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COST ESTIMATING & COST CONTROL
ON
ENGINEERING & CONSTRUCTION PROJETCS

Prepared for

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Presented By

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COST ESTIMATING & COST CONTROL

ON

ENGINEERING & CONSTRUCTION PROJECTS

SEMINAR

BY

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I N T R O D U C T I O N

The word "Cost Engineering" was coined as an engineering discipline only 2 decades ago. Already it has found common usage in the engineering and construction industry throughout North America and indeed in Europe and other parts of the world. Spearheaded by this newly formed "Cost Engineering Profession" great progress has been made in that area of engineering where engineering judgement and experience are utilized in the application of scientific principles and techniques to problems of cost estimating, cost control, economic evaluation, business planning and management.

This seminar will concentrate on cost estimating and cost control, reflecting the general concepts and practices that have developed on the North American continent in recent years. Broadly speaking, the seminar concerns the capital costs of process plants such as chemicals, petrochemicals, nuclear plants, and all similar type projects. It should be of interest to management and supervisory technical personnel concerned with capital costs and cost control in construction, engineering and process industries.

In today's dynamic economy, the accent in capital cost estimating is on short cuts and speed. Not only is the speed required, but there must be a high degree of confidence in the reliability of the figures. Emphasis will be placed on new developments and sophistication that have emerged through a more scientific study of the anatomy of capital costs, breaking them down into like components and finding cost patterns and relationships which reflect their individual behaviour.

Estimate types and techniques will be discussed starting at an early stage when scope is limited and few drawings (if any) are available, and progressing through to the method of building up detailed estimates.

In recent years, some form of factor estimating has come to dominate the entire "front end" in the estimating of project costs. In fact, in its broadest meaning, all forms of estimating, except detailed estimating of manhours, making material take-offs or obtaining quotations, may be classified as factor estimating. The presentation is oriented towards this fact, placing emphasis on the various application of "front end" techniques starting with the so called "Broad Factors" and progressing towards the use of detailed factor estimating.

Under the heading of Time & Scale Factors, a section on Cost Indexes will review various U.S. indexes, illustrating their differences, uses and pitfalls.

The 4 area concept of building up capital cost estimates will be presented to demonstrate their different cost patterns and the advantages of such an approach. This will lead into size factors and discussion of the much touted sixth tenths factor. The sixth tenths factor will be reviewed in considerable detail to highlight discrepancies and pitfalls. Discussion of economy of scale will focus attention on economic size plants.

Capital costs will be broken down into specific components of direct and indirect costs. Emphasis will be placed on precise definitions and good semantics and on the importance of a good cost code. An excellent modern code with complete flexibility for use on small projects or large projects will be presented. Using the cost code, a standard format will be used to show how to build up a complete estimate to get the bottom line number and be confident that everything is in.

A thoroughly tested, reliable Factor Estimating System will be presented in detail. A complete set of factors will be included. Coupled with certain refinements, it will be shown how this factor system has reached a degree of reliability that it is used frequently for the appropriation of funds.

A session on "Cost Control" will be presented covering the basic principles, application and organization.

Cost control involves more than cost. It also concerns "time" i.e. planning and scheduling. In its full ramifications, the words "Project Control" may be a better title.

Cost Control starts with a "Management Directive". The role of management is stressed followed by discussion of 11 basic requirements for good cost control.

The cost control cycle of Realistic Targets, Monitoring, Trending & Forecasting, and Analysis & Action is discussed in detail. The application of each one of these functions is reviewed under the separate headings of Design, Procurement and Construction.

Sample procedures and formats are provided to illustrate methods of trending and forecasting in each of the 3 areas. The use of S curves and similar graphs are highlighted in their many applications in the cost control system. Emphasis is placed on trouble spots.

By way of illustration, a complete written procedure for controlling draughting manhours is presented along with sample graphical depictions used for trending and forecasting.

Similarly, recommended documents which contribute greatly to the Procurement Control are discussed in detail.

Field Control on Construction projects is a never ending challenge. It involves field work orders, material control, manhour control, indirect costs, physical progress, etc. It will be demonstrated that whether it is concrete work, equipment, piping, electrical, etc. each one can be attacked through the basic principles of cost control.

Effective cost control calls for integration or unification. It must be all one system, not a multiplicity of separate systems. The cost code is the unifying factor and finally the computer becomes essential to complete the integration.

Ultimately, cost control requires an organizational set-up designed with cost control in mind. This will be discussed with particular emphasis on the cost engineer and his responsibilities.

Notes will be supplied, including certain data applicable to North American operations and time will be provided for workshops.

COST ESTIMATING AND COST CONTROL
ON
ENGINEERING AND CONSTRUCTION PROJECTS

PROGRAM

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E S T I M A T E S

TYPES

In practice, the many types of cost estimates can be categorized into about five general types. The type to use necessarily depends on:

- its purpose
- the time and manpower available
- the data available, and
- the accuracy required

Table "A" illustrates the five types, their purpose, the techniques used, the time requirement and depicts graphically the information required and the expected accuracy. Table "B" elaborates on the specific requirement for each type of estimate. Refer to both Table A and Table B for the foregoing discussion.

ESTIMATES

TYPE	PURPOSE	TECHNIQUE	TIME
E BALL PARK	INITIAL INVESTIGATION	$/TON/LB GRAPHS	HOURS
D STUDY	EARLY FEAS. JUSTIFY FUNDS TO GO FURTHER	FACTOR LARGE COMP.	DAYS
C PREL.	FEASIBILITY AUTHORIZE LIMITED FUNDS	FACTOR LARGE COMP. UNIT COSTS SOME QUOTES	(1) WEEKS
B DEF.	APPROPRIATION REQUEST COST CONTROL	SOME FACTOR LARGE COMP. UNIT COSTS MANY QUOTES	(1) WEEKS MONTHS
A BID	BID EVALUATION NEGOTIATE EXTRAS	QUANTITY TAKE-OFFS UNIT COSTS QUOTES PRICE LISTS	(1) WEEKS MONTHS

(1) VARIES WITH PROJECT SIZE

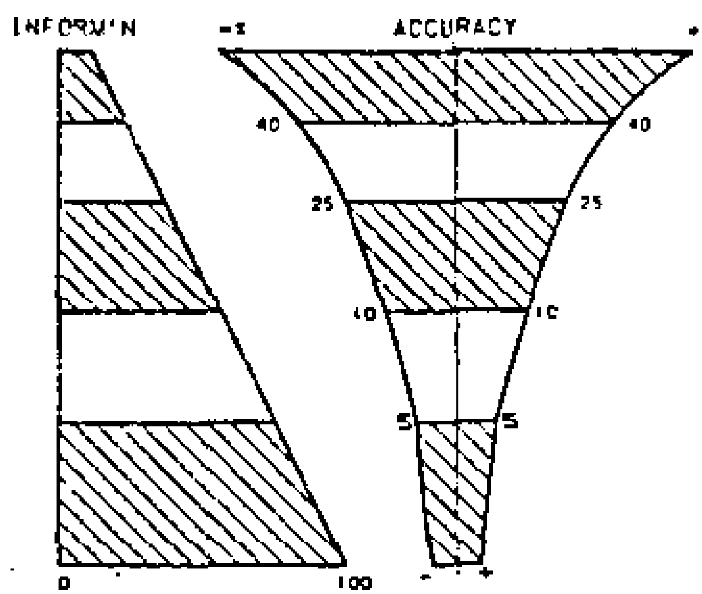

Table A

ESTIMATE TYPES

CLASSIFICATION AND APPROXIMATE RANGE OF ACCURACY	A [illegible]	B [illegible]	C [illegible]	D [illegible]	E [illegible]
INTENDED PURPOSE	- FOR USE [illegible] EVALUATION [illegible] OF A PROJECT - TO [illegible] COST OF [illegible] CONTRACTS - [illegible] FOR COMPLETE PROJECTS	- [illegible] LEVEL OF ESTIMATE [illegible] FOR AN APPROPRIATION REQUEST - TO PROVIDE THE BASIS FOR A COMPLETE PROJECT COST CONTROL PROGRAM	- FOR APPROVAL IN [illegible] FUNDS [illegible] LIMITS OR MAJOR [illegible] - FOR ESTABLISHMENT OF PRELIMINARY BUDGETS	- FOR APPROVAL IN PRINCIPLE TO OBTAIN AUTHORIZATION FOR FURTHER EXPENDITURE OF FUNDS - TO ESTABLISH A PRELIMINARY CAPITAL COST FORECAST FOR PROFITABILITY CALCULATIONS AND PROGRAMS BEYOND THE CURRENT YEAR - FOR PROCESS SELECTION AND [illegible]	- [illegible] ESTIMATES TO PROVIDE [illegible] - FOR MANAGEMENT DECISIONS ON FEASIBILITY PRIOR TO JUSTIFICATION OF FURTHER STUDY
REQUIRED INFORMATION					
1.0 SITE	- ALL FINAL DOCUMENTS INCLUDING SPECIFICATIONS AND DRAWINGS	- ALL SITE CONDITIONS KNOWN - PLOT PLAN ESTABLISHED	- GENERAL DESCRIPTION OF SITE AND PROPOSED LAYOUT INCLUDING STORAGE AND HANDLING, UTILITIES AND SERVICES	- SITE LOCATION [illegible]	
2.0 PROCESS FLOW SHEET	- ALL FINAL DOCUMENTS INCLUDING SPECIFICATIONS AND DRAWINGS	- FLOW SHEET FINAL	- WELL DEVELOPED FLOW SHEET WITH ALL PROCESS STEPS [illegible]	- PRELIMINARY FLOW SHEET	- CAPACITY AND [illegible] ESTABLISHED
3.0 EQUIPMENT LIST (INCLUDING SERVICE EQUIPMENT)	- ALL FINAL DOCUMENTS INCLUDING SPECIFICATIONS AND DRAWINGS	- PROPOSED FINAL LIST AND SPECIFICATIONS WITH QUOTATIONS FOR MOST MAJOR ITEMS	- PROPOSED FINAL LIST WITH BUDGET QUOTATIONS FOR SOME MAJOR ITEMS	- PRELIMINARY LIST OF MAJOR ITEMS	
4.0 BUILDINGS STRUCTURES AND CIVIL	- ALL FINAL DOCUMENTS INCLUDING SPECIFICATIONS AND DRAWINGS	- BUILDINGS SHAPE AND SIZES FIRM. PRELIMINARY LAYOUT DRAWINGS OF BUILDINGS [illegible] PLAN & ELEVATIONS, PLUS [illegible] ROADS [illegible] SIZES OF MAJOR STRUCTURAL MEMBERS AND NATURE OF SUPPORTING STEEL. GENERAL MATERIAL SPECIFICATIONS. FLOOR LOADING REQUIREMENTS. PILES, SPREAD FOOTINGS OR GRADE BEAMS. FLOOR SLABS AND FILL REQUIREMENTS. EQUIPMENT FOUNDATIONS - OUTLINE OF SHAPE AND SIZES. GENERAL [illegible] FOR [illegible]	- [illegible] LAYOUT [illegible] SHOWING SIZES AND OUTLINE SPECIFICATION. - PRELIMINARY SOIL BEARING DATA AND INFORMATION ON LOADINGS. - UNUSUAL CONDITIONS TO BE NOTED.	- FLOOR AREA AND TYPE OF CONSTRUCTION	
5.0 UTILITY [illegible] AND WATER	- ALL FINAL DOCUMENTS INCLUDING SPECIFICATIONS AND DRAWINGS	- ALL QUANTITIES ESTABLISHED AND [illegible] PRELIMINARY LAYOUTS [illegible] [illegible] BUDGET QUOTES ON [illegible] MAJOR ITEMS.	- ALL UTILITIES ESTABLISHED AND QUANTITIES WITH DEFINITION OF SOURCE AND DISTRIBUTION	- ROUGH QUANTITIES OF STEAM, AIR AND WATER	
ELECTRICAL	- ALL FINAL DOCUMENTS INCLUDING SPECIFICATIONS AND DRAWINGS	- GENERAL DESCRIPTION OF SCOPE OF WORK. PRELIMINARY POWER LIST. EQUIPMENT LOCATION OF [illegible]. CAPACITY OF MAJOR COMPONENTS AND DISTRIBUTION SYSTEM SUCH AS [illegible] IN DRAWINGS. EMERGENCY POWER REQUIREMENTS. BUDGET QUOTES ON MAJOR ITEMS.	- GENERAL DESCRIPTION OF SCOPE OF WORK INCLUDING SIZE AND CAPACITY OF MAJOR ITEMS AND DISTRIBUTION SYSTEM - PRELIMINARY MOTOR LIST	- AN OUTLINE OF GENERAL REQUIREMENTS NOTING ANY SPECIFIC REQUIREMENTS	
6.0 PIPING	- ALL FINAL DOCUMENTS INCLUDING SPECIFICATIONS AND DRAWINGS	- WELL DEVELOPED P & I DRAWINGS AND PIPING SPECIFICATIONS. DETAILED VALVE LIST. [illegible] [illegible] AS [illegible] [illegible] PIPE [illegible]	- PRELIMINARY P & I DRAWINGS AND PIPING SPECIFICATIONS	- NATURE OF PIPING COMPLEXITY AND MATERIALS KNOWN	
7.0 INSULATION	- ALL FINAL DOCUMENTS INCLUDING SPECIFICATIONS AND DRAWINGS	- PRELIMINARY LISTS OF EQUIPMENT AND PIPING TO BE INSULATED. INSULATION SPECIFICATIONS.	- PRELIMINARY LISTS OF EQUIPMENT AND PIPING TO BE INSULATED - INSULATION SPECIFICATIONS.	- INDICATION OF EXTENT OF INSULATION ON PIPING AND EQUIPMENT	
8.0 INSTRUMENTATION	- ALL FINAL DOCUMENTS INCLUDING SPECIFICATIONS AND DRAWINGS	- WELL DEVELOPED P & I DIAGRAM INSTRUMENT LIST, NATURE OF PANEL, PRELIMINARY LIST OF MOTOR CONTROLS AND RELAYS ON PANEL. BUDGET QUOTES ON MAJOR ITEMS. PRELIMINARY SPECIFICATION AND BUDGET QUOTE ON COMPUTER IF REQUIRED. EMERGENCY POWER REQUIREMENTS	- PRELIMINARY INSTRUMENT LIST AND P & I DIAGRAM DECISION ON COMPUTERIZED CONTROL	- INDICATION OF AMOUNT OF CONTROL REQUIRED AND COMPLEXITY	
9.0 SCHEDULE	- FIRM PLAN FROM START TO FINISH WITH REALISTIC MILESTONE EVENTS	- FIRM PLAN FROM START TO FINISH WITH REALISTIC MILESTONE EVENTS.	- PRELIMINARY PLAN WITH DATES FOR [illegible] DESIGN, START CONSTRUCTION AND PLANT START-UP.	- REQUIRED COMPLETION DATE	- REQUIRED COMPLETION DATE
10.0 CONSTRUCTION	- [illegible] CONSTRUCTION PLAN IN REASONABLE DETAIL WITH INPUT FROM CONSTRUCTION SECTION	- PRELIMINARY CONSTRUCTION SCHEDULE, STRATEGY AND MODE OF [illegible] CONSTRUCTION.	- PRELIMINARY CONSTRUCTION PLAN	- [illegible] CONSTRUCTION PROBLEMS IDENTIFIED (E.G. RENOVATION DURING OPERATIONS, INTERRUPTIONS DURING [illegible], ETC.)	
11.0 ENGINEERING		- ENGINEERING STRATEGY [illegible] ESTIMATE BY DISCIPLINE: ENGINEERING DRAUGHTING [illegible]			

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Ball Park Estimates (Type "E")

Based on little information, has poor accuracy but serves the purpose of the executive who may only want to have some indication of how many million dollars are involved.

"Ball Park" estimates are generally based of figures of $/lb. or $/ton of capacity, or frequently graphs are used which plot the capital cost versus capacity. Such graphs take into account the variation in unit cost with size and hence are better than simple $/ton type of estimates.

Study Estimates (Type "D")

Made by using factor techniques or a combination of factor and large component techniques. Used for early feasibility studies and to justify funds for further study. It requires enough information to provide the general scope of the project, and depending on how much of this information is known, its accuracy may range from ± 25% to ± 40% and it is generally done in less than a month.

Preliminary Estimates (Type "C")

An elaboration of type "D" using the same techniques along with refinement due to the addition of some unit costs and some quotes. Scope of work is better defined and accuracy ranges between ± 10% to ± 25%.

Definitive Estimates (Type "B")(Appropriation of Funds)

A definitive estimate may take months to make. It involves some factor techniques but relies greatly on large components and unit cost techniques and many quotes. The scope of the project is required in considerable detail, engineering design will need to be fairly well advanced and the accuracy will improve to a range of ± 5% to ± 10%. This type of estimate is normally used for the appropriation of funds and is expected to have an accuracy of 10%. A well defined good quality estimate in this category is used during the subsequent project life for cost control purposes.

Bid Estimates (Type "A")

Used by contractors in making a competitive bid. Requires considerable time to produce more or less complete drawings and specifications. Also requires another 2 to 6 weeks, depending on size of project, for the contractors to make their bids. Theoretically the accuracy of this type of estimate should be within 5% but because of special factors such as contractors' profits, contractors' overheads and the competitive climate, bid estimates may spread as much as 20% and sometimes more. Regardless of the spread a successful contractor is probably estimating his 'direct' costs within 5%.

TECHNIQUES

Reference has been made to 3 estimating techniques:

- Factor estimating
- Large component unit costs
- Detailed unit costs

Factor estimating - arrives at a total cost by assessing the cost of unknown items as a factor or percentage of specific known costs. Usually the known cost is the process equipment.

This technique is used mainly in making 'Study and Preliminary' estimates but may be used at times for the appropriation of funds.

Large Component Unit Costs are based on the theory that many specific components of a plant follow a definite cost pattern in relation to size or capacity. Hence there are large components such as buildings based on $/sq. ft. of floor or per cu. ft., refrigeration plants based on $/ton, compressor installations on $/CFM etc.

Detailed unit costs - imply that a plant is broken down into many minute construction items and each one is individually assessed as to unit cost and quantity. Hence there is concrete in $/cu. yd., form lumber in cents/sq. ft. reinforcing steel in cents/lb., piping in $/lin. ft. and $/fitting, etc.

COST INDEXES

The great inflationary spiral which has hit economies all over the world has made estimating more challenging than ever and has added at least one more dimension to all previous considerations. Because of inflation, cost feedback goes out of date quickly and must be continuously up-dated.

Cost indexes are factors which reflect the effect of inflation. They are used to update the past to the present. Since most estimates are based on data from the past, the inflationary effect through time must be considered and cost indexes are being widely used for this purpose.

There are many cost indexes and many applications. Further, since all of them are classified as approximations, for maximum reliability it is important to understand exactly what they do and be able to select the one which is most suitable for the application.

Definition

A cost index may be defined as a series of factors that represent the change in cost with time. (See Figure-1).

Most cost indexes are based on the weighted cost of selected items which constitute a major part of the subject being covered with the belief that the total cost will follow more or less the same general trend as the selected components. In other words they are based on a principle that says, "as goes a selected sampling, so goes the entire whole". By their very nature then, cost indexes only approximate the truth and in no way should they be taken as precise. This fact should never be forgotten. A great many indexes are published to cover many subjects. A general index covers a broad field and has limited accuracy for a specific topic within the broad field. A special index directed at a narrow field of subjects becomes more reliable but is limited in its application.

Applications

What are the applications of cost indexes in the Engineering function?

1. The main application is in updating the capital cost of plants, or updating cost data.

2. To a lesser degree they are used in contract price adjustment.

3. Updating the fixed asset ledger.

4. Establishing the replacement value of plant and equipment for insurance purposes.

5. Placing the capital cost of 2 or more plants on an equal time basis so that proper comparisons may be made.

Generally speaking, if an index or indexes can satisfy all the requirements for item 1, they will also be adequate for all the other items.

Following is a sample list of questions that might arise in a capital cost estimate:

1. A certain compressor, vessel, or other piece of equipment was purchased 7 years ago for a certain price. What will it cost today?

2. The entire electrical installation for a specific project cost "$X" when the plant was built. What will it cost now on a similar project?

3. A large warehouse and process building cost $X in Houston, Texas in 1966. What will it cost today in Chicago?

4. A complete project erected in 1965 to manufacture "Y" lbs/yr. of ABC product cost $X. What will it cost today to double the size of the plant.

5. In item 4, $Z was spent on construction labour for the original project. What will the labour cost be for the expansion project? Does this estimate allow for the change in labour productivity that has taken place?

A little thought will indicate that the results are not likely to have much reliability if the same index is used for all examples. At the same time it is not practical to have an endless supply of cost indexes to satisfy each and every demand.

Thus in selecting an index, one must be careful to choose one which has a combination of material and/or labour which most nearly represents the real life situation.

Such an index may be very good over a short period of time, but should a long period of time be involved, 2 additional factors may prevent the index from providing a good answer. One is the effect of labour productivity which is not incorporated into many indexes. The other is the effect on costs due to technological improvements which are rarely ever built into an index. A selling price type of index (i.e. one based on the actual selling price of representative items) compensates to some extent for both of these factors, while an input type of index (i.e. one based on the cost of primary materials) does not compensate for them unless a specific adjustment is made.

I do not know of any index which makes a specific allowance for technological improvements. Because the effect of technological improvements on costs is so erratic over the years, it is necessary to consider them as a separate entity.

Indexes in the Process Industries

At this stage we can discuss various indexes, all of which have found use in the process industries.

Our remarks will be limited to U.S. indexes, which are used extensively in the process industries, mainly because of our familiarity with them. However the main purpose of this section is to illustrate differences in cost indexes and to highlight those issues which should be considered in selecting the best index for a particular application. Thus the same reasoning can be applied in considering indexes in any country.

Table 1 is a listing of several U.S. indexes and a compilation of their pertinent features:

TABLE 1

	(3) Boeckh Index	ENR Const'n. Index	NELSON (1) Refinery Const'n. Index	CHEMICAL ENGINEERING	MARSHALL and (2) STEVENS
Publisher	Gen. Appraisal Company	Eng. News Record McGraw Hill	Oil and Gas Journal	Chemical Eng. McGraw Hill	Marshall and Swift
Index for complete chemical plants	NO	NO	YES	YES	YES excl. bldgs.
Index for General process equipment	NO	NO	YES	YES	NO
Specific classes of equipment	NO	NO	YES	YES	NO
Separate index for buildings	YES	YES	NO	YES	YES
Index for large civil projects high in unskilled labour	NO	YES	NO	NO	NO
Correction for labour productivity	YES	NO	(1) NO	[illegible]	YES Details not divulged
Correction for technical improvement	NO	NO	(1) NO	NO	NO

(1) Oil and Gas Journal has published various other indexes and articles on the subject of productivity and technological improvements which require considerable study in order to apply them with any confidence.
(2) Name Marshall and Stevens recently changed to Marshall and Swift. M & S also includes building indexes for 45 Canadian cities.
(3) Boeckh is strictly a building index and includes separate indexes for 20 Canadian cities

The Boechk Index is strictly a building cost index and for this application we have found it to be very good. The overall system includes indexes for 10 different types of buildings and provides them for about 200 cities in North America. These indexes not only indicate the change in cost with time for all the cities listed, but are also claimed to show the relative cost between any of the cities at any given time. Of specific interest to the Chemical Process Industries is their index for brick and steel factory buildings. (See Figure-2).

A further scrutiny of Table 1 quickly raises the question: What is the ENR Index used for?

Our reason for raising this question is because we believe that the ENR Construction Index is the most misunderstood and most misused index in the process industries. This index, developed and published by the Engineering News Record, seems to be used at times for up-dating the cost of plants, updating the cost of equipment and for various other applications when costs are involved.

The entire index consists of 4 items which are costed out at current rates. Thus the following illustrates the entire index when it was equal to 1800:

6 bbls. of cement @ approx. $5.00	=	30.00
1088 fbm of lumber @ approx. $185.00	=	200.00
2500 lbs. of steel @ approx. 6¢	=	150.00
200 manhours of common labour @ approx $7.10	=	1,420.00
Index = Total		1,800.00

NOTE: The above costs are approximate throughout, merely to indicate the development of the index. There is no labour productivity correction. Note also that the labour component at this time was 79% of the index.

It becomes clear that the ENR Index is heavily dominated by construction labour costs in a far greater proportion than the normal percentage of labour on chemical plant projects. Obviously it has no valid application in reflecting the costs of chemical plant projects.

In essence the ENR Index was designed to assess the change in the cost of civil engineering works of the type that uses large quantities of unskilled labour. It was never intended for the process industries. (Nevertheless, because it is one of the oldest and most well known indexes, it has been used incorrectly for many applications).

For process plants the other 3 indexes are much more suitable. (See Figure-3).

The Nelson Refinery (inflation) Construction Index has been published by the Oil and Gas Journal since 1949 and is basically an overall plant index aimed at pertroleum refining. It has no labour productivity correction as such except for the built-in effect due to various equipment components of the index being developed from manufacturer's selling prices.

As far as the cost of run-of-the-mill chemical plants are concerned the Nelson Refinery (inflation) Index is a reasonably good guide, and is used extensively by the U.S. process industries.

Nelson also publishes a variety of equipment cost indexes, many being selling price indexes. Of particular interest is the Nelson "Miscellaneous Equipment" Index which is a good index reflecting the overall average price change of process equipment.

The Marshall and Swift Index (Figure-4) consists of two main indexes, one for buildings and the other for equipment (which in this application means the cost of a complete plant excluding buildings). The main index is a composite of many industries and separate indexes are provided for each industry entering into the composite. Two of these are 'chemical plants' and 'petrochemical plants'. These indexes provide a fairly good reflection of the change in plant costs. It may have a slight downward bias.

The chemical engineering plant cost index is an attempt to tailor make an index specifically for chemical plant construction. It is a rather sophisticated index composed of many sub indexes for the various components of a chemical plant, all of which utimately contribute to the overall plant index.

It has a built-in labour productivity adjustment which has been established at 2-1/2% per year. Unfortunately, it appears that the value of 2-1/2% is over-correcting so that the index is biased downwards.

It also appears that the material/labour weightings used for the fabricated equipment and process machinery components may not be in the right proportion to allow for overhead and profit in a fabricating shop. This again could create a slight downward bias when labour rates are rising faster than material costs.

Nevertheless, the Chemical Engineering Index is an excellent one inasmuch at it has been thoroughly researched to reflect the composition of a chemical plant, and is well documented and easy to understand. With the multiplicity of sub-indexes and their weightings, which are published, it has great flexibility and enables the user to modify it to suit his own purposes.

If it were not for the certain lack of confidence over the productivity correction this index could be ideally suited for the process industries in the U.S. In fact, with a little bit of effort, one could delete the 2-1/2% productivity correction and build in one's own.

Pitfalls

In using cost indexes one should beware of certain pitfalls:

Labour productivity changes and technological improvements have been mentioned already. Most indexes don't incorporate labour productivity changes and this fact should be recognized and considered separately. If an index does incorporate a labour productivity correction - it is well to remember that this is a very difficult area to evaluate and hence the index could be over or under corrected.

Technological breakthroughs are not normally incorporated into indexes. Again, this fact should be recognized and a separate allowance made for it if need be.

Cost indexes represent averages and trends and it is very difficult for them to incorporate the effect of competition in the market place. A selling price type of index is more likely to catch swings from a buyers' market to a seller's market or vice versa than an input type of index. However, none are likely to recognize a very competitive situation since the data flowing to the index maker is not likely to include the competitive price. Figure-5 is an extreme example of what can happen at times.

Lastly an index will not reflect special situations in a specific locality and therefore it should be adjusted to reflect local conditions.

For example:

A local union could negotiate a very large increase in wage rates in a specific locality while a construction labour index may be reflecting an overall average for a large region or an entire country.

In summary, cost indexes are tools in producing estimates. All indexes require some background knowledge before application, and for best results it is desirable to use an index tailored to one's specific needs.

Like all cost estimates cost indexes are merely "Estimates". They are not an exact science and whoever uses them needs to understand them. However, when properly selected they produce reasonably good answers with great rapidity. No other technique offers the same speed and versatility for assessing the effect to "Time" on capital costs.

CONSTRUCTION LABOUR INDEX

CANADIAN 14 CITY COMPOSITE   BASE YEAR 1961 = 100

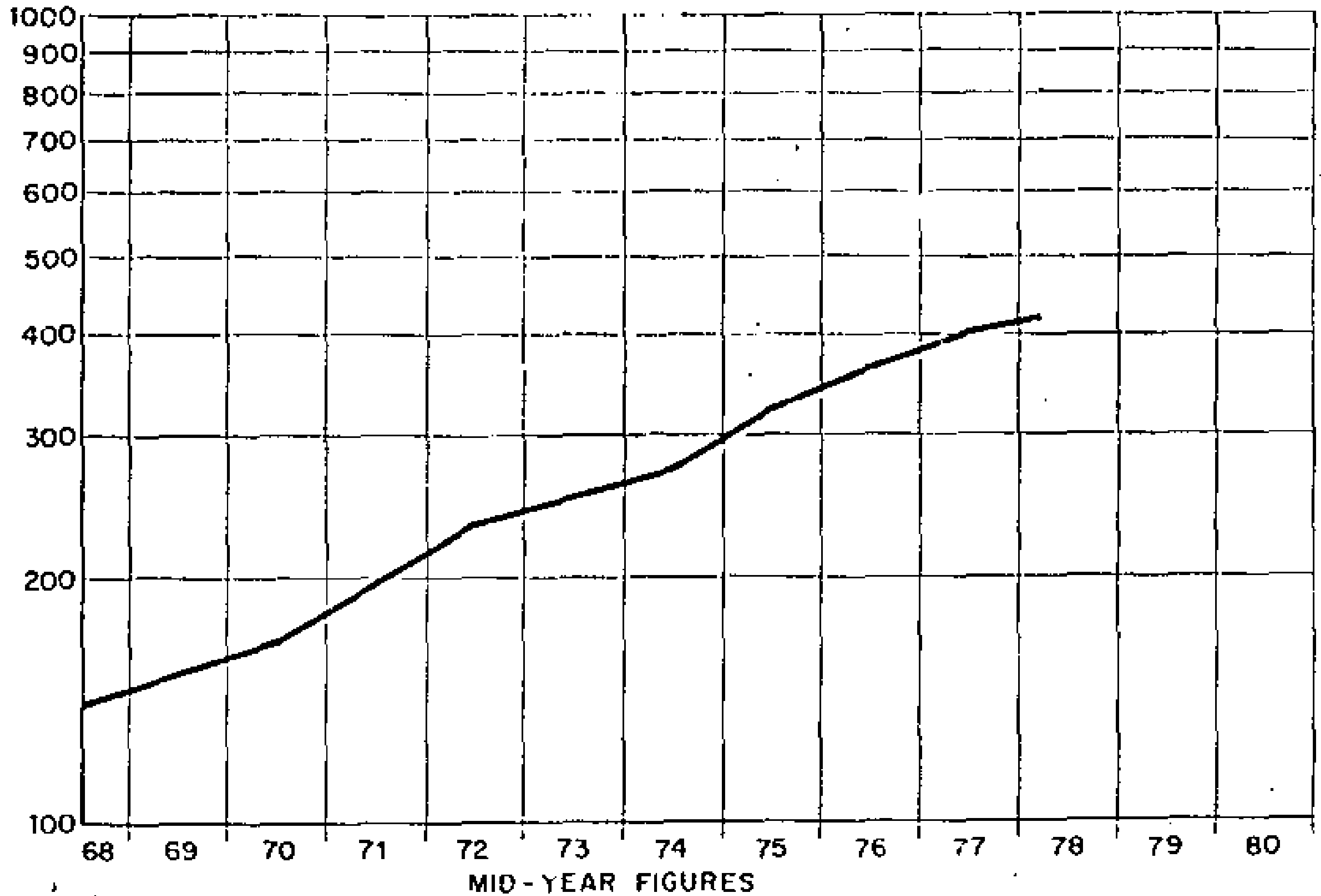


FIGURE 1

BUILDING INDEX

BOECKH - BRICK & STEEL FACTORY BUILDINGS

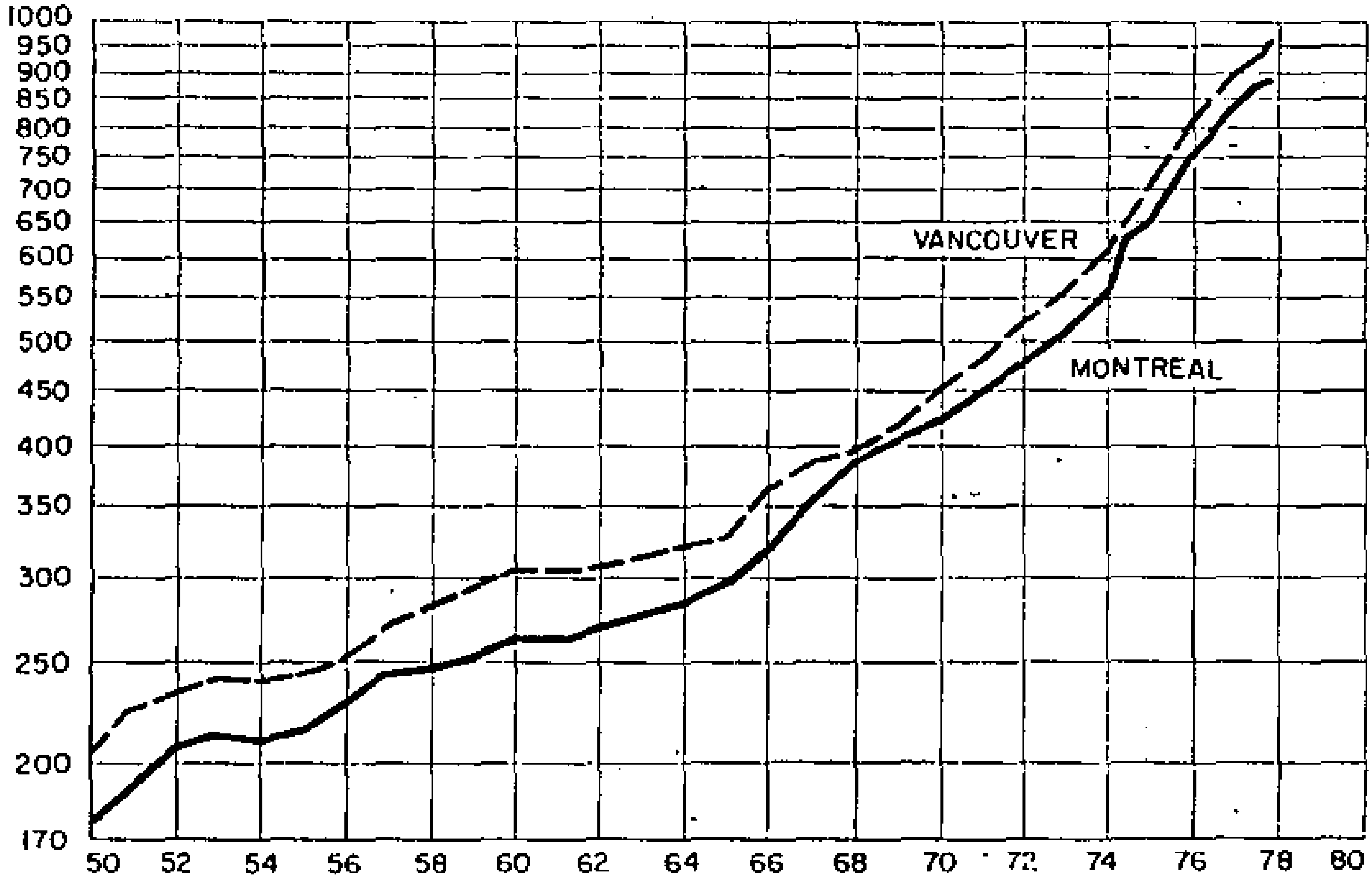


FIGURE 2

COST INDEX

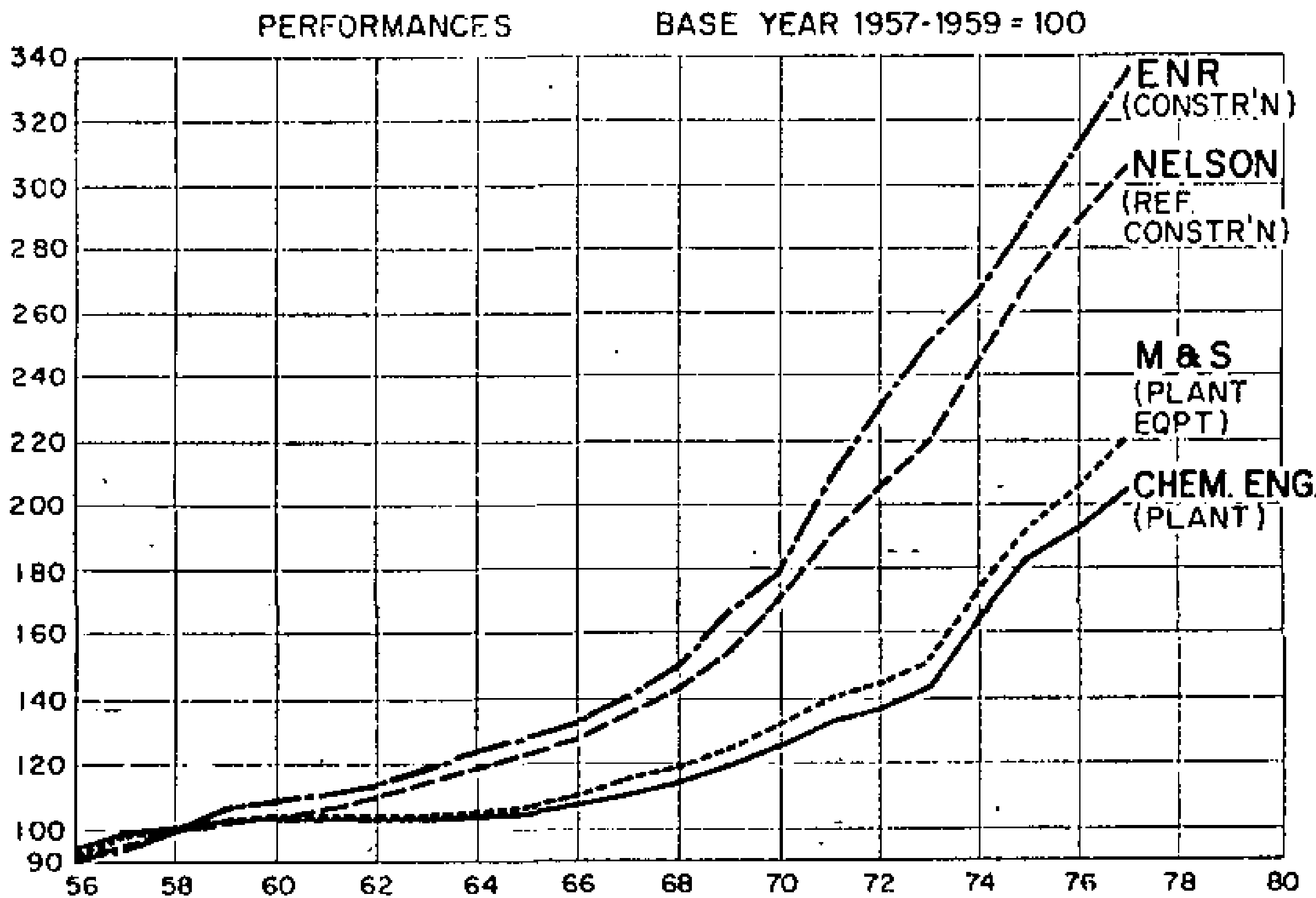


FIGURE 3

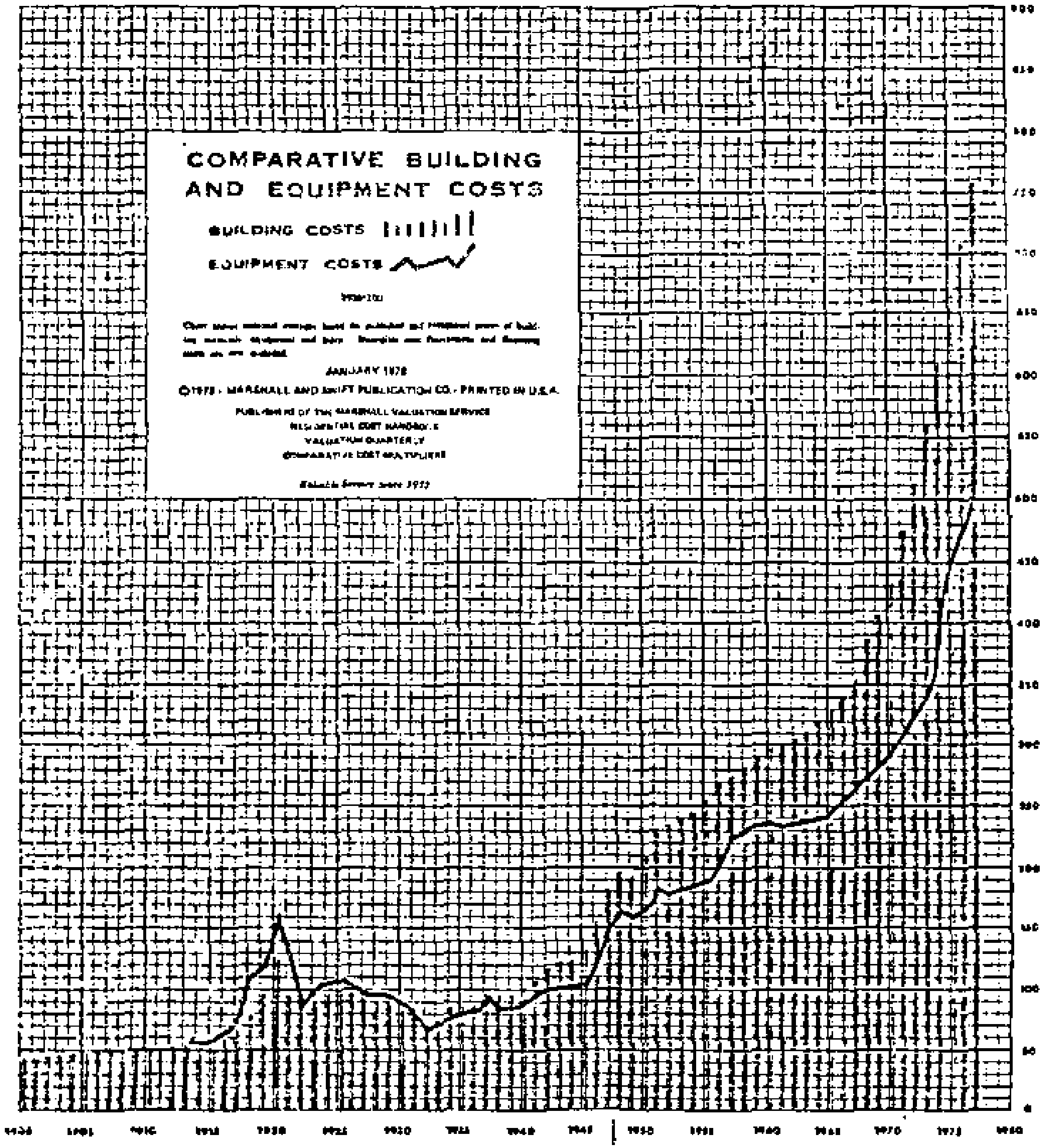
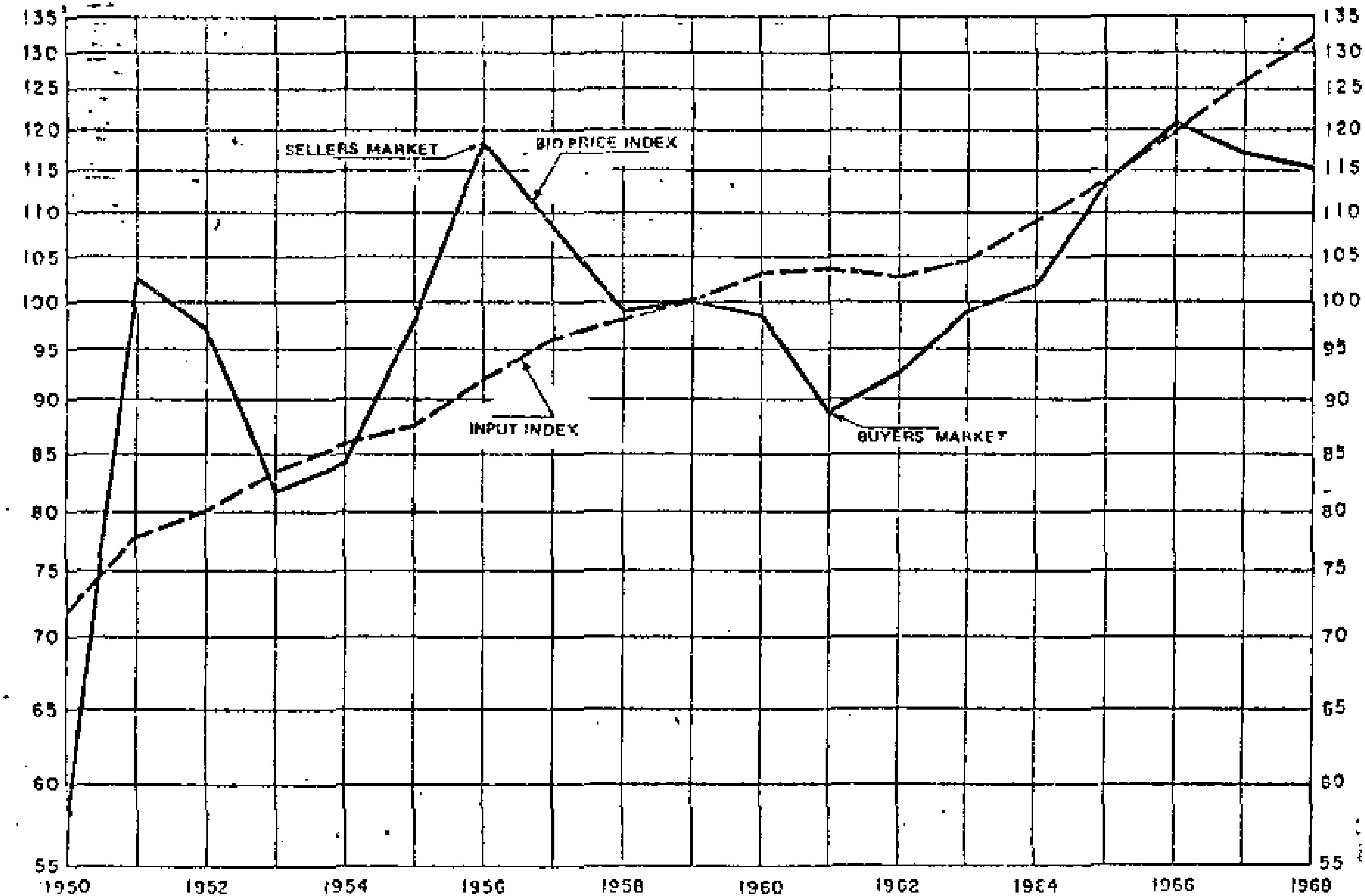

COMPARATIVE BUILDING
AND EQUIPMENT COSTS
BUILDING COSTS
EQUIPMENT COSTS

FIGURE 4

HIGHWAY CONSTRUCTION PRICE INDEXES: ESTIMATED CANADA BID PRICE INDEX COMPARED WITH A SIMULATED INPUT INDEX

1959 = 100



Source: Prices special tabulation

FIGURE 5

AREA RELATIONSHIPS

A basic requirement for successful factor estimating is an orderly, methodical and consistent method of breaking down a process plant into logical components

A first impression of a process plant may be a chaotic maze of equipment, piping, buildings, etc. No two plants appear to be the same.

