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CRITICISM OF THE ENGINEERING SCHOOLS¹

FRANCIS BACON said in the introduction to his "Maxims of the Law":

I hold every man a debtor to his profession; from the which as men, of course, do seek to receive countenance and profit, so ought of duty to endeavor themselves by way of amends to be a help and ornament thereunto.

This quotation is so enriched by age that it can be constantly quoted without attracting the charge of being trite; and its meaning is particularly apposite to my subject. I press it upon your attention the more willingly because teachers and professional men generally are given to overlooking the importance of its precept. An engineering school has a hard duty, for it must teach science and business, humanity and common sense, and withal it must give its students professional ideals. The present is a period of discussion and adjustment of the relationships of engineering courses to the preparatory schools and to the so-called liberal college courses. Various of our universities are setting up requirements for entrance into their engineering courses which include a part of the subjects leading more particularly to the bachelor of arts degree; and one of our greatest universities has made the possession of a bachelor of arts or equivalent degree the prime requirement of entrance into the studies of its engineering school, and has called its school a "graduate school of engineering." The adopted name for that school seems to me a misnomer, for the major portion of its teach-

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ing must be substantially of the same nature as that done in the undergraduate classes of the Stevens Institute of Technology and many other engineering schools, while engineering graduate study has come to be accepted in engineering circles as more advanced study of the sciences and their relations than can be pursued under limitations of time and subject matter pertaining to teaching classes rather than individuals. Whatever objections may be associated with the chosen name, "graduate school of engineering" for the particular work to be there done, it is an undoubted fact that the agitation accompanying the reorganization of the engineering courses of Harvard University and the establishment of the new school has been serviceable to the cause of engineering education. Even the chosen name has emphasized the effect by giving an impression of the extent and depth required in an adequate engineering education which has never before been grasped by the American public.

How many of you young men, students of engineering, composing this audience have reflected upon the meaning of the profession which you are intending to follow, or of the duties which are associated with it? How many of you have in mind a clear-cut definition of the character of the mental processes used by experienced engineers in executing their duties? How many of you have a clear recognition of the distinctions of mind and method which compose the differences between an engineer and a well-educated mechanic of unusual skill? You must reflect on all of these points and come to adequate convictions before you can become of the ablest and most distinguished ranks of engineers. These things can be organized in one's mind only by the thoughtful reflection which arouses the imagination. Thought-

ful reflection is, to paraphrase Lowell, as needful for the imagination as society is wholesome for the character; and an engineer's education can be scarcely begun until he learns that an exact and truthful imagination is one of his most important professional possessions.

France seems to be the only one of the civilized nations in which the engineers are given a full professional recognition. In Great Britain the machinists at the bench divide with the professional men the name "engineer," and when a great machinists' strike occurs the newspapers herald it with large headlines as the "strike of the engineers"; but who ever heard of professional men on strike? Many things occur as matters of commonplace in the average of human life that are unthinkable as parts of the lives of professional men.

Personally, I do not sympathize with requiring all young men who wish to enter an engineering school to first spend three or four years in obtaining a degree of bachelor of arts. President David Starr Jordan one time said in his apt way, "It is the business of the college to give the young man the secret of power. It should train him to be efficient, self-reliant and capable of team work to make the most of his actual abilities in the conduct of life." This applies equally to the engineering school and the so-called liberal college, and there is no exclusive hold on this important business possessed by either. If we must contrast the two, it may be seriously enquired whether the engineering schools have not in this respect usefully occupied a position formerly occupied by the liberal colleges but partially relinquished by them with the general adoption of elective courses of study unaccompanied by adequate advice and guidance—compulsion, if need be—which would lead the students to choose their studies with logic and reason.

But we must also remember that a truly influential man must know something of literature, biography, history, art and music. He must be a man of complete living. "To prepare us for complete living," Herbert Spencer said in his interesting book on education, "is the function which education has to discharge; and the only rational mode of judging of any educational course is to judge in what degree it discharges such function." Spencer also defines what he means by complete living, and every able, reflecting man may give a similar definition out of his own consciousness and experience: An education for complete living includes training the faculties of self-preservation, the faculties of self-support, the faculties of the domestic life and proper parentage, the faculties of good citizenship including interest and activity in the betterment of our political and social relations, the faculties of properly enjoying one's leisure and lending enjoyment to others.

