Social Organisation Limited

SOLVING PROBLEMS IN ORGANISING CHEMICAL PLANT PROJECTS

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PROBLEMS IN ORGANISING CHEMICAL PLANT PROJECTS

An examination of the problems of organising complex large-scale projects and suggested methods of solving them

by M. DAVIDMANN, B.Sc.

LARGE process plants result from the joint work of many specialists. Difficulties have been experienced in obtaining effective teamwork and, as a result, the chemical plant contractor tends to organise his work into project teams. The project engineer, in charge of the team, is responsible for the project. Difficulties arise when a number of projects are being handled at the same time, particularly when the contractor is working at top capacity, quoting short delivery periods in a competitive market.

Organisation Charts

A company's effort consists of a variety of tasks. The larger company is arranged, according to size or task, into work units such as divisions, departments and groups. Responsibility is assigned to each work unit's manager for the work done by the unit he commands.

Organisation charts, a form of line diagram, depict work units in relation to each other. Titles of senior executives are given. Such charts indicate the arrangement of work units and the delegation of responsibility. They vary in scope and detail from those depicting the organisation of related companies to those showing the detailed organisation of a small work unit.

Part of an organisation chart for a chemical plant contractor is shown in Fig. 1. It is seen that its levels of position indicate the superior/subordinate relationship between individual executives. In general, an executive is responsible to his immediate superior for his own work and for that of his subordinates, and this is shown by the lines on the chart. Hence the organisation chart is used to illustrate: (a) the division of the company's task into work units; and (b) the executive chain of responsibility and command.

Activity Diagrams

Within an organisation there exists also, apart from the superior/subordinate relationships called "line" relationships, the constantly occurring activity between work units which is not shown by the organisation chart.

Intergroup activity is illustrated by an activity diagram, such as Fig. 2a, which illustrates the activity surrounding the purchasing function, that is the Buying Department, generally within the organisation defined by Fig. 1; outside suppliers are here regarded as a distinct work unit. Each separate area represents a work unit, common boundaries indicate activity between the work units on either side of the boundary, and the diagram also shows contacts related to purchasing, but between work units that exclude the Buying Department.

The system of activity of Fig. 2a is as follows: Technical, Works and Erection requisition purchases, which Buying arrange with outside suppliers. Erection contact Works to find out if requirements can be met from within the organisation, purchases being arranged through Buying. A similar situation exists between Technical and Works, but only seldom are Erection in contact with Technical on matters of purchasing. Buying is in direct contact with outside suppliers but Technical, and to a smaller extent Erection, are also in direct contact with outside suppliers. Buying are supported by Legal for contract clauses and keep Accounts informed on orders placed. All Works purchasing is negotiated through the Buying Department.

The main characteristics of this type of activity, which we will call Type "A", are apparent complexity, and consultation between work units which excludes the Buying Department.

Activity Between Groups

Type "A" activity surrounding a Buying Department is illustrated by Fig. 2a. Three separate departments are in contact with outside suppliers and this may lead to a threefold overlapping. This can create difficulties, as Buying Department may not be aware of contacts made with outside suppliers by other departments. In particular, difficulties can arise if company regulations call for a number of competitive bids each time a contract has to be placed. It is not clear which department decides how the order should be placed. Difficulties are particularly marked in large organisations facing complex tasks. Further, a considerable amount of consultation has to take place between other departments of which Buying Department has no knowledge, and there is the possibility of contradictory letters being sent to outside suppliers.

