centro de educación continua
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CONTINUING EDUCATION SEMINAR

ON

COST ENGINEERING APPROACH TO PROJETC EVALUATION - CONCEPTION TO OBSOLESCENCE

Prepared for

6th International Cost Engineering Congress

October 19 1980

Mexico City

Presented By

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AND

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Cost Engineering Approach To Project Evaluation

VII. Project Control
- A. an Engineer/Constructors Cope With Tomorrow's Challenge?
- B. Control Project Costs Effectively
- C. Get Ready For Megaprojects
  1. Part 1
  2. Part 2
- D. Control Small Projects
- E. Check Project Progress With Bell And 'S' Curves
- F. Cost Control Procedures
  1. Overview
  2. Organization Charts
  3. Information Center Approach To Cost Engineering
  4. Change Notice Information
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VIII. Facility Operation
- A. Maintenance Trends
- B. Equipment Design Trends
- C. Operational Spending
  1. Expenditures 1977-1981
  2. Energy Requirements
  3. Operating Costs Surge Ahead
- D. Environmental Managements Trends
- E. Fire Protection/Safety And Job Training Trends

IX. Workshop/Open Forum

CONTINUING EDUCATION SEMINAR

3.5 COST ENGINEERING APPROACH TO PROJECT EVALUATION--CONCEPTION TO OBSOLESCENCE

19 OCTOBER 1980

MEXICO CITY

General Description

This seminar will provide both Owners and Contractors with a broad, but pertinent introduction to the critical success factors involved in project evaluation. The impact of the economic environment will be examined through specific examples starting with project conception. Key aspects of the market systems will be examined. Supply, demand and price on a worldwide basis will be evaluated. Management and control of the resulting capital project will be highlighted through specific examples of the priority ranking of the various cost elements that affect the final capital investment. Operating cost considerations that will determine the ability of the plant to survive until obsolete in a competitive environment will be examined and evaluated.

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Cost Engineering Approach To Project Evaluation--
Conception To Obsolescence

I. Introduction -- Philosophy of Industrialization

II. Planning An Industrial Complex

III. International Project Finance

- A. Know Finance Scope and Structure
- B. Analyze Risks With This Method
- C. How Finance Impacts Profitab-lity
- D. When Engineers Are On The Team
- E. How Banks Aided Brazil's HPI
- F. Major Factors To Consider In Project Finance
- G. World Money Resources For Project Finance

IV. Market Evaluation

- A. Supply/Demand
  - Trends - Energy, Construction
    - Petrochemical, Refining, Gas Processing, Solid Fuels
- B. Price/Cost Forecasting
  - Forecasting HPI Plant Cost
  - Market Factors, DRI Cost Forecasting, Purchasing Application
- c. Labor Productivity/Availability
  1. Increase Your Plants' Productivity

V. Project Evaluation

- A. Model
  1. Capital Investment
  2. Benefits
  3. Costs
  4. Expenses
  5. Income Taxes
  6. Cash Flow
- B. Profitability
  1. Instantaneous
  2. Net Present Value
  3. Discounted Cash Flow
- C. Cash Flow
  1. Payout Criteria
  2. Monies Required Over Times

VI. Workshop - Case Problems

It is our intention to address this topic from both the owners as well as the contractors points of view. Also, we will attempt to outline the importance of the role each must play in the successful establishment of an industrial complex.

Also, we will direct our discussion more towards the smaller projects in the 'Developing' or 'Emerging' countries. My recent travels have taken me more and more to the developing areas of the world. These areas are just beginning industrialization on a significant scale.

Mr. Templeton and I will divide this in such a way so that my part will relate more to the philosophy, basic planning and the ultimate decision to proceed with an industrial complex. Mr. Templeton will join also on these basics but in addition will place emphasis on the 'hard core' Cost Engineering aspects of this concept.

Philosophy of Industrialization

Industrialization in 'Developing' or 'Emerging' countries carries many connotations and just as many definitions. Areas can range from extremely remote, severe climates, unpopulated desert areas of the Middle East to countries such as Mexico and Brasil who already possess considerable infrastructure.

Industrialization does not come without its penalities, its costs, its gains and its losses. And great sacrifice is required for each change. Cultural changes which must accompany modern industrial development are often overlooked in the rush to join the so-called 'Modern World.' The influx of strange expatriates bring with them a counter-culture that can drastically affect a fragile way of life.

To me, this is a very important decision. I have visited areas where industrialization has almost completely destroyed a historic way of life--with all of its beauty, culture, cruelity, honesty and most of the heritage. Therefore, everyone should realize that any 'magnum step' toward the modern world must bring drastic changes. And they must be prepared to pay the price!

Our first assumption is that a country has decided to make this step and industrialize. You must decide what you want to give up for what you expect to gain. Is the goal to seek maximum employment? If that is the goal, then industries which are labor intensive should be considered. If the goal is to satisfy the food needs of the people? Then agriculture and those industries serving and using agricultural products should be selected.

Of course, goals are never easy to set or for that matter even to define. And further, there may be multiple goals

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which call for interlocking mutually supportive types of industries.

What usually happens is a series of plants--most popularly the 5-year plans. The resources and efforts are spread throughout the various sectors of the plan. Priotities are assigned to the various sectors.

The sad part about most of these plans is that they never succeed. Too many resources and too much effort is used in the planning. The planners worked hard and did a good job. But the final decision was made by politicans or managers who's first responsibility was to politics. Thus, after 5-years, another 5-year plan is again formulated.

We are going to introduce this subject so the the first 5-year plan will finish with the ultimate goal--a functioning industrial complex.

Walk before you run!

Without knowing for sure, I would assume that when a 'boy' hippo sees a 'girl' hippo we would think 'big is beautiful.' He would never concern himself about providing food and shelter for his 'beautiful' girl friend.

Lets look quickly at some of the meanings of size of industrial complexes. On Plot No. I-1 we can see how the investment per ton of daily production declines as an ammonia plant becomes larger.

Plot No. I-2 compares a large and a small ammonia plant built in a developing area. While the large plant would be constructed by conventional means at the plant site, the smaller unit would be largely pre-fabricated at an indsutrial site and transported to the developing area. Please notice that the principal added cost areas are the permium for difficult field construction and the longer term for construction interest and escalation.

On Plot I-3 lets see what happens to production costs when we are forced to 'turn down' the larger unit because of any one of a multitude of reasons. Plot I-3 clearly shows thay by operating the small plant at full capacity we are always below the total cost of production per ton than the larger plant. Of course, this is over simplified and there are many valid reasons for building larger plants under the proper conditions.

Therefore, small can be beautiful as well as profitable. It is much easier to operate a smaller plant and to develop the infrastructure as well as train operating personnel.

One other example is shown in Plot No. I-4. This is what can happen to production costs when a large LD-Polyethylene poant must be turned down. Production costs are actually 30 % higher when operating rate is reduced by 50 %.

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Unless you are prepared to take one of these 'giant' plants and operate it at full design capacity, it is better to 'wald before you run.' We have seen this happen so often, even with the best planning. We will get into this as we continue.

International project financing

Many things enter into this question of industrialization and except for the few extremely wealthy areas of the world, the most important question is financing.

Just as there is 'truth in lending' there is also the corresponding 'truth in borrowing.' The lender only has a small stake in any endeavor--they are lending monies which can be replaced. Contrast this with the stake of the borrowers.

The 'borrower' often has the highest risk. For he is staking his entire future and his reputation on his ability. Not only to repay the loan--but his future ability to go to the lenders in the future for another loan.

Therefore, the integrity of both parties will be placed under the highest power microscope. And both sides had best have their 'houses in order.'

Basic needs

The basic needs in most developing countries can generally be defined as food, clothing and shelter for the inhabitants. Aside from climate conditions the absence of sufficient infrastructure to supply these basic needs is part of the definition of a developing country.

Therefore, the infrastructure required to prepare the initial survey of the basic needs may need to be imported. The first step is to approach the world agencies which supply aid to help a developing country in these initial studies and basic plans.

Since this initial stage will have continuing impact on any industrialization, it is perhaps the most important and often times the most poorly handled. Nevertheless, this first step must be taken before meaningful and lasting developments can begin. It is also a subject which deserves much more time than we can devote to it here. Therefore, we must assume that this has already been accomplished.

Step two consists of reviewing the results of the initial study and comparing assets and liabilities with national goals. National goald--except in the broadest and most generalized statements--are difficult to set. And perhaps even more difficult to adhere to.

This is a very complex topic, wrought with many inputs including heritage, culture, customs, religion and the general way of life. Since it requires years to study, even

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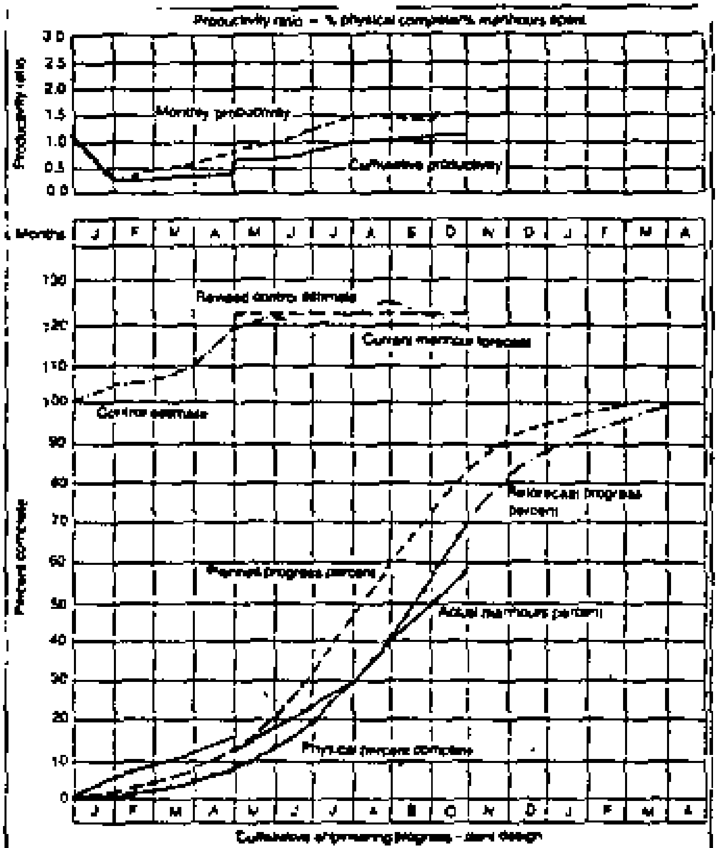


Fig. 3—Engineering discipline trend curve

ing manhour expenditure and progress achieved against the plan.

• **When work within discipline has been completed, close the job out for that discipline.** Consider the formation of a small general purpose task force to finish off the project.

In addition to home office manhour costs there are non payroll costs such as computer charges, travel, communication, and reproduction. Continual vigilance is required to cut unnecessary expenditures in these areas.

CONSTRUCTION

Construction costs include the following:

• Wages and benefits of the direct hire construction labor
• Salaries, benefits, and expenses of construction supervisors
• Rental, purchase and maintenance of construction tools and equipment
• Provision of temporary construction facilities, buildings, utilities, construction supplies, and protection materials.

Of the above, the major cost is the wages of the construction labor which can be controlled if the labor hours can be controlled.

Detailed estimate. As with engineering, the first step towards control is to prepare detailed labor manhour estimates for each trade. These manhour estimates must identify specific activities to be performed by code of accounts such as equipment items to be erected, cubic yards of concrete to be placed, feet of pipe to be laid, etc. The better the quality of the labor manhour estimate, the better the opportunity for comparing physical progress and manhours expended against the original plan and budget.

Normally, the initial field labor manhour estimate is prepared in "standard" labor manhours and then converted to the project labor manhours by dividing by the anticipated productivity factor. For example, if the "standard" manhour estimate is 100 and the productivity factor is 0.8, then the project manhour estimate becomes 100 divided by 0.8 equalling 125 manhours or an increase of 25%. Because labor productivity is a reciprocal factor, a relatively small drop in the factor creates a large percentage increase in the manhours. This increase is exponential as the productivity drops. Therefore, the assessment and subsequent control of labor productivity is of overriding importance to achieve control of construction costs.

Control field manhours. The following are some general guidelines for controlling or reducing field labor manhours:

• **Ensure that the construction management team is strong with experienced construction planners, estimators, and cost engineers.** It is important that the detailed construction planning is performed at the jobsite and is responsive to the day-to-day needs.

• **Do not allow work to start in the field until all the necessary information and materials are available.** An early start which cannot be sustained will only waste labor manhours.

• **Pay proper attention to material receipt, identification, storage, and protection.** Insure that material is controlled and used for the intended application only. Maintain material usage trend curves against design quantities to give early warning of potential shortages.

• **Plan the logistics of man and material movement.** Many manhours can be wasted moving men and materials around the jobsite.

• **Ensure that methods of measuring physical progress are factual.** Weight construction activities by proper allocation of the labor manhour estimate and measure progress by means of predetermined physical units or yardsticks.

• Maintain individual trend curves as illustrated in Figure 4 for each of the major trades showing productivity, manhour expenditure, and progress achieved.

• Do not work out of sequence. Plan the work from the ground up and the inside out. Maintain a clean and tidy site with clear and well maintained access roads and drainage ditches.

• Provide optimum working conditions for labor. Consider early erection of plant buildings to provide prefabrication and assembly areas under cover.

Construction supervision is scaled to the size of the project and the estimated number of labor manhours. A low labor productivity requiring a larger labor force will require a greater number of supervisors. The quality of the supervision is important for the control of labor productivity which in turn has the major influence on field costs. Review periodically to ensure that there is the proper level of supervision.

Adequate construction equipment, tools, and supporting facilities will help improve labor productivity. However, excessive construction equipment which is available but not used, is merely an added expense to the job. When construction work is approaching completion, it is sometimes difficult to run down and reduce supervisory staff and labor. A formal construction closeout plan is required which is implemented towards the final phases of construction. Any field purchases of commodities and construction consumables should be controlled in the same way as for commodities purchased by the home office.

FIELD SUBCONTRACTS

The organization and planning of subcontracts must occur during the engineering and purchasing phase prior to start of work in the field. The following are some general guidelines for controlling or reducing subcontract costs:

• Preselect subcontractors to whom inquiries will be issued on the basis of their past performance, work experience, and capability.

• Do not issue subcontract inquiries prematurely. Be sure that the inquiry documents are complete and final, cover the scope of work, and fully define the subcontractors responsibilities.

• Check that the inquiry puts the responsibility on the subcontractor to familiarize himself with site conditions and for movement and removal of materials and labor.

• Do not impose schedule start and completion dates on the subcontractor which are dependent upon completion of work by others without provision for adjustment prior to the start of work without cost penalty.

• Attempt to obtain lump sum quotations when the scope definition is firm. Do not attempt to obtain lump sum quotations with an inadequate definition or if the work may be changed. In either case, obtain a full scale of unit rates to allow for additions and extensions.

• After bids have been received, meet with the recommended subcontractor and review with him the total scope of the work to be sure he understands and accepts it before the contract is awarded.

• Do not allow the subcontractor to start in the field until such time as his work can proceed without interruption.

• If changes are required, ensure there is a proper definition and that the subcontractor provides a fixed price quotation before work is started.

• On reimbursable type contracts require the subcontractor to pro-

Weekly piping costs - manhours per lin. ft

Client XYZ Oil Company — Job No 1234
Location Southwest Tx — Account [illegible]
Description [illegible] U.G pipe — Period Sep 7

Period Ending	Linear feet installed		Manhours expended		Manhours per lin. ft	
	This week	To date	This week	To date	This week	To date
Aug 3	100	100	600	600	6.0	6.0
Aug 10	200	300	600	1200	3.0	4.0
Aug 17	200	500	600	1800	3.0	[illegible]
Aug 24	150	650	600	2400	4.0	3.7
Aug 31	250	900	600	3000	2.4	3.3
Sep 7	100	1000	300	3300	3.0	3.3
Sep 14						
Sep 21						
Sep 28						
Oct 2						

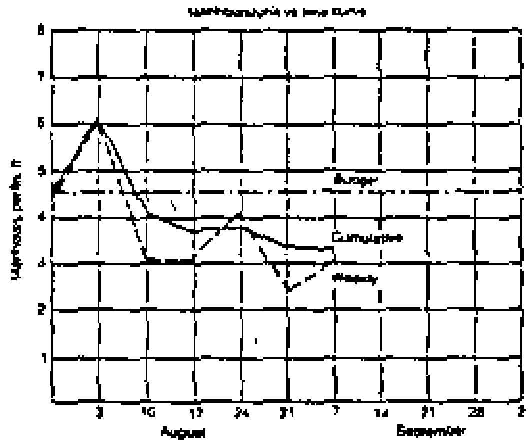


Fig. 4—Construction trade trend curve.

vide work schedules, progress measurement and performance reports in a manner which can be monitored. Require that the subcontractor's method of costing and invoicing is subject to audit.

SCHEDULE

There is an optimum project schedule which is the most efficient and which will yield the lowest cost. Below this optimum period cost may increase due to the following:

- Equipment and materials purchased for shortest delivery and not lowest price.
- Extra men applied in engineering and/or construction to reduce time at the expense of efficiency.
- Overtime hours worked requiring overtime premium.
- Arbitrary decisions made in the interest of speed without proper analysis of the cost impact on engineering or construction.

Although a reduction in the project schedule below the optimum may increase the capital cost, it may not increase the total cost to the owner. The increase in cost to reduce the construction period may be more than recovered by the reduced interest on capital and the earlier earnings generated.

An increase in the project schedule over the optimum also adds to the project cost due to the following:

- All costs related to calendar time are extended such as,
    - Supervision in the home office and the field.
    - Use of facilities, rental equipment, and tools.
- The impact of escalation may be significant. Escalation, like interest, compounds upon itself so that its effect is increased when the project schedule is extended.
- An overextended schedule tends to allow more manhours to be spent unproductively with consequential loss of efficiency.
- Interest costs and other financial charges are extended.

Optimize schedule. The above establishes the importance of developing an optimum schedule period at the start of project execution and thereafter making every effort to hold to this schedule. Every member of the project team is jointly responsible for keeping to schedule for the activities within his control. This responsibility is better appreciated if all members of the project team have an awareness of the impact that schedule delays have upon project costs.

About the author

Arthur E. Kerridge is project controls manager for C-E Lummus, Houston, where he is responsible for Scheduling, Estimating, Cost Engineering and Computer Services departments. He has 30 years of experience with engineering construction companies in the United States, Europe, Middle East and Canada. He has worked as process/project engineer, engineering manager, senior project manager, and in a variety of technical and administrative special assignments. Mr. Kerridge holds a B.S. degree in chemical engineering (with honors) from Imperial College, London University, U.K. He is active in several professional societies.

PROJECT CHANGES

Project changes are the chief cause of late schedules and cost overruns. There is an appropriate time in the project schedule allocated for review and approval when minor comments and changes can be accommodated. Changes introduced after approval become extremely costly.

Changes must be controlled by a formalized procedure which requires that all changes be recorded with an estimate of the effect on schedule and cost.

The cost estimate should take full account of the disruption and rework. In most cases there is inadequate allowance for the cost of schedule slippage, the cost of rework, and the potential for increased error. The project management should resist changes at all times and only allow them if . . .

- it can be proved that the project will not work without the change
- the change has been fully recorded and has been authorized by the owner who has accepted the impact upon cost and schedule.

This resistance to change must be applied equally firmly by all members of the project team.

Use the basics. Project costs can be controlled if there is proper cost control and cost reporting supported by a cost conscious project team applying the basic rules of cost control. Every project has its unforeseens for which there must be the contingency. ■

VII.-B-6

Part 1

Get ready for megaprojects

Tomorrow's superplants will demand a streamlined engineering construction organization. Here's one author's view of what will be expected of such a company.

C. J. Kurzawa, Associated-Pullman Kellogg, Ltd., Calgary, Alberta, Canada

THE ENGINEER/CONSTRUCTOR (E/C) that hopes to secure "megaproject" contracts needs a very special type of organizational structure involving eight features:

1. The E/C can function as a single contractor or as one of a combination of contractors on a single venture.

2. Managing contractor (MC) organization acts not in an advisory capacity to the client, but is responsible for project execution within the client's guidelines and policies.

3. Managing contractor (MC) organization is flexible enough to take advantage of engineering-procurement-construction contractors for specialized portions of the megaproject.

4. Engineering within the managing contractor (MC) organization is executed not only by the MC's ... staff, but also by engineering ...ontractors.

5. There is centralized procurement management and execution by a procurement organization established and experienced in worldwide procurement activities.

6. Managing contractor (MC) organization is responsible for construction management.

7. Construction execution is handled by a member of the joint venture management or by a prime construction contractor.

8. Construction involves all available construction resources by engineering-procurement-construction contractors, by direct hire forces and by construction subcontractors.

MANAGING CONTRACTOR RESPONSIBILITIES

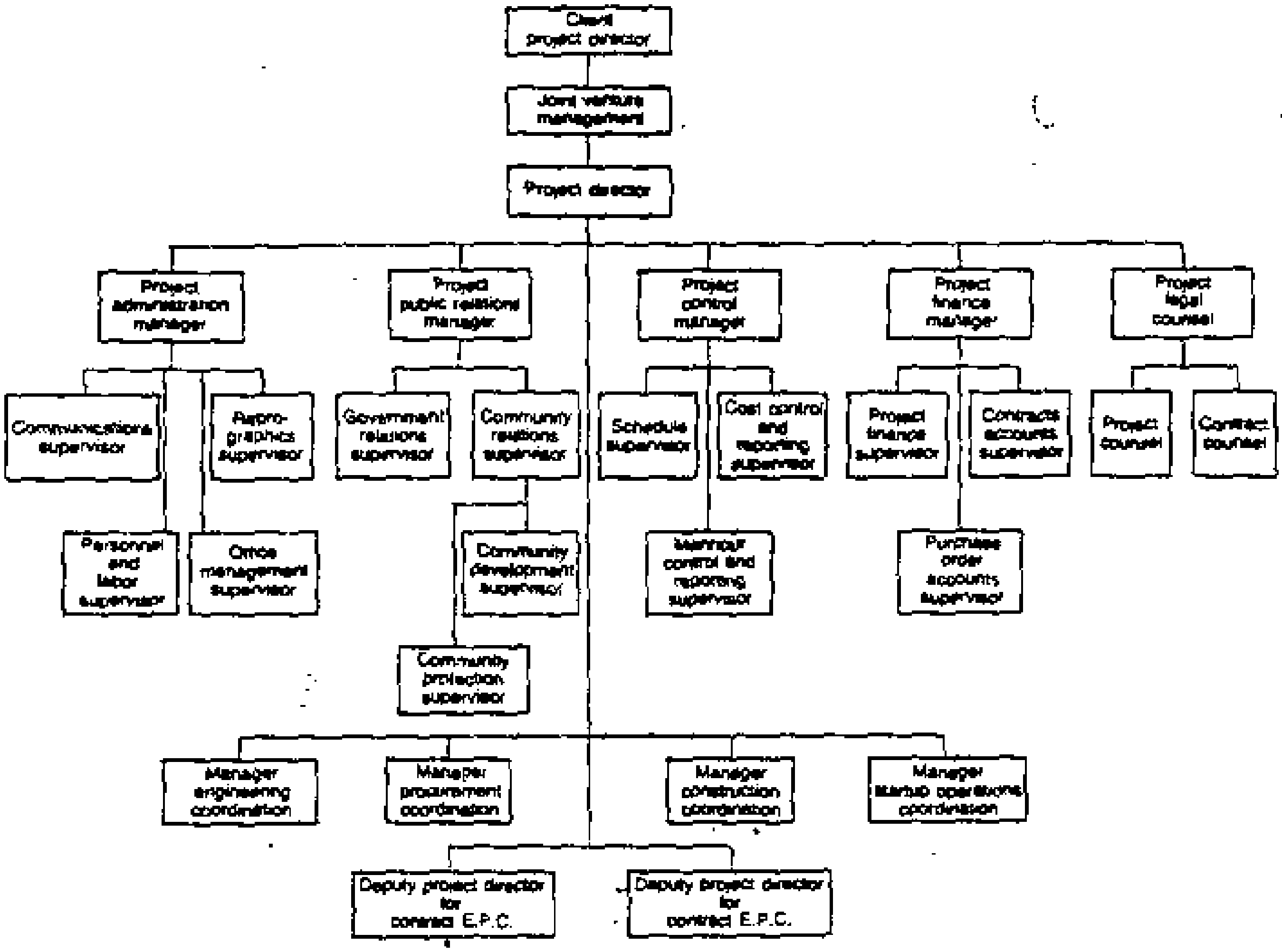
1. **Client's execution arm**
2. **Control of staff functions**
   - Project administration
   - Project master planning
   - Project costs
   - Project finances
   - Public and government relations
   - Project legal counsel
3. **Control of operational functions**
   - Engineering management
   - Procurement management
   - Construction management
   - Startup management

What is a megaproject? It is one so large and complex that its execution has a major impact on (1) the availability and usage of the engineering, procurement and construction capabilities within the area of project execution; and a major effect on (2) social and economic circumstances of communities within the project's geographic area of influence.

The first of the above relates to manpower required in execution of the project. This is influenced by the geographic location. But it is also influenced by political or nationalistic influences wherein established parameters require the maximum usage of manpower from within a county, state, province or nation.

The second of the above relates to such factors as the capability of the communities to absorb and to furnish support facilities for the temporary but significant increase in population, housing, schools, churches, and commercial enterprises. The community will also have to deal with "outsiders" who may bring crime, drug use and abuse, and violate traditional customs. The same community will then have to readjust to a different life-style when the temporary population leaves.

Synergism. In short, the megaproject requires skills and talents not normally available from one single



ig. 1—Functional organization of an engineering construction company's "megaproject" effort.

source. Rather, success depends on combining skills and talents from several organizations by a *joint venture organization*, by a series of interrelated contracts and subcontracts, or by a combination of both. Such a synergistic approach requires direction, instruction and supervision of the overall project by *one* common unifying organization—a managing contractor—(MC).

The "managing contractor" (MC) concept isn't new. The Egyptians no doubt used some form of MC to organize and execute building the pyramids. The engineering requirements were most intricate. Specifications called for not a 40-year life but a 40-century life span. Procurement of materials and their transport from their source to the desert construction site were an extraordinary logistic accomplishment. Con-ıction involved a completion :dule to serve burial-place preparation of the client.

The pyramids brought a major set-back to the MC profession, however, because the contractor failed to fully comprehend liabilities associated with the contract's confidentiality clause—that is, all contractor personnel had to be put to death upon project completion to preserve the pyramid's secrets.

Responsibilities. The MC must:

- Plan, organize and manage the execution of a project
- Use correct technology
- Meet schedules within the Client's cost objectives
- Recognize and place in proper perspective the project's political and socio-economics considerations. (See Box on page   ).

The E/C is an extension of the client's staff. A significant concept must be recognized in this responsibility. The MC is functioning not in an advisory capacity to the client. Rather, it is responsible for the execution of the project within guidelines or directives either established by the client or developed by the MC and approved by the client.

- **Project administration.** The MC establishes, executes, supervises and controls communications channels between the client's organization, the MC's organization, the contractors and the subcontractors. It also establishes and monitors personnel policies throughout the combined organization; that is, hiring, firing, vacations, sick leave, promotions, demotions and other myriad problems associated with personnel.

- **Project master planning.** The MC develops the master plan such that the project will progress through various stages to completion within time schedules required by the client. Once developed, there is the continuing responsibility for directing, supervising and monitoring the execution of the master plan.

- **Project costs.** The MC develops,

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Many megaprojects will be built in developing countries. The E/C will need project managers and team leaders with unusual depth and cultural sensitivity.

establishes and directs cost control and reporting policies in fulfillment of the client's requirements.

• **Project finances.** Money must be spent, payrolls met, vendor payments made. These expenditures will be made by a number of contractors and subcontractors. All expenditures must be fully accountable to the client's satisfaction. This requires that appropriate fiscal policies be established, directed and monitored.

• **Public and government relations.** Although the MC has major responsibilities in public and government relations, this responsibility is generally undertaken by both the client and the MC in a coordinated execution. It is a major function which affects not only successful completion of the project, but also has a continuing effect during the full extent of project operations. Its significance must be given appropriate recognition.

• **Project legal counsel.** Legal counsel is not restricted to the negotiation and implementation of a contract between MC and client. Legal counsel must function in all areas of contracting and subcontracting as well as in various areas of governmental and public relations.

Operational control. The MC is responsible for managing engineering, procurement, construction, and startup. Each of these four has one common denominator. Execution of work within each area will be by a number of independent organizations. This factor makes it mandatory that their efforts be coordinated by establishment of common policies, procedures and practices. Goal: completion of the project efficiently and effectively. The MC must be staffed to direct these independent organizations.

SINGLE CONTRACTOR VS. JOINT VENTURE MANAGEMENT

Megaprojects can be undertaken either by a single contractor or by a combination of contractors in joint venture. There are distinct advantages and disadvantages to each approach. Factors that must be analyzed:

- Scope or substance of the project
- Geographic location of project execution not limited to construction but inclusive of management
- Engineering and procurement
- Geo-political restrictions which may be imposed for the project execution
- Economic relations established between client and contractor
- Time schedule to accomplish various phases of the project
- The client's own philosophies or requirements in the project execution.

Single contractor. The easiest of the above two approaches is the single contractor concept. Here, all personnel are assigned from one company organization. They are fully accustomed to working together under well established procedures and routines. This organization does not require the "learning curve" period of working together and getting accustomed to new or varied procedures necessary when several companies are involved. Of course, for true megaprojects this restricts the client's choice of the MC to only a few major contractors. Not many E/Cs have the depth of organization to staff such a megaproject and still maintain a reasonable distribution and balance of personnel for other in-house projects.

If the project is a series or a combination of specific inter-related process units (such as ammonia, urea, ammonia nitrates, complex fertilizers, etc.) a single contractor concept may be advantageous. There is a similarity of approach for each of these units. And the "know-how" or knowledge of each of these units can be vested within one contracting company.

On the other hand, suppose the project is integrated from sourcing or production of raw material through various successive stages of purification or process production, transport of finished product and disposal of waste materials. For such a project, the joint venture approach (wherein each member of the joint venture is a specialist in a specific phase of the project) may bring together a more effective combination of talents.

Location. The geographic location for the execution of the management, engineering and procurement functions and the geo-political restrictions which may be imposed are closely interrelated. The single contractor can best furnish these services at its home office location. There, it has personnel and supporting facilities. Geo-political restrictions may require that MC headquarters be at other than the contractor's home office, requiring a dislocation of staff. This is more significant if such dislocation is international and if restrictions are imposed on the number of personnel that can be brought in from one country to another. Under these circumstances, a joint venture could be advantageous. The principle member of the joint venture could import key personnel within the restrictive limitations and depend on local joint venture members to complete the MC staff.

Economics. Economic relations between client and contractor, although contractually specific, may also be interpretive in application. On the surface such economic relations appear to be identical whether the client looks to a single contrac-

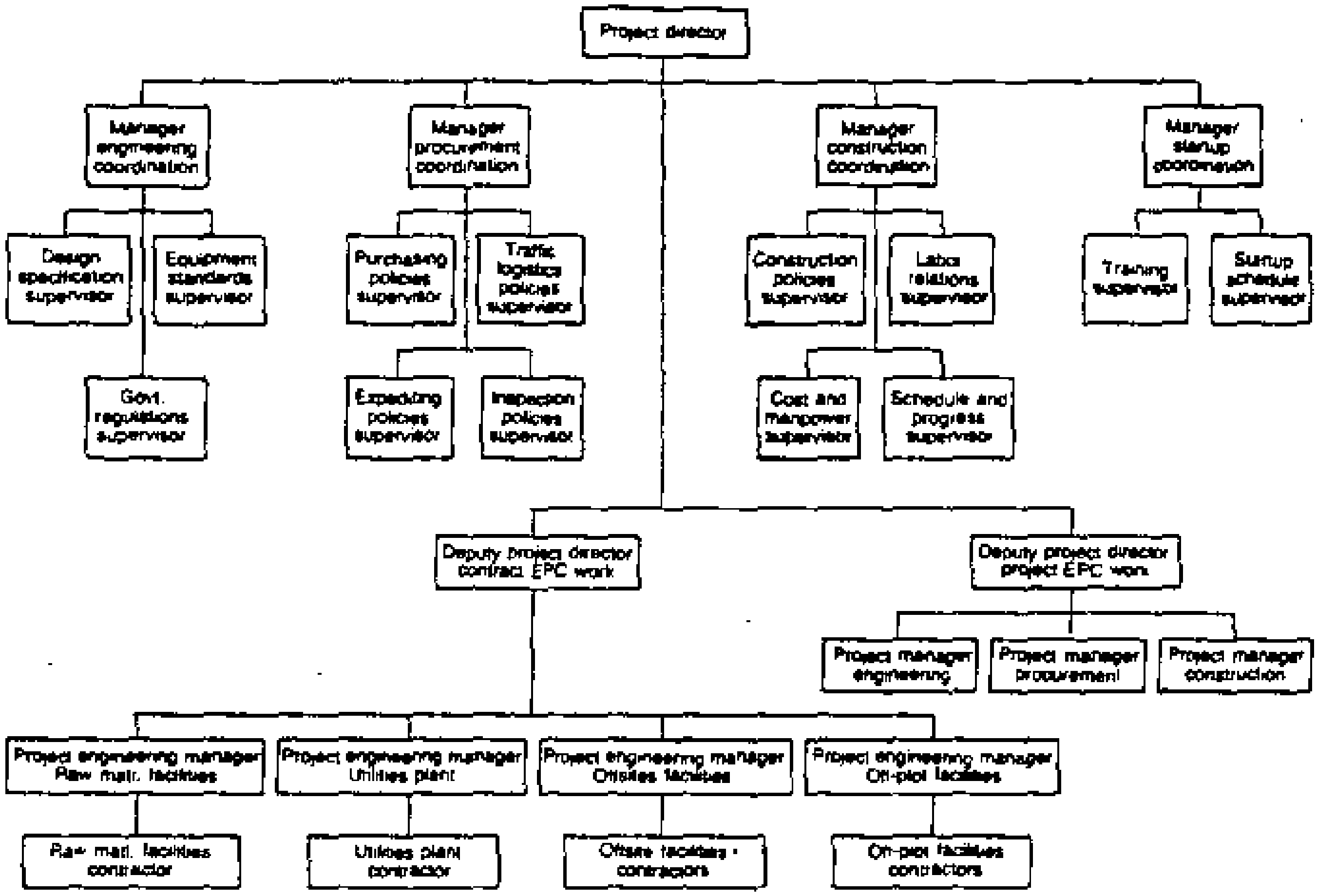

Fig. 2—With this type of organization, the managing contractor (MC) coordinates engineering, procurement, construction and startup functions.

tor or to a joint venture. However, the client has an inherent, although not direct, interest in the economic relations between members of the joint venture.