The study of science and its applications as carried on in the atmosphere of our better engineering schools may surely be made an important stimulus to each of the powers and faculties which are required for complete living. It has been asserted that it lends itself more particularly to the earlier and less disinterested ones; but that this is necessary I must deny. The profession of the engineer demands a creative imagination cultivated to the sober clear sight which sees things as they are, and from which springs an appreciation of art, literature and music which rivals that produced in any other manner. But the physical sciences and their applications, even when coupled with desirable dilettantism, are not adequate to the requirements of engineering in its broadest sense; and the political and social sciences must be added to the list.

In this latter respect most of our engineering curricula have been startlingly deficient. I even lay the charge at the door of your own great institute; an institute which has instructed the spirit of many who have become of the nation's leading engineers. Will you look through that list of distinguished engineers and tell me how many have become notable for activities in the political and social affairs of the nation? We can count to your credit your distinguished alumnus and president and a few others of corresponding public spirit, but they are few when noted in comparison with the importance of the engineer's work in civilization and civic life and the important influence which this institute has borne in American engineering. Remember that the existence of civilization as we know it, and to a large degree its advancement, depend upon transportation and intercommunication, which are fundamentally engineering industries. Are the engineers then to allow those important political and civic activities which cling around civilized life to fall under the sole direction of others?

It is an easy answer to say that the engineers are too busy in working and directing the economic advances of civilization to afford attention to the way in which political and civic activities are guided; but this answer is inadequate. The lawyers, the physicians, the merchants are also busily engaged in affairs of importance, in their kind, and they might make a similar excuse for abstaining from political and social activity; in which case, I think we must all admit, our forms of government would soon break down from want of adequately trained and disinterested leaders.

It seems to me, gentlemen, that this rather general failure of the engineering graduates to keep a wide-open eye on the political activities of our land is a serious

fault that must be laid at the door of our education. Why is it that the professors of philosophy, literature and allied subjects in Columbia University are recognized as in interest with, or active forces in, the movements for civic good in New York City, while its professors of engineering are not counted in the same ranks, however great may be their unexpressed individual interest? Why is it that the professors of engineering in Harvard University and the Massachusetts Institute of Technology are constantly called on for expert engineering advice relating to the affairs of city and commonwealth, but are not found in relatively as important association with movements relating to the political welfare of the same portions of society? This is obviously not due to the fact that engineers are not experts in sociology and political economy, because that fact equally applies to the lawyers, physicians, bankers and merchants who take notable parts in such activities. It can be explained only on the ground of lack of interest taken in such questions by engineers individually and as a class. This leaves the profession without color of impression on such activities. That this is a fault which may be corrected is apparent when one thinks of the number of graduates of the Polytechnic School in France who have not only become distinguished in science and engineering, but have also made strong impression on the nation's affairs. The query at once arises—Have the engineering school curricula in this country been adequate in this particular, and have they brought to their students the breadth of human vision and the altruistic motives required for these activities? If this query is not answerable in the affirmative, we must look earnestly for the most appropriate way of correcting our defect. Having scrutinized a situation and discovered a

defect, engineers find that duty demands that a plan be devised to correct the error.

Have we the error and are we devising a useful plan to correct it? Some not only urge the error's existence, but also advocate a liberal college course antecedent to the engineering course as its cure. The appeal of this plan seems to take strongly with educated people so that the number of college graduates in the junior and senior classes of our better engineering schools is steadily increasing. Forty per cent. of the young men graduating from the electrical engineering course of the Massachusetts Institute of Technology last June had previously graduated from college and thereafter spent from two to three years in the study of electrical engineering at that Institute. I believe this is a good token and that the tendency is to be encouraged; but I do not believe that this is the only way to arrive at the results that we desire, or that without careful cooperation it is sure to produce the desired results. We must first take needed precautions to bring the studies into their logical relations in the curricula and to prevent too great time being occupied in the double course. It would be unfortunate for all our engineering students to be prevented from completing their studies and getting into the experiences of their earlier engineering employments until their twenty-fifth year had been entered or even passed. Circumstances now make that necessary for many of our students, and it is undesirable to add requirements which would make it necessary for all of our students. The particularly able may most readily carry the handicap of entering their professional service late, but some at least of them ought to have the opportunity of true graduate study, that is, advanced study of engineering sciences, before they have gone beyond their twenty-fifth year.

