PLANNING THE WORK OF A DESIGN GROUP

How a Chemical Plant Design Group can meet completion dates and keep within the cost estimates

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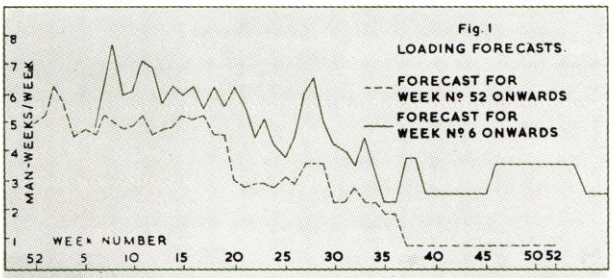

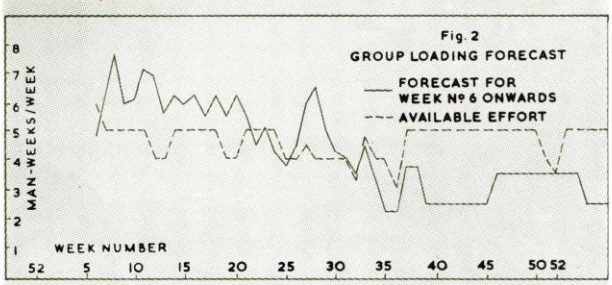

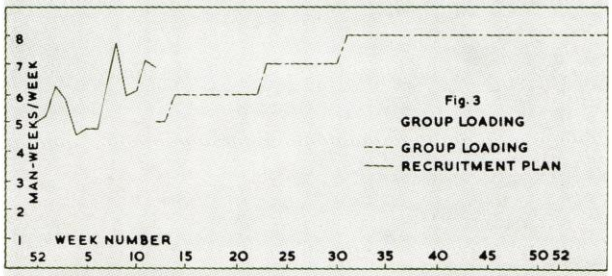

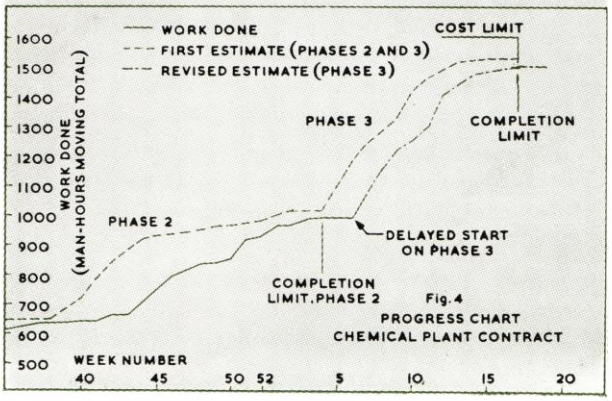

Fig. 4
PROGRESS CHART
CHEMICAL PLANT CONTRACT

THE chemical plant contractor has to hand over the plant he has designed, manufactured in part, erected and operating to his customer's satisfaction by a promised date. At the same time, he has to operate within the limits set by his cost estimate. The various work units which constitute the contracting organisation work together to achieve these ends and a method by which they can do this effectively has been described.[1] As a rule, in the case of design work, each design group is responsible for its own expenditure and timing.

In order that design work can be carried out so that cost and timing limits are not exceeded, a system such as that described here is required. Although this system applies equally well to other design groups, it is discussed and illustrated here with reference to the group which carries out chemical engineering design.

The Basis

A plan must include an estimate of how the amount of work, and the rate at which it is done, varies as the project progresses. At the time the plan is made, it must provide the best possible estimate, taking into account the total situation as then seen.

Managers then make decisions which take this situation into account. One decision may be to concentrate work on one project rather than another, should the necessity arise. The need for such a policy decision has to be appreciated at a time when it is still possible to take corrective action without endangering other work, and the decision has to be based on the most comprehensive view of the total situation that can be obtained. The comparison between plan and actual work completed reveals this need and provides the basis for the decision. Once the decision has been made, the plan has served its purpose. The decision in itself alters the plan, which thus changes as the total situation changes.

A work plan will contain limits, examples being target dates and allowed costs. As long as these limits are not exceeded, the plan may be varied at the discretion of the manager concerned. Should the limits be in danger of being exceeded, then the policy decision has to be made either at the next higher management level or by the manager, following discussion with the relevant group.