Some form of economic incentive must exist between members of the joint venture. This will encourage and give assurance that each member is willing to place his "cream of the crop" personnel on the project: in short, share in the profits to the extent of valued participation. The client will look to these economic incentives to gain his assurance that the project organization will be staffed adequately and not depend wholly on the good will, honor and reputation of joint venture members.

Timing. Megaprojects are time oriented but with certain significant variations. Because of the large investment required, the approval phase is generally more extensive and more time consuming. Once the "go" decision is made, time is of essence for three basic reasons. (1) reduce the effect of inflating costs, (2) reduce the time span of investment in manpower, equipment and material at no interest bearing returns and (3) start production and profit flow as early as possible to pay off the investment. Use of a single contractor is the quickest way to start the project after the "go" decision. This necessitates only basic negotiations and understandings between client and contractor and a letter of intent.

This same situation can be true in the joint venture approach only if sufficient assurance is given to the contractor to organize and establish the joint venture before the "go" decision. This necessitates a risk commitment of effort should the final decision be "no go." Depending on the project's complexity and the number of participating members in the joint venture, this effort could be one to three months.

Client philosophy. It can be as-

Use of a single contractor is the quickest way to start a project. It results in a need for only basic negotiations between contractor and client.

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of engineering, procurement, construction and start-up.

The MC's functional organization must consider geo-political circumstances that may call for maximum use of host-country resources—both people and materials.

sumed that the client and its staff has done detailed study and analysis to determine a preferred approach. These conclusions can be discussed between client and contractor. But the client determines the course of action.

THE MC's FUNCTIONAL ORGANIZATION

A functional organization is based on several specific premises or assumptions. Changes are permissible. But they will require appropriate changes in the functional organization as herein presented. These basic premises are:

1. The organization is for a *mega-project* as previously defined.

2. The project is of the integrated type. It is not restricted to specific process units. It calls for specialized major activities such as development of raw material source, transport of raw materials to the process site, processing of raw materials to finished products, disposal of waste products and transport of finished products to marketing sites.

3. The geo-political circumstances involve a nationalistic spirit which requires special considerations for maximum use of local resources of the host country.

The functional organization is portrayed in Fig. 1.

PROJECT DIRECTORATE

The overall general supervision and broad direction of the project are under the client's project director and his administrative staff. The extent and the organization of this administrative staff are the client's prerogative.

Again, bear in mind that the MC is the client's "arm of execution." It is directly responsible for carrying out the client's policies. On this basis, the client's project director staff should have sufficient depth to establish policy matters on a timely basis without a need to participate in execution of these policies. Naturally, this staff will involve itself in the project enough to assure that client policies are being properly implemented and executed by the MC.

Organization. The MC's organization is under the direction of a joint venture management. One member of this joint venture will be the *principle* member and will represent the joint venture.

This joint venture management places overall control of the project in one project director. He has authority and responsibility to manage and execute all phases of the project. It is his task to complete the job on schedule and within cost parameters established by the client. He must evaluate and adjust to political and socio-economic considerations influencing the project.

The project director has three major functions:

1. Staff or administrative functions.

2. Management coordination of engineering, procurement, construction and startup.

3. Execution or accomplishment

STAFF OR ADMINISTRATIVE FUNCTIONS

The staff or administrative functions encompass five basic endeavors, each headed up by a qualified project manager.

1. Project administration manager has the following basic areas of activity:

- **Communications**—Establish and control channels of communications among *all* levels of the project organization (contractors, subcontractors, MC team and client's directorate staff).
- **Personnel and labor supervision**—Home office or branch office personnel. If the headquarters offices are in the country of project origin and not at the MC's home office, this will also include the adoption, interpretation and execution of personnel policies as decreed by the project-origin country.
- **Office management**—Office administrative routings, forms and formats, pencils and paper, typewriters, space allocations, office equipment, office security; the attention to the day-to-day routines and requirements which contribute to effective, smooth office operation.
- **Reprographics**—This area embraces copiers, blue lines, mylars, color prints, reduced computer prints, microfilms. These require management control.

2. Project public relations manager responsibilities include:

- **Government relations**—Including interpretation of governmental policies applicable to the project and the submittal of reports or presentations required by various governmental agencies.
- **Community relations**—Recognition of the project's social and economic impact on surrounding communities, and subsequently administering two approaches—community development and community protection.

3. Project control manager has responsibilities for:

- **Schedule development and con-**

trol—Preparation of the project master schedules, the review of independent detailed schedules prepared by individual contractors and subcontractors for conformity with and in support of the master schedule. The monitoring of engineering, procurement and construction progress for compliance with the master schedule.

• **Cost control and reporting**—Preparation of unified cost control and reporting procedures, the monitoring of the cost control practices and reports submitted by the various sections of the organization, including contractors and subcontractors, the conduct of trend analyses and contingency risks, the monitoring of cost forecasts and cash flow estimates.

• **Manhour control and reporting**—Establishment of manhour budgets, monitoring of manhour expenditures and forecasting of manhour usage, including trend analyses and manpower contingency planning.

Reports in these categories may be submitted by a significant number of engineering organizations and contractors, as well as construction contractors and subcontractors. These reports must be organized, monitored, controlled and summarized. This must be done in a manner as to furnish the project director, the joint venture management and the client's directorate staff information they need.

4. Project finance manager is responsible for:

• **Project financial accounts**—Establish and execute the project's fiscal policies in conformity with the contract between client and MC. This includes, in part, payroll, direct and indirect expenses, and fee payments subject to the client's approval and audit requirements.

• **Purchase order accounts**—Establish the system of payments to purchase order vendors. This includes processing of invoices and payments and all required cash-flow procedures between purchase order vendors and client.

• **Contractor and subcontractor accounts**—Basically, the same responsibility as stated for the purchase order accounts, but applied to various contractor and subcontractor accounts.

Expenditures will be made by the MC staff, contractors and subcontractors under the MC's control. Fiscal procedures must be developed and monitored such that unified financial accountability statements can be prepared and presented to the client to fulfill his requirements.

5. Project legal counsel is responsible for:

• **Project counsel**—Including not only legal relationships between the client and the joint venture, but also legal interpretations and understandings in public and governmental relations.

• **Contractor counsel**—Contractual documentations with contractors, subcontractors and vendors of equipment and material.

Although these staff functions are MC responsibilities, the client may want to keep some functions, such as public relations, within its control.

Project control can be best administered by the principle member of the joint venture. But it needs personnel support from other members of the joint venture to bring together the most effective project staff administration.

MANAGING COORDINATION

Because of a megaproject's scope, the execution of engineering, procurement and construction will be done by various approaches:

• Independent engineering-procurement-construction contractors

• Engineering by direct project staff not limited to the supply of equipment and material but including supply and erect purchase orders

• Procurement by direct project staff not limited to the supply of equipment and material

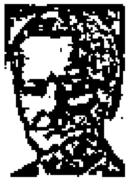
• Construction by direct hire forces and by construction contracts and subcontracts

• Startup of individual units or plants within the project by client's forces, by MC forces and by various contractors and subcontractors.

This necessitates management coordination of the engineering, procurement, construction and startup functions as portrayed in Fig. 2. The management coordination of these functions is subdivided into four areas of responsibility, to be discussed in Part 2, next month.

NEXT MONTH: Part 2 . . . Management coordination: project execution; contract and project engineering; procurement activities and administration; construction organization.

About the author



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Part 2

Get ready for megaprojects

Pay special attention to management coordination, project execution, contract and project engineering, procurement activities and administration, and construction organization

C. J. Kurzawa, Associated-Pullman Kellogg, Ltd., Calgary, Alberta, Canada

THE MANAGING CONTRACTOR'S (MC) managerial activities can be broken down into four sub-divisions (See also Fig. 2, Part 1, April 1980 issue). These four are:

1. Manage engineering coordination

Design specifications supervisor
Governmental regulations supervisor, including environmental regulations
Equipment standards supervisor

2. Manage Procurement Coordination

Purchasing policies supervisor
Expediting policies supervisor
Inspection policies supervisor
Traffic and logistics supervisor

3. Manage construction coordination

Construction policies supervisor
Cost and manpower supervisor
Schedule and progress supervisor
Labor relations supervisor

4. Manage Startup Coordination

Training supervisor
Startup scheduling supervisor

Responsibilities. This four-function organization has two major responsibilities: (1) to establish and monitor the common ground rules e used by all contractors and ontractors in execution of their portions of the project, and (2) to determine and give assurance that the combined work of each execution group will result in a completely integrated, operable complex.

To assure unanimity of administrative effort, the control of this coordinating organization is best staffed and administered by the same MC which administers the staff functions previously described. This organization is the principle member of the joint venture. It has the personnel support as required or available from other members.

PROJECT EXECUTION

The execution of engineering, procurement and construction is divided into two approaches, (1) that which can be contracted to independent engineering-procurement-construction contractors under the MC's overall control, and (2) that undertaken by the MC's project staff.

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CONTRACT ENGINEERING—PROCUREMENT—CONSTRUCTION WORK

The type of work most suitable for an engineering-procurement-construction contractor is specialty work. Such work is not directly associated with the intricacies of process units or that which is heavily equipment cost oriented in contrast with construction labor cost. Examples of specialty work: water front development or raw materials source development such as oil field gathering systems or mining development. An example of more broad-based work would be solids materials handling systems.

The advantage an MC gains by contracting specific areas of work to independent engineering-procurement-construction contractors are reduced workload by direct project staff, the capability of assigning specialized work to contractors knowledgable in the specialty areas, and use of contractors who are local or national to the country of project origin.

The engineering-procurement-construction contractors would be under the direction and supervision of the MC's deputy project director as shown in Fig. 2. (See Part 1, April 1980 issue).

PROJECT ENGINEERING—PROCUREMENT—CONSTRUCTION WORK

Some of the work could be done by specialized engineering-procurement-construction contractors. But most of the project work would be engineered, procured and constructed by the MC staff. This relates specifically to the chain of interrelated process units as well as the integrated off-site facilities.

Whether the MC is a single contractor or member of a joint venture management, the client normally wants the MC to have prime qualifications in process design and engineering. Only with such qualifications can the MC perform its work with fully experienced and qualified personnel from its parent staff, supported by its own established proce-

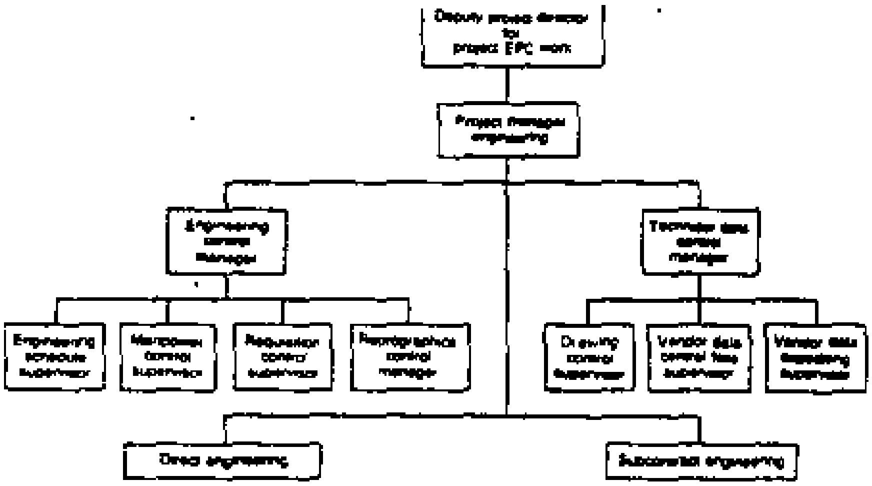

Fig. 3—Organization for the engineering undertaking.

dures, proven techniques and tools of the profession.

Engineering organization. The organization for the engineering undertaking is shown in Fig. 3. This is a typical organization chart. Note that engineering can be done by the MC staff and by subcontract engineering. Personnel for the direct engineering should be supplied by the principle member of the joint venture. This member should handle the intricate process units and also, as a minimum, the analytical or planning of off-site facilities.

There are good reasons for engineering via subcontractors. Distribution of the engineering work load can be leveled out by these smaller qualified engineering organizations. This permits MC personnel to concentrate on developing major process units. Smaller but qualified engineering contractors can be involved.

Use of sub-contractors can reduce the number of personnel that must be imported from the home office into the country of project origin, and results in greater usage of the country's resources.

... nization for the procurement function is shown in Fig. 4. It is composed of four major activities.

- Procurement administration
- Major equipment purchasing
- Bulk material purchasing
- Traffic and logistics

Procurement administration is the unglamorous activity of controlling paper within the overall procurement operations. It involves four major undertakings:

- Document distribution
- Computer input and reports
- Purchase order verification
- Reprographics

Although these groups do not supply one nut or bolt to the jobsite, they are critical in supplying the paper work and the reports network to the other subdivisions of the procurement operation. They thus make those subdivisions effective in carrying out their duties.

Because of the large volume of equipment and material that must be purchased, inspected, expedited and delivered to the jobsite, the procurement operation must be under a centralized control. It can best be administered by an MC (single contractor or a joint venture member)

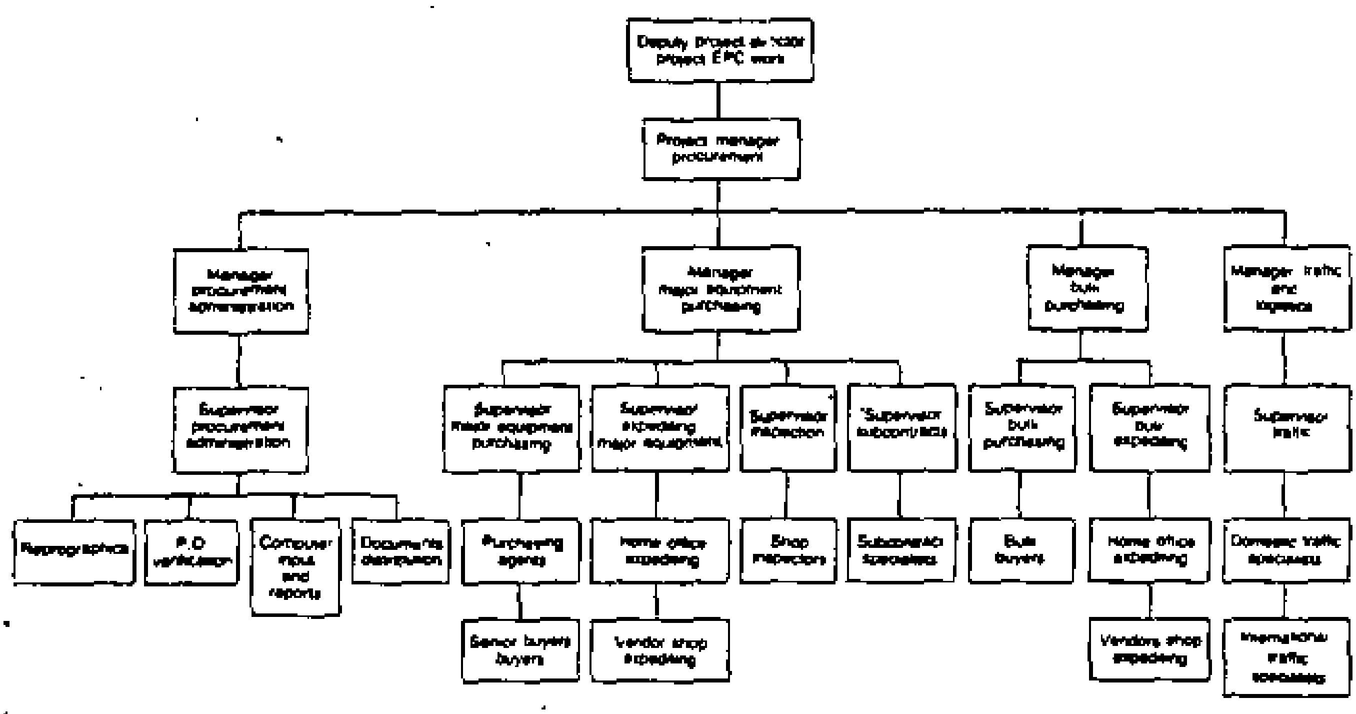

Fig. 4—Organization for the procurement function.

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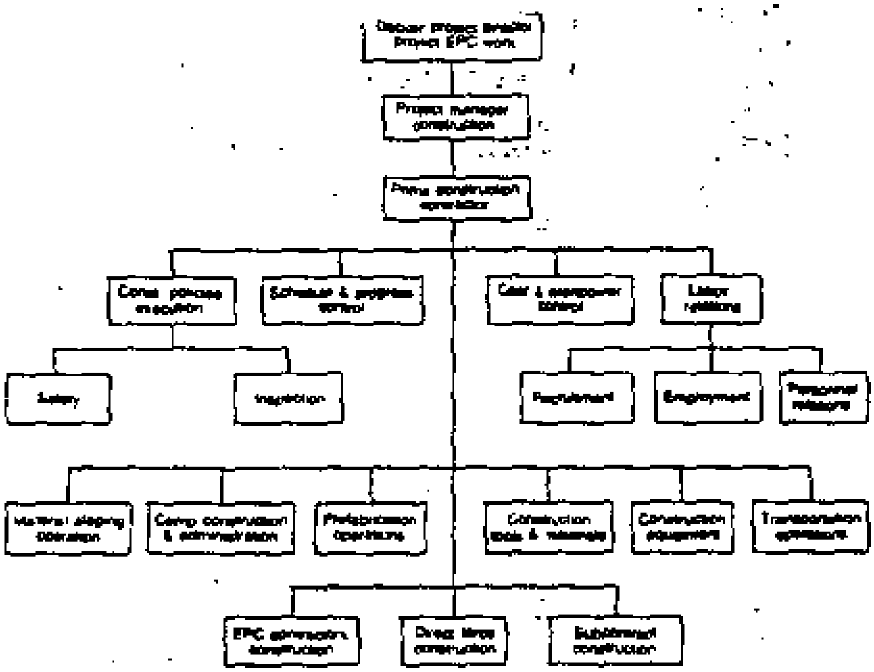


Fig. 5—Organization for the construction function.

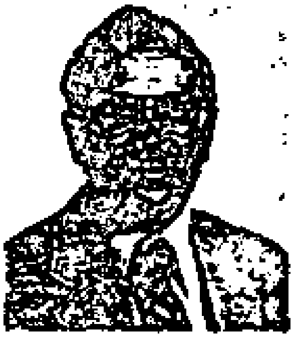
that is familiar with the manufacturing capabilities of the country of project origin. Such an MC also has already established and operated a world-wide procurement organization in all major manufacturing centers throughout the world. This will bring to the megaproject organization the knowledge of manufacturing capabilities, workload and pricing structure on the world market. It will bring to the project a well-established, experienced staff of shop inspectors and expediters in all major manufacturing centers. It will bring to the operation personnel who understand traffic and logistics requirements for the movement of equipment and materials from the world wide manufacturing centers to the job site.

Construction organization. The organization for construction is shown in Fig. 5. This chart foresees a prime construction contractor undertaking the construction activities under overall direction and control of the MC. For a single-contractor MC this would give the MC the capability of retaining construction management responsibility. It [illegible]d at the same time bring to the [illegible]ct a construction organization capable of undertaking the large volume of construction activity required on a megaproject. For a joint venture management, it would be logical that the prime construction contractor would be, in fact, one member of the joint venture.

• Three levels. The organization as portrayed has three basic levels of project execution. The first is the staff or administrative level, which encompasses construction policies execution with special emphasis on safety and inspection, schedule and progress control, cost and manpower control, and labor relations. The second level is the control and execution of the common or centralized construction activities required for the megaproject such as:

- Material staging areas
- Camp construction and operation
- Prefabrication operations
- Construction tools and materials
- Construction equipment
- Transportation operations

The third level is execution of construction. To take maximum advantage of all available resources, this construction would be accomplished by the engineering-procurement-construction contractors, by the prime contractor's direct hire forces and by construction subcontractors, all under the administration of the prime construction contractor. ■



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CONTROL OF SMALL PROJECTS

In recent years, we've witnessed the growth of both the number and size of the so-called "super projects". The Alyeska Pipeline, one of the first of the generation of billion dollar projects was the largest single project ever undertaken by private industry. Since then, many more projects have been announced world-wide in the hundreds of millions and in the billion dollar range and much attention has been given to the unique problems associated with the project management of these monsters.

In our anxiety to bring these super projects under control, we may have been neglecting another growing problem, one which has been with us for a much longer time . . . that of managing the so-called "miscellaneous small project". These projects, although individually involving a mere fraction of the r rces and capital investment, because of their s number, can and often do, total as much in owner capital requirements and consequently are as critical to the owner from an overall economic standpoint. In many ways, they can also rival the larger projects in the difficulty of execution and control.

Figure 1

SMALL VS. LARGE PROJECTS

	50MM PROJECT EXPENDITURE	
	LARGE	SMALL
No. PROJECTS	1	100
No. ESTIMATES	1	100
No. SCHEDULES	1	100
No. P.O.'s/S/C's	100 – 200	500 – 1000
... PROJECT DURATION	3 YRS.	6 MONTHS
FULL TIME PM TEAM	YES	NO
CONTROL PROCEDURES	YES	UNLIKELY

There has been, and still is, a pressing need for the development of new project manage techniques for controlling these small projects. Not only has this problem been with us for many years, but in recent years, with the construction of the much larger, complex plants, we are starting to see these plants spawn additional small projects as the need arises for additions and technological improvements. This is true not only onshore, but also offshore. After all, many of the more complex offshore platforms are nothing more than refineries on stilts, some of them not so small either. They also are subject to changes and additions after they are in operation. (Unfortunately, many are subject to this before they go into operation!!).

What is a small project?

Figure 2

WHAT IS A SMALL PROJECT?

- RELATIVELY SMALL PERCENTAGE OF BUDGET
- ADDITION OR CHANGE TO EXISTING PLANT
- MAINTENANCE WORK
- SHUTDOWN, TURNAROUND WORK
- MISCELLANEOUS CAPITAL BUDGET ITEMS

The definition of such a general term as a "small project" will obviously vary from company to company. For the purposes of our talk, we have defined small projects as being those jobs costing between $10,000 and 10 million dollars, and each job is a relatively small percentage of the company's overall capital budget. These projects are an addition or a change to an existing plant. They are being done as part of maintenance, a "programmed budget", ie, a specific plan for development, growth, or modernization over a number of years, or as part of a group of miscellaneous small projects budgeted as a "contingency" item along with other better defined capital budget items. They also could be related to shutdown or turnaround work. For the purposes of our discussion today, we will be using a capital budget item as an example. The principles, however, apply to any of these categories.

In many respects, these small projects are no different than their big brothers. They have to be estimated, scheduled, budgeted, and project managed. They, like the large projects, are being built to make money for the owner, and they require good people to manage and control their execution.

Why then, are small projects such a big problem?

Figure 3

WHAT'S THE BIG PROBLEM WITH SMALL PROJECTS?

- SMALL SIZE BELIES IMPORTANCE/COMPLEXITY
- OFTEN INVOLVES REVAMP WORK
- SCHEDULE SHORT/CRITICAL ... LITTLE TIME TO REACT
- REALISTIC BUDGETS NOT AVAILABLE
- LESS QUANTITY/QUALITY RESOURCES ... OFTEN SHARED
- STANDARD APPROACH, TECHNIQUES OFTEN ABSENT
- LESS MANAGEMENT ATTENTION/SUPPORT
- STEWARDSHIP RESPONSIBILITIES NOT CLEAR

Because of the relatively small amounts of capital investment involved in a small project, there is a tendency to underestimate the importance and the complexity of managing and controlling these projects. Many of the projects are of a revamp nature with short but critical schedules. As a result, there is little time to react to problems and set into motion corrective action.

One of the basic problems often is the lack of a realistic budget for both time and money. Part of this problem stems from the lack of detailed attention given to these jobs individually. Even when reasonable predictions are made to establish an estimate and schedule for the budget, documentation is rarely made in a form which will allow later planning and control. A second reason why control estimates and schedules are often not available is that because many of these projects are of a revamp nature, more estimating and scheduling effort is required to come up with reasonable predictions and therefore, adequate control tools. It is often rationalized that there is not time for this extra effort.

But, even if the project engineer following the job had a good budget estimate and schedule to use for tracking, many of the jobs are so small and are completed in such short periods of time, and the amount of time and money budgeted is so small, that overruns of double or more can easily happen, even when problems are uncovered prior to completion. The usual problem is simply that you find out too late to do anything about it.

This brings us to cost and schedule reporting, one of the key problems related to the control of small projects. Most of you are familiar with the difficulty on a normal single large project of securing timely cost and schedule reports. In many cases, we consider ourselves fortunate if we have in our hands the control report within four weeks of the closing date. On a small project, this eight-week "black-out" period (four weeks progress + four weeks getting the data assembled, analyzed and issued) would (and often is) unacceptable. In fact, on a very small project, with a two month total schedule, the job would be completed before the first report was issued!! So, obviously, a much different reporting approach is called for.

Unfortunately, resources applied to these small projects are also often far less than provided on equivalent overall investments for larger projects. Supervision, project management, procurement, and contracting are usually carried out by the existing plant organization as a part-time job, often shared with operations and maintenance functions. As a result, standard project management and project control techniques are usually not being utilized as they would be on a larger project. Also, because of their size and relatively low profile, small projects tend to receive far less management attention and hence less support than the larger projects.

Finally, often, except in a very global way, the stewardship responsibilities for each item is not clear. Since many of these items are part of annual budget, they are often treated as such, ie, to be reviewed annually like an operating cost, rather than monthly or weekly. In most cases, the plant manager nominally has overall stewardship responsibility, but this is usually delegated loosely to others, who in turn pass it on. To make matters worse, it's not unusual to see a distinct split in responsibility between engineering, construction, and/or maintenance because of the operating organization of the plant. As a result, it is difficult to pinpoint specific responsibilities in small jobs.

Faced with all these potential problems, is it possible to manage and control small projects, or, because of the reasons shown on this vu-graph and many more which I'm sure you yourselves could add from your own experiences, must we accept lack of control as being the only realistic conclusion? We feel that control is possible, but only with the application of a systems approach, utilizing some basic project management methods and techniques which can be relatively simple to develop and use and, overall, very cost-effective.

What are some of the things we can do?

Figure 4

CONTROL OF SMALL PROJECTS - WHAT CAN WE DO?

- ESTABLISH STANDARD PROCEDURES
- ESTABLISH A BASIS
- DOCUMENT!!
- STREAMLINE ESTIMATING METHODS
- DEVELOP SIMPLE, TIMELY REPORTING SYSTEM
- ASSIGN CLEAR-CUT RESPONSIBILITIES
- CONSIDER COORDINATOR ROLE
- MONTHLY REVIEW MEETINGS
- BE PRACTICAL
- EMPHASIZE TEAMWORK, MANAGEMENT INVOLVEMENT

First, we need to get ourselves organized. Standard procedures and policies specifically geared for small projects need to be developed, with management involvement and support. There's a need to document clear lines of organisational communications and responsibilities.

[illegible] ed to insure that a design and execution basis has been established for the project. If one hasn't, then those responsible for eventually establishing the basis must be made to sit down and do it now, before the job is planned and budgeted. If the job is being accelerated and certain items must be progressed before an overall firm basis is established, we need to avoid making immediate hasty commitments. Instead, an assumed basis should be developed, again, by those who will eventually be establishing the final basis. This normally can be done in a short period of a day or so, or even at a single meeting with all the parties involved.

The next step is to document this basis, whether it be firm or assumed. This is extremely important for a number of reasons. Often times, just writing something down forces one to think through the basis even more thoroughly. A more important reason, of course, is related to the fact that this basis will be used for such critical purposes as establishing the budget, the schedule, and hence, the control tools for the execution of the project. In fast-moving projects, a description fitting most small projects, the discipline of documentation is absolutely essential.

Another area where special attention is needed is in the area of estimating methods. Because of the, l[illegible] number of projects to be estimated and the sh[illegible] time frame normally involved, it is important that the approach to estimating both cost and schedule requirements be simple and relatively quick. Considering the variable nature of the work being estimated and the revamp nature of most of the work, developing any realistic approach is not easy, but it can be done. The large number of jobs being executed annually in this case is an advantage, since it provides a broad base of historical data for any averaging technique used in developing the estimating methods. Whatever approach is used, the important thing to remember is to make the end product simple, flexible and quick.

For similar reasons, there is also a need to develop a simple reporting system, one which provides the minimum information required for analysis and control in a timely fashion, but one which is not overwhelming. We will be providing an example of how this can be done utilizing an integrated and responsive control system.

As mentioned earlier, it is essential to assign clearcut responsibilities to each functional department and to each individual having any involvement with the project. Ideally, one would like to have a task force for each project, with a Project Manager, Project Engineer, Cost Engineer, Scheduler, etc, but considering the average project size, this is not practical. However, the task force concept should not be rejected out-of-hand. There may very well be situations where a Project Analysis/Control group, consisting of one or more fulltime cost/schedule engineers can be justified to handle all of the small projects being implemented by a company.

Where this cannot be done, at minimum, consideration should be given to the assignment of a full-time small projects coordinator. This person would be responsible for coordinating budget and schedule preparation, cost and schedule reporting, and cost and schedule analysis. He would also be responsible for preparing overall reports to upper management having overall stewardship responsibility.

In most cases, where there are literally dozens or even hundreds of small projects involved and the project and field engineers following the work are numerous, ten or more, then justification of a full-time coordinator can often be easily made. The total manpower can remain the same, since at least 10% of each individual's time should have been allocated to the functions now to be done by the coordinator.

Regardless of what the organization finally ends up looking like, monthly review meetings are a must. Small projects have too many interfaces, There's normally too much split responsibilities, and they move too fast to be allowed to go from start to finish without all the parties involved not sitting down at least once a month to review the cost and schedule status of each project. If a coordinator has been assigned, he can chair the monthly meetings. If not, then the person within the company responsible for preparing the overall status reports to management should run the meeting. The important thing is to actually meet and review and thereby avoid "blackout" periods and unpleasant surprises.

Two final points which need to be kept in mind and which are essential ingredients to any successful small projects control system. If the system doesn't work, it will likely be because it was not practical or because it did not involve management or [illegible] ive management supports. When developing any [illegible] em there's usually a driving force to make the system perfect or nearly so. With small projects, again because of their size, their number and their short duration, we should not be striving for perfection as much as we should be looking at the practical side - half a loaf is better than none - and once the system is working and we have everyone involved, including management, then improvements leading to perfection can be implemented, based on actual experience.

We will now look at a practical example of what a typical integrated control system for small projects might look like.

In addition to the management solutions which have already been mentioned, there are some specific tools and techniques which are simple to develop and very effective in easing the burden and increasing the effectiveness of small project management. The rest of our talk today will describe a systems-based approach for doing this.

From what has been said so far, we can set down the main features we would like to have in a small projects control system:

SMALL PROJECT CONTROL SYSTEM

DESIRED FEATURES

- CAN HANDLE LARGE AMOUNT OF DATA
- EASY INPUT ... COMPATIBLE WITH EXISTING PROCEDURES
- FAST ACCESS TO DATA ... REPORTS PRODUCED INSTANTLY
- SIMPLE TO USE EFFECTIVELY
- USE FOR CONTROL OF ANY ONE SMALL PROJECT ... AND FOR OVERALL CONTROL PROGRAM FOR ALL PROJECTS

·Since we can expect to handle a large number of small projects simultaneously, any control system must be able to handle a lot of data quickly and easily.

·Since we can't afford to take a lot of time to prepare input (for example, filling out coding sheets and waiting for keypunch), data must be input easily. If possible, we would like to be able to use existing forms, such as timesheets and purchase orders, for our input.

·S[illegible] e these small projects move so rapidly, we must [illegible] le to get information out of the system quickly and easily, with meaningful reports available instantly to anyone needing them. And these reports should be formatted and provide a level of detail that is appropriate.

·Since small project management usually involves many people in various departments for whom this is a part-time function, any system, if it is to be accepted and used, must be simple and easy to use effectively. Our system must be a genuinely helpful tool to everyone, or it will be unused, abused, or create even more problems.

·And finally, our system must address both of the aspects of small project management - the problem of managing each small project and the problem of managing a total program of many small projects.

Now that we've got an idea of the desired features for our small project control system, let's think about the specific capabilities we would like the system to have:

SMALL PROJECT CONTROL SYSTEM

INTEGRATED NETWORK MODEL

- PROJECT REPRESENTED BY SIMPLE (50 ACTIVITIES) NETWORK
- FOR EACH NETWORK ACTIVITY ... DEFINE RESOURCES REQUIRED TO COMPLETE IT IN REQUIRED TIME
  - MANPOWER
  - CONSTRUCTION EQUIPMENT
  - MATERIALS
  - CASH
- ONCE IN THE COMPUTER, NETWORK INTEGRATING RESOURCES, TIME, AND COST BECOMES "MODEL" OF PROJECT

·Naturally, for this group, a cost engineering capability comes first; and by this we mean an ability to support our cost estimating, cost forecasting, cost analysis and cost control activities.

