, healthy, and contented employees. And as engineering has become so complex, a man even of extraordinary ability can master only a small part of the underlying pure sciences or their application to construction of industrial works or to such adjuncts as steam and water power plants, which furnish the energy to propel the machinery of production, railways, canals, and highways as aids to transportation, bridges which leap across chasms for the benefit of man, docks, harbors, and other terminals which distribute the manufactured products. Therefore, the interdependence and cooperation of all branches of engineering are essential to the successful completion of any important industrial undertaking.

Since in the creation of an industrial plant the proper planning and assembling of factory and administrative buildings, of transportation facilities, and of water supply and drainage constitute the first step, and since these elements lie within his field, the civil engineer is among those first to be utilized. The creation of such an assemblage of productive units is a product of the imagination, and hence it is of such great importance that collegiate training should have for one of its objects the proper development of the imaginative faculty. To a great engineer is attributed the remark that a college course should consist of descriptive geometry and economics, the former as a stimulus to imagination, the

* Consulting Engineer, General Electric Company, Black Gap, Pa.

latter to correlate properly the elements of production. Unfortunately, the problem of education is not solved by such a simple formula; nevertheless, the value of training the imagination can scarcely receive too much emphasis.

As the civil engineer is concerned with design and construction of industrial plants he is one of the first to be called upon in any individual project. Unfortunately for him he is the first to be confronted with unemployment when business depression begins, but he is very likely to be the first to feel a revival in industrial activity following the depression.

After completion by the combined effort of many administrators, engineers, and artisans, the industrial plant must be maintained in good condition, and to the civil engineer falls the task of supervising the maintenance of buildings, transportation facilities, water supplies and similar features, while other branches of engineering generally have the responsibility of caring for the machinery. It is much more interesting to build a new structure than to keep an old one in repair. Hence, one who is concerned with plant maintenance must possess patience and perseverance. But maintenance of an industrial plant engaged in producing goods, while necessary, important, and requiring an intimate knowledge of the materials of engineering, is only secondary to the main purpose for which the plant is constructed, and, therefore, the civil engineer upon completion of the plant should endeavor to enter either the department which directly produces the goods or that which sells them, provided his desires and abilities make this possible. Other things being equal, he who builds a plant should be the best qualified to operate it. But oftentimes other things are not equal. Experience with students in engineering colleges teaches us that there are in general two very distinct types of young men—those so deeply interested in the technical features of their courses of study as to be more concerned with the manner of solving a problem than with the ultimate solution itself, while the other group looks principally at the finality and its application to commercial life. Both groups are important. Both are interesting to the teacher; but they are distinctly different.

For many centuries engineering works were constructed by military engineers, that is, by men who were a part of the military organization of the ruler. Under their jurisdiction came not only works of a purely military nature such as fortifications, but also undertakings more intimately concerned with the peaceful occupations of man, such as canals and aqueducts for supplying cities with water. In those times there were only engineers—military engineers; civilians had little to do with the design and supervision of these great works. Today, army engineers have the responsibility of building all military works both in peace and war, and they are actively engaged in constructing harbors and docks, the canalization of rivers, and other features connected with navigation. On the whole, the nature of the work of the military engineering has changed relatively little, but as governments have merged from absolute monarchies to democracies much of his work has been transferred to the civilian branch. So it came to pass that during the last century and a half a group of engineers not connected with the army has undertaken the task of building many public works. And with the growth of large corporate bodies civilians rather than military men have been employed to create industrial plants, railroads, highways, bridges, and even in some cases harbors, docks, and canals. This group of civilians thus engaged came to be called civil engineers, and in the year 1848, when the Boston Society of Civil Engineers was established, as the first engineering society in the United States, the members were classed as civil engineers and their activities embraced the comprehensive field.

In 1852 the American Society of Civil Engineers was established. But as the demand arose for men more thoroughly trained in special lines there gradually developed a group whose interests were more intimately bound up with machines, and these soon became known as mechanical engineers, whose interests prompted them to organize a society. There followed electrical, metallurgical, chemical, and several other divisions, each with a national society sponsoring local branches.

One may now ask whether this division has not been carried too far, and whether it would not be beneficial both to industry and to engineers if these technical societies were consolidated into one which could maintain and stimulate the interest of each group while correlating the activities of all. Such a centralized organization, similar to the American Institute of Architects, the American Medical Association, or the American Bar Association, would have unified action, command greater respect from other societies, from the public, and from legislative bodies, reduce duplication of effort, stimulate research, and broaden the outlook of its members.

Colleges of engineering have in general adopted the policy of specialized courses, some beginning the differentiation between the curricula in the Freshman year; others later. This segregation of students like engineering society duplication also has gone too far, and we who have been responsible for planning technological courses of study have been guilty of crowding out pure science by elementary work in some industrial activities. Pure science with sufficient applications to show the student how to apply it to industrial problems is the ideal, but often the physical limitations of the college preclude reaching the ideal. And to some extent some industrialists lessen the ultimate value of graduates by insisting on their having qualified at graduation a fair acquaintance with the technical details of industrial operations; but this is much less a fault now than it was a few decades since, in the earlier stages of industrial development in the United States. On the other hand, industry has been of immeasurable assistance to engineering colleges, by supplying advice and financial aid for plant, equipment, and men, by affording opportunities for graduates, by aiding collegiate research, and by serving as examples of successful effort.

