What Is an Engineer-Constructor?*

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One prominent element of modern industrial life is bigness. We have large business corporations, combined railroad systems, extensive manufacturing concerns and comprehensive enterprises in all lines of commercial activity.

Another dominant element is efficiency, which may be taken as the key word of modern business life and engineering practice. The constant aim is not cheapness in construction or equipment, but effectiveness, the greatest return for the outlay.

These two elements chiefly have brought about a condition in which we have the necessity for a technical organization ready to produce large results in an effective way. Between the desire for bigness and efficiency and its fulfillment is the field of operation for the creative and constructive abilities of the engineer-constructor.

An Engineer-Constructor Is an Organization

and not an individual. It makes possible the most effective combination of technical theory with practical experience, and provides for the use of team work in connection with the designing and building of properties. Its aim is to attain the greatest economy in effort, time and money—its province is to do things in the most effective way.

In its broadest development such an organization need not be confined to any one class of enterprise. Here is something to be built which requires for its completion a combination of conception, technical knowledge, constructive experience and executive ability. Whatever it is the engineer-constructor should be prepared to carry the proposition through from beginning to end without technical assistance from outside the organization. To be most effective such an organization should have at its command the technical knowledge and experience of the past, the ability to analyze situations and discover the truth from conflicting testimony, the imagination to conceive unprecedented results and courage to overcome obstacles, the ambition to improve existing systems and the honesty to spend money without favor or graft, and finally loyalty to itself and to its client, which will protect in every way the interests of all concerned.

An engineer-constructor, therefore, is nothing less than an ideal employee who has the best possible preparation, the widest experience and the natural aptitude to do in a large way the big things which the development of this country is constantly requiring. Such an organization substitutes for the isolated efforts of one or more individuals an effective combination of the aggregate abilities of a number of experts and adds the enthusiasm and inspiration which comes from the contact of fellow workers.

The expression that "the team plays as one man" suggests the comparison of our ideal engineer-constructor organization to a modern football team, and as this idea grows upon us we can find considerable instruction and inspiration in the analogy.

Character of the Organization.

All the things that might be said in regard to getting together and developing a winning football team could be applied equally well to the building up of an organization to do the work of an engineer-constructor. To carry the illustration further, let us line up the candidates for this new kind of team—the more material to select from the better—we will always have use for substitutes.

We need a civil engineer, electrical engineer, mechanical engineer, structural engineer, sanitary engineer, chemical engineer, gas engineer, fire protection engineer, hydraulic engineer, mining engineer, architect, industrial expert, statistician, purchasing agent, construction superintendent, operating engineer, accountant.

An engineer-constructor, therefore, is nothing less than number of these candidates are fitted together as a mechanic would build a machine, and the efficiency of such an organization for the purpose for which it is created depends upon, first, the perfection of its individual parts; second, the skill with which these parts have been brought together; and, third, the absence of any unnecessary friction during operation.

Such an organization should not be the maker or manufacturer of any equipment, nor be connected with the exploitation of any system of apparatus, nor interested in the introduction of any patented devices. In its highest stage of development it will not be connected except in a technical way with the financial interests which control the enterprise.

Carrying our analogy even farther, let us look at some of the plays with which the candidates will become familiar in some of the big games which they must be prepared to play.

Duties Entailed.

The carrying out of every big enterprise will entail nearly all of the following duties: Investigations and reconnaisance; preparation of preliminary reports; estimates of costs; estimates of probable earnings and operating expenses; surveys; preparation of plans and specifications; getting proposals and purchasing; letting contracts; field engineering; construction and erection; inspection; preparation of progress reports; record of costs; tests; operations; final reports and statistics; accounting.

It is important to gain as much ground as possible on every play. In playing an entire game from start to finish different men will have the ball in nearly every play, but the precision of the team work should be so perfected that every man will be in every play. To assist is fully as important as actually carrying the ball. Look over the various situations which this engineer-constructor team which we are developing is sure to face—is there any detail which the candidate for responsibility can afford to ignore? Is it not better to have an organization of trained men prepared to help each other do these various things, rather than depend upon unsupported individual effort?

Granted that such an organization of technically trained men can be brought together, what are some of the things which they may be called upon to do? A few of the things requiring such ability and experience in design and construction which first occur to us are as follows: Complete steam railroads; complete electric railroads; electrification of steam roads; hydro-electric plants; transmission systems; power plants; gas works; electric lighting systems; industrial establishments; buildings for all purposes; public service works.

