Paper No. 5340.

" Organization and Execution of Engineering Work."†

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Mr. E. M. Barnard observed that to have knowledge of the subject, and to be capable of using it, was an essential part of an engineer's duty. Yet it seemed to be left to the individual to acquire that knowledge as opportunity occurred, which might be very seldom.

Many people considered that programmes were a futile waste of time, and would point out at the end of a job how far the original scheme differed from that which was actually executed. However great that variation, the engineer who had beforehand examined in detail the quantities of every item of work which had to be performed, thereby determining the quantity of work to be done by plant, and by hand labour respectively, was far better off than the engineer who had not. Knowing the time given to complete the job, the order in which various portions were required, and the quantity of work which an average man could do per hour for each item that occurred, a labour curve might be drawn up and the progress chart adjusted to suit.

Much useful information had been collected by the Ministry of Works in pamphlets entitled " Payment by Results " (issued by H.M. Stationery Office). Those pamphlets formed a good guide to the basic output per man per hour for most kinds of work encountered. From that information a financial curve might be drawn up, following which, a curve showing the output per man-hour should be plotted at regular intervals during the job. That curve necessitated considerable labour in compilation, but it showed at a glance whether the job was running successfully or not. Each change of grade had a meaning, and the engineer should be capable of giving the correct interpretation.

Colonel C. C. H. Brazier, O.B.E., observed that the engineering and allied professions in Great Britain had, for many years, been content to accept a purely " back-room boy " position in the industrial life and government of the nation. Engineers had, generally speaking, kept to the drawing-board, slide rule, workshop, and construction, leaving questions of administration to financiers, lawyers, and other commercially

† Journal Inst. C.E., vol. 20 (1942–43), p. 115. (Apr. 1943.)

minded people. He was aware that in framing policy, bodies such as Royal Commissions, etc., frequently consulted engineers in a purely technical capacity, but, to his mind, that did not go far enough.

Very few members of the profession seemed to take any interest in public affairs, but were content to leave all such matters to more politically minded folk. Starting with parliament, how many engineers were found shaping the nation's destinies? If the study were carried through all public bodies and corporations the same feature would be found. If the great industries of the country were compared with those of, say, America or Germany, it would be found that abroad one invariably met qualified technicians at the top, running the large engineering, chemical, and allied processes, whereas in Great Britain the directorate of any technical process frequently consisted mainly of stockbrokers, lawyers, salesmen, business men, and professional directors. Whilst it could be argued that the primary task of any great industry or organization was to make a profit (a debatable point in the present days), surely a technician with a suitable administrative and financial outlook should be the better fitted to manage the affairs of such undertakings.

The conversion from peace to total war had brought up that point on many occasions. The conflict had been styled " an engineers' war ", but it was necessary to look a long way to discover technically qualified people directing affairs, even in places where that would appear paramount for a proper consideration of all the factors. Colonel Brazier considered that in a mechanized age that handicap was a loss to the nation.

When turning over the pages of the " Journals " of the senior technical Institutions, one usually looked in vain for any deliberations on matters of policy, and the Papers seemed to be content with the purely technical aspects of engineering problems. The Author's paper was an exception, and was at once a challenge and a stimulus to the profession to put its house in order.

The present system and curriculum of technical education gave the impression of being drawn up exclusively for those who *designed*, whereas in fact the vast majority of the profession had to *execute* in a world governed by politics and economics. Where economics and kindred subjects were included, they were frequently relegated to such a subsidiary position as to influence the student in the wrong direction. The fault appeared to be mainly the responsibility of engineers themselves, in being content to leave the direction and administration of their work to others, and in not training the younger members of the profession to a broader outlook upon life. Too early specialization was probably one of the main causes which tended to cramp the outlook of the younger members of the profession.

Two factors had emerged which indicated the necessity for change, namely :—

(*a*) the training of engineers should provide for a greater appreciation of administrative, economic, and even political considerations ·

(*b*) the Institutions should encourage a greater interest in public affairs among members of the profession, and, where possible, should take a lead in discussing policy and securing representation of their views.

Mr. N. M. Brydon observed that the civil engineering profession was not alone in its inability to provide *young* men with executive and organizing ability allied to technical skill. Although a system might be devised for training the young military engineer in organizing and executing the highly standardized type of work carried out by him, Mr. Brydon would be loath to attempt to devise a programme of training and examination which would purport to turn out a young civil engineer capable of designing, organizing, and executing one-hundredth part of the types of works the world expected of him.