Laws of nature are so complex, the search in undiscovered fields of science so alluring, the reward so great to him who successfully unearths an infinitesimal grain of nature's vast store, that research—the finite searching for the infinite—is playing an ever increasing part in industrial development. Research may be carried on by individuals, universities, industrial organizations, and governments. It may be in either pure or applied science or in both. Only a few years ago, universities constituted the principal sources of effort in this field, but because of their inability to finance the necessary buildings and equipment, and because they attempted in most cases to add research to teachers' overburdened schedules, the results of their efforts were not sufficient to meet the needs of industry. Consequently research laboratories were established on a large scale. The corporations interested in electrical and chemical activities and in building materials have been outstanding in this work. Civil engineering has contributed principally to research in materials of construction, but its contribution to improved methods of building large private and public works is none the less striking but of a slightly different nature. Research has reached such importance, and industry depends so largely on it, that all organizations engaged in manufacturing must either establish research laboratories or fail to keep pace with industrial progress. Recent years have witnessed a growing tendency for the companies engaged in a given field of production to seek common research facilities, either through government laboratories, through associations, or by means of technical societies, which may receive financial and other aid from the companies interested.

Civil engineering, formerly a generic term covering a vast variety of constructions, has on the whole maintained its identity well, but even in this field many subdivisions have been made so that now its principal activities lie in construction of railroads, highways, bridges, buildings, docks, wharves, canals, water supplies, sewage disposal works, dams, and some other adjuncts of water power plants. And each of these fields is so highly specialized as to be classed under a separate name, such as municipal, structural, or hydraulic engineering. The American Society of Civil Engineers recognizes these separate interests by organizing groups within the parent body, each group being principally interested in its subject, but having much in common with other groups.

Some college graduates make the mistake of not taking an active part in any of the engineering societies. He who contributes most receives most. Presentation of papers, taking part in the discussions, assuming responsibilities of office when requested to do so, are all valuable and essential parts of an engineer's education. And let me impress most strongly on the graduating class of this institution the importance of realizing that study should not end with receipt of the diploma.

Throughout the ages in each major division of human endeavor a few men stand out like beacons to light the path of human progress, to inspire those who follow with an incentive to reach great heights of accomplishment. This is true of pure and applied science, of music, art, government. Each of these supermen contributes only a little to the fund of human knowledge in his sphere of thought, but by such infinitesimal increments has the whole been accumulated through millions of years until we have arrived at the stage where you and I are now trying to add our mite. Each tiny insight into God's beautiful creation spurs one on in the hope that further beauties may be discovered.

The few outstanding minds in a given line are the torch bearers. In his "Watchers of the Sky" Alfred Noyes has given us a marvelous picture of the Torch Bearers who have kept aglow the light of inspiration in Astronomy, have given us a wonderful glimpse of God's handiwork, have carried the torch a little while and in turn passed it on to younger hands, each saying to the next:

> "Take thou the splendor, carry it out of sight
> Into the great new age I must not know,
> Into the great new realm I must not tread."

The torch bearers of astronomy are Copernicus, Tycho Brahe, Kepler, Galileo, Newton, and Adams.

Copernicus had the courage to reject the accepted astronomical theory of his day, to doubt that the sun and stars revolved around the earth. When he stated his belief that the earth moved around the sun he was attacked from all quarters. Pathetic is the picture of this torch bearer awaiting on his death bed word that his book setting forth his ideas had been approved, but the good tidings came for him too late.

Tycho Brahe became inspired to study astronomy after marveling at the accuracy with which an eclipse had been predicted, and, being a nobleman, was required to renounce nobility to engage in astronomical research. Night after night he observed and charted thousands of stars, and finally discovered the planet Uranus. And Tycho Brahe passed on the torch to others.

John Kepler carried forward the torch by discovering three laws:—

> "First, how the speed of planets round the sun
> Bears a proportion, beautifully precise
> As music, to their silver distances;
> Next, that although they seem to swerve aside
> From those plain circles of old Copernicus
> Their paths were not less rhythmical and exact,
> But followed always that most exquisite curve
> In its most perfect form, the pure ellipse;
> Third, that although their speed from point to point
> Appeared to change, their radii always moved
> Through equal fields of space in equal times."

Galileo, with his newly found telescope, while observing the planet Jupiter discovered its four moons, and named them after the house of Medici. Alfred Noyes was thrilled at the sight of these four moons as he recently viewed them through the one hundred inch telescope at

Mount Wilson and one can gain something of Galileo's joy from the poet's words:—

"Then I, too, looked,
And saw that insignificant spark of light
Touched with new meaning, beautifully reborn,
A swimming world, a perfect rounded pearl,
Poised in a violet sky; and, as I gazed,
I saw a miracle,—right on its upmost edge
A tiny mound of white that slowly rose,
Then, like an exquisite seed-pearl, swung quite clear
And swam in heaven above its parent world
To greet its three bright sister-moons."

