Earlier Payout Through Tight Project Scheduling and Control

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MONEY INVESTED in market research, project development, plant design and construction does not begin to be returned until the plant is in operation and producing satisfactory product. Therefore, the shorter the time between management's decision to invest in new production facilities and the successful operation of the facility, the earlier the investment will start to earn a profit. Management must be alert to recognize and examine any decision, whether conscious or unconscious, which causes a delay, in light of the effect that delay may have on the return on the investment. Until product is being sold, all investment costs represent idle money.

The most expensive plant is one that does not do what it was built to do in quality of product, capacity, and operating costs, or which is in the wrong market location. Engineering is a poor place to economize, although money should not be thrown away needlessly. Engineering effort expended should more than pay its own way in:

1) Lower procurement costs through better, tighter specifications and good shop drawings.
2) Lower construction costs through less expensive materials and less manhour usage.
3) Reduced start-up time through adequate instrumentation, efficient process design, and adequate manuals.
4) Lower operating costs: utility savings, lower corrosion rates, etc.

Good engineering can save money in procurement and during construction as well as during operation. For example, process engineering using simulation or other computer mathematical techniques can sometimes eliminate the cost of a pilot plant.

To quote from *Chemical Week*, "... there's a [difference] between a batch of engineering and design principles, and knowing how to [turn] them into an efficient plant." This paper will discuss various techniques in planning and control for getting a plant into operation rapidly and thereby starting the payout earlier.

The principal techniques for shortening the time between the decision to build a facility and its starting production are:

1) Efficient approval and decision-making techniques.
2) Well-defined project specifications.
3) Experienced plant location survey.
4) Competent and experienced design, procurement and construction personnel.
5) Effective design approach.
6) Complete service contract.
7) Use of documentation in control and scheduling.
8) Use of critical path scheduling and EDP techniques.
9) Use of plant models.

Approval and Decision Making

Management should assign a project manager to coordinate the work of the various groups involved, whether or not an outside engineering firm is handling the design. The lack of any single decision-making contact is one of the crosses engineer-contractors have to bear, and this situation is almost sure to retard a project. Engineer-contractors assign a project engineer or project manager to each contract. The client's project manager should have sufficient authority to make most on-the-spot decisions. He should understand the policies of his company so that he can obtain even major decisions from his superiors in a reasonably short time.

Once assigned, he should keep management objectives and pertinent contractual agreements in mind, making approvals efficiently and rapidly, expediting all decisions to keep the project on schedule and within the budget.

Change orders or extras may be one of his biggest personal problems. Again, having a clear understanding of the original concept and what changes are desired will facilitate the development of accurate costs, and a rapid approval of the change will minimize delay.

Project Specifications

The preparation of clearly defined objectives before proceeding with any significant amount of design can save time and money. This is particularly true when a fixed price contract is solicited. Definition of scope will list the raw materials required, the capacity, product specifications, etc., but should also cover such matters as:

1) Amount of architectural finesse desired.
2) Standardization of equipment suppliers.
3) Degree of instrumentation and control.
4) Company standards for pipelines, lighting intensity, etc.
5) Accessory facilities: fire protection, storage capacity, maintenance shop and laboratory facilities.
6) Future expansion provisions.

Site Survey

Selecting a location for a new plant is a most important decision in the life of a company and is one of the most exacting. Many companies that undertake their own plant location surveys find that it is difficult to prevent premature disclosure of plans; customers, supplies, personal friends, utilities, railroads, and chambers of commerce exert considerable pressure, and there are many conflicting claims; these advisors lack the necessary experience and technical resources.

Of more importance, a "do it yourself" campaign of plant location takes more time than can be justified by company executives. This results in a relaxation of normal managerial control while the site survey is being made, or an unnecessarily long survey. Management should consider the overall economy of retraining an experienced, unbiased organization for this vital function.

Organization and Personnel

Procurement and construction of process facilities requires extensive design work to insure that equipment and buildings will function as required, and to minimize purchase and erection costs. While it would be possible to have an involved process plant built without preparing engineering specifications or drawings, common sense and years of experience indicate that a certain amount of engineering and drafting will save many times its cost in procurement and construction.

There is a limit to the amount of engineering that can be performed economically on a given project but, except for corrections or major design revisions, engineering expended within usual limits usually saves more money than the cost of the engineering.

The most effective tool in maintaining a tight design schedule is to have a competent technical organization experienced in all phases of activity required to design, procure, and construct the plant; with a clear understanding of the individual responsibilities and interdependencies; and then to provide that organization with accurate information clearly identified, and as quickly as possible.