Nevertheless there are certain components that are common to any and all process plants. This is demonstrated in Figure-6.

All chemical plants have a process area, storage and handling facilities for raw materials and finished product, an electrical system, steam system, air system, water system, sewers and effluent treatment, etc. and in all probability a laboratory, an office, roads, etc.

For some time now the process area has taken on a specific title with the name 'Battery Limit' while the balance of the plant has been named the 'Off Sites' or the 'Auxiliaries'.

More recently the off-sites have been broken down into 3 components, namely the Storage and Handling Facilities, the Utilities and the Services. Thus we have what might be called the '4 area concept' of capital costs. This is illustrated in Figure-7.

PLANT COMPONENTS

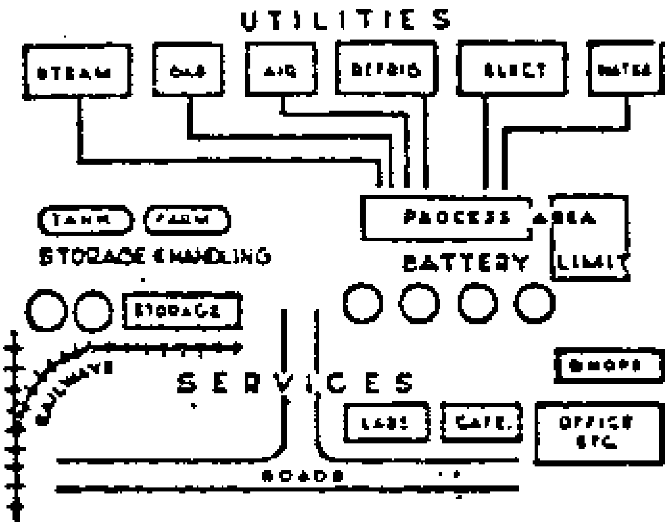


FIGURE 6

4 AREA CONCEPT

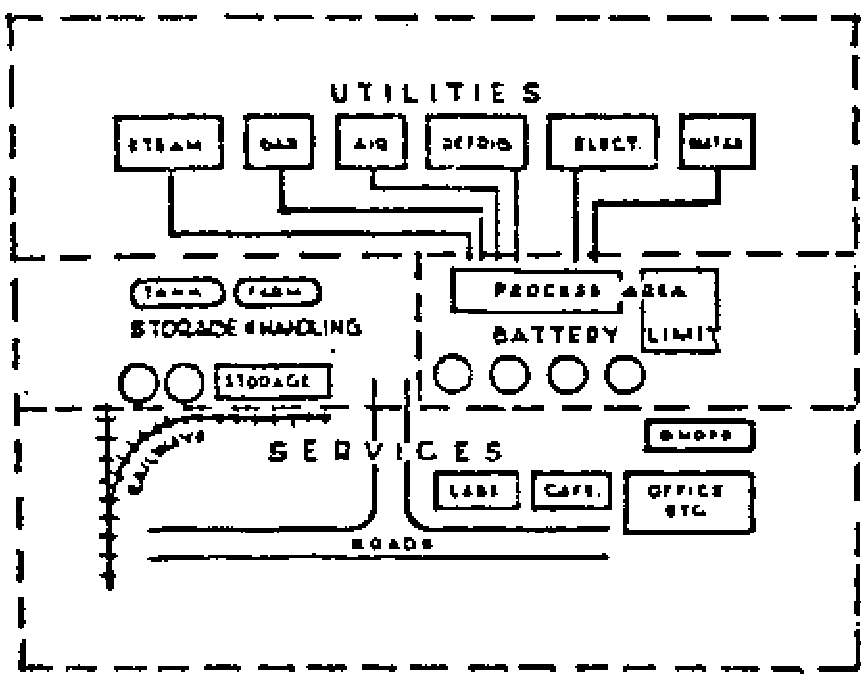


FIGURE 7

These areas are defined as follows:

Battery Limit (Referred to as B/L)

This area represents all the process operations. It can be defined as the boundaries enclosing a plant or process unit so as to include those facilities directly involved in the conversion of raw material to finished product. It applies to all buildings, equipment, piping, instruments, etc., which specifically involve the process or manufacturing operation and includes that portion of the compressed air, electrical, refrigeration, steam, water, plumbing, fire protection, process waste disposal, and air conditioning systems, etc. that are inside the process area, but does not include the outside lines, etc. which convey such utilities or services to or from the 'Battery Limit' buildings. Where practical the wall of a 'Battery Limit' building forms a suitable boundary, but where outside process facilities exist the boundary should include these facilities.

Storage and Handling (Referred to as S & H)

This Area consists of all warehouses, storage tanks, loading, unloading and handling facilities, etc. required for raw materials and finished products associated directly with the product being made. It includes the necessary pipelines from the point of storage to the walls or boundaries of the battery limit. It does not include storage and handling of raw materials for utilities, such as coal, fuel oil, etc., which are included with the cost of the utility. Similarly it does not include 'in process' storage, which is normally charged to the battery limit, unless it is a large intermediate storage station.

Utilities (Referred to as U)

Utilities refer in general to the production of energy and its transportation to and from the battery limit as well as to other buildings on the site. They consist of:

Compressed air plant if located outside the battery limit and outside air lines.

Electric power supply consisting of substation, outside lines, and yard and fence lighting.

Refrigeration system if located outside the battery limit consisting of refrigeration machines, and outside refrigerant lines.

Steam plant and outside steam lines.

Water supply, pumphouses, main cooling tower, and outside water lines.

Drains and sewers including normal sewerage treatment systems, Note: process waste treatment systems are part of battery limit up to point where the discharge is safe to enter a main effluent sewer.

Storage and handling facilities for raw materials used in the production of utilities.

Services (Referred to as S)

This area represents all the remaining items of investment that are necessary to round out the plant into a fully operating unit. They include items such as offices, laboratories, shops, lunchrooms, change houses, gatehouses, roads, ditches, railways, fences, communication system, service equipment, track scales, etc.

It is these last three areas that are referred to as the 'off sites' or 'Auxiliaries' or as the 'outside battery limits'.

What is the value of having this type of breakdown?

Table-2 will start to indicate the potential of attacking the costs on this basis.

The cost of some 13 chemical plants were broken down into 4 areas and each one was then determined as a percent of the total cost. With the exception of the storage and handling facilities the correlation between each major area is remarkable.

COST BREAKDOWN OF 4 AREAS

PLANT	B/L	S & H	U	S
A	47	33	11	9
B-1	38	35	13	14
B-2	56	23	9	12
C	56	7	24	13
D	65*	-	22	13
E	65*	-	22	13
F	64*	-	23	13
G	65	10	11	14
H	52	16	16	16
I	54	6	26	14
J-1	70	6	18	6
J-2	63	5	23	9
K	71	2	13	14

* INCLUDES STORAGE AND HANDLING

TABLE-2

Area Factors

This knowledge provides another basis for Factor Estimating, i.e. if the cost of the battery limit is known, other areas can be determined as a factor of the battery limit cost.

Table-3 provides the first broad set of cost data which can be used in preliminary types of estimates. If the cost of the battery limit is known, a reasonably close approximation of the plant auxiliaries can be determined by applying the percentages in this table with good judgement.

In this table it will be noted that the Storage & Handling and the Utilities are factored as a percent of the Battery Limit Cost while Services are factored as a percent of (B/L + S & H + U).

Services tend to be a function of the 'Storage and Handling' facilities and the 'Utilities', as well as the 'Battery Limit': hence a better correlation is obtained when the Services are expressed as a percentatge of the (B/L + S & H + U).

COST OF PROCESS PLANT AUXILIARIES
AS A PERCENT OF B/L COST

			GRASS ROOTS PLANT	B/L ADDITION ON EXISTING SITE
			% OF B/L COST	
STORAGE & HANDLING	LOW -	Raw Material by pipeline. Little warehouse space.	2	0
	AVG -	Average raw material Storage & Finish product Warehousing	15 - 25	2 - 6
	HIGH -	Tank farm for R.M. Substantial warehousing for finished product	70	20
UTILITIES	LOW -	Steam, water & power, more or less available for purchase with little investment required.	10	3
	AVG -	Average Situations	20 - 30	6 - 14
	HIGH -	Investment required in Boiler plant, pump house & Sub-stations, etc.	50	30
			% OF [B/L + S&H + U]	
SERVICES	LOW -	Minimum investment required for offices, personnel facilities laboratories, machine shop etc.	5	0
	AVG -	Average conditions	10 - 16	2 - 6
	HIGH -	Substantial provisions	20	15

TABLE-3

COST PATTERNS AND SIZE FACTORS

The 4 area concept can lead to some interesting cost relationships. For example if we study the cost pattern of the 4 different areas we find that each one has a different cost versus capacity curve. Thus Figure-8 is a typical set of cost graphs for 4 different areas of a process plant plotted on log/log paper.

4 AREA CONCEPT

ILLUSTRATING DIFFERENT COST PATTERNS

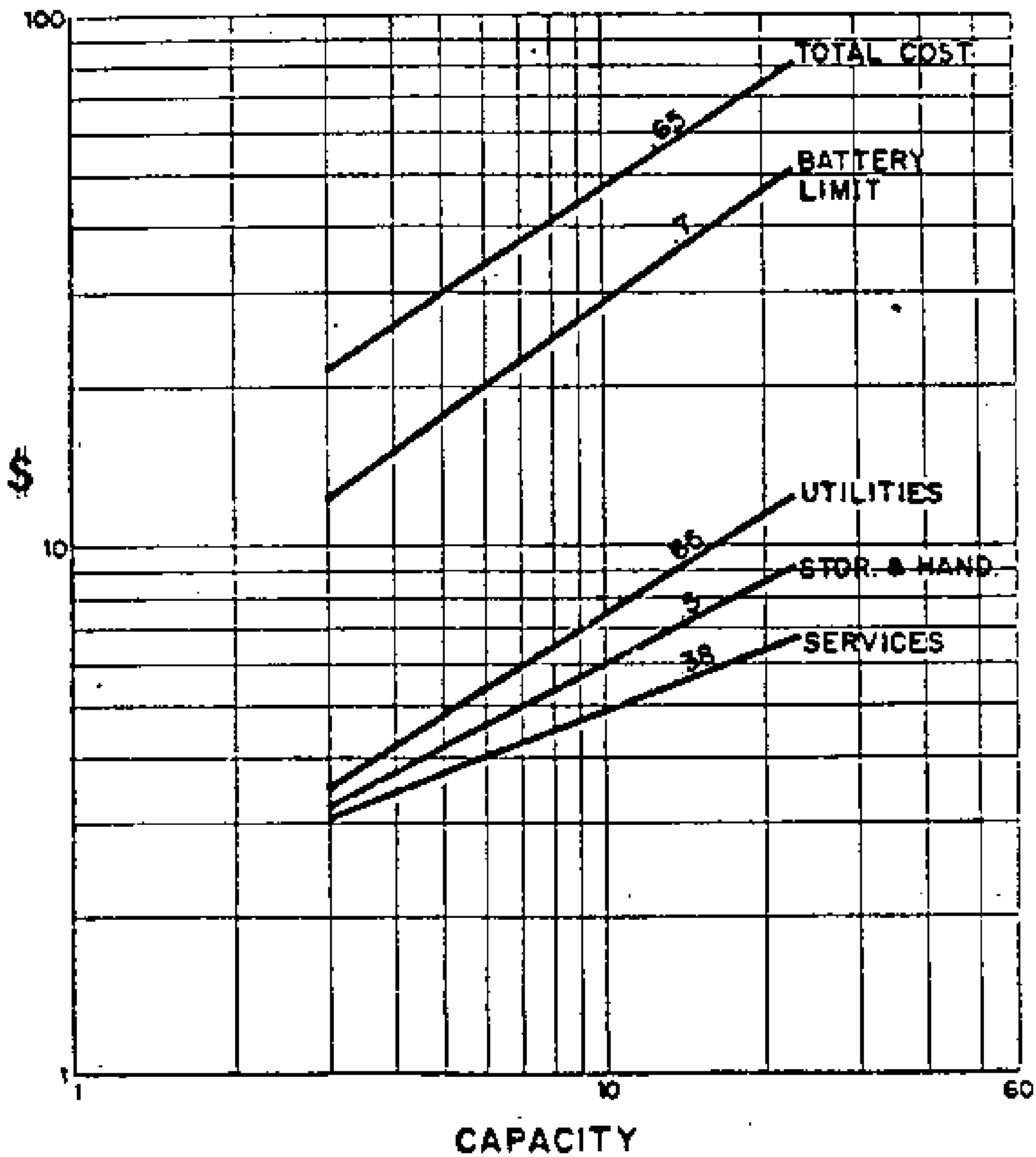


FIGURE 8

S E S S I O N

O N

C O S T   E S T I M A T I N G

C. A. MILLER

FACTOR ESTIMATING SEMINAR

Group 1 Problems

Based on US locations & costs

1. A 500 metric ton/day medium sized battery limit chemical plant consisting of reactors, fractionating towers, heat exchangers, pumps, tanks, etc. cost $ "A" in the U.S.A. in 1960?

   What will it cost today in 1978 dollars?

2. Referring to question No. 1 what will be the cost of a very large plant with a capacity of 3,000 metric tons/day in 1978 dollars?

3. Assuming that you have very little additional information except that the plant would be erected on a site adjacent to the Company which supplied the raw material and that the finished product was shipped out by tank car and only required one week of storage, what would be the approximate cost of a complete grass roots plant at 3,000 tons/day? Be prepared to explain how you arrived at it.

4. If the B/L plant were built on an existing site which could provide a lot of existing services but had no excess capacity available in electricity or water what would be the expected cost?

5. Given the total direct cost of an average type chemical plant as $10 million. What would you expect the total cost of the entire project to be?

6. If your boss stated that the XY Company had just given him a budget price of $10 million to design and build the battery limit for an average type of chemical plant and that he was going into a meeting in 10 minutes and wanted to report the possible cost of a complete grass roots plant - what would your answer be? Show how you arrived at your answer.

7. If your boss also asked you to determine the total number of direct construction manhours required to build the plant, and bring the answer to his meeting as soon as you got it, how would you go about it? Assume composite base wage rate in the USA to be $10. per hour.

8. Referring to the attached graph, the cost of the cellroom of a mercury cell chlorine plant consisting of 50 cells is "X" dollars. Draw a cost graph to reflect the expected cost of chlorine plant cellrooms ranging in capacity from a small plant of 50 cells to 1,000 cells.

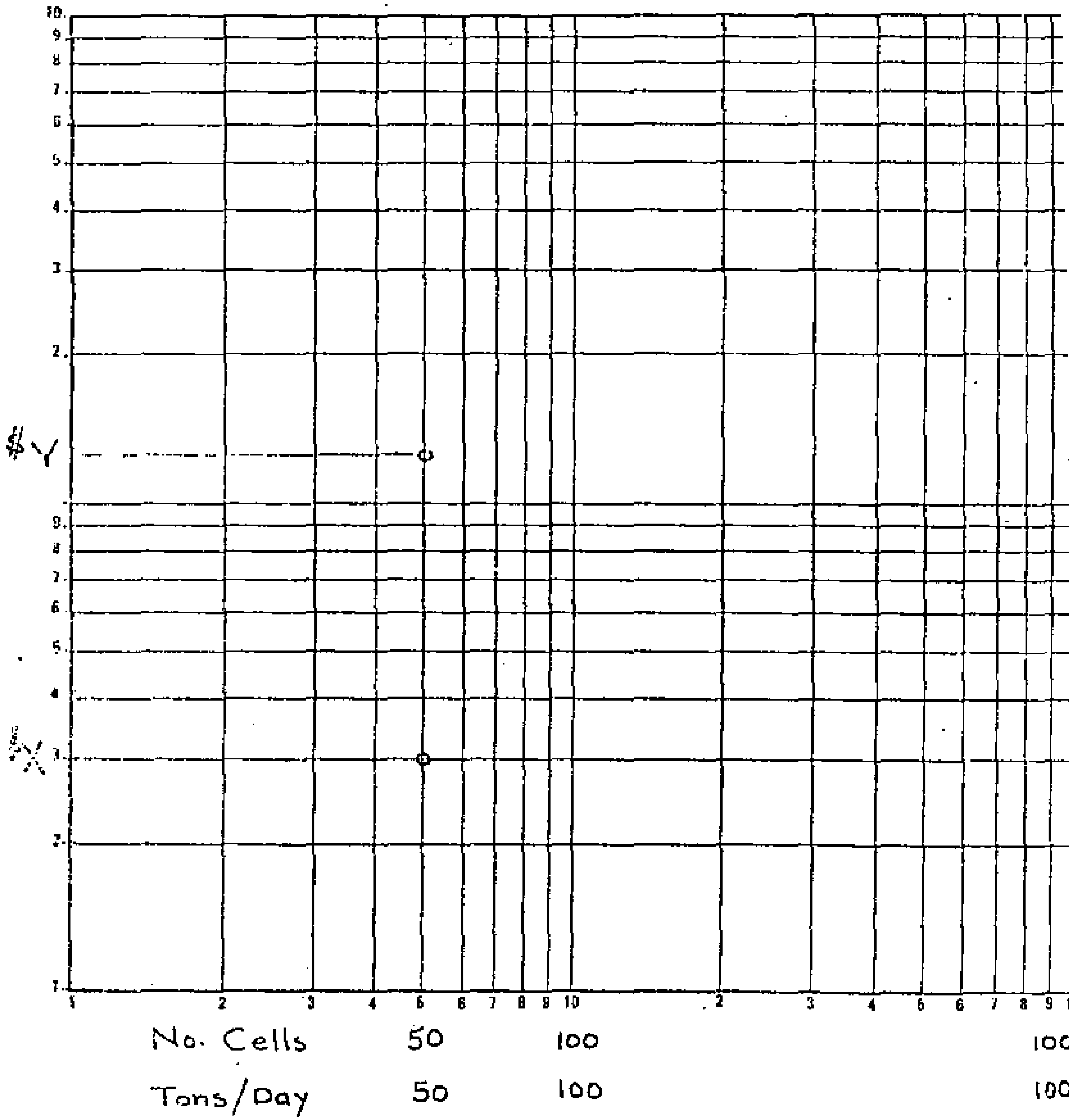
   Plot directly above the cellroom cost curve, the shape of the expected cost curve for grass roots chlorine plants ranging in capacity from 50 cells to 1,000 cells when the cost of the 50 cells grass roots plant is "Y" dollars.

   Be prepared to explain why you think your graph is correct?

9. Using the same graph as in question No. 8 the cost of the B/L of a 50 ton/day chemical plant consisting essentially of centrifugal compressors, reactors, fractionating columns,heat exchangers and mixing tanks is "X" dollars. Draw a cost graph to reflect the expected battery limit cost for plants ranging in capacity from a small plant of 50 tons/day to 1,000 tons/day.

   (As in Question No. 8) Plot directly above the battery limit cost curve, the shape of the expected cost for grass roots chemical plants when the cost of the 50 ton/day grass roots plant is "Y" dollars.

Problems 8 & 9



GROUP 2

FACTOR ESTIMATING PROBLEM

1. Develop a factor estimate for the cost of a 1200 metric ton/day metallurgical sulphuric acid plant in 1978 dollars to be erected on an existing site.

The following information is provided:

Battery Limit

Flow sheet attached.

Roaster gas from a smelter is supplied to the plant in a large diameter mild steel duct approximately 2 meters in diameter and is fed into a stainless steel scrubbing section. The solid impurities are then removed in lead lined electrolytic precipitators.

The resulting wet gas is passed through S. S. piping to brick lined drying towers and the dried gas is then passed through a system of heat exchangers to a converter where the SO_2 gases are converted to SO_3 gas.

The SO_3 gases in turn pass through the heat exchange system and are absorbed to H_2SO_4 in a brick lined absorbing tower.

The resulting product is passed through a stripping tower which yields high strength H_2SO_4.

The plant operates at atmospheric pressure.

All vessels are regarded as relatively large, the converter being approximately 10 meters in diameter.

The acid plant will be erected on an existing sulphuric acid plant site and where possible will take advantage of any existing facilities that may be available. The site is somewhat congested and practically all foundation work requires rock excavation.

The process equipment consists of a high percentage of mild steel acid brick lined vessels and a combination of large mild steel and stainless steel heat exchange equipment much of which is bought on an "erected basis".

The heat exchangers, towers and converter are insulated including the interconnecting piping.

Process control is straight forward and simple with instruments mounted on a panel in a small control room plus some local instruments. Overall the little instrumentation is simple compared to most Chemical plant operations.

Battery Limit
Continued

The main electrical load in the process area consists of one motor @ 1400 HP, about 15 motors ranging from 5 to 75 HP, the electrolytic precipitators plus miscellaneous minor motors.

The Battery Limit consists of 64 main plant items which have been estimated to cost $4,300,000 ± 5% in 1978 dollars.

The catalyst required for the converter is estimated to cost $400,000.

Storage and Handling

Provide for 10 days' storage, the necessary additional product pipelines and a new loading station. About 300 meters of 2mØ pipeline are required to feed the supply gas direct to the battery limit.

Utilities

Allow for main substation, cooling tower to handle 65 m^3/ minute, cooling tower pumphouse, waterlines, fire protection, a 2,000 kg/hour standby steam boiler including necessary steam piping, plus minor additions to effluent treatment system.

Main power supply consists of 6,900 volts, 3 phase, 50 cycle and the estimated total load 4,000 H.P.

Services

New railway spur line about 500 meters long
New road to site of B/L
Relocate 150 meters of fencing and install 300 meters of new fencing.
Provide small welfare building of approximately 30m^2 complete with lockers, washroom and lunch room.

No investment is required for offices, maintenance shops, stores facilities or laboratories.

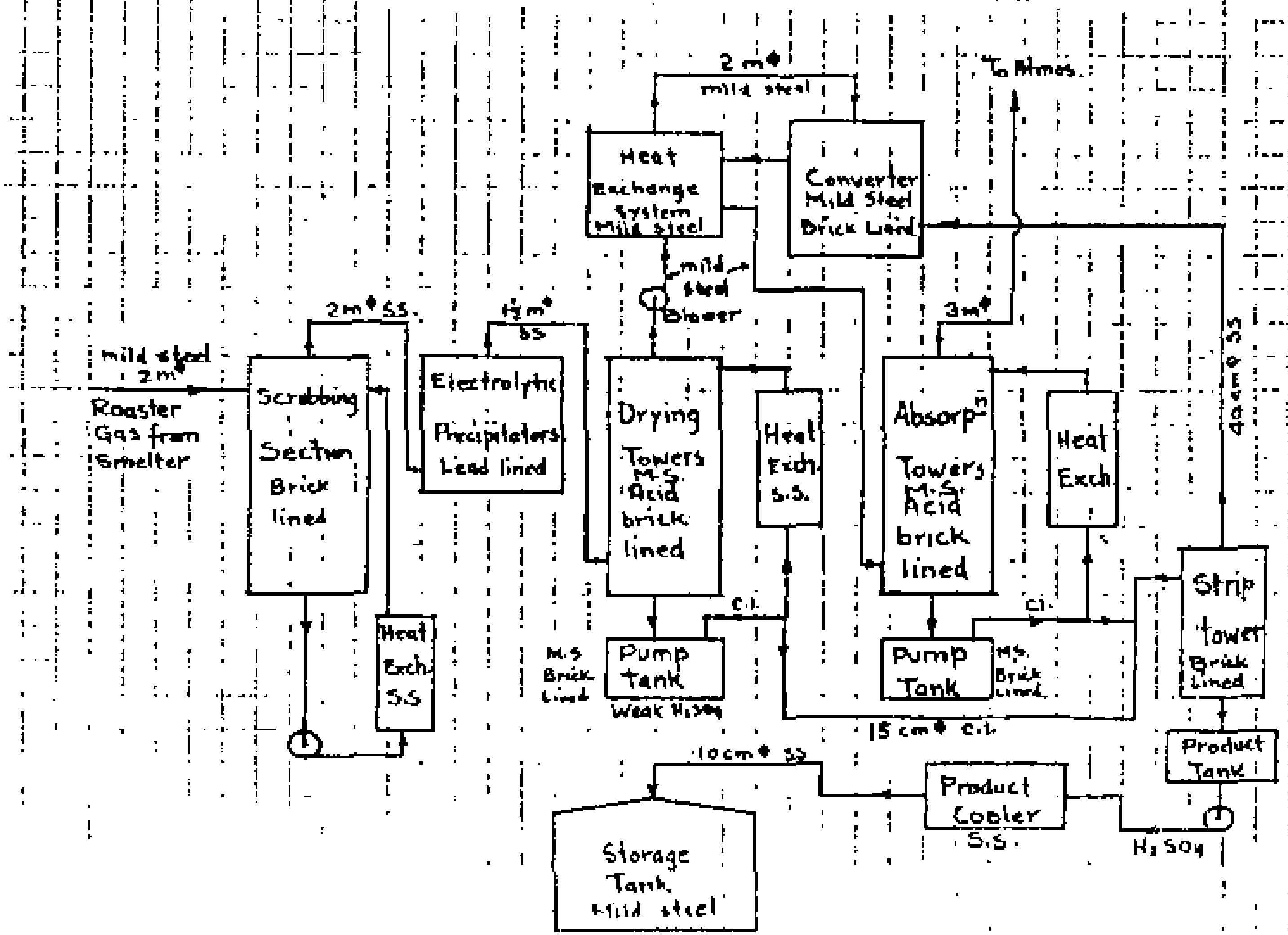
Allow $100,000 for spare equipment.

Problem 2

What would the Battery Limit cost in 1978 dollars if the capacity were 600 metric tons/day?

If the capacity were 2,500 metric tons/day?

FLOWSHEET - METALLURGICAL H_2SO_4 PLANT



BATTERY LIMIT FACTOR ESTIMATE

Page

Division & Location	Proj. or Study No. / Requested by	TITLE / CAPACITY	DATE

NO. OF M.P.I.'s	COST INDICES 1978	COST INDICES CURRENT	FACTOR OR ACCURACY	LOW	PROBABLE	HIGH

Item	Remarks	Factor or Accuracy	Low	Probable	High
AVERAGE UNIT COST OF M.P.I.'s IN 1978 DOLLARS ________					
M.P.I. (Main plant items)		Estimated			
M.U.E. (Miscellaneous unlisted equipment)					
BASIC EQUIPMENT (M.P.I. + M.U.E.) (Excluding sales taxes and catalyst)		100			
Field erection of Basic Equipment					
Equipment Foundations & Structural supports					
PIPING					
INSULATION: Equipment, Piping					
ELECTRICAL					
INSTRUMENTATION					
MISCELLANEOUS					
BUILDINGS Architectural & Structural					
BUILDING SERVICES: (% of Arch'l & Struct'l) Compressed air, Electrical lighting, Sprinklers, Plumbing, Heating, Vent. & Air Conditioning					
TOTAL SERVICES					
SUB TOTAL-FACTORED ITEMS					
ADJUSTMENTS: LOWS + HIGHS –					
TOTAL FACTORED ITEMS ADJUSTED					
DIRECT COST OF B/L (Excluding taxes and catalyst)					

ESTIMATE SUMMARY

Page

Division & Loc'n	Proj. or Study No. / Requested by	TITLE / CAPACITY	DATE

	FACTOR OR ACCURACY	LOW	PROBABLE	HIGH
DIRECT COST OF B/L				
STORAGE AND HANDLING				
UTILITIES				
SERVICES (in per cent of (B/L + S&H + U)				
TOTAL B/L + AUXILIARIES				
TAXES				
TOTAL DIRECT COST				
INDIRECT COSTS				
CONSTRUCTION FIELD, O.H. & PROFIT				
CATALYST				
ROYALTIES, LICENCES AND PATENTS				
ENGINEERING				
TOTAL INDIRECT COSTS				
TOTAL DIRECT AND INDIRECT				
CONTINGENCIES				
TOTAL COST IN ________ $ (date)				
ESCALATION FOR COMPLETION IN ________ (date)				
TOTAL CAPITAL COST				

Table 4 has been developed from these graphs and records the costs and percentages for a small plant taken at a capacity of 3 and for a large plant taken at a capacity of 20.

AREA	LOW CAPACITY Cost from Graph	% of B/L	% of B/L+S&H+U	HIGH CAPACITY Cost from Graph	% of B/L	% of B/L+S&H+U
B/L	13	100		47	100	
S & H	3.2	24.6		8.5	18	
U	3.5	26.9		12	25.5	
S	3.1	23.8	15.7	6.4	13.6	9.5

TABLE-4

It is interesting to note how these compare with the set of factors in Table 3. It is also interesting to note that the factors are different for a large plant than for a small plant - especially those of the S & H and Services.

This occurs because the various cost curves have different slopes.

The B/L curve may have a curve with a slope of 0.7, the utilities 0.6, the Storage and Handling 0.5 and the Services 0.4 Specific knowledge of these cost patterns enable you to synthesize the total cost of a complete plant at any capacity.

Six Tenths and Other Factors

Since we are discussing cost graphs and their slopes, this brings us to the much-talked-about six tenths factor. Simply stated, the factor refers to the relationship between cost and capacity and is explained by the equation:

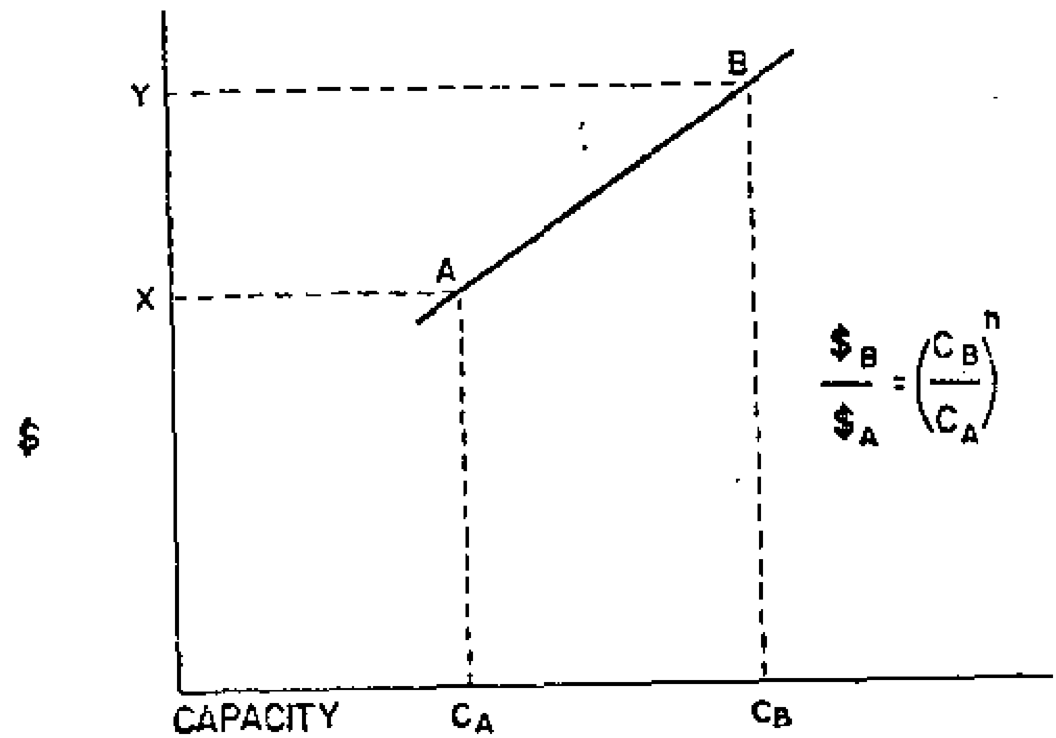
$$\frac{SB}{SA} = \left(\frac{C_B}{C_A}\right)^n$$

Where: C_A = Capacity of plant A

C_B = Capacity of plant B

The six tenths factor refers to the exponent 'n' and implies that its value is 0.6. If the cost graph is plotted on log log paper it forms a straight line and the slope of this line is the value of the exponent 'n'. See Figure 9.

Figure 9



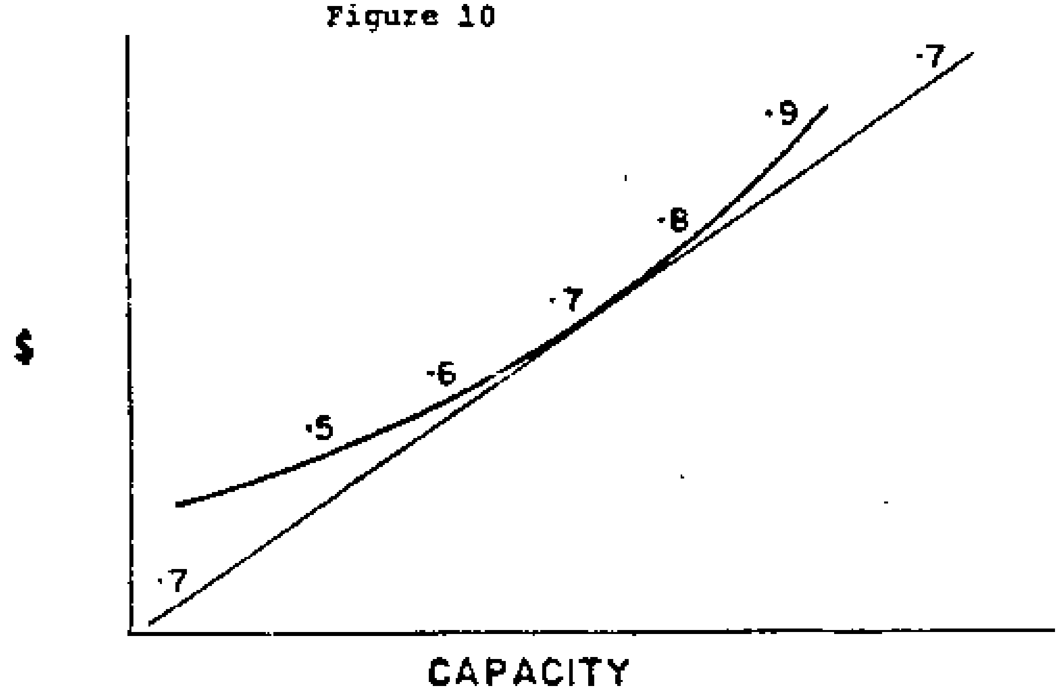
Capacity Tons/Day

C. H. Chilton was probably the first to publish comprehensive information and data on the six tenths factor. He provided data on some 35 complete plants which indicated that the cost curves for process plants were straight lines on log log paper. Their slopes ranged from 0.33 to 1.02 but the bulk of them were closer to 0.6 and their overall average was close to 0.6.

This became a good rule of thumb. However, one never knew how reliable it was, and there was conflict in the published data. One article would state 0.75 or 0.8 for some process while another article would state 0.5 or 0.6. Further, a person with some experience with the same process may disagree with both.

The problem lies in the fact that these lines are not straight lines. Rather they are slightly curved, turning upwards as the capacity increases. See Figure 10.

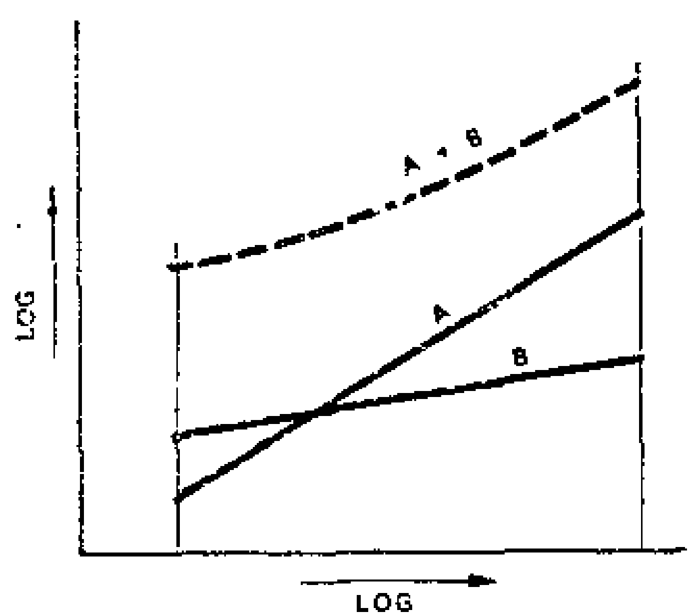
Figure 10



It will be seen now, that where the exponent 'n' may be given as 0.7, in reality it may vary from 0.5 to 0.9 depending on capacity. It is obvious that a straight application of the 0.7 exponent could produce an error at either end of the scale. Further, if the 0.7 is not the true average slope of the curve or if the capacity, at which the 0.7 slope was originally established, is not known, then it will not be readily apparent where the point of greatest error is likely to occur.

This may be illustrated as follows:

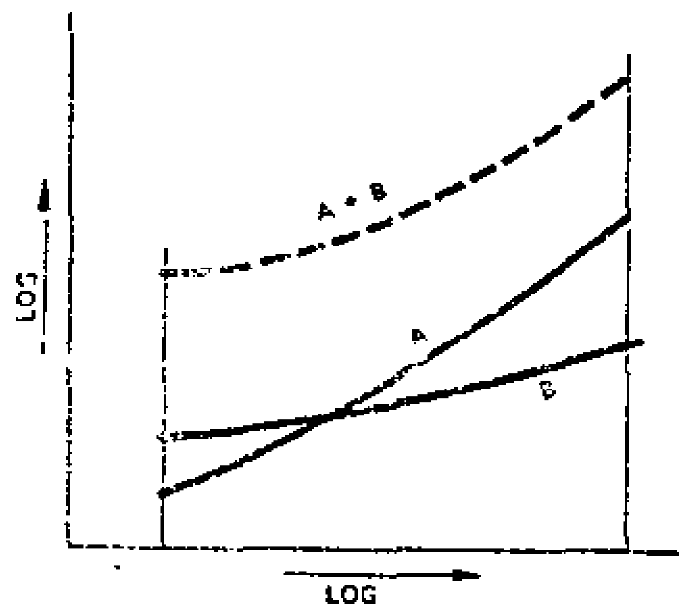
FIGURE 11
SUM OF 2 STRAIGHT LINES → CURVE



Referring to Figure 11, if 2 straight lines are drawn on log log paper at different slopes the sum of the 2 will have slight curvature.

Further if the 2 original lines are curved then their sum will be another curve of even greater curvature. See Figure 12.

FIGURE 12
SUM OF 2 CURVED LINES —
GREATER CURVATURE



A complete plant is the summation of many items such as equipment, piping, electrical materials, buildings, etc. all of which follow some power rule.

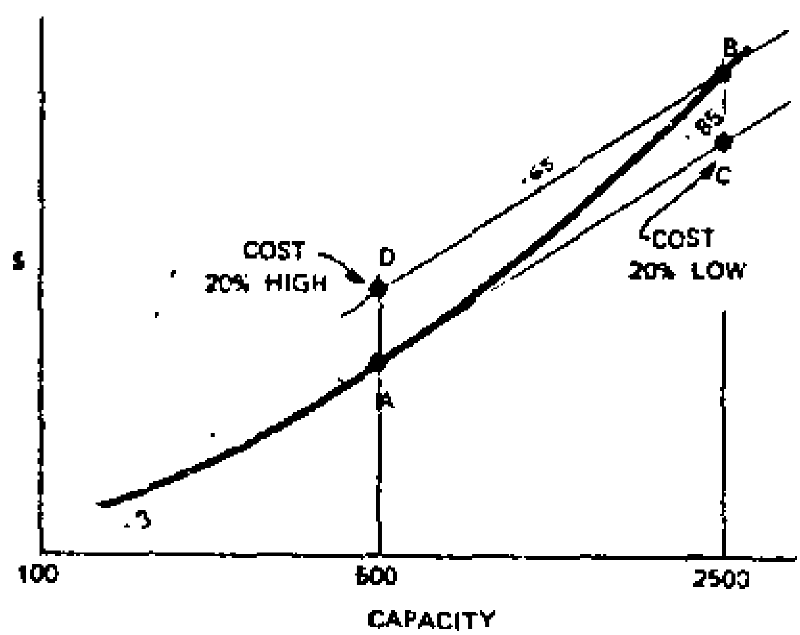
It is safe to say that they all form a curve sloping upwards, and in no case do they turn downwards. It can be concluded that their summation, which becomes the cost of a complete plant, is a curve sloping upwards and not a straight line.

Knowledge of this fact represents a significant improvement in accuracy when developing cost graphs and cannot be overly emphasized.

To illustrate this Figure 13 is an approximate cost graph for battery limit sulphuric acid plants.

FIGURE 13

POSSIBLE ERRORS IN USING THE POWER RULE



Note that in the range of 100 to 200 tons per day the curve is extremely flat with a slope of 0.2 or 0.3, while in the range of 1,500 to 2,500 tons per day, the slope is .85. The average slope of the entire curve is approximately .65.

If the cost is projected up from A to C, on the average slope of 0.65 to give a capacity increase of 5 times, the forecast cost at C would be approximately 20% low. On the contrary if the cost at B were known and it was projected down to D on the 0.65 power rule to give a capacity reduction of 5 times, then the forecast cost at D would be high by 20%. The next time reference is made to a process having a specific exponent, 'beware'.

Recognizing this fact, Figure 14 now illustrates a new set of corrected graphs for the 4 different areas. Note that we have also included a graph for indirect costs and another for engineering and design costs. (These will be discussed in more detail, later.) Thus there is a separate cost graph for every major component of cost. Each one has a different cost pattern and their summation at any capacity will provide the total cost of a complete plant.

It will also be noted that as the plant becomes progressively larger the slope of the cost curve keeps increasing until at some point it reaches 45°. Once this point is reached, the exponent 'n' becomes 1.0 and from here on there is no further reduction in the unit cost of a plant with increasing capacity. This is known as the economic size of the plant meaning that there is no particular economic advantage in terms of capital costs by building bigger. (Other things being equal.)

PLANT COSTS

ILLUSTRATING CORRECTED COST PATTERNS OF MAJOR COMPONENTS

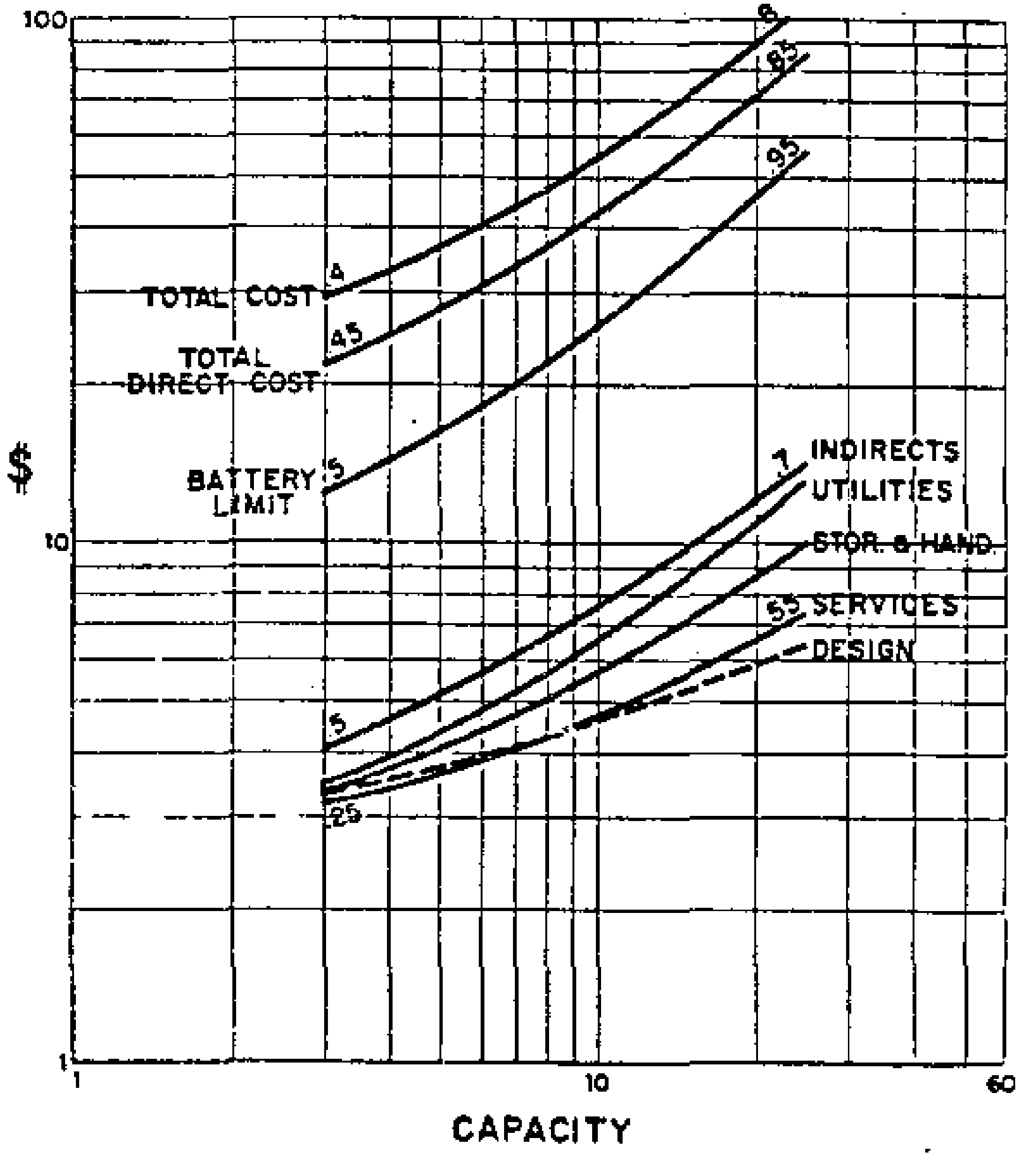


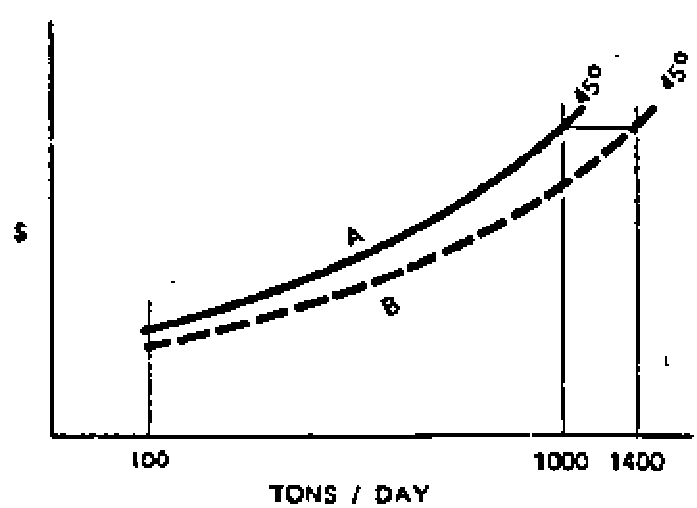
Figure 14

In actual practice these curves are not necessarily smooth. They may be 'stepped' along the way or at the point of economic size. For example: in a large single stream plant the point of economic size is reached at the capacity limit of the major equipment involved. A further increase in capacity means 2 trains or at least twinning of the major equipment. This immediately creates an upward step in the curve at the point of economic size.