Under these conditions it seems desirable that some more effective correlation of the liberal and professional curricula, using the terms liberal and professional in their usual but rather narrow significance, should be devised than can be obtained by putting them end to end. A butt joint does not appeal to an engineer as a desirable arrangement for use where a well-knit and smooth splice is needed. Something better must be devised. A joint five-year course of elective groups would apparently meet the requirements and could be arranged by cooperation between educational institutions. Whatever the plan, however, economic subjects ought, in my opinion, be given a place alongside of and in close relation to the professional scientific studies.

However well a man knows the physical and mathematical sciences, he can not make the most of his abilities as an engineer unless he also understands the human character and the trend of human progress. The study of historical and economic subjects is of an importance in the engineering curriculum that rivals the study of science subjects; and in order that the relations to each other of engineering science and political economy may be understood and appreciated by the students, the study of such subjects may preferably be carried on side by side. A span of horses makes a more effective team for cooperative work than a tandem pair, though it may not be so showy.

I do not propose here to discuss the question much argued in some educational circles of what qualities makes one study "liberal" and another study "professional." Personally, I believe that most studies are "liberalizing" when studied with a spirit of enthusiasm, seeking for thoroughness and the reception of truth, at least when accompanied by that reflective

consideration which makes for imagination; and the same spirit is needed to make any study of much value as a preparation for a profession. Highly developed powers of observation and induction go far to determine a man's success in most professional branches, and also in those branches of business that count. That is a collateral reason why chemistry, physics, mathematics and applied mechanics are such important studies for engineers. They teach their disciples to observe closely and accurately and to draw correct conclusions. An industrial engineer must also know the thoughts of the world, the flux of society, the ambitions of nations. He can not be a "hermit wrapped in the solitude of his own originality," but must have broadly humanistic sentiments and sympathies. These facts being obvious, what truly humanistic studies can we rightfully exclude from the list useful as preparation for engineering professional life? Our solicitude need only be exercised to see that sufficient of the mathematical and physical sciences, the historical and economic studies, and the languages make constituent parts of the curriculum, and that the spirit and order in which these are studied are right. It is probably in the latter that we are erring. The sciences, historical and economic studies, and languages are well represented in the curricula of many of our engineering schools, but there is a failure to impress on the mind of the student that the economic subjects are intimately related with the work of his profession. Perhaps here lies the explanation of the apparent failure of engineers to play their reasonable share in civic affairs. If that is the explanation, our methods of teaching ought to be promptly reformed.

Another serious fault has been charged against the graduates of the engineering schools as they come newly from the

schools, and this is an unwillingness or inability to work faithfully in cooperative organization with others. This fault has been trenchantly presented by your very distinguished alumnus Mr. Frederick W. Taylor, and he ascribes it to an overesteem and a lack of seriousness on the part of newly made graduates. The lack of seriousness I am not now ready to admit, and I think the fault more likely to be caused by the failure of our instruction to inform students of the tremendous importance of cooperative effort and common-sense business processes in industrial life. It is true that the same fascination as heretofore lingers around independence in spirit and in work, but industrial affairs have grown so large and complex that a man can not singly make a large influence. Cooperation with others is necessary—loyal cooperation. The conditions of the old-time one-man shop have passed away, probably forever. However high up a man may now go, he must cooperate cordially and loyally with associates, and they and their subordinates must cooperate loyally with him. It is said of Napoleon that, "Grand, gloomy and peculiar, he sat upon the throne a sceptered hermit, wrapped in the solitude of his own originality"; and Napoleon was an influence of tremendous effect. But historians point out that even Napoleon finally failed from lack of cooperation. However forceful, however original, a man may be, and however far he may go by his own unaided mind and effort, well-planned cooperative effort of lesser men can always accomplish his defeat. Also, besides the pervading importance of personal cooperation, students must learn the importance of cooperative or associate use of the mental processes gained from their study of science and from the dictates of common business sense. Some electric light plants make money because they are operated in ac-

cordance with principles of sound science and economics; others make money because they are managed with admirable business sense, though it may be without conscious guidance of science or economics; but in relatively few are found the invincible association of sound engineering with sound business sense.