Policy, as laid down by the board of directors, can be considered a statement of general long-term aims for the organisation as a whole. When this policy is put into effect, it is interpreted differently at successively lower levels within the organisation. The lower the level, the smaller is the area of activity, the greater the detail and

the smaller the time-span. Planning of work has thus to be adapted to the level at which it is applied.

A general overall plan for a wide area of activity is required at one level, a more detailed plan covering a smaller specific area of activity at the next lower level. The two plans should not be regarded as separate and independent of each other. The general policy statement at level A determines in outline the plan for the next lower level B. The resulting detailed plan for level B affects the plan at level A.

The plan thus has to point out the need for a policy decision and to provide the basis for making the decision. It has to be flexible in order to meet changes in the entire situation. It has to be adapted to the level at which it is applied.

The planning system proposed is based upon estimates. Seldom does a project run according to initial rate estimates. Policy decisions have to be taken. The system is dynamic, in that it points out the need for such decisions. Being but an aid to management, it is not a substitute for it. The system of work planning described here enables the manager to plan ahead effectively, within the framework of general policy determined by his own executive superior. It also enables him to determine the extent to which policy is being carried out and to compare results against forecasts. It enables his subordinates to plan and carry through the work for which they are responsible. Also, it provides factual data for increasing accuracy of estimates and forecasts and for determining that part of the work where improved effectiveness would produce most gain.

The Group

The name given to any particular work group should clearly reflect its work. Mechanical engineers work in Mechanical Design Group and carry out mechanical design. The name, associated with the function of the group, assists the individual in visualising its work. No clear picture is brought to mind by names given to chemical engineering design groups such as, for example, Process Design Group or Chemical Design Group. It is therefore proposed to call the group doing this work the Chemical Plant Design Group.

The head of the Chemical Plant Design Group bears the title Chief Chemical Engineer. From a technical point of view, he is responsible for chemical engineering development and chemical engineering design, for commissioning and proving, for satisfactory operation and performance of the plants designed by his engineers. As a manager, the Chief Chemical Engineer has, amongst other responsibilities, the task of ensuring that work in his group is planned so that it is carried out effectively, taking into account limits set on costs and timing.

Estimating Department is responsible for estimating costs and would have received, from the design group, an estimate of design effort required, at the pre-quotation stage. As soon as the order is received, Estimating Department tell the design group the design cost included in the estimate. Planning Group is responsible for estimating the completion date and would have received an estimate of time required for design work and its starting date. Again, as soon as the order is received, Planning Group issue to the design group the timing chart which indicates the completion dates for the work, upon which the overall delivery date is based. The design group, knowing both the allowed cost and the allowed time, now has the information for planning its work.

The initial design work for a chemical plant contract is carried out by the chemical engineers, so that delays on their part immediately affect other groups and departments. To enable the head of the Chemical Plant Design Group to plan ahead, he must know at the earliest possible moment that an order has been or is about to be placed and requires quickly to receive the relevant data from Estimating Department and the Planning Group. His work comes also when the contract is almost completed, and then his own work is affected by delays caused by other groups and departments. To plan ahead he must be told regularly by the Planning Group how actual progress is likely to affect his work. Note that information on costs and timing is being passed to the design group, but that it is the design group which is responsible for its own expenditure and work planning.

Accounts Department have to receive a statement of man-hours worked on each project, so that they, in turn, can report back the up-to-date design cost. We are not here concerned with returns made by the design group to other groups or departments, but it is possible that the report from Accounts Department will be received too late for effective action to be based on it. In that case a policy decision is required; namely, should Accounts Department provide the information at the required speed, or should the analysis be done by the design group? In the latter case, to avoid duplication of work, the data required by Accounts Department would be supplied by design group, summarised for the group as a whole. The system described here assumes that the design group carries out its own analysis, on the assumption that the total man-hours spent on any particular project gives a sufficiently accurate indication of cost, the difference in cost of work done by senior and junior engineers being neglected. It could, however, have been based equally well on more exact cost returns from Accounts Department, had this been thought necessary.

