

The following Note by Professor Cormack was read before a meeting of members from all the sections of the Conference.

### “Apprenticeship in Engineering Training.”<sup>1</sup>

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THE subject of this discussion is wide and complex. “Engineering” is to be understood as including all branches—to be in fact Civil Engineering in the widest meaning of the term. An apprentice is simply a “learner”; whatever be the branch of engineering, or whatever be the aim or the ultimate end of a young engineer—whether he is to be a workman, or whether he is to be an employer—during his apprenticeship he is a learner. The title therefore includes “pupil,” although in certain branches this term is sometimes used to distinguish the “paying” apprentice, who aims at being an employer or designer, from the “paid” apprentice, who becomes a workman. These definitions embrace too wide a field; and it is necessary to limit it to the training of youths who are destined to be men in responsible positions, employers, manufacturers, consulting engineers, designers, heads of departments, or technical managers. Whether or not such apprentices should pay, or should be paid, is a matter for the decision of individual engineers, or of engineers in different branches; and this question may therefore be left out of the discussion.

Until the beginning of last century, entrance into the trades and the professions could be obtained only by means of an apprenticeship extending over 7 years, during which the apprentice was bound to serve a master, who on his part undertook to keep him and to teach him his work. The system, as it then was, led to many abuses, which the Act of 1814 was designed to counteract. It opened wide the doors to all except a few professions; and no restriction was placed either upon the manner in which a youth learned his future occupation, or upon the duration of his training. At that time engineering, except in a few branches, was just emerging from its position among the crafts. The removal of the restrictions to entrance may have been harmful in some ways; but at all events it allowed free entrance to many

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<sup>1</sup> *The Engineer*, vol. xcv. p. 641. *Engineering*, vol. lxxv. pp. 847 and 872. See also Paper and Discussion in Proceedings of Institution of Mechanical Engineers, 1903, pages 281–349, on “The Education of Engineers in America, Germany, and Switzerland.”

men who, although trained for other pursuits, became pioneers in different branches of engineering.

Although the restrictions were removed, there still remained the idea that the proper way to become an engineer was to spend a period of 5 or 7 years in the workshop or office. Probably, in the then existing state of what engineers are now proud to call the profession, that was desirable; but now, after a century which has seen vast developments in engineering practice, and during which, with ever-increasing rapidity, scientific discovery is turned immediately to practical utility, it seems reasonable that some more generally recognized plan of apprenticeship should be devised, to suit the new conditions. The inadequacy of the old apprenticeship has been realized for some time. So long ago as 1866, Sir John Fowler<sup>1</sup> laid stress on the importance of combining the study of science and engineering theory with the ordinary apprenticeship. Since then it has become more generally recognized that the proper training for an engineer involves training both in theory and in practice; and this has for the past 7 years been emphasized by the Institution in demanding a knowledge of theory from candidates for Associate Membership.

When the technical education fever was at its height, opinion to some extent went to the other extreme; and it was thought by many that at last the solution of the problem had been arrived at. The numerous universities and technical colleges were expected to be able to turn out young engineers equipped not only with the necessary technical knowledge but with experience gained in the college workshops. In the United States and on the Continent this system of training has to a large extent been adopted; but there are indications of an increasing tendency to diminish the workshop practice in the colleges, and to substitute a training in workshops under commercial conditions. Especially in the United States is there excuse for such a system; for there the extraordinary rapidity of the increase in engineering business has created a corresponding demand for young men possessed of scientific knowledge and of some technical training, and capable of filling responsible positions.

In this country however, starting with a pre-eminent position in engineering, and advancing with the times—perhaps at a less rapid rate than elsewhere, but still with sufficient prosperity—interest in the training of young engineers has not been so generally aroused. Biassed as were some by the old traditions,

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<sup>1</sup> Minutes of Proceedings Inst. C.E., 1866, vol. xxv. p. 219.

infected as were others by the technical education fever, the advice given to young engineers has been highly discrepant: with the result that at present their training is in some quarters found to be in a rather chaotic condition. The ever-increasing keenness of international competition should alone be sufficient to urge a solution of the problem. But the call seems still more emphatic when, remembering that the art of the engineer consists in "directing the great sources of power in nature for the use and convenience of man," his cosmopolitan duties are realised. The beneficial direction of the forces of nature implies a knowledge of the laws governing their behaviour. The definition of the title "civil engineer" demands from him both theoretical knowledge and practical experience; whence it may presumably be taken as agreed that both are essential in his training.