The exact type of organization is not important. It is important that there be definite lines of authority, and sufficient technically-capable personnel in various categories. A project cannot be performed effectively if part of the important activities have to wait for someone to finish other essential duties, or if some personnel are slow to complete

(Continued on page 70)

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Earlier Payout . . .

(Continued from page 58)

their operations due to unfamiliarity with the assignment or lack of data from other groups.

On smaller projects a man may wear more than one hat and the plant layout could be made by the same man who later selects mechanical equipment and instrumentation, prepares the ductwork drawings, and checks the piping. On large projects a more strict compartmentalization is necessary, and the engineering organization must have personnel with experience in such areas of engineering and design as:

Chemical Process Designers to make chemical engineering calculation, design flowsheets, make preliminary equipment and line sizing, and prepare heat and material balances.

Plant Layout Designers to prepare equipment arrangement drawings that combine maximum operating efficiency with minimum cost of materials. This group may also build plant models.

Equipment Selection Engineers to design and specify vessels, bins, pumps, conveyors, boilers, etc., to analyze quotations and to check certified vendors' prints.

Piping Designers to prepare piping and insulation specifications and make process and utility piping drawings and bills of materials.

Architects and Structural Designers to prepare building designs and equipment supports.

Civil Engineers to make plot plans, lay out roads, tracks, make site, storm sewer, and drainage drawings.

Electrical Engineers to prepare specifications and drawings for power supply and distribution, lighting, alarm systems, communications, and interlocking.

Project Staff for project coordination and scheduling, liaison between management, purchasing, construction, engineering, accounting, and the client.

Plant start-up. The chemical process designers prepare operating instructions for use by plant personnel; conduct training programs for operating personnel; make initial "dry-run" checks of process equipment; supervise the initial period of operation to insure successful performance.

Design Approach

Proper execution of any task requires that the scope of the problem be known, and that responsibility for satisfactory performance of the various components be assigned. It is generally most effective in plant design to "cut the problem into little pieces," and then assign each part to the proper group.

On larger installations the project should be divided into convenient physical areas. For example, these areas could be established in a cottonseed processing plant: 1) yard and storage; 2) delinting; 3) prepress; 4) utilities; 5) extraction.

This area breakdown enables drawings, purchase orders, specifications, and other data to be keyed numerically so that various parts of the process can be readily identified. The biggest value of area breakdown lies in allowing the scheduling of engineering, procurement, and construction separately for each area while not losing sight of the over-all problem. It is easier to put maximum push on one area in preference to other areas, or to assign similar problems in different areas to different personnel.

The next step is to separate the overall design effort into individual problems. The design basis for each unit is then prepared by process designers in sequence according to schedule requirements, and issued to the engineering groups responsible for final design. Design data, process flow sheets, and layout drawings form the basis of the final design work.

The design data comprise statements of process, contract, and site requirements, such as: construction materials; adherence to FDA requirements; operation of equipment; sizes of vessels, pumps, piping, etc.; properties of process materials; degree of instrument control; other data developed from the contract documents, from the client information, from site information, or from the chemical engineer's process calculations.

Release of design data and flow sheets allows the engineering department to prepare layout drawings, issue mechanical specifications, and the vessel drawings for quotation and purchase.

Vessel drawings and layouts, plus the certified manufacturer's prints, form the basis for the final engineering design allowing preparation of piping, concrete, steel, and electrical drawings, specifications and bills of material for use in bulk material procurement, and in construction.

The key to rapid completion is to be able to finish some parts of the work while other sections may be held or released only preliminarily without affecting adversely the completion of engineering, procurement, or construction. When a technique is used to define for separate handling the various composite problems on the project, even where some important information is missing, much engineering design can proceed without later scrapping.

Complete Service Contracts

The fastest way to design, procure, and construct a facility is to give entire responsibility to one organization, or undertake the entire project yourself if you have a staff of experienced personnel required. This is sometimes called a turnkey or complete service contract which might start with a site survey and end with start-up and contract maintenance. Single responsibility allows various phases of design work to proceed simultaneously or in sequence, according to the overall requirements of the schedule, with procurement and construction of certain portions occuring concurrently with design of other phases of the project. In essence, the work is performed according to the needs of a master schedule rather than finishing major sections, such as the engineering, before starting the procurement.