However, one cannot feel secure even with an economic size plant since there are 2 more points to consider and these concern the dynamics of change in a technological society with an inflationary economy.

Assume that we have a standard curve for a process in which 100 tons/day is a small plant and 1,000 tons/day is a very large plant at which the slope has become 45°. See Figure 15.

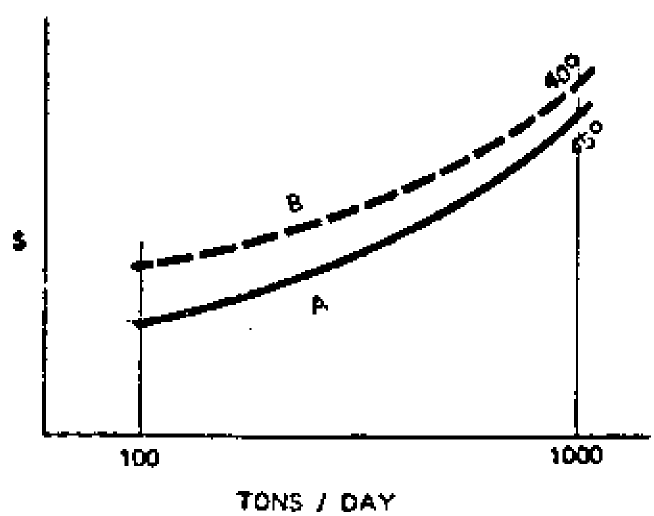
FIGURE 15
EFFECT OF TECHNOLOGICAL BREAKTHROUGH



The 1,000 t/d plant is thus at economic size and other things being equal, it should be able to compete with all comers. However, with a rapidly advancing technology someone soon finds a way to make a major breakthrough either by way of process improvement or equipment improvement. This immediately enables a larger plant to be built for the same price, or the same size plant to be built for less money. The cost pattern for this process immediately shifts from curve A to curve B and all plants built along curve A move rapidly into obsolescence. Ammonia plants are a typical example and the most significant breakthrough which brought this about was the centrifugal compressor.

The other point concerns the effect of labour escalation.

FIGURE 16
EFFECT OF ESCALATING LABOR COSTS



In Figure 16, curve A represents the cost pattern for a complete range of plants built several years ago, in which the slope at a capacity of 1000 t/d has reached 45°. Since then, the cost of construction labour has increased by a factor of about 2-1/2. Thus the labour portion of the plant at a capacity of 100 t/d has increased by 2-1/2 and similarly the labour portion at 1000 t/d has increased by 2-1/2. However, the labour content of the small plant will be a greater percentage of the total cost than for the large plant. Thus, it can be reasoned that a new cost curve B will develop for which the slope at 1000 t/d is no longer 45° but rather something like 40°. We may have exaggerated somewhat to illustrate this point - but nevertheless, it is valid to say that the rapidly increasing labour rates are causing the cost curves to become flatter with time, thereby forcing an economic size plant into larger and larger capacities.

It can now be concluded that cost patterns for complete plants do not remain static; they become progressively flatter with time, and the economic size is getting larger and larger.

An intimate knowledge of all the above issues will enable one to exercise good judgement in applying factor estimating techniques and will contribute to greater accuracy.

D I R E C T   A N D   I N D I R E C T   C O S T S

The factors discussed so far, relate to complete plants or to large components of a plant (i.e. the plant areas).

Such factors are invaluable for order of magnitude estimating. However, the time comes when a much higher degree of accuracy is desired and for this purpose we progress to more detailed factor estimating. The system to be discussed later involves a broad range of detailed factors which can be selected with judgement to suit a wide range of applications. This is where maximum accuracy comes into play and for this purpose it is very important that you have a clear understanding of the scope of the factors. This cannot be understood without knowing the composition of capital costs. This is especially important because the practice in building up the components varies from one country to another and also from the precise way in which they are built up in this presentation. Hence to clearly understand and apply the factor system being presented it is essential to know how the costs are built-up.

The first major separation in costs for this system is "direct costs" and "indirect cost".

DEFINITIONS

Direct Costs are those costs associated with the actual erection or assembly of the physical part of the plant. They include all material which enters into and becomes a physical part of the plant, along with the labour and supervision (at base wage rates) associated with its installation.

Examples:

The cost of all equipment delivered to the site plus the labour to install it. Ditto for piping, electrical, instrumentation, buildings, etc.

Indirect Costs represent those additional costs which are not directly associated with or readily traceable to a specific physical part of the plant itself but which are still essential to enable the plant to be built. Under this heading are construction field expenses, contractors' fees, temporary buildings and services including snow removal and winter protection, insurance, security and safety, fire protection, travelling expenses, construction equipment, small tools, etc.

Note: There is mixed practice in where payroll burdens are charged. Some companies include them z. part of the direct labour cost and others treat them as an indirect cost. In this presentation payroll burdens are part of the indirect costs.

Engineering is also an indirect cost but is generally assessed as a separate item by itself.

A study of the direct and indirect costs for a great many plants provides another set of useful factors. See Table-5.

Direct & Indirect Cost Factors

A. Total Direct Cost	100
B. Indirect Costs	20 to 35% of A
C. Eng'g and Administration	12 to 22% of (A + B)
D. Contingencies	5 to 15% of (A + B + C)
TOTAL COST =	A + B + C + D

TABLE-5

By separating the direct labour from the direct material we get another useful breakdown of the cost of a plant. See Table-6.

	Direct		Indirect	Eng'g Admin.	Total
	L	M			
Range	12-20	45-62	12-25	10-20	100
Average	14	54	16	16	100

TABLE-6

Note: In applying these factors it is important to know the exact definition of each column, e.g. in this illustration the labour component represents the labour cost at "base wage rates" while payroll burdens are included under the "indirect" column.

Knowledge of this distribution is invaluable in coping with day to day problems in estimating. A breakdown for a specific project may be developed by starting with the typical distribution and then modifying each number in accordance with the nature of the project and the ranges indicated for each component.

If the direct costs are broken down into their various equipment classes, another set of factors evolve. (See Table 7).

Battery Limit Cost Factors

Direct Costs:

	Range	Weighted Average
Process equipment f.o.b. site	100	100
Labour to install the process equipment	5 to 20	12
Buildings - installed	20 to 100	40
Civil Work - installed	5 to 25	12
Piping - installed	10 to 100	45
Insulation - installed	5 to 30	18
Electrical - installed	5 to 25	15
Instrumentation - installed	10 to 90	30
All remaining items - installed	1 to 5	3
Total direct cost of B/L - Installed	230 to 325	275

TABLE 7

If these data are coupled with the Indirect cost factors as in Table 5, the overall total cost of the battery limit can be estimated.

From the above, two conclusions can be reached:

1. If the cost of the process equipment is known, the cost of a complete battery limit project can be built up from factors.

2. Ranges are fairly wide and to get maximum accuracy there must be some way of arriving at more precise factors for the buildings, civil work, piping, electrical, etc.

This requires a study of those issues which affect the specific factor for each of the above items.

C O S T   C O D E

Refinement of detailed factors calls for good reliable cost keeping. A good cost code properly applied is the mechanism for collecting the cost feedback in a consistent manner, in the form desired. For this reason it is desirable to refer briefly to cost codes.

It is probably safe to say that all companies are concerned with collecting costs and cost data; not only do they collect cost data but most of them collect similar cost data and collect it for the same purposes.

In spite of this few companies have identical cost code systems.

The need for standardization was recognized by the AACE at its founding meeting. The subject has received a great deal of discussion and there have been attempts to develop a standard code. Unfortunately there are numerous hurdles to overcome and while there has been progress in thinking there is still no standard cost code which has widespread acceptance.

The modern cost code must satisfy both the Owner or producing company as well as the general contractor, and it must be adaptable to computers ~~and machine accounting. It must~~ provide the cost feedback necessary for proper cost accounting and cost control, for researching the cost patterns of the 4 areas mentioned previously as well as many sub-components and it must also provide the detailed data required by contractors in the language of the contractor.

A standard cost code is not actually a part of this presentation and is such a large subject that it could be a complete talk in itself. Consequently, without going into details the next two pages provide a summary of the objectives of a modern construction cost code and a summary outline of a code which fulfills these objectives.

The code serves as an excellent check list of all items that must be considered in making an estimate. Also note that the first column of the code is a summary picture of all the main components of a project including the 4 area concept.

OBJECTIVES OF A MODERN CONSTRUCTION COST CODE

1. Provide cost feedback for estimating purposes in the most efficient form.

2. Provide a framework for good cost accounting and good cost control. Thus it will facilitate the control of engineering, of construction labour, the control of material and the control of contracts.

3. Facilitate the payment and refund of Taxes.

4. Provide information required for insurance purposes.

5. Provide a basis for compiling the capital assets ledger.

6. Provide the type of cost breakdown that will be useful to Companies in developing both reliable product costing as well as reliable distributive costs.

7. On one hand it must provide the information required by the owner; on the other hand the data is developed and accounted for by a contractor. Therefore, to guarantee the maximum accuracy in cost keeping it must be easy to understand and apply to a contractor.

8. It must be easily expandable and contractable to provide the simplest accounting or extreme details according to the requirements of each project.

9. It must have consistency, i.e. the accounts must be well defined and charges applied in the same way on all projects.

10. It should be oriented to machine and computer accounting.

CONSTRUCTION COST CODE

	PLANT AREA AND FUNCTION CODES (Columns 1 to 3)			CONSTRUCTION ELEMENT CODES (Columns 4 to 7)
DIRECT COSTS	0 Open 1 Battery Limits 2 Storage and Handling 3 Utilities 4 Services	Numbers 0 to 9 to be used to identify Function Codes	Numbers 0 to 9 to be used to identify Sub-Function Codes	0000 to 0999 Vessels 1000 to 1999 Heat Transfer Equipment 2000 to 2999 Mechanical Equipment 3000 to 3999 Buildings 4000 to 4999 Civil 5000 to 5999 Electrical 6000 to 6999 Instrumentation 7000 to 7999 Piping 8000 to 8599 Protective Coverings 8600 to 8799 Service and Maintenance Equipment 8800 to 8899 Catalysts and Chemicals 8900 to 8999 Special Direct Accounts
INDIRECT COSTS	5 Construction Indirects	1 Owner's Field Indirects 2 Plant Forces 3 Contractors	Numbers 0 to 9 to be used to identify Sub-Function Codes	9000 to 9099 Contractor, H.O. & all field staff salaries 9100 to 9199 Temporary Facilities 9200 to 9299 Construction Services and Supplies 9300 to 9399 Payroll Burden 9400 to 9499 Open 9500 to 9599 Open
	6 Engineering	1 H.O. Eng. 2 Plant Eng. 3 Purchased	Numbers 0 to 9 to be used to identify Sub-Function Codes	9600 to 9699 Engineering
	7 Special Indirect Accounts	Open	Open	9700 to 9799 Special Indirect Accounts 9800 to 9899 Open
SUPPORT ACCOUNTS	8 Operations and Start-Up	Numbers 0 to 9 may be used to identify Accounts	Numbers 0 to 9 may be used to identify Sub-Accounts	May use either Direct or Indirect Accounts as Required
	9 Reserves	Numbers 0 to 9 to be used to identify Reserve Types	Numbers 0 to 9 may be used to identify Sub-Reserve Accounts	9900 to 9999 Reserves

CONTRACT CODE (Column 8)	
C	S & E / LS / Up Contracts
L	Labour Only CP Contracts
E	Purchased Equipment
M	Material Only CP Contracts
O	Operations & Start-Up
V	Journal Entry Vouchers
W	Work Orders
X	Reserves

Basic Concept

The code is essentially an 8 digit code in which the 1st three digits are used to classify fixed assets into specific "Functions and Areas" while the next four digits classify the work content into the normal construction elements familiar to contractors. The 8th digit classifies the work into labour, material and methods of contracting.

Following the above concept, the first digit of the code breaks the total cost of a plant into the most significant components of "Direct" and "Indirect" costs followed by any special items that don't fit logically into the above. (e.g.: Charges to Operations and Reserves).

Functional Codes

The Functional Codes, as discussed above, consist of the 1st three digits of the Code (Columns 1 through 3) as illustrated below:

000	Open	
100	Battery Limits	
200	Storage and Handling	
300	Utilities	
400	Services	
		Total Direct Costs
500	Construction Indirects	
600	Engineering	
700	Special Indirect Accounts	
		Total Indirect Costs
900	Reserves	
		Total Fixed Capital
800	New Money to Operations (Including Start-Up if Applicable)	
		Total New Money

NOTE: The above breakdown provides the desired summary sheet breakdown for all cost estimates and final cost reports. (See Section 2.0).

The second digit (Column No. 2) of this grouping identifies the <u>Prime Function</u>. Each number within this column is not unique, but is dependent on the number to its left. This would identify specific Battery Limits, Storage and Handling facilities, etc. that would exist at a CIL location, e.g.

<u>Chloralkali Plant</u>

110 Battery Limit - Chlorine
120 Battery Limit - Brine
130 Battery Limit - Caustic
330 Utilities - Water System

The third digit (Column No. 3) is used to identify the <u>System</u> or <u>Sub-Function</u>. Each number within this column is not unique but is dependent on the number to its left. e.g.

Chloralkali Plant.

```
┌──── Battery Limits
│┌─── Chlorine
││┌── Sulphuric Acid System
111
```

```
┌──── Battery Limits
│┌─── Chlorine
││┌── HCl System
112
```

Each element of the first two columns has the possibility of 10 sub-elements being identified in the column immediately to its right. On major projects, a chance exists where 10 numbers may be insufficient. In these instances, letters "A" to "Z" may be introduced.

<u>Construction Element Code</u>

The next four digits (Columns 4 through 7) denote the elements (e.g. piping, pumps, vessels, etc.) that are used in the design and construction of a project. Codes 0000 to 8999 are used for 'Direct Cost' elements and codes 9000 to 9899 are used for 'Indirect Cost' elements. The series 9900 to 9999 are utilized in the control of Reserves.

The main concept of this code is that any number on the left is the number which has priority over all other numbers to the right, as follows:

Chloralkali Plant

```
┌──────────────────── Utilities
│    ┌─────────────── Water System - Pump House
│    │    ┌────────── Pumps and Drivers
│    │    │    ┌──── Centrifugal Horizontal Cast Iron
3   61   21    1

1   23   45    6      Columns
```

Column 7 is used to identify extreme detail, if required, as indicated below:

e.g. Chloralkali Plant

```
┌──────────────────────── Utilities
│    ┌─────────────────── Water System - Pump House
│    │    ┌────────────── Pumps and Drivers
│    │    │    ┌──────── Centrifugal Horizontal Cast Iron
│    │    │    │    ┌─── Unload and Move to Pumphouse
3   61   21    1    1

1   23   45    6    7      Columns
```

Contract Code

When construction work is planned, column 8 provides the means of re-casting the estimate to reflect the way in which the actual construction is carried out. Thus, contracts may be identified and related to all the preceding codes. Similarly for equipment purchases by the owner, or cost plus labour contracts, etc. This column is used as an alpha code and is illustrated by the following:

To be used with both Direct & Indirect Costs:

C = Supply & erect lump sum or unit price contracts. Different contracts can use another alpha letter or a numerical subscript to the C.

E = Owner purchased equipment.

L = Labour only type of contract.

M = Contractor material on a cost plus contract.

Etc.

This code offers great flexibility for adapting to various ways of executing construction work, can be contracted and simplified for small projects or expanded for large projects. It fulfills the objectives as outlined on P.38.

S T A N D A R D I Z E D   F O R M A T

The cost code provides a framework on which a system of detailed factors can be built. Taking the main components from the cost code we can develop a format for a complete estimate composed of every significant item that can be factored. See Table 9.

Collecting costs in a consistent manner in accordance with some such standardized breakdown will eventually yield a wealth of data for factor estimating.

TABLE 9

CAPITAL COST SUMMARY OF ESTIMATED COSTS

Project Title and Reference	Location	Capacity	Proj. No./W.O. No.	Date

Const. Code	Description	No. of MPI's	Subcontracts or E & E (L, M + O.H.)	Direct Field Labour	Direct Material	Total	As a % of Total Equip.	As a % of Direct Cost	Direct Field Labour in Manhours
0000	Vessels								
1000	Heat Transfer Equip.								
2000	Mechanical								
	Misc. Unlisted Items (F.O.B. Site)								
	TOTAL PROCESS EQUIPMENT						100		
	Erection of Above (Field Labour)								
3010	Building (Arch. & Struct'l)								
3070	Building Services								
4300	Civil								
5000	Electrical								
6000	Instrumentation & Control								
7100	Piping Above Ground								
7500	Piping Below Ground								
7700	Sewers and Drains								
8000	Protective Coating								
8600	Service Equipment								
8800	Catalysts & Chemicals								
*	Spares								
9099	Sales Tax								
	TOTAL DIRECT COSTS							100	

COMMENTS

CONSTRUCTION INDIRECTS	*	Contractor's Indirects		
	*	Field Indirects		
	*	Purchased Construction Management		
		TOTAL INDIRECTS		
	(A)	Sub-total of all above		
ENGINEERING	9610	E & D (Admin. Design & Drafts)		
	9620	Support		
	*	Contract Engineering		
	9600	TOTAL ENGINEERING		
SPECIAL IND.	9720	Royalties, Licences etc.		
	9700	TOTAL SPECIAL INDIRECTS		
		Sub-total of all above		
RESERVES	9911	Design Changes ___ %		
	9912	Standard Changes ___ %		
	9913	Contingencies ___ %		
	9910	TOTAL RESERVES ___ %		
		TOTAL CAPITAL COST OF ERECTED PLANT IN ______ date ______ $		
INF.	9940	Inflation Allowance for Mechanical Completion at ______ date ______ ___ %		
		INFLATED TOTAL CAPITAL COST		

PREPARED BY.

ESTIMATE TYPE

Capital Cost

Man Yrs Tech'l Staff

= ________ $/Man Yr

[illegible]	
Sanction Date	
Turn-Over Date	
Start-up Date	

Centre of Gravity of Spending	
Engineering	
Drafting	
Procurement	
Construction Labour	

Assets to be Written-off

$

New Money To Operations

$

Date	Cost Index

Date (C of G)	Cost Index

(*) See Cost Code Manual

At this stage we are ready to discuss the development of detailed factors to yield the "total direct cost" from the basic cost of the equipment.

Referring back to the direct cost factors in Table 7, we now propose to discuss how these ranges can be narrowed down to more precise factors.

THEORY

Basic Theory: Total cost = f($x)
where x is a known independent variable.

In general terms, 'x' is the total cost of equipment. Thus we have:

Cost of a Plant = a Factor x Total Equipment Cost.

OR Cost of a Plant Component = a Factor x Total Equipment Cost.

Our method applies this theory and is called the 'Average Unit Cost' technique. This method highlights 3 variables which have a significant effect on the accuracy of factor estimates and provides a system for taking them into account.

These 3 variable are:

Size of equipment
Materials of construction
Operating pressure.

If the size of the equipment gets larger, the overall factor becomes smaller.

If the equipment is made from more expensive material such as stainless steel, glass lined vessels, etc. the factors again become smaller.

If the operating pressures increase, it is also known that the overall factor will decrease.

To a considerable degree all these items can be taken into account by one single number, i.e. the 'Average Unit Cost' of the process equipment.

By 'Average Unit Cost' of the equipment, is meant

$$\frac{\text{Total Cost of Process Equipment}}{\text{No. of Equipment Items}}$$

Figure 17 illustrates a plot y = f(x) where x is the average unit cost and y is the corresponding factor. It will be seen that as the average unit cost increases, the 'factor' decreases.

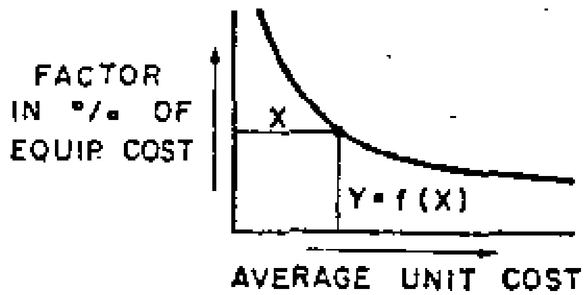


FIGURE 17

Thus:

1. If the size of a plant is increased, the equipment becomes larger and the average cost per item increases. Thus our point on the curve will be farther to the right and the corresponding factor will be lower.

2. Alternatively, if the equipment has been carbon steel and is changed to stainless steel, the average cost of each item will increase and again the point on the curve will be farther to the right and the factor will be reduced.

3. Similarly, if the operating pressure is increased from atmospheric to a high pressure operation, the average cost per item will again increase and the resulting factor will go down.

It follows, that regardless of what issues are causing variations in the 'factors', the principle of basing them on 'Average Unit Cost' of the equipment will have a narrowing effect on the differences.

In practice, the curve becomes a band, as indicated in Figure 18.

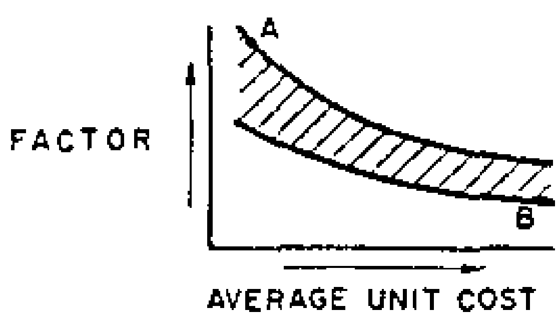


FIGURE 18

Thus for any 'Average Unit Cost', the problem is to select the right position in the width of the band at that point.

In overly simplified terms, it may be stated that point "A" indicates the factor for a very small plant, operating at atmospheric pressure and with mild steel equipment, while point "B" represents the factor for a very large high pressure plant with stainless or other similar equipment.

Based on these principles a large selection of factors have been developed from a study of a wide range of plants including ethylene, fertilizers, caustic/chlorine, polyethylene, TNT and other miscellaneous chemicals. The factors provide the direct cost of the foundations, piping, insulation, electrical, instrumentation, etc. all as a percent of the cost of the process equipment. (See Table 10).

Each column represents a value for Average Unit Cost of process equipment and all factors are given as a range. The precise selection must be based on knowledge of the project and experience of the estimator. In practice, a 3-number selection (as in PERT) has been used, thus picking a high, probable and low. An experienced estimator with a detailed appreciation of the system should be able to select ranges such that there is little likelihood of them being exceeded. Further, there is little probability of all the 'lows' or all the 'highs' occuring at the same time. Thus in establishing the range of cost the sum of the lows can be increased, while the sum of the highs can be decreased. This may be done by the method of least squares or it may be regarded as an interesting problem in probabilities. On average we have found that the sum of the 'lows' can be increased by 10% to 15% and the sum of the 'highs' can be decreased by 10% to 15%. In any event the method used in applying the 'highs' and 'lows' will provide an upper and lower figure for the estimate in which there will be a high degree of confidence.

If the process equipment estimate is order-of-magnitude, the total cost will be order-of-magnitude. However, if a good estimate has been made for the process equipment and scope of work is fairly well defined, then this type of estimate is frequently satisfactory for the appropriation of funds.

Note: One must remember that these factors only provide the "direct cost" of "battery limit" plants.

For a complete estimate, allowance must still be made for indirect costs, engineering, etc. and if the estimate is for a grass roots project, the offsites must be estimated.

TABLE 10

FACTORS FOR ESTIMATING BATTERY – LIMIT COSTS

RANGE OF FACTORS AS PERCENT OF BASIC EQUIPMENT

		AVERAGE UNIT COST OF M P I IN 1978 DOLLARS						
		UNDER $9,500	9,500 to 16,000	16,000 to 22,500	22,500 to 32,000	32,000 to 41,500	41,500 to 54,500	OVER 54,500
BASIC EQUIPMENT Delivered to site, excluding sales taxes & catalyst	M P I (Main plant items)	x	x	x	x	x	x	x
	M U E (Miscellaneous unlisted items) Early flowsheet stage	20 to 10% of M P I 's in all categories						
	Scope of work well defined	10 to 5% of M P I 's in all categories						
	NOTE: Top of ranges: Complicated processes Many process steps Bottom of ranges: Simple processes Few process steps							
	BASIC EQUIPMENT = M P I + M U E	100	100	100	100	100	100	100
FIELD ERECTION OF BASIC EQUIPMENT	High percentage of equipment involving high field labor	29/23	27/22	25/20	24/19	22.5/18	21/17	20/16.5
	AVERAGE (Mild steel equipment)	23/16	22/15	20.5/14	19/13	18/12	17.3/11	16.7/10.3
	High percentage of corrosion materials and other high unit-cost equipment involving little field erection	16/9.6	14.9/8.6	13.8/7.7	12.8/7	11.8/6.7	10.9/6.4	10.2/6.2
EQUIPMENT FOUNDATIONS AND STRUCTURAL SUPPORTS	HIGH - Predominance of compressors or mild steel equipment requiring heavy fdns.			17.5/12.4	15.5/10.3	13.7/8.7	12.2/7.3	10.8/6.2
	AVERAGE - For mild steel fabricated equipment			12.9/7.2	11.3/6.2	9.8/5.2	8.2/4.3	7.2/3.1
	AVERAGE - For predominance of alloy and other high unit-price fabricated equipment	7.2/3.1	9.2/3.4	8.6/3.1	7.7/3.1	6.7/2.6	5.7/2	4.8/1.5
	LOW - Equipment more or less sitting on fl.	5.2/0	4.3/0	3.1/0	2.4/0	2.1/0	1.5/0	1/0
	PILING OR ROCK EXCAVATION	Increase above values by 25 to 100%						
PIPING Includes ductwork Excludes insulation	HIGH - Gases and liquids, petrochemicals, plants with substantial ductwork	115/71	91/63	87.5/53.5	76.5/44	63/37	55/33	46/27
	AVERAGE FOR CHEMICAL PLANTS Liquids, electrolytic plants	71/36	63/29.5	52.5/24	44/17.5	37/13	33/11	27/10
	LIQUIDS AND SOLIDS	36/14	29.5/11	24/9	17.5/6.6	13/5.5	11/4.5	10/3.3
	LOW - Solids	14/6.5	11/4.5	9/3.3	6.6/2.2	5.5/1	4.5/0	3.3/0
INSULATION OF EQUIPMENT ONLY	VERY HIGH - Substantial mild steel equipment requiring logging and very low temperatures	14/11	12.5/9.3	11/8	10/6.4	8.5/5.7	7.4/4.7	6.3/3.8
	HIGH - Substantial equipment requiring logging and high temperatures (petrochem's)	11.3/8.2	10/7	8.5/5.7	7.3/4.6	6.2/3.7	5.3/3	4.3/2.7
	AVERAGE FOR CHEMICAL PLANTS	8.5/3.7	7.1/3.8	6/2.4	4.9/1.9	3.9/1.5	3.2/1.2	2.4/0.9
	LOW	3.6/0	2.7/0	2.2/0	1.4/0	1.5/0	1.2/0	1/0
INSULATION OF PIPING ONLY	VERY HIGH - Substantial mild steel pipe requiring logging and very low temperatures	24/17.5	21/14	17.5/12	15/10	13/7.7	10/5.5	6.6/3.8
	HIGH - Substantial piping requiring logging and high temperatures (petrochemicals)	20/15	16.5/13	14/11	12/8.5	10/6.5	7.7/4.4	5/2.7
	AVERAGE FOR CHEMICAL PLANTS	17.5/13	15/11	13/9	11/6.5	9/6	6.6/3.3	4.4/1.6
	LOW	15.4/9	13/6.6	11/5.5	9/4.4	6.6/3.3	4.4/2.2	2.2/1.1
ALL ELECTRICAL Except building lighting and instrumentation	ELECTROLYTIC PLANTS (Includes rectification equipment)		55/42	50/38	45/33	40/30	35/26	
	Plants with mild steel equipment, heavy drives, solids	26/17	22.5/15	19.5/12.6	17/10	14/8.5	12/7	10/6
	Plants with alloy or high unit-cost equipm't, chemical and petrochemical plants	18/9.5	15.5/8.5	13/6.5	11/6.5	9/4.5	7.3/3.5	6/2.5
	NOTE: Above figures include 1 to 3% for B/L outside lighting which is not covered in Building Services							

FACTORS FOR ESTIMATING BATTERY-LIMIT COSTS

		AVERAGE UNIT COST OF M P I IN 1978 DOLLARS						
		UNDER $9,500	9,500 to 16,000	16,000 to 22,500	22,500 to 32,000	32,000 to 41,500	41,500 to 54,500	OVER 54,500
INSTRUMENTATION	Substantial instrumentation, central control panels, petrochemicals, sophisticated	107/60	67/47	49/36	56/27	44/21	35/15	27/10
	MISCELLANEOUS CHEMICAL PLANTS	60/30	48/22	39/16	30/11	23/8	17/6	12/3
	Little instrumentation, solids .7		32/14	26/11	15/8	15/6	11/3	6/2
	NOTE: Total instrumentation does not vary a great deal with size and hence is not readily calculated as a percent of Basic Equipment. This is particularly true for distillation systems. If in doubt, detailed estimates should be made.							
MISCELLANEOUS (includes site preparation, painting & other items not accounted for above)	Top of range: large complicated processes Bot. of range: smaller, simple processes	RANGE FOR ALL VALUES OF BASIC EQUIPMENT 4 to 1%						

BUILDINGS — ARCHITECTURAL & STRUCTURAL (excludes building services)

NOTE: When building specifications and dimensions are known, a high-speed building cost estimate is recommended especially if buildings are a significant item of cost. If a separate estimate is not possible, evaluate the buildings as follows before selecting the factors.

BUILDING EVALUATION
when most of process units are located inside buildings

	HIGH Brick and Steel	MEDIUM	LOW Economical	EVALUATION
QUALITY OF CONST.	+4	+2	0	

	VERY HIGH UNIT COST EQUIPMENT	MOSTLY ALLOY STEEL	MIXED MATERIALS	MOSTLY CARBON STEEL	
TYPE OF EQUIPMENT	−3	−2	−1	0	

	VERY HIGH	INTERMED.	ATMOS.	
OPERATING PRESSURES	−2	−1	0	

BUILDING CLASS = ALGEBRAIC SUM =

	BLDG. CLASS	UNDER $9,500	9,500 to 16,000	16,000 to 22,500	22,500 to 32,000	32,000 to 41,500	41,500 to 54,500	OVER 54,500
MOST OF PROCESS UNITS INSIDE BUILDINGS	+2	95/70	85/63	76/58	69/51	61/46	54/40	47/34
	+1 to −1	74/51	63/44	56/39	52.5/34	46.5/30	42/27	37/22
	−2	51.5/38	45/34	41/30	36/26	31/22	28/19	24/16
OPEN-AIR PLANTS WITH MINOR BUILDINGS		38/16.5	33/13.5	29/11.5	25/8.5	20.5/6	17.5/4	14.5/2

BUILDING SERVICES

NOTE: The following factors are for Battery Limit (process) buildings only and are expressed in percent of the Building-Architectural & Structural cost. They are not related to the Basic Equipment cost.

	HIGH	NORMAL	LOW
Compressed air for general service only	4	1½	5
Electric Lighting	18	9	5
Sprinklers	10	6	3
Plumbing	20	12	5
Heating	21	16	8
Ventilation: without air conditioning	10	4	0
with air conditioning	45	35	25
TOTAL OVER-ALL AVERAGE *	85	55	20

The above factors apply to those items normally classified as building services. They do not include:

1. Services located outside the building such as sub-stations, outside sewers, outside water lines, etc., all of which are considered to be outside the Battery Limit, as well as outside the building.
2. Process services.

* The totals provide the ranges for the type of building involved and are useful when the individual service requirements are not known. Note that the over-all averages are not the sum of the individual columns.

Tables 5 & 6 provide data for indirect costs & engineering.

If a "grass roots" plant estimate is required Table 3 provides a set of factors for a quick assessment of the Storage and Handling, Utilities and Services.

However, these factors may be considered too broad for the accuracy desired in the estimate. Further refinement can still be carried out without resorting to detailed estimating. Thus Table 11 provides a set of factors for the various components that make up the utilities and Table 12 provides more detailed factors for building up the cost of Services.

'UTILITIES IN PERCENT OF BATTERY LIMIT COST'

(See notes for definition of 'Utilities')

		Range for Grass Roots
UTILITIES BUILDINGS		3-10
Arch'l and Struct'l	2-7	
Mechanical Serv.	.5-4	
COMPRESSED AIR SYSTEM		.1-4
ELECTRICAL SYSTEMS		1.5-6
Substation	.5-3.5	
Distribution	.5-3	
Outside Lighting	.15-1.5	
GAS SYSTEM		0-.6
SEWERS AND DRAINAGE SYSTEM		1.3-3.5
STEAM SYSTEM		1.5-11
Generation	1-9	
Distribution	.5-3	
WATER SYSTEM		1-10
Pumphouse	1-8	
Cool. Towers & Recirc.	.5-5	
Distribution	.15-3	
Fire Protection	.2-1	
Water treatment	.2-1.5	
MISCELLENEOUS		.5-3

	Grass Roots			B/L Additions		
	Low	Avg.	High	Low	Avg.	High
Overall Averages for all Utilities	10	20-30	50	3	6-14	30

TABLE 11

SERVICES IN PERCENT OF (B/L + S & H + U)

(See notes for definition of Services)

						Range for Grass Roots
Main Office						1 - 5
Laboratories						0 - 2.8
Shops & Stores						1 - 8
Lunch Rooms						0 - 2.2
Change Houses						0 - 2.2
Personnel & Gateshouses						0 - 1
Roads, Railroads & Fences						1.3 - 5.5
Service Equipment						.5 - 4.5
Miscellaneous						.5 - 2
	Grass Roots			B/L Additions		
	Low	Avg.	High	Low	Avg.	High
Overall Averages for Total Serv.	5	10-16	20	0	2-6	15

TABLE 12

DEVELOPMENT OF ESTIMATES

Armed with the foregoing data, we can now develop a complete factor estimate for a battery limit or a grass roots plant. Tables 13 and 14 provide sample estimating forms for developing the estimates.

Division & Location	Proj. or Study No. Requested by	TITLE CAPACITY	DATE

NO. of M.P.I.'s	COST INDEXES 1976	COST INDEXES CURRENT	FACTOR OR ACCURACY	LOW	PROBABLE	HIGH
AVERAGE UNIT COST OF M.P.I.'s IN 1976 DOLLARS ________ M.P.I. (Main plant items) M.U.E. (Miscellaneous unlisted equipment)			Estimated			
BASIC EQUIPMENT (M.P.I. + M.U.E.) (Excluding sales taxes and catalyst)			100 + –			

	REMARKS	FACTOR OR ACCURACY	LOW	PROBABLE	HIGH
Field erection of Basic Equipment					
Equipment Foundations & Structural supports					
PIPING					
INSULATION Equipment Piping					
ELECTRICAL					
INSTRUMENTATION					
MISCELLANEOUS					
BUILDINGS Architectural & Structural					
BUILDING SERVICES: (in % of Arch'l. & Struct'l.) Compressed air Electrical lighting Sprinklers Plumbing Heating Vent. & Air Conditioning					
TOTAL SERVICES					
SUB TOTAL-FACTORED ITEMS ADJUSTMENTS: LOWS + HIGHS –					
TOTAL FACTORED ITEMS ADJUSTED					
DIRECT COST OF B/L (Excluding taxes and catalyst)					

ESTIMATE SUMMARY

Page

Division & Loc'n	Proj. or Study No. Requested by	TITLE CAPACITY	DATE

	FACTOR OR ACCURACY	LOW	PROBABLE	HIGH
DIRECT COST OF B/L				
STORAGE AND HANDLING				
UTILITIES				
SERVICES (In per cent of (B/L + S&H + U)				
TOTAL B/L + AUXILIARIES				
TAXES				
TOTAL DIRECT COST				
INDIRECT COSTS				
CONSTRUCTION FIELD, O.H. & PROFIT				
CATALYST				
ROYALTIES, LICENCES AND PATENTS				
ENGINEERING				
TOTAL INDIRECT COSTS				
TOTAL DIRECT AND INDIRECT				
CONTINGENCIES				
TOTAL COST IN ________ $ date				
ESCALATION FOR COMPLETION IN ________ date				
TOTAL CAPITAL COST				

Procedure

1. Estimate cost of the process equipment. (This is not within the scope of this paper).

2. Estimate cost of B/L from the process equipment. (Table 10)

3. Estimate S & H by factors from the B/L cost. (Table 3)

4. Estimate Utilities as a function of B/L. (Table 3 & 11)

5. Estimate Services as a function of (B/L + S & H + U). (Tables 3 & 12)

Note: It should be noted that the above procedure applies to grass roots plants or to battery limit additions. Although the factors can be applied to less than a battery limit project their reliability diminishes greatly.

Estimating The Battery Limit (Table 13)

Starting with the B/L, it is necessary to break it down into its major components so that all items are included and the summation adds up to the total cost of the entire B/L. Strict definition and understanding of process equipment is particularly important since this is the base for all the factors.

The process equipment is called "Basic Equipment" and it is defined as the cost of ALL process equipment, delivered to the site. It does not include foundations or structural supports, insulation, painting or erection.

For practical purposes:
Basic Equipment = Main Plant Items + Miscellaneous Unlisted Equipment.

Where: Main Plant Items (M.P.I.) represent all the usual major items of equipment that would be indicated on a flow sheet down to and including pumps.

Miscellaneous Unlisted Equipment (M.U.E.) represents the minor miscellanous equipment that turns up on all projects, but rarely gains a position on the flow sheet or on the early equipment lists.

The cost of these two together, delivered to the site, represents the "Basic Equipment" cost which will be the basis of the Factor Estimating System.

Since the complete factor estimate depends on the cost of the "Basic Equipment", it is most important that this cost be estimated as accurately as possible.

The "average unit cost" is based on the M.P.I.'s only, and does not include the M.U.E., i.e the total number of M.P.I.'s are counted and divided into the total delivered cost of the M.P.I.'s.

It is the Basic Equipment, however, which represents "100" when applying the factors.

To compensate for inflationary effects, the "Average Unit Cost" of the M.P.I.'s should be in constant 1978 dollars.

The factors are selected from the data in Table 10 and the estimate can be completed easily by following the format of Table 13. The following trouble spots, however, are worthy of mention:

Sales taxes are treated as a separate item later on in the estimate and should not be included in the cost of the "Basic Equipment". Similarly, for catalyst. Based on the specific knowledge of the project, an accuracy evaluation is placed on the Basic Equipment. Subsequently, when factoring the various components, the low factor is applied against the low Basic Equipment cost, and the high factor is applied against the high Basic Equipment cost.

Reference to Table 10 shows that buildings can constitute the largest single component of cost next to the process equipment, and it is also known that its correlation with Basic Equipment is not too reliable.

If such a significant item of cost could be assessed with greater accuracy than that attainable with factors, it would make a considerable improvement in the accuracy of the overall estimate. With the fast techniques now available for estimating building costs it is only necessary to have the main building dimensions and general specifications in order to refine this portion of a factor estimate.

Piping is also a significant cost item, but unfortunately, unless a very substantial amount of piping design is available, there are no quick methods for estimating its cost that will provide any greater accuracy than the factor method.

One warning is necessary on instrumentation because it is not a true variant of process equipment cost. For example, the cost of instrumentation on a fully instrumented distillation system is approx. the same whether the towers are 18 inches in diameter or 5 feet in diameter. The factors provided more or less cope with this situation but it is well to remember that the cost of instrumentation on a fully instrumented sophisticated plant of small capacity could conceivably exceed 100% of the process equipment cost.

Building Services are estimated as a function of the Architectural and Structural cost of the buildings. Once established, these can then be converted to a factor of the Basic Equipment so that all factors placed in the 'Factor' column refer to Basic Equipment.

When the total of all the factored items is determined, the range is extremely wide since the extreme factors have been applied against the extremes of the Basic Equipment. Since all the 'lows' or all the 'highs' will not occur at the same time, an adjustment may be made by adding 10 to 15% to the lows and deducting 10 to 15% from the highs. (See previous comments).

Estimating The Auxiliaries (Table 13)

Table 14 provides the estimate for the outside battery limit facilities. Referring to tables 3, 11 and 12 suitable factors are selected for Storage and Handlings, Utilities and Services.

Use of high or low factors again poses a problem inasmuch as all the lows will not occur at the same time nor all the highs at the same time. In this case, because the B/L estimate is significantly larger than the auxiliaries and is, generally more accurate, the 3 factors for each auxiliary are applied against the 'Probable' cost of the B/L. The values so obtained are then added without any other adjustment.

This total provides the total cost of the B/L + Auxiliaries before taxes and indirects.

Sales Taxes

Sales taxes are calculated individually for the B/L & Auxiliaries and will vary from country to country.

Estimating The Indirects

1. Normal Indirects (construction field, O.H. & Profit): Can be estimated using one or both of the following rule-of-thumbs, one based on total direct cost and the other based on construction labour.

   (a) = 20 to 35% of total direct cost (excluding catalyst) (See Table 5).

   (b) = 90 to 150% of total direct labour.

Note: If (b) is used, the total direct labour is estimated first as a per cent of the total direct cost from the ranges given in Table 6.

2. Catalyst: This is treated separately and includes the cost of installation and any other costs associated with catalyst.

3. If applicable, add in cost of land, royalties, licences, and patents.
   Note:
   None of these items should enter into any of the factoring processes.

4. Engineering & Administration can be assessed from the ranges in Table 6.

Contingencies

Contingencies may be in the range of 10% to 20% and 10% is a common allowance.

However, it is preferable to assess contingencies in the light of 'high' or 'low' estimates. For example, it can be said with a fair degree of confidence that the 'High' figure has already provided for all the contingencies. That is why it is high. On the contrary, the 'Low' figure has no allowance for contingencies and all the lows are not likely to occur on one project. Hence there is ample good reason to provide a contingency. Thus, when determining how much money should be appropriated, there seems to be a valid reason to assess it in the range of the ('Low' + 10% to the 'High').

Escalation

The factors provide an estimate in current dollars corresponding to the time frame of the basic equipment costs.

A final addition to the estimate is an allowance for escalation based on the proposed schedule for the project and the forecast inflation rates in the countries involved.

ACCURACIES

One of the problems in assessing the accuracy of the foregoing system has been the lack of the precise project definition at the time of the estimate and subsequently identifying what was a change in scope.

Nevertheless a broad scope definition is generally available with some portions very precise. In the light of our experience we believe that Table 15 reflects the type of accuracies that may be expected and Table 16 records the actual performance on a number of projects.

TABLE 15

ACCURACY CONSIDERATIONS

ACCURACY ON EQUIPMENT	ACCURACY ON ESTIMATE		ACCURACY WITH CONTINGENCY ALLOWANCE	
	B/L PLANT	GRASS ROOTS	B/L PLANT	GRASS ROOTS
± 10%	± 15%	± 19%	± 11%	± 14%
± 5%	± 10%	± 15%	± 6%	± 10%

TABLE 16

PERFORMANCE ON FACTOR ESTIMATES

PROJECT	ESTIMATED COST OF EQUIPMENT	FACTOR ESTIMATE	CONVENTIONAL ESTIMATE	ACTUAL COST	REMARKS
A	$ 3,397,100	$ 8,370,000	$ 6,476,500	$ 8,014,000	
B	89,000	263,000	288,000	—	BUILT WITH SCOPE CHANGED
C	122,600	357,800	354,000	—	BUILT WITH SCOPE CHANGED
D	202,780	456,400	433,720	—	BUILT WITH SCOPE CHANGED
E	1,360,000	4,400,000	4,392,000	4,229,479	
F	693,000	1,894,000	1,716,000	—	NOT BUILT
G	474,000	985,000	922,300	—	NOT BUILT
H		6,624,000	6,709,000	6,421,500	
I	257,000	407,000 TO 497,000	450,000	—	NOT BUILT
J	1,869,000	4,796,000	4,310,000	4,610,100	

REFINEMENTS

Certain vulnerable and significant parts of a factor estimate can be improved through refinement without resorting to burdensome detailed estimating, as illustrated by the following examples:

Buildings

The factor approach to buildings can be replaced by large component techniques such as square foot costs. Thus data like Table 17 can be developed to apply to buildings of various types, qualities and sizes.