To return to Chemical Plant Design Group, the Chief Chemical Engineer has organised his group into a number of specialist sections, and he has delegated responsibility for work planning to the head of each section. The head of such a section is here, for ease of reference, called the "manager", his subordinates being referred to as "engineers". Each engineer is responsible to the manager, amongst his other responsibilities, for giving and/or maintaining cost and work-completion estimates and for planning his own work accordingly. The engineer points out to the manager the need for a policy decision. He keeps the manager informed on progress, difficulties and delays.

The Work

The work of the engineer may be classified as follows:

(1) Enquiries;
(2) Contracts;
(3) Development;
(4) General.

It should be noted, in passing, that the term "project" is taken as referring to any main work task, no matter under which heading it is classified, and also that we are not here analysing administrative work. The work analysed is that of the engineer, who spends most of his time on work tasks which can be classified under headings (1), (2) and (3).

The work done for inquiries includes design work as well as technical discussions which are generally required so as to assist the prospective customer in defining the most suitable plant for his purpose. Also, an estimate has to be made of required effort. By estimate of effort is meant an estimate, for each work task, of:

(a) volume of work, that is, man-hours required for completion of work task;
(b) start and duration of effort, that is, start and time-span required for completion, allowing for dependence on other works groups and work tasks; and

(c) intensity of effort required each week.

Keeping a check on how an inquiry is progressing, as distinct from work planning to meet limits, is not discussed here, but a note is kept of when the inquiry was received, when work was completed, when the quotation was sent to the customer and of its value, and also of Sales Department's follow-up visits. Sales Department arrange technical follow-up visits at either the customer's or Chemical Plant Design Group's request.

Contract work includes the necessary detailed design work, advising other groups and departments, preparing flowsheets and operating instructions, commissioning and proving, and associated reporting.

"General" work includes such items as work analysis, project analysis, training and attendance at professional meetings. As it is work which cannot directly be allocated to any one project, it can conveniently include such items as illness, leave, statutory holidays and absence for personal reasons, as well as late-coming or not settling down to work at any particular time.

Each engineer works a 40-hour working week and, as a first approximation, we take the effective effort available from him as being 35 man-hours, that is, $\frac{7}{8}$ man-weeks/week, allowing separately for holidays and leave. The effective effort available is the difference between normal working hours and time accounted for by general work.

For accounting purposes, "general" work can be carried as an overhead charge. It is of some value, although by no means necessary, thus to separate out the general work content, when both small and large projects are being handled at the same time, there being some indication that otherwise larger projects carry a disproportionate part of this charge.

The System

Loading Forecasts

The loading forecast is an estimate of the anticipated future work load, that is, of required effort which can be foreseen.

Each engineer prepares an estimate of future effort required for the projects for which he is responsible, allowing for work content and target dates which may have been previously agreed. How far ahead he can plan depends on the type of work he does and on his level within the organisation, but the forecast is made for each week up to between three months and a year ahead. He distinguishes between development, inquiry and contract work, breaking down the work for each project into individual work tasks. His forecast is made in the form of a table. How quickly it is revised depends on how quickly the situation changes.

The manager prepares a more general forecast based on those received from his engineers. His forecast, again in tabular form, indicates the estimate for each project, under the categories of development, inquiries, contracts. Not only should each engineer's load be reasonably even, but also that for the group as a whole. It is in preparing this forecast that the manager, in discussion with his engineers, anticipates periods of light and heavy loading. He levels out the work distribution, considering both expected and existing projects. He also considers how policy can be carried out as regards division of work between the categories and considers possible staff changes that may seem indicated. He will look further into the future and his forecast covers a longer time-span than the engineers' forecasts.

The manager's forecast forms the basis for the work of the group in the immediate future. It is built up from the individual forecasts he has agreed with his engineers. Its main use is for planning ahead.

Work Plans

Each engineer prepares his work plan from the forecast he has agreed with his manager. It indicates when work is expected to start on any part of a particular project and by when it has to be completed. In other words, it clearly indicates the anticipated duration of effort as well as target dates.

The work plan enables each engineer to see how work is proceeding as regards timing. He is thus in the position either to make up lost time or else to see when it is necessary to approach his manager to point out the position and to ask for a policy decision.

The work plan gives no information on either the volume of work or on the intensity of effort allowed for individual work tasks or projects. This information is depicted on project progress charts.