Mr. F. T. Bunclark observed that, in his view, it was essential that qualified engineers should be employed on the contracting side of the industry as well as on the consulting side, in order that confidence might be maintained in the workmanship of firms of repute in carrying out works of an engineering nature. In view of the casual nature of employment from which the industry had so far suffered, it was to a great extent by chance on which side of the profession a young engineer's interests might develop, and training should therefore equip for both sides, in the interests of both the profession and the individual.

The present scope of the Associate Membership examination was limited to training of a technical nature, and as the young engineer concentrated during his early years upon qualifying to pass that examination, he was forced to the design side to attain his object, with a consequent lack of experience in the execution of work and of commercial knowledge. It was usual, in Section " C " of the examination, for the candidate to be presented with sketch drawings of a small engineering work from which to take out and bill quantities according to the standard method of measurement. Mr. Bunclark suggested that that might be extended and the candidate asked to make up order lists for the materials, in a form understandable to suppliers and merchants, for the work under consideration ; and with that was allied commercial methods of measurement and knowledge of current prices of materials.

With regard to the execution of work, it was difficult to supply training except by practical experience, but the questions put to the candidate at the oral examination could cover the field of method of carrying out the work, and economic job layout, type of plant to be employed, probable period of construction, and type and quantity of labour necessary, to test the candidate's adaptability in those important factors of construction.

If those matters were mentioned in the curriculum for the examination, an indication would be given of the lines of training required to cover the practical execution as well as the design of engineering works, and of the bearing of execution upon design.

Mr. S. C. Doughty observed that he was pleased that a subject of such prime importance had been brought to the light of open discussion. The variety of views expressed formed a measure of the need for light on the darkness. The Author's courage in broaching matters too often regarded as outside the province of the engineer was very gratifying.

Mr. Doughty's experience had been about equally divided between engineers' and contractors' service, in the office and in the field. When he had first had to make up an estimate of cost he had not known where to begin. How many men would be required to perform a certain operation, how long would they take, and what would they be paid? The output of machines was equally a mystery. Yet the information he had required—or enough to form a guide to judgment—had been available out on the works he had seen carried out, had he but had the impulse to use his eyes. Those were fundamentals. It was necessary to develop the simple and useful habit of counting the number of men at the points of work. At first sight one could not say how many there were, as a fair number were always " hidden ", and the total force always turned out to be bigger than would have been expected. Then there were the " stragglers " or supporting men of all kinds needed to keep a job going. It had been said that fifteen men were needed in the Royal Air Force to keep one man aloft: and it was safe to say that two men were needed in average conditions to keep one man producing permanent work on construction.

Mr. Doughty believed that such matters could be only lightly touched upon in any training course; but the latter should stimulate the pupil's curiosity or " inquisitiveness ". He should make it his business, when he entered the world of practice, to find out for himself the factors making up the cost of work. To do that he should be trained in the fundamentals —to know what to look for. No two jobs were alike. When costs and how to ascertain them had become familiar to an engineer through intimate acquaintance, he would have little difficulty in making up estimates for future work.

Keeping detailed progress records was closely bound up with cost keeping, and was essential to good judgment in estimating for the future —in being able to say how long a new job should take.

Those matters were also closely related to organization. Nowadays more than ever it was important to be able to say what labour force would be required week by week, and that could not be done without a knowledge of output or of the progress of gangs and the machines they operated. It was unlikely that labour would ever again be available at short notice in unlimited numbers, and such requirements should be planned and forecast. Organization of the labour supplied, or to be supplied, demanded considerable knowledge of technical and administrative problems, as well as of human nature and the latest Acts of Parliament.

It might be asked, why recapitulate the obvious? Mr. Doughty

endorsed the Author's views on p. 117, *ante*, with the qualification that the training referred to could not be assimilated in great measure in formal courses. It could and should be obtained largely in the course of actual construction work. The responsibility to the community in that respect fell partly on the employer, whether contractor or engineer, who should encourage his young assistants to familiarize themselves with all matters relating to costs and labour management, and partly on the young engineer, who would find it well worth while to cultivate a consuming curiosity on all matters on which he was in the dark. Instead of money matters remaining a closed book to him, he should develop a facility for juggling with wage rates and hours of work, numbers of men, and outputs, if only to see what kind of answer resulted. An intelligent estimate, however wide of the mark, was preferable to guesswork, or no estimate at all.

Mr. Doughty agreed with the Author that the " difference " between a Resident Engineer and a Contractor's Engineering Agent was deplorable, and had been unnaturally fostered by prejudice and tradition. The more they became " mixed up " the better it would be for the good of the work. Deficiencies in that respect were widely exhibited at the present time. Large volumes of work were being carried out by Departments under contracts which paid all costs out of public funds and thereby imposed on the departmental engineer a high degree of responsibility for organization and execution. In that respect there had been a failure to adjust the point of view and to participate sympathetically and constructively in the contractor's problems. The easy way was to sit back and say " Oh, that is the contractor's problem ", or on the other hand " Why on earth doesn't he do so and so ? " With government controls and service requirements seriously complicating the normal routine of contract work the engineer's responsibility was inescapable. Interference and criticism without knowledge and understanding did more harm than good.