The activity around the Buying Department could be quite different, however, as departmental functions and interdepartmental practices vary from company to company. For example, the activity might be as illustrated by

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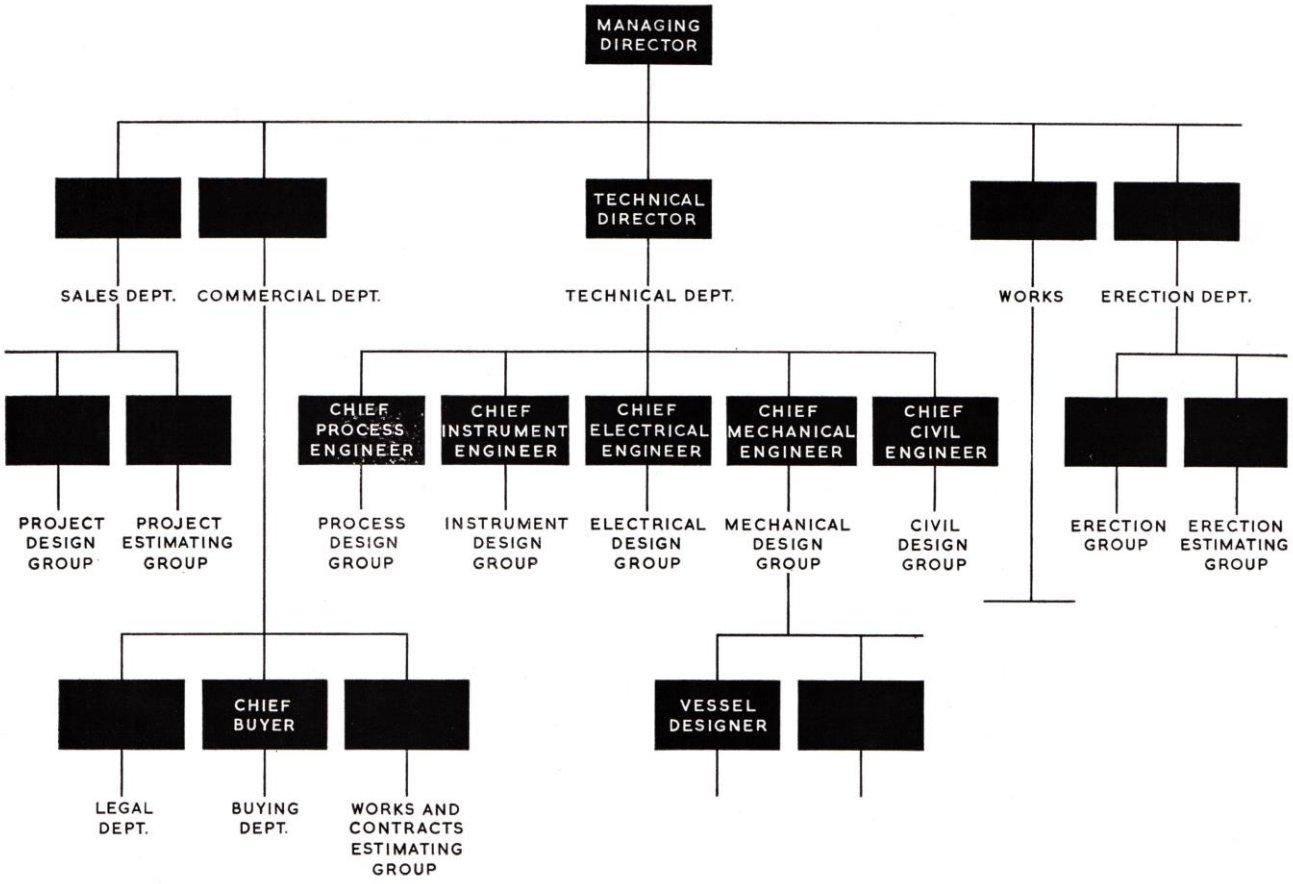

Fig. 1. Organisation of a chemical plant contractor.

activity diagram Fig. 2b, which we will designate Type "B". Here all contact with suppliers is through the Buying Department; contact between the various departments served by the Buying Department is discouraged. All inquiries are sent out by the Buying Department, including inquiries from Technical Department or Erection Department for supplies from Works. In consequence, Buying Department arrange technical discussions with outside suppliers.