A further refinement of greater accuracy for buildings involves a high speed "square foot of construction" (SFC) technique as illustrated by Tables 18 and 19.

In this method, square feet of construction refers to surface area of construction i.e. square feet of foundation wall from bottom of footing to top of concrete,
square feet of walls,
square feet of floors,
square feet of roof,
etc.

Structural steel is estimated by the ton, which in turn is assessed quickly on the basis of lbs. per cubic foot of building for various types of buildings.

The costs given in Table 18 provide a range of SFC costs for Canadian conditions, and Table 19 provides a quick means of assessing the corresponding indirect costs with improved accuracy, taking into account the type of contract which applies.

Note that the unit SFC costs provided in Table 18 include payroll burdens and that the Indirect Costs given in Table 19 are based on this fact.

"Building Services" are assessed using the percentages given in Table 10 page 46.

Thus the total cost of a building is built up as follows:

Direct Cost	- as per Table 17 or 18.
Building Services	- as per Table 10, Page 46
Indirect Cost } Profit }	- as per Table 19
Total Cost	- Sum of Above

Inter Battery Piping

On large grass roots plants consisting of several distinct battery limit operations, the factors in Table 10 don't provide for the substantial amount of piping on pipe racks which is necessary to connect up the various battery limit plants. Such piping which may be called "inter battery piping" can normally be quantified in lineal feet at an early stage of a project and specific estimates made to add on to the factored estimate.

Indirect Costs

Indirect costs are a very significant item of cost, especially on large general contracts. Where the ranges given in Table 5 are of insufficient accuracy, then Table 20 may be used and, in this case, the various components are determined as a percent of the total direct field labour cost (excludes shop fabrication labour). Ranges given are for Canadian conditions and are different for different countries. Where suggested ranges are omitted, they must be assessed on their individual merits.

DIRECT COST OF

PROCESS BUILDINGS EXCLUDING SERVICES

IN $ PER SQUARE FOOT OF FLOOR (1979)

		SMALL BLD'G. 5000 S.F.	LARGE BLD'G. 25000 S.F.
1 STOREY PROCESS ABOUT 16' HIGH LOW RANGE = WAREHOUSE	STD. BUILDING	15.00 TO 30.00	12.00 TO 25.00
	HIGH QUALITY	30.00 TO 55.00	20.00 TO 40.00
SEVERAL STOREY PROCESS	STD. BUILDING	20.00 TO 40.00	15.00 TO 30.00
	HIGH QUALITY	40.00 TO 60.00	25.00 TO 45.00

Table 17

REF. NO. ________

Proj. or Study No. ________ Date Prices - 1st Quarter 1979.

Request By ________ Bldg. No. & Name ________

Division & Location ________ Type of Building ________

O/S Length ________ Overall Ht. ________ Year of Construction ________

O/S Width ________ Height under Chord ________ Volume in Cu. Ft. ________

Sq. Ft. of Floor ________ S.F.C. ________

COMPONENT	SPECIFICATION	QTY.	UNIT	Date ____ UNIT COST	AMOUNT
FOUNDATIONS incl. excavation backfill, forms, reinf., concrete and interior piers	Std. Fdns. 5'-6" overall		SFC	10^{00} to 12^{50}	
	Retaining Fdns. 5'-4" overall		SFC	12^{00} to 14^{00}	
GROUND FLOOR incl. gravel fill, reinf. concrete & concrete finish or haunched slab	6" Floor slab on 12" Fill, 80# met. Hardener		SFC	2^{50} to 2^{75}	
	As above but 4'-0' Fill		SFC	3^{00} to 3^{15}	
FRAME (r.c. or steel) incl. struct. steel L/S joists & misc. steel	Struct. steel - primed		Ton	800^{00} to 1000^{00}	
	" " " - epoxy		Ton	1000^{00} to 1300^{00}	
SUSP. FLOORS incl. concrete, steel grating, etc.	Grating		S.F	6^{00} to 8^{00}	
	6" concrete - 80# hard.		S.F	5^{00} to 7^{00}	
ROOF including deck, insulation, flashing, and covering	22 ga Q Deck, 2" Fiberboard, Built-up roofing & Flashing		S.F	2^{50} to 3^{00}	
EXTERIOR WALLS including sash and doors	12" Conc. block		SF	2^{75} to 4^{00}	
	10" " "		SF	2^{50} to 3^{75}	
	8" " " + 4" Brick		SF	5^{00} to 7^{50}	
INTERIOR PARTITIONS incl. doors, etc.	4" Conc. block			1^{75} to 2^{50}	
	6" " "			2^{25} to 2^{75}	
	8" " "			2^{75} to 3^{00}	
	1/2" Gypsoc - steel studs - painted			1^{70} to 2^{50}	
MISCELLANEOUS	Steel stairs incl. stringers, handrails, etc.		Riser	75^{00} to 120^{00}	
SUB-TOTAL					
INTERIOR FINISH incl. floor tile painting, etc.					
TOTAL DIRECT COST OF BUILDING					

	%	
DIRECT COST OF BUILDING		
Lighting		
Plumbing		
Fire Protection		
Heating		
Ventilation		
Air Conditioning		
DIRECT COST OF SERVICES		
TOTAL DIRECT COST		
INDIRECT COST		
PROFIT		
TOTAL ESTIMATED COST		

UNIT COSTS	PER CU. FT.	PER S.F.C.	PER SQ. FT. FLOOR
Direct Building			
Direct Services			
TOTAL incl. indirects & profit			

Table 18

CONTRACTORS INDIRE... ON CIVIL TYPE PROJECTS
(NOTE: FRINGE BENEFITS ARE INCLUDED IN DIRECT COST)

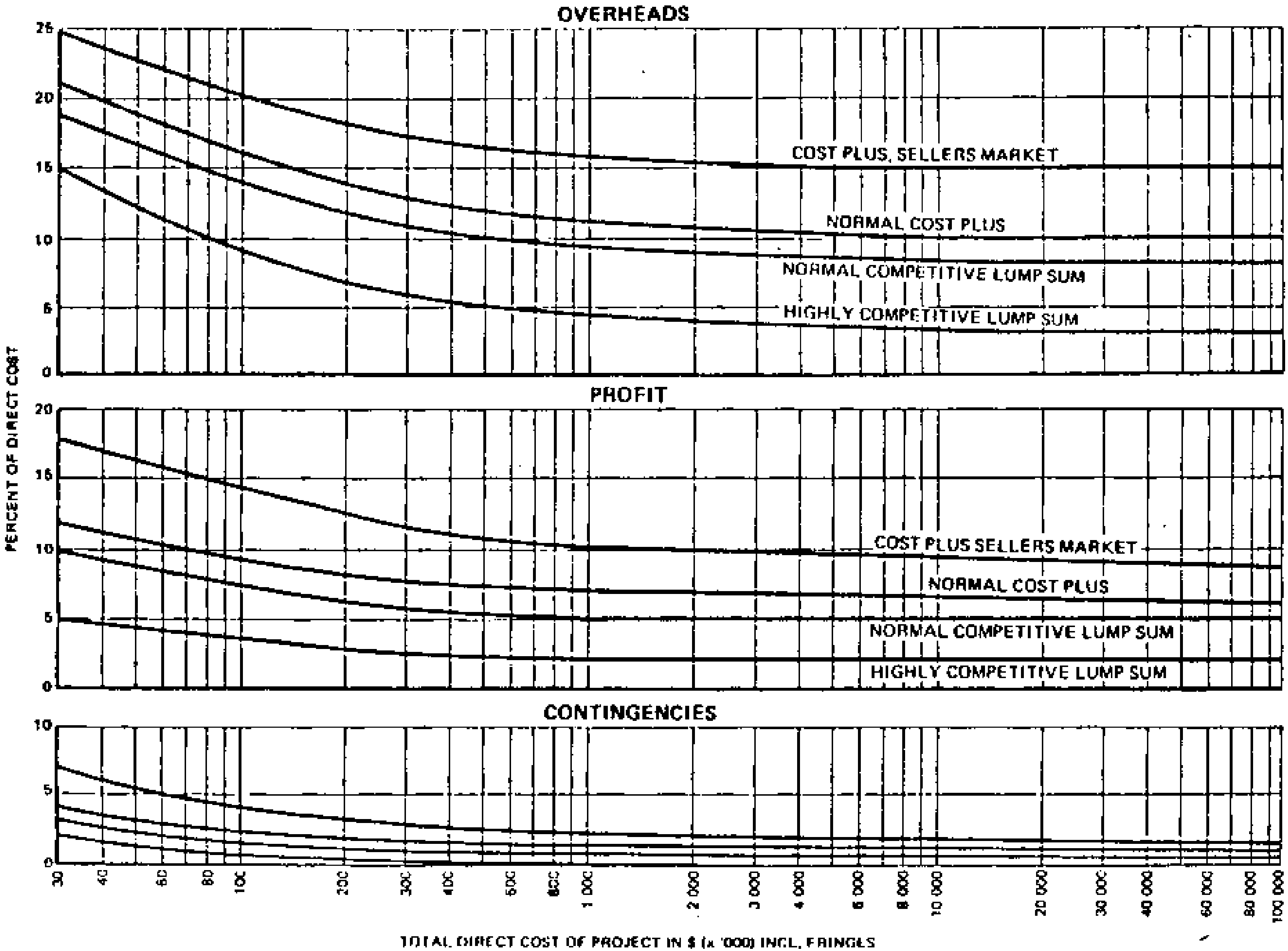


Table 19

ESTIMATED INDIRECT CONSTRUCTION COSTS

INDICATE FUNCTION
Contractors
Construction Management ______________
CIL Field

Project No. ______
Location ______
Date ______
Prepared By: ______

TOTAL DIRECT LABOUR (incl. 1st level foremen) $ ______

	CONST. COST CODE	CONTRACTED CONSTRUCTION INDIRECTS	SUB CONTRACTS	% OF TOTAL DIRECT LAB: LOW	AVER.	HIGH	% OF TOTAL DIRECT LAB
	9001	Contractor's Head Office (Salaries, Living, O.H., Profit or Fee)		5	10	15	
FIELD OFFICE	9002	Contractor's Field Office – Supervision (incl. Burden, Travel & Living Allowances) For Details of Field Supervision and Support Personnel See Reverse of This Form		20	25	30	
	9007	Subtotal Field Office					
TEMPORARY FACILITIES	9110	Temporary Buildings					
	9120	Temporary Facilities		10	24	30	
	9130	Temporary Utilities					
	9140	Temporary Office Equipment & Supplies		3	5	7	
	9100	Subtotal Temporary Facilities					
CONSTRUCTION SERVICES AND SUPPLIES	9210	Construction Supplies		7	10	13	
	9220	Construction Equipment and Tools		20	25	30	
	9230	Construction Services					
	9240	Stores					
	9250	Security					
	9260	Safety					
	9290	Permits, Licences and Fees					
	9200	Subtotal Construction Services & Supplies					
	9012	Hourly Paid General Foremen					
PAYROLL OVERHEADS	9310	Direct Labour Payroll Burden		29	32	35	
	9320	Indirect Labour Payroll Burden		2.5	5	6.5	
	9300	Subtotal Normal Payroll Overheads					
		TOTAL NORMAL INDIRECTS					
ABNORMAL INDIRECTS	9330	Non-productive Labour		4	7	10	
	9341	Scheduled Overtime Premiums		0		100	
	9342	Unscheduled Overtime Premiums		1	2	3	
	9343	Shift Differential					
	9351	Living Allowances 15$ to 25$/day		0		30	
	9352	Travel Allowances 20¢/mile					
	-						
	9300	Subtotal Abnormal Indirects					
	*	Additional Supervision if applicable (incl. Burden & O.H.) To Supervise S & E Items					
		TOTAL		135	150 (1)	160	

(1) Exclude O.T., Living & travel.

Table 20

ESTIMATING ENGINEERING COSTS

NOTE: The following system is predicated on the basis of a single engineering dept. executing the entire engineering design function in house. However, provision is made for a situation where some outside engineering may be purchased.

In general, engineering estimates are developed in three stages:

1.	At early study stage	i.e. for Class E or D estimate
2.	At Preliminary Estimate and Sppropriation Request stage	i.e. for Class C & B estimates
3.	At definitive stage	i.e. when a class B estimate is made for control purposes

Each stage involves a different estimating technique.

Method 1. Early Study Stage

At this stage, the cost of engineering is estimated as a percent of total project cost and relies a great deal on past experience. Basic reference is Appendix "A". The dotted lines indicate the range of the swings which take place, and experience will indicate if one should select a value different from the average line.

Method 2. At Preliminary Estimate Stage and Frequently the Appropriation Request Stage

This method develops the engineering cost from the manhours which in turn are developed from the estimate which has been made.

The manhours are related to the total delivered cost of all construction material required for the project. Because material cost is constantly changing due to inflation, the cost of the project material must be brought to constant dollars, and for this evaluation, all material costs have been equated to 4th Quarter 1978 dollars.

To develop the engineering cost from this point, a clear understanding of the composition of engineering costs (as required for this application) is essential. Thus Appendix "B" illustrates the composition or building blocks which are used. Referring to Appendix "B".

D + D represents the total Design and Draughting manhours required to engineer the project. It includes all engineering manhours required to develop the design up to and including the project engineer, and all draughting manhours and its supervision to provide the drawings.

The total D + D manhours represent the "Base" on which the entire engineering estimate is developed.

Other components of Engineering are:

Project Management

This represents the time input from any Supervising Engineers plus that of a Project Manager.

Support

Consists of all manhours required by the following groups:

Cost Estimating
Accounting
Contracts and construction supervision
Project control i.e.,P & S, cost control, expediting
Inspection
Drafting support and drawing records

Liaison

Only applies when an outside engineering firm is used. In this event, it represents the "additional" manhours which become necessary to direct the outside work, maintain good communications and monitor the progress. This is intended to cover only those manhours which would be additional to a complete "in house" type of engineering job.

Expenses

This item is assessed in dollars and provides for travelling expenses and other miscellaneous expense items associated with all engineering work.

Profit re Outside Engineering

For purposes of this estimate, we are assuming that all engineering whether done in-house or by an outside firm, or part of both, will require the same number of manhours and at the same unit costs.

Thus there would be an additional cost to provide profit to the outside firm.

However, if the outside firm were known and exact charge out rates were known and used in the estimate, then this item would not apply.

With this understanding of the various components of engineering, the total engineering cost may be built up as follows:

Procedure

A manhour graph vs material cost in 4th Quarter 1978 dollars, provides the BASE D + D manhours. (See Appendix "D").

The Base manhours are corrected by a Project Evaluation Factor as described in Appendix "E" which provides an "Adjusted Base".

Note: The Project Evaluation Factor provides a unique way of allowing for very important variables which have a significant effect on engineering costs.

All remaining components are developed from the "Adjusted Base". The step by step procedure is as follows:

1. Use Appendix "C" for reference.

2. Determine the total delivered cost of all material required for the project and then convert it to 4th Quarter 1978 dollars.

3. From graph in Appendix "D", select Base D + D manhours.

4. Develop Project Evaluation Factor as per Appendix "E".

5. Adjusted Base = Project Evaluation Factor x base manhours.

6. Split the adjusted base (i.e. total D + D manhours) into Engineers and Draftsmen using the graph in Appendixes "F" and "G".

   Note: The total D + D graph in Appendix "D" is more reliable than the individual engineers and draftsmen graphs.

7. Calculate manhours for Project Management, Support and Liaison by percentages as indicated in Appendix "C".

   Note: That the overall average for support is 23% of the adjusted base. This could be somewhat higher if a large amount of foreign inspection is visualized.

8. Extend manhours by applicable unit rates. Rates used should be "all in" rates to embrace salaries, burdens, and all overheads such as rent, lighting, heating, etc.

9. Calculate travel, miscellaneous, and profit using percentages as in Appendix "C".

10. The overall total provides the estimated total cost of engineering.

Method 3. <u>At Definitive Stage</u>

At this stage, all scope is well defined and a complete detailed count of drawings required will be available.

As a result, a detailed estimate of all engineering, draughting, technician and clerical manhours is required and Appendix "H" is to be used for this purpose with extensions at current "all-in" unit rates.

At this stage, a specific estimate might be made for expenses or in its absence the percentages given for the "Preliminary Estimate Stage" may be used.

Further, specific arrangements would be known regarding purchased engineering and thus a specific estimate or quote would be expected at this stage.

Note: This form also makes provision for Purchasing Department costs and Field Supervision and Support which are not normally regarded as an Engineering Department cost.

A general guide for the overall total of draughting manhours is:

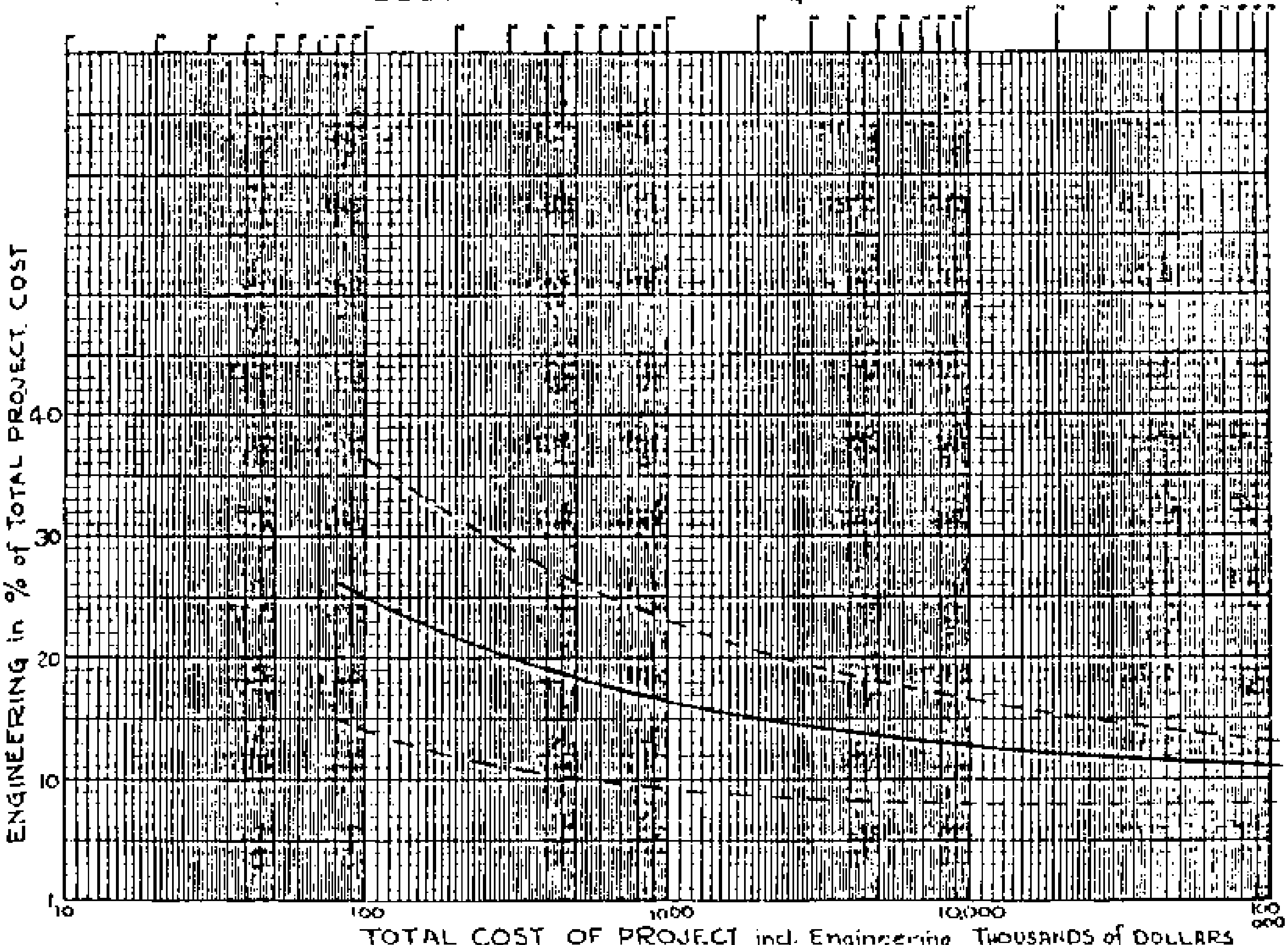
	S.F. per dwg.	Manhours per S.F.		
		Low	Average	High
Full Size	6	11	14	16
ISO's	2	3.5	4.5	5.5

Unit manhours for each discipline varies considerably from the overall average. However, the above guide provides fairly reliable overall averages.

This table could be used in conjunction with Method 2 to get a better estimate than would otherwise be obtained.

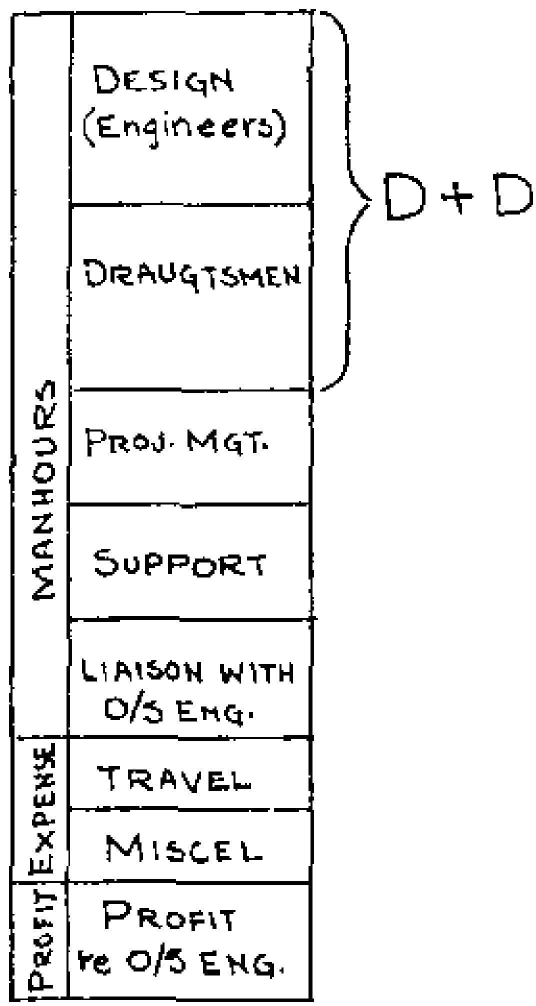
Appendix "H" is both an "Estimate Form" as well as a "Recapitulation Form" to record all essential data re engineering on completion of the project. When completely filled in with the various percentages and ratios, it provides valuable feedback on performance and for future estimating.

COST of ENGINEERING 1978



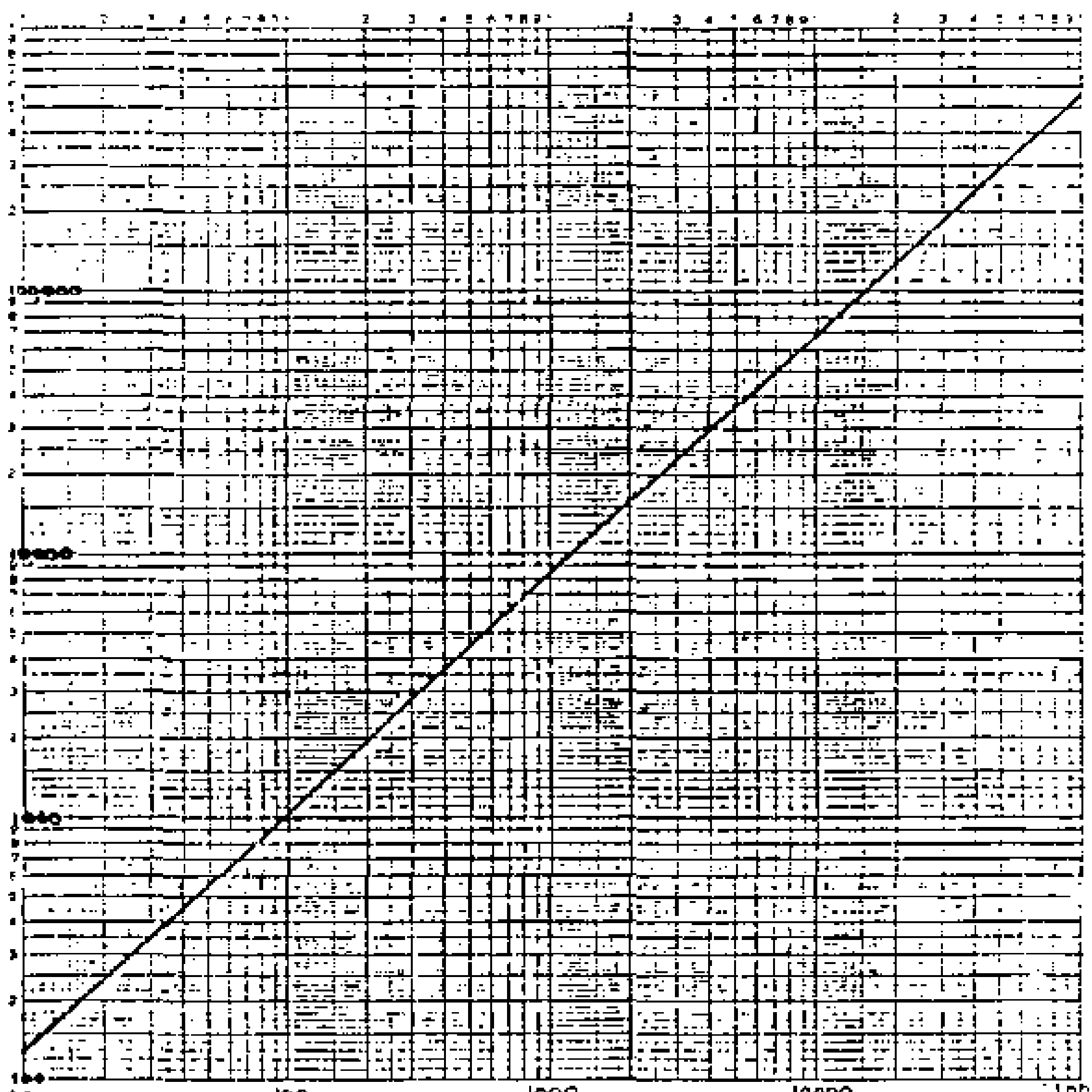
APPENDIX A

ENGINEERING COSTS



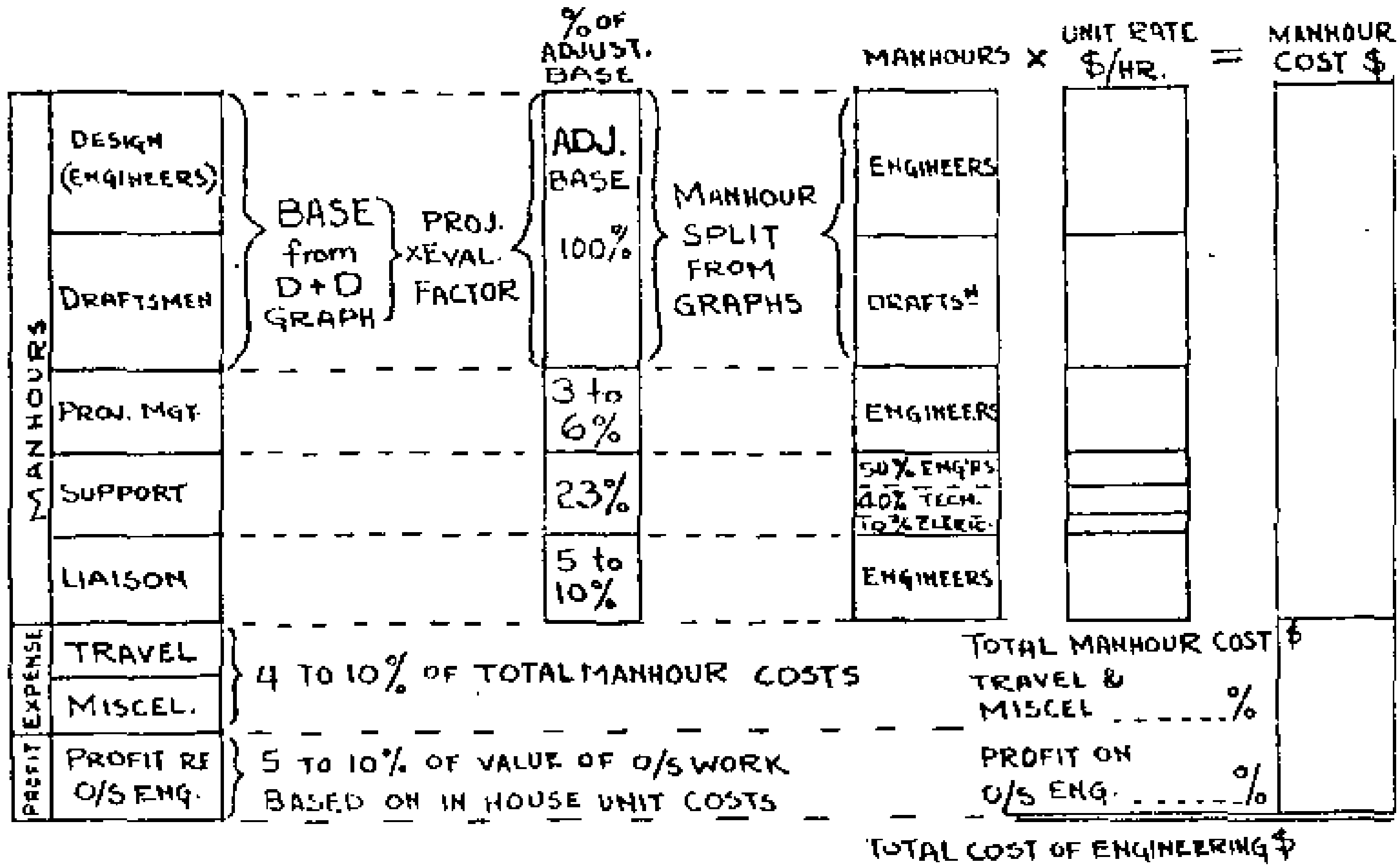
COST OF ENGINEERING

D + D MANHOURS VS MATERIAL COST



MATERIAL COST 4th QUARTER 1978, MACH.&EQT INDEX-200
IN THOUSANDS OF DOLLARS

ENGINEERING COSTS



APPENDIX "E"

PROJECT EVALUATION FACTORS

Select suitable factors within the limits given.

STUDY AND DEVELOPMENT FACTOR	RANGE
Expectation of extensive study and development work, many preliminary designs, etc. prior to final design, plus expectation of even further changes after the so-called final design. Charging a large amount of work to a project which is normally charged to a study.	+40
Average amount of study and development work	0
Minimum amount of study and development work. Process engineering studies done by others thereby enabling the Engineering Department to commence final design with a minimum of preliminary work. Good scope and no changes.	-10

EXPERIENCE AND REPETITION FACTOR	
First project of this nature to be designed by Engineering Department. Engineering Department personnel not familiar with it. Expected start-up difficulties.	+20
Similar to previous designs and well within the experience and capabilities of Engineering Department personnel.	0
Maximum gain from past experience and by duplicating previous designs and taking advantage of existing drawings.	-15

COMPLEXITY FACTOR	
Very Complex	+30
Average	0
Very Simple	-15

Project Evaluation Factors
Continued

CLIENT INPUT FACTOR	RANGE
Considerable interference and changes by Client. Client slow in making decisions and changing mind frequently.	+30
Normal	0
Client knows what it wants. Scope is well defined and no expectation of changes. Rapid decisions. High degree of Client co-operation.	-10

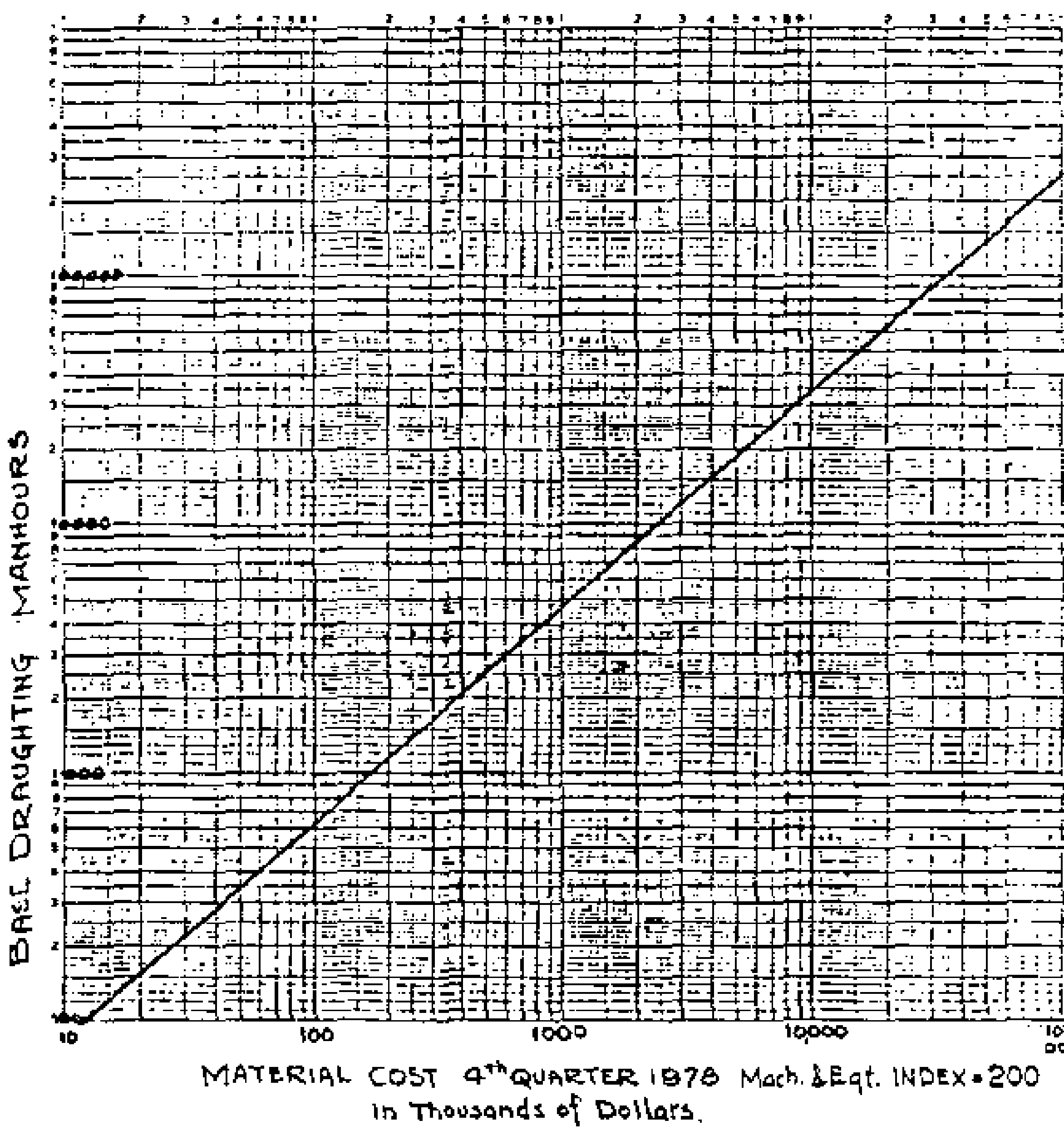
SPECIAL CIRCUMSTANCES FACTOR

In addition to the above factors, this provides for abnormal or unusual circumstances which are known and do not fit into the above classifications and for which an allowance should be made.

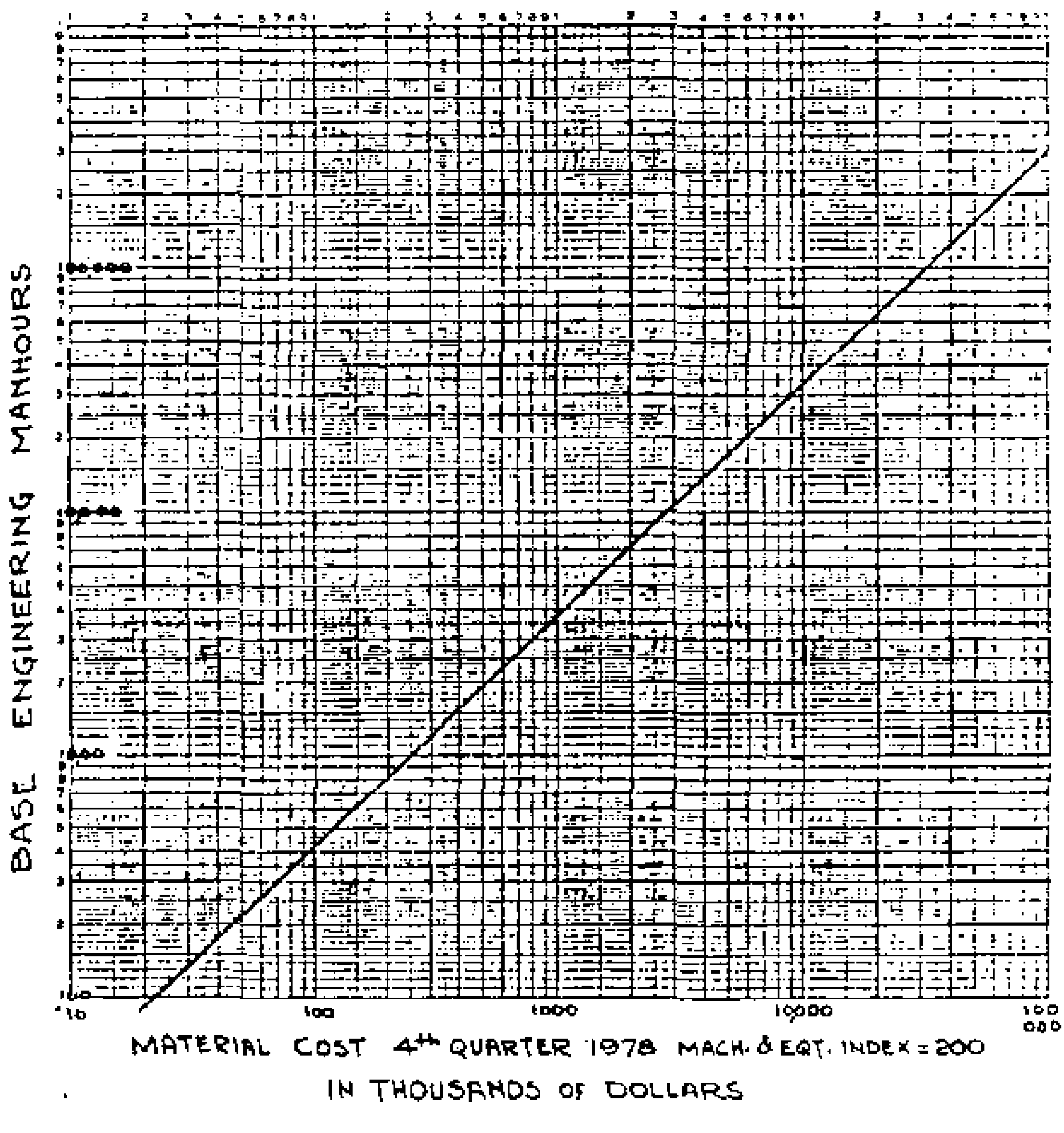
This is strictly an arbitrary judgement factor. It should not be used if the circumstances clearly belong to one of the foregoing classifications. +25

$$\text{Project Evaluation Factor} = \frac{100 + \sum \text{individual evaluations}}{100}$$

COST OF ENGINEERING.
DRAUGHTING MANHOURS



COST OF ENGINEERING
ENGINEERING MANHOURS



PROPOSED SCHEDULE

ENGINEERING ESTIMATE OR RECAPITULATION

SANCTION DATE	START DESIGN	COMPLETE DESIGN	START CONSTRUCTION	TURN OVER	PROJECT TITLE / CAPACITY	SCOPE OF PROJECT	DIVISION / WORKS	W.O. NO. / PROJECT NO. / DATE OF ESTIMATE

	FUNCTION	ENGINEERING				DRAFTING					TECHNICIANS			CLERKS		EXPENSES		TOTAL	
		REMARKS	MAN HOURS	% OF DESIGN TOTAL	COST AT ___ $/HR	NO. DWGS	MAN HOURS PER DWG	MAN HOURS	% OF TOTAL	COST AT ___ $/HR	REMARKS	MAN HOURS	COST AT ___ $/HR	MAN HOURS	COST AT ___ $/HR	TRAVEL M$	OTHER M$	MAN HOURS	M$
DESIGN AND DRAFTING	01 PROJECT MANAGEMENT/ENGINEERING																		
	11 CHEMICAL ENGG. PROCESS																		
	12 ENVIRONMENTAL																		
	13 COMPUTER APPLICATION																		
	21 MATERIALS OF CONSTRUCTION																		
	22 MAINTENANCE																		
	23 MATERIAL HANDLING																		
	24 POWER HOUSE (EQUIPMT. & PIPING)																		
	25 OTHER SPECIALISTS (ENERGY CONS., ETC.)																		
	30 MODELS																		
	31 EQUIPMT. DESIGN & PROCUREMENT																		
	32 PIPING DESIGN & PROCUREMENT																		
	41 CIVIL DESIGN (ROADS, R.R.'s, [illegible])																		
	42 STRUCTURAL																		
	43 ARCHITECTURAL																		
	44 U.G. PIPING																		
	45 FIRE PROTECTION (OTHER THAN U/G P.)																		
	46 BUILDING MECHANICAL (HVAC, PLUMB.)																		
	51 ELECTRICAL																		
	61 INSTRUMENTATION & CONTROL																		
	SUB-TOTAL DESIGN & DRAFTING																		
SUPPORT	71 COST ESTIMATING																		
	72 ACCOUNTING																		
	73 CONTRACTS & CONSTRUCTION [illegible]																		
	74 PROJECT CONTR. (SCHEDULE, COST, ETC.)																		
	75 INSPECTION																		
	76 DRAFTING SUPPORT (RECORDS, ETC.)																		
	SUB-TOTAL SUPPORT																		
TOTAL CO. ENGINEERING																			
	PURCHASED ENGINEERING ●																		
TOTAL ENGINEERING																			
	PURCHASING DEPARTMENT																		
	81 FIELD SUPERVISION & SUPPORT																		

RECAPITULATION

EST. TOTAL MATL. COST $ ______ CONSTR. CMPT. MACHY. & EQUIP. INDEX ______

		DESIGN AND DRAFTING		SUPPORT	PURCH. ENGNG	CLERICAL	TRAVEL	TOTAL ENGINEERING
		DRAFTING	TOTAL D & D					
TOTAL PROJECT COST	$	%	%	%	%	%	%	%
$ ENGRG / $ 1000 MATL								
TOTAL MAN HOURS	* Mhrs	%	%	%	—	%	—	100 %
MATL COST AT INDEX 300 / $		Mhrs/$M	Mhrs/$M	Mhrs/$M	Mhrs/$M	Mhrs/$M	—	Mhrs/$M

*INDICATE: INCLUDES/EXCLUDES PURCHASED ENGNG

● USE SEPARATE SHEET FOR PURCHASED ENGNG. IF DESIRED

RATIOS

TOTAL DESIGN ENG. MHRS / TOTAL DRAFTING MHRS = ______

TOTAL SUPPORT MHRS / TOTAL DRAFTING MHRS = ______

TOTAL SUPPORT MHRS / TOTAL DESIGN ENG. MHRS = ______

REMARKS

APPENDIX H

CONTINGENCIES

There are many opinions on what a contingency is and what it includes. Table 21 is a clear graphical depiction of contingencies with explanations. Note that it does not include Major Changes in Scope.

Major Changes in Scope are a common and significant contributor to project overruns and are not intended to be provided for under the standard meaning of contingencies.

CONTINGENCIES

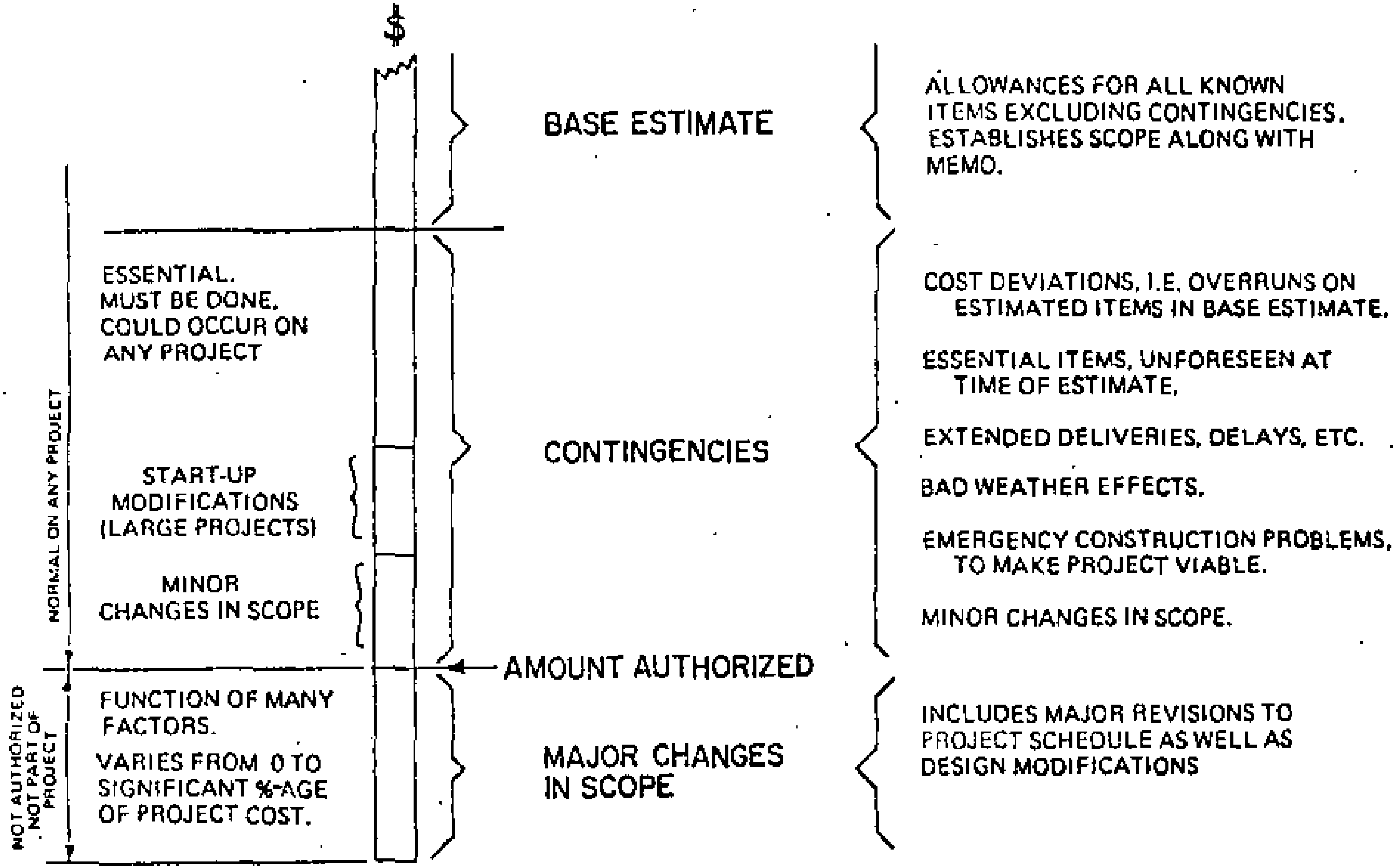


Table 21

ESCALATION

In recent years, inflation rates have become so great that separate allowances must be made for the escalation of costs during the project life.