Sir Frank Gill observed that the kernel of the Paper seemed to have been missed by some of those who contributed to the discussion ; and, still more significant, the silence of those who might have been expected to speak was a testimony to the correctness of the Author's views. For the theme of the Paper was surely that whilst more was required in engineering than a brain crammed with technical information (much of which would undoubtedly be forgotten in a short time), the laying out of a job in an economical manner, the methods required to check the progress, and generally all that had to be done by an engineer, apart from the technical matters, were sadly neglected in education and were not tested by Institutions when investigating candidates' qualifications for membership.

Dr. Faber was very right when he said " Surely the essence of a good designer was to be able to make several designs to satisfy a problem and decide, among other things, what their relative cost would be." But whilst it was correct to say that there should be : (1) a statement of the problem, (2) several designs to satisfy it, and (3) a decision (guided by

economic analysis), to select the design to be approved, yet that was not enough and would merely leave the young engineer struggling to find the most suitable methods. It was quite easy to teach methods of analysis which would arrange alternative plans in economic order, whether those plans were for the design of a piece of apparatus or a system, a method of execution of the work, a question of the desirable speed of execution, the period for which it was economical to plan a given work, or whether to scrap or continue existing plant. In short, a general system of economic analysis was available which could be adapted to meet any case for which sufficiently correct financial estimates could be prepared.

It would probably be untrue to say that those methods were not taught at any of the Engineering Schools in Great Britain ; but if the Institutions wished to ascertain that, they could, through their members who were connected with the Schools, some of whom acted as Assessors for the National Certificate Examinations, no doubt readily compile a list of schools where such teaching was really given.

Mr. M. E. Habershon observed that no exception could be taken to the contention of the Author that an engineer should have executive and economic, in addition to technical, qualifications, and for that reason consideration of his training in such branches of the profession was an important matter.

Whilst the Author's subdivision might be appropriate for the military engineer, it was not so suitable for the civil engineer. From the latter's point of view there appeared to be little advantage in separating " organization of execution " from " execution " itself, and Mr. Habershon considered that it was desirable to differentiate between technical execution and non-technical management or administration. The latter section would include the Author's " economic " section in addition to items of a non-technical nature such as stores and labour control, set out under " appreciation of the situation."

That grouping of the main duties of a civil engineer would thus comprise the following three main categories, and with those in mind training could be considered in a more satisfactory manner :—

(1) technical design ;
(2) technical execution ;
(3) management or non-technical administration.

Technical design was the basis of the civil engineer's work and certain fundamentals had to be mastered before any further progress could be made. That had been recognized both by The Institution and by the Universities.

Technical execution was the technical means by which the design was put into effect, and was largely complementary to the design. It should form an essential part of the young engineer's training at a University or Technical College, and should be supplemented by practical work in the field under the direction of a trained engineer.

Non-technical administration was something which did not seem appropriate either to a University or a Technical College engineering course. Until a person had obtained reasonable technical knowledge and had acquired practical experience in the world of affairs, he would not usefully acquire administrative knowledge. To attempt it was not to arrange an already crowded syllabus to the best advantage. That was not to say that that phase of work was not important, but that it was something which could be acquired more efficiently in connexion with normal work after general technical qualifications had been obtained.

Administrative experience needed, however, a general background of human values which should be obtained in the early years of training. Any further specific training of an administrative nature which was necessary should be dealt with by means of a post-graduate or staff college course during the period when the engineer was actually engaged in practical office or field work.

Mr. Rolt Hammond pleaded for less time to be spent in a college on chasing the square root of minus one, and more time to be devoted to methods of carrying out large engineering work.

On tunnel works, for example, the job could not be brought to successful conclusion without complete collaboration between engineer and contractor, particularly in those cases where intricate and dangerous operations were concerned. It was no part of the duty of a resident engineer to act as a super-detective, but to be firm in his decisions and not to compromise.

In view of the many complex problems involved in large engineering works, the full energy of the engineer would be required to keep abreast of his technical problems, and it was hard to understand how he could possibly hope to be an expert manager as well.

In planning a college curriculum, therefore, more time, should be devoted to studying how difficult constructional problems had been overcome, the technical means by which speedy construction had been attained, and in learning something of mechanical plant and its capabilities.

It was almost a platitude to say that every large work of construction had its own varied problems, and that a study of engineering literature would show that precedents seldom existed for their solution. Experience was therefore the greatest teacher; neither managerial skill nor high technical achievement could be learned from books.