On the surface, Type "B" activity seems a simpler arrangement of activity than Type "A" and thus seems more effective, as the Buying Department have full control over contact with outside suppliers and over internal contacts regarding supplies from Works. However, the Buying Department now acts as a forwarding agency and are concerned with matters not directly related to purchasing, and a large amount of interdepartmental correspondence is unavoidable. In one case, a large company had the ruling that letters to outside suppliers had to be signed by the Chief Buyer, in an effort to reduce the volume of internal correspondence resulting from Type "B" activity. Confusion exists as to who is responsible for what; for example, it is not clear whether the Chief Buyer is responsible for the letters he signs. Also, a considerable amount of time is now spent by Buying Department staff in arranging and taking part in technical discussions.

The method used here for illustrating and describing activity between work units can be applied equally well to analysing activity between a number of work units within one department, such as, for example, the design groups within a technical department which is responsible for designing a range of chemical process plants. We are considering here only design work on a plant for which the order has been received, but not contact with client or other departments, the organisation being that of Fig. 1. It should be remembered that a number of dissimilar plants are being dealt with at the same time.

Type "A" activity is illustrated by Fig. 3a. Process specify process requirements to all other groups. Mechanical specify their requirements to Instrument, Electrical and Civil. Electrical have to contact Instrument, Civil and Mechanical. Instrument have to contact Electrical for supplies. Civil take into account other groups' requirements. The activity diagram indicates the complex activity that makes up the design of just one process plant and there are thus opportunities for inefficiency and muddles. An effort can be made to keep all groups informed of each other's work, but generally this will fail. Considerable overlapping is likely and some work may not be done at all. Work done by one group can run contrary to the requirements of another.

Type "B" activity is illustrated by Fig. 3b. A new executive has been appointed to co-ordinate work of the design groups and once again this appears to be a more effective arrangement. Direct contact between the design groups is frowned upon and Project Group act as post office. The Project Engineer now assumes responsibility for design. As a number of plants are being designed at the same time, it is likely that a designer now has his responsibilities divided among his own immediate superior and two or more project engineers.

We can draw some conclusions by comparing the two

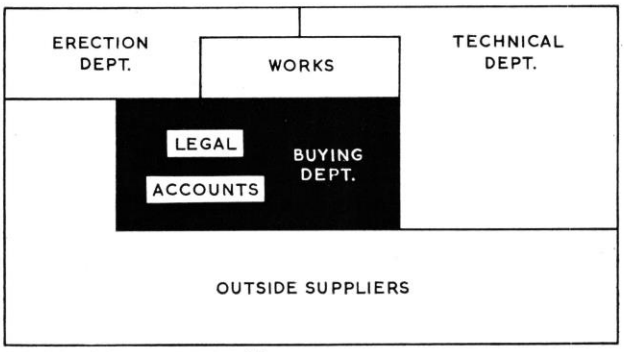

FIG. 2A.—ACTIVITY TYPE 'A'

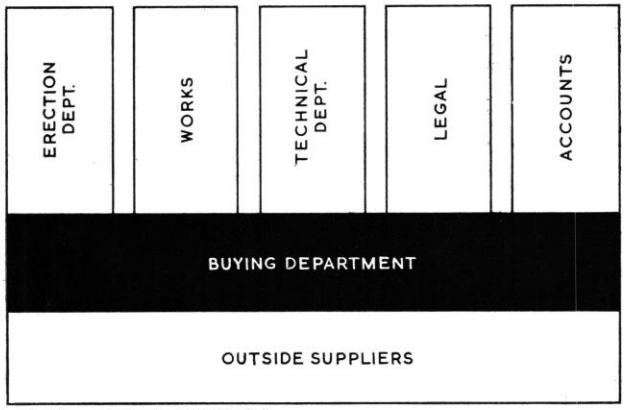

FIG. 2B.—ACTIVITY TYPE 'B'

Fig. 2. Activity diagrams for buying department.

types of intergroup activity based on the examples given. Type "A" is too complex to be shown on an organisation chart. Type "B" is much simpler; it is in fact no more than a type of organisation chart in which the lines which interconnect positions have been replaced by contact between boundaries. A chart for Type "B" activity which shows the relative positions of the groups concerned looks straightforward, but cannot be superimposed upon the chart for the entire organisation without confusing diagonal lines which indicate divided responsibility between executive chains of responsibility and command. In the Type "B" scheme one group co-ordinates the work of other groups.