The Institution has for many years devoted most careful attention to the conditions of training which should be fulfilled by those coming under its purview. The "regular training" prescribed by its by-laws is defined by the Council's rules to involve a *minimum* period of 3 years' pupilage, or training as an assistant, where the standard of education is simply that required for admission as a student; and such *minimum* period of practical training may be reduced to 2 years where a recognized college course of study is taken. In each case the practical training must comprise experience both in the office and in or upon the works. The questions to be discussed are therefore:—

(1) How should the knowledge and experience in each be acquired?

(2) Is there any arrangement suitable for all branches of engineering? and if not, what modifications are required for the different branches?

(3) Over what period of time should the complete training extend? and what is the best arrangement and division of the time?

Leaving out of account the genius who may achieve eminence in engineering without special training, the raw material is a youth of seventeen or eighteen, fresh from school, educated perhaps to a standard below that which might be desired or expected, and supposed to be endowed with common sense, natural aptitude for the profession, and sufficient physical strength. The finished product is a blend of scientific and technical knowledge, practical experience and business method. Our colleges should supply the first two requirements; but it is submitted that the last two can properly be acquired only in the workshops and offices,

and that no training can be considered efficient which does not include a considerable period of practical apprenticeship. Colleges may supply knowledge relating to the properties of materials, the theory and structure of machines, instruction in testing and in the methods of attacking new problems; but it is only under actual commercial conditions that the novice can acquire the proper kind of practical experience, adequate knowledge of the design and construction of machines, experience of the workman and sympathy with him. It is in the factory or office that he can gain, by observation and imitation, some knowledge of routine, estimating, organization and management, business methods and administration, the production of the maximum amount of work with the minimum friction and at the minimum cost. Imitation of good example counts for much in engineering, as in other professions; and to this no doubt can be largely traced the continued success of British engineering, despite its comparative slowness in advancing with the times. It is in this respect that Continental and American modes of training will be found deficient. There the young engineer is launched upon his future occupation after a college training of four or five years, with workshop experience gained, especially in America, only in the college, and with sometimes a total commercial experience of only a year or less.

When he enters the profession it is seldom that a youth knows what special line he will eventually follow. The organization of this Engineering Conference indicates at least seven important branches of the profession. He may be trained as a mechanical engineer, and eventually end as a railway engineer, an electrical engineer, or a naval architect. There is no broad line of distinction; the branches are so closely related. The mechanical engineer must not build machines without considering the purposes for which they are intended. The dynamo manufacturer cannot look at a combined set solely from the commutator or collector end; the railway engineer cannot confine his knowledge to the finished girder or the finished locomotive; and the naval architect is not concerned simply with the lines or hull of a ship. Underlying all branches there is to some extent the same practical foundation. All demand knowledge of the properties and uses of materials of construction, and of the methods and processes whereby these are converted into structures and machines. In many of the branches it is generally realized that a man must go "through the shop"; and after all, the processes in one "shop" do not greatly differ from those in another. Workshop experience however is not generally included in the training of all engineers; but surely it

is desirable for all, and especially and increasingly so when steel has to a large extent displaced masonry and timber, when all sorts of motors bulk largely in engineering work, and when machines of all kinds are utilized for constructing to engineers' designs.

If it is considered desirable that the training of all engineers should include experience in suitable workshops and factories, while specialization is confined more or less to the drawing-office, the discussion becomes limited to the consideration of the time required, and the best division of that time between the college and the workshop. The duration of training depends to some extent upon the arrangement of the course; but probably it may be safely said that, in order to produce the ideal young engineer, the training should extend over five or six years, which might be about equally divided between the college and the workshop. Whether there is any one system that is the most desirable is a question which may be left for discussion chiefly by engineers in practice; for it is certain that the colleges are anxious to have a solution of this problem, and to adapt their courses to any scheme or schemes that may be thought preferable.

In this country at the present time the systems in operation may be classed as—*a* and *b*, "separate" systems; *c* and *d*, "combined" systems; *e* and *f* and *g*, "compromises."

(*a*) *Workshop only*.—This is a survival of the old traditions. It demands physical exertion during the day and mental strain at night, if theory is to be acquired. Many eminent men in the past have undergone the strain and emerged successfully; but in the future the ever-increasing demand upon the engineer will render it unpractical, and almost impossible. Many clever youths enter the shops on this system, with limited opportunities but with great ability; and provision should be made for them in any scheme of training.