·One aspect of cost control that I have found to be particularly difficult and unrewarding is expenditure forecasting. Most of you probably know from your own experience how time-consuming the preparation of expenditure profiles is, how they are almost bound to be wrong, and how much time is spent trying to reconcile them to actual expenditures. It would certainly be great to have a system which could do all that.

·Planning and scheduling activities are essential to project management and lend themselves well to a systems-approach. As many of you who have used one or more of the available systems know, you can do a lot more than prepare barcharts. Proper planning and scheduling must be applied also to manpower (such as engineering, supervision and field labor), materials and construction equipment. Whatever system we use for our small projects must give us these capabilities.

- The capability to forecast and control the project's schedule as well as critical material is, of course, also essential.

Finally, we would like to be able to cut down the time and effort required to administer the many subroutines involved in our small projects.

Let's recap this figure for a moment by noticing that we have asked for a small project control system which will give us all the project management capabilities we would like to have (and seldom do!) for large projects. And, we have made it more difficult by asking on the previous figure for the speed, ease of input and output and flexibility we particularly need for small projects.

Now that we know what we want in a small project control system, we must face the question: "Is it possible to put together such a system?". Well, it is possible and, in fact, it's not even all that difficult. Let's take a look at how it can be done.

There are three essential guidelines to this approach:

SMALL PROJECT CONTROL SYSTEM

GUIDELINES FOR DEVELOPMENT

- o USE MODERN "INTERACTIVE" COMPUTER SYSTEM ... PERMITS DIRECT COMMUNICATION BETWEEN MAN AND MACHINE
- o USE SIMPLE NETWORKS TO REPRESENT ALL PROJECT DATA ... PROVIDES COMPUTER WITH "MODEL" OF EACH PROJECT
- o USE APPROXIMATIONS/SIMPLIFICATIONS AS APPROPRIATE TO PROJECT SIZE AND COMPLEXITY

- First, take advantage of today's interactive computer systems, which put the power of full-size computers literally at your fingertips. By using terminals with a keyboard and visual display, you can communicate directly with the system, keying in data, commands or questions, and getting back results on the screen or in printed form, much like a giant calculator. We'll go into this in more detail in a few minutes.

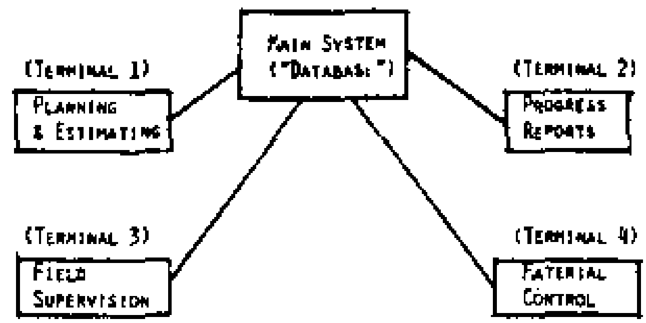
- Second, use a simple network to represent each project. Networks enable you to create an actual model of each project, a model which can be fixed (like a budget) or which can change as the project progresses. We'll have more to say about this later, too.

- and Third, bear in mind the nature of the small project - controls must be effective, but they need not be precise. For example, on a project that lasts four weeks, detailed analysis of long-range productivity trends may not be terribly meaningful- but a quick indication of schedule slippage could save the day! So we need to be willing to give up some of our cherished dogmas of project control and look for approximations and simplifications which fit our small-project situation.

Now let's take a closer look at an interactive computer system:

SMALL PROJECT CONTROL SYSTEM

AN INTERACTIVE COMPUTER SYSTEM



"DISTRIBUTED PROCESSING" FROM COMMON DATABASE ALLOWS ALL PROJECT FUNCTIONS TO INPUT OR ACCESS PERTINENT INFORMATION.

What we see here in this figure is an example of "distributed processing" in which the computer system comes out of its closet in the Data Processing Department and goes right to the point at which the work is being done. This is done through the use of remote terminals, each of which has a keyboard, visual display and/or printer.

Imagine, if you will, a system in which the main computer contains the data base for the project, that is, an organized set of data describing each and all the small projects being managed. The data base also has a lot of supporting information. Connected to the main system are four remote terminals, each located in an area of project management activities. For example, the planning and estimating group is using the system for planning, optimizing and estimating the cost of each case under consideration. The project engineering group is using the system to prepare progress reports, analyze problem areas and take corrective action, and to keep management informed. In the field, the supervisors are using the system for detailed plans and budgets relating to their specific jobs, and they are also inputting manhour and progress data. And in the Procurement Department, the system is being used to keep track of purchase orders and deliveries.

What is truly amazing is that all these activities can be going on at once with all using the same data base, resulting in a great improvement in consistency and efficiency.

Let me point out that we are not here to sell computers, but we are here to say this: Look at the new generation of mini- and micro-computers for part of the solution to your small-project management problems.

Now let's turn to the concept of the integrated network model. To have a meaningful system-based con- -l system, we must be able to express each project i mathematical way so the computer can understand .., but it has to also be a way that we can understand. This computer model must also be easy to prepare, input and update.

Instead of turning to the newest technology for this part of our system, we have found success in one of the oldest techniques. No doubt everyone here is familiar with network analysis and CPM. But have you ever wondered - Why do we only use networks for scheduling? Why not use a single network to represent all the aspects of a project by including the resource, time and cost data required for each activity?

Small Project Control System

Desired Capabilities

- Cost estimating, forecasting and analysis
- Expenditure forecasting and control
- Planning and scheduling ... manpower, material, equipment
- Schedule forecasting and control
- Material forecasting and control
- Subcontract administration

Any project, large or small, can be represented by a simple network, and by simple we mean a network of 50 activities or less. Once the network has been defined, we can define the resources required to accomplish each activity - resources being manpower, construction equipment, materials and, of course, cash. You can also think of time as a resource against which the others are balanced.

If we have the right software, this network, integrating resources, time and cost becomes a model of the project on our computer system.

Just think for a moment what we can do with this computer model of a project. We can define a "static model", fixed in the planning stage, which is our budget plan - the basis on which the project was approved. We can also generate dynamic models as the project progresses - a dynamic model being a cost and schedule forecast, a current report, or even a hypothetical case study of what might happen if a particular thing occurred. With an interactive computer system, this modelling exercise is quick and easy - exactly right for the small project.

We now have the desirable situation where we can let the computer do what it does best - and what we do worst - the many simple but repetitive calculations and data management procedures required to control a project. So, let's see what happens when we let the system do the number-crunching for our multitude of small projects.

Let's bear in mind as we go through this list that our motto for small projects is, "Keep it simple and do it fast!".

During the planning and estimating phase, our system can help by performing all scheduling functions

Small Project Control System

How It Can Be Used

For:	Tell the System:	System Provides:
• Planning	Network, dates, labor & equip. reqmnts.	Schedules resource levelling labor & equip. costs
• Estimating	Mat'l costs	Total project costs expenditure forecasts
• Project control	Actual dates actual manhours remaining duration	Complete progress reports'
• Material control	P.O. data receipt data	Material status & exception reports
• Subcontract Admin.	Invoice amount	Check on invoice

& many other applications are possible.

such as barchart preparation, resource labelling, and critical path analysis. It can also estimate labor and equipment costs, since the applicable rates can be easily stored. If material costs are input, we can use the system to prepare and document the estimate for the project. And, since it uses the schedule and costs, the system can prepare the expenditure forecast.

Once a project is underway, management and control by frequent updating, analysis and reporting can be achieved. By periodic updating with actual start and finish dates, actual manhours spent, and remaining duration for each activity, complete and comprehensive progress reports can be prepared very quickly. Bear in mind once again the importance of using the optimum amount of detail or sophistication. Use just enough to be effective.

There are additional jobs to be done while the project is underway, such as material control and subcontract administration. These jobs involve a great amount of time and paperwork, which can be reduced by effective use of the system. Exception reports can be generated showing material not yet on order or not yet received, or subcontractor invoices that are too high and need to be checked. These reports focus people's attention and efforts where they are needed, and help prevent the multitude of small projects from getting bogged down in paperwork.

Of course, many other applications are possible, depending on the particular situation.

It is worth considering too the overall improvement in coordination and communication which occurs when all people involved on the project are using uniform and consistent systems and procedures.

To sum up, we hope we have communicated these ideas:

- Small projects deserve to be taken seriously and need project management discipline and techniques just as large projects do. Both organizational and technical solutions are available to improve the management of small projects. Particular attention should be paid to the new generation of interactive computer systems which make sophisticated project management techniques practical for small projects for the first time.

Check project progress with Bell and 'S' curves

Today's project control systems—CPM, PERT and Activity Network Analysis—are powerful but complex tools. In contrast, "S" and Bell curves are remarkably simple, yet effective

Arthur E. Kerridge,
C-E Lummus Co., Houston

"S" AND BELL CURVES can't replace present means for planning and controlling projects. Nor can they identify critical paths or specific trouble spots. Nevertheless, the fact that they are *quantitative* rather than qualitative can be an asset.

After all, many planning and scheduling problems are quantitative. For example, 8,000 isometrics must be produced in five months, or 50,000 tons of fabricated piping must be erected over the same period. In these cases, it doesn't really matter which isometrics or which pieces of pipe are erected by a specific date. The important thing is to know whether the job is being handled volumetrically at a rate appropriate for the time span. This is where "S" and Bell curves can be valuable adjuncts to the more complex systems. They can be developed rapidly and have great flexibility in their application.

Visual impact. The visual impact of "S" and Bell curves may be influenced by changing the horizontal or vertical scales. Most of the figures in this article have equal vertical and horizontal scales. A larger horizontal scale will flatten or elongate the curves. A larger vertical scale will increase the slope and the peaks and valleys, which may be desirable for dramatic effect.

A basic "S" curve (Fig. 1) is drawn on a grid with a horizontal axis showing percentage calendar time from 0 to 100 percent and a vertical axis showing percentage completion from 0 to 100 percent. Any single activity, group of activities, or overall project expressed in the form of an "S" curve must start at 0,0 in the bottom left hand corner and to be complete must reach the top right-hand corner at 100,100. The shape of the curve between 0 percent and 100 percent can be an indicator of comparative performance and efficiency.

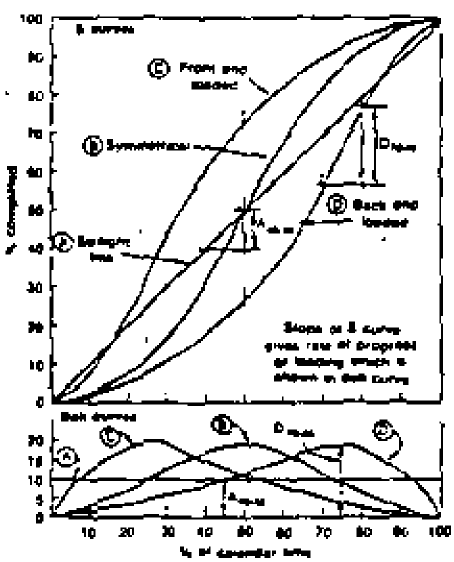
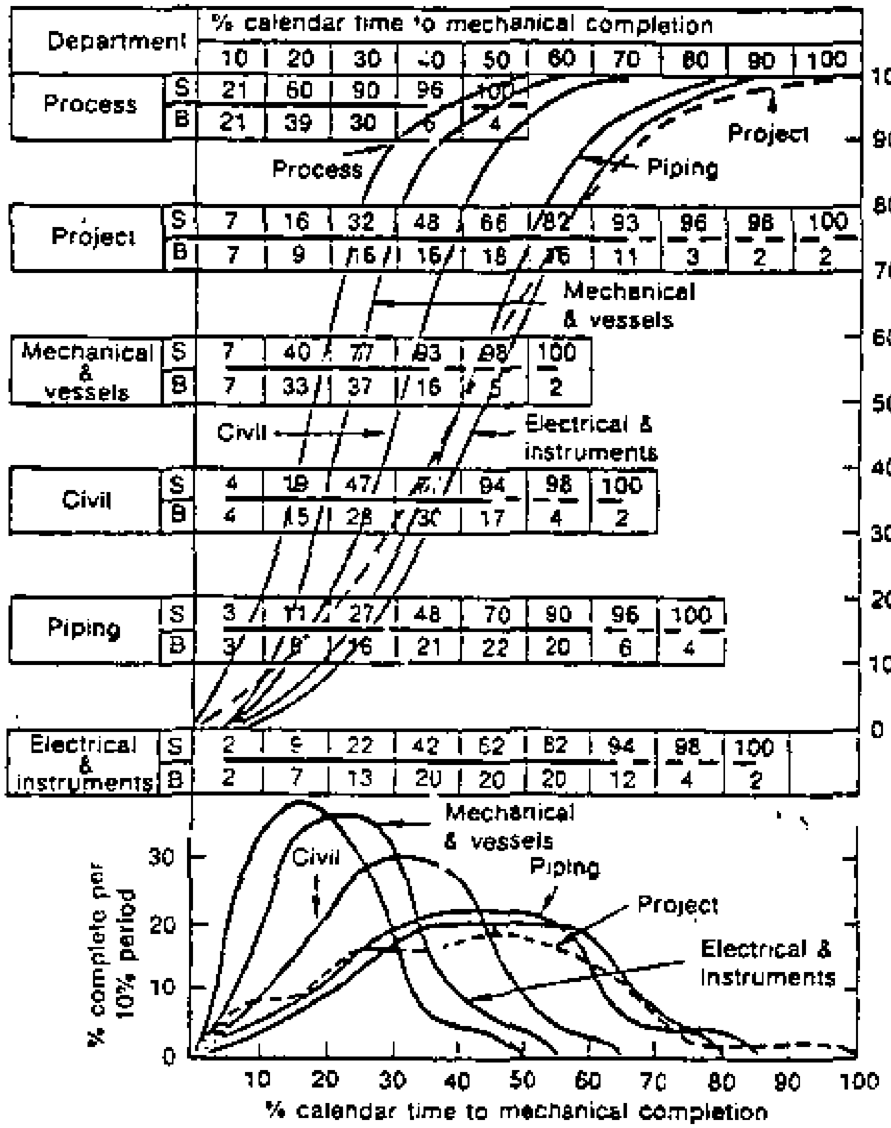


Fig. 1—These examples show basic Bell and "S" curve shapes.

Simplicity. The simplest "S" curve is a straight line as shown in Fig. 1, curve A. An "S" curve shows cumulative values from 0 to 100, and its shape shows the rate of progress or loading at each point in time. In reality, it is rarely feasible to apply full loading instantly and to maintain a constant load throughout the time span. Usually, there must be an initial lead-in period for mobilization before peak effort can be applied and a tail-off period towards the end. Fig. 1, curve B, shows a typical symmetrical "S" curve which has an equal buildup and tail-off.

The Bell curve is derived from the "S" curve and shows the amount of vertical movement of the "S" curve (the rate of progress or loading) for a finite interval of time. In the case of the straight line "S" curve, the slope or loading is constant indicating a constant effort throughout the total period. Thus, the derived Bell curve



Department		% calendar time to mechanical completion									
		10	20	30	40	50	60	70	80	90	100
Process	S	21	60	90	96	100					
	B	21	39	30	6	4					
Project	S	7	16	32	48	66	82	93	96	98	100
	B	7	9	16	16	18	16	11	3	2	2
Mechanical & vessels	S	7	40	77	93	98	100				
	B	7	33	37	16	5	2				
Civil	S	4	19	47	[illegible]	94	98	100			
	B	4	15	28	30	17	4	2			
Piping	S	3	11	27	48	70	90	96	100		
	B	3	8	16	21	22	20	6	4		
Electrical & instruments	S	2	9	22	42	62	82	94	98	100	
	B	2	7	13	20	20	20	12	4	2	

Fig. 2—These curves are typical of engineering work.

is also a straight line. This shape of curve is normally the most efficient and hence the most desirable when related to manpower loading. It may not necessarily be so for dollar expenditures where it may be more desirable to defer expenditures to the latest possible date.

The loading curve developed from a symmetrical "S" curve shows the conventional Bell shape with a symmetrical peak considerably higher than the average. This indicates a lower rate at the beginning and end with the maximum rate during the central period.

Symmetry. "S" curves are not usually symmetrical. They may be front end loaded or back end loaded as illustrated in curves C and D in Fig. 1. An actual "S" curve might follow any shape within the grid but will probably fall between the extremes of the two "S" curves shown. The closer the "S" curve is to the 45° straight line, the greater is the degree of resource leveling that has been achieved and the greater the theoretical efficiency.

"S" CURVE APPLICATIONS

- Engineering by manhours or by physical completion
- Drawings by number or weighted value
- Requisitions by number or dollar value
- Purchase orders by number or dollar value
- Construction by manhours, by units of work activity, or by physical completion
- Expenditures or cash flows in dollars.

"S" curves can be applied equally effectively to a variety of miscellaneous activities or items such as:

- Material take-off quantities
- Isometrics drawn and checked
- Cubic yards of earth excavated
- Cubic yards of concrete placed
- Feet of pipe placed
- Feet of cable installed.

The most common "S" curves used for overall project review are for Engineering, Procurement, Material Delivery and Construction.

Engineering curves. Fig. 2 contains a tabular spread sheet distributing engineering planned progress and manhour expenditures by discipline from project start to mechanical completion. The figures show the percent manhours expended and progress achieved in each period and cumulatively. Superimposed on the spread sheet is the same information expressed in the form of "S" and Bell curves. Notice how much greater is the visual impact and information given by the curves than by the figures.

In a normal project, the work flows through Process, Equipment Groups (Vessel and Mechanical), Civil and Structural, Plant Design, and finally, Instruments and Electrical. This typical relationship between the "S" curves for the various engineering disciplines holds for most projects. If the progress for any one discipline runs late, then all succeeding disciplines must be affected and will also be forced to run late.

If planned manhour and progress curves are prepared at the start of a project and actual manhour expenditure and progress recorded at each reporting date, any deviation from plan is very visible. Even more important, schedule slippage in one area can be easily trended to evaluate the potential impact upon the schedule of other areas.

Individual discipline curves. Fig. 3 shows individual discipline curves plotted over the scheduled completion·

VII.-E-1-2

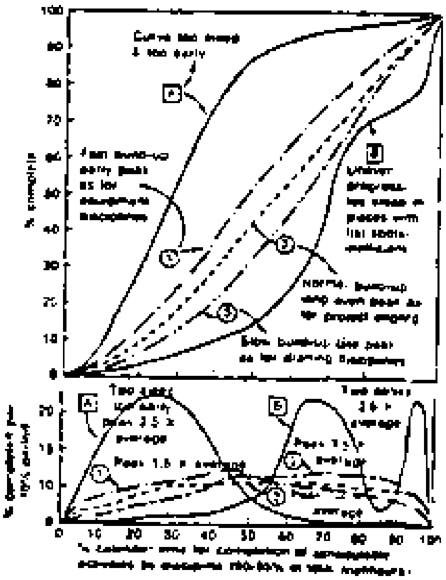


Fig. 3—Note the contrast in these normal and unacceptable engineering curve shapes.

time for the discipline. In these curves, 100 percent completion refers to completion of schedulable activities within the scheduled completion time for the discipline. For engineering disciplines, this is normally at a point when 90 to 95 percent of the manhours have been expended. The final 5 to 10 percent of the manhours are required for engineering closeout and follow-up of vendor and field queries.

Basically, three typical curve shapes cover all engineering disciplines. Fig. 3, curve 1 shows a fast buildup, early peak which applies for Process, Mechanical, Vessels and Equipment disciplines. Fig. 3, curve 2 shows a normal buildup with a long even peak which applies for Project and Support Engineering disciplines. Fig. 3, curve 3 shows a slow buildup and late peak which applies for the major Drafting disciplines.

Generally speaking, a planned "S" curve for any engineering or drafting discipline will fall somewhere within this envelope. For preliminary planning purposes, this typical shape of "S" curve can be assumed for manhour, manpower and progress planning. Note that the normal "S" curves produce corresponding Bell curves where the peak is about 1.5 times the average.

Unsuitable curves. Also shown in Fig. 3 are curve shapes unacceptable for engineering disciplines. Fig. 3, curve A is too steep and too early. It shows an unrealistic peak of 2.5 times the average with a long slow tailoff. Fig. 3, curve B shows two steep portions with a central flat area. The derived Bell curve shows two short term peaks with low progress achievement over the central portion of the project. These curve shapes show inefficient manpower loading. If they were produced either as planned or actual, there is something seriously wrong with project planning or performance.

Plan, measure, report. Fig. 4 illustrates the method of preparing a planned, weighted progress "S" curve for an engineering discipline for comparison against physical achievement and manhour expenditure. First list the activities and estimate the manhours for these activities. The "weight" of an activity is the ratio of the activity manhours to the total discipline manhours expressed as a percentage.

Next prepare a bar chart schedule showing the planned periods for the activities. The planned percentage completion for each activity at each reporting period is marked above the bar. The planned weighted percent completion is the multiple of the activity percent complete times the activity weighting. The vertical totals for each reporting period generate a weight percent planned progress "S" curve as illustrated.

At the time when the planned "S" curve is prepared, the Bell curve generated should also be examined. This will show the planned manhour and manpower expenditure for each reporting period. Any excessive peaks or fluctuations should be corrected by adjusting the bar chart schedule to achieve more even loading.

Periodic recording. At each reporting period, physical completion for each activity is recorded. This physical percent completion is multiplied by the activity weighting. The sum of these multiples gives the total physical percentage completion for the over-all discipline. Physical completion and manhour expenditures are plotted on the same form with the planned progress curve. A comparison between the planned percent complete, the physical percent complete, and the percent manhour expenditure

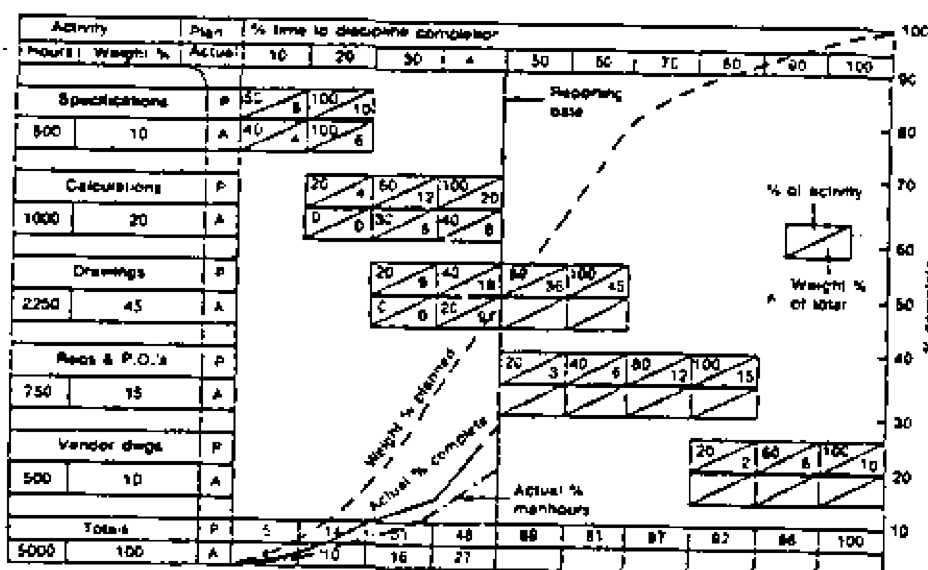


Fig. 4—Curves can be used to prepare a weighted progress report.

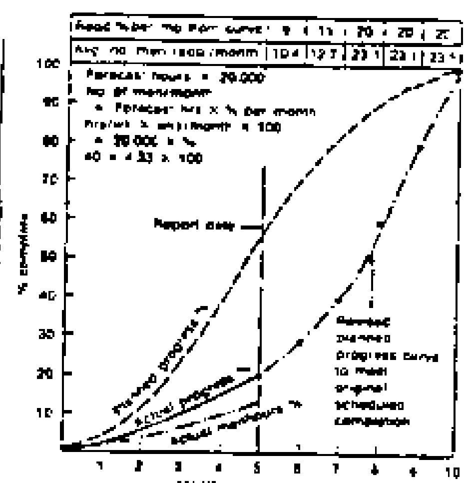


Fig. 5—Manpower forecasting can be done from curves.

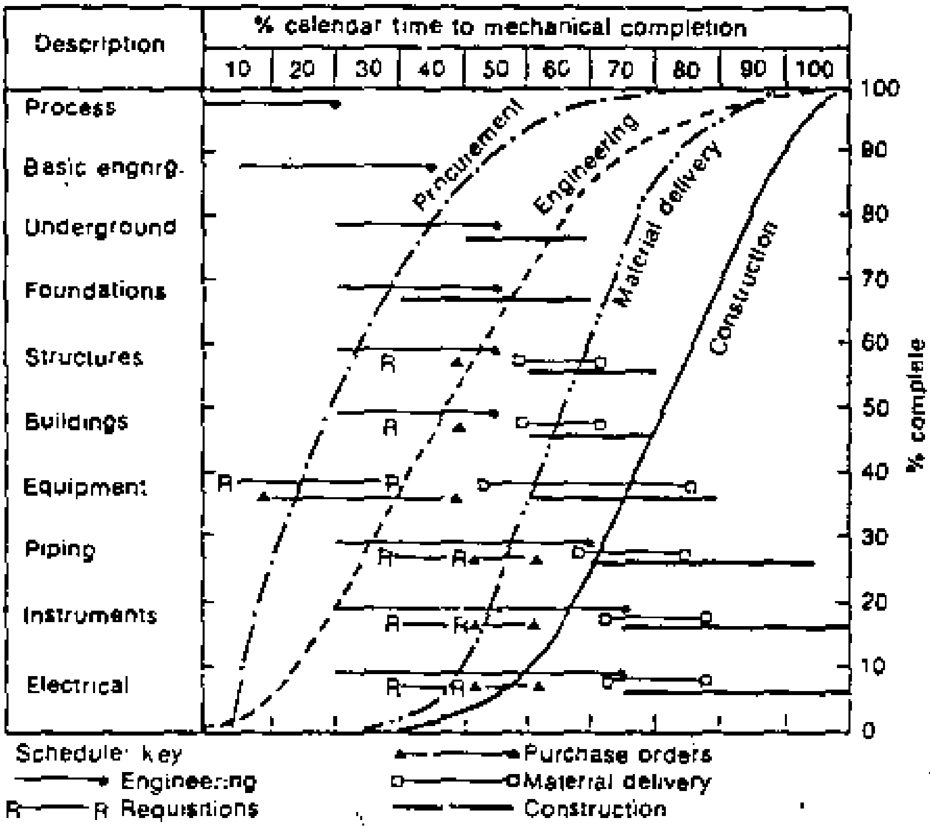


Fig. 6—These are typical master project schedule and curves.

will quickly show the productivity and performance trend. It is then possible to forecast over-all completion and over-all manhour expenditure.

This method of developing planned progress "S" curve is a basic method. Many variations can be done manually or by computer with networks and/or bar charts.

Manpower forecasting. Fig. 5 shows how curves can be used to forecast manpower requirements. Normally the planned progress curve is prepared after the manpower requirements have been determined and leveled to even out peaks. However, sometimes during the progress of a job, when the end date has been fixed, and progress and manhour expenditures have varied from the initial plan, it is necessary to redetermine the manpower requirements to meet the original schedule. The steps are as follows:

1. The current position is the end of the actual progress curve, assuming the method of measuring physical percent completion is realistic.

2. From this point extend a revised planned progress curve approximating to the shape of the previous planned "S" curve and meeting the required completion point.

3. Note the cumulative percent completion required at the end of each month on the revised planned progress curve.

4. Tabulate for each monthly reporting period the required percent to be completed per month which is the difference between the cumulative numbers noted under 3.

5. To predict the number of men required per month, take the total forecast hours based upon productivity and performance to date. Multiply the total hours by the percent to be completed per month and divide it by the hours worked per month. This will give the number of men required per month.

6. Review the number of men required thus calculated and even out the numbers if there are large differences on a month-to-month basis.

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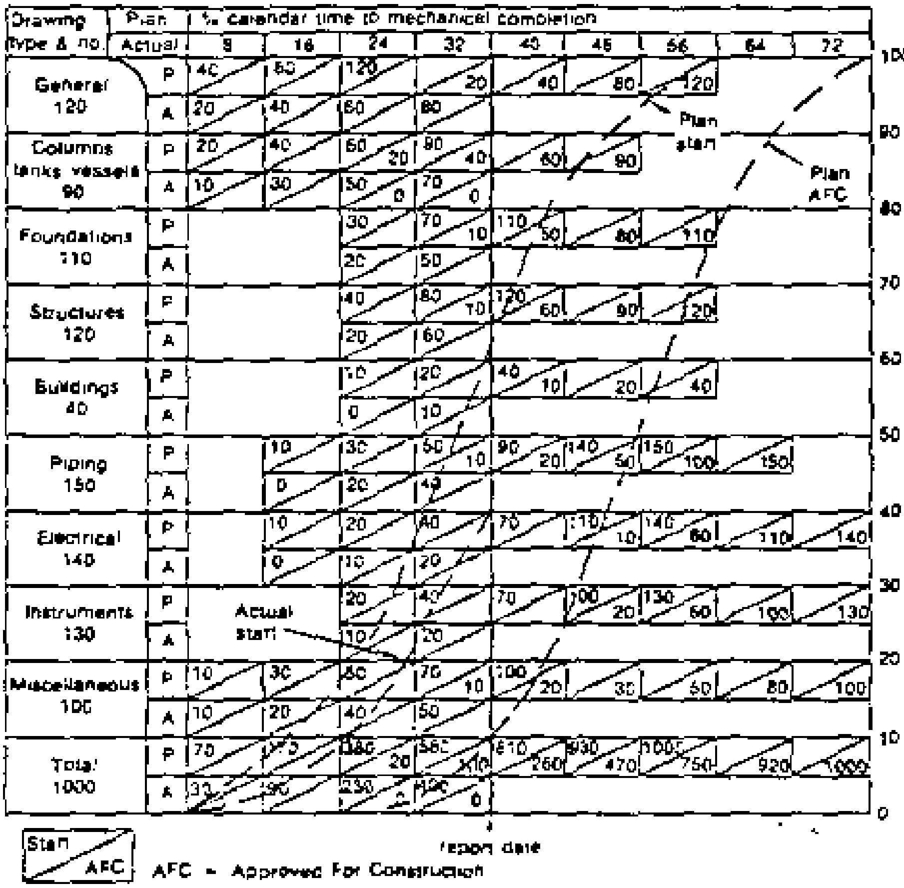

Fig. 7—A drawing summary schedule can be plotted like this.

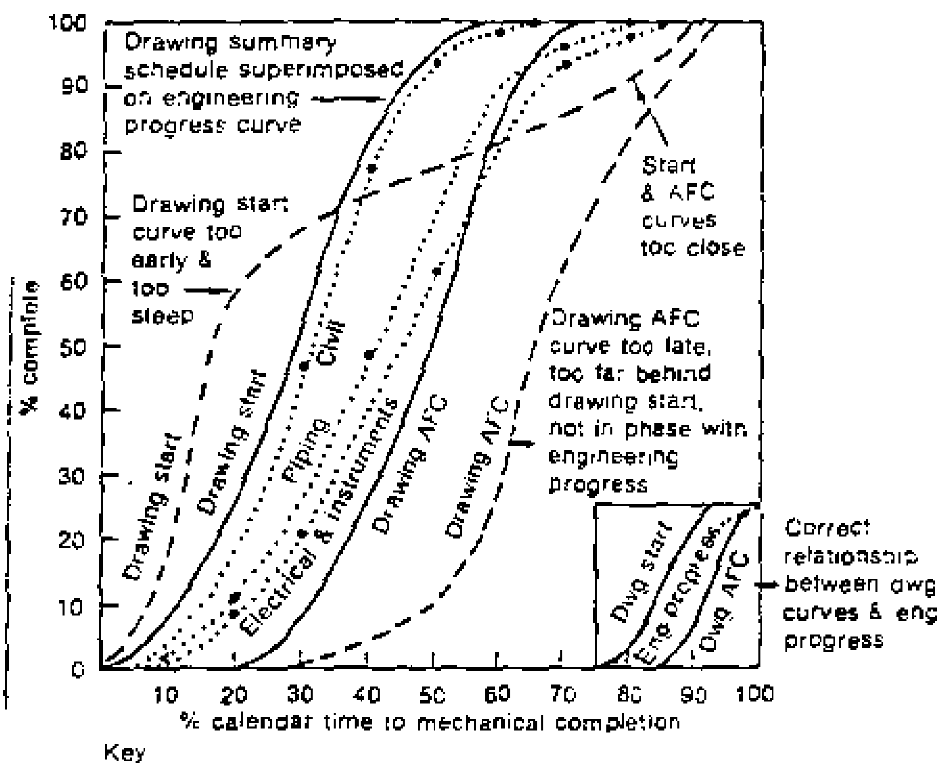

Fig. 8—These curves show the relationship between drawing start/AFC and engineering progress.

7. Confirm that the number of men indicated can be realistically applied to the job. If the number indicated is greater than can be obtained or realistically applied to the job, then the schedule will have to be extended. Alternatively, if more men are available and can be applied to the job than is required, it may be possible to reduce the schedule.

Master project schedule. Fig. 6 shows a typical bar chart master project schedule. Start/complete dates and relationships between the various major activities are expressed as a percentage of calendar time to mechanical completion.

Superimposed on the bar chart are "S" curves for Procurement, Engineering, Material Delivery, and Construction, which are normally considered the key progress measurement curves for an overall project. The relationship between the "S" curves matches the relationship between the corresponding activities in the bar chart. Whereas the bar chart shows specific start and finish dates for activities, the "S" curves show required rates of progress and cumulative completions at various stages of the project.

A narrow band. The shape of the "S" curves, their relationship to each other, and their position with regard to overall project completion, fall within a fairly narrow band for all projects. For example, Procurement, Engineering, and Material Delivery all should be essentially complete at the 50 percent, 70 percent and 80 percent points, respectively. Little is to be gained by starting construction much earlier than at the 30 percent point. If any one of the these curves moves significantly out of its place, then the overall schedule will be affected. The typical relationships between these "S" curves and their position in the overall project completion provide excellent data for preliminary planning. Also the curves help to check the realism of any detailed plans developed for a specific project.