Work Records

Each engineer keeps a daily informal record of how he has spent his time. He divides this record into the four main categories of development, inquiry, contract and general work. Each project is separately recorded and divided into individual work tasks.

The record for the week is entered up at the end of each week on the engineer's work record form, which covers a period of thirteen weeks. This work record provides the basic data for bringing up-to-date the work plans and project progress charts.

Progress Records

The anticipated, or allowed, volume of work and intensity of effort has already been agreed between manager and engineer, as recorded on the loading forecast. This is used to draw a progress chart for each project, consisting of a plot of the estimated moving total of effective man-hours expended against time. On these charts are entered target dates and any limits which should not be exceeded, such as, for example, a work content equivalent to the cost agreed previously with Estimating Department.

The effective man-hours worked on each project is extracted from work records and the up-to-date moving totals are plotted on the progress charts. The charts are brought up to date once a week or once a fortnight, as the need may be. The graph of actual effort expended does not usually correspond with the estimated curve, and indeed it is the difference between anticipated and actual work which is of importance.

Each progress chart indicates how the design group's rate of progress compares with estimated rates, both for cost and for timing. The charts are drawn up not only for contracts, but also for work on inquiries, for development work, for individual projects and/or for the category as a whole.

The Application

The system is discussed with those concerned, modified in detail, where necessary, to suit local conditions, and put into effect.

The extent to which statistical and clerical work is done locally, and how this is to be done, is one of the points to be determined before the system is put into effect. The records and charts are available to those who compile or need to consult them. They are brought regularly to the attention of those who need to see them.

Those who operate the system can judge how effective it is in enabling them to carry out their responsibilities. It is made clear that any engineer or manager should, once some experience in operating the system has been gained, propose to his own immediate superior such modifications as would, in his opinion, increase the effectiveness of the system.

The engineer prepares his loading forecast and his work plan at relatively infrequent intervals. He keeps a detailed record of the way he has divided his time between different work tasks and enters this information on his work plan. The keeping of these routine records usually takes up less than one and a half hours each week of each engineer's time. His tools are his work plan and the project progress charts with which he is concerned and on which he notes any matters which have affected progress or cost.

The manager regularly reviews project progress charts and his overall forecast. His tools are those charts which are based on loading forecasts and the project progress charts.

In between recording the data and the progress charts lies the statistical work of analysing the work record sheets to obtain the weekly data in useful form.

The Records

The records used for planning are:

(a) Loading forecasts;
(b) Work plans;
(c) Work records;
(d) Progress records.

As these records relate to the work being done by the manager and his team of subordinates, they have immediate meaning to those concerned.

Loading Forecasts

Fig. 1 illustrates the overall loading forecast for the group. Two successive forecasts are shown, made at an interval of about six weeks. The situation has changed considerably during these six weeks but, even so, one might judge that the load will be considerably reduced after six months or so, and that the group would then be looking for work. However, the way in which such forecasts can assist forward planning is illustrated by Figs. 2 and 3, derived from Fig. 1.

Fig. 2 shows the then up-to-date loading forecast. Plotted to the same scales is a graph of the available effort which can be applied by the group. This allows for known staff changes, for leave and for statutory holidays. Planned recruitment is not taken into account and engineers are included only after they have been with the group for one or two months. This chart is used for forward work planning, that is, for fitting in new work. It indicates in this case that the group ought not to accept new work which has to be done during the first nine months from the date of making the loading forecast, should its strength remain at a constant level.

The second type of chart used for forward planning, illustrated by Fig. 3, shows the actual loading of the group. Loading forecasts are made here at intervals of six weeks and the loading estimate for the first six weeks of each forecast is assumed to be an accurate representation of the work load for the group as a whole. These estimates are then plotted consecutively and the graph drawn represents the loading of the group. The first six weeks' load estimates from each of the forecasts given in Fig. 1 are plotted in Fig. 3 to show the group loading, and it is seen that the work load is increasing steadily. On the basis of this graph the forward recruiting plan is prepared and this is plotted on the same chart.