Mr. E. C. Hodgson observed that experience showed that the acquisition of a knowledge of organization depended upon three essentials, namely, (*a*) ability; (*b*) the supervision and wise guidance of the Corporate Member under whom the trainee served, and (*c*) the full development of ability and training by vigorous practical experience on a variety of works.

With regard to (*a*), although a certain amount of knowledge was usually acquired during training, marked ability and qualities of leadership had to be present naturally for a high degree of competence in organization to be attained. Training in organization would largely depend on (*b*), since

it was necessary for the trainee to apply his technical knowledge to practical problems and to see the result. He had to learn to " know " men and the use (and misuse) of plant and labour forces and, in short, get *himself* organized. Obviously his chief would be in the best position to see that that was done. A young man was indeed fortunate if he had achieved (*c*) at the average age of completing his examinations for Associate Membership, and, therefore, might it not be assumed that the examinations were set to prove a candidate's " potential " at an important stage in his career, rather than a result ?

Having those points in mind, it would appear difficult to devise a course of study covering more than the superficial requirements of sound organization, and even more difficult to assess the extent of a candidate's knowledge by means of a written paper. It could be judged only by the methods he adopted in his duties. However, once he had found by experience that more difficulties were created by man than were ever created by nature, and that most engineering was largely a matter of *organized* common sense, he would have learned some important lessons necessary towards further development.

Messrs. Donald Leech and **N. A. Pritchard** observed that, as two of the young engineers referred to by the Author, and having experience of works organization both in and out of the Army, they had read the Paper with great interest.

They were in agreement with the Author's suggestion that some form of training in the organization of works was essential to the young engineer ; but they considered that it should take place on actual works, and not in theory—as it was surely a case where practical experience was the best.

Mr. Quartermaine had appeared to convey the impression that all works carried out by the Corps of Royal Engineers were of a standardized nature. That applied in part to the Divisional Engineers, but the sapper units in more rearward areas were called upon to do as wide a variety of jobs as was a civilian contractor, ranging from simple joinery to steel erection and reinforced-concrete work, in addition to Mr. Quartermaine's " set tasks ".

In civil practice the criterion was cost, but in military engineering the controlling factors were time and execution of work with materials and plant at hand. That required great care and accuracy in organizing the execution of the works in order that the job should not be held up, particularly as special items of plant might be available only for definite fixed periods.

They appreciated that accuracy of organization entailed by the above-mentioned points was not so vital in civilian life, but they were of the opinion that experience gained in that respect could well be applied to the economics (materials, labour, and cost) of civilian engineering works—thus

achieving to a finer degree the Author's definition of an engineer as "a man who can do for one pound what an ordinary man can do for two".

They considered that the experience gained by young engineers in the Corps, coupled with their civilian technical knowledge, would be greatly beneficial to them on their return to civil engineering.

Mr. R. L. McIlmoyle observed that most engineers who had been responsible, in either an executive or an administrative capacity, for the planning and execution of engineering works would endorse the views expressed by the Author, although there might not be the same measure of agreement about the effectiveness of the remedies proposed.

The method outlined under the heading of "Organization of Work" was satisfactory for small schemes, but the present tendency (which should be encouraged) was for the method of construction to be taken into consideration during the design stages and laid down in the working drawings and specification, thus reducing considerably the planning which had to be carried out on the site. Scope still existed for organization, particularly in the preparation of detailed programmes for the various stages, which, in many cases, had to be completed within specified periods, and the only satisfactory way of ensuring that was to analyse the work to as many simple operations as possible, to which definite times could be allocated.

The preparation of such a detailed programme would reveal any weaknesses in the scheme, and might suggest alternative or better ways of carrying out the work. It was essential that the operations should be reduced to the simplest possible terms; for example, in the case of the erection of a bridge, a simple operation would be to lift a girder and place it in position. That might be reasonably estimated as taking 15 minutes. The operation could be analysed further as follows:—

Sling and hook on crane	2 minutes.
Lift and move to position	2 „
Lower and adjust to exact position	5 „
Unhook crane and return to position to lift next girder	2 „
Total time for complete operation	11 minutes.

The operations mentioned above could be sub-divided even further, but a sub-division which would reduce the time to less than a minute was hardly worth while. In the example given a saving in time of 4 minutes per operation was indicated, but the analysis might equally well show that the original time assumed was too short. A further refinement would be to record the actual time for each operation against the estimated time, as that information would be of great assistance when similar work was being undertaken.