Drawing summary schedule. Fig. 7 illustrates the preparation of drawing summary schedule curves showing drawings started and drawings issued "Approved for Construction" (AFC).

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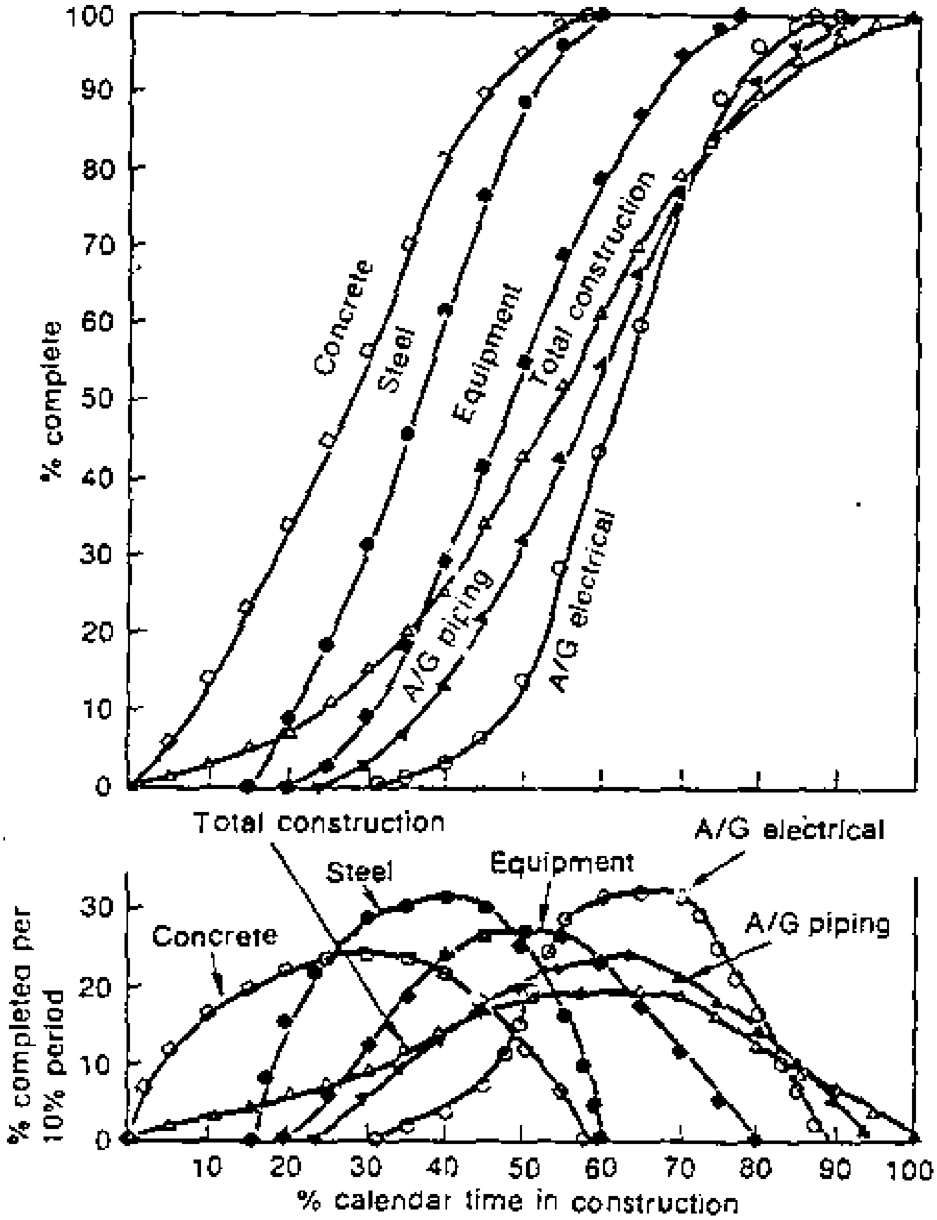

Fig. 9—Construction craft curves may look like this.

The major categories of drawings and their numbers are listed on the left-hand side. The numbers of drawings to be started and issued AFC are spread out across the form corresponding to the activity periods established in the project schedule. The column totals are the total numbers to be started and issued AFC in each period. From these, the "S" curves can be generated as illustrated.

As the project proceeds, the actual number of starts and AFC issues can be entered and compared against the ...an. This simple but effective method ...elps assure that overall drawing progress is maintained to meet the requirements of the project schedule.

Fig. 8 shows the drawing summary schedules (in heavy solid line) superimposed on the engineering curves for the drafting disciplines (reference Fig. 2). Note that the engineering discipline progress curves fall right between the drawing start and drawing AFC "S" curves. This is where they should be.

Unacceptable curves. Fig. 8 also shows unacceptable drawing curves (in heavy dotted line) in relation to the drafting discipline progress curves. The following points are unacceptable:

1. The drawing start curve is too optimistic. Drawing starts should not be made too early and too fast. Progress cannot be maintained since it runs well ahead of the engineering development.

2. The drawing AFC curve is too late. This is running too far behind the planned progress.

3. There is too wide a gap between the drawing start and the drawing AFC curve in the early phases. This means the drawings are started and left incomplete for too long. This usually reflects inefficient operation.

4. The end portions of the curves are too close showing an unrealistic expectation. Drawings cannot be started and issued AFC without adequate time in between for the actual drawing, checking, review and finalizing before issue.

5. The average slope of the drawing curves from start to completion is offset from the required engineering discipline progress curves. In general, the rate of progress of the drawing production has to be equal to or greater than the overall engineering progress curves.

The correct relationship between an engineering discipline progress curve and its drawing start and drawing AFC curves is illustrated in the insert. Entirely similar types of curves can be generated for equipment requisitions, purchase orders, and deliveries. Again, the requisition and purchase order curves must have a fixed relationship, one to the other and also to the progress of the engineering disciplines.

Construction curves. Fig. 9 shows typical Construction Craft "S" and Bell curves. The actual shape of Construction "S" and Bell curves differs from those of the engineering disciplines. Nevertheless, the overall concept for their preparation and application is entirely similar. In a normal project, construction work flows through concrete, steel, equipment, piping and electrical as shown.

This typical relationship between the "S" curves for the various Construction Crafts holds for most projects. If progress for any one craft runs late, then all succeeding crafts will be affected and will also be forced to run late. Planned manhour and progress curves may be prepared at the start of the project against which

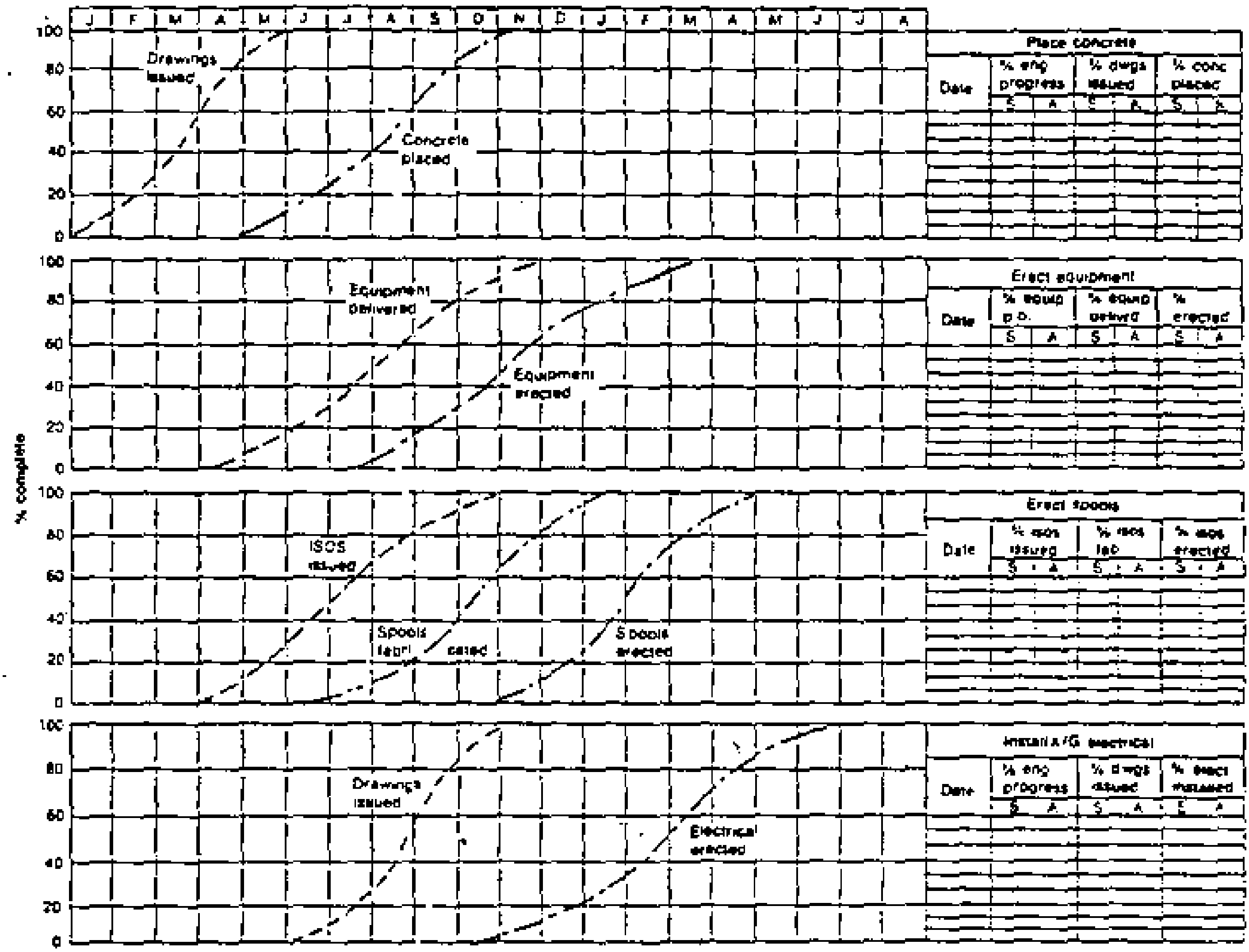

Fig. 10—Progress is seen at a glance with use of planning and tracking curves.

actual manhour expenditure and progress achieved can be recorded for schedule control and forecasting.

Plan and track. Fig. 10 shows use of "S" curves for construction planning and tracking. In just the same way as there is a relationship between the equipment and drawing curves and engineering progress curves, there is a similar relationship between the construction progress curves. Construction cannot proceed until AFC drawings and materials are received.

A good way of planning and monitoring construction progress is to plot the AFC drawing release and equipment delivery "S" curves with the corresponding construction craft curve. Good planning allows an adequate lead time between receipt of AFC drawings and material and planned construction progress. Thereafter, if a record is maintained of the actual AFC drawing releases and actual material deliveries, it is possible to determine ahead of time whether or not construction progress can be maintained.

Fig. 10 illustrates a selection of only four out of the many construction crafts and activities. But it is an exceptionally effective and easily followed method of tracking construction progress. A full set of these curves set out on one wall of a field planning office can be updated frequently. Any deviation from plan immediately shows up the potential impact upon subsequent activities.

Simple but useful. The difficulties of plant construction today demand that the most appropriate of the available comprehensive specialized control systems be used. However, do not scorn the simple approach. "S" and Bell curves can be applied in conjunction with any system. Their message is understood from top management to junior supervision.

About the author

ARTHUR E. KERRIDGE *is project controls manager for C-E Lummus, Houston, where he is responsible for Scheduling, Estimating, Cost Engineering and Computer Services departments. He has 30 years of experience with engineering construction companies in the United States, Europe, Middle East and Canada. He has worked as process/project engineer, engineering manager, senior project manager, and in a variety of technical and administrative special assignments. Mr. Kerridge holds a B.S. degree in chemical engineering (with honors) from Imperial College, London University, U.K. He is active in several professional societies.*

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COST CONTROL OVERVIEW

OUTLINE

1. INTRODUCTION

2. GENERAL INFORMATION

   a. Company Policy
   b. Intent
   c. Responsibilities

3. PROJECT SCHEDULE

   a. Proposal Phase
   b. Process Design Phase
   c. Planning/Analytical Phase
   d. Production Design Phase
   e. Construction Phase
   f. Project Completion Phase

4. COST ELEMENTS-SYSTEMS APPLICATION

   Open Cost Job

   a. Estimates

      1. Proposal
      2. Interim Control Estimate (ICE)
      3. Initial Approved Cost Estimate (IAC)
      4. First Check Estimate (FCE)
      5. Production Check Estimate (PCE)

   b. Project Control Estimate Basis Form
   c. Client and Project Changes
   d. Project Cost Status Reports

      1. Client Report
      2. Kellogg Report

   Fixed Price Job

   e. Differences

5. SUMMARY

   The intent of the Cost Control System is to control and monitor cost. The control of costs must be accomplished at the working level where expenditures are being incurred. LINE PERSONNEL CONTROL COST by (1) performing their specialty operation within authorized costs and schedules (2) predicting significant changes before they occur, and (3) implementing changes only upon authorization by the Project Manager.

There are several ESTIMATES prepared throughout the project. The quality of these estimates gets progressively better with job development.

For open cost jobs, initially a Proposal Estimate is prepared, if requested by the client. This is followed by the Interim Control Estimate, the first control estimate for the job. A CONTROL ESTIMATE establishes the working budgets for departments. The Interim Control Estimate is replaced by the Initial Approved Cost Estimate which is replaced by the First Check Estimate, the final control estimate for the job. Following the First Check Estimate, the Production Check Estimate is prepared. This is not a control estimate but an estimate prepared late enough in the job to provide the most accurate prediction of final job costs.

The basis for operational inputs to these estimates is documented on the PROJECT CONTROL ESTIMATE BASIS FORM.

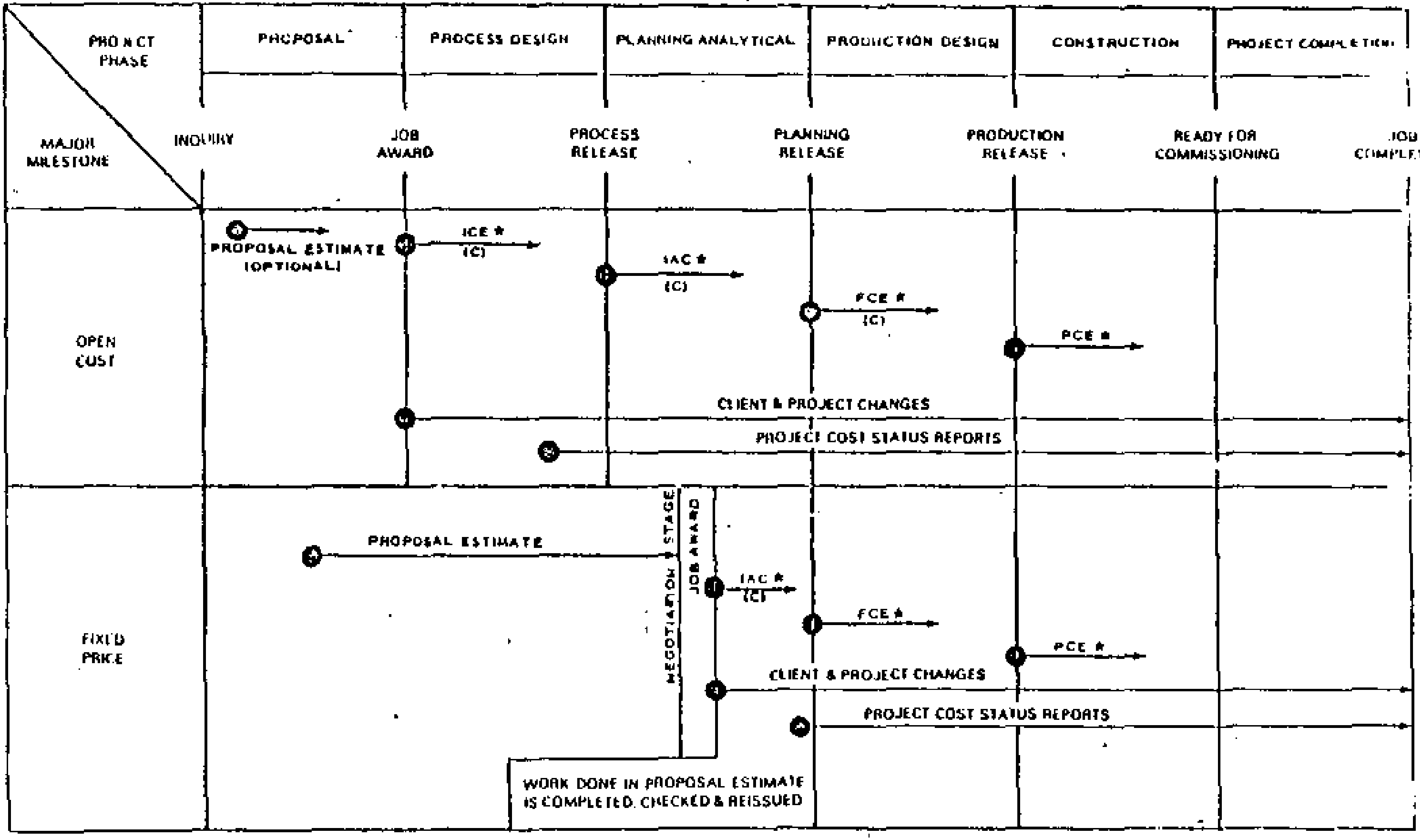
Significant changes to the control estimates or the working budgets are documented, authorized or rejected on CLIENT AND PROJECT CHANGES. The intent is to highlight anticipated changes in a minimum amount of time so that effects on costs and schedules can be minimized and optimized.

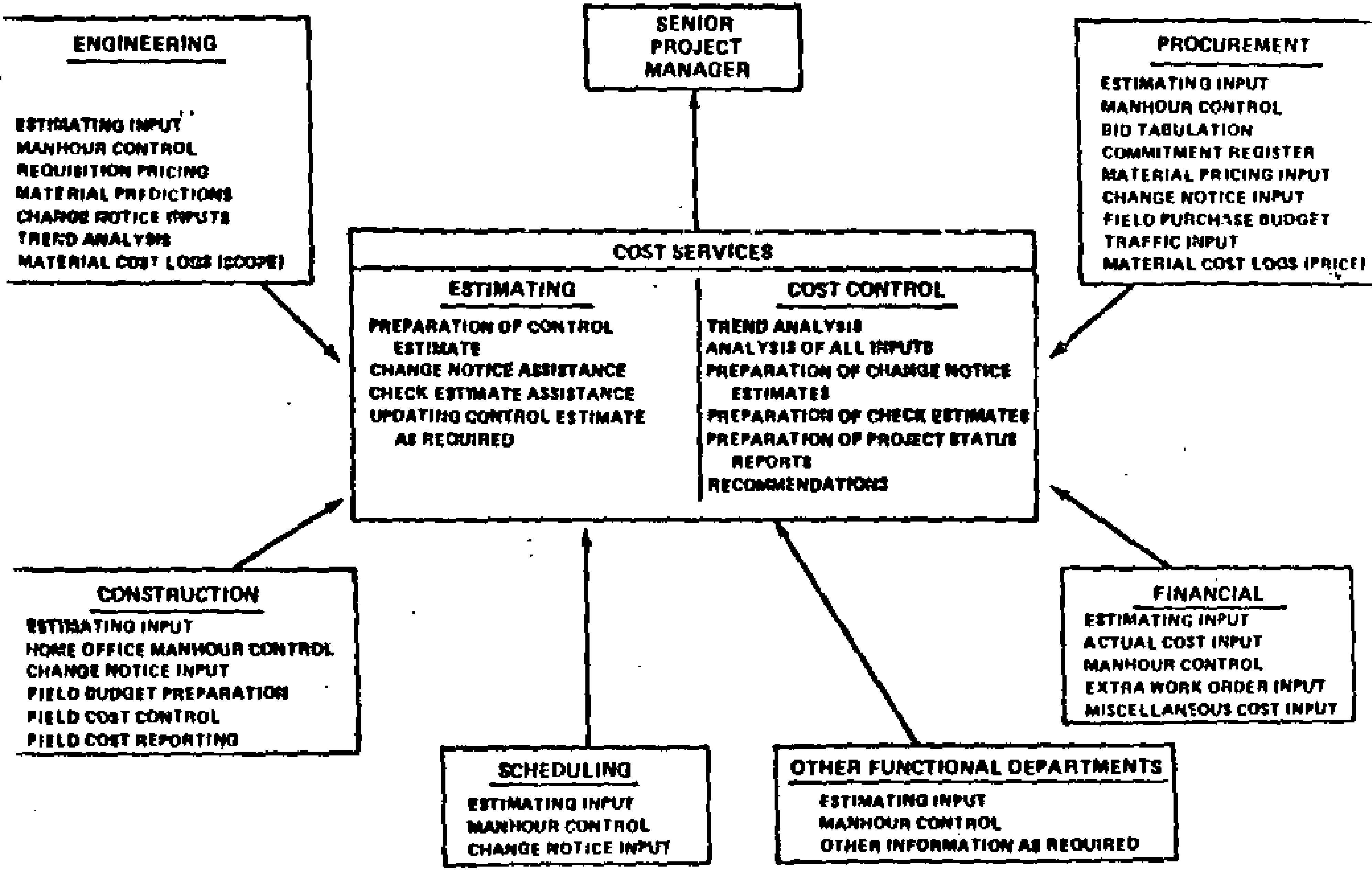
PROJECT COST STATUS REPORTS are prepared on a periodic basis throughout the project. They provide a means of continually appraising actual and predicted costs against authorized costs.

COST CONTROL OVERVIEW

*ESTIMATE INPUT BASIS DOCUMENTED ON PROJECT CONTROL ESTIMATE BASIS FORM

CE - CONTROL ESTIMATE
ICE - INTERIM CONTROL ESTIMATE
IAC - INITIAL APPROVED COST
FCE - FIRST CHECK ESTIMATE
PCE - PRODUCTION CHECK ESTIMATE





THE INFORMATION CENTER APPROACH TO COST ENGINEERING

EXHIBIT (1)

ENG PROJ 43 (2-78)

Pullman Kellogg

CLIENT CHANGE

CLIENT	PROJECT MANAGER
LOCATION	REFERENCE CLIENT REQUEST

JOB NO

CHANGE NO

PAGE OF

ISSUE NO (CIRCLE LATEST)

1 2 3 4 5

☐ SENT FOR ESTIMATING

DATE

EFFECT ON ENGINEERING SCHEDULE:

EFFECT ON CONSTRUCTION COMPLETION

☐ ESTIMATE ATTACHED

PRICE OF THIS CHANGE EXPIRES ON

DATE

SUBSEQUENT TO THIS DATE AN ESTIMATE WILL BE REQUIRED

PROJECT MANAGER

☐ ACCEPTED BY CLIENT

BY

DATE

REFERENCE CLIENT LETTER OF ACCEPTANCE

☐ AUTHORIZED

BY PROJECT MANAGER

DATE

DISTRIBUTION BY PM

PROJECT ENGINEERING MANAGER - NAME

PROJECT PLANNING SERVICES - NAME

CONTRACT FINANCIAL SERVICES - NAME

PROC CONTRACT ADMINISTRATION - NAME

CONST TECHNICAL SERVICES - NAME

COST SERVICES - NAME

PRINCIPAL JOB ENGINEER

SALES REPRESENTATIVE - NAME

MGR ENGINEERING ADMINISTRATION

ADDITIONAL NAMES

CIRCLE AFFECTED CLASSES:

A B C D E F H J K L M N O P U V W Z

AFFECTED: ☐ ENGINEERING
☐ PROCUREMENT

EXHIBIT (4)

ENG PROJ 42 (7-76)

Pullman Kellogg

PROJECT CHANGE NOTICE

JOB NO.

CHANGE NO.

CLIENT

PROJECT MANAGER

PAGE ______ OF ______

LOCATION

PCR. NO.

DATE

DESCRIPTION & REASON FOR CHANGE – BE SPECIFIC; LIST DOCUMENTS AFFECTED; ATTACH SKETCHES, DRAWINGS, SPECIFICATIONS, & OTHER INFORMATION IF NECESSARY:

☐ ESTIMATE ATTACHED

☐ AUTHORIZED

BY ______

DATE ______

COMMENT:

DISTRIBUTION BY PM

PROJECT ENGRG. MGR.

(NAME) ______

PROJECT PLANNING SVCS.

(NAME) ______

ENGRG. ADMINISTRATION

(NAME) ______

PROC. CONTRACT ADMIN.

(NAME) ______

CONST. TECH. SVCS

(NAME) ______

PROJECT COST SVCS

(NAME) ______

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CIRCLE AFFECTED CLASSES :

A B C D E F H J K L M N O P U V W Z

AFFECTED : ENGINEERING ______, PROCUREMENT ______,

CONSTRUCTION ______.

VII-F-4-3

Pullman Kellogg

CHANGE ESTIMATE SUMMARY

PROJ. NO.	
CHANGE NO.	
ISSUE & DATE	○

CLIENT ______________________ PROJECT MGR. ______________________

LOCATION ______________________ EST. BY __________ DATE __________

DESCRIPTION ______________________ VALID UNTIL ______________________

ENG EST 1619 (9-78)

CODE	DESCRIPTION	TO ESTIMATE	← TO IMPLEMENT →				TOTAL COST
B	FURNACES						
C	EXCHANGERS						
D	CONVERTERS						
E	TOWERS						
F	DRUMS & TANKS						
J	PUMPS & COMP						
L	SPEC. EQUIP						
U	UTILITY EQUIP						
V	TRANS. & CONV. EQUIP.						
Z	FIRE & SAFETY EQUIP.						
A	FDNS. & CONC. STRUCT.						
H	STEEL & INDUS. BLDGS.						
K	ARCH. BLDGS.						
M	PIPING						
N	ELECTRICAL						
O	INSTRUMENTS						
P	INSULATION & PAINT						
W	CATALYST & CHEMICALS						
	SUBTOTAL DIR. MAT'L.						
	INPLACE SUBCONTRACTS						
	SALES & USE TAX						
	IMPORT DUTIES						
	OCEAN FRGT. & TO SITE						
	TOT. MATERIAL COSTS						
	FLD. ADMIN. & DIR. SUPV.						
	CONST. FORCE						
	TOOLS & FRGT.-ON TOOLS						
	FIELD OFF. & INDIR. MAT'L.						
	TOTAL FIELD COSTS						
	PROJECTS						
	PROCESS AND R & D						
	COST SERVICES						
	ENGINEERING						
	H.O. PROCUREMENT						
	H.O. CONSTRUCTION						
	FINANCIAL AND M.I.S.						
	TOTAL H.O. SERVICES						
	INSURANCE						
	OTHER COSTS						
	THIRD PARTY CLAIMS						
	ADDT'L. CLIENT CHARGES						
	GUARANTEE PROBLEMS						
	COMM. COSTS & OPERATORS						
	SUBTOTAL OPERATIONS						
	CONTINGENCY						
	TOTAL OPERATIONS COST						
	FEE:						
	TOTAL PROJECT COST						
	TOTAL H.O. MANHOURS						
	CONST. FORCE MH						

CMS EST 10417-78P

PROJECT COST SUMMARY (ALL FIGURES ARE IN THOUSANDS)

Pullman Kellogg

CLASS	DESCRIPTION	1 CONTROL ESTIMATE	2 AUTHORIZED CLIENT CHANGES: CLIENT APPROVED	3 AUTHORIZED CLIENT CHANGES: PENDING APPROVAL	4 INTERNAL TRANSFERS	5 ANTICIPATED APPROVED COST	6 TOTAL PREDICTED COST	7 VARIANCE FROM AAC	8 VARIANCE FROM PREVIOUS PREDICTION	9 TOTAL COMMITMENTS TO DATE	10 TOTAL EXPENDITURES TO DATE
B	FURNACES										
C	EXCHANGERS										
D	REACTORS										
[illegible]	TOWERS										
F	DRUMS & TANKS										
J	PUMPS & COMPRESSORS										
L	SPECIAL EQUIPMENT										
U	UTILITY EQUIPMENT										
V	TRANS & CONV. EQUIP										
[illegible]	FIRE & SAFETY EQUIPMENT										
[illegible]	FOUNDATIONS & CONCRETE STRUCTURE										
[illegible]	STEEL STRUCTURES PLATFORMS ETC										
[illegible]	ARCHITECTURAL BUILDINGS										
[illegible]	PIPING										
[illegible]	ELECTRICAL										
O	INSTRUMENTATION										
[illegible]	INSULATION & PAINT										
[illegible]	CATALYST & CHEMICALS										
	SUB TOTAL DIRECT MATERIAL										
	SUB TOTAL INDIRECT SUBCONTRACTS										
	SALES & USE TAX - UNALLOCATED										
	[illegible] SPARES										
	OCEAN FREIGHT, INLAND FREIGHT										
	VENDOR [illegible]										
	TOTAL MATERIAL & RELATED COSTS										
	FIELD ADM. & SUP. SUPERV.										
	CONSTRUCTION [illegible]										
	TOOLS & RENTAL OF TOOLS										
	FIELD [illegible] EXPENSE										
	[illegible]										
	TOTAL FIELD COSTS										
	H.O. CONSTRUCTION										
	H.O. PROCUREMENT										
	H.O. [illegible] ENGINEERING										
	H.O. [illegible]										
	TOTAL H.O. SERVICES										
	INSURANCE										
	THIRD PARTY CLAIMS										
	START UP COSTS										
	COMMISSIONING & OPERATIONS										
	ADDITIONAL CLIENT CHANGES										
	SUB TOTAL OPERATIONS COST										
	[illegible] CONTINGENCY										
	TOTAL OPERATIONS COST										
	KELLOGG FEE										
	TOTAL PROJECT COST										

PROJECT NO.:

REPORT NO.:

STATUS AS OF:

CLIENT

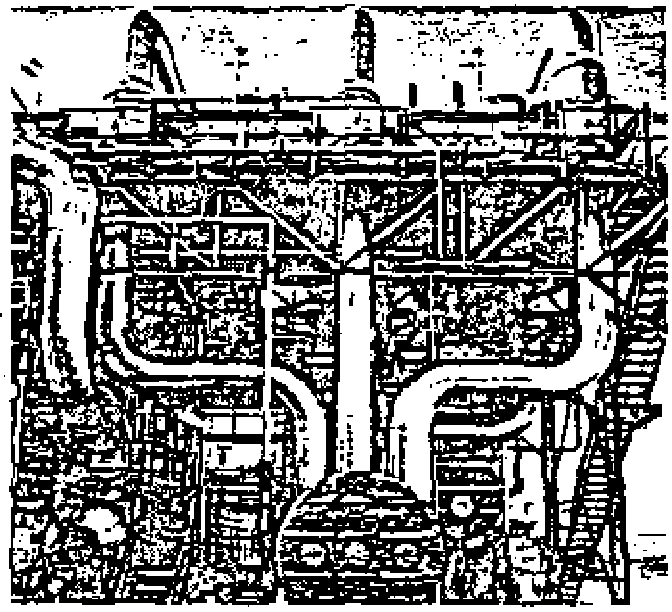
LOCATION

PREPARED BY __________ DATE ______

PROJECT MGR. CERTIFICATION __________ DATE ______

PAGE ____ OF ____

MAINTENANCE TRENDS



U.S. refinery maintenance costs will increase about 19% in 1981 over 1980. In addition to inflation, U.S. refinery crude availability continues to cause maintenance problems and although crude runs were down in mid-1980 and will probably continue into early 1981, maintenance costs will increase. U.S. petrochemical maintenance costs will be up only about 6% in 1981 over 1980. Before the next big wave of petrochemical expansion starts, possibly in late 1981, many units are now operating at reduced capacity and a number of older units are being shut down which will reduce somewhat the normal increase in maintenance costs. U.S. gas processing maintenance costs, on the other hand, will be up about 35% because of additional capacity and more ethane recovery which increases maintenance costs. However, because the total gas processing maintenance costs are low relative to refining or petrochemicals, the 35% gain will not contribute significantly to total U.S. maintenance costs.

Outside the U.S., refining costs will be up only about 4% over 1980 and outside-U.S. petrochemical maintenance costs will be down about 10%. One of the major reasons for these figures is that new data received indicates the total gross investment in both refining and petrochemicals was somewhat less than indicated by previously available data. However, maintenance costs for gas processing outside the U.S. will be up about 55% because the large gas processing units in the Middle East that have come onstream in the last few years will now require rather significant maintenance work.

Maintenance expenditures estimated for materials and equipment listed in the table are 1981 actual costs excluding installation. Maintenance labor costs are higher than the cost for new construction because the equipment must be removed and disassembled. Maintenance labor costs in this study are estimated at 60% of the total maintenance costs in HPI plants.

Maintenance costs listed in the tables on preceding pages are based on estimated maintenance costs as a percent of gross investment.

U.S. refining maintenance costs are currently estimated at 5½% of the gross investment in refining. Outside-U.S. refining maintenance costs are estimated at 4% of the gross investment in refining.

U.S. petrochemical costs are estimated at 6% of the gross investment in petrochemical plants, whereas maintenance costs for petrochemical plants outside the U.S. are estimated at 5½% of the gross investment.

U.S. gas processing plants are estimated at 3% of the gross investment, whereas outside U.S. gas processing maintenance costs are estimated at 3½% of the gross investment.

Solid fuels processing plants are not included in the maintenance expenditure tables because there are no commercial plants in the U.S. and few outside the U.S.

In U.S. refining, considerable capital expenditures will be made in the next 5 to 6 years to upgrade the bottom of the barrel into lighter products. When refinery engineering departments are concentrating on major downstream capital expenditures, engineering manpower will not be available for existing units. Maintenance departments will concentrate on equipment reliability to keep existing units in operation. The same philosophy applies to U.S. petrochemicals.