The general practice is to develop the estimate in current dollars on the basis that the entire project could be purchased and erected at 1 point in time. This provides a "Base Cost". An escalation allowance is then added to recognize the forecast project schedule and forecast inflation rates.

Three techniques are used, each one becoming more detailed and more accurate.

Method 1

Establish the center of gravity of spending for the entire project i.e. the point in time when 50% of the entire project cost is spent. The total escalation is then calculated against the total project cost and based on the expected inflation over the period. Forecast projections of a suitable cost index is used for this purpose.

Figure 19 illustrates an overall project cash flow graph showing the escalation period to be 1 year.

Method 2

An improvement in accuracy is accomplished by breaking a project into major components and applying Method 1 to each component. Thus, the cost of a project could be broken down into engineering, procurement of material, and construction and separate escalation periods and rates would be assessed for each component. This is illustrated by the cash flow curves in Figure 20.

Method 3

Table 22 provides a format and procedure for calculating escalation in considerable detail, including separate assessments of equipment imported from various countries and also incorporating an assessment of the effect of changing rates of exchange.

ESCALATION

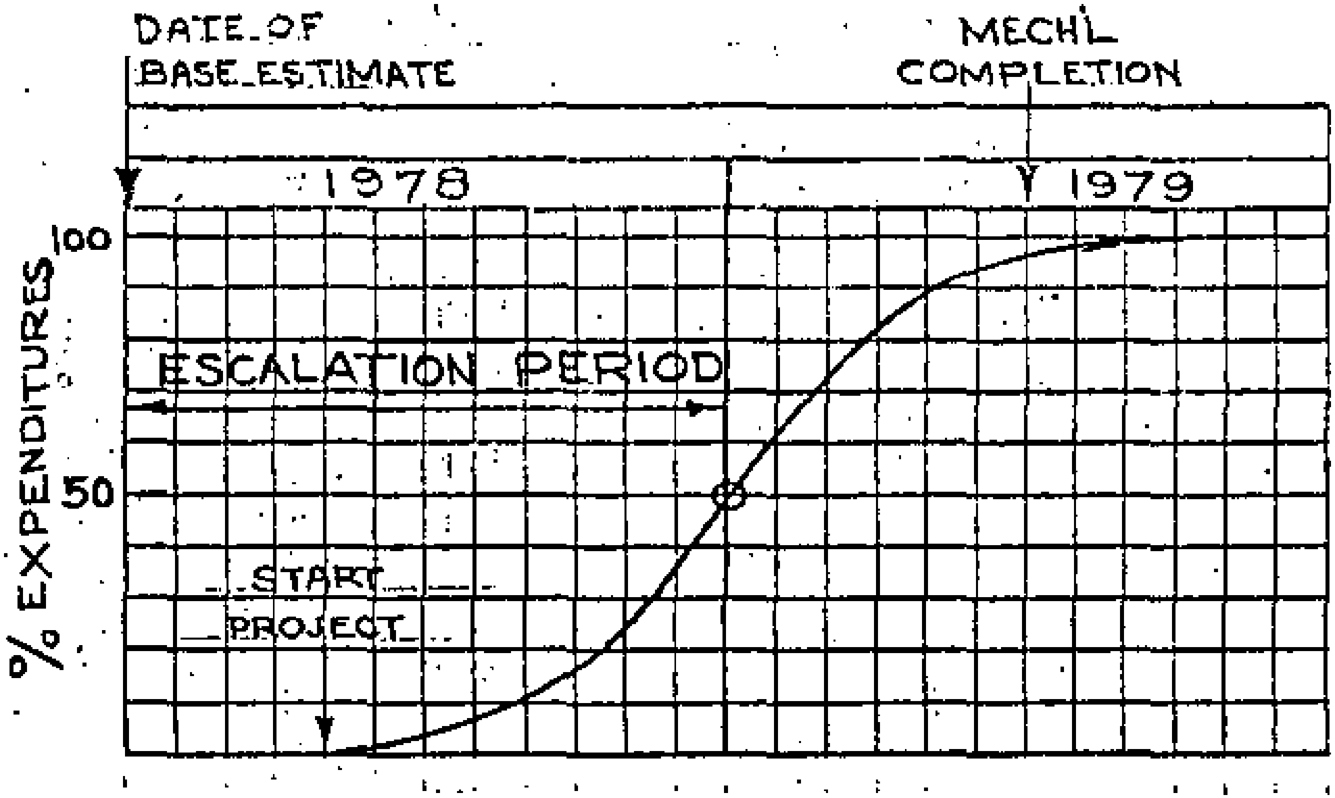
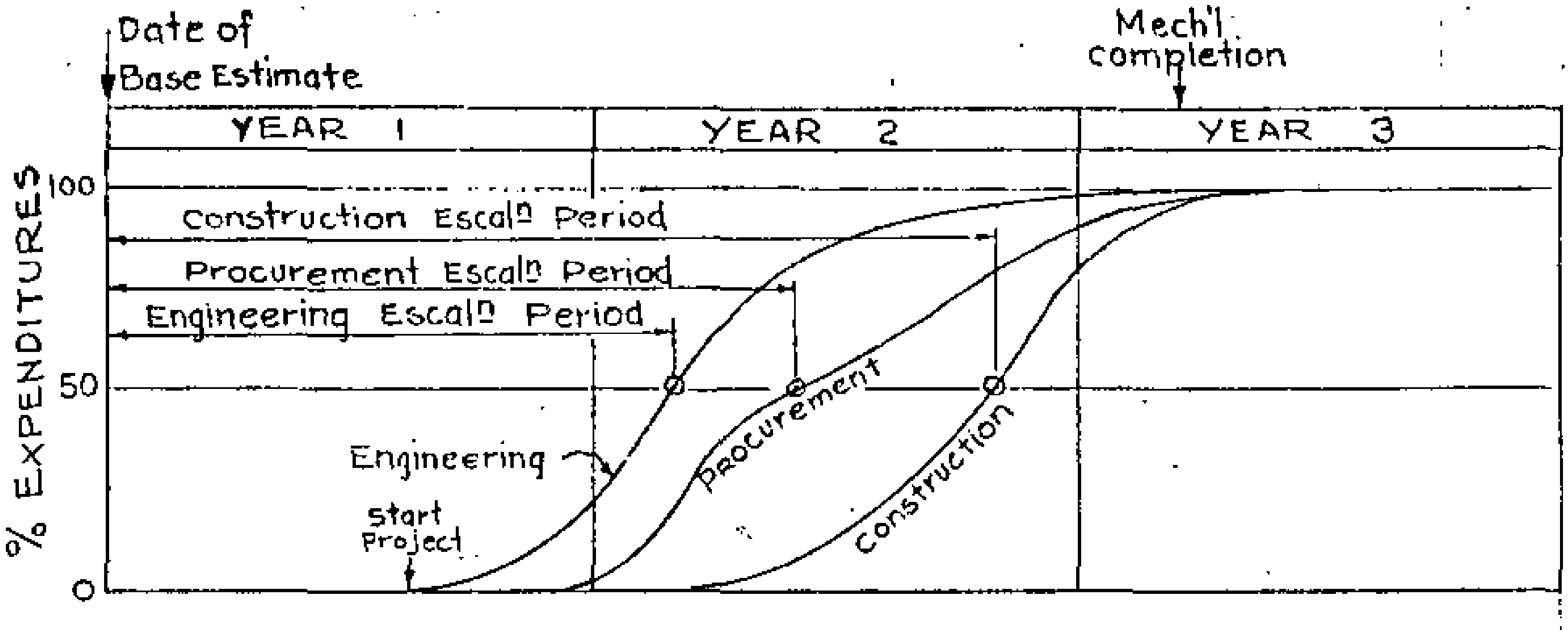


Figure 19

ESCALATION



Based on Cash Flows

Figure 20

ESCALATION CALCULATION Date Jan. 1979

Item	Am't in Estimate $000 (1)	Base Date in Estimate (2)	Expected Date of Expend. or C/G Spending (3)	Escalation Period (4) = 2 TO 3	Annual Escalation Rate % or Cost Index Ratio (5)	Escalation Factor (6)	Rates of Exchange: Current Estimate Basis (2) (7)	Rates of Exchange: Forecast Rate of Exch. at Time of Expenditure (8)	Rate of Exch. Factor (9) = 8/7	Overall Factor (10) = 6 x 9	Am't of Escalation $000 (11) = 10 x 1 − 1
Material from: UK - Equipment	3810	Jan. '79	Mid '80	1.5 yrs.	390/330	1.18	$2.4025/£	$2.15/£	.895	1.056	213.5
Italy "	1479.7	"	"	"	More same as UK.	1.18	$0.001435/lire	0.001265	.882	1.04	59.5
US "	2283.1	"	"	"	7%	1.107	$1.195/$US	1.14	.954	1.056	128.
" "	2115.6	"	2nd Q '80	1.4 yrs.	7%	1.10	$1.195/$US	1.14	.954	1.05	106.
Germany "	799.8	"	2nd Q '80	1.4 yrs.	4%	1.06	$0.645/DM	0.662	1.026	1.09	72.
Canada	10334.8	"	3rd Q '80	1.65 yrs.	'79 - 7½% '80 - 8%	1.13	—	—	—	1.13	1344.
Total Material	20823.										1923.
Direct Const. Labour	456	"	'79	1 rate change	'79 - 5¾%	1.0575	—	—	—	1.0575	26.
	3595	"	'80	2 " "	'80 - 8%	1.142	—	—	—	1.142	511.
	1013	"	'81	3 " "	'81 - 8%	1.233	—	—	—	1.233	236.
All const^n Indirects	9189	"		Same overall average as labour.						1.153	1406.
All Engineering:											
	2291	"	'79		'79 - 9%	1.09	—	—	—	1.09	207.
	3804	"	'80		'80 - 10%	1.2	—	—	—	1.2	761.
	1077	"	'81		'81 - 9.5%	1.31	—	—	—	1.31	334.
Total	$42,254.										$5404.

S E S S I O N

O N

C O S T   C O N T R O L

COST CONTROL PROGRAM

INDEX TO FIGURES & TABLES

C O S T   C O N T R O L

This paper concerns cost control as it applies to the capital cost of process plants and similar projects.

DEFINITION

Cost Control may be defined as the execution of a project so as to minimize the cost which is generally measured against a budget.

Any project must be defined by scope and quality. Hence, Cost Control may be defined as the optimization of quality and cost in executing a plan.

More broadly speaking, it may be defined as the most efficient use of money, men, materials and time to attain an overall objective at the most advantageous cost. Thus, cost control reaches out far beyond a specific budget and embraces every facet of the engineering procurement and construction function.

BROAD PRINCIPLES

Consider the purchase of an automobile.

Some people always buy top quality and are convinced that it pays off. Others buy on price and are equally convinced that it pays off. One person buys a Rolls Royce to get the very best in quality. Another person may buy a standard, relatively low price automobile on the basis that it will perform reasonably well, and will take him where he wants to go and bring him back again with few breakdowns. A third person may buy a standard type car, but insists on loading it up with chrome, push buttons, radio, power steering, etc.

If we relate this to a plant project, we find there are engineers who promote a good sound and reliable design that has many built-in extras which provide for future modifications far into the future; another wants the plant buildings to be all dressed up to create a special public image; another may want to provide a stripped down plant to keep first costs to a minimum and let some-one else worry about subsequent costs; and ultimately the person charged with the responsibility of operating the plant after it is built, will strive to obtain every conceivable item that could reduce his operating costs and minimize his operating problems.

Each person may be sincere in what he is promoting, but it is obvious that there must be a uniform consistent policy, so that all persons involved understand it and apply it. Thus, cost control starts with a "Management Directive". Such a directive will outline the policy to follow as regards:

- quality
- design philosophy
- basic objectives
- responsibilities

Operating within this policy, a cost control system must operate and be effective.

In its broad concepts, cost control in any organization is an integral part of a management system. It cannot be readily separated from other management functions. Management must believe in it and want it.

Management must bear responsibility for it.

Management must be accountable for it.

Essentials of Good Control

Looking at the broad picture, what then are the essentials of good cost control?

The following requirements are all significant:

1. Good management leadership; hence, good morale.
2. Good capable and experienced personnel.
3. Good organization.
4. Good approval system.
5. Good procedures.
6. Good scope definition.
7. Good planning and scheduling.
8. Good estimating.
9. Good cost control system.
10. Good reporting.
11. Good communications.

1. Good Management Leadership

Cost control starts at the top.

Management must want it.
Management must demonstrate that it wants it.
Management must organize for it.
Management must understand the system set-up for it.
Management must manage so as to make the system work.
Management must give credit and develop pride when such is justified.
Management must instill in its personnel a positive approach to cost control and foster a climate of cost consciousness and awareness of the cost impact of every significant decision.

Unless Management is prepared to lead in the above manner, it should not expect its subordinates to perform with top efficiency.

2. Good Capable & Experienced Personnel

It's an old adage: If you want a good job, use good experienced personnel. Don't send a boy on a man's errand. There is no substitute for good personnel. A cost control system

2. Good Capable & Experienced Personnel (cont'd)

will provide support and assistance to enable good personnel to perform well - but a good system cannot make up for the shortcomings of inexperienced or incompetent personnel.

3. Good Organization

Good personnel cannot perform at peak efficiency if they are operating in a poor organization.

Management must set up an organization geared to the requirements of the project with responsibilities clearly defined so that each person understands where he fits into the organization and what his responsibilities are.

4. Good Approval System

A firm hand is required on expenditures at all times. Hence, an approval system.

For good control no one person should have free licence to spend unlimited funds. All persons in responsible positions should be given limits in spending or scope for which they alone are accountable. Beyond the limit or scope, some other person of higher rank must give his approval before the funds can be committed. Thus, the greater the sum of money involved, the higher the approval body. This process must be practiced right up to the Project Manager. The Project Manager in turn is held accountable for the entire project within a precise scope and a precise cost. If any departure from the limits are anticipated, then he in turn should require the approval of a higher authority before the change or expenditure can be made.

A good approval system would also incorporate specific cost reviews at certain periods in the project life. These would occur in addition to the regular reporting procedures.

5. Good Procedures

Not only are procedures required to spell out the requirements and operation of the cost control system, but similar procedures are required to embrace all facets of design, project operation, responsibilities, documentation etc. A project team must work together to attain common goals and procedures are essential for unifying this purpose. Procedures should be clearly written, complete with examples and sample forms. Such procedures provide excellent check lists and reference lists.

6. Good Scope Definition

One of the greatest contributors to overruns is changes in scope. The first requirement for any project is to define the scope in as much detail as possible and most certainly at the time that an appropriation type estimate is submitted for sanction, a very detailed scope definition is essential. Only too often are estimates submitted for sanction of funds when the scope has not been adequately detailed or adequately investigated. Whenever this occurs, it is a red warning flag - even before the project has scarcely begun.

7. Good Planning & Scheduling

Planning starts at the early estimate stage and intensifies as the project progresses. Management should recognize that planning and scheduling is a very important function on any project, and provide proper and adequate planning and scheduling staff to suit the project in question.

Failure to maintain schedules is another large contributor to overruns. Hence, schedules must be well planned, realistic, and maintained.

8. Good Estimating

A cost estimate should reflect within a reasonable degree of accuracy exactly what the project or item in question ought to cost. If the estimate is too high, it fails to provide proper target guidelines and, in all faithfulness to Parkinson's Law - all costs rise to meet the amount of money available. If the estimate is too low - sooner or later the persons involved will realize that it is unrealistic, become discouraged and lose their enthusiasm to equal the challenge.

Estimates are a major part of the control system and must, therefore, be realistic in terms of attainability with good productivity. When an estimate is used for cost control, not only should the bottom number be realistic, but all individual items of any significance should also be realistic.

9. Good Cost Control System

The cost control system embraces the procedures, documentation, responsibilities, activities, etc. required to enable the Project Manager to answer the questions:

where he's been
where he's at
where he's going
what action he needs to take.

In recent years, the execution of this function has become a specialized discipline under the title of "Cost Control Engineer". On large projects, the title may be Project Control Manager or Project Services Manager, etc. Regardless of title,

9. <u>Good Cost Control System</u> (cont'd)

the function has become so important that the person responsible for it is often regarded as the Project Manager's right arm.

10. <u>Good Reporting</u>

To be on top of any project, those responsible must have reliable information on the status of the project at all times. Reports must be timely, they must be reliable and they must reflect the type of information that is required. All reporting is an integral part of the cost control system.

11. <u>Good Communications</u>

The best report system in the world will have little value if the persons involved are not aware of the information in them. The general procedures should spell out the desired distribution of all reports and documents which should be distributed promptly. Similarly, for attendance at meetings.

To maintain good morale and team effectiveness, there must be good communcations. The left hand must know what the right hand is doing.

If we consider all the foregoing items, it becomes apparent that cost control in its broader sense, embraces nearly every facet of the engineering function.

It doesn't matter whether we are talking about contractors, or engineering companies or owners, the same principles apply and they are all essential for good control.

At this point, let us discuss in more detail the "Specific Principles" of the Cost Control System.

COST CONTROL CYCLE

Assuming a company has all the prerequisites for good cost control, ie. established quality and philosophy, good management, good personnel, good organization, etc. what then is necessary to have effective cost control?

Figure 1 depicts the cost control system.

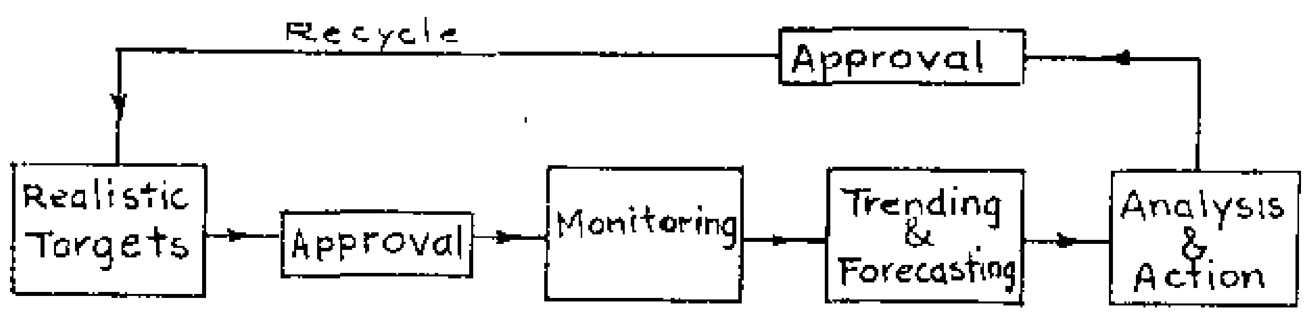


Figure 1

In very simple form, it is a 4 stage system with an approval system superimposed on it. There needs to be a realistic target to shoot at. There needs to be a way of measuring the progress, i.e. monitoring.

Based on the feedback from the monitoring process, a trend can be established and from this trend a forecast of the final picture. The forecast will indicate if a potential overrun exists and, if so, it must be analysed to determine what action can be taken to bring it back to plan.

Thus, cost control has been likened to an instrumentation system. A control point is established, a sensing device measures the current status, if a departure from the control point is indicated, a control valve or similar device is altered to make the correction and then the cycle repeats itself.

All cost control, no matter how complex a project may seem, boils down to this simple process. Thus, in attacking the complexities of a large project, this simple system should be the framework on which to relate all activities. All future discussion will relate back to this simple principle.

Thus, Figure 2 is an elaboration of Figure 1.

BASIC COST CONTROL SYSTEM

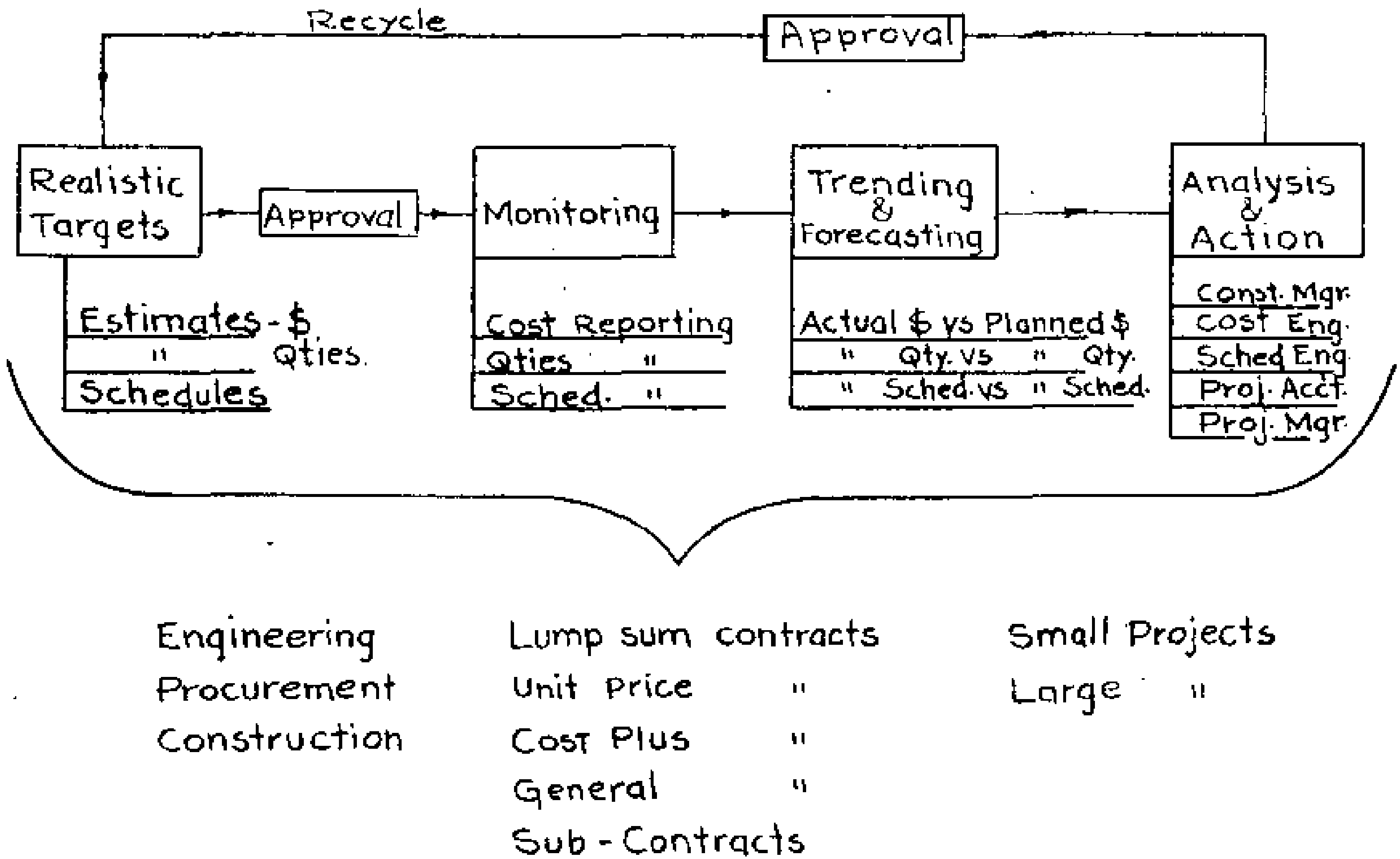


FIGURE 2

Realistic Targets

This calls for good reliable estimates and schedules tailored to the purpose for which they are made and, in the final stages, a definitive estimate and detailed schedule which are used specifically for control purposes. The breakdown of the estimate must be kept up-to-date to reflect the changing dynamics of the project; similarly for the schedule.

Estimates were discussed previously.

Generally, the progression is from an "E" or "D" type estimate to a "B" type definitive estimate which becomes the project control estimate. At this stage, the scope is thoroughly defined through the detailed items of the definitive estimate plus a memo or document which complements the estimate and provides a descriptive outline of the scope.

On a large project, initial approval may be required in advance of when such a control estimate can be produced. In this event, a 2 stage approval is followed. The first approval is based on probably a good quality "C" type estimate and authorizes engineering to proceed to complete a "B" type definitive estimate and possibly to order long delivery equipment. When engineering is approximately 25 to 35% complete, a good definitive estimate can be produced. Final approval is based on this estimate and this establishes the realistic control estimate for the project. In practice, the actual control is exercised through the medium of various quantities as well as cost. Hence, it may be based on numbers of drawings, manhours of engineering and draughting, construction manhours, yards of concrete, tons of steel, etc. etc. In every case, the principle is to establish realistic quantities all related to the costs in the definitive estimate.

The approval also applies to the Master Project Schedule, which has been developed in conjunction with the definitive estimate. This schedule becomes a control document of equal importance to the control estimate. It represents the precise plan for the project, pinpointing the time frame and all key dates that apply to the control estimate. Failure to attain the schedule generally results in higher project costs and hence may be a significant contributor to an overrun. The late project completion could also have a bearing on the marketing of the product and hence the profitability of the operation. An extension of the schedule could thus have a double barrel effect on the profitability.

Clearly, the definitive estimate and the master schedule represent the base against which all performance and progress is measured and compared. They must be generally tight, but yet attainable.

Monitoring

The monitoring process concerns the entire system documentation and reporting which is necessary to indicate the progress to date. Thus, there are cost reports, manhour reports, quantity reports and schedule reports. The heart of the system is the cost code and the master schedule. The process starts at the conceptual stage and continues through engineering, draughting, procurement and construction.

Monitoring provides an up-to-date record of the financial and time picture of the project on a regular basis, consistent with the requirements of the various levels of management.

In recent years, computerized techniques coupled with the cost codes have made a tremendous contribution to this function, improving the number of reports that can be made, increasing the flexibility of reports that can be requested and improving communcations.

Trending & Forecasting

Data from the Monitoring System plus progress to-date and detailed knowledge of the project scope enables trends to be developed and hence, a forecast of the final picture. This process is applied to many selected components of engineering, procurement and construction, all related through the cost code or the schedule to the basic targets that were initially established. Where manpower is involved, it will include trends in productivities.

In this area, graphical depictions are commonly used, generally involving "actual vs. plan". Thus:

Actual cost vs. planned cost
Actual manhours vs. planned manhours
Actual quantities vs. planned quantities
Actual progress vs. scheduled progress.

Based on the above data forecasts of final costs or final completion dates are developed which can be compared with the original targets.

Analysis & Action

Significant deviations from the targets can be investigated and action taken wherever practical to bring the issue back onto plan.

Obviously, all departures from plan cannot always be corrected. The success of the system depends on the speed at which problems can be detected and the speed at which a corrective action can be taken. Management must be on top of the problem areas at all times and this, in turn, depends on the efficiency of the system and its effectiveness.

Approval System

The Approval System is an ever present process superimposed on the overall system. It starts with approval of the project itself. It comes into play for "changes in scope". A work order system may be used as a means of controlling engineering. Field Work Orders are essential on construction work and require tight control.

Some construction companies execute all work on a work order system with specific approvals. Contingencies should be controlled through certain approvals. Changes on lump sum contracts require approvals, etc. etc.

The entire approval system is based on the principle that responsibility for a complete project be divided into many components, that responsibility for each component be delegated to specific individuals, that the individual be given authority to carry out the responsibility and also be held accountable for it. The approval system is a formal procedure to assist him to stay on top of the issues and his approval is a constant reminder of his accountability.

The foregoing principles apply to:

Engineering
Procurement
Construction

They apply to:

Small projects
Large projects

They apply to:

Lump sum contracts
Unit price contracts
Cost plus contracts
General contracts
Sub-contracts

The only difference is in the details and how they are adapted to specific applications.

APPLICATION AND DOCUMENTATION

The following sections describe and illustrate some of the forms and documents which are used in applying the foregoing principles.

Project Cost Statement

The Project Cost Statement compiled in keeping with the Cost Code, provides the financial picture of the project. It is the ultimate and official financial document which reflects the fruits of the overall cost control system.

It must be fully integrated with the cost estimate, the cost code and with all the supporting back-up documents which collectively contribute to the cost control on the project and generate data for the statement.

Consistent with the flexibility of the Cost Code, the Cost Statement must also be flexible to provide the information required by various levels of Management. Thus, senior management may require a condensed summary to reflect the general financial status, project supervision will require more detailed breakdowns especially in their areas of responsibility, while the cost engineer and accountants will want the most comprehensive, detailed extension of the entire report.

The ideal system will have the flexibility to provide two types of reports:

1) The first will provide the cost breakdown exactly the same as the cost estimate and essentially in the form as desired by the owner. (i.e. based on the breakdowns in Column 1 of the Cost Code).

2) The second will be based on a re-cast of the estimate to reflect the various construction contracts and the manner in which the construction work is executed. Thus, in re-casting the estimate, Column 8 of the Cost Code would take priority.

Table 1 is an example of a typical format for such a report.

Table 2 is a sample summary of an actual project which is suitable for senior management. Note that Column 12 is dynamic and incorporates justified changes in order to reflect the "realistic targets". Thus, valid comparisons can be made with the Forecast Final Cost in Column 11. Also, note the comments which indicate the status of the reserves and the extent to which they have already been allocated.

The Cost Statement is generally issued on a monthly basis and on large projects is computerized. Numerous back up reports and

Table 1

PROJECT COST STATEMENT

Proj No ____________

Title ____________

Period from ____________ to ____________

All Figures in $ x 000's

Sheet No. ____________

Date of Issue ____________

Report No. ____________

CODE	DESCRIPTION	AM'T AUTHORIZED (DEF. EST.)	APPROVED MAJOR CHANGES IN SCOPE	ALLOCATED RESERVES	EXPENDITURES		OUTSTANDING COMMITMENTS	EXPEND. + COMMIT. TO DATE	ESTIMATE TO COMPLETE	FORECAST FINAL COST	REVISED BUDGET COL. 3 + COL. 4 REDISTRIBUTED	(OVER) OR UNDER
					THIS PERIOD	TO DATE						
1	2	3	4	5	6	7	8	9 = 7 + 8	10 = 11 − 9	11	12	13 = 12 − 11

Table 2

PROJECT COST STATEMENT

Proj. No. ____________ Sheet No. ____________

Title ____________ Date of Issue ____________

Period from ____ ____ to ____________ Report No. ____________

All Figures in $ x 000's

CODE	DESCRIPTION	AMT AUTHORIZED (DEF. EST.)	APPROVED MAJOR CHANGES IN SCOPE	ALLOCATED RESERVES	EXPENDITURES THIS PERIOD	EXPENDITURES TO DATE	OUTSTANDING COMMITMENTS	EXPEND + COMMIT. TO DATE	ESTIMATE TO COMPLETE	FORECAST FINAL COST	REVISED BUDGET COL. 3 + COL. 4 REDISTRIBUTED	(OVER) OR UNDER
1	2	3	4	5	6	7	8	9 = 7 + 8	10 = 11 − 9	11	12	13 = 12 − 11
	DIRECT COSTS											
100 / 0000	BATTERY LIMIT											
200 / 0000	STOR. & HANDLING											
300 / 0000	UTILITIES											
400 / 0000	SERVICES											
	Sub-Total Direct Costs											
	INDIRECT COSTS											
500 / 0000	CONSTN. INDIRECTS											
600 / 0000	ENGINEERING											
700 / 0000	SPECIAL INDIRECTS											
	Sub-Total Indirects											
	Total	(C) 15,900	(D) 300	(E) 900						17,500	(X) = 17,100	(400)
900 / 0000	RESERVES	R = 1,600								ESTIMATED 1,100	(Y) = 700	
	Total Project	(A) 17,500	(B) 300							18,600	(Z) = 17,800	(800)
800 / 0000	COMMISSIONING											
	Total Commissioning											

THESE COLS. MAY BE OMITTED ON CONDENSED REPORTS (columns 6, 7 and 8)

Sample Summary Sheet with Key Totals Illustrating an Actual Case.

LEGEND.

A + B = Am't Approved

X = C + D + E

E = Am't of Reserves Justified, Approved & Allocated to Specific Items

Z Max = A + B

Y = Z − X Indicating Am't of Reserves Still Available supporting documents are necessary in order to compile it, mostly involving the accounting and cost engineering groups. The accounting group takes responsibility for generating all data up to and including Column 9, i.e. Expenditures + Commitments to date. The Cost Engineer is responsible for generating the data for Columns 10, 11, 12 & 13.

Regardless of whether it is engineering, procurement or construction, the same cost control cycle is followed, using specific documents suitable to the particular need or situation and these provide the data which generate the input for the Cost Statement.

The comprehensive detailed copy of the Cost Statement will be the most detailed cost breakdown of the entire project. It will include each individual equipment item, all bulk materials, construction labour, components of indirect costs, etc. all properly coded and in a form which can be identified, charged and forecast consistently. Thus, each item can be assessed individually by the Cost Engineer to forecast the expected final cost - using various techniques and trending documents (to be discussed later) plus experience and good judgment.

Where lump sum contracts are let, they may be recorded on one line or by agreed breakdown, but an on-going assessment of extras and potential extras must be added in order to develop the forecast final cost.

Design

The definitive estimate provides target figures for:

- Engineering Costs
- Engineering Manhours
- Draughting Costs
- Draughting Manhours
- No. Drawings
- Master Schedule

Engineering costs and manhours can be monitored and trended using typical "S" curves. The shape of the "S" curves is generally based on experience in relation to the schedules and it is advisable to first develop a set of "S" curves for the complete project. Figure 3 illustrates a typical set of "S" curves for a complete project showing separate graphs for engineering, procurement and construction. The start of project, start of construction and completion of construction provide the framework on which the graphs are built. Thereafter the following "rules of thumb" are recommended for developing the "S" curves.

FIGURE 3

DATE	DRAUGHTING		ENGINEERS		
	Am't	%	Am't.	%	

MAT'L COMMIT		CONSTRUCT'N		COST + COMMIT TO-DATE	
Am't	%	Am't	%	Am't	%

PROJECT NO. ______

______

______

______

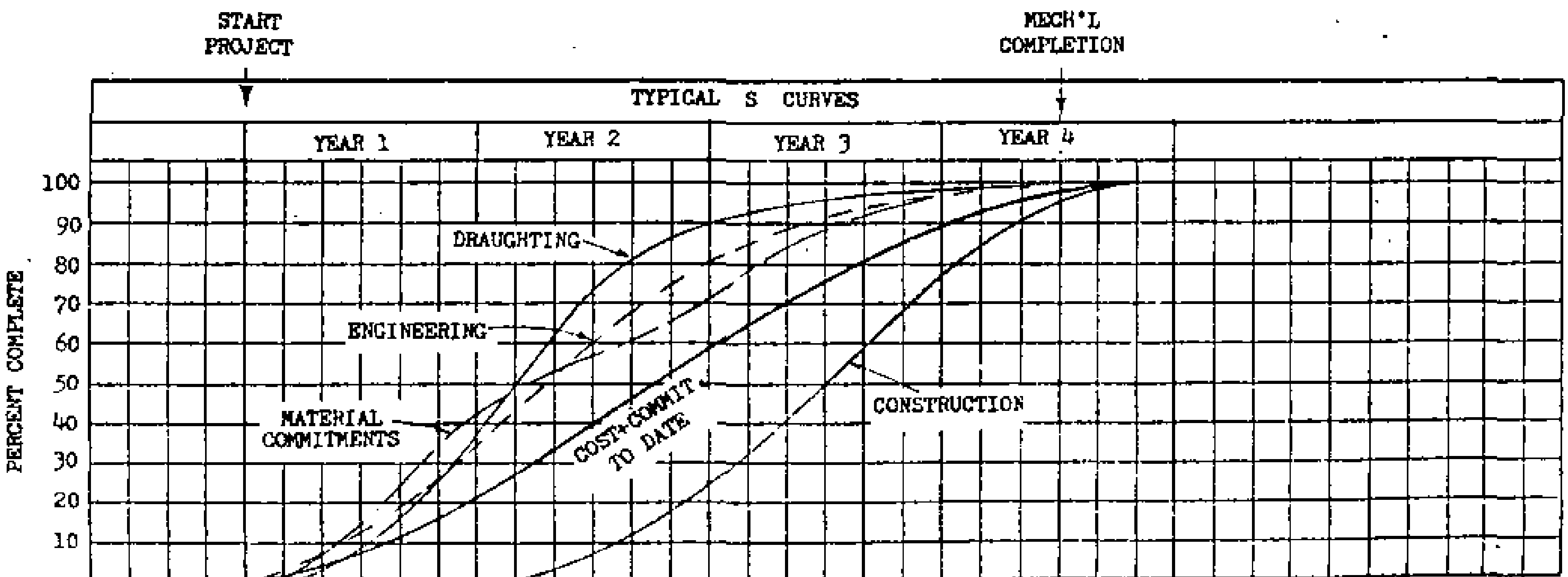
______

______

______

SCHEDULED ————

ACTUAL — — — — —



Start of construction	- Draughting 40 to 50% complete Engineers 30 to 40% complete Material Commitments 35 to 50% complete
Construction 50% complete	- Draughting 90 to 95% complete Engineers 75 to 85% complete Material Commitments 90% complete
Construction 75% complete	- Draughting 95 to 98% complete Engineers 92 to 97% complete Material Commitments 90 to 95% complete
Construction 90% complete	- Draughting 99% complete Engineers 98% complete Material Commitments 99% complete
Mechanical Completion	- Construction 95 to 98% complete.

These rules of thumb, coupled with the Master Schedule for the engineering, enable the "S" curves to be developed.

Figure 4 is a typical Master Schedule drawn up to highlight the "front end" of a project.

The above rules of thumb, coupled with this schedule, enable a general set of "S" curves to be developed.

Thus, "S" curves may be developed for engineering manhours or dollars, draughting manhours or dollars, number of drawings, etc. Such graphs may be developed for "Total" manhours, or for individual disciplines such as civil engineering, mechanical engineering, electrical engineering, etc.

These "S" curves are refined as more precise details of scope and schedules are developed.

A decision as to what graphs to develop is a judgmental one depending on the size of the project and the significance of the specific items on total project cost. Thus, for a small project, separate "S" curves for total engineering manhours and total draughting manhours may be sufficient, while for a large project, it would be advisable to develop separate curves for each discipline.

Figure 5 illustrates a typical "S" curve for "Engineering Manhours versus Time". Note the tables which are convenient for recording the month to month data.

Figure 5

PROJECT NO. ______

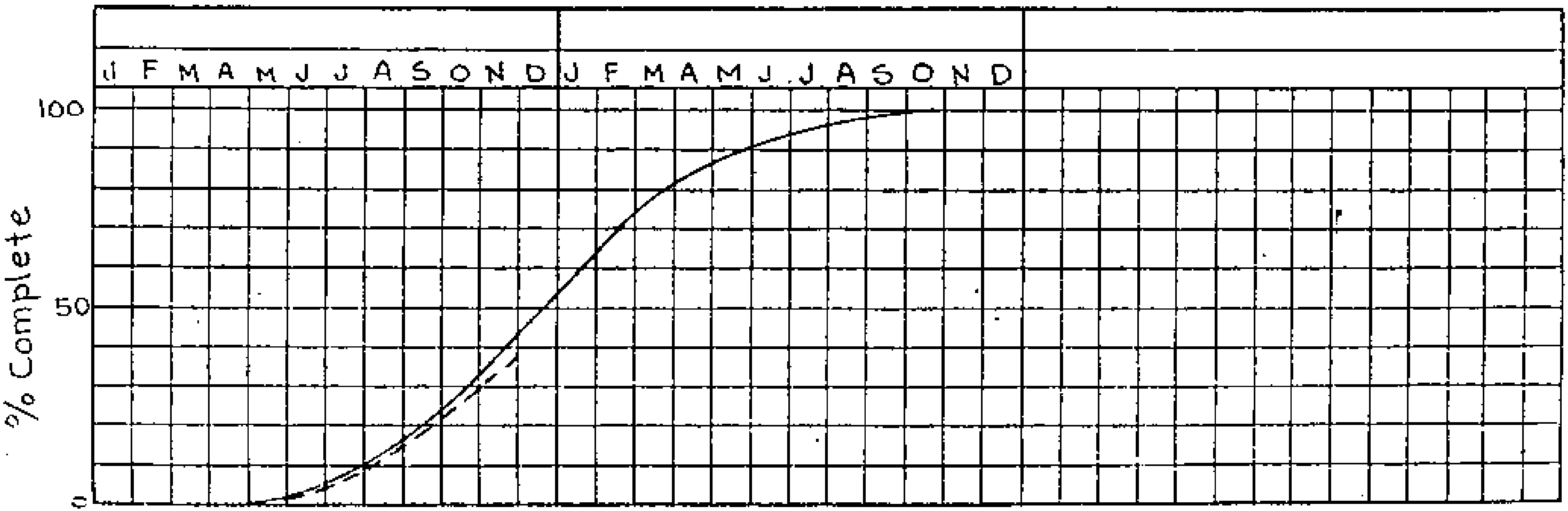
Engineers Manhours vs Time

Date	Sched. Mhrs.	Cum. Sched. Mhrs.	% Sched	Cum. Actual	% Compl.
May	400	400	2	350	
June	700	1100	5.5	1000	5
July	900	2000	10	1800	9
Aug.	1400	3400	17	3000	15
Sept.	1600	5000	25	4200	21
Oct.	1600	6600	33	5800	29
Nov.	2000	8600	43	7600	38
Dec.	2000	10600	53		
Jan/80	2000	12600	63		
Feb	2000	14600	73		
Mar	1800	16400	82		
Apr.	1000	17400	87		

			% Sched.		
May	800	18200	91		
June	600	18800	94		
July	400	19200	96		
Aug.	400	19600	98		
Sept.	200	19800	99		
Oct.	200	20,000	100		

SCHEDULED ————

ACTUAL - - - - -



E X H I B I T 1

EXHIBIT 1 which follows contains a complete procedure for the control of draughting. Note particularly the Productivity Report, which contains an "S" curve of "Drawings versus Manhours" and the corresponding "Productivity". These graphs include tables for recording data and developing the forecast final manhours and forecast final cost on a monthly basis. They become the source of the forecast final cost to be incorporated into the overall Cost Report for the project. Similar graphs can be used for many applications in the cost control function.

Such "S" curves are the documents which show up quickly a departure from the plan. They provide the red warning flags which call for immediate investigations into the cause, followed up by a decision as to what action can be taken to correct it. Some times, in order to maintain the desired schedule, additional costs must be incurred. This is a decision for the Project Manager, always remembering that Cost Control is the optimization of cost and time.

DRAUGHTING	DRAWING PROGRESS AND CONTROL PROCEDURES	EP No. DRG 1 Page 1 of 9 Author Responsibility Cost Engineering Date

This Engineering Procedure contains six appendices.

1. SUMMARY

This Engineering Procedure provides information concerning documents to use and procedures to follow in the planning and control of Design/Draughting Manhours and Drawing Units.

2. PURPOSE

The purpose of this Engineering Procedure is to advise project engineers of the procedures used in the Department for project design control. Selected use of the procedures and documents described herein can be a useful means of measuring drafting progress and performance and relating activity in this area to the project schedule and budget.

3. PRINCIPLE

There exists several control documents of which all or some may be used, depending upon the control requirements of any given project. These are as follows:

a.	Drawing List and Control	EDF-54	Appendix "A"
b.	Drawing Progress and Control	EDF-79	Appendix "B"
c.	Progress Report	EDF-81	Appendix "C"
d.	Productivity Report	EDF-82	Appendix "D"
e.	Draughting/Engineering Summary Manhour Report	EDF-99	Appendix "E"
f.	Draughting/Engineering Summary Cost Report	EDF-83	Appendix "F"

3.1 RESPONSIBILITY FOR PREPARATION

The Supervisior - Draughting is responsible for the preparation and maintenance of the Drawing List & Control, and Drawing Progress & Control Reports. The Project Engineer is responsible for all the remaining charts and reports but may obtain this service from the Cost Engineering Section. At the commencement of each project, the Project Engineer is required to arrange with the Cost Engineering Section the exact responsibility in developing the various control procedures for the particular project. Assistance on the detail preparation of this data may also be obtained from the Cost Engineering Section.

3.2 DRAWING LIST AND CONTROL (APPENDIX "A") FORM EDG-54

This document must be used to identify every project drawing, its date of issue, revisions and its degree of completion. It is maintained by the Supervisor - Draughting and up-dated on a regular basis consistent with the size of the project.

The form is generally self-explanatory with the exception of the following:

A. CODE (Column "A") refers to the stage the drawing is currently in and is coded in accordance with the first four codes outlined in the lower left corner of the form.

B. PERCENT COMPLETE (Column "B") is to be filled in, in accordance with the last two codes identified in the lower left corner of the form.