(*b*) *College only*.—This plan has already been alluded to (page 93). Under exceptional circumstances, such as obtain in the United States, it may be expedient, but it is undesirable.

(*c*) *Works before College*.—A youth entering college after say three years in the factory and office is in many respects a good student. He has gone through the shops at the receptive and imitative age; he has ascertained whether engineering is still to his liking; and he comes to college with a knowledge of processes, materials, and machinery. He has some idea of what he wants to know, and which branch he wishes to enter; but has often wrong theories, which are difficult to uproot. Teachers prefer such a student, provided he has continued his studies during his appren-

ticeship; but this he has not always or even generally done. He may have forgotten much of his school training, and, what is worse, he may have forgotten how to study. If he has studied, it has been under trying conditions, when he was physically tired; and he may wish to confine his studies to the more interesting technical subjects, neglecting more or less the science underlying them; and in consequence his progress is less rapid. He comes to college, disinclined probably to have to begin again in order to gain the scientific knowledge which ought to precede all its applications.

(d) *College before Works.*—A youth fresh from school and sufficiently educated is likely to make good progress in his scientific studies. In the technical work he is handicapped by his want of knowledge of manufacturing processes and of the operation of machines, and is unable to associate his theoretical studies with practical examples, of which he has had no experience. Laboratories help to some extent to reduce the handicap. If this was to be the standard training, there would be a greater plea for college *workshops*, which would supply some little practical experience, but could not supplant, even partially, the workshop training under commercial conditions. It may sometimes be urged that this plan produces a youth disinclined to undergo what he may call the “drudgery” of the workshops; but it may be as readily admitted that the proper sort of youth acquires his practical experience at a much more rapid rate after he has undergone a college training, and that he has no such disinclination. Plan (d) may be preferred by employers, while plan (c) may be preferred by teachers.

Other plans are in vogue, either by accident or design, of which the object is either to avoid the disadvantages connected with “separate” and “combined” systems, or to minimize the required period of training.

(e) *Intermittent systems.*—These include the Works-College-Works and College-Works-College plans. Many arguments can be advanced by the advocates of each. The first arrangement has to a lesser extent the disadvantages of system (c), and the latter those of system (d). Both waste time, in so far as the usual college terms extend over only 9 months of the year, and the remaining 3 months may be wasted, because few engineers care to take youths for only 3 months in the year. But probably on the whole either of these intermittent systems is preferable to (c) or (d). In the College-Works-College plan the youth fresh from school has an opportunity of acquiring a foundation of science, on which to rest his works experience; but if study is not continued, his knowledge may evaporate in the works; and again at the end

of his second college training he will be out of touch with his employers.

(f) *Sandwich system*.—This plan goes one step further. During a period of say 5 years training, in the first 4 years 6 months of each year are spent in the factory or office, and 6 months in the workshops; and the fifth year is spent in the workshops or office. It lessens the discontinuity between the two parts of the training; and effects a saving of time, inasmuch as the college long vacations are utilized. An objection which may be put forward is that the youth is always “on the move.” He has no time to settle down either to the workshop or to college work; and he may have difficulty and extra expense in arranging for lodgings. It must not be forgotten however that each part of his work forms a recreation for the other; and he is likely to return to each with considerable keenness.

(g) *Concurrent systems*.—These either give time for study in classes in connection with workshops, or offer workshop training in connection with college. Both systems have already been alluded to under (c) and (d). The objections to (a) and (b) may be applied here. Time taken off the workshops for study leaves less time for gaining practical experience, and the latter is not acquired under strictly commercial conditions. Except in the largest works, it is impossible to provide the requisite standard of teachers; and if it is necessary that a youth should breathe the atmosphere of the shops, probably it is equally necessary for him to breathe that of the college.

The foregoing list may not comprise all the plans in vogue, and the arguments for and against them are merely indicated; but it serves to emphasize the diversity of the ways in which a youth may enter engineering. Is it not possible, at least to some extent, to standardize the training?

The following speakers took part in the discussion of the subject:—Messrs. D. Drummond, J. P. E. C. Stromeyer, W. H. Allen, A. Jamieson, H. Davey, T. Parker, A. F. Yarrow, and R. C. Parsons; Lieut.-Col. Crompton, Messrs. B. H. Blyth, B. Hopkinson, — Jenkins, J. W. Chenhall, and M. Robinson; Professors Ayrton, Burstall, and Capper; Messrs. Ferguson and J. M. Moncrieff; Captain Sankey, Mr. C. Bell, Sir William White, and Mr. E. B. Ellington.