European refineries continue to operate at reduced capacity which reduces maintenance costs. They will follow America's lead in converting their fuel oil oriented refineries into light ends refineries.

Considerable attention will be given to training maintenance engineers and craftsmen in better techniques for pump and driver alignment. Because considerable effort has been made in recent years to upgrade alignment methods for compressors and drivers, maintenance costs on these items are dropping. However, pump maintenance costs are 3 to 4 times as much as compressor maintenance costs and we can expect to see major attention given to reducing pump maintenance costs while increasing overall plant reliability.

As energy costs continue to climb, worldwide refinery and petrochemical operations will be subjected to greater and greater pressures by management to reduce energy costs. Much of this effort will be borne by the maintenance departments because they must retrofit existing process units to achieve energy reductions. New and improved techniques for insulating process heaters will be tried on a scale never before attempted. Improved heat transfer in exchangers will be studied extensively.

Probably the most important development in maintenance will be the installation of microprocessors to monitor many more variables than was previously possible. In addition to standard temperature, pressure and flow conditions normally monitored by the process operators, microprocessors can monitor vibration levels in all rotating equipment or certainly in critical machines as well as corrosion rates, flue gas conditions, air cooler and cooling water quality.

In the U.S., there is a definite trend toward government regulations requiring zero discharge from cooling towers. This will be accomplished by increasing the solids concentrations in recirculating cooling tower waters substantially over what it would normally be with blowdown. Some of the cooling water will be diverted to a bank of centrifuges to concentrate the solids removing all water which will be recirculated back to the cooling tower. Maintenance departments will be faced with a substantial work load in maintaining a zero discharge cooling water system, but microprocessors coupled with appropriate sensing instrumentation will make the job manageable.

MAINTENANCE PROBLEMS

Barrel-type compressors are being used to an increased extent because the barrel design confines gases more effectively than horizontally-split cases. However, barrel-type machines must be removed from their foundations for total maintenance. Some of these compressors weigh up to 30 tons which presents a field and shop problem. In addition, the barrel-type compressor consists of a bundle contained within the pressure walls of the barrel making alignment and positive positioning difficult.

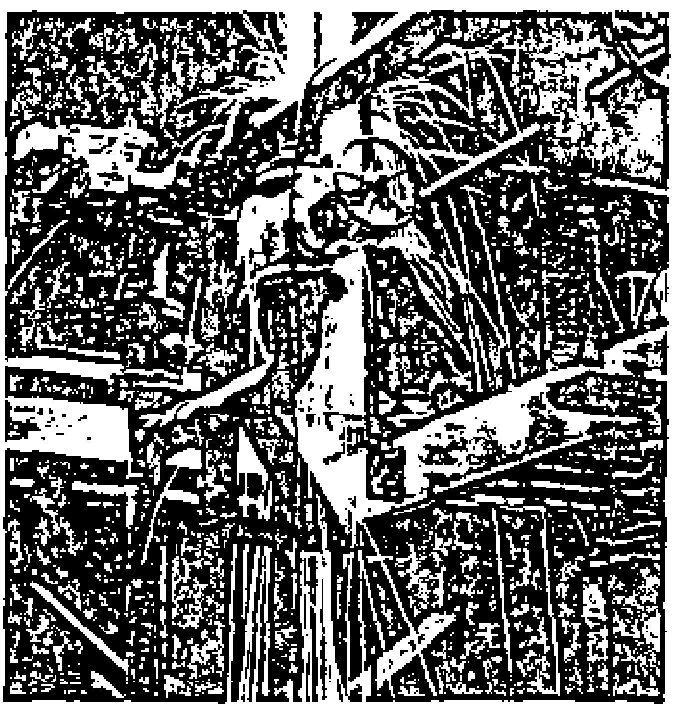
Tilting pad-type thrust bearings are used in most large pieces of rotating equipment. Leveling plates in this type bearing present major problems in determining the amount of wear on the leveling plates. Although the leveling plates are normally surface hardened a few mils deep, wear is a major problem that could be improved with new thrust bearing designs.

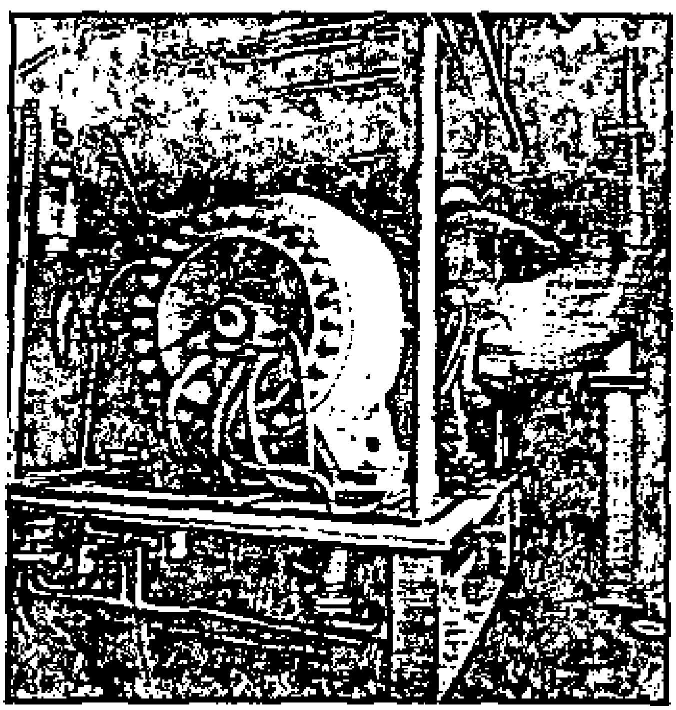
Manufacturer's instruction books are often inadequate for maintenance requirements. Many process plants are writing their own maintenance guides for the mechanic, using 35mm slides illustrating the details of compressor and pump repair.

Pump problems continue to be the major source of maintenance repairs in process plants. One of the reasons is that there are simply too many pumps in a process plant to apply sophisticated vibration monitoring methods as has become common place with expensive, large compressors. However, a new technique using high frequency acoustic surveillance is being used successfully to detect a flaw or incipient failure that could lead to complete failure a few days or weeks later. Equipment ranges from a relatively inexpensive portable monitor to a computerized incipient failure detection (IFD) system that can be justified for large investment-intensive plants.

Coupling problems continue even though the current generation of analysis equipment, including real time spectrum analyzers and shaft orbit displays, provides a better understanding of the sources of coupling vibration. Most coupling problems cause vibration because of a reduced ability to compensate for misalignment. As drivers become larger, coupling problems will probably increase, requiring a better interpretation of vibration data provided by a new generation of analysis equipment.

Pump seal failures are probably the number 1 cause of pump repair. Failures can usually be traced to improper seal selection, pump application or improper operation. To increase pump reliability, these areas will receive considerable attention in future years by the maintenance department.





EQUIPMENT DESIGN TRENDS

INSTRUMENTATION

Instrumentation continues its rapid growth in the HPI as technological improvements continue and more plants are learning to implement advanced control. Government restrictions are also providing incentives for new applications in the areas of pollution and safety monitoring/control. Machinery surveillance systems are growing in sophistication, providing microprocessor-generated data interpretation and enhanced cathode-ray tube (CRT) displays. New test instruments are simplifying electronic maintenance and aiding equipment inspections.

Engineers are busy learning to apply the new microprocessor-based distributed control systems introduced in 1980. New designs will concentrate on improving CRT display capabilities. A significant trend as a result of distributed control is greater application of direct digital control (DDC). In DDC, microprocessors perform control calculations and send signals directly to control valves. A few years ago, digital control was almost entirely supervisory with computers sending control points to analog controllers which performed the actual control functions. Increased reliability of distributed control is making this possible.

Demand for process controllers will increase about 15% in 1981. Digital controller demand will increase about 20% while demand for pneumatic analog controllers will decrease by about 10%. Electronic analog controller shipments will remain about constant.

Most new instruments introduced in 1981 will be analytical. Increased efforts to improve process efficiencies and monitor/control pollution in spite of lower quality feeds will create the demand. A few manufacturers now offer on-line octane, boiling point and BTU monitors, and their numbers will increase in 1981. Other analyzers normally associated with the laboratory will be available for field use. Availability of "single package" analyzers for monitoring greater numbers of components, particularly for pollution monitoring, will also increase. Analyzers incorporating laser technology for multiple component analysis are also under development.

Data acquisition equipment manufacturers will have another good year in 1981 as engineers probe deeper into processes. More fiber optic multiplexing and data acquisition systems will be available offering more data transmission per cable and noise immunity.

Transmitters will also receive advanced design attention in 1981. More products will be available with electronics to compensate for non-linear calibration curves and perform square root and temperature/pressure compensation calculations.

This revolution in instrumentation is changing the way processes and control systems are designed. The resulting change in engineering responsibilities and required knowledge cannot be overemphasized. Instrumentation must now be considered very early in process design. Process engineers are being encouraged to look for instrumentation solutions to process problems. Therefore, process engineers must keep up to date with instrumentation developments and will have an increasing influence in instrument selection. Instrument engineers must familiarize themselves with HPI processes to help determine which variables should be controlled and the best way to do it. Increased integration of these 2 engineering disciplines will be required in 1981.

ROTATING EQUIPMENT

Efficiency and reliability are the dominant forces in rotating equipment design. These goals will be accomplished both by improved machinery design and greater use of more advanced instrumentation for monitoring and control. Current design and specification trends include a slight increase in the use of large reciprocating compressors because of higher process pressures. New capacity controls are also incorporated to permit compression of only the required demand by these units.

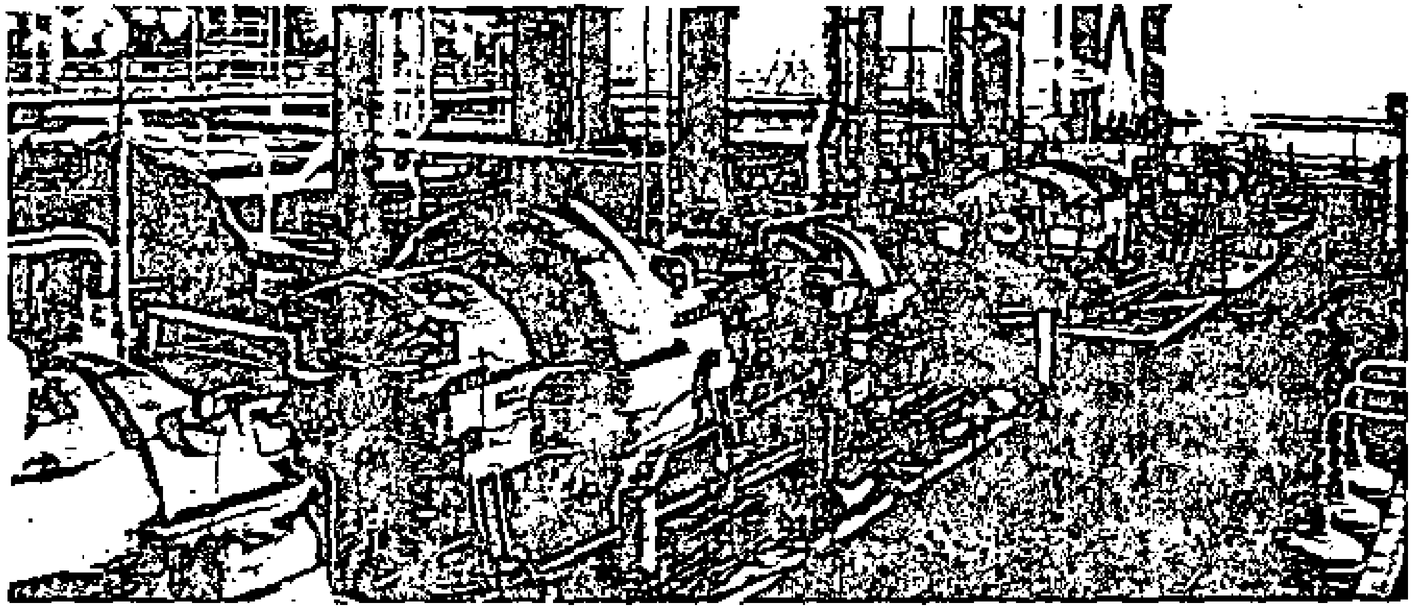
Centrifugal units, however, continue to dominate the HPI compressor and pump market. These units are also going through design changes to improve efficiency. These include tighter clearances and smoother passages. As a result, they will be available in smaller sizes than they are at the present.

Gas turbine driver manufacturers will be looking into more exotic materials to increase efficiency and provide more power recovery applications. Power recovery, in particular, usually involves severe service conditions with materials being the limiting factor. Gas turbine manufacturers have also begun studies on the effects of using synthetic fuels.

Specification practices for turbo-machinery increasingly emphasize efficiency. Mechanical, instrumentation, electrical and process engineers are being encouraged to work more closely to insure that turbo-machinery is better matched to the process. Specification is a trade off between minimizing energy losses from oversizing and bottlenecks from undersizing.

Electric motor manufacturers continue to improve the efficiency of their designs through better insulation and core materials. Soon almost all manufacturers will offer "high efficiency" designs.

New advanced instrumentation for machinery monitoring and control will be introduced in 1981. Microprocessor-based surge control systems are being developed which enable compressor control closer to surge limits. The number of manufacturers offering electronic variable speed motor drives will increase. These can offer significant savings by minimizing energy loss.



The use of new monitoring equipment is greatly increasing machinery availability. Acoustic monitoring devices can predict pump and motor bearing failures, as well as other possible problems, by analyzing high frequency sounds. Flaw conditions can be detected long before vibration and displacement monitors indicate a problem. Vibration spectrum analyzers will be available with enhanced graphics and computational abilities. Some already provide 3-dimensional readouts to aid vibration analysis and balancing. Continuous lube oil analyzers to detect wear particles in oil are becoming less expensive and more reliable.

STATIONARY EQUIPMENT

Heat exchangers will probably see greater demand than most stationary equipment in 1981. New materials and more efficient designs are increasing the already long list of heat recovery applications. Tax credits for these projects provide additional incentive.

Furnaces and boilers will continue to benefit from new equipment development. New burner designs offering greater efficiency, less pollution and the ability to burn a greater variety of fuels are being introduced. New chemical antifoulants, corrosion inhibitors and dispersing agents will also be used to a greater extent in 1981. Fluidized bed combustion systems will be available from more manufacturers.

New control systems incorporating stack gas analyzers and electronics to perform efficiency calculations will lower fuel requirements, provide printouts for government compliance purposes and distribute heat load to the more efficient boilers and furnaces. In multiple boiler and furnace installations, efficient load sharing can save large amounts of fuel.

MATERIALS

In refinery crude unit vacuum towers, Type 410 stainless steel cladding is commonly used but there was a recent report that cracks occurred in the cladding of one tower. A caution has been issued that Type 410 stainless steel cladding should not be used if inclusions of aluminum or titanium occur in the cladding because this material will suffer 885°F embrittlement.

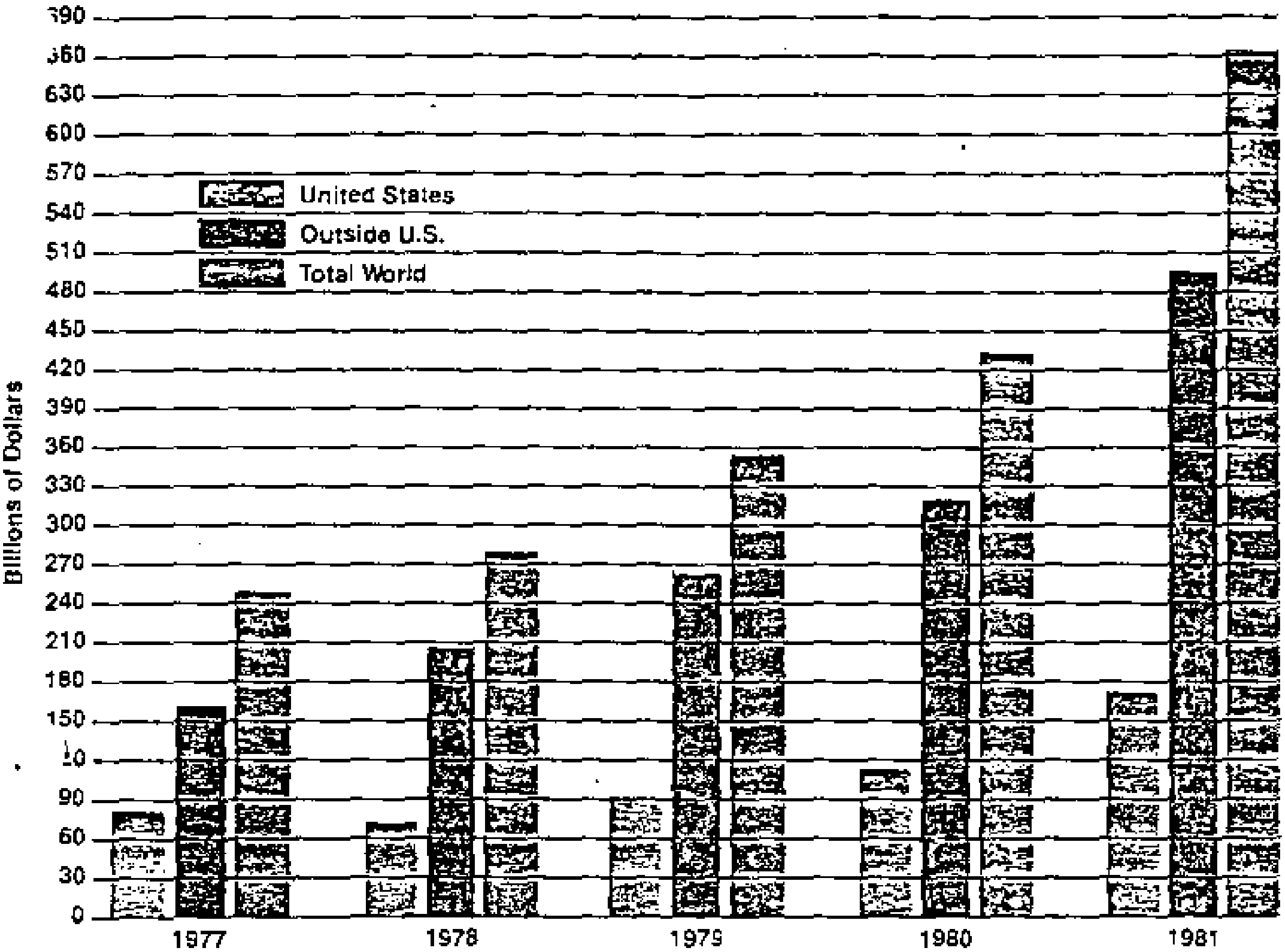
In refinery process vessels where hydrogen blistering is known to occur, such as high pressure separators and intermediate separators with high partial pressures of hydrogen, dual-phase corrosion inhibitors are becoming popular and are successful in controlling hydrogen blistering.

For non-hydrogen service at 1,000°F, most metallurgists today would select IN 625 over Type 321 if there were a choice between the two for a pressure vessel material. Although it has been estimated that IN 625 costs about 30% more than Type 321, the as-fabricated costs should be about the same although delivery may be a problem.

Refinery furnaces are frequently insulated with castable refractories. Today, stainless steel needles are added to castable refractories for strength and erosion resistance. The major failures reported have been caused by poor application rather than material failures. Contractors are being cautioned that a different technique is required for gunned applications of needle-reinforced refractory than is used with standard castable refractories.

With changing process conditions, refiners are concerned that the materials of construction used with the process equipment have a safe remaining life. Sophisticated computer programs are being installed to digest onstream inspection data and calculate the corrosion rate and remaining life. Inspection data are collected using corrosion probes and hydrogen probes. Also, onstream ultrasonic inspection data as well as x-ray are collected and fed to the computer. Previously, all this data was collected and analyzed manually which not only increased manpower but reduced the number of inspection points possible throughout the process units.

TOTAL WORLD HPI OPERATING EXPENDITURES FOR 1977-81



$667,000,000,000 TOTAL WORLD HPI OPERATING EXPENDITURES IN 1981

Sector	U.S.	O.U.S.	Total
Refining	$133,750,000,000	$401,250,000,000	$535,000,000,000
Petrochemicals	$ 34,620,000,000	$ 86,380,000,000	$121,000,000,000
Gas Processing	$ 3,330,000,000	$ 7,670,000,000	$ 11,000,000,000
Totals	$171,700,000,000	$495,300,000,000	$667,000,000,000

ENERGY REQUIREMENTS FOR THE HPI

According to "U.S. Energy Outlook," published by Exxon in December, 1979, the demand for energy in the United States will be 40 million barrels per day of oil equivalent in 1981. Converting this to energy terms, the U.S. will require 77.7 Quads (quadrillion BTU or 10^{15} BTU). The department of energy estimates that 35% of all U.S. energy requirements are consumed by industry and we estimate that 25% of all industrial energy will be required by the HPI in 1981. Exxon estimates that U.S. energy requirements will grow 1.1% per year during the next 10 years. Although the U.S. growth rate in energy demand is lower than any other industrial area of the world, it is also the highest single energy consuming area, currently accounting for 41% of the world's energy demand. Exxon estimates that the U.S. will require only 33% of the total world energy demand by 1990 because of America's relatively slow energy demand growth rate in the '80s.

The HPI will continue its effort to reduce energy consumption by another 15% between 1980 and 1985 which will be in addition to the 20% reduction already achieved over 1972 energy consumption rates. In the last part of this decade, it is quite possible that HPI companies will convert process heaters and power boilers to coal firing instead of oil or gas firing. Oil will then be upgraded into more valuable light materials for transportation and residential-commercial building heating. By that time, coal will be relatively inexpensive as a fuel source for the large energy requirements of the HPI.

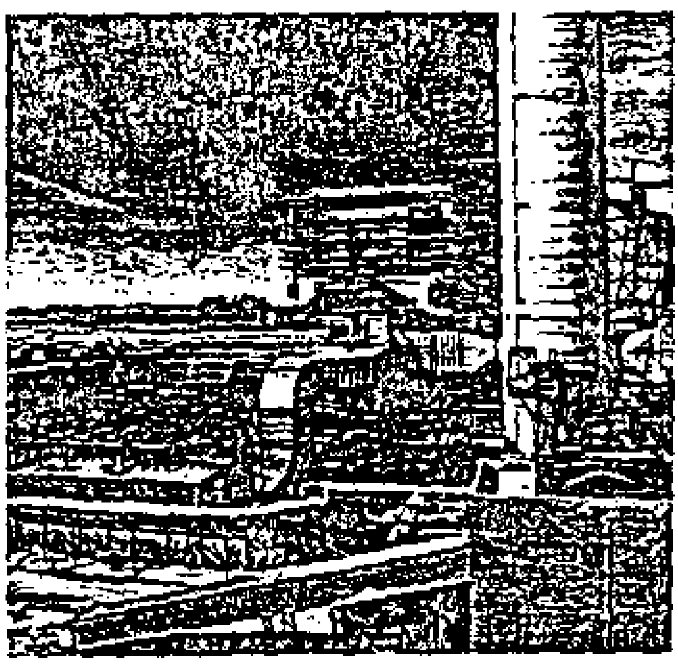
Major efforts will be made by individual process plants to operate in the most economical energy conservation mode. Microprocessors and computers will be used as major tools in reducing total energy consumption within a plant because they aid plant operators in maintaining an optimum energy balance. In addition, we will probably see conversions of electric motor drives to variable frequency control which will allow pumps to operate at optimum speed for better energy efficiency.

Process heaters and boilers will operate very near stoichiometric conditions with much less excess air because microprocessors will constantly monitor the firing conditions in heaters and boilers to prevent the accumulation of explosive mixtures. More installation of air preheaters to reduce fuel consumption can be expected along with other heat recovery in the form of steam from stack gases. Major efforts towards complete sealing of heaters and boilers will be made to prevent air leaks which reduce efficiency. Improved burners will be installed for optimum heat distribution within the furnace and boiler.

ENERGY REQUIREMENTS FOR THE HPI IN THE U.S. QUADS (BTU x 10^{15})

	1981	1986
REFINING		
Purchased Electricity	0.29	0.28
Purchased Fuel	1.51	1.58
Internal Fuel	1.69	1.86
TOTAL	3.5	3.72
PETROCHEMICALS		
Purchased Electricity	0.27	0.28
Purchased Fuel	2.23	2.32
TOTAL	2.5	2.6
GAS PROCESSING—NG/LNG/SNG		
Purchased Electricity	0.008	0.008
Purchased Fuel	0.07	0.067
Internal Fuel	0.67	0.68
TOTAL	0.75	0.76
TOTAL HPI	6.8	7.1
% OF ALL U.S. INDUSTRY ENERGY	25%	23.5%

The table accompanying the description illustrates the various forms of energy required in each of the three segments of the HPI. Energy requirements for the solid fuels processing industry are not included because the industry will be in the demonstration plant stage during 1981 and sufficient data are not available on the actual commercial scale plants proposed. Purchased fuel is the highest energy requirement for petrochemicals and is also high for the refining industry; however, refineries are able to use a considerable amount of internally-generated fuel which is not a saleable product in the fuels market nor useful as a feedstock to petrochemicals.



HPI OPERATING COSTS SURGE AHEAD

The composite price of U.S. crude oil is slowly moving toward the world price and OPEC is likely to raise crude prices in 1981. The change to coal for power generation in the U.S. from natural gas or fuel oil will not be significant in 1981, which will cause electric power costs to increase substantially. OPEC crude price increases will have the same effect on HPI feedstocks, electricity and fuel costs outside the U.S. Worldwide inflation adds to these costs, which simply means that the cost of fuels and petrochemicals will be passed along to the consumer.

Currently, we estimate that worldwide operating costs, exclusive of labor costs and capital depreciation, for the HPI will amount to about $667 billion. In the U.S., data are available to make a more precise estimate and operating costs are shown in Table 1.

Outside the United States, operating costs for the same items total about $401 billion for refineries, $86 billion for petrochemical plants and $8 billion for gas processing plants.

Data on page 29 gives more detailed estimates for 1981 operating expenditures for chemicals and catalysts used in the HPI, particularly as they apply to the United States.

In the U.S., expenditures for chemicals and catalysts will total almost $5 billion in HPI operations. Outside the U.S., spending for chemicals and catalysts should total about $11 billion. A partial listing of U.S. chemical and catalyst expenditures for segments of the HPI is shown in tabular form.

TABLE 1
1981 HPI OPERATING COSTS IN THE UNITED STATES

Item	Refining	Petrochemicals	Gas Processing
Crude Oil & Intermediates	$122,000,000,000	$ 24,000,000,000	$ 1,100,000,000
Electricity & Fuels	9,400,000,000	6,700,000,000	2,000,000,000
Chemicals & Catalysts	1,850,000,000	3,000,000,000	90,000,000
Containers & Packaging	270,000,000	650,000,000	63,000,000
Miscellaneous	230,000,000	270,000,000	77,000,000
Totals	$133,750,000,000	$ 34,620,000,000	$ 3,330,000,000

PETROCHEMICAL FEEDSTOCKS AND INTERMEDIATES

A surprisingly heavy percentage of petrochemical feedstocks and intermediates is available on the open market — *about 45%*. Expenditures for these feedstocks and intermediates total about $24 billion for the U.S.A. and about $53 billion for the rest of the world.

The sale of all these commodities to the HPI follows the same pattern: No HPI buyer has less than 3 sources of supply and usually has 4. Also, about 70-80% of the business for these staples is fairly well apportioned among the suppliers, with little prospect of change in this pattern that exists between the various suppliers. This is primarily because the price of these items depends so much on *transportation costs*.

However, the remaining 20-30% is very competitive and actively fought over by all of the major suppliers. Advancing from No. 4 supplier with 10% of an account's business to No. 1 supplier with 50% of the business can be profitable, indeed! Because price and delivery are important, the purchasing agent has to be sold because he functions as an expediter. On the other hand, technical service, quality and delivery are extremely important to those who will use these items in the manufacture of their fuel, petrochemical and lube products. Any failure to cover these people can be very costly to you.

For your guidance in advertising and selling these commodities to the HPI, a breakdown of these people by job function and buying influence for 8 chemical and raw material classifications is presented on page 39. This chart shows that the Technical Service, Operating and Research Departments are extremely important in the selection of suppliers for these commodities and, we repeat, any failure to cover these people can be very costly to you.

CHEMICAL CONSUMPTION BY U.S. REFINERIES — 1981 ESTIMATE

Items	Millions of Dollars
Additives	
Lead Antiknock	$ 440
Others for Motor Fuels	200
For Lubricant Products	350
For Other Products	100
For Processing, Water Side	70
For Processing, Oil Side	20
Solid Catalysts	
Catalytic Cracking	190
Catalytic Reforming	70
Hydrotreating	70
Hydrocracking	20
Others	
Sulfuric Acid	180
Caustic	60
Miscellaneous	60
Total	$1,850

CHEMICAL CONSUMPTION BY U.S. AND O.U.S. GAS PROCESSING PLANTS — 1981 ESTIMATE

ITEMS	Millions of Dollars U.S.	O.U.S.	Total
Activated Alumina	$20.0	$20.2	$ 40.2
Sodium Hydroxide	16.9	16.6	33.5
Amines	6.5	6.2	12.7
Copper Chloride Sweetening	5.0	5.0	10.0
Glycols	12.5	12.5	25.0
Sieves	4.9	4.6	9.5
Water Treating Chemicals	5.5	5.4	10.9
Other Treating Chemicals	6.8	6.9	13.7
Total	78.1	77.4	155.5
Lead Antiknock Compounds	3.2	3.5	6.7
Mercaptans	1.4	1.4	2.8
Kerosenes	1.3	1.3	2.6
Absorption Oils	2.2	2.5	4.7
Lube Oils	1.6	1.8	3.4
Methanol	2.2	2.3	4.5
Total	11.9	12.8	24.7
Grand Total	$90.0	$90.2	$180.2

PETROCHEMICAL REQUIREMENTS FOR SELECTED CATALYSTS (1981 ESTIMATED)

	U.S.A. MM Lbs	U.S.A. $ MM	Western Europe MM Lbs	Western Europe $ MM	Japan MM Lbs	Japan $ MM
Synthesis Gas Preparation (NH_3, CH_3OH, etc.)						
Pretreatment	1.72	$ 2.1	1.75	$ 2.5	0.56	$ 0.7
Reforming	60.30	17.1	65.00	18.4	18.30	5.0
Shift Conversion	10.10	16.8	10.60	18.0	2.91	2.4
Methanation	0.85	2.5	0.85	6.1	0.23	0.7
Ammonia Synthesis	4.00	5.2	3.30	5.6	0.84	1.4
Methanol Synthesis						
Hi-Pressure	0.06	0.2	0.06	0.2	0.02	0.1
Lo-Pressure	0.13	0.6	0.13	0.6	0.04	0.02
Butadiene	0.21	0.5	—	—	—	—
Styrene	3.70	6.4	3.00	5.2	1.53	2.6
Ethylene Oxide	3.38	27.9	2.33	19.1	0.82	6.8
Acrylonitrile	1.95	13.9	2.87	20.6	1.65	11.8
Vinyl Chloride Monomer	0.57	1.6	0.89	1.1	0.41	1.2
Polyvinyl Chloride	3.79	23.4	5.60	34.6	2.13	13.2
Polystrene	1.85	2.3	2.03	4.8	0.68	1.6
Polyethylene (LD and HD)						
Oxides	0.43	1.3	0.57	1.7	0.18	0.5
Peroxides	6.98	23.2	9.30	30.9	2.95	9.6
Metal Alkyls (Merchant and Captive)	25.20	69.7	33.60	92.9	10.50	28.9
Polypropylene ($TiCl_3$ only)	3.90	21.9	4.10	22.9	2.60	14.7
Total $ MM		**$236.6**		**$285.2**		**$101.22**

HPI ENVIRONMENTAL MANAGEMENT

Worldwide HPI environmental spending will total more than $6.9 billion in 1981, down slightly from $7.1 billion in 1980. A significant change from 1980 is in the category "Land and Other" (Table 1) — up 28% for the U.S. petrochemical industry as it attempts to respond to the demands of legislation — especially the Resource Conservation and Recovery Act (RCRA).

Table 2 shows where the money will be spent, along with additional money going into environmental controls for processing equipment. Cat cracking, for example, will incur costs amounting to about 10% of the total spent. Other areas, and the percentage of their expenditures allocated to environmental, include: stacks (10-70); flare gas recovery (75); flare system (50); new floating roof tanks (20); hydrocracking (10-30); regenerative caustic systems with sulfur recovery (25); sulfuric acid (35); cooling tower (50); sour strippers and/or oxidizers (50).

Among industries, the U.S. HPI ranks first in EM investment, says the U.S. Department of Commerce. Some 106 petrochemical companies reported that by mid-1979 they had spent $3.36 billion — in a 5-year period — on new pollution control facilities. (And they are spending $350 million a year to maintain and operate these facilities). The corollary figure for refiners is $2.96 billion.

As more demanding regulations emerge, the cost of compliance rises exponentially. In the U.S., the expenditures level increased dramatically after 1977 in response to the more stringent requirements of the Clean Air and Clean Water Acts enacted that year. Chemical Manufacturers Association (CMA) estimates that another $3.5 billion will be spent by petrochemical manufacturers between 1980 and 1985. Refiners and natural gas processors will spend about $3 billion in the same period. If proposed new regulations from EPA go unchallenged, this capital cost estimate increases 57%!

The petrochemical industry accounts for 12.5% of *all* U.S. pollution control expenditures. Refining and natural gas segments of the HPI account for about 10%. And each dollar of investment for pollution control adds 23¢ to annual operating and maintenance costs, according to CMA.

For some companies, the percentage of capital expenditures devoted to EM can run higher than 20%. DuPont, for example, estimates that it will spend $1 billion through 1985 for new plant, and that 33% of this money will be for overall environmental regulations. The company installed $17 million worth of emissions controls at a Texas City plant 3 years ago. Now, ozone non-attainment there will cost DuPont an *additional* $27 million.