3.3 DRAWING PROGRESS AND CONTROL (APPENDIX "B") FORM EDF-79

This form is self-explanatory. It will be used in conjunction with form EDF-54, as a back-up document containing all pertinent statistics required to schedule manpower and identify productivity and progress. These will be kept in a three-ring binder for each major project and will be up-dated and replaced throughout the duration of the design period by the Supervisor - Draughting.

3.4 PROGRESS REPORTS AND PRODUCTIVITY REPORTS (APPENDICES "C" AND "D") FORMS EDF-81 AND EDF-82

These documents provide standard forms which should be used for various applications in depicting quickly and graphically the status of manhours, output, progress and productivity. They are primarily for internal control and monitoring and have their greatest application on the larger, longer duration projects. They are also very valuable in monitoring work being done by consultants.

These two documents are used in conjunction with one another. The Progress Report identifies forecast completion dates of the drawing package being monitored. The Productivity Report summarized the statistics of the latter together with manhour data to produce a productivity factor with forecast final manhours and forecast final costs.

These two forms are similar in appearance with relative statistics identified on the left against a plotted "S" curve of actual vs. scheduled progress on the right. Although somewhat self-explanatory, the following points should be noted.

a. The original scheduled "S" curve will be drawn on the chart on the right side of the form and the actual progress line plotted against it. Although every endeavour will be made to align the actual progress with that which is scheduled, occasionally, for one reason or another, the actual may deviate from the scheduled to a point where realistically it cannot return. Should this occur, it is of vital importance to overcome natural resistance to such changes and recognize that the problem must be identified in order that a new "S" curve can be drawn to reflect the probable trend. With the new curve showing, it will then be possible to realize the impact of the progress of the area and/or discipline in question against the overall Design Schedule. This may result in early changes to construction phasing and/or types of contracts.

b. The lower right chart on the productivity Report is used to graphically illustrate the overall productivity to date. A Productivity above 1.0 is favourable while a productivity below 1.0 is unfavouable.

These forms will normally be prepared by the Cost Engineer and will be distributed at the discretion of the Project Manager in accordance with the scale and scope of the project.

Note: On all graphs if the actual curve is above the scheduled curve, it indicates a favourable situation. If below the scheduled curve, an unfavourable situation exists.

4. DRAUGHTING/ENGINEERING MANHOUR AND COST REPORT SUMMARIES (APPENDICES "E" AND "F" FORMS EDF-99 AND EDF-83

These two Management Reports are identical, except one is in "Manhours" and the other is in "Dollars" and shall be used on all major projects. The Manhour Report (EDF-99) summarizes the scheduled, actual, forecast and trending manhour expenditures. These statistics are then directly related to dollars on the Summary Cost Report (EDF-83). The documents are self-explanatory in nature and must be completed monthly in conjunction with the project review meetings. Their circulation is at the discretion of the project manager, with copies always sent to the Cost Engineer.

5. COORDINATION WITH OTHER PROJECT GROUPS

It is essential that any deviation in the forecast duration of the design work be noted with all inherent problems and/or opportunities identified and that this data is immediatley delivered to such members of the project team which would be directly affected by such information (e.g. Scheduling, Construction Management, Procurement/Expediting, Cost Engineering, Project Management, etc.).

DRAWING LIST & CONTROL

PLANT OR PROCESS	WORKS OR LOCATION	DIVISION OR GROUP	PROJ NO.	SECTION AREA

STAGE	CODE	DRAWING NUMBER	TITLE	ISSUED FOR CONSTRUCTION — REVISION / DATE OF ISSUE	% COMPLETE AND REMARKS — DRAUGHTING	CHK

CODE

- — DWG STARTED
- ┌ DWG COMPLETED (NOT CHECKED)
- ☐ DWG CHECKED & APPROVED
- [ ] ISSUED FOR CONSTRUCTION
- PROGRESS LAST PERIOD
- PROGRESS THIS PERIOD

REVISED

ISSUED

E.P. NO: DRG 1
APPENDIX: A (1)

SHEET OF

EDF 51

DRAWING LIST & CONTROL

PLANT OR PROCESS	WORKS OR LOCATION	DIVISION OR GROUP	PROJ NO.	SECTION PLOT PLANS : PLANT LAYOUT AREA GENERAL FLOWSHEET

STAGE	CODE	DRAWING NUMBER	TITLE	ISSUED FOR CONSTRUCTION: REVISION / DATE OF ISSUE						% COMPLETE AND REMARKS: DRAUGHTING	CHK
	'A'									'B'	
	□	FS-107	General Flowsheet								
	□	AEG-21700	Site Plan	0 INFO MAY. 31 73							
	□	AEC-21701	Plant Layout Sh. 1.	2 Jul. 6. 73							
	⌐	AEG-21925	Location Plan (WAS AEK-214)								
C-4		ADG-22992	Site Plan for Unheated Warehouse								
	⌐	BDG-22893	(Telephone Equip. Rm) Off. Shops & Stores Telecom Building Architectural	1 15. 7. 74							
C-4	—	PEG-23057	Laboratory Piping Arrg't	0 AUG. 7. 74							

SAMPLE

CODE
— DWG STARTED
⌐ DWG COMPLETED (NOT CHECKED)
⊓ DWG CHECKED & APPROVED
□ ISSUED FOR CONSTRUCTION
PROGRESS LAST PERIOD
PROGRESS THIS PERIOD

REVISED | ISSUED

SHEET OF

E.P. NO: DRG 1
APPENDIX: A (2)

LOF 71

DRAWING PROGRESS & CONTROL

Completed by: ______ Date: ____________

Discipline	No. of Dwgs	Man Days/ Dwg	Total Man/ Days	Units Complete	% Complete	Previous % Complete	Remarks
							E.P. NO: DRC 1 APPENDIX: B(1)

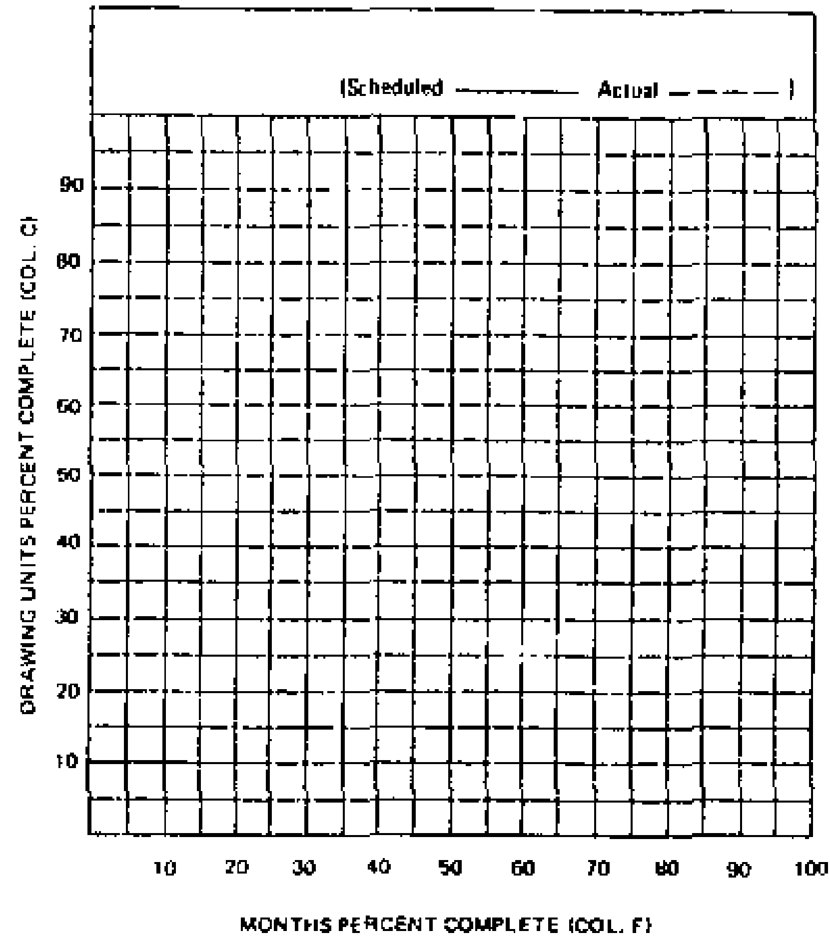
PROGRESS VS TIME

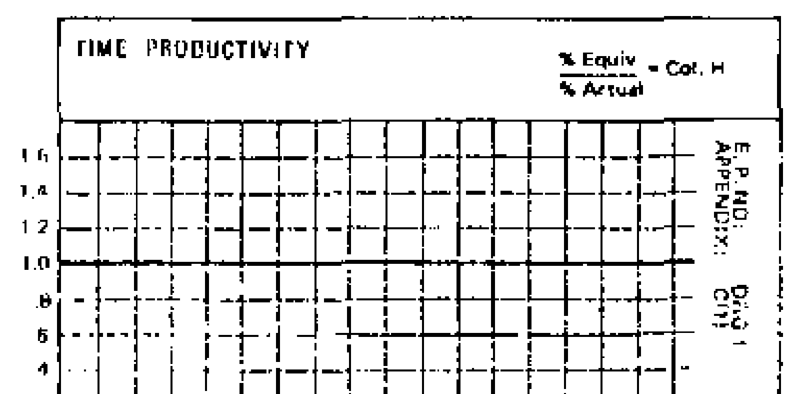
Project No. ______________
Project Title ______________
Completed by ______________

CODE ______________ ITEM ______________

Date End of Month	PROGRESS			TIME			Equiv. % from S-Curve	Time Prod'y % Equiv. / % Actual $\frac{G}{F}$	Forecast Total Time Months $\frac{D}{H}$	Overrun? from Plan Months I − D? =
	Total Budget Units & Changes	Total Units To Date	% Progress $\frac{B}{A}$	Sched. Total Months	Months To Date	% To-Date Actual $\frac{E}{D}$				
	A	B	C	D	E	F	G	H	I	J

Date	Remarks	Date	Remarks





E.P. NO. APPENDIX: Drwg 1 C(1)?

Project No. ____________________
Project Title ____________________
Completed by ____________________

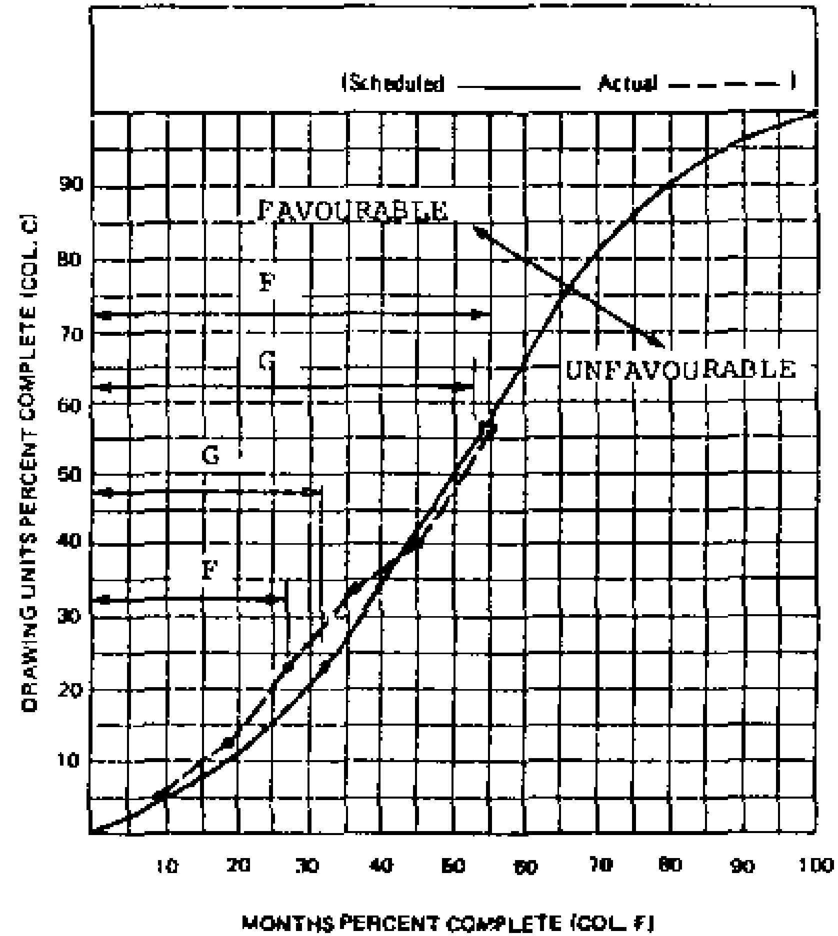
PROGRESS VS TIME

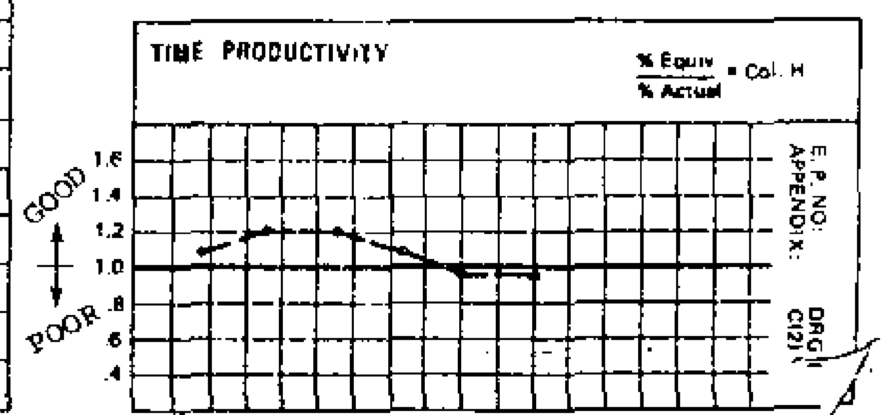
CODE ____________________ ITEM TOTAL DRAUGHTING

Date End of Month	PROGRESS			TIME			Equiv. % from S-Curve	Time Prod'y % Equiv. / % Actual $\frac{G}{F}$	Forecast Total Time Months $\frac{D}{H}$	Deviat'n from Plan Months + or −
	Total Budget Units & Changes	Total Units To-Date	% Progress $\frac{B}{A}$	Sched. Total Months	Months To-Date	% To-Date Actual $\frac{E}{D}$				
	A	B	C	D	E	F	G	H	I	J
Feb.	230	11½	5	11	1	9	10	1.1	10	-1
Mar.	230	30	13	11	2	18	22	1.2	9.2	-2
Apr.	230	53	23	11	3	27	32	1.2	9.2	-2
May	250	85	34	11	4	36	40	1.1	10	-1
June	250	112	45	11	5	45	43	0.96	11.5	+ ½
July	250	141	56	11	6	55	53	0.96	11.5	+ ½

SAMPLE PROGRESS REPORT FOR DRAUGHTING. ILLUSTRATES EFFECT ON TREND OF ADDING ADDITIONAL UNITS.

Date	Remarks	Date	Remarks
May	Added 20 Drawing Units		





Project No. ______________________

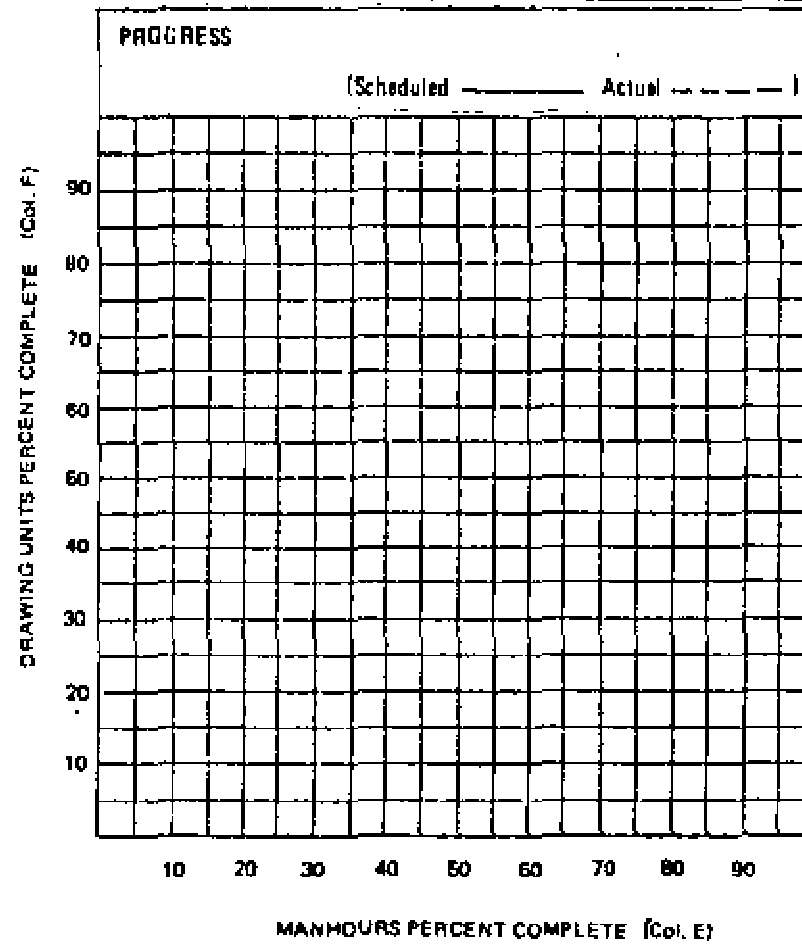
Project Title ______________________

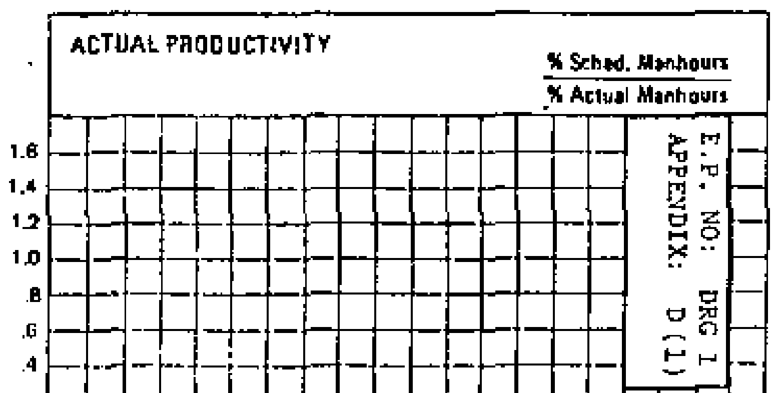
Completed by ______________________

Date	BDGT TOTAL M/HRS & CHNGS	TO DATE M/HRS	SCHED. DWG UNITS & CHNGS	TO-DATE COMPLT. DWG UNITS	% ACTUAL M/HRS USED $\left(\frac{B}{A} \times 100\right)$	% PROG. $\left(\frac{D}{C} \times 100\right)$	PRODUCTIVITY % SCHED M/HRS / F	BDGT M/HRS COSTS & CHNGS ($)	TREND FINAL M/HRS $\left(\frac{A}{G}\right)$	TREND FINAL COST FORCST $\left(\frac{H}{G}\right)$
	A	B	C	D	E	F	G	H	I	J

Date	Remarks	Date	Remarks

PRODUCTIVITY REPORT: (Discipline/Area) ______________________





E.P. NO: DRG 1
APPENDIX: D (1)

Project No. ____________________

Project Title ____________________

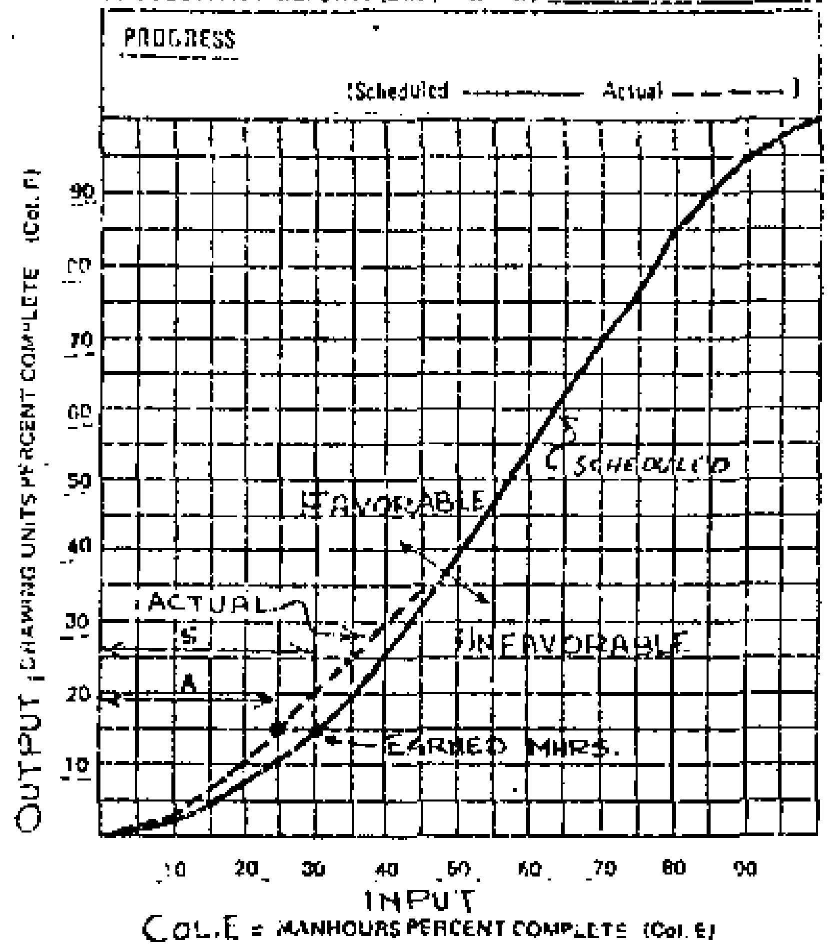
Completed by ____________________

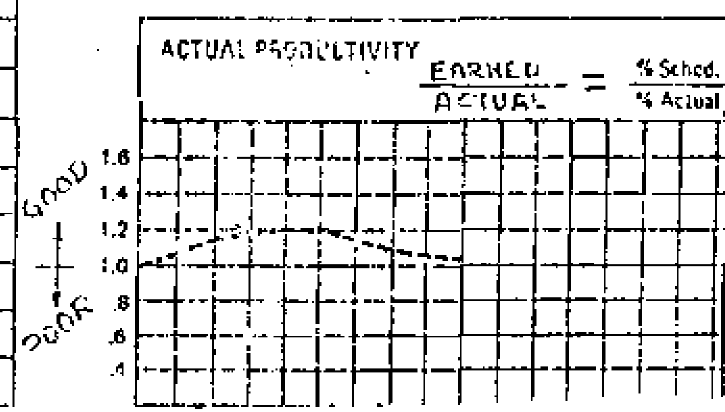
Date	BUDGET TOTAL M/HRS & CHNGS	TO-DATE M/HRS	SCHED. DWG UNITS & CHNGS	TO-DATE COMPL. DWG UNITS	% ACTUAL M/HRS USED ($\frac{B}{A}$ × 100)	% PROG. ($\frac{D}{C}$ × 100)	PRODUCTIVITY % SCHED M/HRS / E	BUDGET M/HRS COSTS & CHNGS ($)	TREND FINAL M/HRS ($\frac{A}{G}$)	TREND FINAL COST FORCST ($\frac{H}{G}$)
	A	B	C	D	E	F	G	H	I	J
15 MAR	10 000	1540	125	10	15 %	7 %	1.2	185,000	9325	154,200
15 APR	10,000	2500	125	20	25	16	1.2	185,000	9315	154,200
15 MAY	10,000	3500	125	35	35	26	1.34	185,000	9770	162,240
15 JUN	11,000	4950	138	48	45	32	1.07	203,500	7580	195,700

SAMPLE

Date	Remarks	Date	Remarks
25 MAY	Added 13 Drawing units ≈ 1000 M/hrs.		

PRODUCTIVITY REPORT: (Discipline/Area) ____________________





E.P. NO: DRG 1

APPENDIX: D(2)

Project Number ____________________

Project Title ____________________

DRAUGHTING/ENGINEERING SUMMARY MANHOUR REPORT

Date ____________ Completed by: ____________________

CONST. COST CODE	DESCRIPTION	MANHOURS							
		Original Budget	Approved Changes	Expended This Period	Expended To Date	Forecast Final Mhrs	Forecast (Over) or Under (A - E)	Trending Final Manhours	Trending (Over) or Under (A - G)
		A	B	C	D	E	F	G*	H

Remarks

* See Column "I" on Productivity Report

E.P. NO: DRG 1
APPENDIX: E(1)

Project Number ______________
Project Title ______________

DRAUGHTING/ENGINEERING SUMMARY COST REPORT

Date ________ Completed by: ______________

CONST. COST CODE	DESCRIPTION	DOLLARS ($)							
		Original Budget	Approved Changes	Expended This Period	Expended To Date	Forecast Final Cost	Forecast (Over) or Under (A - E)	Trending Final Cost	Trending (Over) or Under (A - G)
		A	B	C	D	E	F	G*	H

Remarks

* See Column "J" on Productivity Report

E.P. NO: DRG 1
APPENDIX: E(2)

Procurement

Long delivery items must be ordered early and frequently are the key to the final completion date. Thus, it may be desirable to place orders for such equipment as soon as the project is approved.

A breakdown of the equipment by code, an appreciation of the long delivery items, numerous quotations and the period during which delivery at the site is required, are all available from the definitive estimate and the master schedule.

This information is expanded into a comprehensive detailed procurement table which lists in detail all key items and the key dates for getting them to the site on time. Table 3 entitled "Equipment List & Material Status Report" is an excellent form for this purpose. Every purchase order must be entered on this form and every column filled in eventually. The report must be updated continuously and reviewed on a regular basis (e.g. monthly or bi-weekly) by the project manager or his delegate for action decisions re items that are off schedule.

Similarly, this report is integrated with the "Cost Statement" where the individual equipment items are costed out and their final cost forecasted. For all significant equipment items such forecasts are required prior to commitment so that overruns can be spotted and action taken in terms of alternative choices or designs.

Thus, this one form is very important in providing data for the complete cost control cycle of targets, monitoring, forecasting and action with respect to Procurement.

On large projects, the document is computerized and in some cases the information may be on line.

Despite the excellence of this form, it has a weakness inasmuch as its first key date is the issuing of a requisition. What must be

EQUIPMENT LIST AND
MATERIAL STATUS REPORT

PROJECT TITLE ______ PLANT ______

PROJECT NO ______
DATE ISSUED ______

ITEM NO	QTY	DESCRIPTION	EQUIP. NO.	SPECIFICATION P.O. NO.	ISSUED ENG.	PROP. RELEASE DATE		PURCHASE ORDER DATE		SUPPLIERS	RATED DEL.	DELIVERIES					INSP. REQ'D	C.P. ON SITE	REMARKS
						SCHED	ACTUAL	SCHED	ACTUAL			REQ'D ON JOB SITE	VENDORS: ORIGINAL PROMISE	VENDORS: LATEST PROMISE	EXPECTED ON SITE	[illegible]			

NOTES: USE DATES: [illegible]

SUB TITLE ______ DWG NO. ______ Page ___ of ___ done to assure that the work required to have the requisition ready on time is being done? This concerns the activities of engineers and their creativity which is varied and difficult to equate.

Table 4, entitled "Procurement Control Report" was developed to provide a control for this purpose. This form provides a means of indicating the progress and status of engineering as well as the procurement status. Under "Engineering Status" a tick mark is entered in the appropriate box each time the specific milestone has been attained. As with Table 1, this form is updated continuously and reviewed for action decisions on a regular basis.

This form is not particularly suitable for computerization since the complete document would be ready for reproduction by the time the input data was available. Thus, there would be loss of time in computerizing it and in essence the computer would function mainly as a printing machine.

It should not be necessary to use both forms on the same project. Depending on the way a project is being handled, one form may be preferred over the other.

While attention is often centered on procurement of equipment, bulk materials, especially piping and electrical supplies, are sometimes overlooked. Bulk Materials pose a special problem and represent a sensitive area where overruns often occur. This is due to the difficulty of providing a good estimate at the time the definitive estimate is made and the subsequent failure to keep abreast of developments as the project progresses.

A "bulk material control" should be set up for every project which starts with the estimate used in the definitive estimate. As P&I diagrams and drawings are completed, a continuous program of quantity take-offs and re-assessments should be made for comparisons with the budget estimate. This data serves three purposes:

1) It provides an on-going check against quantities in the definitive estimate, thereby identifying a potential overrun at the earliest possible date.

2) It provides an on-going check against bulk materials on order and hence identifies any shortages in ordering which could have a significant effect on the schedule.

3) It is valuable in estimating construction manhours and scheduling work in the field.

The latest trend is to handle bulk material control on computer programs and there are various software programs on the market.

PROCUREMENT CONTROL REPORT

TABLE 4

Project No.: ______ Project Title: ______ Date: ______ Page ___ of ___

ENGINEERING STATUS

PROCUREMENT STATUS

[illegible]

Construction

Construction is the most vulnerable and most difficult of all functions in the control of projects. It's a major study in itself and hence we propose to limit our remarks to certain items which we consider to be important and significant. Thus, I propose to comment on the following:

- General Policy
- Planning & Scheduling
- Labour Control
- Firm Price Lump Sum Contracts
- Field Indirects

General Policy:

This concerns the method of handling work in the field. For good control in the field:

Accurate charging of all work to its specific cost code is imperative.

Supervision must know where the men are at all times and what they are doing.

Work should be done in blocks of work that are like in nature (mostly by trade and confined to one foreman), small enough to be manageable, and such that charges can be made reliably so that feedback can be analysed quickly to assess progress, productivity, expected final completion and expected final cost.

Frequently, a work order system is used. The coding on the work order ties it in with the cost code and estimate and foremen are assigned one work order at a time. The best principle here is "No work order - no work". In other words, a work order becomes a "must" for all work on the site and thereby provides a mechanism for good reliable feedback, and a knowledge that work is not going on which supervision is unaware of.

The ultimate in this system is known as "Pre Planning". In this system, all work is broken down into work orders in advance of construction. A precise estimate of the manhours is made, all material and equipment required is listed, information sketches may be made, a copy of the bill of material is sent to the site stores to have it checked for availability and readiness for use, and only after this is done is the work order assigned to a foreman. Some work assignments are evaluated, estimated and written up in much more detail than others, e.g. erection of special equipment, or pipe fabrication and erection. This system requires a substantial staff of planners and estimators but excellent claims have been made for its overall effectiveness. Savings in direct costs equal to 400% of the money invested in the system have been claimed.

A common method for charging time is for the foremen to record all their men on a daily timesheet, identify the work and cost code and submit this on a daily or weekly basis. With cost codes as complicated as they are to-day, this system often results in incorrect charging. A means of compensating for this has evolved in the use of "Time Checkers". The time checkers have thorough training in the cost code, work closely with the cost engineers and scheduling engineers and visit their assigned area on the site 2 to 4 times each day - identifying each worker in his area, checking what job he is working on and recording the proper cost code.

In all cases, the feedback flows to the field cost engineer who maintains an ongoing procedure for following the cost control cycle. Thus, he marshalls the data under the basic headings of target and monitoring and then develops the trend curves that have been developed for the project and forecasts a final cost. All such data is used to compile the final figures that go into the overall Project Cost Statement.

Planning & Scheduling:

No construction job will be executed efficiently without good planning and scheduling. The larger the project, the greater its importance. Qualified, capable planning and scheduling personnel should carry out the function and it should start long before the start of construction.

The Critical Path Method is used widely by scheduling personnel, but actual work in the field is more likely to be related to bar chart schedules, i.e. the professional schedulers develop the CPM diagrams, analyse the results, and highlight the priorities. Then the resulting field work is drawn up on bar graphs which are more readily understood by construction personnel in the field.

The schedules should be closely related to the cost code and the definitive estimate so that costs can be collected correctly against specific codes and so cost control mechanisms can function properly.

Attempts have been made at complete integration of cost and schedule. i.e. the schedule is completely married to the cost estimate through the cost code. Such an integration is a complex and costly challenge to the planning, scheduling, costing and computerization operations. As yet, it must be regarded as in its infancy.

Regular Field Scheduling Meetings, independent of regular Construction Job Meetings, should be organized on a weekly basis to review progress and problems, and make decisions for the coming week. These meetings should be attended by the key construction supervision as well as the Project Manager, Scheduling Engineer and Cost Engineer. In other words, the power to make decisions should be present at the meetings.

Note that the prime purpose of this meeting is to review and make decisions pertaining to scheduling. The agenda for the meeting would be set up by the Scheduling Engineer with prior discussion with the Construction Superintendent. This meeting must not be allowed to be side tracked into a regular Job Meeting involving lengthy discussions on other construction problems that are not related to scheduling.

Labour Control

Except in those periods of completely unpredicted high inflation rates, such as those that struck North America in 1973-75, construction labour may be regarded as the greatest single contributor to project overruns.

Thus, the cost control cycle is extremely important on construction work and it must be applied to quantities, manhours and costs. The Cost Engineer, in conjunction with the Project Manager, will establish what graphs and controls will be maintained.

Forms similar to that already discussed for the control of draughting can be used universally in the cost control cycle.

Thus, Figures 6 to 8 all illustrate the type of graphs that are useful in construction control. Figure 6 is a typical, commonly used plot of the monthly construction forces and the corresponding accumulated manhours. This graph is a guideline in seeing how actual labour build-up and manhours to-date compare with the plan. However, a project could be right on plan in staff build-up and manhour expenditure but could be out of control in terms of progress. Thus, the following 2 figures are much more useful as cost control documents.

Figure 7 illustrates construction progress vs. time, while Figure 8 illustrates progress vs. manhours. The illustration is for pipe erection and progress is assessed in terms of equivalent feet or equivalent units erected. In this method, each elbow, tee, valve or length of pipe, etc. has an equivalent value in terms of manhours required to erect. The same chart can be used for concrete in yards of concrete, or structural steel in tons, etc.

In all applications, the above two comparisons are highly desirable to obtain good control, i.e.

1) Progress vs. Time to determine the forecast completion date.

2) Progress vs. Manhours to determine the forecast final manhours and hence the forecast final cost.

These forms can be developed for total project progress and total direct manhours and they can be equally applicable to individual disciplines and trades. Note that these specific control documents by trade provide the input data for graphs such as those in Figure 7 and ultimately the data that goes into the Project Cost Statement.

FIGURE 6

Project No.: ______ Project Title: ______ Date ______ Page ______ of ______

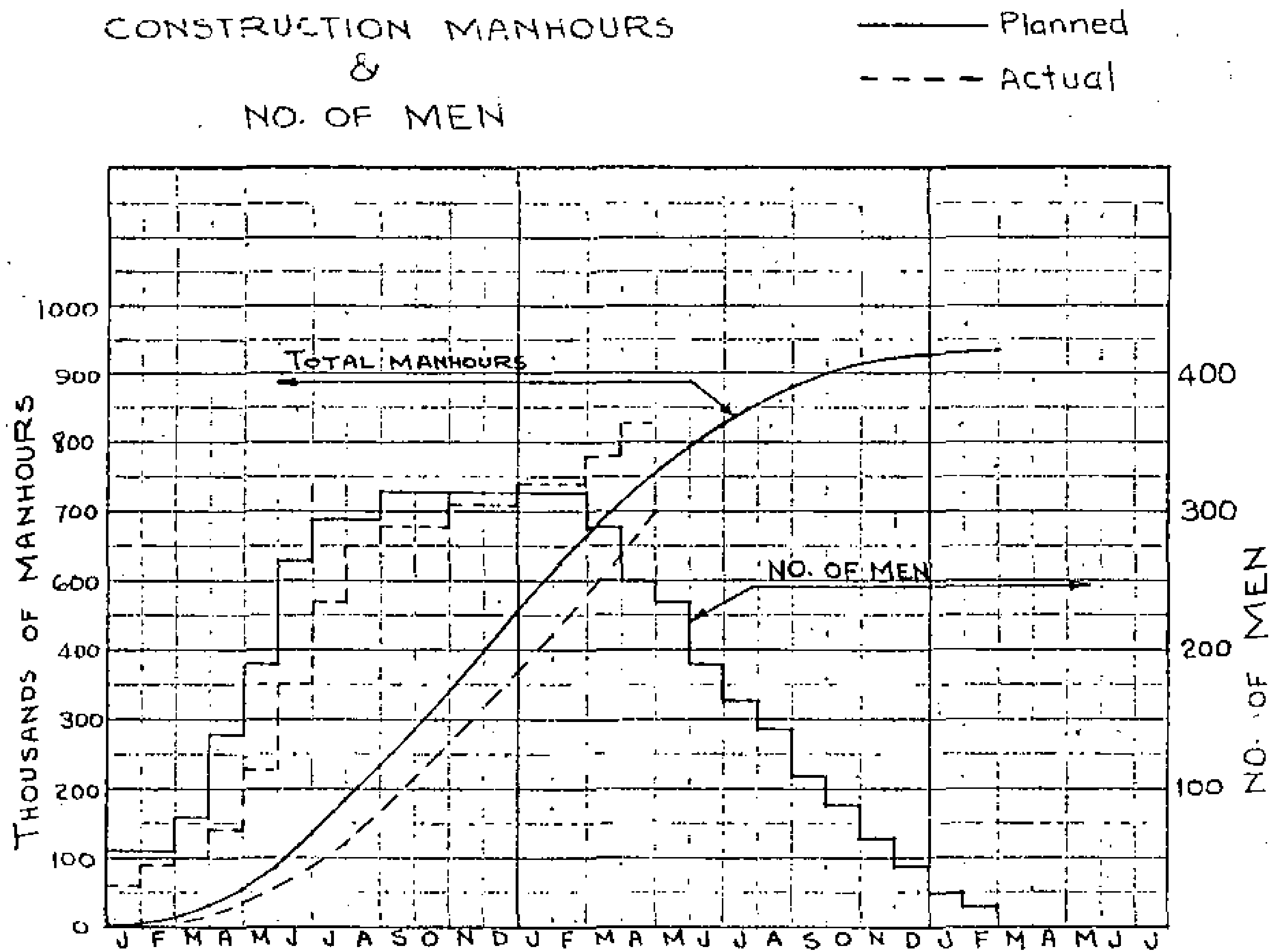
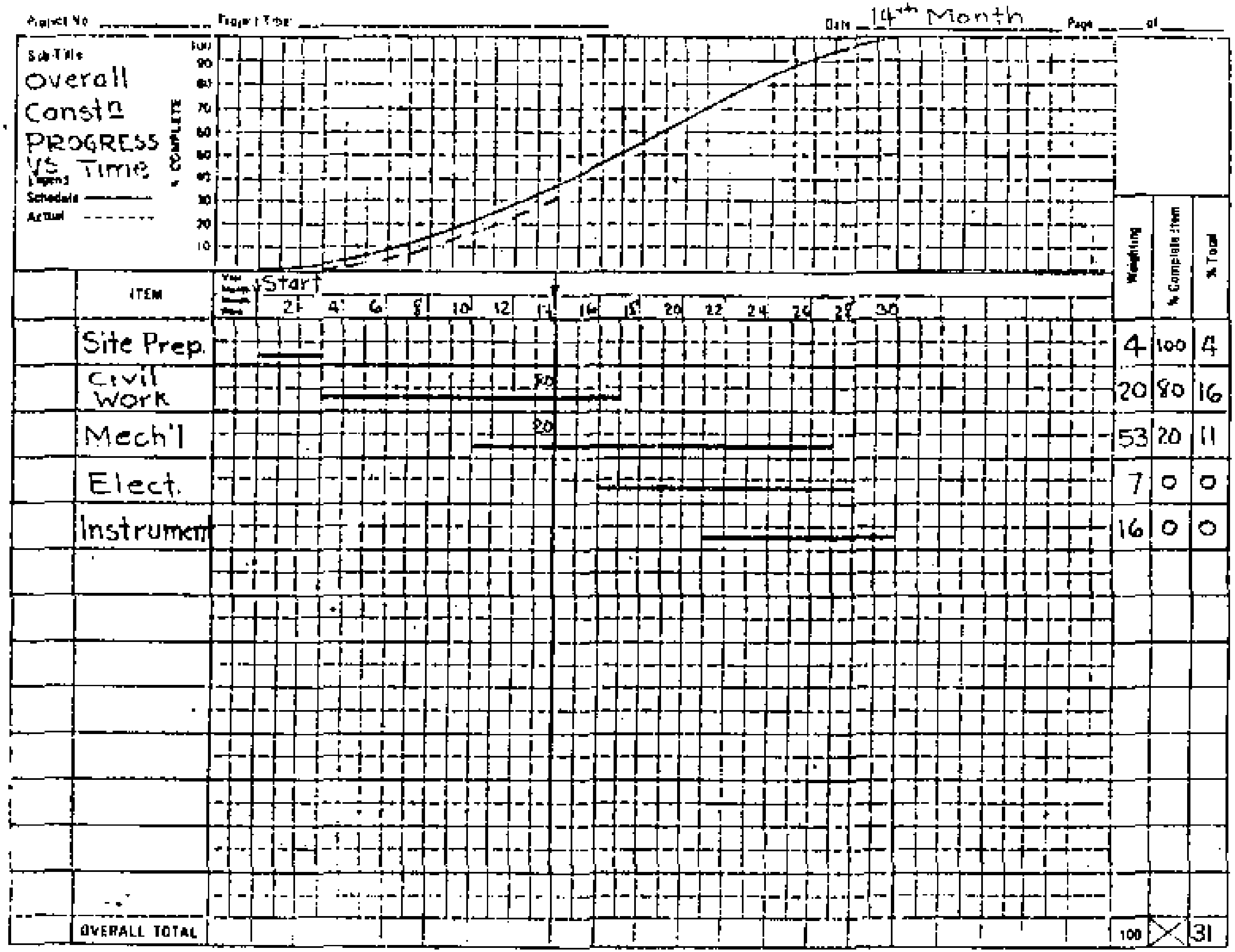


FIGURE 7


Project No
Project Title
Date 14th Month
Page of
Sub-Title
Overall Constn PROGRESS VS. Time
Legend
Schedule
Actual
% COMPLETE
Start
ITEM
Site Prep.
Civil Work
Mech'l
Elect.
Instrument
OVERALL TOTAL
Weighting
% Complete Item
% Total
4 100 4
20 80 16
53 20 11
7 0 0
16 0 0
100 31

Project No. ______
Project Title ______
Completed by ______

FIGURE 8

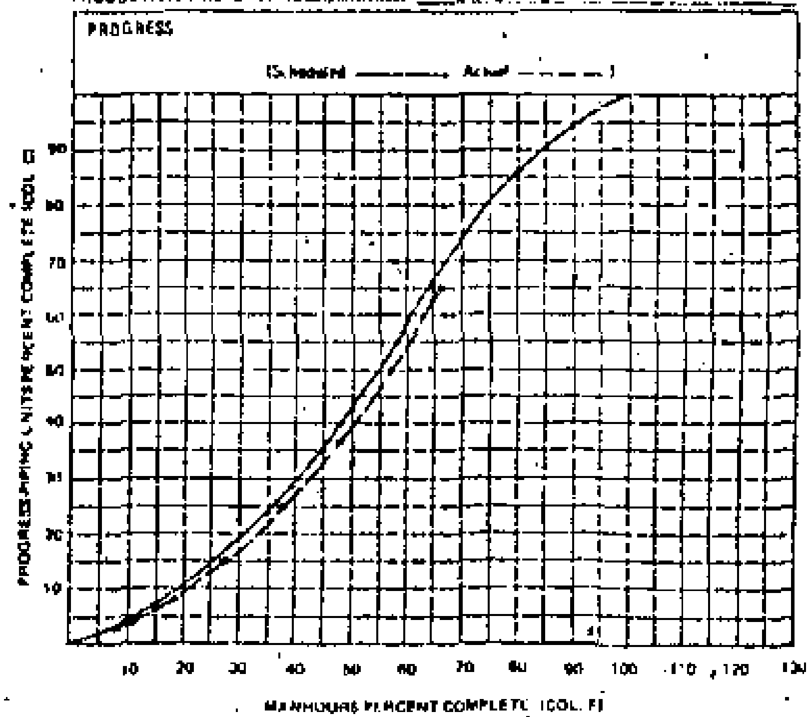
PROGRESS VS MANHOURS

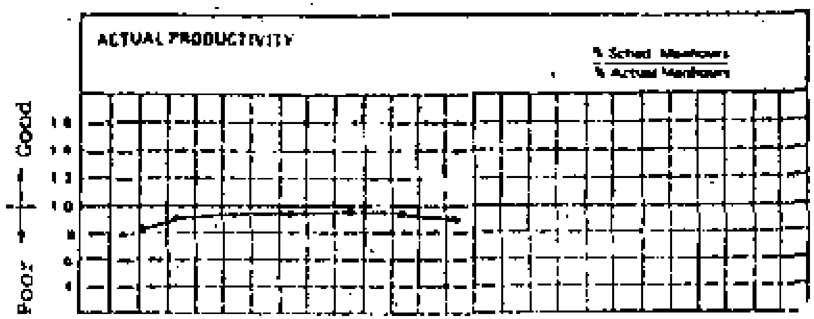
CODE ______ ITEM Overall Piping

Date	Sched. Equiv. Length of Units	To-Date Compl. Equiv. Length of Units	% Prog. B/A x 100	MANHOURS: Budget M/Hrs & Chngs	To-Date M/Hrs	% F/D x 100	Equiv. % Sched.	Productivity	Budget M/Hrs Costs & Chngs	Trend Final M/Hrs	Trend Final Cost Forecast
	A	B	C	D	E	F	G	H	I	J	K
June	225	1.125	0.5	250	3.75	1.5			2500		
July	225	3.4	1.5	250	8.75	3.5			2500		
Aug.	225	5.6	2.5	250	16.25	6.5			2500		
Sept.	225	9.0	4	250	27.5	11.	9	.82	2500	305	3050
Oct.	225	18.0	8	250	45	18	16.5	.92	2500	272	2720
Nov.	225	33.8	15	250	67.5	27	26	.96	2500	260	2600
Dec.	225	56.3	25	250	93.75	37.5	36	.96	2500	260	2600
Jan.	225	83.3	37	250	120.	48	46	.96	2500	260	2600
Feb.	225	112.5	50	250	142.5	57	54.5	.96	2500	260	2600
Mar.	225	146.3	65	250	167.5	67	63.5	.95	2500	263	2630
Apr.											
May											
June											
July											
Aug.											
Sept.											