As a plant worth a million dollars, on an installed-cost basis, should provide a minimum return on investment of $20,000/month, the potential savings in going out for separate design bids and construction bids should be considered carefully, since experience has shown that the turnkey approach will save two to six months' time. In other words, $40,000–120,000 of returned capital will be available for use. There are instances where management decides that design should be done by a different organization than the one that does the procurement and/or the construction. There are also occasions where management wants different portions of the facility handled by different contractors. Often the reasons are justifiable, but adequate consideration should first be given to the overall cost of such an approach. The tighter the schedule the more economical undivided responsibility becomes.

Documentation

Certain paperwork is helpful in keeping track of details in design and construction of a plant so that nothing is omitted which will affect completion. Some examples are:

Division of Responsibility. Establishing responsibility between home office engineering, client, subcontractors, field office, etc., for every portion of the work.

Engineering Check List. Maintained by each supervisor to list work for which he is responsible.

Cost Status Report. Records of amounts committed to date against original estimate, and the amount of money yet to be spent. This should be issued at least once a month.

Schedules. A schedule is only as worthwhile as the accuracy of the input data. Out-of-date information on a schedule is worse than no information. Some important schedules are:

Manpower Schedule. To insure that the needed technical specialists are available and are assigned at the right times.

Drawing Schedule. To list each drawing to be prepared,

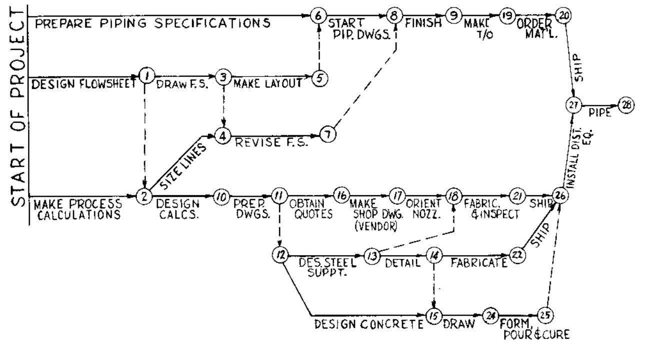

FIG. 1. Portion of arrow diagram for distillation equipment.

with date of release. This helps procurement and construction planning.

Progress Schedule. The "time-honored" bar chart will show the anticipated elapsed time for engineering, procurement, and erection.

Material Control. All material that is required to be designed, specified, or procured, listing schedule dates of quotation, purchase, dates of vendor's prints, and required delivery dates.

Critical Path Scheduling

New approaches have been developed in recent years which can eliminate misdirected engineering effort through poor planning.

One technique is Critical Path for use where the duration of each job required to finish the project can be reasonably predicted. While the method is most often discussed in connection with the use of a computer, its most significant advantage is that it substitutes for the bar chart an arrow diagram which must first be prepared prior to determination of critical path.

Arrow diagramming is an excellent planning procedure. It requires that those doing the planning determine all important functions necessary to execute the project and the interrelationship between the various functions (Fig. 1). Following this diagramming the expected duration of each job is established and recorded. This should be done in consultation with engineering supervisors, purchasing agents, expediters, construction superintendents, etc. It is a useful tool to minimize the duration of the project. For smaller projects with less than 100 job items, it is possible to set up a matrix and solve for the critical path, using hand computation. For over 100 items it is less expensive to use a computer, and this is almost a necessity on large projects.

We have prepared a 170-job arrow diagram for an extraction plant project and had a Critical Path program run and revised twice, using an outside computer service for the minimum charge of $100 per run.

A computer also enables an analysis to be made of the effect of speeding up various phases of the project. The durations of various steps shown on the arrow diagram can be shortened and the computer used to redetermine the project completion date by critical path. The computer can be programmed to determine the cost of such acceleration in order to arrive at the most economical means for accelerating the schedule. At some point, of course, so many paths become critical simultaneously that the expense of further acceleration is prohibitive. Critical Path method of scheduling allows a determination of the cost of acceleration by various means, as well as selection of the most economical method.

While the discipline imposed by the arrow diagram is the most important advantage gained for this technique, the second most valuable is that it enables management to explore the cost of significant changes in scheduling.

Punched Card Analysis

We have developed a system using punched cards for continuous checking of whether each item or block of material is on schedule. Once the overall detailed schedule is established, the scheduled dates for each significant operation for each item are punched into cards.