By mid-1979, U.S. petrochemical companies had invested more than $100 million in solid waste facilities alone. They cost $50 million annually to operate.

Legislation is the impetus for much of the EM activity worldwide. It will cost the U.S. petrochemical industry about $1 billion just to upgrade surface impoundments of landfills under the RCRA, estimates Union Carbide. Meanwhile, in the refining segment of the HPI, it is reported by API that refiners will bear the brunt (75%) of the petroleum industry's overall expenditures.

The HPI will have particularly high spending levels during the next 5 to 10 years as the response to legislation matures, and as numerous expansion/revamp projects get under way. With them will come the need to make these projects environmentally responsive.

TABLE 1
1981 HPI CAPITAL EXPENDITURES FOR ENVIRONMENTAL MANAGEMENT
Millions of Dollars

	AIR	WATER	LAND & OTHER	TOTAL
U.S. Refining & Natural Gas Processing	$ 505	$ 177	$ 15	$ 697
U.S. Petrochemicals	376	302	193	871
TOTAL U.S.	$ 881	$ 479	$208	$1,568
O.U.S. Refining & Natural Gas Processing	$2,525	$ 885	$ 76	$3,486
O.U.S. Petrochemicals	956	542	374	1,872
TOTAL O.U.S.	$3,481	$1,427	$450	$5,358
TOTAL WORLD HPI	$4,362	$1,906	$658	$6,926
% OF TOTAL	61	28	11	100

TABLE 2
MAJOR AREAS OF HPI SPENDING FOR ENVIRONMENTAL MANAGEMENT

AIR

1. Bag filters
2. Closed pressure and relief valves system
3. CO boilers
4. Crude or residual desulfurization
5. Dust suppression systems
6. Electrostatic precipitators
7. Emission and ambient air monitoring
8. Environmental monitoring equipment
9. Fabric filters and baghouses
10. Floating roof tanks (conversion to)
11. Fuel gas desulfurization (amine, etc.)
12. Incineration of waste gases
13. Increased processing for lead reduction
14. Instrumentation
15. Leak detection systems
16. LPG odor control facilities
17. Monitoring equipment
18. Odor control
19. Sampling equipment
20. Smoke control of fired heaters
21. Smokeless flare systems
22. Sour H_2O stripper O.H. recovery facilities
23. Sulfur recovery plants and systems
24. Vapor recovery systems

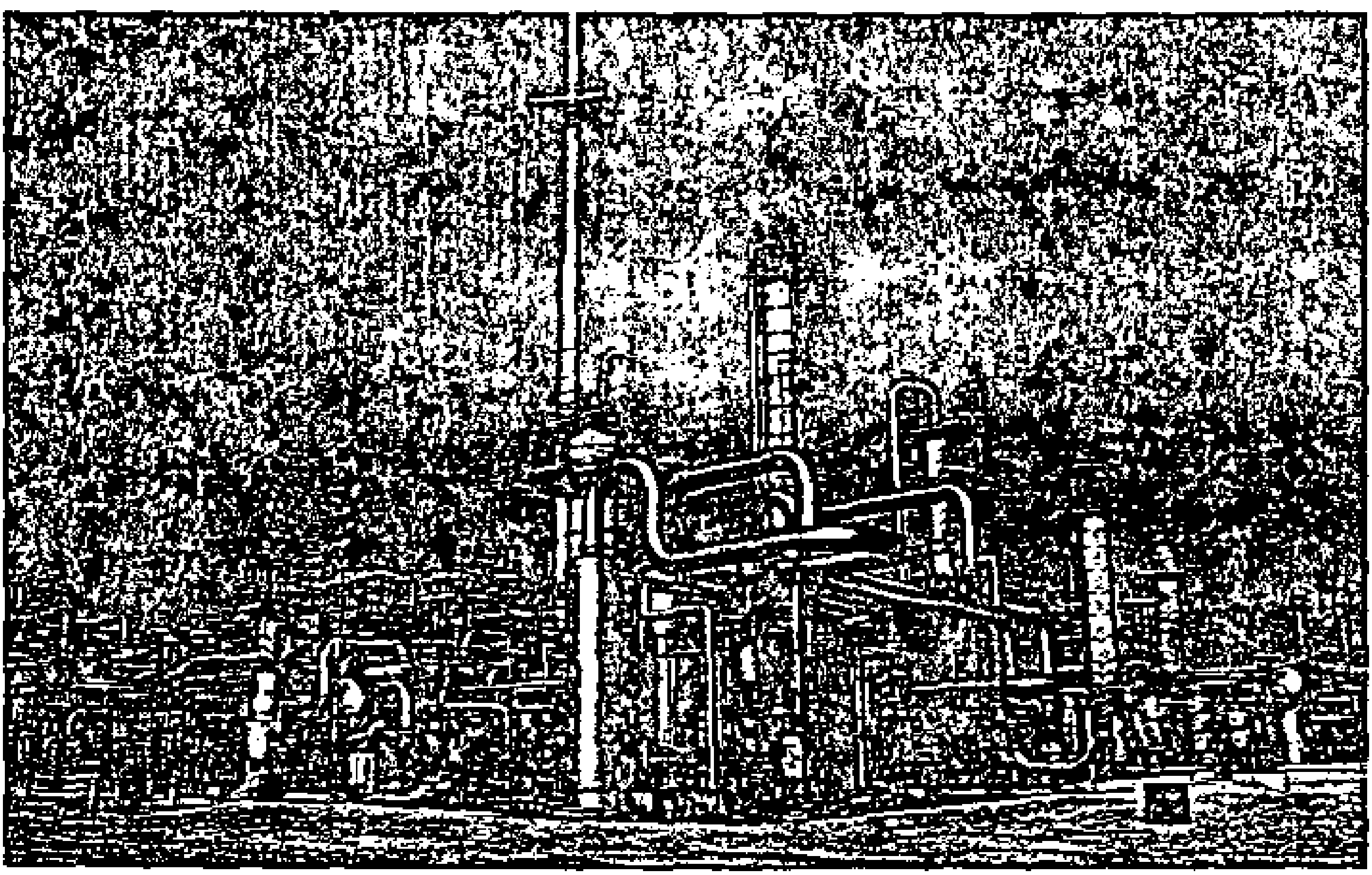
WATER

1. Activated carbon absorption
2. Activated sludge plants
3. Air flotation
4. Ballast and bilge shore treatment facilities
5. Caustic treating (spent)
6. Clarification
7. Collection systems — separate sewer, etc.
8. Deep well disposal
9. Environmental monitoring equipment
10. Flocculators
11. Flotation equipment
12. Mechanical aerators
13. Monitors
14. Oil recovery and handling systems
15. Oily waste treatment
16. Oxidation ponds and mechanical aerators
17. Sampling equipment
18. Sanitary sewerage systems
19. Sludge dewatering equipment
20. Sludge farming
21. Sludge incinerators
22. Spent caustic treating systems
23. Spill booms and other spill cleanup equipment
24. Tank bottom disposal and treatment facilities
25. Trickling filter plants

LAND AND OTHER

1. Baffles (noise reduction)
2. Environmental monitoring and sampling equipment
3. Equipment noise insulation
4. Fire walls or tank dikes
5. Incinerators
6. Insulation
7. Land restoration, revegetation, etc.
8. Landscaping
9. Mufflers
10. Noise instrumentation
11. Noise protective equipment (personal)
12. Sanitary land fills
13. Screening or buffering
14. Solid waste hauling and disposal equipment

NOTE: Many other HPI areas have allocated 10%-75% of their capital spending to EM (see text).



VIII.-D-1-2

[illegible] PROTECTION/ SAFETY AND JOB TRAINING TRENDS

FIRE PROTECTION

Massive capital expenditures on HPI fire protection are expected for 1981 — about $1.15 billion in the U.S. alone, and another $6 billion elsewhere. The driving force for this capital outlay is the soaring cost of HPI losses. It takes almost twice the number of dollars in 1981 as it did in 1974 to replace, for example, a burned-out processing unit. So concludes Industrial Risk Insurers, major insurer of HPI facilities. IRI also reports that 85c of each premium dollar now goes to pay off losses.

Another influence on 1981 fire protection expenditures is the expected surge in refinery modifications [illegible] to process the growing quantity of heavy, sour crude oils. In the petrochemical sector, a number of new plants will be under construction — large ones that will call for management to go the "extra mile" on fire protection.

With these developments will come the need for modern fireproofing insulation and cladding, valves, control instrumentation, deluge systems and explosion-proof electrical gear.

Roughly half of the fire protection capital investment will be for vapor detection equipment, arrestors, extinguishing agents, sensors, pipe racks and sprinklers, foam delivery equipment, all types of fail-safe controls and operating equipment, fire trucks, hoses and nozzles.

Systems to protect storage facilities will be the subject of special attention, as the value of feedstock and product rises exponentially. Of particular interest, in this area, are new systems developed for inert gas blanketing of tanks and sub-surface foam injection.

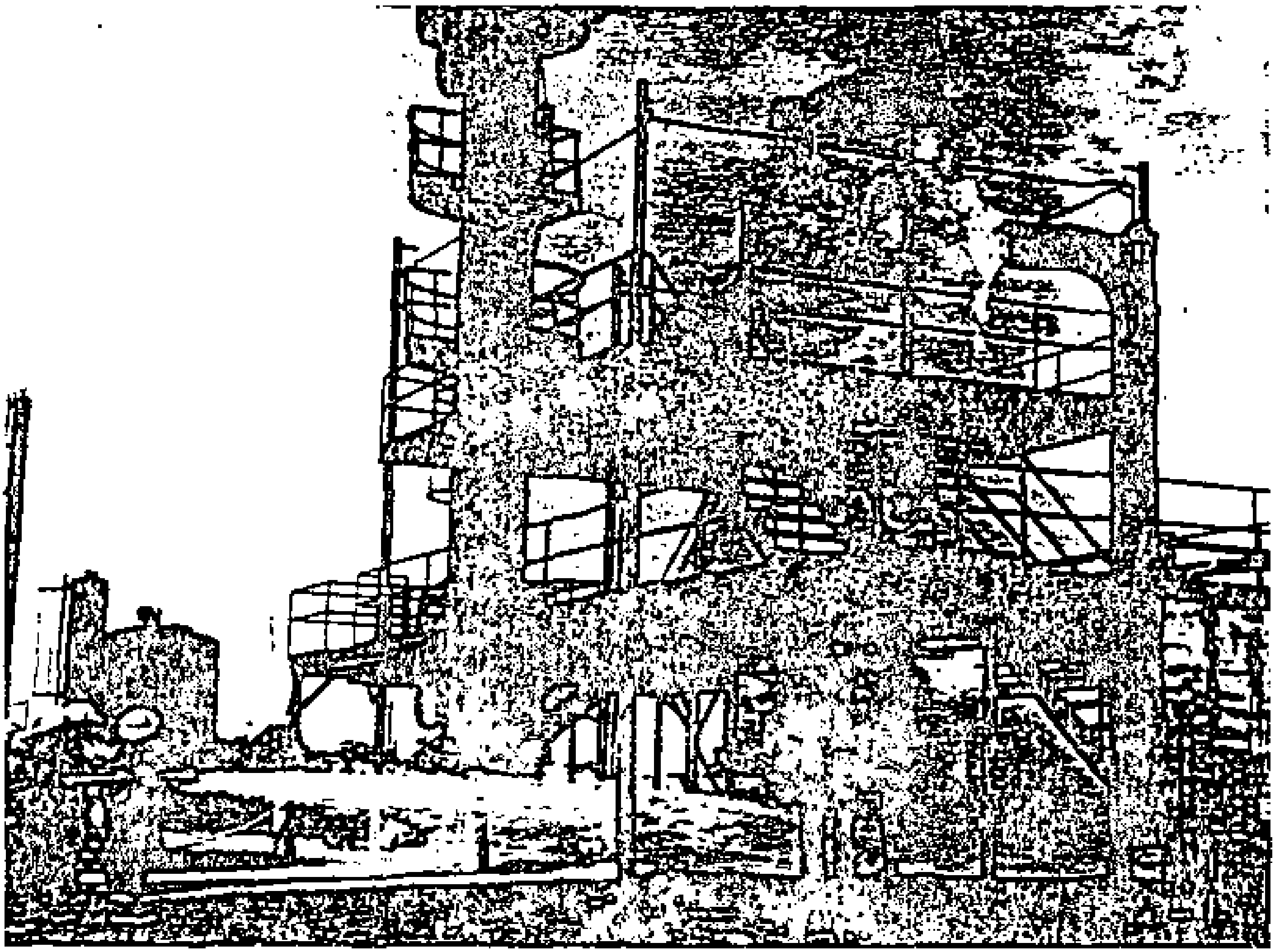
Additional loss-prevention dollars will go for replacement packing, gaskets, fittings and other sensitive equipment that has a history of causing fires, explosions and detonations when it fails.

A more complete listing of HPI fire protection and fire fighting materials, equipment and services is given in Table 1.

TABLE I

HPI FIRE PROTECTION/FIRE FIGHTING MATERIALS, EQUIPMENT AND SERVICES

Alarms	Extinguishing systems	Hydrants	Resuscitation trainer
Arrestors	Face masks, protective	Indicators	Resuscitators
Barricades	Fire door closing devices	Inhalators	Rope
Books, manuals	Fire doors	Instructional materials	Scaffolding
Boots, rubber	Fire doors, fusible links	Instrumentation	Schools, fire
Breathing apparatus	Fire exit hardware	Insulation	Signs, fire security
Brooms, fire fighting	Fire-explosion hazard evaluation service	Ladder accessories	Simulators, training
Chemicals for fire extinguishing	Fire trucks	Ladders	Sirens, signals (see alarms)
Closed circuit TV	First aid materials	Masks, protective	Sprinkler heads, valves
Clothing	Fittings	Megaphones	Sprinkler systems
Coatings	Flame retardant building materials	Monitors	Static control fabric
Compressor, air, portable	Flame retardants	Nozzles	Static electric detector
Controls	Foam	Piping	Static electric eliminator
Covers, self-closing	Generators	Powders, dry chemical	Static electric grounders
Deluge systems	Ground fault circuit interrupter	Public address systems	Training aids
Detectors	Grounding devices	Pumps	Trucks
Dry chemical extinguishers	Headwear	Purification equipment, air	Vacuum, wet pickup
Electrical equipment, explosion-proof	Hose	Radio, two-way	Valves
Extinguishing agents		Rescue equipment	Vehicles
		Respirator accessories	Ventilating devices
		Respirators	Water delivery system



SAFETY AND HEALTH

Personnel safety and health will be the target of $800 million in U.S. capital expenditures. The focus on health continues, as OSHA intensifies emphasis in that area. Health has dominated the agency's concerns since about 1976. Added pressure stems from the Toxic Substance Control Act. The result will be a "boom" year for marketing of analyzers, detectors, sensors, respiratory equipment of all kinds, protective clothing, first aid and rescue equipment, toxicology and hygiene literature, and health-oriented training programs.

Expenditures in 1981 for personnel safety and health will be much larger outside the United States.

TRENDS IN HPI JOB TRAINING

Training activities will extend far beyond the health-care type mentioned above. In the U.S., HPI companies will invest about $30,000 to train each new operator in 1981. Similar outlays can be anticipated for entry level craftsmen and technical professionals.

How will this training be designed and administered? As in recent years, lecturing will be deemphasized in favor of multi-media, interactive systems in which trainees test their skills and knowledge throughout the program. Much of the instruction will be self-administered and self-paced as more programed instruction materials come on line.

Supplementing custom-tailored training modules will be many from "off the shelf," delivered in a variety of forms — from filmstrips and slides to color videotape.

Workbooks, texts and related literature will be in great demand, especially if written for novices and if readily translatable into other languages. This is to facilitate the growing market in technology transfer through training.

The year 1981 will see a record expenditure for training materials, consultation, equipment and services. As in the past, operator training — especially — will be individualized for each plant. This lack of uniformity leaves the door open for a host of opportunities for training-material script and manual writers, consulting firms, publishers and audio visual companies.

There is also a growing market for high quality seminars and short courses that can meet the continuing education needs of technical professionals, and for the "how to cope" aspect of compliance with health/safety/environmental laws.

Prepared by HYDROCARBON PROCESSING

ENGINEER-CONSTRUCTORS

Inquiry received & approved → **PROPOSAL** (1 to 8 Months) → Contract award → (1 to 2 Weeks) → Start of engrg.; early process data release → **PROCESS DESIGN & JOB COORDINATION** (1½ to 2 Months) → Process release

	PROPOSAL (1 to 8 Months)	PROCESS DESIGN & JOB COORDINATION (1½ to 2 Months)
SALES	Prepare proposal requirements & commercial bid package; review with senior mgt., issue bid & technical proposal for client review, discussion, negotiation.	
PROJECT MANAGEMENT	[illegible]	
	[illegible]	[illegible]
FINANCE	Establish manhour rates, payment schedules; develop financing program if required by client.	
INFORMATION SYSTEMS	Provide services as required to fulfill proposal needs.	Computer use for process analysis & design.
ESTIMATING & COST ENGINEERING	Prepare proposal estimate.	Prepare & issue initial approved cost estimate or initial control estimate.
PROJECT SCHEDULING	Schedule proposal effort; prepare proposal schedule.	Issue starter schedule (first 30 days).
[illegible]CESS [illegible]EERING	Assist in defining proposal by reviewing client inquiry & process requirements.	Complete process design; early release of process data to engrg. for critical items.
PROJECT ENGINEERING	Develop engrg. manhour requirements for project; provide team leadership for engrg. proposal effort.	Prepare engrg. plan; coordinate all technical effort (process & engrg.).
PROJECT SYSTEMS	Provide services & information as required to fulfill proposal needs.	Issue data sheets & requisitions on long delivery items to procurement.
CIVIL-MECHANICAL	Provide services & information as required to fulfill proposal needs.	Issue data sheets & requisitions on long delivery items to procurement.
DESIGN	Provide services & information as required to fulfill proposal needs	
PROCUREMENT	Provide delivery lead times for scheduling.	Prepare procurement plan; begin quote cycle for critical items.
[illegible]TRUCTION	Provide activity duration times for scheduling	Develop detailed construction philosophy.
OPERATING & TECHNICAL SERVICES	Provide services & information as required to fulfill proposal needs.	Review process design; comment on operating/startup requirements.

PROJECT MANAGER ORGANIZES AND STAFFS PROJECT TEAM

(Project Manager, Project Cost Engineer, Project Schedule Engineer, Project Process Engineer, Project Engineering Manager, Project Procurement Manager, Project Construction Manager, Resident Construction Manager, Chief Operator)

PROVIDE TOTAL SERVICE

4 to 6 Months ANALYTICAL & PLANNING ENGINEERING → Planning release → 8 to 10 Months FINAL ENGINEERING & PROCUREMENT → Start of construction → 12 to 18 Months FIELD ERECTION → Ready for commissioning → 1 to 2 Months START-UP → Client acceptanc

4 to 6 Months ANALYTICAL & PLANNING ENGINEERING	8 to 10 Months FINAL ENGINEERING & PROCUREMENT	12 to 18 Months FIELD ERECTION	1 to 2 Months START-UP
Maintain constant check on client relations.			
[illegible]			
[illegible]			
Prepare cost reports & bills to client; pay vendors and/or subcontractors.			Issue final cost report.
Prepare computer programs for detailed designs. Generate manpower printouts; CPM schedule, material status reports.			
Initiate monthly cost control reports.	Prepare planning check estimate.	Prepare production check estimate.	
Periodically issue detailed engrg. schedule, materials status reports & up-datings of overall project schedule.			
...lt with engrg. analytical groups.	Assist in preparing test run procedures.		Provide consultation & advice during start-up; direct performance test run.
Provide overall engrg. direction, coordination & assistance.		Resolve field questions & trouble reports.	
Issue balance of data sheets & requisitions to procurement, P&I diagram #1 to planning & client; check vendors certified drawings; issue P&I diagram #2 for design.	Issue P&I diagram #3 to design for checking.		Provide consultation & advice during start-up
Prepare drawings & data sheets for balance of equipment; make preliminary bulk material takeoff.	Finalize design; check vendor drawings; prepare material take-off; issue requisitions.		
Prepare plot plan; complete underground planning; build plot plan model & complete design model.	Complete & issue piping, instrument & electrical drawings; issue final requisitions.		
Obtain quotes; make equipment purchasing commitments; expedite vendors for certified drawings.	Preliminary purchase of bulk materials; issue delivery date predictions based on delivery cycle inspection & expediting shipment activities.	Make final bulk material purchasing commitments.	
Dev... preferred material delivery sequence & ... for scheduling; prepare preliminary ri... studies.	Prepare tool & equipment list; develop temporary activity layout; complete rigging studies; refine input for scheduling; obtain equipment; install temporary buildings; hold pre-job labor conference.	Set up field management, budget & cost control; subcontract administration, mechanical erection, insulation, testing & pre-commissioning.	Assist in commissioning as required.
Develop operating philosophy; review P&I project control diagrams; start preparation of operation instructions manual...	Prepare test run & lab test procedures; prepare operator training program; establish chemical cleaning procedures...	Assist in pre-commissioning; prepare lubrication manuals & start-up schedule; conduct operator classroom training...	Give on-the-job training; direct start-up activities; ...

to discuss this subject, and I feed very unqualified to hardly describe this phase, we must assume that step two has been accomplished, to some more or less degree of success.

Steps one and two cannot usually be accomplished without outside aid. However, every area of the world--no matter how remote--has its entrepreneurs. These may range from the small boy selling water from his sholder bag all the way up to the Royal Shiek. These people are gamblers, but they are willing to take risks. And above all they know their market and they know their customers and they can contribute to these developments.

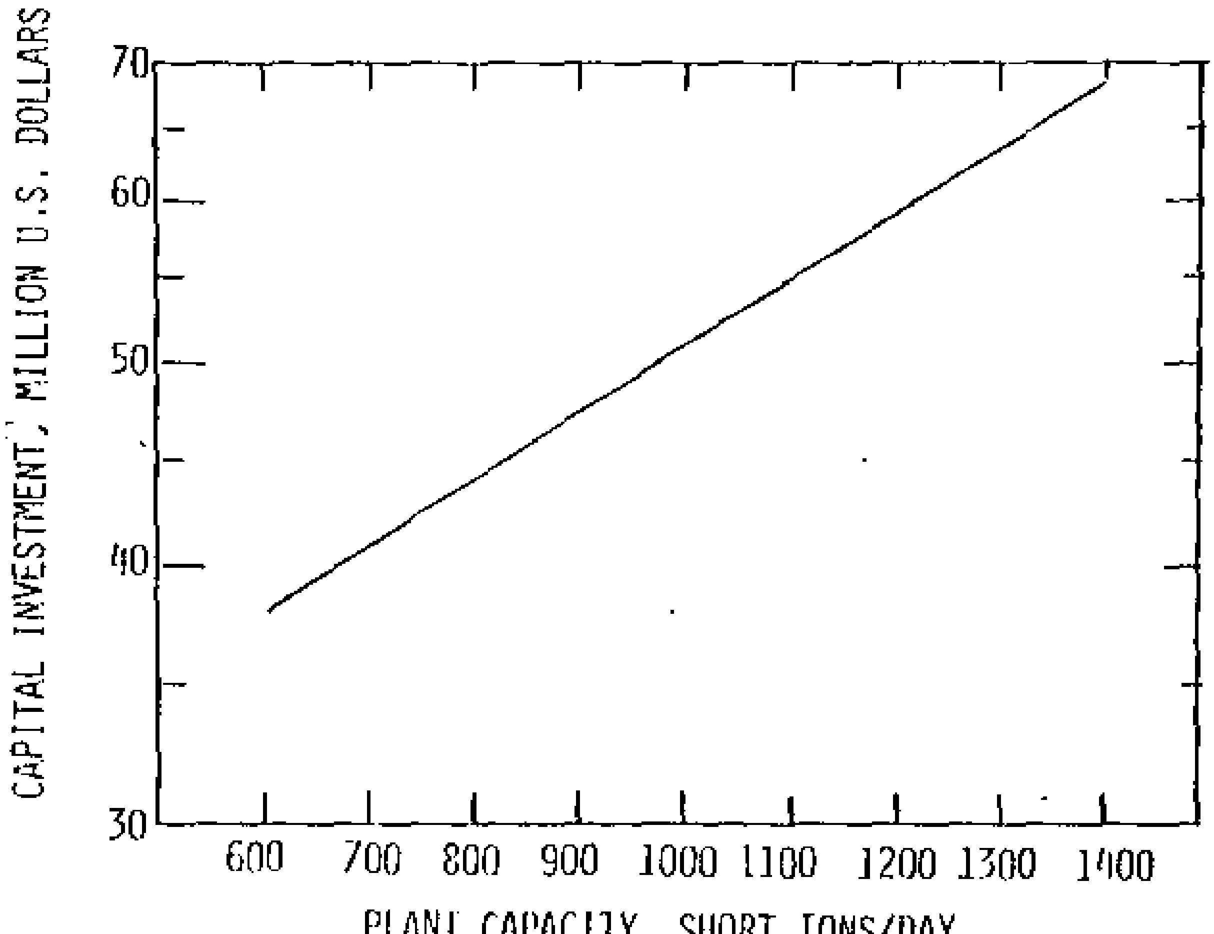
In speaking before the Society of Chemical Industry in The Hague this past October (22 OCT 1979) on the subject of "A Positive Attitude to New Producers," Mr. W. C. Thomson, Director Shell International Chemical Company concluded with these remarks:

"European chemical companies have not been renowned for failing to seek out opportunities for profitable ventures. With the balance of advantage on costs of production for some chemicals shifting towards new areas, I would expect to see an increasing number of European companies taking positive steps to associate themselves with new producers in their venture."

"That we have the skills to do so, there can be no question. That we have the enterprise, I have but little doubt.But is is fundamental that we should seek to obtain a fair reward for making these available to the rest of the world."

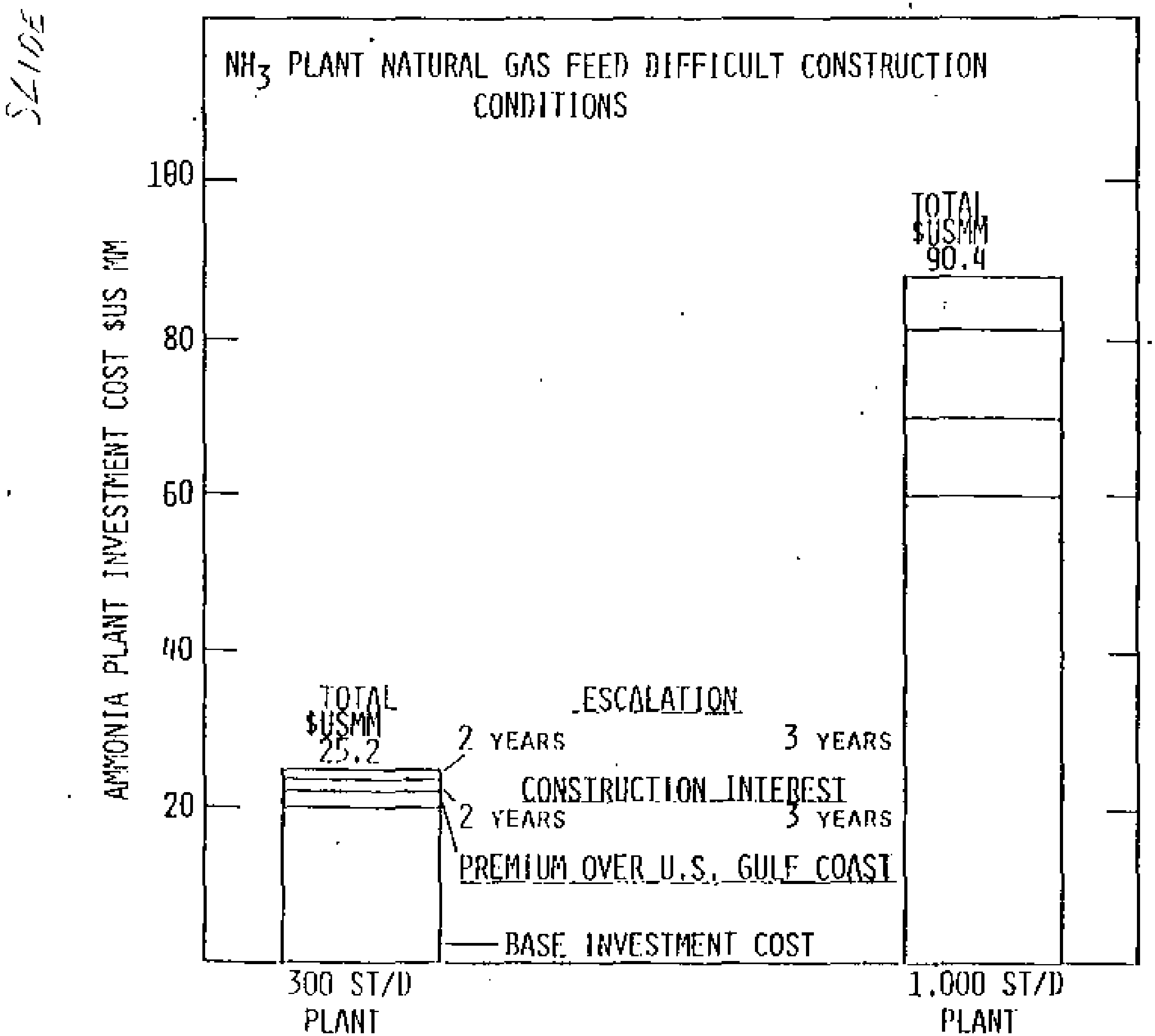
Mr. Thomson had mentioned earlier, "The notion of making room for new producers in the markets of Europe is completely alien to the tradition of ferocious competition in the chemical industry . . . New entrants must expect therefore to be treated exactly as other competitors in the industry."

Mr. Thomson also presented two interesting illustrations which bear directly upon the problems of industrialization which we have reproduced here as Plot No. I-5 and Plot I-6. In Plot No. I-5, European costs have been indexed to 100 for 1979 for comparison. The difference in the 1979 projections and the 1974 projections reflect the doubling in the price of naphtha for Europe and the increase in the Arabian Gulf location factor from 1.2 times Europe to 1.67 times. Freight costs have been assumed as the same with an increase in duty of about 40 %.Notice that with these increases and holding the cost of energy constant in the Arabian Gulf that production costs have shifted to favor the developing areas except for vinyl chloride monomer.