In the example illustrated here the loading forecast seemed to give the impression that the group would be underloaded within about six months or so. In fact, the work capacity for the first nine months had already been reserved in advance at the time the estimate was made, and the work load was steadily increasing. Hence it is charts such as those illustrated by Figs. 2 and 3 which are used for forward planning.

The ordinate on these charts has units of man-weeks/

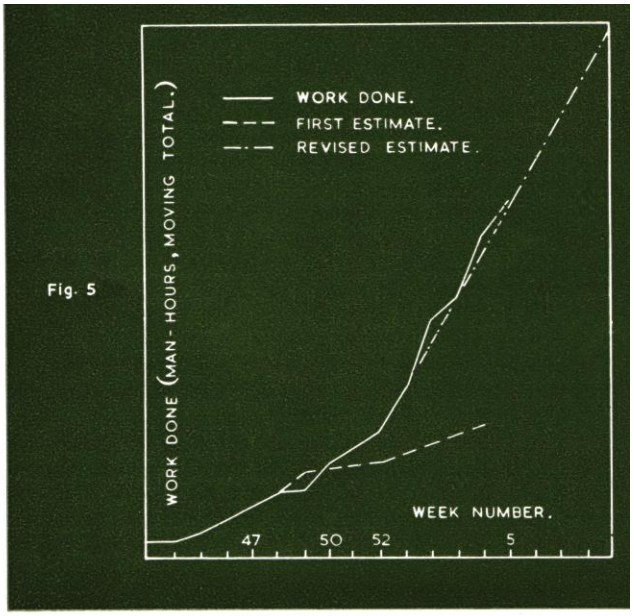

Fig. 5

week, whether general work is included or not. This is of no concern, as long as general work is consistently included or excluded and as long as the appropriate conversion factor is used for converting man-hours to man-weeks.

Work Plans

The work plan is no more than the normal project bar chart, itemised in accordance with the engineer's loading forecast. Anticipated duration is shown in black; actual work carried out is entered up in green.

Work Records

The work record sheet is illustrated by Fig. 6. It is a simple blank form which enables the engineer to enter up his own projects and to subdivide his work into suitable work tasks, as required.

Progress Records

Fig. 7 illustrates a project progress form. The total work done by the group on each particular project is recorded weekly on such a form, and these forms are used to bring up to date the project progress charts. Note that the distinction between individuals has almost disappeared. Although work done by senior and junior engineers is separately recorded, the data are already that for a project.

The progress charts, and the use to which they are put, are illustrated by Figs. 4 and 5. Fig. 4 gives the data for a medium-sized chemical plant, Fig. 5 that for a complete category such as work done on development.

Fig. 4 gives the estimate made in week 33 for phase 2 and phase 3 of the particular project used as example. In making the estimate, account was taken of time and effort allowed for completion, and also of the available man-power, in the way already described. Four weeks had passed after the estimate had been made, and when work was to have started on phase 2 the situation had changed so that a policy decision was required to decide whether effort should be concentrated on this project or on another. Work on phase 2 had to be completed before starting work on phase 3. The work done by other groups was not affected by delay, as long as work on phase 2 was completed by the end of week 4. The decision was therefore made to concentrate work on the other project, but to ensure that this project would not be delayed as a result. Fig. 4 clearly shows how this decision was effectively implemented. There is the initial delay with comparatively little work done on this project, followed by an intense effort to get

Fig. 6

WORK RECORD - HOURS WORKED.

NAME :- YEAR:- 1959. PAGE:- 1.

PROJECT.	WORK TASK.	"WEEK ENDING" AND "WEEK NUMBER."												
		4 1 59	11 1 59	18 1 59	25 1 59	1 2 59	8 2 59	15 2 59	22 2 59	1 3 59	8 3 59	15 3 59	22 3 59	29 3 59
		1	2	3	4	5	6	7	8	9	10	11	12	13

Fig. 7

PROJECT PROGRESS RECORD - HOURS WORKED.

PROJECT:- YEAR:- 1959. PAGE:- 1.

WEEK NUMBER	SENIOR	JUNIOR	TOTAL	MOVING TOTAL	COMMENTS.
1					
2					
3					
4					
5					
6					

Fig. 8

PROJECT ANALYSIS - HOURS WORKED.