In so far as an organization is prepared to carry out any of these enterprises effectively, just that far will it reach its highest development.

Laying Out a Large Proposition.

To show the possibilities of such an organization, let us pick out a team for the building of some large proposition. Let us take, for instance, the design and construction of a steam railroad locomotive repair shop, involving the expenditure of from $2,000,000 to $3,000,000.

In deciding on our men, we will make a study of the qualifications of each one, and at the same time we must have a clear conception of the work each one must be familiar with in order that there be no weak spots in our line or break in the organization. The selection of men with their chief duties will be as follows:

Industrial expert:
- Designing layout of shops.
- Planning method of handling work.
- Arrangement of tool and transportation equipment.

Electrical engineer:
- Providing power and lighting equipment.
- Laying out transmission systems.
- Planning telephone and signal systems.

Mechanical engineer:
- Design of power plant.
- Plan of heating and ventilating.
- Laying out air, gas and steam systems.

Structural engineer:
- Building foundations.
- Designing steel structures.
- In charge of reinforced concrete construction.

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Architect:
- Designing building superstructure.
- Choice of fixtures.
- Laying out landscape work.

Civil engineer:
- Directing grading.
- Testing of soil.
- Construction of track.

Sanitary engineer:
- Design of sewage system.
- Construction of water works.
- Choice of plumbing.

Purchasing agent:
- Selecting markets for material.
- Checking bills of material.
- Arranging for delivery of material.

Constructing superintendent:
- Organization of construction force.
- Consideration of time element in construction.
- Settling labor difficulties arising in connection with construction work.

Operating engineer:
- Consideration of economies in operation.
- Securing reliability in operation.
- Insuring effectiveness in operation.

Accounting department:
- Keeping pay rolls.
- Making record of costs.
- Preparing progress reports.

Here are eleven men—each one selected for his particular ability to solve the problems suited to his individual training and experience. Each man has won his position as the result of a gradual growth which has demonstrated his reliability and resourcefulness. Many of these men have played this game before, and together, and are always eager for a proposition which will tax their strength and skill.

Let us watch the play. First will come a number of preliminary studies, showing the proposed sizes, designs and relative arrangements of the buildings. There will next be forthcoming a carefully prepared report, showing the advantage of the finally selected arrangement, and the suggested construction of each of the buildings, together with a description of the equipment required. An important part of this preliminary report is an approximate estimate of cost, based upon a careful consideration of all the items involved in the construction.

With the general layout and the preliminary report and estimate approved, the next move is to prepare the plans and specifications. To indicate the scope of this work the following illustrative classification is shown, the numbers being the key which is placed in each drawing, specification, data sheet, report, or letter which may be originated as the work progresses:

CLASSIFICATION FOR BATTLE CREEK (MICH.) SHOPS, GRAND TRUNK RAILWAY SYSTEM.

Contract No. 74.

GENERAL INDEX.

Sections of Classification.

74000—Organization.
74100—Building structures.
74400—Track.
74600—General equipment.
74700—Power plant equipment.
74800—Tool equipment.

Parts of the Work.

A—Yard.
B—Power house.
C—Storehouse.
D—Oil house.
E—Office building.
F—Locomotive shop.
G—Forge shop.
H—Iron foundry.
I—Pattern shop.
J—Frog shop.
K—Car machine shop.
L—Truck shop.
M—Coach and paint shop.
N—Freight car shop.
O—Planing mill.
Q—Dry kiln.
R—Scrap platforms, sheds, &c.
S—Turntables.
T—Yard crane.
U—Pipe tunnel.

Detail Classification.

74000—ORGANIZATION.
74001—Contract.
74002—Home office fixed charges.
74003—Legal expense.
74004—Preliminary reports.
74005—Surveys.
74006—Engineering.
74007—Accounting.
74008—Construction Tools.
74009—Construction office supplies.
74010—Temporary construction.
74011—General construction labor.
74012—Superintendence.
74013—Insurance.
74014—Traveling and living expenses of representatives.
74015—Tests.
74016—Preliminary operation.
74100—BUILDING STRUCTURES.
74101—Preparation of site.
74102—Excavation and fill.
74103—Piling.
74104—Foundations.
74105—Superstructure masonry.
74106—Structural steel and iron work.
74107—Carpenter work.
74108—Mill work.
74109—Roofing.
74110—Sheet metal work.
74111—Plastering.
74112—Painting and glazing.
74400—TRACKS.
74401—Preparation of right of way.
74402—Grading.
74403—Tie and Track laying.
74404—Switches and special work.
74405—Ballasting.
74406—Fencing.
74407—Cattle guards, crossings, signs, &c.
74408—Bonding.
74600—GENERAL EQUIPMENT.
74601—Drainage system.
74602—Plumbing and lockers.
74603—Water system.
74604—Heating system.
74605—Piping system (except for heating system).
74606—Lighting system.
74607—Power system.
74608—Telephone and signal systems.
74609—Transportation systems:
- Transfer tables.
- Turntables (large).
- Yard cranes.