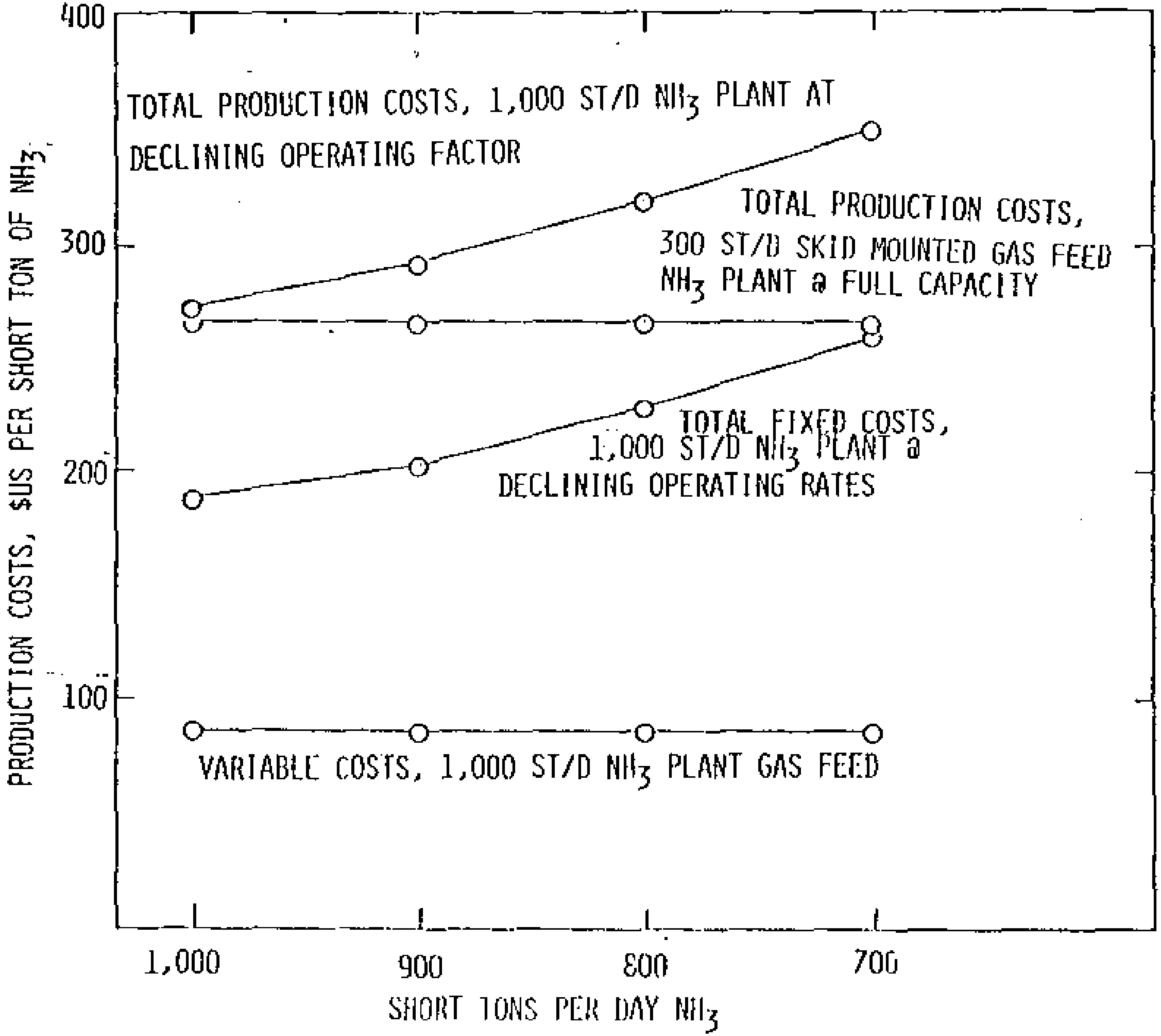
BASIS: 1978 INSTALLED COSTS, U.S. GULF COAST,
NATURAL GAS FEED, ALL CENTRIFUGAL COMPRESSOR,
MOST MODERN PLANT

Plot No. I-1



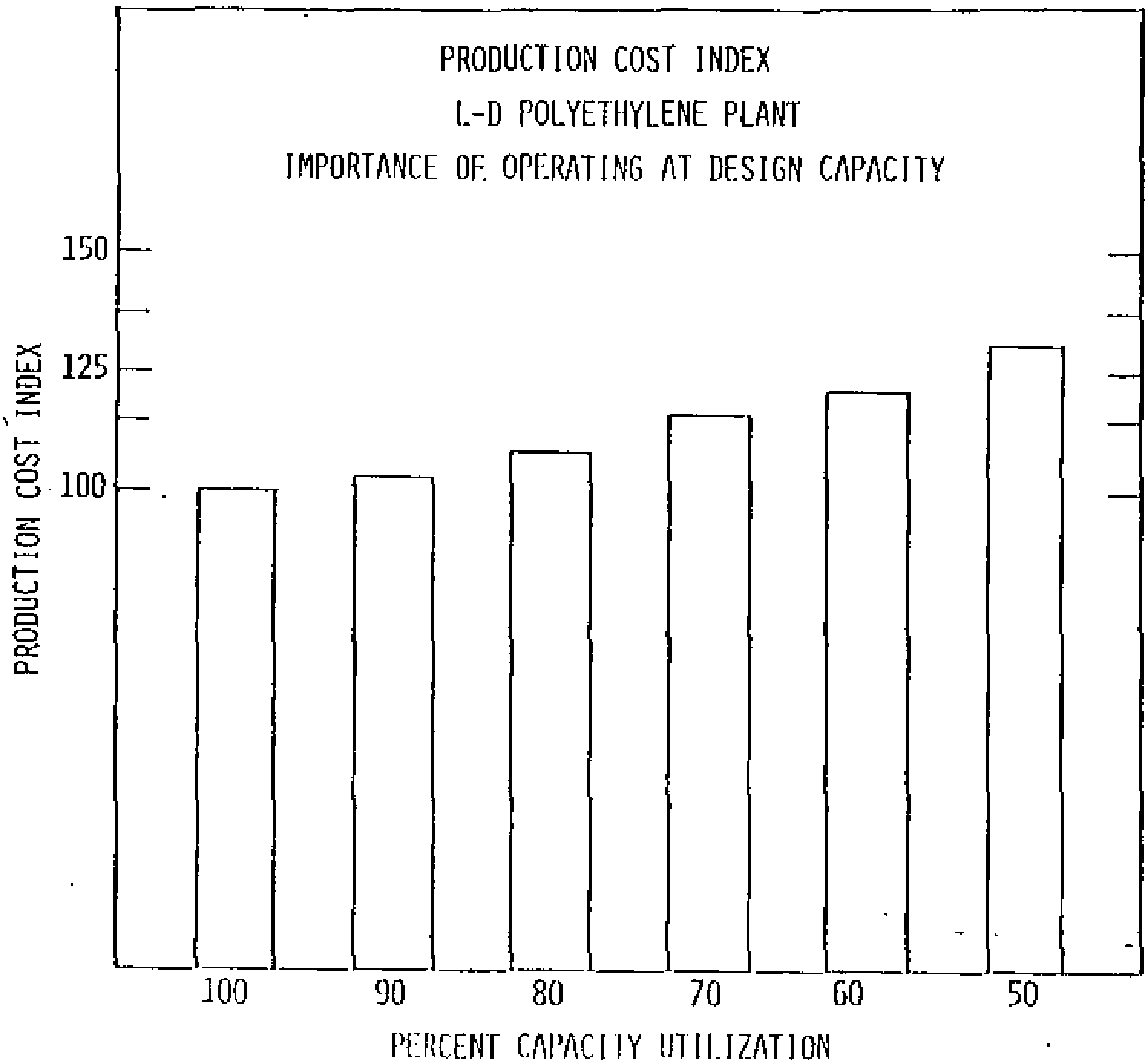
SLIDE
NH3 PLANT NATURAL GAS FEED DIFFICULT CONSTRUCTION CONDITIONS
AMMONIA PLANT INVESTMENT COST $US MM
100
80
60
40
20
TOTAL $USMM 25.2
TOTAL $USMM 90.4
ESCALATION
2 YEARS
3 YEARS
CONSTRUCTION INTEREST
2 YEARS
3 YEARS
PREMIUM OVER U.S. GULF COAST
BASE INVESTMENT COST
300 ST/D PLANT
1,000 ST/D PLANT

Plot No. I-2



TOTAL PRODUCTION COSTS, 1,000 ST/D NH3 PLANT AT DECLINING OPERATING FACTOR
TOTAL PRODUCTION COSTS, 300 ST/D SKID MOUNTED GAS FEED NH3 PLANT @ FULL CAPACITY
TOTAL FIXED COSTS, 1,000 ST/D NH3 PLANT @ DECLINING OPERATING RATES
VARIABLE COSTS, 1,000 ST/D NH3 PLANT GAS FEED
400
300
200
100
PRODUCTION COSTS, $US PER SHORT TON OF NH3
1,000
900
800
700
SHORT TONS PER DAY NH3

Plot No. I-3

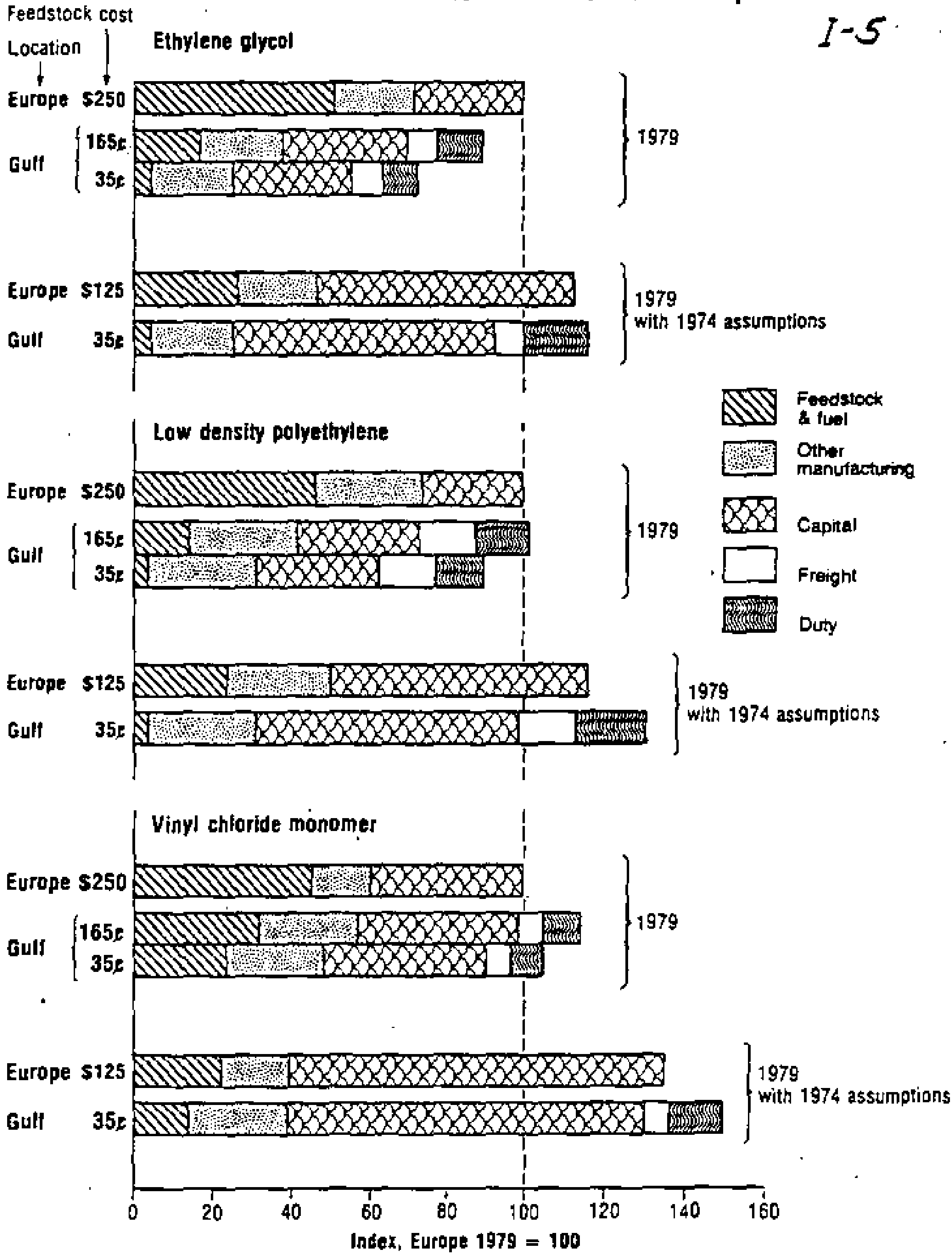


PRODUCTION COST INDEX
L-D POLYETHYLENE PLANT
IMPORTANCE OF OPERATING AT DESIGN CAPACITY
PRODUCTION COST INDEX
150
125
100
100
90
80
70
60
50
PERCENT CAPACITY UTILIZATION

Plot No. I-4

Comparative costs of chemical production in the Middle East and Europe

I-5



Ref: W. C. Thomson, Shell International Chemical Co., 22 Oct 1979

Principal assumptions for 1979

Feedstock/fuel

Naphtha in Europe at $250/tonne.
Ethane in Gulf states at 35¢ or 165¢ per million Btu.

Capital

Location factor for process plant (alone) erected in Gulf equals 1.35 times Europe.
Extra infrastructure costs in Gulf raise the overall location factor to 1.67 times Europe.
Loan finance (100%) in both Europe and Gulf states.

Manpower cost

Cost per operator man-year in Gulf states equals two-thirds cost in Europe.

Plant loading

Long run plant loading equals 80% in both locations.

Different assumptions as were applied in 1974

Feedstock/fuel

Naphtha in Europe at $125/tonne.
Ethane in Gulf states at 35¢ per million Btu.

Capital

Location factor in Gulf equals 1.2 times Europe.
Financing by 100% equity, with real return on capital, in both Europe and Gulf states.

Manpower cost

Cost per operator man-year in Gulf states equal to that in Europe.

Ref: W. C. Thomson, Shell International Chemical Co., 22 Oct 1979

Planning an industrial complex

When beginning the study of any industrialization on a significant scale in a developing or emerging country, the first assumption must be that there exists a Central Planned Economy led by the Government in power.

It must be fully understood that this basic assumption carries no endorsements or condemnations for Central Planned Economies. This is simply a statement of fact. We find that because of the many complex socio-economic and politico-economic circumstances which exist, it is required that central planning exist and function for any industrialization--on a significant scale--to come into being.

Out purpose here will not be to discuss the development or organization of the planning agencies or as they are often known--The Ministrys. It is a simple fact of life that they do and must exist and that their functioning is the initial step towards industrialization within developing and/or emerging countries.

Therefore, we will refer simply to The Ministry and emphasis the important initial and continuing role they must play as we proceed from project evaluation to conception to commissioning and finally to obsolensecence.

We will illustrate the importance and application of all facets of Cost Engineering as we proceed very rapidly through the vast and complex exercise of conception to obsolescence.

The Ministry and the Contractor

This first Plot No. II-1 highlites the importance of this relationship. It overlooks the details and complexities we shall discuss latter.

Planning an industrial complex

- Requires close cooperation between The Ministry and the Contractor
- Starts with a 5-year plan (or similar government goal)
- The Ministry develops the Master Plan using planning studies by Contractors (and others) as inputs

The Planning Study usually includes these basic tasks (See Plot No. II-2):

- Market study (domestic and export)
- Feedstock availability study
- Site survey
- Definition of possible feedstock/product combinations
- Techno-economic comparison of selected combinations
- Selection of optimum combinations
- Detailed analysis and specifications for selected systems

MORE

o Feasibility Report

Next we must consider another important part in this exercise, and this is--

o The Makeup of the Study Team

This is the most important. The best and most qualified individuals from both The Ministry and The Contractor must be directly involved. They must develop mutual respect and trust so that all transactions will be completely and clearly understood by all concerned. The Leadership in this Study Team is often a deciding factor upon the success of the Industrial Complex which is the Goal. Often personal traits can become as important as technical qualifications. At this stage in planning there will be much compromise and perhaps modifications of methods and means toward achieving the goals established by The Ministry. The people involved must be flexible and trustful of each other.

Now let us look somewhat more in detail at some of the different components or groups which comprise this Study Team and what they must accomplish toward the completion of the Industrial Complex.

On Plot No. II-3 we show some of the activities of the Market Study Sub-Team.

- Master Plan defines goals/possible products
- Analysis of domestic demand
- Effect of proposed Complex on pricing and the domestic economy
- Projections for future domestic demand
- Analysis of regional demand
- Projections of possible export market
- Projections of total market potential for proposed industrial complex

You can readily see the importance of the overall Master Plan--it actually establishes the ultimate goals each of the sub-teams must attain.

Also, The Ministry plays an important role in performing the domestic demand analysis. Often, other agancies or Ministries must supply 'per capita' and population distribution data so essential to a market study.

The econometric model established for internal pricing must be obtained directly from The Central Planning Ministry.

The Social Ministry can often supply important inputs regarding the acceptance of the new domestic products. This can provide insight into possible future growth in domestic demand.

The External Affairs Ministry will certainly be helpful to the study team in analyzing regional demand. Often, near-by markets can go negelected if there is incomplete effort applied in studying regional demands.

Export markets are rather special and usually a team will call in outside Consultants whose resources can help in the analysis of possible exports.

Once all of these efforts are completed, then the analysis should indicate the total market potential for the proposed Industrial Complex.

The next sub-team is referred to as the Raw Material Study Team.

- Feedstock availability study
- Pricing analysis
- Process comparison of plants based on alternate feedstocks
- Transportation analysis

In an emerging/developing country with vast domestic availability of hydrocarbons, the desired feedstock for the Industrial Complex may not necessarily be available. This may call for additional processing or another type of complex to supply the desired feedstock.

Establishing transfer prices, even in a completely industrialized country, is often difficult at best. We have observed how suddenly a natural resource with absolutely no value--flare gas, for example--suddenly became a valuable and highly priced commodity when an internal need no demand developed. Any viable Complex must establish realistic prices for its raw material or feedstocks. You just can't fool Mother Nature. We do not necessarily pretend 'world prices' but real cost prices in order to prevent problems developing latter.

Any feedstock or raw material study will surely discover alternate feedstocks. These should be compared with those originally intended and a careful process analysis performed. If any changes are contemplated, now is the best time to consider them and not after the Complex is completed.

The feedstocks may not be located at the optimum Complex site. Or, the transportation resources to move the products to the consumer may not be near either the feedstock source or the resired marketing areas. Therefore, transportation resources for both must be carefully studied by this sub-team.

Site surveys might appear to be a very simple task. However, there should be a very systematic approach to site selection. On this Plot No. II-5 we show a very abbreviated version of such a system.

- Site surveys
- Check list

MORE

- Site comparisons
- Transportation/Shipping

This sub-team must actually visit each proposed Complex site. The Check List must be applied equally to all proposed sites. This subject of Site Selection is very complex and could very well be the subject for a full weeks intensive study. Time does not permit a discussion of the Check Lists. However, these are available from many sources in the published literature.

This sub-team must then sit down and compare each site--its advantages and disadvantages. They must then select the optimum site for the Industrial Complex.

When considering the Transportation/Shipping aspect of any proposed site, this team must consider getting the original equipment and materials with which to construct the Industrial Complex to that location. They must consider the infrastructure needs during construction and latter the operation of the Complex. Also, the products must be moved out continuously to the consumer. And feedstock must be moved into the Complex.

Environmental control for each site will vary considerably and these must also be taken into consideration.

Let us assume the Study Teams have all been doing their job well and their reports are in hand. The Ministry must now make some difficult decisions. They have before them the reports and findings of several study teams. When all these data are compared with the Master Plan, we come to the next cross roads as shown in Plot No. II-6.

<u>Selection of possible feedstock/product combinations</u>

- Minimum economic size for alternate flow scheme
- Feedstock availability/pricing
- Projected size of market

Now that The Ministry knows what feedstocks are available and their likely availability and price along with some idea of the projected market--some important decisions can be made. Along with the Contractor, they can study feedstock/product combinations. The physical data for each site also enters into this process. And when and how shall all this product be marketed. This is indeed an important phase in Complex Planning.

Even tentative agreements reached at this stage will have direct implications throughout the remainder of the study. It is here that the Contractor and the other Consultants working closely with the team from The Ministry can make an important input.

The Contractors expertise can be quickly brought to play when studying alternate flow schemes. He can introduce the many other variables into the equation and advise The Ministry of the available options.

The next important step must now be faced head-on. And this is outlined on Plot II-6.

- Block flow diagrams/material and energy balances
- Analysis of available technology
- Utility and offsite requirements
- Investment cost estimates
- Operating cost estimates
- Economic comparisons
- Sensitivity analysis (feedstock/product price, production level, and total investment)

A well qualified Contractor can make these comparisons rather quickly for The Ministry. At this stage in the planning, until the scope is firmly established for the Industrial Complex, estimates are usually made on an order of magnitude basis or at best plus or minus 15-20 %. This permits The Ministry to make rapid decisions. Of course, the basis for all the estimates and comparisons must be understood by all parties concerned. From these will come the guidelines for the final analysis which is discussed latter.

This tudy team from The Ministry along with the Contractor and other Consultants are now at the point where firm committments must be made. This is really the selection step as shown in Plot No. II-7.

Fianl selections

- Selection of optimum FEEDSTOCK
- Selection of optimum PRODUCT
- Selection of optimum SITE
- Selection of optimum PRODUCTION RATE
- Selection of optimum PROCESS CONFIGURATION COMBINATIONS

All of the data collected and analyzed along with trying to conform as closely as possible with The Ministrys overall plan are used in these final selections.

When agreement has been reached on these selections then detailed analysis and a complete set of specifications for the selected system is prepared.

Plot No. II-8 shows the final culmination of this planning effort.

Feasibility report

- Provides basis for international financing
- Provides basis for proceeding immediately into the bidding stage of the project

MORE

At this time The Ministry is ready to call upon the finance agencies. He can present them the package from the Planning Study and seek aid in constructing the Complex.

At the same time, The Ministry can use these same documents to open the Complex for tenures from qualified engineering and construction firms.

PLOT NO. II-1

PLANNING AN INDUSTRIAL COMPLEX

- REQUIRES CLOSE COOPERATION BETWEEN MINISTRY AND CONTRACTOR
- STARTS WITH 5-YEAR PLANT (OR SIMILAR GOVERNMENT GOAL)
- MINISTRY DEVELOPS MASTER PLAN USING PLANNING STUDIES BY CONTRACTORS (AND OTHERS) AS INPUT

PLOT NO. II-2

PLANNING STUDY INCLUDES BASIC TASKS

- MARKET STUDY (DOMESTIC AND EXPORT)
- FEEDSTOCK AVAILABILITY STUDY
- SITE SURVEYS
- DEFINITION OF POSSIBLE FEEDSTOCK/PRODUCT COMBINATIONS
- TECHNO-ECONOMIC COMPARISON OF SLECTED COMBINATIONS
- SELECTION OF OPTIMUM COMBINATION
- DETAILED ANALYSIS AND SPECIFICATIONS FOR SELECTED SYSTEM
- FEASIBILITY REPORT

Plot No. II-3

MARKET STUDY DETAILS

- Master Plan defines goals/possible products
- Analysis of domestic demant
- Effect of proposed complex on pricing and domestic economy
- Projections for future domestic demand
- Analysis of regional demand
- Projection of possible export market
- Projection of total market potential for proposed industrial complex

PLOT NO. II-4

RAW MATERIAL STUDY

- FEEDSTOCK AVAILABILITY STUDY
- PRICING ANALYSIS
- PROCESS COMPARISON OF PLANTS BASED ON ALTERNATE FEEDSTOCKS

Plot No. II-5

SITE SELECTION

- Site surveys
- Check list
- Site comparisons
- Transportation/Shipping

PLOT NO. II-5A

SELECTION OF POSSIBLE FEEDSTOCK/PRODUCT COMBINATIONS

- MINIMUM ECONOMIC SIZE FOR ALTERNATE FLOW SCHEMES
- FEEDSTOCK AVAILABILITY/PRICING
- PROJECTED SIZE OF MARKET

PLOT NO. II-6

TECHNICAL-ECONOMIC COMPARISONS

- BLOCK FLOW DIAGRAMS/MATERIAL AND ENERGY BALANCES
- ANALYSIS OF AVAILABLE TECHNOLOGY
- UTILITY AND OFFSITE REQUIREMENTS
- INVESTMENT COST ESTIMATES
- OPERATING COST ESTIMATES
- ECONOMIC COMPARISONS
- SENSITIVITY ANALYSIS (FEEDSTOCK/PRODUCT PRICE, PRODUCTION LEVEL, AND TOTAL INVESTMENT)

Plot No. II-7

FINAL SELECTIONS

- Selection of optimum FEEDSTOCK
- Selection of optimum PRODUCT
- Selection of optimum SITE
- Selection of optimum PRODUCTION RATE
- Selection of optimum PROCESS DONFIGURATION COMBINATION

PLOT NO. II-8

FEASIBILITY REPORT

- PROVIDES BASIS FOR INTERNATIONAL FINANCING
- PROVIDES BASIS FOR PROCEEDING IMMEDIATELY INTO BIDDING STAGE OF THE COMPLEX

Know finance scope and structure

Consider these aspects of risks relevant to supply and sales, construction period, operating profit margin, and political and exchange incontrovertibility

E. A. Tondu, Stone & Webster Engineering Corp., New York, N.Y.

IN THE INTERNATIONAL field the proportion of "true" project financing—projects financed by lenders without full recourse to the project's shareholders or other sponsors—is small, but growing rapidly. Even in the Third World and Socialist Bloc countries where projects are normally financed against government guarantees on the corresponding loans, there is emerging a growing interest in financing plants—including those that do not have a foreign joint venture partner/offtaker—with only supplemental host country financial support in the form of certain undertakings.

Some of the following comments may only be partially relevant to cases where the owner, often a Third World government agency, wants to build a project regardless of economics or cost, and has the creditworthiness to do so.

Protection sought. If the debt financing of a project relies for repayment primarily on the cash flow of the project itself, in addition to proven technology, owners/sponsors with acceptable credit standing and a hospitable political environment, potential lenders will insist on protection against:

1. Supply and sales risks.
2. Construction period risks.
3. Operating risks.
4. Operating profit margin risks.
5. Political and exchange inconvertibility risks.

Supply and sales risks. After analyzing the project's economic feasibility study, potential lenders will next verify long-term raw material/energy supply and product offtake agreements. Ideally these agreements should include deliver-it-or-pay (i.e., if you don't deliver, you pay instead) and take-or-pay (i.e., you pay regardless of whether the product is available for delivery or whether you take delivery) provisions, preferably with specific starting dates.

U.S. suppliers/offtakers, in particular, are reluctant to agree to these types of clauses. They represent a direct rather than a contingent financial obligation. They are thus classified as such by their auditors.

Primary considerations. When arranging the financing package with private-sector owners/sponsors, structure their various undertakings so that their auditors will classify them as footnote contingent liabilities rather than direct liabilities shown on their balance sheets.

The price provisions specified in supply-offtake agreements are usually a major bone of contention. Offtakers aim either for a predictable price structure or for a tie to international market prices for the product. Suppliers naturally want to maximize their revenues and at least cover their costs by an adequate margin. Lenders wish to see the relation of supply to offtake prices structured so that an adequate project company operating profit margin and cash flow are assured.

Construction period risks. Cost overruns, completion delays and plant operability in accordance with contract specifications are the principal risk areas.

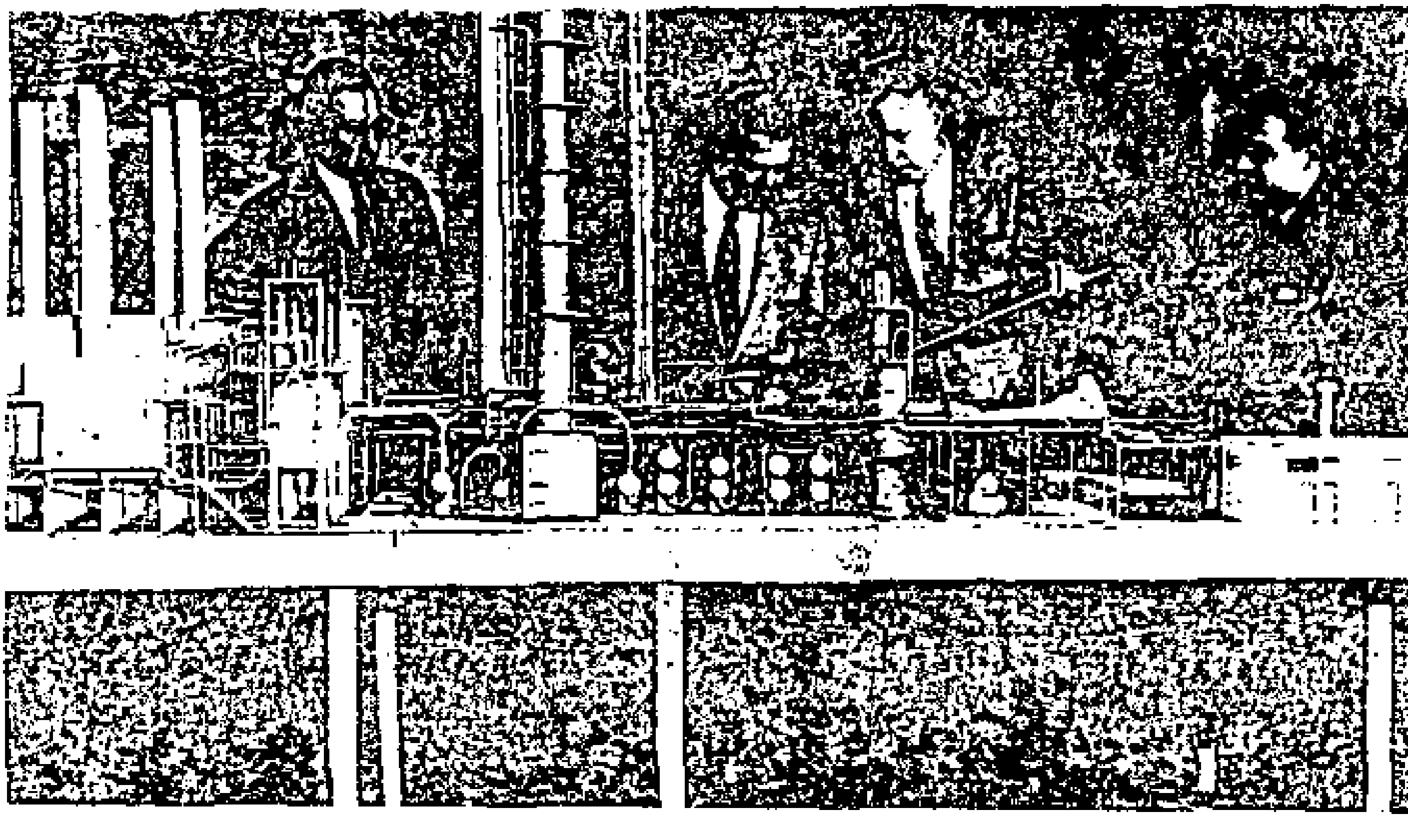
- **Cost overruns** often are provided for by a cost overrun standby agreement (i.e., if costs exceed a predetermined target, the owners/sponsors agree to inject more equity capital or subordinated debt into the project company to cover the additional costs).

More unusual is a formula price offtake agreement which includes a factor to cover amortization of the additional financing required for cost overruns.

Lump sum/fixed price turnkey contracts are another possible solution. However, the contractor may be bidding in an inflationary environment. The plant location may be in an area where historical construction costs are not available or imprecise. Thus, the contingency margin the contractor has to include in his bid price may make the project economically unfeasible.

Lenders generally insist on cost overrun standby

III.- A - 1



The engineer needs a perspective that allows him to view the over-all project in its technological development. But even beyond this is the need to understand financing aspects and other economics factors. They are as large a part of project "viability" as any facet of technology.

agreements from the owners/sponsors even if a lump sum turnkey contract for the facility is awarded. This is because of the risk that the contractor may walk away from his contract. It has happened in the international field more than once in recent years. Recovering, from the contractor, sufficient funds to complete the facility has proven difficult.

If a project has in effect only one owner/sponsor with an impeccable credit rating, it is possible to finance a project during the construction period against a firm take out commitment. And this includes funding of cost overruns. There need be no additional financing agreements. A firm take-out commitment states that the owner/sponsor will:

(a) either arrange permanent financing by a certain date, or

(b) pay out the short-term note holders by a certain date.

• **Completion delays** can be covered by completion agreements. Here, the owners/sponsors undertake to guarantee the project company's debt if completion delays beyond agreed-upon allowances occur.

Take-or-pay, deliver-or-pay and take-out commitments with specific starting dates may be a satisfactory substitute to lenders depending on the project concerned.

• **Plant operability** in accordance with specifications is often guaranteed by the turnkey contractor. His guarantee is normally limited, however, to a specified liability amount which may not cover the funds required to bring plant production up to agreed-upon standards. Therefore lenders will often ask for the owners/sponsors to directly guarantee the project company's debt if specified amounts of production at specified costs are not achieved during the plant testing period.

Again, certain other overlapping undertakings may be a satisfactory substitute to lenders.

Operating profit margin risks. Adequate operating profit margins could be covered by factors in the formula product price allowing for cost of raw materials, power, labor, etc. Lenders usually ask, however, for a more encompassing working capital maintenance agreement. Under this agreement, owners/sponsors are to maintain the working capital balances in the project company at a certain minimum level. This is to protect lenders after the plant commissioning date against all unforeseen events not covered by catastrophy insurance.

Note that a working capital maintenance agreement may obviate the need for certain other owners'/sponsors' key undertakings such as deliver-or-pay supply provisions, take-or-pay offtake contracts and plant operability guarantees. However, auditors may want to classify working capital maintenance agreements as a financial guarantee of all the project company's obligations.

Political and exchange inconvertibility risks. In areas of the world where these risks are significant, lenders may ask for an insurance policy issued by Overseas Private Investment Corp. or private insurers such as Lloyds of London.

The definition of events under which political risk claims are paid are subject to interpretation at the time

III. - A - 2

claims are filed. Lenders therefore often prefer to rely on other owners'/sponsors' undertakings that already are included in the project financing structure. In particular if one of the owners/sponsors is a host country government agency, the value of the rather expensive political risk insurance is often questionable.

An exchange inconvertibility event is easier to demonstrate to the insurer. Therefore additional owners'/sponsors' undertakings are normally not required by lenders to cover this contingency.

Increasingly, where an international agency participates in the project as owner or lender, other sources of financing insist on a cross default clause in their loan agreements, tieing automatic default on the international agency financing directly to default on their loans.

IMPLEMENTATION

In particular, when export credit/procurement agreements with several supplier countries form part of a project's financing structure, implementation of the various financing agreements deserves close attention.

More than once both contractors and owners/sponsors have found they have signed commercial contract conditions that cannot be implemented because of the terms of the financing—in particular export credit agreements.

Look carefully at these areas:

Vendor guarantees. Is the project owner or the contractor the direct beneficiary? In the case of all lump sum contracts plus certain cost reimbursable contracts, the contractor is required to order in his own name, not as purchasing agent for his client. In such cases, the client recovers for latent defects, etc., from the contractor. The contractor incurs the contingent liability of having to attempt to recover in turn from the relevant vendors, i.e., "Standing in front of the vendors."

In the case of exports to Third World countries, especially, government export credit agencies often try to include a provision in their credit agreements specifying that all vendor guarantees be issued to the contractor, even if the contractor is placing the orders as purchasing agent on behalf of his client. From the export credit agency point of view, this avoids disputes between their local vendors and the agency's debtor.

For the same reason (avoidance of disputes with their debtors) these credit agencies also often try to include a provision in their loan agreements stating that: if their debtor refuses to pay, citing as reasons faulty work or inherent defects, the agency has full automatic recourse to the contractor for the amounts owed to it.

Vendor progress payments. Suppose the contractor is purchasing materials and equipment in his own name. Here, care should be taken that the progress payment provisions—including documentation requirements—of the export credit agreements and the relevant Letters of Credit (L/Cs), are similarly included in his procurement contracts with vendors.

Letters of credit. Disbursement of the loan proceeds for a project is normally effected through the lead commercial bank for the financing package opening one or more L/Cs in favor of the contractor and/or vendors.

About the author

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"OPIC Program for Insurance of Contractors' Bid, Performance and Advance Payment Guarantees"

The methods-of-payment section of the commercial contract, the export credit agreements and the other loan agreements should provide for:

1. A regular automatic loan disbursement procedure to increase the unused amount of the L/Cs to match future expenditure estimates, including purchase order commitments, or an agreed-upon progress payment schedule in the case of lump sum contracts.

2. Issuance of L/Cs directly in favor of vendors if the contractor is ordering as purchasing agent on behalf of his client.

3. Documentation required to draw on the L/Cs. Can the contractors/vendors draw unilaterally or only against invoices and other documentation countersigned by the client?

Performance bonds. In particular, in Third World countries, the performance bonds often are issued by commercial banks. These may be in the form of Standby Letters of Credit rather than the bonds issued by insurance companies—standard procedure for U.S. domestic projects.

These performance standby L/Cs often contain provisions permitting the beneficiary to draw at first demand without presenting documentary justification. If drawn upon, the opening bank automatically debits the account of its client. As a result, such L/Cs are classified by banks as demand loans extended to their clients.