The more complex Type "A" activity, unless clearly defined, results in inefficiency and difficulties. When an attempt is made to overcome the disadvantages by causing the work of some groups to be co-ordinated by one, Type "B" activity results. It is significant that an explicit organisation chart gives rise to Type "A" activity and that activity Type "B" corresponds to a confused organisation chart. In other words, when it is realised that intergroup activity is the cause of inefficiency, an attempt to overcome this is made by trying to fit a co-ordinating function across executive chains of command and responsibility. This generally makes the organisation more cumbersome, creating more paper work. Where two people worked together in Type "A" activity, there now stands between them the third, the co-ordinator. Responsibility and specialist activities are divided and the organisation has lost, rather than gained, efficiency in changing from Type "A" to Type "B" activity.

The following points arise in transition from "A" to "B".

(1) The organisation is a functional one; each division or unit corresponds to a function or service.
(2) Interdepartmental activity, being of Type "A", leads to individuals in different departments not working together as an efficient team.
(3) A solution is attempted along the lines of co-ordinating the work done by the various departments. Co-ordinators are appointed, not because "co-ordinating" is an essential part of the task the organisation is tackling, but because of internal defects in organisation.
(4) The co-ordinator relies on the co-operation of those whose work he co-ordinates. If they did not work in harmony before his arrival, they are scarcely likely to work well subsequently, especially since the position and work of the co-ordinator appear vague. Hence he has to be given authority so as to command co-operation. He cannot be given authority without responsibility and thus he is given responsibility for at least some functions.
(5) This immediately cuts across the functional division of the organisation, that is, across established chains of responsibility and command, bringing in its wake divided responsibility and going some way towards breaking up specialist departments. The organisation loses efficiency.
(6) To meet this situation the co-ordinator may be given still more responsibility, reducing efficiency further.

In the case of the chemical plant contractor, evidently the Project Engineer is the co-ordinator, and his function is the unreal one of "co-ordinating". In the end functional departments disappear altogether, and are replaced by teams, each being a small contracting organisation of its own. Each team at this stage is likely to repeat all the mistakes made already by other teams. Project teams take precedence over functional groups and specialists have difficulty in keeping abreast of their subject as know-how tends to be scattered in project files instead of being absorbed and correlated by the specialist's own group.

The appearance of a co-ordinator within an organisation signifies that functional departments do not work well together. His appointment makes the situation worse and is no solution. Hence one has to examine the explicit form of organisation chart together with its corresponding Type "A" intergroup activity, so as to isolate the defects. Once known, they may be treated and removed.

Line Relationships

One feature, the lines of Fig. 1, reveals that the Vessel Designer does not report to the Technical Director, either directly or through the Chief Process Engineer, as this would mean that he is by-passing his immediate superior, the Chief Mechanical Engineer. Such by-passing would mean that the Chief Mechanical Engineer could not effectively control the work done by his subordinates; and it would antagonise him. It would in due course upset the subordinate as well, as he would appear to be working for two superiors, with resultant uncertainty of position. In other words, by-passing upsets the organisation, the by-passed executive being unable effectively to carry out or have carried out the work for which he is responsible.

Extending this argument to positions on the same level, we can take the Chief Process Engineer, the Chief Mechanical Engineer and the Chief Instrument Engineer as examples. They report to their immediate executive superior, namely the Technical Director, only on matters for which they are responsible; for example, on work done by themselves or their subordinates. The Chief Process Engineer does not report to the Technical Director on work done by the Chief Instrument Engineer or on

work for which the latter is responsible, and the Chief Process Engineer should not be asked to do this. If the Technical Director were to ask the Chief Process Engineer to report on or to do work which falls within the limits of the Chief Instrument Engineer's area of responsibility and command, then two executives at the same level would, in effect, be responsible for similar and overlapping work, and immediate conflict between the two executives can result, to the detriment of work done by either one or the other or both. Divided responsibility would mean that two work units could be duplicating each other's work, that some work might not be done at all, since each work unit assumes that it is being done by the other, and it is possible that through lack of definition of responsibility neither will benefit from results obtained in the field.