74700—POWER PLANT EQUIPMENT.
74701—Machinery foundations.
74702—Coal and ash handling apparatus.
74703—Grates and stokers.
74704—Boilers and settings.
74705—Breeching and connections.
74706—Stacks and draft equipment.
74707—Heaters, superheaters and economizers.
74708—Water softening plant.
74709—Pumps.
74710—Air compressors.
74711—Engines.
74712—Condensers.
74713—Piping and covering.
74714—Generators, compensators, transformers and exciters.
74715—Switchboard and generator leads.
74800—TOOL EQUIPMENT.
74801—Line shafting and all shafting and motor supports.
74802—Forge shop blast and exhaust ducts.
74803—Individual cranes and hoists.
74804—Traveling cranes.
74805—Work benches and material racks.
74806—Fire protection apparatus (except piping).
74807—Foundations for machine tools.
74808—Machine tools.
74809—Erection of machine tools, countershafts, &c.
74810—Planing mill shavings exhaust system.

In purchasing, the engineer-constructor should find some advantage over an occasional buyer. He is in the market constantly, is favorably known by the manufacturers of standard equipment, and buys apparatus delivered f.o.b. cars, doing all erection work as far as possible with his own experts, and calling on the factory for assistance only when necessary.

All Departments Should Work Together.

There should be the greatest unity between the engineering, the purchasing and the construction department. It is always better to have the construction superintendent in the office while preliminary decisions are being made and bills of material are being prepared.

Throughout the entire progress of the work systems are in use to keep all concerned informed as to each move. The construction office is advised by the home office as to the material ordered and as to the probable delivery of this material. The home office is advised as to the receipt of material on the job, as well as to the progress of the construction work, and any reports and advices as to the labor situation. To accomplish the former copies of contracts for apparatus and orders for material are sent to the superintendent in charge of construction. Such reports and orders contain exact information as to the material covered by them, as well as to the time at which this material is expected to arrive on the work. A card system in which are entered all orders and contracts is used in the home office, and is designed to follow up and secure prompt delivery of all material and apparatus. In case of any changes in time of delivery of material, the construction superintendent is advised in advance, and is thus in position

to make any alterations necessary in his programme. The importance of promptly delivering the material on the job cannot be over estimated, and the value of a system that will provide for the delivery of the materials in accordance with an approximate schedule previously arranged for will appeal to all interested in construction work.

Records of all material received on the job are kept by the superintendent in the form of a material report. These reports are written out in a duplicate book as each shipment is received, and one copy is sent without delay to the main office. This serves to keep the home office very closely in touch with the field work, so far as the receipt of material is concerned.

Progress Reports.

In construction work consisting of a great many items, such as will be found in railroad shops, it is very desirable to know with a fair degree of accuracy the exact progress of the work. Certain lines of the work, such as the delivery and installation of machinery, are dependent upon the progress of other work, such as the completion of the buildings and foundations. In order that this information may be always at hand, progress reports from the work are received at stated intervals, usually two weeks apart, giving in detail the progress of the work under each classification head. This information is kept in form for convenient reference, and is useful in a variety of ways. Not only do these reports keep the engineering force in touch with the progress of the work, making it possible to more efficiently insure the work coming in proper sequence, but they also provide the information necessary to make decisions as to changes in detail, in case such are found necessary after the work has been begun. These progress reports, together with a record of moneys expended for material and labor at any date, give timely information as to the actual cost of the work as compared to the estimated cost. As such reports are made on the work under each classification heading, any variation of the cost from the estimate is at once detected. This is of importance to the constructor who proposes to complete a certain improvement within a definite estimated cost, and to the client's official who may be charged with the responsibility of protecting a definite appropriation.