Date	Remarks	Date	Remarks

PRODUCTIVITY REPORT: (Discipline/Area) Piping





Firm Price Lump Sum Contracts

The Contractor who offers a lump sum bid obviously must practice every aspect of good cost control.

On the contrary, the person who has a lump sum contract would be remiss to assume that he has a guarantee of his final cost. The record is full of experiences where lump sum contracts have overrun substantially due to "extras". This is the area where a contractor is inclined to charge excessively and make his profit. Hence, the need to have a set of good contract documents with the scope fully and precisely defined and the subsequent challenge not to make changes.

If changes must be made, two practices should be followed to keep costs to a minimum:

1) Contract documents should request a unit price for deletions or additions of all items which might be involved, e.g. excavation, concrete, structural steel, etc. This will establish in advance of awarding the contract, the cost of a great many potential extras and will be part of the contract bid analysis in determining the successful contractor.

2) All other extras should be established on the basis of negotiating a firm bid with the contractor. In essence, this is saying that no work can be done on extras to a contract without an authorized approval. The method of obtaining this approval should be established by a rigid procedure and the company awarding the contract should be fully prepared and capable of negotiating.

Figure 9 illustrates a procedure for controlling costs on such changes. The procedure could be called a Change Notice/Change Order System. In summary, it consists of issuing two documents to the contractor through the cost engineer or estimating unit.

The first document, a "Change Notice", is a formal notice that a change is desired and requests the Contractor to submit a firm price. Included with the Change Notice are the drawings and other documents which identify the changes. This is strictly a request for a bid and is not a request to do work.

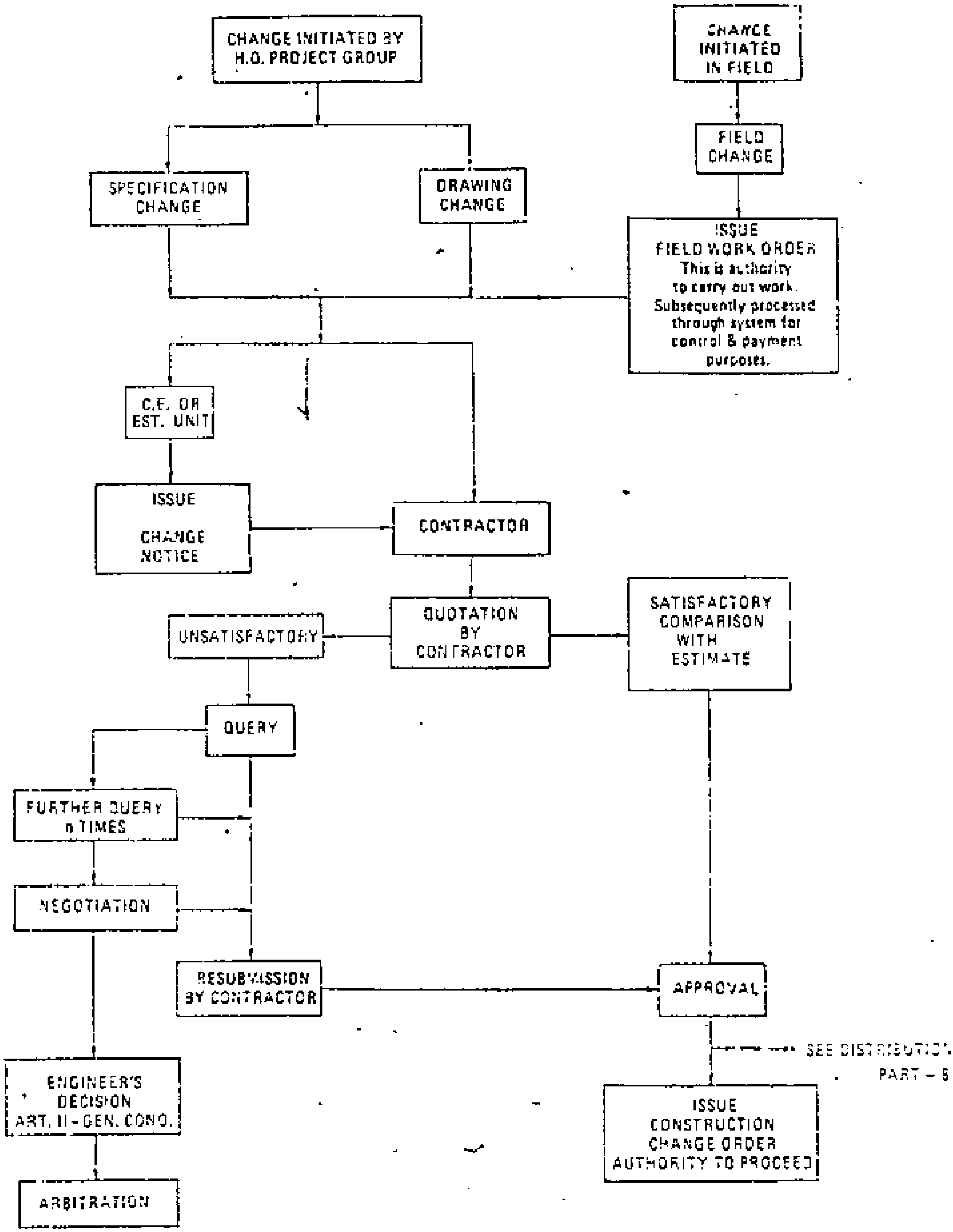
When the bid is submitted, it is compared with the estimate which has been made by the owner and if there is a reasonable check between the two estimates, a "Change Order" is then issued to the Contractor which authorizes him to proceed with the change.

If the two estimates do not agree, the owner must be prepared to negotiate a revised price with the Contractor. To execute this function effectively, his estimators must be fully qualified in detailed estimating and knowledgeable in construction work and contractor practices.

Sometimes the above procedure results in a delay to the schedule which cannot be tolerated. This applies especially to day to day construction problems on the site. For this purpose, a Field Work Order System (FWO) is employed. Under this system, the resident representative of the owner (Resident Engineer) has authority to issue a FWO to the contractor which gives him immediate authority to proceed with the work.

This is a necessary expediency but is not a good means of controlling costs. Thus, in the interest of cost control and in keeping with the philosophy of an approval system, the Resident Engineer should have a clear directive as to the type of work he may approve and a limit on the amount of money he may authorize. Beyond these limits, the procedure would call for a higher approval before proceeding with the work.

PROCEDURE FOR A CHANGE ON LUMP SUM CONTRACTS



Field Indirects

Indirect construction costs represent another sensitive area where excessive costs often contribute to overruns. This concerns those items referred to on Table 20 P-62 under Cost Estimating.

It has been long established that indirect construction costs are related more or less directly to direct labour costs, i.e. as goes labour, so goes the indirect costs. It may be concluded that if direct labour is under control, so are the indirects. This relationship may be useful for estimating but not for cost control.

A look at Table 20 will indicate that temporary construction and construction equipment both represent significant cost items under indirects. Both can go completely out of control, especially when a contractor is operating on a cost plus type of contract.

Temporary construction should be fully appraised and justified before embarking on the expenditures.

Rental of construction equipment is costly and hence requires ongoing control throughout the construction period. It requires good planning so that when expensive equipment is required to perform several operations, every effort should be made to schedule them at the same period and then release the equipment as quickly as possible. If many items are in use on the site, such as five cherry picker cranes or 25 welding machines, etc., a regular review of their "active vs. idle" time is required so that those not needed can be released as soon as possible. The starting point would be a planned schedule such as illustrated in Figure 10 and this should be reviewed on a regular basis.

Construction equipment must not be brought to the field and then forgotten. Its need must be under regular surveillance.

Figure

EXAMPLE

CONSTRUCTION EQUIPMENT RENTAL

DESCRIPTION	1976 J F M A M J J A S O N D	TOTAL MTHS.	RATE	TOTAL	REMARKS
150T Crawler Crane		7	10,000	70,000	
50T Crawler Crane		6	10,000	60,000	
50T Crawler Crane		9	4,800	43,200	
50T Crawler Crane		9	4,800	43,200	
25T Crawler Crane				310	Used for one day.
25T Crawler Crane		12-1/2	4,400	55,000	
15T Cherry Picker		12-1/2	2,400	30,000	
15T Cherry Picker		11-1/2	2,400	27,600	
15T Cherry Picker		9	2,400	21,600	
15T Cherry Picker		6-1/2	2,400	15,600	
15T Cherry Picker		5	2,150	10,750	
15T Cherry Picker		5	1,900	9,500	
600 CFM Compressor		11	1,100	12,100	
150 CFM Compressor		9-3/4	450	4,400	
Miller IV Weld Mach.		13	400	5,200	
Miller IV Weld Mach.		11-1/2	400	4,600	
Miller IV Weld Mach.		11-1/2	400	4,600	
Miller IV Weld Mach.		6-1/2	400	2,600	
Miller IV Weld Mach.		6-1/2	400	2,600	
Miller IV Weld Mach.		6	400	2,400	
Miller IV Weld Mach.		6	400	2,400	
Miller IV Weld Mach.		5	400	2,000	
Miller IV Weld Mach.		5	400	2,000	
300A Gas Weld		12-1/2	160	2,000	
300A Gas Weld	Bought				
Sedan	Through Jan./77	22	160	3,520	
Van-12 Passenger		17	215	3,660	
	C/Forward			440,840	Sub-Total

SAMPLE COST CONTROL PROCEDURE

The importance of good procedures and the need to have them embrace all facets of design, procurement, responsibilities, etc. has already been stressed.

The following is a sample illustration of a Cost Control Procedure.

PROJECT:
LOCATION
PROJECT NO:

S A M P L E

COST CONTROL PROCEDURE

1. The procedure outlined herein describes the various operations that will ensure effective Project Cost Control. It is important that the key personnel on the project team be aware of and guided by this procedure to enable the Cost Engineer to work effectively and better assist the Project Manager accomplish his responsibility for the Cost Control of the project.

1.1 SUB-PROCEDURES OUTLINED IN DETAIL

1.1.1 Establishment of the Project Code of Accounts

1.1.2 Establishment of the Project Budget

1.1.3 Commitments and Expenditures *

1.1.4 Cost Variation Procedure

1.1.5 Forecast Final Cost Calculations

1.1.6 Backcharges

1.1.7 Monthly Cost Report

1.1.8 Final Cost Analysis

* As per Project Accounting procedure, manual systems for recording commitments and expenditures will be run concurrently with the system outlined herein. Such systems are not included within this procedure.

1.2 ESTABLISHMENT OF THE PROJECT CODE OF ACCOUNTS

The responsibility for production of the Project Code of Accounts rests with the Project Cost Engineer and will be accomplished as follows.

1.2.1 The Cost Engineer will review the Code of Accounts used before the Project Approval stage, with the Estimating Department and compare with the latest equipment list.

1.2.2 The Project Code of Accounts will be prepared with identification of all anticipated cost components, whether or not they appeared in the A.R. Estimate. The base guide will be the revised Construction Cost Code.

1.2.3 The Project Code of Accounts will then be reviewed with the Project Manager, the Manager of Cost Engineering and the Project Accounting Supervisor to ensure,

(i) adequacy for cost control purposes,
(ii) that historical data required for future projects will be readily available,
(iii) compatability with accounting requirements,
(iv) that the intent of the Code of Accounts has been construed correctly, and
(v) that a practical level of coding is envisaged.

1.2.4 The Cost Engineer will then distribute the Code of Accounts as directed by the Project Manager.

1.3 ESTABLISHMENT OF THE PROJECT BUDGET

1.3.1 The purpose of the Project Budget is to list all the funds allocated against the approved Code of Accounts. This funds listing is essentially the breakout provided by the Appropriation Request Estimate, modified to reflect changes to the equipment list and revisions to battery limits which have occurred since the A.R. Estimate was compiled. The total Project Budget figure will not be altered unless a Supplementary Appropriation is granted.

1.3.2 The preparation of the Project Budget listing is the responsibility of the Cost Engineer. He does this for and under the guidance of the Project Manager and Manager of Cost Engineering. Input from the Estimating group is required to ensure the Budget breakdown reflects the intent of the A.R. Estimate.

1.3.3 Immediately upon issue of the Code of Accounts, preparation of the Project Budget will be initiated. For all items except Engineering, Sales Taxes, Services, Indirects, Contingencies and Inflation allowance, the Budget will be broken down by area. (Battery limit areas). The following areas apply on this project.

Area	Description
110	Raw Materials Preparation Building
120	Mixing and Cartridging Building
130	Cartridge Conveyor
140	Case House
210	Raw Material Unloading (Dries)

Area	Description
220	Raw Material Storage (Dries)
230	Raw Material Storage (Liquids)
300	Utilities

Funds not allocated to these areas are coded as follows.

400	Services
500	Indirects
600	Engineering
700	Legal
900	Contingencies and Reserves

Within each of the above areas, the Budget will further be allocated as per the Project Code of Accounts Construction Elements of the Code, and by Cost Component (Mtl, S&E, etc.).

1.3.4 Funds set aside in the A.K. Estimate for Escalation will be allocated across the 100-700 code accounts.

1.3.5 Upon completion of 1.3.3, the Cost Engineer will obtain concurrence from the Estimating group of the distribution of costs. The budget will then be reviewed by the Project Manager and Manager of Cost Engineering and their approval obtained. Distribution of this Budget, or elements contained therein will be determined by the Project Manager.

1.3.6 The Definitive Estimate referred to in 1.6 will form the basis for forecasting the Final Project Costs.

1.3.7 It has been decided that a computerised Cost Report will be produced for this Project. Consequently, the Budget Allocation will be input to the computer using pre-printed forms. A printout will subsequently be produced tabulating the Budget by Area, Construction Element and Cost Component Codes. It is the responsibility of the Cost Engineer to review this print-out and ensure compatibility with the initial input.

1.4 PROCESSING OF EXPENDITURES AND COMMITMENTS

1.4.1 To ensure proper control all Expenditures and Commitments will be analysed by the Cost Engineer and Project Accountant before being absorbed into the Project Cost Report. Expenditures and commitments fall into the following categories.

(i) Head Office Manhour Costs
(ii) Head Office Expenses
(iii) Purchased Engineering
(iv) Purchased Materials (Incl. S. & E.).
(v) Contracts
(vi) Contract Extras
(vii) Plant Purchases or Labour
(viii) Field Office Manhour Costs
(ix) Field Office Expenses

1.4.2 H.O. Manhour Costs

Within the Engineering Department "Time Analysis System" manhours spent by personnel on each Project are listed. These manhours are subsequently priced at rates pre-determined by the Project Accounting Section and the computerised Report EN9 produced around the end of the 3rd week of every month. As a backup to this Report, the C7 Audit Trail is also produced by the E.D.P. Department.

The Cost Engineer will analyse these reports simultaneously and produce a written report for the Project Manager listing substantial bookings by employee. The Project Manager then has the option to query any substantial bookings and, if they are found to be in error, the Cost Engineer will inform the Project Accounting Section.

Computer input sheets will then be prepared to rectify any misbookings.

1.4.3 H.O. Expenses

Employees will submit expense reports promptly for approval by their Engineering Departmental head. The Cost Engineer will analyse these expenditures monthly from the C7 Audit Trail and bring any incorrect entries to the Project Manager. Should any corrections be necessary, the procedure outlined in 1.4.2 will be followed.

1.4.4 Purchased Engineering

Should it become necessary, due to work overload, to utilise the services of consultant engineering groups, adherence to E.D.P. ADM 3 is required.

Although recommendation of the use of outside Consultant services rests with Specialist Engineering Managers, the responsibility for Project costs rests with the Project Manager. For this reason, the Project Manager needs to be kept closely informed of all such developments in order that any cost variations may be reflected in the Project Cost Statement.

It is the responsibility of the Specialist Department Managers to approve manhours spent by Consultant Engineering Groups and to monitor their progress.

The Project Accountant will check invoices approved by Specialist Engineering Managers for compatability with agreed rates etcetera.

The Cost Engineer will ensure that the C7 Audit Trail reflects only invoices as approved above.

1.4.5 All the expenditures approved in 1.4.2, 1.4.3 and 1.4.4 above will subsequently be input to the E.D.P. Department by the Project Accountant for production of the Monthly Cost Report. There will be a separate input for Engineering, Drafting, Support, Expenses and Purchased Engineering.

1.4.6 Purchased Materials

(i) Commitments

Upon receipt of a Purchase Order, the Project Accountant will check the coding and cost to ensure compatibility with the Code of Accounts and Purchase Requisition. The Accounting Supervisor, who also sees all Purchase Orders, will advise the Project Accountant if F.S.T. and P.S.T. are applicable. If so, these additional costs will be calculated by the Project Accountant and committed along with the item(s) being purchased.

If the Purchase Order is placed outside Canada, the Project Accountant will, after discussion with the Distribution Department, commit applicable duty along with the item(s) being purchased. A copy of all Purchase Orders will be transmitted to the Distribution Department who will negotiate duty remissions with the Government Department of Industry Trade and Commerce. Any funds remitted will be deducted from the Purchase Order Commitment value.

A separate account will be set up to cover freight charges not included in Vendors quotations.

(ii) Expenditures

The Project Accountant will check invoices to ensure compatibility with Purchase Orders (costs, coding, retentions, etc.). A cheque requisition is then prepared and authorised by the Project Manager. Once the payment has been made and appears in the Accounts Payable Voucher computer print-out, it is entered into the Project Cost Report as an expenditure.

1.4.7 Contracts

(i) Commitments

It is proposed that all Contracts let on this Project will be lump-sum. Upon receipt of the approved contractual documents, the Project Accountant will check for a correct coding breakdown, enlisting the Cost Engineer's help, if necessary. The dollar value of the Contract will then be input by area, construction element and cost component onto computer input sheets as a commitment.

(ii) Expenditures

As the Contractor completes work, he will submit invoices to the Project Accounting Section on a pre-specified format. (See EDP. ACC 2). Invoiced amounts will be related to Contractor's progress which will have been agreed with the Resident Engineer. These invoices will be checked by the Project Accountant and Cost Engineer for compatability with the Contractual Agreement. A cheque requisition will then be made out by the Project Accountant and approved by the Project Manager. The expenditure is subsequently input into the Cost Report as specified in 1.4.6 (ii).

1.4.8 Contract Extras

At the bid quotation stage, Contractors will be asked to provide unit prices for undefined work. As subsequent additional work becomes apparent, the Contractor will be asked to:

(i) undertake the work on unit rates,
(ii) undertake the work on dayworks,
(iii) submit a lump sum price for the extra works.

Option (i) will be used largely for work which is undefinable, such as rock blasting. Unit rates for such work and for the plant equipment will be specified in the quotation. The Site Representative will sign for plant equipment usage on a daily basis. Upon completion of such work, the Contractor, Site Representative and Engineering Department Quantity Surveying Section will agree the total scope of work for payment. A Change Order listing the work will be raised by the Q.S. Section on form EDF-52 (See EDP COS 1).

Option (ii) will be used largely at the discretion of the Site Representative, for work of an urgent nature or minor additional work not included in the lump sum scope and for which unit rates are not available. A Field Extra Work Order will be raised by the Site Representative to cover this work and an Estimated Final Cost of the work added to the Work Order. Time Sheets will be signed for on a daily basis by the Representative and material purchases and plant equipment costs also signed for. It is imperative that the F.E.W.O. number, allocated by the Representative, be written onto all time sheets, material purchase orders and plant equipment sheets, to allow calculation of the final cost of the Work Order. The F.W.O. is subsequently confirmed by a Construction Change Notice (Form EDF 51) and Change Orders (EDF 52). EDP COS 1 Section 4D clarifies this procedure in more detail.

Option (iii) will be used for extra work wherever possible. Again, the Engineering Department Q.S. Section will check and appraise such lump-sum quotations and raise a Change Order for final approval by the Project Manager.

Invoices from Contractors will quote the applicable Change Order number in order that the Project Accountant can identify the cost source and gain the Project Manager's approval for payment. Invoices for extra works should only be submitted and approved at the 50% or 100% of extra works completion stage unless otherwise reflected in contractual documents.

- The attached diagram extracted from EDP COS 1 graphically illustrates the Extra Works procedure. (Appendix 1.4.8.1). To allow extras to be coded correctly, the Q.S. Section is also asked to use the form (Appendix 1.4.8.2) to split down costs.

1.4.9 Plant Purchases/Labour

Use of Plant resources is at the discretion of the Field Representative, but should be kept to a minimum. Should such work be necessary, the Field Representative will issue a Plant Work Order Authorisation carrying an estimate of material and labour costs. This will allow the Cost Engineer to reflect these costs in the Estimated Final of the Project Cost Report.

Subsequently, the Plant will submit a J.E.V. which will be picked up by the Project Accountant from the A.P.V. printout. Once the Project Accountant has identified the cost and gained Project Manager approval, it is input into the Project Cost Report as an expenditure.

1.4.10 Field Manhour Costs

Timesheets are submitted to the Project Accounting Section of the Engineering Department and input into the Time Analysis system. Subsequent approval of these timesheets is given by the Manager of Construction.

From the EN9 printout, these costs will subsequently be entered into the Project Cost Report as expenditures.

1.4.11 Field Expenses

Expense Reports submitted are approved by the Manager of Construction before input into the Time Analysis System. Subsequent input into the Project Cost Report follows the same pattern as in 1.4.10.

1.5 COST VARIATION PROCEDURE

1.5.1 Differences between Budget (A.R. Estimate) costs and Estimated Final Costs are termed Cost Variations. Although Cost Variations occur for many different reasons, they may be split into two categories.

(i) those which occur as a change to Project Scope (EDP COS 2).
(ii) the remainder.

1.5.2 Changes in Scope

These may be further subdivided into:

(i) those which change the Project Scope of work,
(ii) those which change a Contractor's scope of work.

These changes identified in (ii) above are covered under 1.4.8. They are not necessarily changes to Project Scope and will normally be allowed for in the Project Estimated Final Costs.

1.5.3 Changes to Project Scope will be controlled and monitored by adherence to the network attached. (Appendix 1.5.3.1). This network allows the speedy identification of Cost Variation and outlines the actions required to control them.

As can be seen, the network incorporates a Holding Account into which Cost Variation* will be logged until they are identified as a cost deviation or approved as changes in scope.

* This Holding Account will only be used for Cost Variations which exceed the Budget (A.R. Estimate) by $1,000 or 5%, whichever is the greater.

Cost Variations must be defined, costed and approved as quickly as possible after they become evident in order to

(i) allow management the option of negating the proposed change before any financial commitment,
(ii) ensure that all parties involved are still familiar with the change and the clearest picture can be presented,
(iii) ensure that in the event of a Supplementary Appropriation Request, all valid documentation outlining the reasons for the increase is available.

Once identified, the Cost Variation is built into the Estimated Final Cost of the Project. The Q.S. Section is asked to use the Form attached (Appendix 1.4.8.2) to allocate costs over the various cost codes.

1.5.4 For this project, a Major Change in Scope is one exceeding $25,000 and a Minor Change in Scope is one costing less than this figure. Preparation of Major Changes in Scope documentation is covered by EDP COS 2. No commitments should be made to Major Scope Changes until approval for the change is forthcoming.

1.5.5 Cost Deviations

These are changes from the Budget costs due to variations from vendor original quotations etcetera. They can be defined as changes to costs occurring within the intent from which the A.R. Estimate was prepared.

These deviations are flagged to the Project Manager for action as outlined in the network attached. (Appendix 1.5.3.1).

1.5.6 It is the responsibility of the Cost Engineer to keep a file on all cost variations from project inception. A reconciliation of differences between the A.R. Estimate and the Estimated Final

Costs can subsequently be prepared quickly, and in detail.

1.6 ESTIMATED FINAL COST CALCULATIONS

1.6.1 All cost variations, unless negated by alternative Engineering, additional bid quotations etcetera, will affect the Estimated Final Cost of the Project.

1.6.2 From the Cost Engineer's file on Cost Variations, new Estimated Final Costs will be input into the Cost Report. These forecasts will be input by area, construction element and cost component.

1.6.3 The Cost Engineer is responsible for keeping the Estimated Final Costs of the Project up to date. Unless additional information is at hand, Budget costs will be used as an Estimated Final Cost.

1.6.4 A Definative Estimate prepared by the Q.S. department will form the basis for Forecasting Costs. Cost Variations will subsequently supplement this Definitive Estimate as the Project progresses.

1.6.5 The Cost Engineer will maintain control curves for the following:

(i) Total Head Office Costs
(ii) Engineering Manhours
(iii) Support Engineering Manhours
(iv) Design/Drafting Manhours (by discipline)
(v) Design/Drafting Progress
(vi) Field Costs
(vii) Field Manhours
(viii) Printing Costs
(ix) Head Office Expenses (plus Cost per Mh. index).
(x) Contractors Progress vs. Extra Work Costs
(xi) Construction Overall Progress

Constant monitoring of these curves will allow the Cost Engineer to forecast Final Costs accurately and quickly.

1.7 BACKCHARGES

1.7.1 Backcharges which may occur on this project fall into two main categories.

(i) deficiencies or errors in . purchased engineered equipment such as pumps, conveyors, etc.
(ii) construction errors by contractors.

1.7.2 Purchased Equipment

A thorough and detailed inspection of all equipment received on site will be undertaken by a nominated contractor immediately upon arrival. Any damages or deficiency should be reported to the Site Representative immediately. Failure to inspect and report immediately may result in the source of damage or deficiency being disputed later. Any damage or deficiency should be recorded on the Delivery Notice and Material Received Notice. A copy of all Material Received Notices will be forwarded to the Project Accounting section in the Engineering Department.

Should damage or deficiency be evident, the Site Representative will phone the Project Manager immediately, and subsequently prepare a written report. A copy of this report with the Material Received Notice will be sent to the Project Accounting Section, where appropriate claims procedures will be initiated.

On no account will damage be repaired by any contractor other than the supplier without Project Manager approval.

1.7.3 Contractor Construction Errors (incl. incomplete work)

Any work undertaken which is defective or not as per drawings and specification will be noted by the Resident Engineer.

The contractor will then be requested to undertake the rework and conform to his Contract. If he fails to do so, he will be informed in writing that the work will be undertaken by others and backcharged to his account. The Project Manager will be kept informed of all such developments. A detailed account of all costs incurred on a contractor's behalf should be submitted to the Head Office and will be deducted from the contractor's future invoices as directed by the Project Manager.

1.7.4 When the Field Office is closed down, backcharge files which have been kept by the Field Representative will be sent to the Head Office. The Project Accountant will then solicit the Project Manager's aid in clearing any outstanding claims.

1.8 MONTHLY COST REPORT

1.8.1 As information related to commitments, expenditures, forecast final costs and Budgets is received by the Cost Engineer and Project Accountant, computer input sheets are infilled and filed. These sheets will be checked and batched by the Project Accountant and Cost Engineer jointly at month end and transmitted to the E.D.P. Department after copies have been taken off. They will be punched and processed by the E.D.P. Department and a computerized Cost Statement printout produced. Copies will be transmitted to the Cost Engineer who will check for compatability with input and collate.

1.8.2 All changes to underrun/overrun will then be analysed by the Cost Engineer and summarised for the Project Manager. A change order register, listing approved changes will then be prepared by the Cost Engineer.

1.8.3 The Project Manager will produce a written covering memo which will explain changes in overrun/underrun since the last report.

1.8.4 Any costs appearing in the 'Holding Account' file will be noted as a separate hand written entry on the front sheet of the Cost Statement at the Project Manager's discretion.

1.8.5 The monthly Cost Statement will then be distributed as per the Project Manager's direction.

1.9 FINAL COST ANALYSIS

1.9.1 At the completion of the Project, the Cost Engineer will prepare a final Cost Report and Analysis of the total Project. The analysis will include a complete record of Cost Variations.

1.9.2 The Cost Engineer must be aware that a declaration by the Project Manager that the Project is physically or mechanically 100% complete does not signal the end of his responsibilities. Until the Project is fiscally complete, his involvement is still necessary.

SYSTEM FOR CONTROLLING CHANGES IN PROJECT SCOPE

Following is a sample detailed procedure illustrating a syetem for controlling changes in Project Scope. It is included here because changes in project scope is one of the major causes of overruns.

Important features of this system are:

It clearly defines what changes in scope are.

It clarifies where contingencies fit in.

It practices faithfully the principle of the approval system, i.e. putting the onus on higher officers in a company as the amounts increase.

It reminds the authorizing officer that the cost of the change is not really a claim against the money in the project and that in signing the change, he must accept responsibility for finding the funds.

SYSTEM FOR CONTROLLING
CHANGES IN PROJECT SCOPE

This Engineering Procedure contains 2 appendices.

1. SUMMARY

This Engineering Procedure describes the procedure for approving and recording costs associated with changes in scope and clarifies the differences between major changes in scope and minor changes in scope. As a certain amount of confusion exists in the true meaning of a change in scope, several items which are not changes in scope are identified and defined. There is also clarification in the use of contingencies with regard to changes in scope.

2. PURPOSE

A "Change in Scope" procedure is used to enable cost control to be executed in a more effective manner by highlighting and recording the variances from the Estimate resulting from changes in scope. It is aimed at controlling the expenditures within the authorized amount for the project. The purpose of this Engineering Procedure is to instruct Project Engineers in their responsibilities in this area and guide them with regard to the documentation and authorizations required.

3. PROJECTS AFFECTED

This Engineering Procedure applies to all projects.

4. DEFINITION OF TERMS

A. Scope of Work

The Scope of Work is a description of the work which is necessary to carry out the intent of the proposal in a viable manner. The description is delineated by the details of the Appropriation Estimate, the associated drawings and the accompanying memorandum. The complete detailed Scope of Work is not established until the estimate is a definitive estimate (type B ± 10%).

On smaller projects, the authorized estimate attached to the Appropriation Request may establish the detailed Scope of Work.

In the case of major projects, the definitive estimate will not be completed until some time after the initial approval and hence the detailed Scope of Work can not be fully established until that time. (See E.P. BRM 7* for more detailed information on Scope of Work definition).

Considerations such as overtime allowances, project schedules, etc. are all part of and help define the Scope of Work.

B. Definitive Estimate

A Definitive Estimate is the capital cost estimate prepared when the design is advanced to the stage where the scope can be accurately defined for all disciplines, and recent quotations are available for all significant items based on current design specifications. The accuracy of this estimate should be ± 10%. (See E.P. COS 4*, Estimate Types).

4. DEFINITION OF TERMS (Continued)

C. Change in Scope

A Change in Scope is any modification, addition or deletion to the scope of work that affects project costs and/or schedules.

Changes in scope are classified as either "Minor" or "Major" and are defined as follows:

(a) Minor Change in Scope: For Projects up to $10,000,000: Not greater than $5,000 or 5% of contingencies, whichever is greater.

For Projects over $10,000,000: To be arranged at less than 5% of contingencies. Specific procedures will be developed for the particular project at less than 5% of contingencies.

(b) Major Change in Scope: Estimated cost exceeds the above limits.

Note: Significant changes in overtime, living and travelling expenses, and changes to project schedule are all "Changes in Scope" and can be either "Minor" or "Major" depending on the dollar amount.

"Extras" to a lump sum project are not classified as a Change in Scope unless they conform to the above definition.

D. Start-up Modifications

Start-up Modifications which are essential at time of start-up to make the project viable are not Changes in Scope. (Non-essential changes are not included.) On larger projects, a separate allowance should be provided in the main body of the estimate for start-up modifications. These items are not classified as "Changes in Scope".

E. Cost Deviations

Cost Deviations are variances in the cost of individual items from the amount in the definitive estimate due to incorrect estimates, cost effects due to extended deliveries, abnormal bad weather effects, etc. Cost deviations are not changes in scope.

F. Field Emergencies

Field emergencies refer to emergency work which arises at the construction site and requires prompt action. These are processed under the authority of the Resident Engineer by means of a Field Work Order. Such emergencies are not classified as changes in scope and are not part of this Engineering Procedure.

4. DEFINITION OF TERMS (Continued)

G. Contingencies

Contingencies in a project cost estimate are allowances for cost deviations, emergencies and minor changes in scope. It is not intended that "Contingencies" provide for Major changes in scope. Depending, however, on the final cost of the project and on the approval of the appropriate authorizing authority, contingency funds may be used for Major Changes in Scope.

H. Reserves

Reserves constitute an arbitrary designation of certain items in an estimate that are generally indeterminate and may or may not occur; as such they are administered for control purposes in a different manner than regular project items. Normally, they consist of the contingencies, but for major projects they may also include items such as overtime allowances, start-up modifications, escalation, etc. The exact content and amount of Reserves will vary with the nature and size of each project and are to be established for each project individually.

5. RESPONSIBILITY

The Engineering Department is responsible for the execution of the project in accordance with the described scope and for controlling the costs within the amount authorized. As such, it is responsible for controlling the contingencies, and hence for Minor Changes in Scope.

On projects up to $10,000,000 the Project Engineer is responsible for controlling Minor Changes in Scope. For projects over $10,000,000 see paragraph 4.C.

Approval of a project does not give the Engineering Department authority to initiate Major Changes in Scope. The Engineering Department must have a specific authorization from the Division or Department involved or higher authority in order to proceed with such a change.

The above is accomplished by a Major Change in Scope Form (Appendix "A") issued by the Project Manager in accordance with the following procedure:

6. AUTHORIZATIONS AND LIMITS

Minor Changes in Scope are handled as per EP COS 1 & 3.

Note: If the cumulative amount of Minor Changes in Scope reaches 20% of the contingencies, a major project review must be undertaken.

Major Changes in Scope must be recommended and approved as indicated on Appendix "A", then processed through the appropriate division or department and finally authorized by the following persons according to their authorized limits. (As per Guidance Manual for Capital Expenditures).

3. AUTHORIZATIONS AND LIMITS (Continued)

AUTHORIZATION OF MAJOR CHANGES IN SCOPE (Individual and cumulative changes)			
Departmental Projects		Divisional Projects	
Changes up to $15,000	Changes up to $50,000	Changes up to $100,000	Changes over $100,000
Authorized by Dept. Managers	Authorized by Distribution and Purchasing Manager	Authorized by Division Manager	Authorized by Vice President or higher authority

4. FUNDING OF MAJOR CHANGES IN SCOPE

Major Changes in Scope usually occur during the design/construction period of a project. It is not always possible to identify at that time whether or not there will be an overrun in excess of ten percent of the authorized amount. Therefore, those who authorize Major Changes in Scope must be prepared to provide the funds by means of a new or supplementary project, should funds not prove to be available at the project completion. A note to this effect is included on the form used to document scope changes (See Appendix "A").

5. REPORTING SYSTEM

Project cost statements are to incorporate information as to Major Changes in scope as indicated in Appendix "B". This method of presentation allows valid comparisons of the impact of Major Changes in Scope on the overall capital cost of a project. A summary of such data is also reproduced on the Major Change of Scope submission form to enable the persons authorizing such changes to visualize the financial status of the project.

Project No.: ______________

Change No.: ______________

Revision No.: ______________

ENGINEERING DEPARTMENT

PROJECT SCOPE CHANGE

Project Title. ______________________________ Estimated Cost of this Change $ __________

Area/Discipline: ______________________________ Date: ______________________________

Description of Change: *Attachments* ☐

Justification for Change:

.ect on Related Portion of Schedule:

Effect on Start-up Date : Advanced by ______ days. Retarded by _____ days. No Change _____

Total Forecast of "All" Changes To-date	$ __________	______	% of Cont.
Net Cost of This Change	$ __________	______	% of Cont.
Current Final Cost Forecast (Excluding this change)	$ __________	______	% (Over) Under
Current Final Cost Forcast (Including this change)	$ __________	______	% (Over) Under
Authorized Amount	$ __________		

Recomm/ Appr. by ____________________ (P. Eng. or P. Mgr.) Recomm by ____________________ (Chief Engineer) Date __________

Recomm/ Appr. by ____________________ (Steering Gr. Chairman) Auth. by:* ____________________ (Div. Mgr. or Exec. Committee Chairman) Date __________

.ected by: ______________________________

Reason for Rejection: ______________________________

* *Authorization of this change is a commitment to make a new or supplemental request for the funds indicated if the final cost of this project exceeds the amount authorized by 10%.*

GENERAL COST STATEMENT FORMAT

COST CENTRE	FINAL COST FORECAST	AUTHORIZED AMOUNT	(OVER) UNDER
DIRECT COSTS			
INDIRECT COSTS			
ENGINEERING			
CONTINGENCIES: DESIGN CHANGES			
: START-UP CHANGES			
: OTHER CONTINGENCIES			
INFLATION ALLOWANCE (IF ANY)			
TOTAL (Incl. Changes in Scope)			
NET COST OF MAJOR CHANGES IN SCOPE INCLUDED IN THE ABOVE			
TOTAL COST (Excluding Major Changes)			

Computers

As projects become larger, (and the size of projects seem to be continuously increasing) computers can make a tremendous contribution to the systems being used to document and control the projects. On the very large projects, they are becoming indispensable.

In general, computers:

- Handle large masses of data quickly.
- Produce reports faster (but can also delay them).
- Can be very versatile, offering a large choice of reports and reporting levels.
- Are consistent in processing data.

The market is flooded with all kinds of computer software programs all aimed at making some type of improvement to the overall engineering function.

The Computer Applications Committee of the American Association of Cost Engineers has published a report entitled "Cost Engineering Related Computer Software" containing a list of programs on the market along with a brief description of the scope and cost of each program.

Some of these programs are very comprehensive with claims that they will provide a fully integrated system for handling every requirement for the accounting and control of engineering projects.

However, a word of caution. Computerization is costly and large sums of money are spent before results can be obtained. Selection of a wrong system could be a costly mistake.

A computer should be used as a tool to assist an organization in accomplishing its objectives. The organization must not be a tool of the computer.

It is well to remember that cost control occurs through people. It concerns their attitude, their commitment, their involvement and is so broad in its application that it embraces more or less every facet of design, procurement and construction.

Most companies start with computer programs for individual operations such as doing data processing for manhours, payroll, purchase order control, etc. Expansion of the programs may result in computerizing the Project Cost Statement. Another program may be used for CPM scheduling. The overall aim may be to integrate all operations into one comprehensive program and ultimately the long range objective may be to have the system operating "on line".

Although the principles of cost control may be universally applicable to all functions, no two companies are exactly the same.

For example: is the Company concerned with design and draughting, or procurement, or construction or all three?

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en setbacks.
common pit-

ly emphasized.
when "scope must
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2. All cost plus contracts are "red warning flags".

3. Cut-off dates for all reports and documents should be consistent and well understood. One cut-off date for "cost + commitment to date" and a different date for "labour costs to date" can be very misleading.

4. Beware of "documents in progress". This refers to commitments which have occurred but for some reason have not yet been officially recorded as commitments and have also been overlooked in arriving at the "estimate to complete". Examples are unpaid equipment rentals due to tardiness in submitting invoices, purchase order requisitions not yet placed, unit price work actually completed but not yet invoiced, any labour accruals not yet invoiced, slow accounting of Field Work Orders, known claims acknowledged but not yet approved, etc., etc.

5. Anticipate factors that could affect labour costs, e.g. bad weather effects.

6. Too much reliance on trending and averaging principle to arrive at forecast final cost. The pattern of trending curves varies, depending on the item being trended e.g. concrete, piping, etc. An intimate knowledge of these patterns can help in making better forecasts.

7. The price on a purchase order at the time it is issued is rarely the final cost. Many add-ons are frequently overlooked such as freight, sales taxes, changes, escalation, etc.

8. Close out all Work Orders as soon as possible after completion. Otherwise someone will manage to get additional time charged against them.

9. When assessing progress and forecasting % complete, remember that the last mile is the slowest and most difficult.

ORGANIZATION

The organizational structures vary depending on the method of execution. For example, at one extreme various companies may be involved, each one having a different responsibility, while at the other extreme one company may be totally responsible for the design, procurement and construction. For example:

O represents an Owner's engineering dept. which may carry out the design, procurement of major equipment, and has construction carried out by contractors. In some cases, an owner will have a complete construction section which carries out construction by direct hire.

DC represents Design Consultants who carry out the same functions as above.

CM represents Construction Management Consultants who specialize in taking the drawings and specifications from others such as O or DC above and undertake to have them constructed by letting contracts and overseeing the work of the contractors.

PM represents Project Managers who specialize in managing the entire project on behalf of an owner and let contracts with design consultants and contractors and oversee the work.

GC & SC represents General Contractors and Sub-Contractors who carry out the construction work whether it be on the basis of lump sum contracts, unit price basis or some form of cost plus.

DB represents Design Build constructors who provide a complete service to design, procure and construct a plant, sometimes using their own construction personnel with direct hire and sometimes by letting construction contracts.

Thus, a project may be executed in any one of the following ways as illustrated in Table 5.

Table 5

Case	Overall Direction	Engineering Design by	Procurement		Constn. Mgt. by	Construction by
			Major Equip. by	Balance by		
1	O	O and/or DC	O	GC/SC	O	GC/SC
2	O	O and/or DC	O	GC/SC	CM	GC/SC
3	O	O	O	O	O	O
4	O	DC	DC	GC/SC	DC	GC/SC
5	O or PM	DC	DC	GC/SC	O or PM	GC/SC
6	O	DB	DB	DB	DB	DB or GC/SC

The above table is still only a partial indication of the combinations which occur.

There are many factors to consider in selecting the method of execution and these would include the eleven essentials for good cost control as discussed previously. Although other factors may be more significant in making the final decision, it is well to remember that as the number of participating organizations increase:

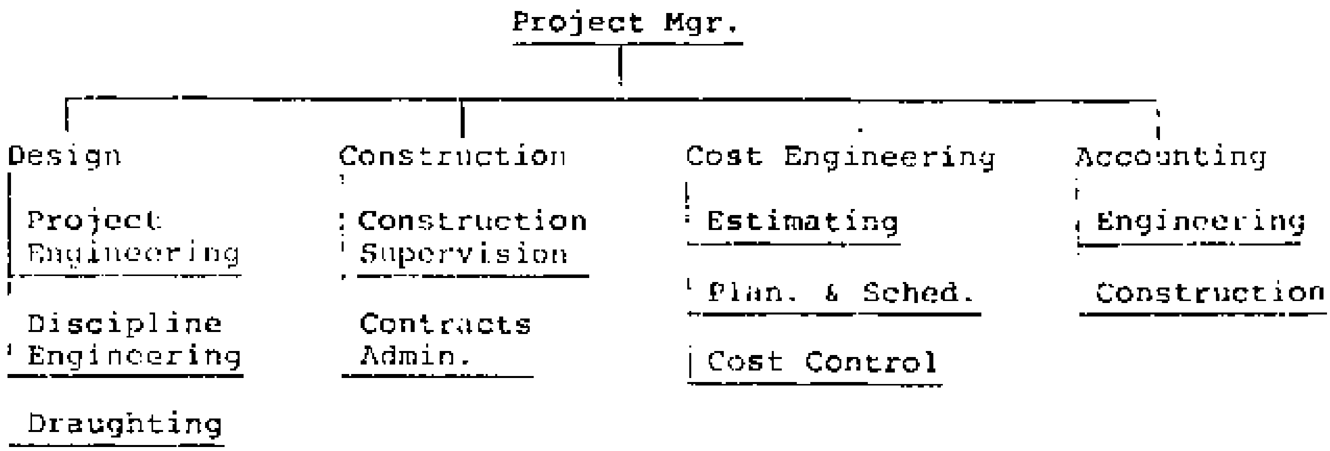
Management becomes more difficult.
Procedures become more important than ever and more voluminous.
Responsibilities are less clear and tend to overlap.
Communications become more difficult and often break down.
Overall control becomes more difficult.

Regardless of the method of execution, the foregoing principles of cost control apply. The only difference is the extent to which they are applied and this will vary with the responsibility.

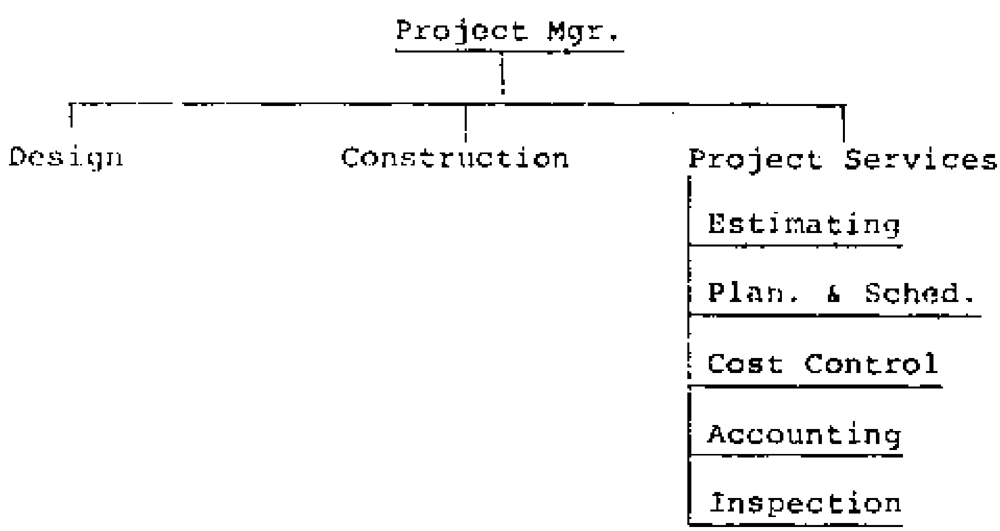
Thus, there are certain key functions which must be performed for good cost control and these must be given a place of importance in the organizational structure. Thus:

Estimating
Planning & Scheduling
Cost Control Activities
Project Accounting

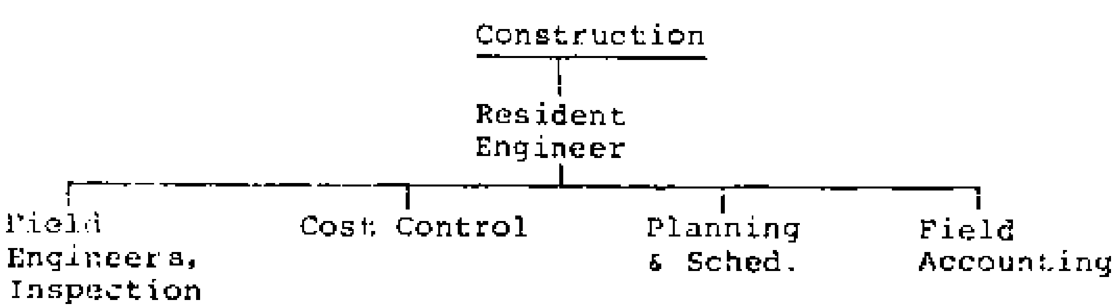
A central organizational structure may look something like:



or it may look like:



The field organization would be an extension of this, such as:



In a minimum size organization, for a very small project, one cost engineer may carry out the entire function of cost control and planning and scheduling with back-up from an estimating group. A project accountant would spend part time directing the clerical staff regarding the normal accounting requirements.