Mr. Taylor's proposal that each student should be required to spend a year or more in commercial shop employment before the end of his course of study in the engineering school would do much to correct this fault. It is to be welcomed as a constructive suggestion in reference to the curricula of the engineering schools; but I believe much can be accomplished by improving the processes used in teaching, without changing the curriculum. Teachers and students when pursuing learning both become so absorbed in the pursuit as to forget the end sought. The result desired may be accomplished largely by the influence of the teachers, by the character of the treatment of the students and by the sort of ambitions that are put into them. It can be done in some degree by the selection of the work assigned to the curriculum, but the subjects studied, in my opinion, are of less importance than that the students learn (as Kipling puts it):

Truth, and God's own Common Sense.

In thus discussing certain faults of the curricula of the engineering schools with this audience, which I understand to be largely composed of the students of this Institute, I take the ground that it is desirable for students as well as faculties to recognize, reflect on and understand the human shortcomings of the courses of training. By no other means, it seems to me, can earnest students be stimulated to make the most of their opportunities and belie the charge of inefficiency that is sometimes laid at the door of engineering grad-

uates. I think there is no doubt that the engineering courses make the best preparation for engineering and industrial life that has been devised. Good engineers lived before the engineering schools; but the engineering schools are doing a tremendous work in providing men with the mental means to extend engineering knowledge and advance engineering practise.

One of the things that students, to their disadvantage, commonly fail to keep constantly in mind is the fact that a man of ability and courage can usually make of himself that which his ambitions dictate. If you set your ambitions right there need be no fear of your reasonable success. Failure by a man of ability and courage, who also has the advantage of education, is scarcely to be condoned. The only sufficient excuse is an inadequate physique or ill health caused through no fault of the individual. In engineering nothing is ordinarily sufficient to excuse failure.

Samuel Lover says in his humorous but human story of Rory O'More:

Now, it was not merely luck was on Rory's side, for he turned all the accidents to good account, which would have been thrown away on a fool; and this, after all, is what makes the difference in ninety-nine cases out of every hundred between a lucky and an unlucky man. The unlucky man often plays life's game with good cards and loses; while the lucky man plays the same game with bad ones and wins. Circumstances are the rulers of the weak—they are but the instruments of the wise.

If a man concentrates his efforts, is honest, is patient, performs his duties with thoroughness, masters the principles relating to his employment, and thinks (it is remarkable "how many never think, who think they do"), he is sure to succeed. True success is a great achievement, and great achievements require long expenditure of well-directed endeavor for their erection. It is a restlessness and discon-

tent born of a failure to note the last precept, often accompanied by an excessive self-esteem, which leads to Mr. Taylor's criticism of engineering graduates to which I have previously referred. For the cure of that I will refer you to Kipling. He says in a burst of autobiographical confidence:

As there is only one man in charge of a steamer, so there is but one man in charge of a newspaper, and he is the editor. My chief taught me this on an Indian journal, and he further explained that an order was an order, to be obeyed on a run, not a walk, and that any notions as to the fitness or unfitness of any particular kind of work for the young had better be held over until the last page was locked up to press. He was breaking me into harness and I owe him a debt of gratitude which I did not discharge at that time. The path of virtue was very steep, whereas the writing of verses allowed a certain play to the mind, and, unlike the filling in of reading matter, could be done as the spirit served. Now, a sub-editor is not hired to write verses; he is paid to sub-edit. At the time, this discovery shocked me greatly; but some years later, when I came to be a sort of an editor-in-charge Providence dealt me for my subordinate, one saturated with Elia. He wrote very pretty Lamblike essays, but he wrote them when he should have been sub-editing. Then I saw a little of what my chief must have suffered on my account. There is a moral here for the ambitious and aspiring who are oppressed by their superiors.

If every young engineering school graduate who becomes discontented with his duties and the treatment he receives would read, ponder and reflect on these words of Kipling, which express his youthful experiences, I believe Mr. Taylor would have few opportunities to repeat his criticism of the new graduates from engineering schools.

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

DOCTORATES CONFERRED BY AMERICAN UNIVERSITIES

THERE are given in the accompanying tables data in regard to the degrees of doc-