In other words, the organisation chart depicts the executive chain of responsibility and command, and if this is by-passed, or if responsibility is divided so that one executive is responsible to two superiors, or if responsibility is divided so that two executives are responsible for overlapping work, trouble can be expected. However, it is worth while mentioning that some executives may be unwilling or incapable of accepting responsibility and that to them a system of divided responsibility appears to have advantages which in fact do not exist as far as the organisation's aim to carry out its work effectively is considered. At the same time, changes upset people and therefore they should be introduced gradually, with the agreement of those affected by them.

Functional Relationships

Activity between work units, however, consists of contact between individuals, and the relationships between executives in different work units are termed "functional" relationships. Neither organisation chart nor activity diagram illustrate or define functional relationships.

Functional relationships, however, have been clearly defined by JAQUES.[1] Of two executives in a functional relationship, one is the "responsible" executive, the other is the specialist, that is, the "prescribing" executive. Each executive is responsible to his own executive superior, and to no one else. The responsible executive assumes responsibility for obtaining specialist advice, which he can accept or reject, and for reporting useful results back to the specialist. The prescribing executive carries responsibility for giving specialist advice, that is for prescribing, and for the quality of his prescription.

This functional relationship is perhaps best illustrated by an example. The process designer is responsible to the Chief Process Engineer for satisfactory operation and performance of the process plant being designed. The instrument engineer is responsible to the Chief Instrument Engineer for his work, which consists of specifying the most suitable instrument types and suppliers, and of laying out and designing instrument panels. In this case, the process designer is the responsible executive, the instrument engineer is the prescribing executive, and the instrument engineer thus provides a specialist service for the process designer. The process designer would issue a general specification, listing instruments, operating conditions and ranges to the instrument engineer, with a request for detailed specifications. The instrument engineer submits his detailed specifications and drawings to the process designer, this being his prescription. His prescription could also be a recommendation for installing one type of instrument rather than another. The process designer is responsible to his immediate superior for accepting or rejecting the prescription; the instrument engineer is responsible to his own immediate superior for its quality.

Similarly, the respective responsibilities of process designer and buyer are immediately clear when it is realised that the process designer is the responsible executive, the buyer being the prescribing executive.

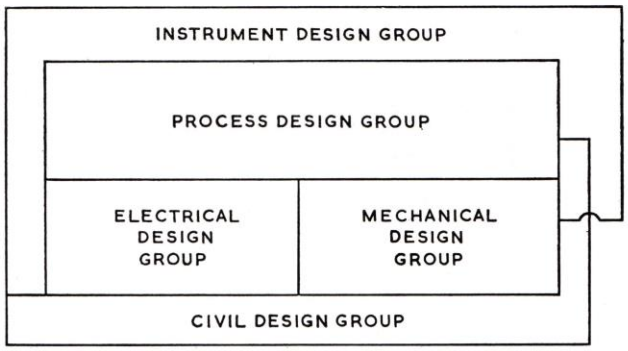

FIG. 3A – ACTIVITY TYPE 'A'

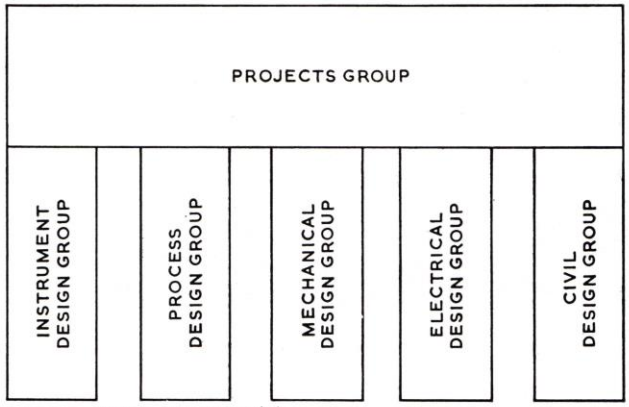

FIG. 3B – ACTIVITY TYPE 'B'

Fig. 3. Activity diagrams for design groups in technical department.