Wherever it is possible curves or diagrams are used to represent the condition of affairs of which record is to be kept. A chart showing the progress of the work on building construction is easily made, and shows very clearly at a glance the exact condition of the work at any time. At the end of each two weeks' period, the total expense that has been incurred during the two weeks previous is plotted under each classification head, and this area on the chart indicated in such a way as to designate the progress made during the particular period in question. A glance at the chart will show the total amount completed under each classification represented on the chart at the time the last entry was made, as well as the amount of work that was done during the various classifications during each period considered.

Moreover, it is at once evident that, during the period of the fifth payroll about 10 per cent. of the work on the engine pits, 20 per cent. of the concrete superstructure, 30 per cent. of the brick work, 15 per cent. of the sills and coping, 40 per cent. of the windows and small doors was completed, and no work was done on the smokejacks and ventilators, none on the roofing and none on the sash operators and foundations. In other words, these progress reports become the graphical history of the job. After having made out the necessary reports covering both the material and the labor that have been used on the work, it is a very simple matter to embody these results in the chart. A copy of this chart is then sent to the main office where it remains until the time for the next report, at which time it is sent back to the job for the additions that have occurred during the period.

Progress Photographs

are taken of the work at intervals of about two weeks. These show at a glance not only the general progress of the work, but many construction details as well, which are of interest and value. These photographs are of a standard size, and mounted on cloth so as to be bound in convenient form for reference. All the reports just referred to, viz., the progress reports, charts and diagrams, while very easily obtained and requiring but little work in their preparation, supply a great deal of valuable information, and are of worth far exceeding the trouble and expense contracted in securing them.

Although every facility is provided for keeping the main office and the construction office in close touch, it should not be understood that the engineering is done at arm's length, and that all plans and specifications are devised and completed by an engineering force in the office to be sent down to the construction superintendent on the job for his execution. A competent engineer is in charge of all construction work, and spends a certain amount of time in the field, thus putting him in close touch with the situation, and enabling him to more efficiently direct the detailed engineering work that is done in the main office.

It would be a big mistake to think that such an organization as we are outlining could be got together and perfected in its work in a short time. A winning team is not made in a week, a month, or even a year. It takes time to find the men, to break in raw material, to perfect the plays, to develop a system and to create a loyalty both inside and outside the team. In the case of our engineer-constructor parallel it will probably take years, and it is evidently for this reason that this very inviting field is occupied by so few organizations who are really prepared to do the work justice. Our football players have learned the benefits of concentrated co-operative efforts when applied to their sport much sooner and better than have technical teachers and graduates recognized the same truths as applied to our life work, and yet the advancement of technical progress is certainly more important than the perfection of the game of football. The technical student of to-day is to be congratulated upon having before him such a splendid opportunity in a field which has not been worked harder than that occupied by the engineer-constructor.

Cost Plus a Percentage.

Most of the work of this company is done on the basis of "cost plus a percentage"—that is, the work is done at actual cost, and then the engineer-constructor gets a percentage fee for his services. By such an arrangement the client or purchaser is relieved of the necessity of organizing a technical force of his own, or of employing a number of individual specialists. If the actual construction work is turned over to the engineer-constructor, then the client is relieved of the inconvenience of obtaining proposals and awarding contracts to a large number of separate contractors, with the attendant delays, conflicts and "extras," which even the closest supervision will hardly avoid.

The difference between the "cost plus a percentage" and the "cost plus a fixed sum" plans is not generally understood. If an engineer constructor is thoroughly trained in drawing plans, has sufficient actual experience to make a reliable estimate, is absolutely honest in all things, and has complete control of a competent construction organization, then the "cost plus a percentage" arrangement is the better; but if the work is planned by an engineer and architect, and the actual building work is turned over to a separate construction organization, thus maintaining the old relationship of engineer and contractor, then the "cost plus a fixed sum" plan, no doubt, has advantages. The "percentage" plans express a shade more of confidence between the client and the builder than the "fixed sum" basis.

If the duties of making a preliminary report, preparing a careful estimate, drawing up the plans and specifications, purchasing the materials, building the structures, erecting the equipment and installing the machinery are turned over to one reliable engineer-constructor organization on a "cost plus a percentage" plan with the privilege to the client of canceling the arrangement at any time, if the progress, quality or cost of the work should prove to be unsatisfactory, it is hard to conceive of a more effective way of getting results, and it is very probable that much of the important work of the future will be done upon this basis.