The young engineer in particular was apt to overlook the importance of the items discussed under the title of "Economics." Too often they were dismissed as being the concern of only the accounts or clerical side of the organization, but in many cases they were more effective tools than

a knowledge of the calculus. On small jobs the young engineer should himself carry out all the routine clerical work, such as the compilation of pay sheets, the ordering of materials, and the preparation of unit costs. The knowledge thus gained would be of considerable assistance to him when he reached more responsible positions.

Mr. McIlmoyle considered that the present practice of preparing estimates on an inclusive rate per unit basis was not suitable for engineering work. A much clearer picture was obtained if the estimates were built up from materials costs, which were easily ascertainable, and labour costs, which could be estimated in detail in terms of man-hours required for each operation and extended by applying the appropriate wage rates. That break-down, which should also be used when compiling unit costs, would provide data for the estimate of man-power required for the work.

The necessity of a progress chart had been very rightly emphasized, but the Author's description did not clearly show if the diagram was to include both estimated and actual progress. The comparison between those two factors was the key to effective control of the work; and in order to enable the maximum benefit to be obtained it was essential that the progress should be recorded currently and promptly. That also applied to unit costs, as if they were several weeks old they were useless as an effective means of control. The modern practice of central purchasing was making the preparation of actual current costs more and more difficult, and the engineer might be forced, through lack of actual data, to use estimates if the correct figures were not available in sufficient time for effective action to be taken.

A strong case could be made out for a knowledge of administration, which was an essential qualification for most senior positions in the profession. That was not a subject which could be easily taught, and experience in an actual organization was essential. There was much to be said for an arrangement where the young engineer spent a few months in each of the several sections or departments and acquired a working knowledge of their functions and inter-relations.

The Author had clearly enunciated the problem, but his solution did not seem to be complete. The subjects which ought to be included in the curriculum were increasing in number and it would be difficult to find room for more. Certain basic instruction could be given at the University, and with that foundation an observant engineer should be able to round off his knowledge by practical application, preferably under the guidance of a senior.

Mr. McIlmoyle wished to endorse the point raised by the Author in his conclusion. The senior positions in engineering were concerned almost exclusively with questions of organization, economics, and administration, and only too often those who attained them found that they had then laboriously to acquire the knowledge which had not been included in their earlier training.

Mr. James Mitchell observed that he could not agree with the Author's statement that The Institution had neglected the executive and economic side of engineering. The example, cited by him, of a piece of work carried out by the Royal Engineers, was highly specialized and did not bear much resemblance to the ordinary work of the civilian engineer. In the case of a direct-labour job, it was necessary for the engineer to make an estimate of the cost, and before the various items could be priced an idea had to be formed of how the work was to be carried out. Finally, the value of the estimate was tested by the actual cost of the work. In the case of a contract job, the estimate of the engineer was confronted with the amounts of the various tenders. Each tenderer had to deal with what was, for him, a direct-labour job. As the work was usually very completely analysed, and the quantities of the various items were measured-up, and had to be separately priced, that involved the most careful consideration of the scheme of operations, the plant necessary, and the smooth and prompt supply of the materials and labour required. In addition, the tenderer had to state the period within which he engaged himself to complete the work, and that involved a progress time-table, as applied to the work as a whole and to its various sections.

The statement that " the real leader is born, not made " had little meaning, beyond the fact that men varied in their native ability and in their capacity for learning, the latter being probably, in most cases, quite as important as the former. The idea that a clear-cut distinction existed between " technical " and " executive and organizing " ability was not in accordance with facts, the two being inextricably interwoven and men being interested in various degrees by the one or the other. Moreover, in every piece of work there was only a certain degree of scope for the two activities. It had to be kept in view that those in charge, from the man at the top to the lowest grade of foreman, were subjected to a constant demand for economy in the carrying out of work and for the organization which that involved. That constituted a training which it was impossible to give at a university.

Mr. J. V. Nimmo observed that in contrasting Civil Engineers with Royal Engineers, it was desirable to compare equals as far as possible. The point made by Colonel Norrie was relevant, namely, that the officers of the Corps of Royal Engineers were carefully selected from a highly educated and able group of competitors, all of whom were subsequently put through the same thorough training and specialized technical education, which was combined with a form of apprenticeship or pupilage, whereas the selection and training of civil engineers was fortuitous. There was not even any obligation on the part of the employer, whether the government, a corporation, or a private individual, to employ members of the Technical Societie and Institutions, who were the only authorities concerned with pro fessional competence. As a result, the standard of professional competence, and even of organizing ability, amongst civil engineers was surprisingly

varied. Indeed those qualities, which sometimes brought success to commercial men, and even politicians, and were not unknown in other activities, rather than real capacity, were also to be found in technical matters.