Functional Organisation

It follows that if an organisation is to be effective it has to be divided into functional work units. The task which the organisation faces thus has to be divided into parts, each of which corresponds to an activity which can be covered by one specialist department.

Fig. 1 illustrates this point by contrast. Three different groups are engaged in estimating, each one located in a different department. Also, design work is carried out by two departments: Technical Department designing for contracts, Sales Department designing for quotations. Responsibility cannot clearly be assigned, the disadvantages of divided responsibility having been mentioned already. Further, the splitting up of a specialist activity into separate parts, situated away from each other in the organisation, tends to prevent accumulated knowledge and experience from being utilised effectively. It is more likely than not that the experience gained by Technical Department during detailed design and commissioning would not effectively contribute to prequotation design by Sales Department.

Cases

OWEN and TURNER[2] have described an organisation for provision of major chemical plants. There is the "Engineering Branch" and the "Purchasing and Accounts Branch", but the Engineering Branch is responsible for cost control. Within the Engineering Branch there are

three departments or chains of responsibility. One of these contains such varied tasks as estimating, electrical design, instrument design, inspection and buying and presumably this is the result of an attempt to combine supporting groups in one department.

However, the service function of buying involves two departments within the Engineering Branch as well as the Purchasing and Accounts Branch. The design engineer in one department passes definition to a buying engineer in another department who, in turn, works through the appropriate contracts group in Purchasing and Accounts Branch who refer back not to the buying engineer, but to the design engineer who recommends acceptance of a particular tender, the placing of contracts being the responsibility of the Director of Accounts! The estimator in one department of the Engineering Branch prepares cost-estimates, but the project engineer in another department is responsible for the estimate.

This is not a functional organisation nor are functional relationships recognised. Nevertheless it makes the process engineer responsible for performance. Hence he has been given additional authority over other specialists such as mechanical engineers and draughtsmen and is consequently called "Project Engineer". We have seen, however, that such an attempt to improve functional relationships succeeds only in making the situation worse and this applies particularly in this case as mechanical engineers appear to be preferred to chemical engineers for "project engineering" appointments. It is not understood that the difference between one process plant and another lies in the process, that is, not in the pipes and shells but in what takes place inside them and how it takes place.

In this scheme the Project Engineer is not the only co-ordinator. A number of "Engineers" have made their appearance whose sole purpose appears to be that of co-ordinating, such as the Buying Engineer, the Planning Engineer, the Progress Engineer. The organisation described by OWEN and TURNER has thus proceeded a considerable way along the path from "A" to "B" activity.

CURWEN[3] has described a number of different project organisations of which he has experience. Unintentionally he illustrates how Type "B" activity arises from lack of understanding of functional relationships. His organisation Type 1 is to some extent functional. The divisions of concern here are Chemical Engineering under a Chief Chemical Engineer and General Engineering under a Chief Engineer. CURWEN cites these disadvantages:

(1) the chemical engineering division act as consultants only, during detailed design and construction, but take over again for commissioning;
(2) construction division have insufficient information in the early stages of the work;
(3) drawing office is responsible both to the (mechanical) engineer and the chemical engineer for various aspects of its work, the drawing office being located in the Engineering division; and
(4) the chemical engineer is responsible for estimating the cost of the project but has no direct control over expenditure (the estimating office, however, is located in the Engineering division).

Since "consulting" is such a vague activity, one cannot be quite sure why point 1 is a disadvantage. Disadvantages No. 3 and 4 illustrate that functional relationships need definition and the same seems to hold for disadvantage No. 2, although this is stated in too vague a form to allow detailed comment. CURWEN concludes that "the function of a project engineer is split" and that the disadvantages arise "largely from the lack of a project engineer". He is in effect saying that there is no co-ordination and that a co-ordinator is required. He has noted symptoms but ignored the causes which prevent effective teamwork and seeks to improve matters by appointing a co-ordinator.