PROJECT:- YEAR:- 1959. PAGE:- 1

WORK TASK.		"WEEK ENDING" AND "WEEK NUMBER"												
		4 1 59	11 1 59	18 1 59	25 1 59	1 2 59	8 2 59	15 2 59	22 2 59	1 3 59	8 3 59	15 3 59	22 3 59	29 3 59
		1	2	3	4	5	6	7	8	9	10	11	12	13
	S													
	J													
	S													

Fig. 5 PROGRESS CHART DEVELOPMENT WORK

Fig. 6 ARRANGEMENT OF WORK RECORD CHART

Fig. 7 ARRANGEMENT OF PROJECT PROGRESS RECORD

Fig. 8 ARRANGEMENT OF PROJECT ANALYSIS FORM

the bulk of the work done. This, in turn, is followed by another quiet period while work is proceeding on the other project, with the subsequent final spurt to get the work completed. The task was, in fact, completed two weeks before the set limit and at a little less effort than had been estimated. Work on phase 3 was started two weeks late, the delay having been caused by another group not completing its work on time. Hence as soon as work could be started the original estimate was replotted, allowing both for the two weeks' delay and for the small saving in effort. The work as a whole is running two weeks late, the effect on the final set limit being clearly shown; but as the estimate relates only to work done by this particular group, it is not altered in any way either in intensity of effort or in time-span to allow for delay caused by the other group. However, an effort will be made to make up the lost time, if at all possible, and its success or otherwise will in due course be clearly shown by the black graph of actual effort expended.

Fig. 5 shows an estimate of effort made in week 48. Again, within four weeks the situation had altered owing to a decision to follow up in strength a promising development. A revised estimate was made during week 1. In this case also it was the estimate which was altered, the revised estimate showing how the new policy could be implemented. Agreement between actual and estimated effort is deceptively good, but it was the available man-power which limited the intensity of effort and this was known at the time the estimate was made.

A colour code can be used to indicate the comparison with the original estimate, but it is usually sufficient to give a green line for the estimate, a black line for actual effort, the difference between them being marked in red when the work is late and in green when the work has been completed within the estimate.

Other colours could be used to show when the estimate was too low and for the case when, in addition, the work has been delayed.

Analysis of Records

At the end of a project the completed work record sheets are analysed in two ways, as required. First, factual data are summarised for each project so as to provide a background of correlated data enabling the accuracy of estimates of design content to be continually improved. Secondly, criteria of performance can be extracted which point to that part of the work where effectiveness can be improved with greatest gain.

Project Analysis

The detailed data for each project are transferred from work records to project analysis forms. Again, the forms record separately the work done by junior and senior engineers. The form is illustrated by Fig. 8.

At the completion of each project, the analysis is completed by summing up the effort expended on each work task within the project. For smaller projects a simple table suffices to present the overall picture. This gives, against each work task, the time-span and the intensity of effort, as well as the percentage of the total effort for the project as a whole which the particular work task represents. At the same time, notes are added which describe the project in general terms, also giving its money value, and any points worth noting, especially such as, for example, that one particular work task was wholly caused by a change of mind half-way through the project. At times progress on a particular project may be limited by available man-power and this also would be noted. Hardly any two projects are exactly alike and these notes should give sufficient information to enable the data for this project to be applied to another similar one.

For larger projects a similar table with accompanying notes is used for summing up, but a single-colour bar chart is used for recording time-span. This is the project bar chart and it records fact, not forecast.

Once analysed, the project records, which include also progress records and progress charts, are filed and kept for future reference. This is done only after original estimates of design costs and time-span have been compared with actual costs and time-span, this comparison being recorded. The records serve to improve the reliability of forward estimates, for example, for Estimating Department and for Planning Group in connection with inquiries.

Work Analysis

When required, criteria of performance may be extracted from the project records. For example, the greater the percentage of the total work devoted to any particular work task, the greater the reward to be gained by increasing the effectiveness of work on that task. Another example is the percentage of the effort expended on any particular work task, or indeed on the project as a whole, by senior as compared with junior staff. This reflects inexperience on the part of junior staff, staff turnover, novel nature of work task, or the degree to which responsibility is being delegated.

REFERENCE

[1] Davidmann, M. *Brit. Chem. Eng.*, 1959, **4**, 7, 403.

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