As the project got larger, there might be one cost engineer on control, one planning and scheduling engineer, back-up from an estimating group and one project accountant. These persons would service the entire project at head office as well as in the field.

As the project got larger, it would require a cost control engineer, a planning and scheduling engineer and an accountant in the field.

Each of these persons would respond to the resident engineer, but would take functional direction from their counterparts in the central organization.

As projects became larger, it would be a case of adding to the staff under these functions to match the requirements.

RECAPITULATION

To sum it up:

Cost control starts with management and must pervade the entire project organization. Management must want it, understand it, and provide the organization and staff to make it function. This applies to the engineering function, the procurement function and the contractors.

Good experienced staff are required and they must be dedicated to the overall philosophy of cost control.

The universal cost control cycle of realistic targets, monitoring, trending, forecasting, identifying problems and taking action was highlighted and underlies the entire concept of cost control.

The system must be dynamic and always pointed to the future. Historical data in itself is of limited value in cost control. Reporting must be prompt and timely.

In a nutshell, the Project Manager must know:

Where he's been.
Where he's at.
Where he's going.
What action he should take.

There's no easy route to good cost control. In essence, if you have it, it means your entire organization is a very efficient and effective well run operation.

RECOMMENDED REFERENCE MATERIAL

Title	Data in	Author	Publisher
Yardsticks for Costing	$	The Canadian Architect	Southam Business Publications Ltd. 1450 Don Mills Road Don Mills, Ontario
Building Construction Cost Data	$	Robert S. Means	Robert Snow Means Co. Inc., 100 Construction Plaza Duxbury, Massachusetts 02332
Commercial-Industrial Construction Estimating and Engineering Standards Volunes 1 and 2 Light Construction Estimating and Engineering Standards Volume 3 Process Plant Construction Estimating and Engineering Standards Volumes 4 and 5	$ & Mhrs.	International Construction Analysts	Richardson Engineering Services Ltd. 10021 Tecum P.O. Box 726 Downey, California 90241 U.S.A.
The Building Estimator's Reference Book	$ & Mhrs.	Frank R. Walker	Frank R. Walker Co. Chicago, Illinois
Fundamentals of Cost Engineering		H.C. Bauman	Reinhold Publishing Corp. New York
Control & Management of Capital Projects		J.W. Hackney	John Wiley & Sons, Inc. New York
Cost Engineers Notebook		Various	American Assoc. of Cost Engineers Morgantown, West Virginia

Title	Data in	Author	Publisher
Estimator's Piping Manhour Manual	Mhrs.	J.S. Page & J.G. Nation	Gulf Publishing Company Houston, Texas
Estimator's General Construction Manhour Manual	Mhrs.	J.S. Page	Gulf Publishing Company Houston, Texas
Estimator's Electrical Manhour Manual	Mhrs.	J.S. Page & J.G. Nation	Gulf Publishing Company Houston, Texas
Estimator's Manual of Equipment & Installation Costs	$ & Mhrs.	J.S. Page	Gulf Publishing Company Houston, Texas
Estimator's Manhour Manual - Heating, A/C, Ventilating & Plumbing	Mhrs.	J.S. Page	Gulf Publishing Company Houston, Texas
Process Plant Estimating, Evaluation & Control		K.M. Guthrie	Craftsman Book Co. of America Solana Beach, California
Managing Capital Expenditures for Construction Projects		K.M. Guthrie	Craftsman Book Co. of America Solana Beach, California

T R I A L S O L U T I O N S

...o ...rs)	Cash Flow	5%		10%		15%		20%	
		Discount Factor	Present Value	Discount Factor	Present Value	Discount Factor	Present Value	Discount Factor	Presen... Val...
-1		.9754		.9516		.9286		.9063	
-2		.9278		.8611		.7993		.7421	
-3		.8826		.7791		.6879		.6075	
-4		.8395		.7050		.5921		.4974	
-5		.7986		.6379		.5096		.4072	
-6		.7596		.5772		.4386		.3334	
-7		.7226		.5223		.3775		.2730	
-8		.6874		.4726		.3250		.2235	
-9		.6538		.4276		.2797		.1830	
-10		.6219		.3869		.2407		.1498	
0-11		.5916		.3501		.2072		.1227	
1-12		.5628		.3168		.1783		.1004	
2-13		.5353		.2866		.1535		.0822	
3-14		.5092		.2593		.1321		.0673	
4-[illegible]		.4844		.2347		.1137		.0551	
5-[illegible]		.4608		.2123		.0979		.0451	
6-17		.4333		.1921		.0842		.0369	
7-18		.4169		.1739		.0725		.0303	
8-19		.3966		.1573		.0624		.0248	
9-20		.3772		.1423		.0537		.0203	
0-21		.3588		.1288		.0462		.0156	

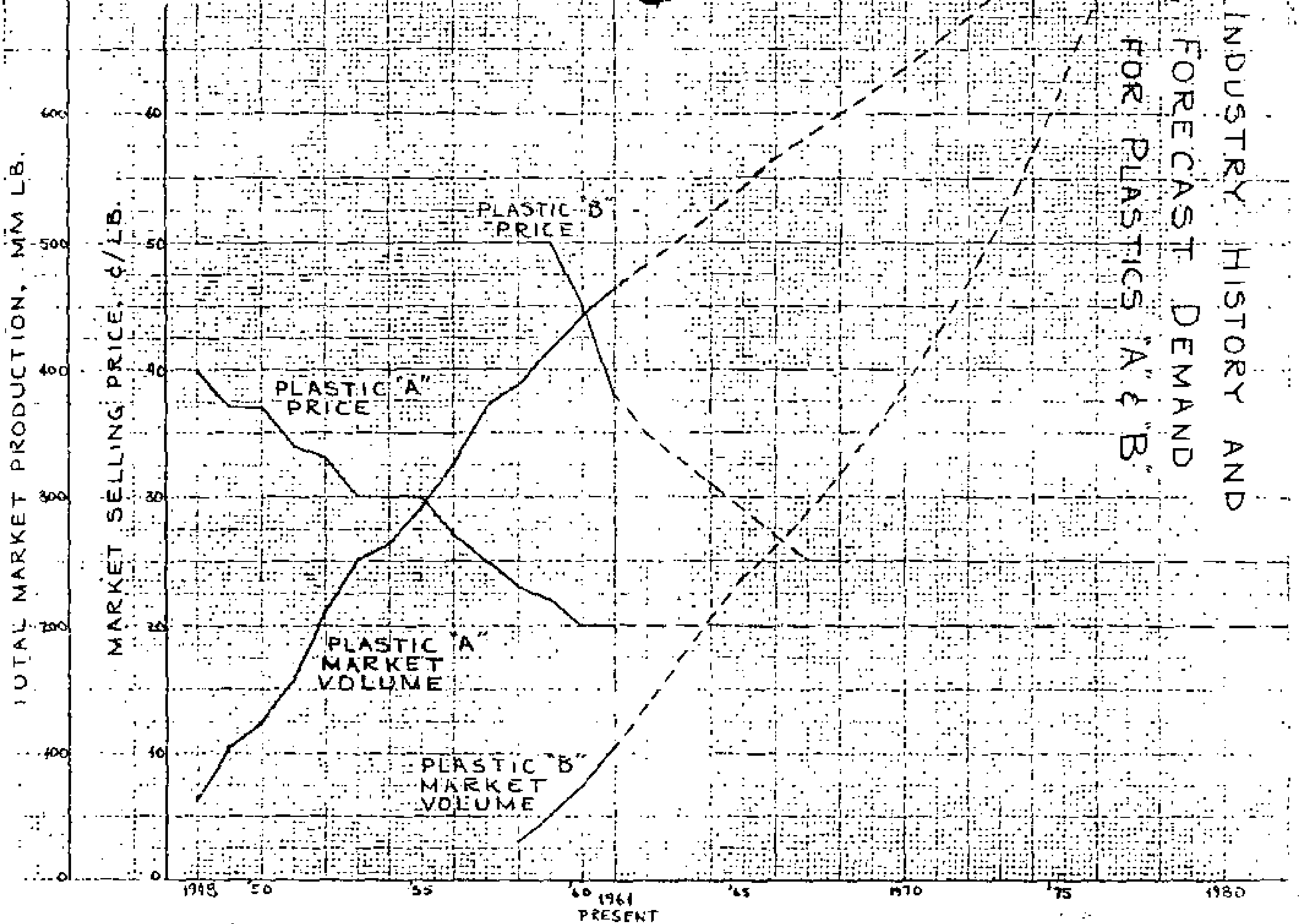


FIGURE 2

INDUSTRY HISTORY AND FORECAST DEMAND FOR PLASTICS "A" & "B"

Solution to Case Problem

I. Market Environment

The business environment is that of 1961. Plastic A has been important commercially since 1948 and Plastic B since 1958. Plots of the historic and forecast industry demand and price trends for each product are shown in Exhibits A-1 and A-2.

Over the past 10 years, Plastic A sales increased 220 per cent, from 210 MM lb in 1952 to 465 MM lb in 1961. Over the same period, prices declined 33 per cent from 30¢/lb. in 1952 to 20¢/lb. in 1961, as industry demand growth slowed from 33%/yr to 5%/yr. Future growth is projected at 4%/yr over the next five years and 3%/yr thereafter. Industry capacity has continually exceeded demand, and in 1961, there was 25 per cent surplus capacity. At forecast growth rates, no new capacity additions will be required until the end of 1967. Loco's 30 MM lb/yr plant represented 14 per cent of installed capacity when it came on stream in 1950 and only 5 per cent in 1961. The plant has not been sold out since 1955, presumably because of gradual obsolescence, and in 1961 operated at only 50 per cent of capacity.

In contrast, Plastic B is a relatively new commercial commodity and is still growing rapidly. Its 1961 sales are 105 MM lb, or only 22 per cent of Plastic A. Demand growth is expected to drop gradually from the current 40%/yr rate to 10%/yr in 1966 and beyond. If Loco builds it's 50 MM lb/yr Plastic B unit to come on stream in 1964, it will enter the market with a plant capable of supplying 24 per cent of the forecast demand with first year sales of 21 MM lb, or 10 per cent of total demand, and an initial price of 31¢/lb. If it defers commercialization three years, as probably will happen if it continues the development of its own process, then it will enter with a nameplate capacity equal to 17 per cent of the 1967 market, but because of increased competition is expected to achieve first-year sales of only 12 MM lb, or 4 per cent of demand, and an initial net back of only 25¢/lb.

Solution to Case Problem

I. Market Environment

The business environment is that of 1961. Plastic A has been important commercially since 1948 and Plastic B since 1958. Plots of the historic and forecast industry demand and price trends for each product are shown in Exhibits A-1 and A-2.

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9

II. Cash Flow Tables

The five basic cases are:

Plastic A (Existing business)	Plastic B (New business)
Continue as is	Purchase Knowhow
Present Plant-aggressive marketing	Develop Knowhow
10 MM lb./yr. expansion	

Possible combination cases will be discussed later.

The pro-forma P&L statements and cash flow tables for these five cases are given Tables A-3 and A-4. Each table summarizes the forecast revenues, expenses, and investment effects, by year. The table form is exactly comparable to that shown in the case description for the Plastic A post-installation appraisal.

The tables have a typical, useful format, which is automatically self-checking; specifically, the cumulative net profit after taxes must equal the cumulative cash proceeds from the project. The calculated annual cash proceeds are then discounted to determine the present values and interest rates of returns, or PI's, for the alternatives compared in these tables.

These tables will be discussed on a case-by-case basis followed by sample calculations. Those working this case should be able to check most numbers exactly. In certain instances, as in the working capital and depreciation calculations, some assumptions have to be made and some variability is acceptable.

What Alternate is the Case compared Against? Since all economics are relative, each cash flow table really summarizes the difference in cash flows between two alternates. It is important to explicitly recognize what these alternates are.

Product	Case	Alternate Compared Against (Base Case)
A	A_1, Continue As-Is	Get Out of business
	A_2, Present Plant-Agressive Mktg.	Get Out of business
	A_3, 10 MM Lb./Yr. Expansion	Present Plant-Aggressive Mktg.
B	B_1, Purchase Knowhow	Do nothing
	B_2, Develop Knowhow	Do nothing

This selection of the base case is to some degree arbitrary, but should be logical. In real life, changes are often made, after preliminary calculations show the relative attractiveness of the several alternates. For example, if the 10 MM lb./yr. plastic A expansion were shown to be an attractive addition to the aggressive marketing plan for the present plant, but the aggressive marketing plan itself was unattractive, then the expansion costs and benefits

9

II. Cash Flow Tables

The five basic cases are:

Plastic A (Existing business)	Plastic B (New business)
Continue as is	Purchase Knowhow
Present Plant-aggressive marketing	Develop Knowhow
10 MM lb./yr. expansion	

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	A_2, Present Plant-Agressive Mktg.	Get Out of business
	A_3, 10 MM Lb./Yr. Expansion.	Present Plant-Aggressive Mktg.
B	B_1, Purchase Knowhow	Do nothing
	B_2, Develop Knowhow	Do nothing

This selection of the base case is to some degree arbitrary, but should be logical. In real life, changes are often made, after preliminary calculations show the relative attractiveness of the several alternates. For example, if the 10 MM lb./yr. plastic A expansion were shown to be an attractive addition to the aggressive marketing plan for the present plant, but the aggressive marketing plan itself was unattractive, then the expansion costs and benefits

Alternate A_1--The current operating costs for Plastic A are supplied for two levels of operation. At one-third of capacity, the manufacturing costs are 45 per cent of capacity costs, with even the so-called fixed costs showing some variability over this wide range of operating conditions. The values shown in the cash flow table were obtained by linear interpolation:

	1962	1963	1964	1965	1966
Per Cent of Capacity	50	43	40	37	33
Expenses					
Raw Materials	525	460	420	385	350
Utilities	450	380	360	330	300
Catalyst & Chemicals	225	200	180	165	150
	1,200	1,040	960	880	800
Labor	1,040	970	935	900	865
Maintenance	225	206	198	189	185
Overhead	194	193	192	191	185
	1,459	1,369	1,325	1,280	1,235

The selling price and marketing expenses are taken directly from Table 4 of the case. Straight line depreciation is used since the investment was made before 1954. (In 1954 the tax regulations were changed, permitting accelerated depreciation of new investments for tax purposes.) The plant is fully depreciated in 1965.

Alternate A_2--Under the aggressive marketing plan, technical service and product improvement investments totalling $450 M, and increased marketing expenses, enable the plant to increase sales and reach capacity in two years. Table 4 in the case gave the yearly sales volumes and marketing expenses. Manufacturing costs are estimated by interpolation, as before.

Accelerated depreciation is possible for the future fixed investments. The four investments must be considered separately, in order to recognize differences in amount, timing, depreciation method, and tax credits on project termination:

Element	Existing Plant	Tech Service Lab	Product Improvement	Future Modernization
Value, $M	1,228	350	100	750
Depreciation Life	4 years	15 years	10 years	10 years
Depreciation Begins	1/1/62	1/1/62	1/1/62	1/1/66
Method	SL	SYD	SYD	SYD
Sample Calculation				
1962 Total, $369 M	$307 M	$44 M	$18 M	-
1966 Total, $179 M	-	$32 M	$11 M	$136 M

It was assumed that the small technical service lab and product improvement investments took little time to complete, and depreciation could begin in the year they were made. The modernization investment is assumed to take a year to complete, with depreciation beginning in the following year.

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III. Discounted Cash Flow Results (Five Alternates)

The DCF results are presented here for the five original cases along with a discussion of related areas of special interest. Combination cases will be covered later. The cash flows are taken directly from Tables A-3 and A-4.

Alternate A_1, Continue As Is

The standard trial and error DCF analysis shows only a 0.75 PI for continuing operation five more years. If this were the only choice, the plant would have to be shut down now. The present value calculations follow, using the cash flows obtained in the previous section:

		Trial Rate--1%			Trial Rate--10%	
Time	Cash Flow,	Factor	Table	Present Value	Factor	PV
0	(1,595)	1.000	-	(1,595)	1.000	(1,595)
0-1	267	.9950	B	266	.9516	254
1-2	201	.9851	B	198	.8611	173
2-3	166	.9753	B	162	.7791	129
3-4	134	.9656	B	129	.7050	94
4-5	(67)	.9560	B	(64)	.6379	(43)
5	935	.9512	A	889	.6065	567
	41			(15)		(421)

The solution rate is obtained by interpolation between 0 per cent and 1 per cent. Discounting the cash flow only at 10 per cent, the cost of capital, would also confirm the project is unattractive showing a negative present value of ($421 M). However, this does not give as clear a picture as to how poor performance really is, as to quote a 0.75 per cent return.

This analysis is incomplete, although correct as far as it goes. Since project performance is continuing to deteriorate, it might be attractive to operate the plant one or two more years, for example, and then shut it down. The best approach is to analyze the shortest life first, i.e., one year, as this should be the most attractive. When this short time span is being considered, it is important to determine the timing of cash flows as accurately as possible . For example, the calculated PI for continuing one more year ranges from 13.1 per cent to 5.4 per cent, with changes in the timing of cash flows from terminating the project.

Recovery Assumption	PI for Continuing 1 Year
Uniformly in 1962 (Year 1)	13.1
Uniformly in 1963 (Year 2)	5.4
At End of 1962	7.0

Recovery of working capital ($935 M) normally would occur at or very close to time of plant shutdown, as it would mainly cover sale of final inventories and collection of outstanding receivables. The timing of the $500 M tax credit on the undepreciated balance may

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15

ance, and illustrate the considerable variability in slopes which are commonly obtained. The three curves shown are:

	PI
A_1--Continue as is, 5 more years	0.75
A_2--Aggressive Marketing	7.8
A_2+A_3--Total Program, Aggressive Marketing, plus 30 per cent Expansion	6.5

Alternate B_1--Purchase Knowhow

Plastic B Cases

The PI for Alternate B_1 (purchase knowhow) is 13.1, and for Alternate B_2 (develop our knowhow) is 11.6. Purchased knowhow is preferred to the continued development of Loco's process in spite of higher investment and operating costs. Successful completion of Loco's process development is expected to take at least three more years, and would force a market entry under much more competitive conditions, with significantly lower sales prices and a slower sales buildup. There is a 16.4 PI incentive for investing in B_1 instead of B_2. This assumes the plant built with purchased knowhow, since it started production three years before the B_2 alternate, will also terminate three years sooner. To eliminate the problem of different lives, assume product is still offered to customers for the B_1 case, but on a resale basis, without profit or loss. This treatment could understate the purchase knowhow incentive by as much as one unit.

Exhibit A-6 shows PI present value curves for B_1, B_2, and the difference case. The B_1 and B_2 curves are normal in appearance, while the difference curve is very unusual. The present values for this are:

	Present Value, $M				
	0%	5%	10%	15%	20%
B_1 vs. B_2	36	2197	1647	366	(936)

This shape is typical of a multiple solution problem. To determine whether or not there is a multiple solution, it is necessary to determine the number of sign changes in the cumulative cash position. The data are:

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The yearly marketing cost effects credited to Alternate A_2, after 54 per cent taxes, are:

	Tech. Service Lab. Avoided	Deprec. Tax Credit Lost	Marketing Expense Savings	Total
1962	350	(24)	-	326
1963		(22)	-	(22)
1964		(20)	69	49
1965		(19)	87	68
1966		(17)	108	91
1967		(16)	129	113
1968		(14)	138	124
1969		(13)	138	125
1970		(11)	138	127
1971		(9)	138	129
End		(24)	-	(24)
	350	(189)	945	1,106

The discounted cash flows for these savings are added to those calculated for A_2, to get the new PI of 13.5.

	Trial Discount Rate				
	0%	5%	10%	15%	PI
A_2, Base Case	1,564	424	(311)	(787)	7.8
Marketing Savings	1,106	881	720	606	
Revised A_2	2,670	1,305	409	(181)	13.5

The PI for the total new investment in A_2 and B_1 is 13.2.

V. Sensitivity Analysis

Results

Once the basic cash flows have been determined, a sensitivity analysis is fairly easy to perform, as cash flow adjustments are required only for the factors that change. The results for A_2 alone, B_1 alone, and the combination case are:

		Sensitivity		
	Base Case PI	+ 1¢/Lb.	+ 10% Fixed Capital	-20% in Volume
A_2	7.8	6.1	-0.3	-3.4
B_1	13.1	1.2	-0.6	-1.6
$A_2 + B_1$	13.2	1.7	-0.5	-1.8

Exhibit A-5 gives the present values used to develop these sensitivities. The calculations supporting these present values immediately follow this discussion of results. The price sensitivity is the easiest to calculate, as only one item changes-- the yearly revenue. The investment sensitivity is slightly more complicated as both the investment and the depreciation tax credits are affected. The volume sensitivity is the most involved, taking into account the years the plant has idle capacity, and for this period, the effects on revenues, expenses, and working capital. For Plastic A, there are lost sales in the first three years of operation; for Plastic B, the sales loss covers five years.

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(2) Discounted Cash Flow (10 year life); T_0 = 1/1/62

	Cash Flow	5% Factor	5% PV	10% Factor	10% PV	15% Factor	15% PV
0-1	83	.9754	81	.9516	79	.9286	77
1-2	115	.9278	107	.8611	99	.7993	92
2-3	138	.8826	122	.7791	108	.6879	95
3-4	138	.8395	116	.7050	97	.5921	82
4-5	138	.7986	110	.6379	88	.5096	70
5-6	138	.7596	105	.5772	80	.4386	61
6-7	138	.7226	100	.5223	72	.3775	52
7-8	138	.6874	95	.4726	65	.3250	45
8-9	138	.6538	90	.4276	59	.2797	39
9-10	138	.6219	86	.3869	53	.2407	33
	1,302		1,012		800		646

b. 10% in fixed capital
This variation applies only to future fixed capital, and associated depreciation tax credits. There is no uncertainty in the initial tax book value and existing depreciation credits. The future investments are $350M in 1962 for a technical service laboratory, and $100M for plant modernization. An additional $750M plant modernization is required in 1965. Assume these new investments are depreciated using 10-year SYD. Ignore the half-year convention sometimes used in determining first year depreciation.

(1) Cash Flow Changes, $M

	Fixed Capital	Depreciation Tax Credits 1962 Invest.	Depreciation Tax Credits 1965 Invest.	Net Cash Flow
0-1 (1962)	(450)	44		(406)
1-2		40		40
2-3		35		35
3-4 (1965)	(750)	31	74	(645)
4-5		27	66	93
5-6		22	59	81
6-7		18	52	70
7-8		13	44	57
8-9		9	37	46
9-10		4	73*	77
		243	405	(552)

*Tax Credit on undepreciated balance, at project termination.

(2) Discounted Cash Flow
Using Table B_1 as before gives the following present value results, based on a 10% change in the above cash flow, and summation of the yearly present values.

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(2) Discounted Cash Flow

Using Table B_1 as before gives the following present value results, based on a 10% change in the above cash flow, and summation of the yearly present values.

II. Development of B_1 Sensitivities

a. +1¢/Lb. margin increase

(1) Cash Flow Changes

1964	21 MM Lb. x 1¢/Lb. x .46	= $ 97 M
1965	28 MM Lb. x 1¢/Lb. x .46	= $129 M
1966	37 MM Lb. x 1¢/Lb. x .46	= $170 M
1967	46 MM Lb. x 1¢/Lb. x .46	= 212 M
1968+	50 MM Lb. x 1¢/Lb. x .46	= 230 M

(2) Discounted Cash Flow Note: t_o = 1/1/62
Use Table B as before, with the same reference point as for Plastic A, to permit adding sensitivity present values for both plastics use a 15 year economic life. The resultant present values are:

	0%	5%	10%	15%
$M	3138	1930	1250	825

b. +10% of fixed capital.
In order to show the maximum effect, it is also assumed that the initial $1,500 MM royalty payment is subject to this uncertainty, and has been included. In real life the analyst could check to see if the license terms were firm or not. Calculating of this sensitivity and excluding the royalty payment is also acceptable.

(1) Cash Flow Changes
The fixed capital and depreciation allowance are therefore taken directly from the pro forma P&L for Plastic B_1. In any year the investment cash flow is the algebraic sum of the fixed investment outlay and 54 per cent of the depreciation.

(2) Discounted Cash Flow
Use Table B_1 and 17 years of cash flow effects.
For a 10 per cent change, the resultant present values are:

	0%	5%	10%	15%
$M	(545)	(671)	(741)	(779)

c. -20% in volume. (Plant capacity is 50MM Lb./Yr.)

	1964	1965	1966	1967	1968	1969	1970
Original Sales Forecast, MM Lb.	21	28	37	46	50	50	
Slow Growth Forecast, MM Lb.	17	22	30	37	46	50	
Lost Sales	4	6	7	9	4	0	
Memo: Original Forecast W/O Capacity Limit	21	28	37	46	57	70	

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Original Sales Forecast, MM Lb.	21	28	37	46	50	50	
Slow Growth Forecast, MM Lb.	17	22	30	37	46	50	
Lost Sales	4	6	7	9	4	0	
Memo: Original Forecast W/O Capacity Limit	21	28	37	46	57	70	

The results are:

	Change in Return	Rate of Return
Original Evaluation		46.7
Higher Tax Rate	1.9	
4-year shorter life	0.1	
Revised Original Evaluation		44.7
Increased Costs	1.9	
Idle Capacity	5.7	
Price Decline	5.5	
Actual Result		31.6

The original Plastic A project was justified by a calculated 1.5 year payout. Although no discounted cash flow calculation was made at the time, enough data exist to estimate an approximate value. The rate of return calculation is very sensitive to the investment pattern assumed, at the high discount rates involved. The original evaluation, as calculated here with a 46.7 PI assumes the same one and one-half year investment pattern as actually reported. Other reasonable investment patterns are also acceptable. The extreme and erroneous assumption of all investment at time zero gives a 74 per cent PI.

Two adjustments are made to the original evaluation before calculating the impact of operating performance. First, the tax rate increased from 38 per ent to 54 per cent in the fourth year of operation. Also, the PIA calculation assumes the original project, without aggressive marketing, would be abandoned by January 1, 1962, giving an 11-year life instead of the 15 years originally expected. (This assumption is justified by the previous economic analysis which showed only a 7.0 PI for continuing as is, for one year.) The effects of the higher tax rate and shorter life are very small at these high discount rates as future years are less important to project profitability.

The very high original estimates with their assumptions of constant price and capacity sales, do not conform to real life, in a normal competitive environment. In fact, the actual result is still very good and was possible primarily because of a high price in the early years. It appears that the original decision to produce Plastic A was a good one, and historic profitability is excellent in spite of the subsequent mistakes made by management.

The order used in making the adjustments to the original evaluation will have no effect on the calculated actual result, but does to some extent affect the change in return calculated for each element. Thus, if effect of price declines was calculated first, and increase in costs, last, the change in return because of price declines would have been slightly greater and the effect of increased costs, correspondingly less.

The cash flow tables for each of the new cases are shown in Appendix Tables A-6 through A-10.

Table A-7

Plastic A--Post Installation Appraisal

Condensed Profit & Loss Statement, $M

Step 2--Original Evaluation with Tax Rate Changes

Year	Time Period	Net Sales	Cash Costs	Deprec.	Taxable Net Income	Tax Rate, %	Net Profit A/T	Cash Return	Investment: Fixed Cap.	Investment: Working Cap.	Cash Proceeds: Annual	Cash Proceeds: Cumulative
1949	0-1								(3,063)		(3,063)	(3,063)
1950	1-2								(1,537)		(1,537)	(4,600)
1951	2-3	10,500	3,708	307	6,485	38%	4,021	4,328		(1,315)	3,013	(1,587)
1952	3-4	10,500	3,708	307	6,485	38%	4,021	4,328			4,328	2,741
1953	4-5	10,500	3,708	307	6,485	38%	4,021	4,328			4,328	7,069
1954	5-6	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	10,359
1955	6-7	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	13,649
1956	7-8	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	16,939
1957	8-9	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	20,229
1958	9-10	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	23,519
1959	10-11	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	26,809
1960	11-12	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	30,099
1961	12-13	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	33,389
1962	13-14	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	36,679
1963	14-15	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	39,969
1964	15-16	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	43,259
1965	16-17	10,500	3,708	302	6,490	54%	2,985	3,287			3,287	46,546
End		-	-	-	-		-	-	-	1,315	1,315	47,861
		157,500	55,620	4,600	97,280		47,861	52,461	(4,600)	0	47,861	

Note
Keep all assumptions the same as in original evaluation, except for tax rate change.

Table A-7

Plastic A--Post Installation Appraisal

Condensed Profit & Loss Statement, $M

Step 2--Original Evaluation with Tax Rate Changes

Year	Time Period	Net Sales	Cash Costs	Deprec.	Taxable Net Income	Tax Rate, %	Net Profit A/T	Cash Return	Investment: Fixed Cap.	Investment: Working Cap.	Cash Proceeds: Annual	Cash Proceeds: Cumulative
1949	0-1								(3,063)		(3,063)	(3,063)
1950	1-2								(1,537)		(1,537)	(4,600)
1951	2-3	10,500	3,708	307	6,485	38%	4,021	4,328		(1,315)	3,013	(1,587)
1952	3-4	10,500	3,708	307	6,485	38%	4,021	4,328			4,328	2,741
1953	4-5	10,500	3,708	307	6,485	38%	4,021	4,328			4,328	7,069
1954	5-6	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	10,359
1955	6-7	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	13,649
1956	7-8	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	16,939
1957	8-9	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	20,229
1958	9-10	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	23,519
1959	10-11	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	26,809
1960	11-12	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	30,099
1961	12-13	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	33,389
1962	13-14	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	36,679
1963	14-15	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	39,969
1964	15-16	10,500	3,708	307	6,485	54%	2,983	3,290			3,290	43,259
1965	16-17	10,500	3,708	302	6,490	54%	2,985	3,287			3,287	46,546
End		-	-	-	-		-	-	-	1,315	1,315	47,861
		157,500	55,620	4,600	97,280		47,861	52,461	(4,600)	0	47,861	

Note
Keep all assumptions the same as in original evaluation, except for tax rate change.

Effect of Timing Assumption on PI

Continuing Plastic A Manufacture One More Year

Time	Cash Flow	Table	Trial Rate 5% F	5% PV	10% F	10% PV	With Linear Interpolation (Approx.)
0	(1595)	-	1.000	(1595)	1.000	(1595)	PI = 13.1
1962	1702	C	.9754	1660	.9516	1620	
1963	-						
	107			65		25	
0	(1595)	-	1.000	(1595)	1.000	(1595)	
1962	267	C	.9754	260	.9516	254	PI = 5.4
1963	1435	B	.9278	1331	.8611	1236	
	107			(4)		(105)	
0	(1595)	-	1.000	(1595)	1.000	(1595)	
1962	267	C	.9754	260	.9516	254	
1	1435	A	.9512	1364	.9048	1298	PI = 7.0
	107			29		(43)	

Effect of Timing Assumption on PI

Continuing Plastic A Manufacture One More Year

Time	Cash Flow	Table	Trial Rate 5% F	5% PV	10% F	10% PV	With Linear Interpolation (Approx.)
0	(1595)	-	1.000	(1595)	1.000	(1595)	PI = 13.1
1962	1702	C	.9754	1660	.9516	1620	
1963	-						
	107			65		25	
0	(1595)	-	1.000	(1595)	1.000	(1595)	
1962	267	C	.9754	260	.9516	254	PI = 5.4
1963	1435	B	.9278	1331	.8611	1236	
	107			(4)		(105)	
0	(1595)	-	1.000	(1595)	1.000	(1595)	
1962	267	C	.9754	260	.9516	254	
1	1435	A	.9512	1364	.9048	1298	PI = 7.0
	107			29		(43)	

FIGURE 10

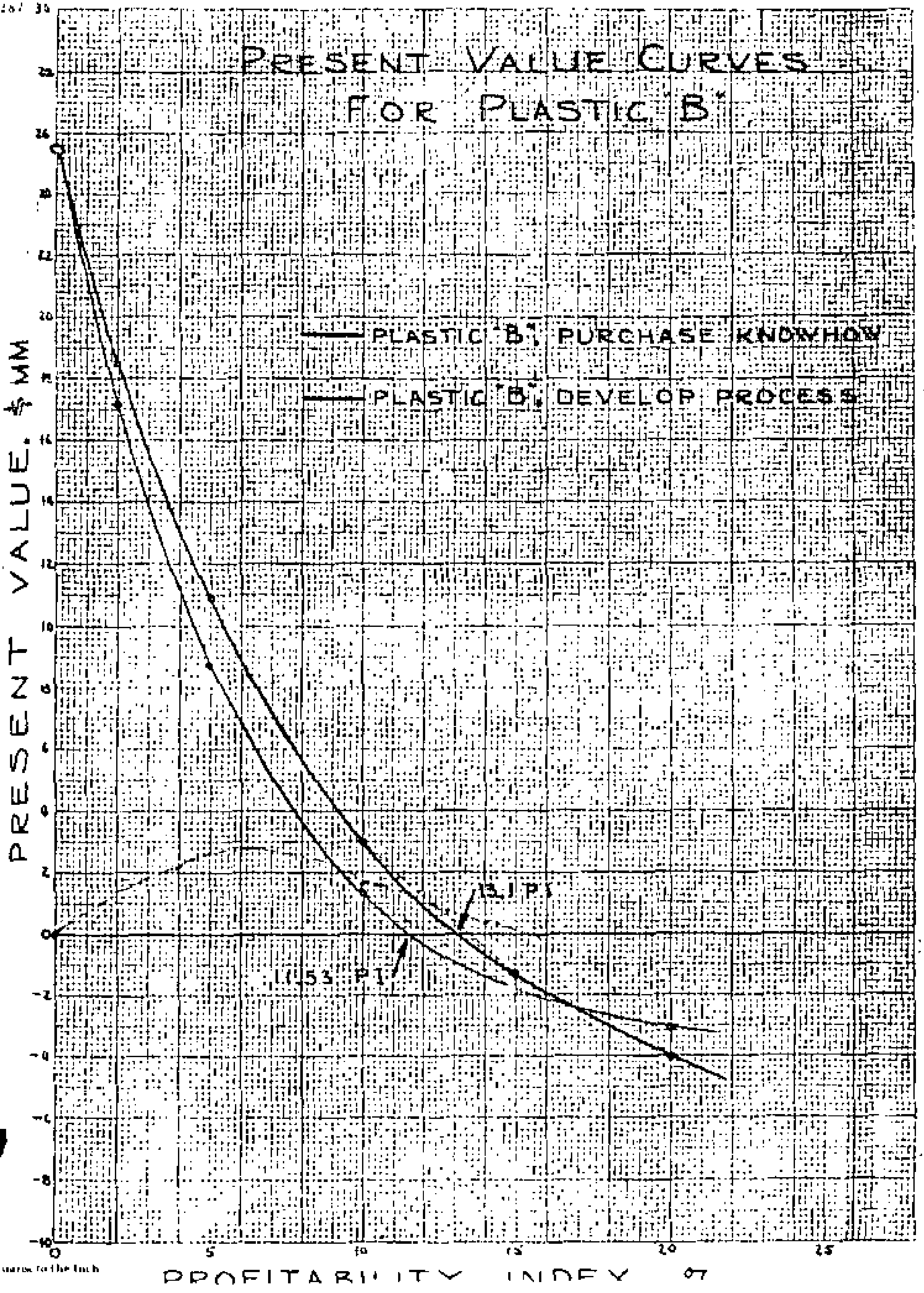
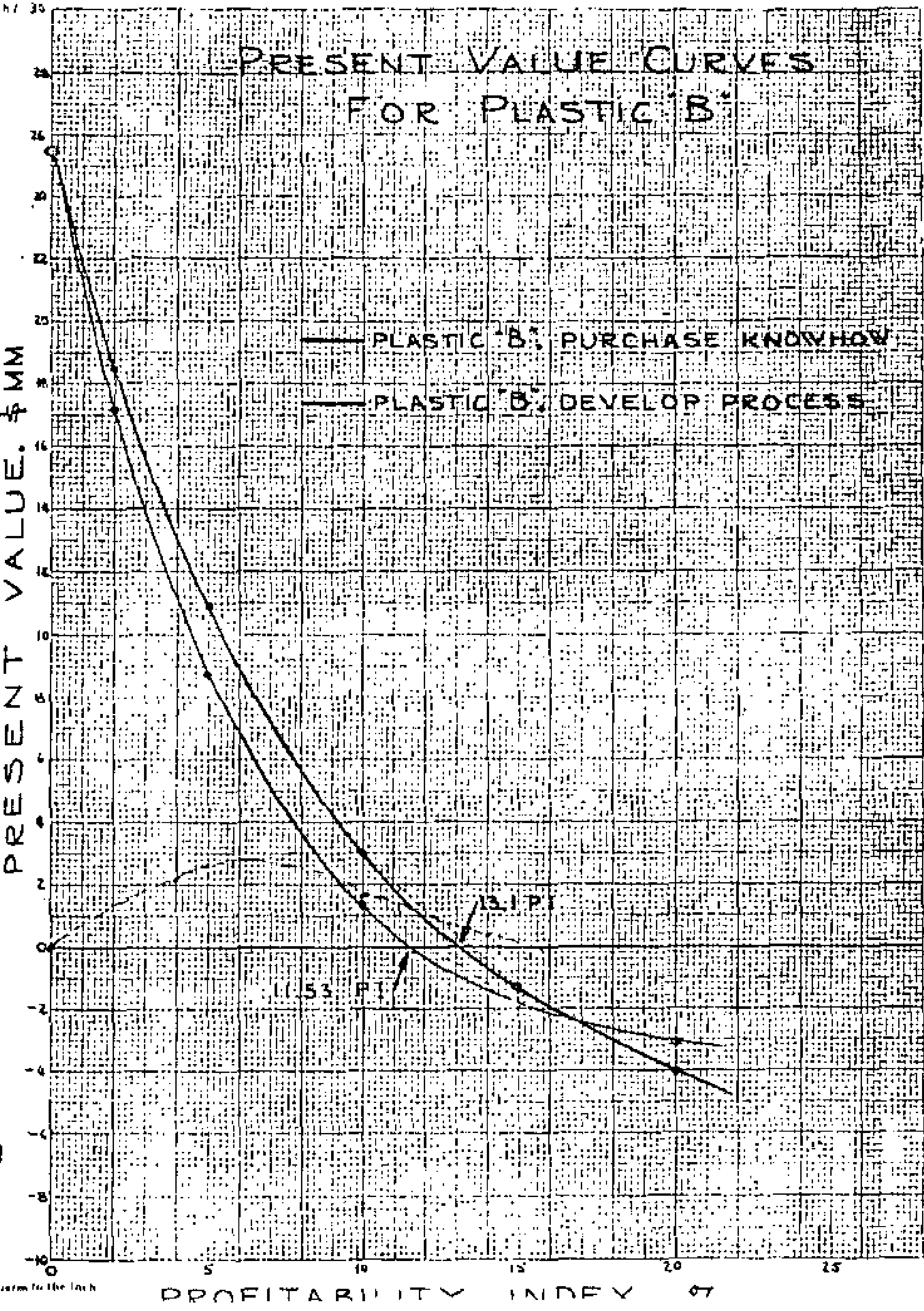

PRESENT VALUE CURVES
FOR PLASTIC "B"
PLASTIC "B", PURCHASE KNOWHOW
PLASTIC "B", DEVELOP PROCESS
13.1 PI
11.53 PI
PRESENT VALUE, $MM
PROFITABILITY INDEX, %

FIGURE 10



PRESENT VALUE CURVES
FOR PLASTIC "B"
PLASTIC "B", PURCHASE KNOWHOW
PLASTIC "B", DEVELOP PROCESS
13.1 PI
11.53 PI
PRESENT VALUE, $MM
PROFITABILITY INDEX, %

Requesting Dept.:		Approval Required:	
Mfg.	X	Board	
S&T		Gen. Off.	
Mktg.		Field Mgr.	
R&D		Other	

Request for Appropriation

Capital Investments (6a,b,c) $ 11,950M
Loans (6d) $
Lease Commitments (6f) $

Date
Appn. No.
Est. No.
Requesting Location

1. Project Title and Location: Plastic A & B Expansion Program

2. Description of Proposal:
Construct 50 MM lb./yr. Plastic B Plant using purchased know-how
Construct Technical Service Lab for Plastic A and Plastic B

3. Purpose of Expenditure:
Increase Profits X — By: Entering new market
Maintain Profits X — Modernize existing plant and improve marketing
Other

4. Timing:

Construction Period	18 mos.
Estimated Start-up Date	1/1/64
Estimated Useful Life	15 yrs.
Term of Lease or Loan	yrs.

5. Effect of Delay in Approval:
Lost competitive position and profits

6. Funds Appropriated:

a. Depreciable Capital	$ 11,950
b. Non-Depreciable Fixed Capital	$ 0
c. Costs Expensed	$ 0
d. Loans	$ 0
e. Total Initial Investment	$ 11,950
f. Lease Commitments (Disc. @ 5%)	$

7. Associated Investments:

a. Change in Current Assets	$
b. Change in Current Liabilities	$
c. Change in Net Working Capital	$ 2,880
d. Other Commitments (Disc. @ 5%)	$
e. Contingent Liabilities	$
f. Possible Future Investments	$ 750M

8. Present Facilities:

a. Approximate Age	11 yrs.
b. Approximate Original Cost	$ 4,600 M
c. Salvage Value	$ 1,228 M
d. Dismantling Cost	$ 0

9. Description of Base Case Against Which PI is Calculated:
A – Versus getting out of business
B – Versus Doing Nothing

10. Profitability Index: B 13.1
a. Sensitivities A 14.3
Likely Total 13.2

	Likely Variation in Value	Change in PI A	Change in PI B	Change in PI TOTAL
Investment	+10%	-0.3	-0.6	-0.5
Price	+1¢/lb.	+6.1	+1.2	+1.7
Volume	-20%	-3.4	-1.6	-1.8
Savings				
Project Life				

11. Effect on P&L and Rate of Return:
(M Dollars except as noted)

	Pre-Start	1	2	3	4	5	6-10	11-15	16-20	20+
Profit After Taxes										
Cumulative Cash Position										
Average Investment										
Book Rate of Return - %										
R of R w/Disc. Commit. - %										

NOT APPLICABLE

12. Related Appropriations Either Recently Authorized or to be Requested:
None

13. Budget Status:
Item L-6, $10 MM

14. Remarks: Plastic B is attractive in its own right. Purchased knowhow is preferred to continue development of Loco's process, in spite of higher investments and operating costs. Successful completion of Loco's process development is expected to take at least 3 more years, forcing a market entry under much more competitive conditions. Because of significantly lower sales prices, and a slower sales buildup, the estimated PI for

Recommended By — Date — Approved — Date

Requesting Dept.:		Approval Required:	
Mfg.	X	Board	
S&T		Gen. Off.	
Mktg.		Field Mgr.	
R&D		Other	

Request for Appropriation

Capital Investments (6a,b,c) $ 11,950M
Loans (6d) $
Lease Commitments (6f) $

Date
Appn. No.
Est. No.
Requesting Location

1. Project Title and Location: Plastic A & B Expansion Program

2. Description of Proposal: Construct 50 MM lb./yr. Plastic B Plant using purchased know-how
Construct Technical Service Lab for Plastic A and Plastic B

3. Purpose of Expenditure:
I. . ease Profits X By: Entering new market
Maintain Profits X Modernize existing plant and improve marketing
Other

4. Timing:

Construction Period	18 mos.
Estimated Start-up Date	1/1/64
Estimated Useful Life	15 yrs.
Term of Lease or Loan	yrs.

5. Effect of Delay in Approval:

Lost competitive position and profits

6. Funds Appropriated:

a. Depreciable Capital	$ 11,950
b. Non-Depreciable Fixed Capital	$ 0
c. Costs Expensed	$ 0
d. Loans	$ 0
e. Total Initial Investment	$ 11,950
f. Lease Commitments (Disc. @ 5%)	$

7. Associated Investments:

a. Change in Current Assets	$
b. Change in Current Liabilities	$
c. Change in Net Working Capital	$ 2,880
d. Other Commitments (Disc. @ 5%)	$
e. Contingent Liabilities	$
f. Possible Future Investments	$ 750M

8. Present Facilities:

a. Approximate Age	11 yrs.
b. Approximate Original Cost	$ 4,600 M
c. Salvage Value	$ 1,228 M
d. Dismantling Cost	$ 0

9. Description of Base Case Against Which PI is Calculated:

A - Versus getting out of business
B - Versus Doing Nothing

10. Profitability Index: B 13.1
a. Sensitivities A 14.3
Likely Total 13.2

	Variation in Value	Change in PI A	B	TOTAL
Investment	+10%	-0.3	-0.6	-0.5
Price	+1¢/lb.	+6.1	+1.2	+1.7
Volume	-20%	-3.4	-1.6	-1.8
Savings				
Project Life				

11. Effect on P&L and Rate of Return:
(M Dollars except as noted)

	Pre-Start	1	2	3	4	5	6-10	11-15	16-20	20-
Profit After Taxes										
Cumulative Cash Position										
Average Investment										
Book Rate of Return - %										
R of R w/Disc. Commit. - %										

NOT APPLICABLE

12. Related Appropriations Either Recently Authorized or to be Requested:
None

13. Budget Status:
Item L-6, $10 MM

14. Remarks: Plastic B is attractive in its own right. Purchased knowhow is preferred to continue development of Loco's process, in spite of higher investments and operating costs. Successful completion of Loco's process development is expected to take at least more years, forcing a market entry under much more competitive conditions. Because of significantly lower sales prices, and a slower sales buildup, the estimated PI for

Recommended By   Date   Approved   Date