CURWEN'S Type 2 organisation is also divided into functional units, although the Chief Engineer is now responsible for all design work and for construction. For this organisation he lists the disadvantages as follows:

(1) too many staff responsible to the Chief Engineer;
(2) while one engineer is supervising a project throughout, he is not fully responsible for all aspects;
(3) designers and draughtsmen in the drawing office are responsible to the chief draughtsman for mechanical design and to the chief chemical engineer for chemical engineering aspects of design;
(4) they are also responsible for co-ordination of instrument, electrical and civil engineering sections;
(5) when construction starts, the project passes to another section, and the construction engineer is responsible to the chief construction engineer and to the chief chemical engineer; and
(6) the chemical engineer is in charge of commissioning.

Point 1 is a comparatively simple management problem. The remaining points are the outcome of misunderstood functional relationships. The symptoms are stated, but the causes are ignored, and the organisation fails to achieve teamwork.

CURWEN sees a completed project not as the result of teamwork but as the result of each specialist taking charge, in turn, of the project as a whole. To him there appears only one solution and that is to appoint a co-ordinator, that is the Project Engineer.

CURWEN'S ideal organisation is his Type 3, and with this he has reached an advanced stage of Type "B" activity. Process Design, including brief specifications for instrument, electrical and civil engineering requirements, is completed and then the project engineer takes complete charge. He is responsible for mechanical design and testing, drawing office, erection, commissioning, timing, cost control, requisitioning of equipment, training operators and requisitioning spares. He also co-ordinates civil, electrical and instrument engineering, ordering, progressing of equipment, inspection and sub-contractors.

The functional division of the company's activity has virtually disappeared, as indicated by CURWEN'S organisation chart for his Type 3 organisation. Specialists are responsible to project engineers and, presumably, to their group heads. This organisation suffers from all the disadvantages of Type "B" activity.

Co-ordination

The work undertaken by a chemical plant contracting organisation, and this includes the supporting administrative work (for example, that done by Personnel Department), can be divided into separate and distinct activities carried out in work units. Each work unit carries out an activity essential to the completion of the work, determined by the work undertaken.

The list of essential activities does not include "co-ordinating". There is no room in an efficient organisation for the co-ordinator, or liaison officer as he is sometimes called. He is unproductive, initials work done by someone else only to pass it on. In fact, he is the man "who has a vested interest in keeping two people apart who should be working together". This applies equally well to the co-ordinator who stands between an individual within the organisation and the customer or outside supplier.

The contemporary chemical plant contracting organisation contains a number of so-called engineers whose sole function appears to be co-ordinating. Examples are:

Project Engineer; Buying Engineer; Planning Engineer; Cost Control Engineer; Progress Engineer; and Expediting Engineer.

The project engineer serves as example. No one man can,

at our stage of specialisation, be directly and effectively responsible for all aspects of larger chemical plant projects. Project engineers are, in practice, given only part responsibility and their area of responsibility varies from contractor to contractor. It is because a project engineer's job is to co-ordinate that this variation in responsibility occurs, the apparent need for co-ordination varying from organisation to organisation.

It seems that the need for co-ordination reflects upon the individuals whose work has to be co-ordinated. To avoid stating this, and thus criticising individuals, co-ordinators are called "Engineers". This implies that they have some sort of engineering function and that some sort of engineering qualifications are required to enable them to co-ordinate. As a result, qualified engineers are doing non-productive work and the extent of this misuse of highly trained personnel is indicated by the larger chemical plant contractor employing perhaps up to 30 co-ordinators, which represent an annual salary bill of the order of £45,000. It is, of course, the responsibility of top management to ensure that line and functional responsibilities and relationships are clearly defined and understood. Hence the need for co-ordination reflects on top management and not those whose work may need co-ordinating.

Individuals in one group engaged in posting or signing letters written by individuals in another group are a clear example of a non-productive co-ordinating activity. When describing or defining functions or responsibilities, one should avoid the use of vague terms such as "co-ordinate", "collaborate" and "consult". They are a means of avoiding serious thought and of avoiding definition of functional relationships.