Using the normal flow of documents within the office, dates of completion of operations are recorded on the cards. At any scanning interval desired, a print-out is

Con	A	Item No.	Description		01	02	03	04	05	06	07	08	09	10	P.O. #	Vendor 3/4/63
108	5	401041	Spent Cake Elev	00	*	*	*	*	*	*	*	*			16	Rex Thong
108	5	402041	Solv Unld Pump	00	*	*	*	*	*	*	*	*			4	Saxon
108	5	402042	Solvent Pump	00	*	*	*	*	*	*	*	*	2/28			W. C. Trunion
108	5	402043	Full Miscel Pmp	00	*	*	*	*	*	*	*	*			14A	Elgin Ross
108	5	402044	Finish Oil Pump	00	*	*	*	*	*	*	*	*	2/28		4	Arco
108	5	402045	Cool W Cir Pump	00	*	*	*	*	*	*	*	*			17	CMF
108	5	402046	Oil Str Con Pmp	00	*	*	*	*	*	*	*	*			4	Saxon
108	5	402047	Stage Pumps	00	*	*	*	*	*	*	*	*	2/20	2/28		W. C. Trunion
108	5	403041	Vent Ejector	00	*	*	*	*	*	*	*	2/25			2	Firme Trucks
108	5	403042	Rfg Vnt Con Ejt	00	*	*	*	*	*	*	*	*	*	*	2	Firme Trucks
108	5	403043	Strip Ejector	00	*	*	*	*	*	*	*	*	*	*	2	Firme Trucks
108	5	414041	Desolv Toaster	00	*	*	*	*	*	*	*	*			24	W. C. Trunion
108	5	414041C	LS Shft Coupling	00	*	*	*	*								
108	5	437041	Extractor	00	*	*	*	*	*	*	*	*				Osso-Peechy Steel
108	5	442041	Cooling Tower	00	*	*	*									
108	5	442042	Stm Con Ret Sys	00	*	*	*	*	*	*	*	*			6	Burns & Blast
108	5	446041A	Presscake Blowr	00	*	*										
108	5	446041B	Presscake Cycln	00	*	*										
108	5	446041D	Prscak Air Lock	00	*	*										
108	5	447 R1	Electric Motors	00	*	*	*	*	*	*	*	*			26	Cuban Electric
108	5	485 41	Gear Reducer DT	00	*	*	*	*	*	*	*	*			95	L. S. Dolinks

FIG. 2. Punched card analysis printout.

made (Fig. 2) showing by means of asterisks all operations which have occurred. Operations whose completion has not been scheduled to have occurred as yet show blank. Late items show as the dates on which the operation should have been completed.

This enables each supervisor, project manager, purchasing agent, or expediter to tell at a glance which items within his responsibility are late. Until the item is brought back on schedule each subsequent print-out will show the behind-schedule event, minimizing overlooking any serious problem.

This technique has worked well, and is less costly and more informative than traditional procurement status lists. It is an example of the "Management by Exception Principle," that only significant variations or deviations from established standards or objectives should be referred to higher management for necessary action.

The mere statement of the various procedures, control techniques, documentation, and schedule which have found acceptance in *designing and building new facilities* may seem expensive or complicated. Their application must follow the same rules laid down for engineering: their use should save more money than they cost. Adequate cost control, starting with a detailed project estimate, and based on the well-defined project scope, continuing with periodic job cost or contract status reports will demonstrate the economics inherent in such project scheduling and control.

Plant Models

Scale models have proven to be an effective tool in the design and construction of process facilities. We have developed our own group of model builders who work with the plant layout group.

It is difficult to prove that the use of process models saves engineering hours or material costs. There is no doubt, however, that the use of models during design results in a better plant design, particularly insofar as operation and provision for maintenance and expansion are concerned.

Another advantage is the use of the completed model by the construction forces in planning work sequences, efficient use of various crafts, storage of construction material, and proper use of construction equipment. It also can serve as a valuable tool in instructing plant operators prior to the start-up.

Summary

Money invested in new facilities does not begin to be returned until start of production. Management must be careful to minimize the time lapse between the decision to build a new installation and its successful operation. A number of time and money saving approaches can be utilized:

1) Efficient approval and decision-making techniques by management.
2) Well-defined project specifications.
3) Use of an experienced plant-location organization.
4) Use of competent and experienced design, procurement and construction personnel.
5) Overlapping design, procurement and construction activities through careful planning.
6) Use of a turnkey contract with undivided responsibility.
7) Use of various documents, schedules and controls including Critical Path and procurement analysis.
8) Use of plant models.

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