But there was a powerful factor which tended to keep the standard of efficiency high in civil engineering which was absent in military engineering, namely, the necessity for obtaining as good a return as possible on the capital invested.

Where unit costs were not studied and interest on invested capital was measured in terms other than cash, as was the case with military engineering, standards whereby efficiency could be judged were vague and largely matters of opinion. Many instances could be quoted of poor organization in wartime; for instance, the transport in France during 1914–16. As to peace—or even war—time conditions, one asked how the Works Directorate of the War Office compared with the corresponding organization of, say, the Canadian Pacific Railway Company.

It was not surprising that the Author had found a difficulty in understanding the difference between the functions of consulting and administering engineers and their representatives and those of contracting organizations. Even amongst civil engineers there was sometimes a lack of understanding on that question; and amongst the general public and in financial circles the ignorance about it was sometimes pathetic. The contractor was a man of commerce with special technical equipment and experience. Like all commercial men, his purpose was to make money by buying in the cheapest markets and selling in the dearest; although the specialities of his occupation sometimes obscured that fact.

Occasionally, it became necessary to organize a department for the carrying out of new construction work; and for that it was sometimes assumed that the business (or practical) man was best fitted. But the first essential in such an organization was good planning and designing; and as the business man—even the contractor—had no more aptitude for such work than any other man of commerce, the results might be, and often were, unsatisfactory.

Engineering did, in general, illustrate more clearly than almost any other occupation the two features necessary for the successful conclusion of any operation, namely, planning and execution. Those activities might be carried out by different or the same individuals, such as in large public works on, the one hand, or in the manufacture of machines on the other hand. And there were a variety of gradations between those two extremes. In large public works, for instance, not only did their planning require special qualifications, which in the main were different from those required for their actual construction, but also the client required someone acting for him who had no other interests than the client's, and who would safeguard those interests during execution; whereas the organization carrying out the actual construction had the primary interest of making a profit consistent with the terms of the contract that had been signed.

On the other hand, in the manufacture of machinery so intimately were the designing and manufacturing interlocked that it was rarely practicable or advisable to separate them. There were a few cases in mechanical construction where it was to the advantage of the purchaser to have a consulting mechanical engineer advising him in much the same way as the consulting civil engineer acted for public works; but those cases were comparatively rare. Just as cases arose in civil (that was, non-mechanical) engineering, where the contractor was able to persuade his client that he had special facilities for designing. Indeed, sometimes in such cases the client was under the impression that his designing was done for nothing.

Both activities, design and construction, called for organizing ability and technical knowledge, but in different proportions and of different kinds. In design, technical knowledge predominated and in construction, organizing ability was the more important factor. It was a mistake, however, to assume that contractors were necessarily better organizers than engineers.

Organization, like any other important activity, required certain essential qualities which should be inborn, but could be developed. Those were clear thinking, a quick recognition of the relevant, a sense of values and of what was practicable, drive, skill in delegating authority, power of command, an understanding of human nature, and the capacity to handle men.

Civil engineers were as likely to be born with those qualities as were Royal Engineers, or contractors, or anyone else. They could be developed to some extent by tuition, but much more efficiently by experience. It was because such experience could be gained more extensively in, and was more essential to, contracting and because it was more readily displayed in a contractor's organization, that contractors were reputed to be better organizers than engineers. Certainly experience with a contractor was of the utmost value to an engineer.

How far college and university curricula should be adapted to teach those subjects was an interesting question. But, since the basic studies of pure and applied science, necessary to make a good engineer, demanded so much time, and since practical experience was such an efficient means of learning about organization and craft-skill, it would seem wiser to instruct the student as to what he needed to learn after he left college and where, during his career as an engineer, he might expect to obtain the necessary training, than to attempt to teach him such subjects at college. An engineer should always be a student, and he could obtain from technical literature all that an instructor could teach him at college on such subjects as organization.

In his inspiring Presidental Address,[1] Professor Inglis had well described the principles that should be applied to the training of engineers at a

[1] Journal Inst. C.E., vol. 17 (1941–42), p. 7. (Nov. 1941.)

University. But did those, into whose service those graduates ultimately entered, make the best use of them ? Mr. Nimmo wished to suggest that it was in solving that problem, rather than in any material change in university curricula, that improvement lay.

Unlike the doctor, the engineer could not display the results of his efforts in terms that were obvious to the community ; only an engineer could say whether a bit of engineering was first or second rate. But the results of second-rate doctoring were soon manifest to all.

In the long run, the organization of engineering work depended upon the efficiency of engineers. To obtain a high standard of engineering, assuming the essential qualities were there to be developed, required a knowledge of the craft, a scientific approach, and the highest integrity. All three were equally essential. Without any one of them, engineering would be second-rate.