Resolving Difficulties in Functional Relationships — Cost Control and Timing

The chemical plant contractor has to control his costs so as to operate at a profit and to plan his work so as to hand over the proved plant on the promised day. The hypothetical example discussed in each case covers only a small fraction of the activity to be regulated for effective control. Only a part of the activity between Estimating, Accounting, Planning and one of the design groups of the Technical work unit is discussed. The examples illustrate how costs and timing can be controlled.

Control relies on functional division of work and for the purpose of this analysis it is assumed that a chemical plant contractor would divide his organisation into the following functional work units: Sales (Selling, Publicity), Technical (Development, Design, Drawing, Commissioning), Works (Manufacture, Inspection), Erection (Site Erection), Commercial (Estimating, Planning, Buying), Secretarial (Accounting, Legal, Office Administration) and Research.

Cost Control

Postulates: Estimating Department is responsible for estimating costs and therefore also responsible for the accuracy of the estimate, for comparing actual costs with estimated costs, and for correlating the results of such comparisons, so as to improve future estimates. Accounts Department is responsible for gathering data on actual costs and for quickly and accurately making these available in useful form. The design group is responsible for its own expenditure.

Requirements: Estimating Department require an estimate of design effort from the design group. They also require actual cost figures. Accounting Department require data for compiling actual costs. The design group requires to be kept informed on its expenditure.

Procedure: Estimating Department request an estimate of design effort from the design group, which supplies this. Estimating Department is "responsible", the design group is "prescribing". Estimating Department may accept or reject the design group's estimate. If Estimating Department include a smaller amount and a loss results, or if they increase the amount and the order is lost as a result of general over-estimating, they are responsible. Estimating Department are responsible to the Commercial Manager for the accuracy of the cost estimate and the design group is responsible to the Technical Manager for the quality of its own prescription. The order is placed and Estimating Department tell the design group the design cost included in the estimate. The design group regularly gives Accounts Department details of design effort made. Accounts Department convert this to £ s. d. and regularly report the moving total to the design group, which then has the necessary information to enable it to control its expenditure. At the end of the project, Accounts Department report the actual design cost to Estimating Department. Estimating Department now have the actual cost data they need for comparing with their estimate. Estimating Department report back to the design group their comparison between estimated and actual costs.

Timing

Postulates: Planning Group is responsible for estimating the completion date and therefore responsible for the accuracy of the estimate, for comparing actual completion dates with estimated dates, and for correlating the results of such comparisons, so as to improve future estimates. Design group is responsible for planning its own work.

Requirements: Planning Group have to be kept informed of work completed. Design requires to know time limits.

Procedure: At the pre-quotation stage, Planning Group would ask the design group to give an estimate of time required for design work. Planning Group are "responsible", the design group "prescribes". The design group gives the stages by which the work would be completed; for example, Process Design Group states final flowsheets available x weeks, and instruments specified y weeks, from starting work. On the basis of information such as this and on known or estimated delivery periods, the time required for completing the project is estimated. The order is placed and Planning Group issue to the design group the timing chart which indicates the time limits by which the various stages of design have to be completed, these being the limits on which the overall delivery period is based.

The design group, knowing both the cost and the time allowed, starts designing. It regularly informs Planning Group of work completed.

Planning Group regularly report back to the design group the comparison between estimated and actual completion dates. Note that the design group is "responsible". While Planning Group can indicate to the design group when increased effort seems to be required, the actual effort expended is the design group's responsibility.

Conclusions

Functional relationships are often not clearly defined and thus misinterpreted. This causes difficulties. It is usual for chemical plant contractors to appoint a co-ordinator in an attempt to eliminate the difficulties. The appointment of the co-ordinator only makes matters worse. There is no room in an efficient organisation for a co-ordinator. Three requirements have to be satisfied before an organisation can operate effectively: (a) the organisation has to be divided into functional work units; (b) line; and (c) functional relations have to be defined.

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