Then Newton, seizing the torch, separated a ray of pure sunlight into its seven primary colors and gave to man a knowledge of the spectrum, one of the greatest astronomical tools. He knew that all planetary motions are controlled by the sun and are influenced by one another. But when he tried to calculate the exact motion and path of the moon about our earth his results would not harmonize with the observed facts till Picard in France published a corrected diameter of the earth. Then Newton, revising his figures and seeing all coming in perfect harmony, was overcome by his emotion, and, unable to proceed, dropped his pencil and cried to his colleague, "Work it out for me."

The torch was seized by Adams in England and by Le Verrier in France who, believing that the variations in the calculated and observed motions of the planet Uranus were due to another planet, calculated the size and location of the unknown, and found the planet Neptune.

Such are some of the torch bearers of astronomy.

From the long list of prominent civil engineers it is difficult to select a group of torch bearers, but such names as McAdam, George Stephenson and his son Robert Stephenson, Robert Stevenson and James B. Eads, must surely be included. But long before these men came one whose versatility as a painter, sculptor, musician, architect and engineer stands preeminent above all others—Leonardo da Vinci. Throughout those years which produced the "Last Supper" and the portrait of Madonna

Lisa, mathematical and engineering studies and writings engaged his thoughts. The science of hydraulics, planning and building canals, construction of military works, received much of his attention. In his letter to the Duke of Milan, Leonardo set forth his abilities as a military engineer and included therein his acquaintance with civil engineering and architecture. Plans made by him included those for irrigation of a portion of the Lombard plain and the canalization of the River Arno. For a period he was chief engineer to Duke Cæsar. Truly Leonardo da Vinci was a great engineer, but he will always be known as the painter of the "Last Supper."

By building roads over a century ago McAdam did more than any other man to lift England out of the mud. In America he had amassed a fortune and upon returning to England started to build an experimental road at his own expense. Like all reformers he encountered much opposition, but he persevered and finally saw great improvements in the English road system. Macadamized roads of today are a monument to him.

Another torch bearer in civil engineering is George Stephenson, the inventor of the miners' safety lamp and the locomotive, who constructed in England the first railroad to carry passengers and freight. His plant for building locomotives and other machines was prominent in England and it was in these works that his son Robert received his early training which enabled him to construct railroads in South America and in many European countries and to span with enormous bridges such rivers as the St. Lawrence at Montreal.

The Robert Stephenson just mentioned must not be confused with Robert Stevenson, another great engineer who built many lighthouses on the coasts of Scotland, invented intermittent and flashing lights for lighthouses, built bridges, harbors, and docks. This Robert is particularly interesting as the father of three sons, each of whom succeeded him as Commissioner of Northern Lighthouses; and as the grandfather of Robert Louis Stevenson whose "Treasure Island" and other writings have given us all so much pleasure. Robert Louis Stevenson studied engineering and although sufficiently proficient to receive a medal for a paper pertaining to lighthouses his heart was not in engineering.

From the European engineers the torch was handed to a great American—James Buchanan Eads, whose greatest achievements consisted in building a large number of iron clads and mortar boats on the Mississippi River in record time during the Civil War, in having spanned the same river at St. Louis with a beautiful arched bridge, renowned not only for its beauty but for being the first steel bridge in the world. And what is more, the steel is an alloy of such good quality and strength that although the bridge has been transporting since 1874 passenger and freight trains on a lower level and highway traffic on the upper deck it still is doing its duty in carrying countless persons over the Father of Waters. Mr. Eads was a remarkable engineer. Conquering such difficult problems as sinking caissons—huge under-water boxes in which men work to lay foundations for the great piers supporting the bridge—to a depth of 136 feet below high water level in the river; packing the steel of the arches in ice in an attempt to join it properly; all these are illustrative of his inventive genius.

However great was the achievement of building the Eads Bridge at St. Louis, Mr. Eads is probably best known from his success in controlling the Mississippi River at its mouth by means of jetties constructed to scour the ship channel to the desired depth.

Such are the torch bearers in civil engineering.

This building which is being dedicated today is a monument to its legislative and private donors and will ever stand as a reminder to Delaware College graduates that some had the generosity and unselfish interest in the cause of education to provide the inspiration and means for its construction. But unless the teachers and students who join hands and brains therein in the solution of engineering and human problems receive from it an equal inspiration it will have been built in vain. To create an inspired engineer with an active imagination and a heart is the real purpose to which this structure should be devoted.

Tremendous is the satisfaction received by the great engineer in constructing a vast project, and it is with keen interest that he watches his structure develop as piece after piece is added till the whole becomes self-supporting. Then will come the satisfaction of having created a monument but unless he bears in mind the good that mankind will receive from his efforts he will not have realized the greatest success. With this conception of his work will come the satisfaction of having done something for his fellowman, and the completed structure will become a true monument to him who conceived it, so that at the termination of the work he may say:

"And it's work, work, work,
With hand and eye and brain,
And it's work, work, work,
With cheerful might and main.
It's clang, clang, clang,
Each man in his chosen place
Beats out on the anvil of human toil,
The good of the human race."