Confusion arose through the use of the terms " Programme ", " Progress ", and/or " Process " (Charts) as if they were synonymous ; although they might be applied to quite different functions.

A Programme chart illustrated a programme which it was proposed to follow in the future. A Progress chart was a record of work, while it was being carried out. The term Process chart was mainly applied to factory work and usually had the same significance as Programme chart.

The designing engineer would programme his work as a help in preparing his general lay-out and as a guide in preparing his contract documents.

The contractor, when preparing his tender, would programme the work so that, amongst other purposes, he might scheme out the most efficient arrangement for the general layout and for the labour, materials, and plant. When the contract had been let to him he would enlarge his programme to include greater detail.

During the course of construction both the engineering and the contracting organizations would keep Progress Charts up to date, the detail and intricacy with which the progress was recorded depending upon the circumstances.

No important undertaking could be carried out efficiently unless both Programme and Progress Charts were prepared and used ; the one being constantly compared with the other.

Unfortunately engineers too frequently allowed the contractor insufficient time to work out his tender in detail ; and prices were hastily entered, after little, if any study. If such a tender were accepted, there were often frictions, delays, poor work and bankruptcy.

To ask for tenders for important work from contractors who were accustomed to work out their tenders with care and thoroughness, and to give them sufficient time in which to do so, was a wise policy in the interests of the client.

As regards the preparation of the Schedule of Quantities and the

measuring of work as it proceeded, that was done (and usually well done) by the supervising engineer and his staff for civil engineering undertakings. But in Great Britain the custom had grown up in architecture for such work to be done by a Quantity Surveyor or Measurer. Often he also prepared all the contract documents; that was to say, the business side of architecture was rarely dealt with by the architect alone. In North America that was not the case, as the architect usually did all that work with his own staff; and, in general, it was done very efficiently.

Perhaps the organization the Author had in mind was not that of engineer and contractor, the more usual procedure in Europe and North America, but that for work carried out departmentally, either by direct labour or piecework, in the latter the engineer being directly responsible for the execution as well as for the design. It was a procedure only followed where there were insufficient competent and reliable contractors.

The engineer then had to make use of such equipment and personnel as might be available; handicapped not only by the absence of a skilled and well equipped construction organization already in being, but also by the fact that he had to guard against either doing the work too meticulously or neglecting the engineering side in his attention to the commercial side. Carrying out work departmentally, therefore, was a less efficient method only to be employed where the more usual procedure was not practicable.

Mr. R. N. Pegg considered that whilst training would not necessarily make a good organizer, it should form part of the curriculum in an engineer's training. He had been impressed by the statement that the opinion of the Corps of Royal Engineers, based upon experience with civilian engineers sent to them for training during the war, was that, whilst technically those engineers were very good, generally speaking they had no knowledge of the necessary organization for executing works. Whilst that statement, was doubtless true, it was of interest to compare it with the views expressed by Professor C. E. Inglis at a joint meeting which was held early in 1939 between the leading Institutions and the Corps of Royal Engineers. That meeting was a confidential one and no Minutes were published. It arose after the Munich crisis, and its purpose was to discuss how best the Corps of Royal Engineers could be expanded in preparation for, or in time of war, from the civilian engineering industry. Professor Inglis stated that after receiving a thorough theoretical training at Cambridge, few Royal Engineer officers were given the opportunity of gaining practical experience sufficient to enable them to be regarded as Royal Engineers. He had pleaded hard with the Army authorities for the time, and with the civilian engineering firms for the provision of opportunities for those young Royal Engineers to obtain practical experience in the field.

Those remarks had been made four years ago, and, considering them alongside the Author's remarks they seemed to require some explanation which might have a valuable bearing on training curricula.

Mr. F. J. Rigg observed that he was entirely in agreement with the

Author in stressing the importance of training civil engineers in organization and execution of engineering work.

The need for economy in planning and carrying out work received a great stimulus on the contracting side, where the profit motive actuated contractors' agents and engineers, and where attention was necessary to many matters not usually dealt with in technical courses. Not the least important was the close contact obtained with the " rank and file " on public works.

For some unexplained reason the young civil engineer did not, as a rule, receive practical training, as was customary in the mechanical engineering profession. Why should he not have more opportunity of " coat-off " work in excavation, timbering, concrete mixing, shuttering, steel erection, diving, etc. ? With such first-hand experience he could better appreciate what he might later call upon others to do, and would know what results to expect.

It would help to the end in view for those still at college if summer vacations could be spent in that way, and, depending upon the variety of experience obtainable on large public works, a written or oral test might be included in the Associate Membership examination.

For those already employed on the engineering side Mr. Rigg suggested a period spent with contractors. The knowledge thus gained of the wide variety of operations, both in the office and on the works, could not fail to be of value on return to the engineering side, if indeed, the experience did not bring to light a capacity more suited to employment on the contracting side.

Captain H. F. Wilmot, R.E., observed that one difficulty leading to estimates going awry (which did not normally happen so often as the Author would lead one to believe) was the reluctance of clients to spend money on exploratory work in the preliminary stages to the extent which was required, in order to eliminate the intangibles as far as possible ; that expenditure was regarded as " money down the drain " instead of essential " insurance." The engineer was sometimes not altogether free from blame in that respect, in that he was persuaded to " take a chance ", but there were some sites where that was justifiable, and others where it was criminal. Recent cases where undue trouble had been encountered in foundations would readily come to mind.

An aspect which Captain Wilmot had very much at heart was that of economic design, where the designer knew his material, and did not add more than was necessary " just to be sure ", to cover ignorance in fact, where such ignorance was inexcusable.

Extravagance in materials could be brought about by (*a*) the above-mentioned type of ignorance, due to lack of knowledge of a given material ; (*b*) an ignorance which the very nature of the external conditions imposed made inevitable, due to indeterminate stresses, and which had therefore

to be amply covered ; (*c*) a type design which, owing to aesthetic reasons, was deliberately chosen rather than a simpler and cheaper form.

The engineer was hardly concerned with (*c*), inasmuch as the choice lay in the power of others, but if it were a sound aesthetic principle that a " form " which gave a definite strength at the cheapest cost was superior to all other " forms " in any one given material (omitting altogether the " detail " as being extraneous), then many existing structures could be criticized under that criterion. The type construction of bridges for varying spans formed an interesting field of discussion in that respect.

The quandary imposed by (*b*) should never be due to the deliberate choice of design.

In estimating, there was a general tendency to " weight " unit prices, in addition to inserting a contingency item ; rounding off of quantities added its further quota. The result, in effect, was to increase the Contingencies by a very considerable amount. It should be possible to rely *only* on the Contingencies item for an accurate figure of final cost.

The Author, in reply, observed that he wished to express his gratification for the interest displayed ; the rather surprising amount of agreement with the views expressed showed that the existence of the problem had been appreciated.

In many of the points raised, discussion ranged far wider than the Paper, which had a strictly limited object, namely a plea for directing the thoughts of the young engineering student in the direction of organization and economics, not to the exclusion of technical knowledge but as an essential complement to it. The necessity for practical experience was fully realized, but the Author contended that more value could be obtained from experience if preliminary thought had been given to it in the early stages of education. No theoretical instruction could hope to replace experience, nor could such instruction do more than suggest basic principles and their application ; it would enable the student, when he arrived at the stage of practical experience, to appreciate the fact that the organization and management of work was a highly skilled task worthy of the closest attention and an essential part of his education as an engineer.

The Author doubted the wisdom of attempting to separate technical execution from management or non-technical administration, though possibly Mr. Habershon was referring to the higher forms of management. Even a ganger in charge of half a dozen men had to combine a knowledge of technical execution with a knowledge of management ; he had to know how to do the job and also how to handle his men.

The criticism directed at the example in the Paper, that it bore little resemblance to the ordinary work of a civil engineer, surely missed the point, which was to emphasize the necessity of considering time, materials, and labour even in the most simple work. A very simple job was selected after working out several more " ordinary " ones, chiefly from consideration of paper limitation.

The advantage of having a financial yardstick in commercial work to measure efficiency was a point which had exercised the mind of the Author very much during the last two years. He had attempted to devise some form of financial yardstick to apply to Departmental organization, but without any success, and he doubted the possibility. Many comparisons with other engineering organizations had been made, but, in the absence of a common yardstick, the results were inconclusive.

The comparison between the views expressed in the Paper on the relative capabilities of the Civil and Royal Engineer and those of Professor Inglis, quoted by Mr. Pegg, was particularly interesting, as the Author was abroad at the time and was therefore unaware of the meeting. The Author expressed his opinion in very general terms and drew the conclusion that elementary training in organization of work on the lines carried out in the Army did help to develop that side of an individual's capacity and would therefore be an equally valuable adjunct in the training of the Civil Engineer.

He had been particularly interested in the points raised by Messrs. Leech and Pritchard, who described themselves as " young engineers ". If young Civil Engineers felt that they were gaining valuable experience in their profession during their service in the Army, it was a happy augury for that closer liaison between the Civil and Military Engineer in the future which was essential for the Army and for the profession as a whole.

The Author wished to take the opportunity of expressing his great regret that military exigencies had prevented him from presenting his Paper in person, and his thanks to Brigadier Harrison for undertaking that task at very short notice.