* Unfortunately, the U.S. government, unlike other governments, does not offer U.S. companies insurance against the unjustified calling of performance bonds.

Clearly, negotiation of the text of performance Standby L/Cs is an important issue. They represent a direct contingent demand charge against an opening party's assets.

As one supplier has found out to his dismay, it is a good idea to order performance Standby L/Cs with first demand provisions to be issued only after you have received and verified the text of the loan proceeds disbursement L/Cs.

* Overseas Private Investment Corp.
[illegible] 20th St. N.W.
Washington, D.C. 20527

III.- A - 3

Evaluation method. First we need to consider the method of economic evaluation of a risky project. A myriad of methods are mainly variations of two major classes—those that consider the time value of money and those that do not. In the second class we have such standards as "payback" or "payout." While these are still used for simpler problems, most analysts use one of the time-value-of-money approaches. These can be divided into "net present value" or "present worth"; or "internal rate of return," "return on investment" or "discounted cash flow rate of return." We will refer to these two subclasses as present worth *(PW)* or internal rate of return *(IRR)*.

While the two methods are very similar, they differ on how they use the rate of discounting and the implicit assumption associated with this. In the present-worth method, a discount rate is selected (subjective and arbitrary). All revenues and costs are discounted back to some common reference point in time:

$$PW = \sum_t R_t / (1 + i)^t \qquad (1)$$

In the internal rate of return method, we do not select a discount rate. We solve for the rate that would make the present worth exactly equal to zero. When we consider the initial investment, this then gives the rate of interest such that the net returns over time just "pay off the mortgage and the interest on the loan."

PW is best. While there is still controversy over which of these two methods is appropriate, *IRR* is more popular. It does not require selecting a discount rate and gives a "ranking" measure where more than one project is being considered. However, we favor the *PW* method for the following reasons. The two methods can give conflicting results and the resolution generally shows that the *PW* method is the correct approach.

PW is also more conservative. This is because of the implicit assumption in both methods. The *PW* method assumes that net returns are "reinvested" at the discount rate while the *IRR* method assumes the returns are "reinvested" at the internal rate of return. This is not usually true in the case of *IRR*. If the calculated *IRR* is very low, we would not reinvest in another loser. And if it is high, we might not find another good project.

Continuous discounting. The second item is the use of continuous discounting. In the classical methods, *PW* or *IRR*, the discounting is performed at fixed points in time—usually annually. This, in essence, assumed all returns and all costs were aggregated to one point in time.

Then the "net income" was determined. In reality, there is effectively a continuous flow of funds. Therefore it is more realistic, and as we shall see easier, to use continuous discounting. If we take the discount factor, $1/(1 + i)^t$ and divide the time interval into smaller [illegible]es, it can be shown mathematically, that in the limit, [illegible] continuous discounting, the discount factor becomes e^{-rt}, where r is the continuous discount rate analogous to an annual discount rate, i.

$$r = \ln(1 + i)$$

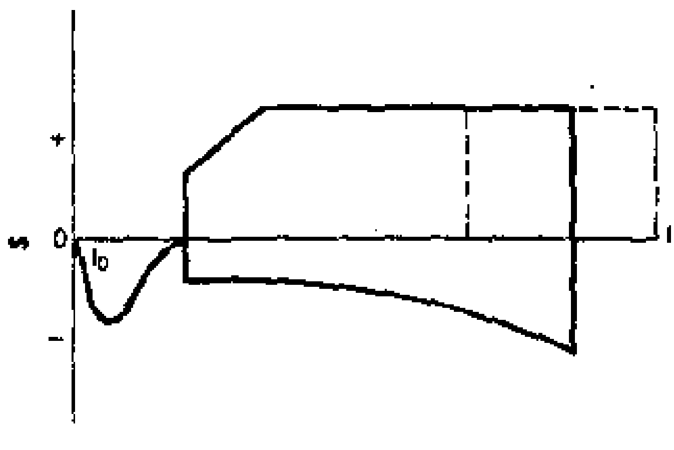

Fig. 1—Graphical portrayal of the problem.

The use of continuous discounting leads to a major innovation in economic analysis, that of "cash profile" analysis. If we take our present worth formula and use continuous discounting we have:

$$PW = \int_0^L R e^{-rt}\, dt \qquad (2)$$

(At this point some readers may remark that they have not done any calculus for many years and wonder how to do it. The quick answer is that you do it the same way you did years ago. The more appropriate answer follows).

An example. To give a simple example, consider an oil well that has an initial flow rate of Q barrels per day, selling at a price P. The flow declines at a rate of g. We can then write the present worth of the revenue from the well over its economic life as:

$$(PW \text{ Revenue}) \int_0^L PQe^{-gt} e^{-rt}\, dt \qquad (3)$$

By applying standard solutions to this and other functions, mainly drawn from Laplace Transform Theory, we can rewrite the present worth of the function as:

$$PW \text{ (Revenue)} = \frac{PQ}{r + g} \left[1 - e^{-(r+g)L} \right] \qquad (4)$$

While its result may look more complicated, it is a lot easier to calculate than estimating the average flow per year for a fair number of years and then discounting and adding together all these terms. For many common cash flow profiles, including depreciations of various types, the standard form of the result has been determined and tabulated. More importantly, we have extended these flow profiles to include risk so as to simplify those calculations as will be illustrated in the next sections.[3,4]

III. - B - 2

TABLE 1—Equations for probabilistic description of project economic life, to obtain ... present worth. Excerpt from [3, 4]

Factor	Expected value of present worth
I_0	$\frac{E[R]}{(g+r)^2(c-a)}\left[\left(c+\frac{2}{(g+r)}\right)e^{-c(g+r)} - \left(a+\frac{2}{(g+r)}\right)e^{-a(g+r)} + c - a\right]$
R_1	$\frac{E[R]}{r}\left(1-e^{-rn}\right)$
R_2	$E[R]\left[\frac{1}{r^2}\left(1-e^{-rn}\right) - \frac{n}{r}e^{-rn}\right]$
R_3	$\frac{E[R]}{r}\left[1 - \frac{e^{-ra}-e^{-rc}}{r(c-a)}\right]$
OM_1	$\frac{E[Com]}{r}\left(1-e^{-rn}\right)$
OM_2	$\frac{E[Com]}{(r-g)}\left[1+\frac{e^{-c(r-g)}-e^{-a(r-g)}}{(r-g)(c-a)}\right]$

Factor	Variance of present worth
I_0	$\left(\frac{\mu_R^2+\sigma_R^2}{(r+g)^4}\right)\left[\frac{d^2M_P(\rho)}{d\rho^2} - \left(\frac{dM_P(\rho)}{d\rho}\right)^2\right] + \frac{\sigma_R^2}{(r+g)^2}\left[\frac{1}{(r+g)^2} + \left(-\frac{dM_P(\rho)}{d\rho}\right)^2\right] + \frac{1}{(r+g)^2}\left[\left(\mu_R^2+\sigma_R^2\right)\left(M_P(\dot\rho) - \left(M_P(\rho)\right)^2\right) + \sigma_R^2\left(M_P(\rho)\right)^2\right]$; $\dot\rho = -2(r+g)$, $\rho = -(r+g)$
R_1	$\frac{V[R_1]}{r^2}\left(1-e^{-rn}\right)^2$
R_2	$V[R_2]\left[\frac{(1-e^{-rn})}{r^2} - \frac{ne^{-rn}}{r}\right]^2$
R_3	$\frac{\left(\mu_R^2+\sigma_R^2\right)}{r^2}\left[M_P(\dot\rho) - \left(M_P(\rho)\right)^2\right] + \frac{\sigma_R^2}{r^2}\left[1-M_P(\rho)\right]^2$; $\dot\rho = -2r$; $\rho = -r$
OM_1	$\frac{V[Com]}{r^2}\left(1-e^{-rn}\right)^2$
OM_2	$\frac{\left(\mu_{Com}^2+\sigma_{Com}^2\right)}{(r-g)^2}\left[M_P(\dot\rho) - \left(M_P(\rho)\right)^2\right] + \frac{\sigma_{Com}^2}{(r-g)^2}\left[1-M_P(\rho)\right]^2$; $\dot\rho = -2(r-g)$; $\rho = -(r-g)$

Before we do the present worth analysis, we must decide on what discount rate to use. This determination is independent of the project. Two groups, viewing the same investment opportunity may legitimately apply two radically different rates.

Also, some analysts increase the discount rate if it is a "risky" project. There is no logical reason for doing so. Using a range of estimates for the major parameters is the appropriate way to account for risk. The fact that a project is perceived as being more risky does not affect the "cost of money" to finance it.

Several approaches. To establish a reasonable discount rate, we can apply several approaches. First, if we were to take the required investment funds from some other form of investment—savings or securities, we could use the interest rate of yield on those as a lower bound. This is known as a "lost opportunity cost." We would hope the new project would "earn" at least as much interest as we were giving up. If instead we were to borrow the funds, then the contracted interest rate would be our lower bound.

More appropriately, we should use the concept of "next best available opportunity." If we do not invest in this project, what is our next best alternative? This may not be easy to determine. So we can use some surrogates. First, if the organization publishes an annual report with either five or ten year summary of financial activity, an average rate of return can be estimated from the equity on the balance sheet and the net returns on the income statement. This gives at least a target value.

A quicker approach based on some surveys of what organizations state that they use as a discount rate,[2] is simply to put the factor at twice the prime interest rate. There is no strong rationale for this method, except that many companies keep half of their net returns as retained earnings and disburse the other half as dividends to stockholders. This makes their yield equivalent to the prime interest rate and attractive from an investment viewpoint.

CLOSED FORM RISK ANALYSIS FOR AN HPI FACILITY

To illustrate the use of closed form risk analysis we will apply this method to the problem of evaluation of the investment of a hydrocarbon processing facility to be located outside of the United States.

For economic analysis, this project can be described by the required investment, revenues and costs over time, the economic life, and the salvage value. Associated with each of these factors is a cash flow/elapsed time relationship which we will simply call "cash flow profile." We will use these cash flow profiles together with a probabilistic description of the variables, i.e., cash flow amounts and time, to build an economic model that will assist us in evaluating the economic return and risk characteristics of the project.

Variables, uncertainties. Let us consider the underlying sources of variability and uncertainty that come into play in a problem of this type.

If we first consider costs, we note that we can break the cost component down into two major categories,

TABLE 2—Summary of inputs and results

Factor	Expected value	Range	Distribution	Cash Flow Shape	Expected duration	Range	Distribution	$E(PW)$	$V(PW)$
Initial inv.	$1 billion	± 10%	Uniform	Unimodal	5	± 1	Uniform	− $650 mil.	$36.24 × 10^{14}
Revenue price	4	± 1	Uniform						
Rev_1	50% of max*			Rect.	5	0	—	424 mil.	102 × 10^{14}
Rev_2				Ramp/triang.	5	0	—	177 mil.	17.8 × 10^{14}
Rev_3				Rect.	10	± 10	Uniform	372.2 mil.	190.89 × 10^{14}
OM	51.7 million	42.5 to 67.5 mil	Beta						
OM_1				Rect.	5	0	Uniform	− 80.1 mil.	.44 × 10^{14}
OM_2				Expenditure @12%	10	± 10	Uniform	− 43.7 mil.	4 × 10^{14}
Total project								$220.3 mil.	$351 × 10^{14}

*Max revenue = expect price × 182.5 × 10^9 scf/yr
*Discount rate: r = .20

capital investment and operations and maintenance. We define capital investment to be costs required to initially put the plant into service, and operations and maintenance to be ongoing costs associated with keeping the plant in productive service.

Generally speaking, capital investment costs will be expended over a relatively short time near the beginning of the project. Operations and maintenance costs will be incurred throughout the life of the project. Uncertainty in the capital costs component can occur because of such factors as (1) inflation, (2) strikes, (3) material delivery delays, and (4) bad weather. Variability in operations and maintenance costs may be due to (1) evironmental effects, (2) worker productivity, (3) inflation, and (4) project life.

The length of time over which a project is economically productive is known as its "economic life." This period of time is subject to variation because of factors such as: (1) premature wearing out of equipment, (2) technical obsolescence, (3) unanticipated deterioration in markets, and (4) expropriation by a foreign government.

On the revenue side, cash flows may be affected by a reduced demand due to competitive products, variation in the selling price of the product, rate of market penetration, and governmental regulations.

When these factors are considered collectively for the evaluation of a capital investment project, considerable variation can be expected in the measure of the economic worthiness of the project.

The Notogafou plant. For illustrative purposes, we will consider a proposal to build a hydrocarbon processing facility on the fictitious island of Notogafou, a nation with vast resources but a somewhat hostile and unpredictable government.

The required capital investment in this project is estimated to have an expected value of $1 billion (1979). However, this amount could vary as much as 10 percent. The expected construction time for the plant is estimated to be five years but could be as short as four years or as much as six years.

Operations and maintenance costs are expected to be five percent of the capital investment costs and will remain approximately constant for five years. These costs will then increase at a rate of 12 percent per year until the end of the project life. (This rate would reflect the prevailing rate of inflation in the country). The range of *O & M* costs could be as much as − 15 percent to +35 percent of our initial estimate.

The plant is designed for an operating capacity of 500 × 10^6 scf/day of product, but it is expected to begin production (around year five) at 50 percent of this amount and build up to capacity in five years. Revenue from operations will be generated by the sale of the product at a price of $4/mcf (1979). However, the price may vary as much as ±$1/mcf.

Expected economic life is 20 years. However, this life may be reduced by a factor of two due to the risk of unfriendly takeover by the Notogafou government. Likewise the actual economic life may be extended by as much as 10 years.

We will now translate this information into a form that is convenient for use with our risk analysis model.

MODEL OF THE PROBLEM

Graphical Model. Based on the description of the problem developed in the previous section, the first step is to develop a graphical portrayal of the various flow of funds. These are shown in Fig. 1.

The initial investment is a negative cash flow that can be realistically assumed to build up slowly, peak out at an early point and then taper off as the construction is finished. For this factor, we chose a unimodal function with the peak at 1-1/2 years with the total expected flow of funds over five years to be $1 billion. The variability in these parameters will be treated in the mathematical model.

Next the Revenue portion starts at 50 percent of potential, rises to that amount in five years and then remains constant for the rest of the economic life. As will be shown, it will be mathematically convenient to break this into 3 parts: R_1—a constant block of revenue at 50 percent of potential for five years, R_2—a ramp or

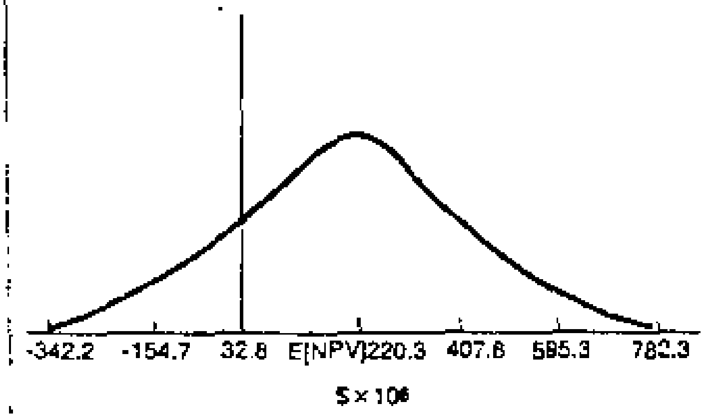

Fig. 2—Distribution of project's present worth.

triangular section over the same time interval, and R_3 —a block of revenues at full capacity over the remaining economic life.

We treat the operating and maintenance costs in a similar manner. Again it is convenient to break this factor into two segments: OM_1—a block of constant costs during the first five years of operation and OM_2 —an exponential increasing block of costs over the economic life (these costs escalate at a rate of 12 percent to reflect some measure of inflation, etc.)

We could have made any series of assumptions with regard to these flow of funds. The purpose here is to illustrate that any set can be handled fairly easily and also incorporate risk. Also, we have not explicitly detailed depreciation or taxes. This is done mainly for brevity of presentation. The analysis can be either considered as being "before taxes" or that these factors are subsumed in the *O & M* costs.

Mathematical model. Based upon the graphical description of the revenues and costs given in the preceding section, we now turn to the conversion of this information into the mathematical forms required for analysis of the problem.

A good model for the total investment is a unimodal cash flow profile that is described by the function:

$$I_t = Rte^{-gt} \tag{5}$$

where the time of the maximum rate occurs at

$$t = 1/g \tag{6}$$

Therefore,

$$g = 1/t$$
$$g = 1/1.5 = .67$$

Also, since $E[I_0] = \$1 \times 10^9$ we have that

$$E[I_0] = \$1 \times 10^9 = \int_0^5 Rte^{-gt} = 1 \times 10^9 \tag{7}$$

$E[R] = 0.53 \times 10^9$ and the range of R is obtained by susbstituting $I_0 = 1.1 \times 10^9$ and $I_0 = 0.9 \times 10^9$ to get

$$.48 \times 10^9 \leq R \leq .58 \times 10^9$$

which yields

$$V[R] = \frac{[(.58 - .48) \times 10^9]^2}{12} = 8.3 \times 10^{14}.$$

The revenue from this project begins in year six when production starts at 50 percent of capacity, i.e., 91.25×10^9 scf/yr, and increases linearly up to full capacity of 182.5×10^9 scf/yr beginning with year eleven. The revenue for this period may be represented by two functions, a constant cash flow of amount times price 91.25×10^9 scf/yr and a linearly increasing cash flow of rate of increase in production, 18.25×10^9 scf/yr times price. From year eleven to the end of the project, revenue is constant at a rate of price times annual production summarizing:

$$R_t = (p \times 91.25 \times 10^9) + p \times (18.25 \times 10^9)(t - 6)$$
for $6 \leq t \leq 11$
$$R_t = p\, 182.5 \times 10^9$$
for $11 \leq t \leq$ project life where
p = price in dollars/ft.³

Operations and maintenance costs are to begin with plant operations in year six and to remain constant for five years. There these costs will increase at a rate of 12%/yr for the remainder of the project life. Therefore,

$C_{OM} = .05 I_0$ for years 6 thru 10
$C_{OM} = .05 I_0 e^{.12(t-10)}$ for $10 \leq t \leq$ project life.

PROBLEM/MODEL SOLUTION

We now wish to combine these cash flow relationships with a probabilistic description of the project economic life to obtain the expected value and variance of the present worth of the project. To accomplish this we will use the equations in Table 1.

Note that these calculations represent not only a discounting to present time, but also the weighting by the probabilities that the variable will take on values within the assumed range. Table 2 shows these values for the example problem for a discount rate of 20 percent. As will be shown, the variance of the present worth will be used to quantify a measure of risk for the project.

TABLE 3—Major pieces of cash flow: expected present value, variance, standard deviation and coefficient of variation

Element	$E[PW]$	$VAR[PW]$	$SD[PW]$	COV
I_0	650×10^6	36.24×10^{14}	602×10^6	.093
R_{1+2}	601.4×10^6	119.7×10^{14}	109.4×10^6	.182
R_3	372.7×10^6	190.89×10^{14}	138.26×10^6	.371
R_{TOT}	994.1×10^6	310.65×10^{14}	176.3×10^6	.181
OM_1	60.1×10^6	$.64 \times 10^{14}$	8×10^6	.133
OM_2	43.7×10^6	4×10^{14}	20×10^6	.458
OM_{TOT}	103.8×10^6	4.64×10^{14}	21.5×10^6	.208

*Note: Discount rate i = .20

RESULTS AND CONCLUSIONS

The results of using the closed-form method for risk analysis are that the *expected* present worth of the project is \$220.3 million and the *variance* of this present worth is 351 × 10.[14] This second number is a bit mind boggling, and is not one that has any intuitive appeal or insight. Rather we must work with the square root of this number, known as the *standard deviation*, which has a value of \$187.5 million. Again, the number may not give any immediate insight. But as we shall see, it can provide a wealth of information.

The standard deviation is a measure of the "spread" or variability of results about the mean, expected, average value. From the laws of probability and statistics, we know that approximately two-thirds of all results will be within plus or minus *one* standard deviation. For this project, this means that there is a two-thirds probability that the actual present value will be between \$32.8 and \$407.8 million. This is quite a spread but still positive.

Standard normal distribution. Further we know that 95 percent of all results are between plus or minus *two* standard deviations and almost all results will be between plus or minus three standard deviations. (We are making an implicit assumption that the probability distribution of the present worth can be modeled by a Normal distribution). Next we can estimate the probability that the project will have a negative present value. Using a Standard Normal Distribution table, this probability is approximately 12 percent (see Fig. 2).

We now have a "feel" for the "odds" or riskiness of this project. We can carry this analysis one step further. We are relating the riskiness of the project to its standard deviation. We can next calculate the *coefficient of variation*. This is the ratio of the standard deviation to the expected value of present worth and for this project is 0.851.

To get a feel for what this number means, consider the following. If the *COV* were less than 0.333, then we would have a "safe" project since minus three standard deviations would still be barely positive. If the *COV* were about 0.5 we would have about a 2-1/2 percent probability of the present worth being negative. If it were near 1.0 this probability jumps to about 16-1/2 percent.

Insights to risks. The intermediate results of our analysis also provides some insights into the risk associated with the project. In Table 3, we have listed the expected present value, the variance, standard deviation and coefficient of variation of the major pieces of cash flow.

(For the readers who wonder how the numbers are handled, a few rules. Only variances can be added together and they are always positive. *SD*'s cannot be added. The expected values can be considered either positive (revenues) or negative (I_0 and *OM*) and hence must be algebraically combined. This is why the "bottom line was $E[PW] = 220.x \times 10^6$ $Var[PW] = 351.53 \times 10^{14}$ and $SD[PW] = 187.5 \times 10^6$).

From the table we can see that the major contribution to the variability are the second parts of *OM* followed by the comparable part of revenue. This is logical because this is where we have the largest uncertainty as to the economic life. In like manner, the lowest variability is in the initial investment because there is less uncertainty in the cost and true estimates associated with this phase of the project.

A good quantitative analysis. In summary, we have demonstrated how a project involving a major capital investment in a petrochemical plant to be built in a foreign country can be analyzed. This analysis can take into account the riskiness of the project associated with the uncertainty in the cost and time estimates. These estimates and their range can be obtained from the knowledgeable people in the project.

These are subjective and properly biased (on experience) estimates that can be converted to probability distributions. These in term are combined to yield the expected value and variance of the present worth. The variance, and thus its offspring, standard deviation gives us a quantitative measure of "riskiness." Such a measure is superior to more subjective qualitative estimates such as "safe bet," "risky," "d– – – risky." The alternative to using a quantitative analysis is to rely on just judgment and hope someone's intuition is right.

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How finance impacts profitability

Cash flow has a dramatic influence on project schedule and on the money to be made. This case history shows how to create an economic model for capital's role in construction.

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AN ECONOMIC MODEL using the discounted cash flow method is useful for plotting interrelationships between project financing, scheduling, and profitability. This is demonstrated here in a case history that goes into operating economics of a typical, modern 1,500-ton-per-day ammonia plant based on natural gas feedstock. But before getting into specifics of this case study, let's consider some important finance-related generalities of good project management.

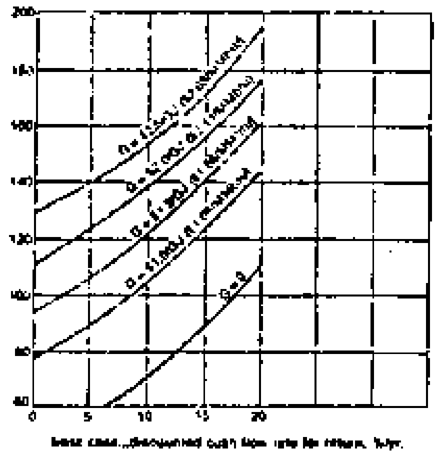

Fig. 1—A curve based on the mathematical model shows the minimum transfer price for ammonia to be $156 per ton.

First of all, once the decision to build an HPI plant has been made and contracts for its project implementation signed, it is most desirable to purchase equipment and services at the lowest prices prevailing (consistent with meeting defined standards of quality). Likewise, it is necessary to minimize the calendar time spent in engineering, procurement and construction phases. Sometimes these requirements conflict. And the resolution of such conflict to the benefit of the project as a whole is an important part of the project manager's responsibilities.

Delays to project schedule occur in a number of ways. Of particular concern are those from procedural constraints imposed upon the project team by sources of investment finance. Here, we'll consider these delays that arise, an estimate of their possible magnitude and their effect on overall project realization.

BACKGROUND TO INSTITUTIONAL PROJECT FINANCING

For the plant owner seeking funds to finance his project, there are several institutional sources operating on a truly international scale. They fall into four main categories, each with special characteristics of loan terms and fields of application. These are broadly as follows:

1. Commercial Banks. The more traditional source of capital funds, characterized today by relatively short loan periods and non-fixed interest rates. Although more expensive than other agencies, an advantage is the lack of commercial or political constraints in project implementation.

2. National Export Credit Programs. These exist to assist and encourage a country's exports of goods and services. Their functioning is based upon the special re-insurance and discount facilities made available to them by government and central banks. Thus they are receptive to political influence and tend to reflect the current trade policies of their respective governments. Loans are at fixed interest over medium to long periods. They are generally tied to purchasing goods and services from the country of origin only. Examples include the U.K. Export Credit Guarantee Department (ECGD), U.S. Export Import Bank, etc.

3. National Aid Organizations. These are essentially government to government loans and are therefore

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subject to some political influence. Loan terms vary but tend to be soft (for long periods at low interest rates). They are sometimes tied to supply of goods and services from the country of origin. Examples include the U.K. Ministry of Overseas Development (ODM), the U.S. Agency for International Development (USAID) etc.

4. International Agencies. These are international organizations employing resources contributed by governments of the participating countries, together with income from international bond issues and placements. Very long loan periods at very low interest rates may be made available to developing countries. Strict procedural rules require open competition for the supply of goods and services from member countries. Examples include the World Bank, the Asian Development Bank, the European Investment Bank etc.

EFFECT OF SOURCE OF FINANCING ON PROJECT SCHEDULE

From the project financing point of view, the shortest project schedule can be achieved when the owner pays cash for the plant, or borrows commercially.

The need to obtain other forms of institutional finance generally extends the time to complete the project for one or more of the following reasons:

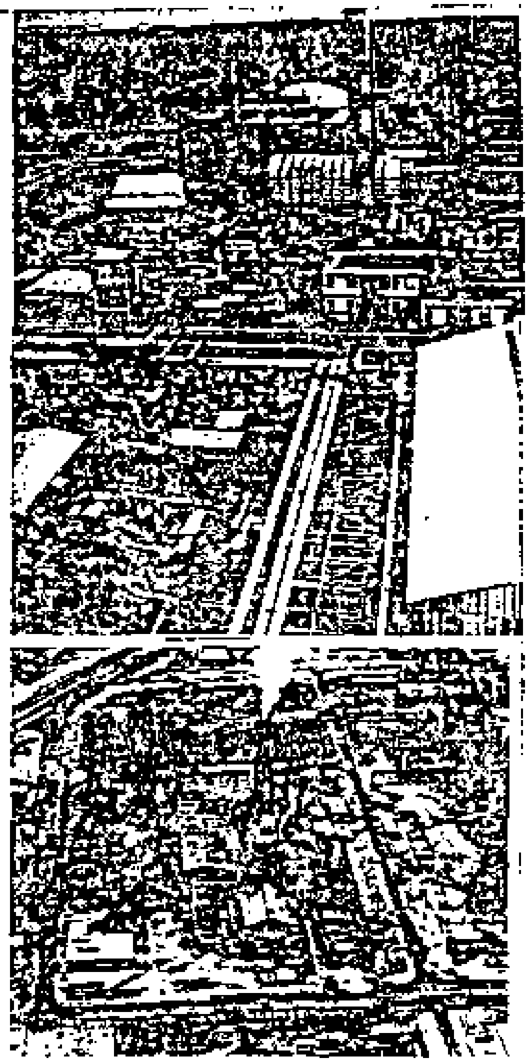
- The time required to negotiate loan agreements.
- The protracted procedures for qualifying bidders which may have to be followed.
- The extra time required to evaluate competitive quotations and select vendors.

It is unusual for the loan agreement to be in force at the start of a project, because the source of finance will often not be known until the contractor has been selected. Indeed, it is frequently the relative attractiveness of the financing packages offered by competing contractors which can help decide who is awarded the contract. The time then taken to negotiate loan agreements and bring them into force depends upon the complexity of the deal, the number of lenders etc. Even in the case of a single source of finance it can often take six months before money is available for payments to the contractor and vendors. For more complex deals involving loans from several countries it can easily take 18 months or more to bring all the agreements into force.

If the owner puts up enough cash to pay for front end engineering and possibly to make down payments on critical equipment, the delays in obtaining finance need not significantly delay completion of the project. However, a delay is almost inevitable if engineering costs and down payments have to be financed.

Vendors' bids. The procedures which have to be followed for jobs financed by International Agencies (such as the World Bank) are designed to ensure that all qualified suppliers in member countries have a chance to bid. As a first step, therefore, invitations to bid must be advertised in well known technical magazines, newspapers and trade publications of wide international circulation. Time must be allowed to enable prospective bidders to request specifications and prepare bids.

Preparation of the advertisement and agreement of



A case study to illustrate how finance impacts profitability (see page 82) is based on a 1,500-ton-per-day ammonia plant similar to these two constructed by Pullman Kellogg

the format and content with all concerned usually takes about one month. Thereafter about six weeks is required for replies to be returned to the contractor. An approved vendors list can then be agreed with the owner and the lenders' representatives. This prequalification period takes about three months. If the prequalification procedure can be run in parallel with the process design, no schedule extension should result. On the other hand, if process design is already complete at contract award, the project completion date will be affected. Special procedures required by the source of financing then become critical activities.

Need for extra time. Extra time is required to evaluate competitive quotations and select vendors for institutionally financed projects. There are several reasons for

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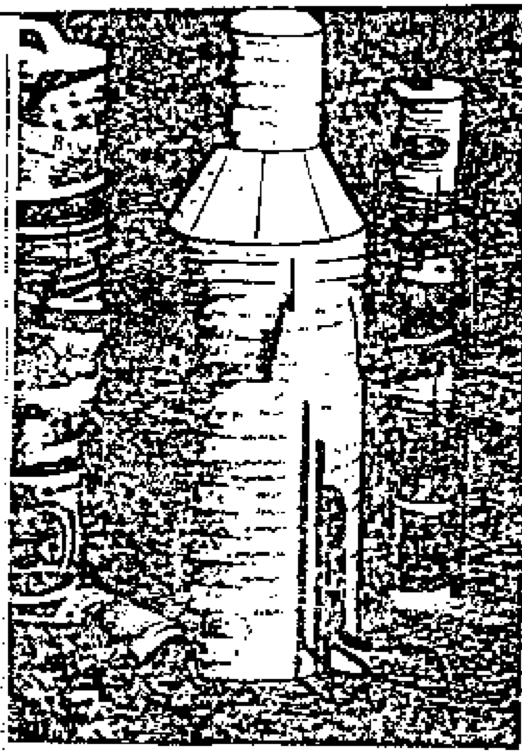

this. Firstly, the contractor is frequently required to solicit bids from unfamiliar vendors. Bids received from such sources may be technically adequate, but frequently they are not. Rejection of bids on the grounds of technical inadequacy is resisted by the lenders. Valuable time is therefore lost while contractors' engineers work with such vendors to bring their bids into line with the specifications. In extreme cases this is not possible. The contractor then has to insist on buying from another source to protect his performance guarantees.

Even when the technical evaluation is straightforward the procedure for obtaining owner and lender approval of bid tabulations can take a month or more. In the case of World Bank and Asian Development Bank projects, any significant change in specification after enquiries have been issued means a repeat of the bidding cycle. Short cuts are not permitted.

Fortunately the full rigor of these procedures is not applied to small orders—currently below about $10,000 in value. A substantial reduction in the work required of the contractor would result from a raising of the threshold.

Ordering and paying. Having selected a vendor, it is then necessary to place a firm purchase order and make a down payment—particularly for equipment items whose delivery time is a critical schedule activity. Even if firm purchase orders are placed on time, a vendor may not start fabrication until a down payment has been received. Therefore the project must have sufficient cash available early in its life for this purpose.

In the case of financing by National Export Credit Programs, where prevailing terms limit the funds available to a fixed proportion of the cost of goods and services (typically 80-85%), critical equipment down payments may suffer unless suitable arrangements are made either from internal capital resources or from top-up financing on the commercial market.

Delays in critical equipment down payments have a cumulative effect. Not only is the project completion time affected directly, but the delay feeds back positively into engineering. The effect on engineering progress is not obvious at first sight, but it can be severe. Unless vendors start their work strictly to schedule, the delivery of drawings for bought-in equipment such as pumps, compressors, air cooled heat exchangers, boilers, cooling towers etc., are affected. Without these drawings, the detailed design of foundation, pipework, steelwork and instrumentation cannot proceed smoothly. This results in further delays in placing the final purchase orders for bulk materials, piping, steelwork etc. Final bills of materials cannot be completed until detailed design is complete.

Impact of payment delay. Thus if sufficient money is not available for down payments on bought-in equipment, the completion date for the plant will extend by an amount equal to the delay in placing the purchase order, even if the equipment is not on the critical path for delivery and erection.

Project financing constraints can seriously lengthen the project schedule. Now let's quantify the effects of such delays on project profitability.

CASE STUDY

The results reported here have been derived from consideration of the operating economics of a typical, modern 1,500 ton-per-day ammonia plant based on natural gas feedstock. This work is part of a comprehensive study of the effect of project implementation delays on overall project economics.

In such an analysis many basic assumptions are necessary. For this example they have been made with a view to generalization of the results as far as possible. They are itemized below to enable reasonable adjustment to the figures to be made to suit any specific situation.

General Industrial Environment

- All ammonia required for captive use in the manufacture of fertilizers for the home market.
- Downstream fertilizer plants assumed to be capable of operating independently of the ammonia plant on purchased ammonia.
- Plant built on an existing site with operating and maintenance manpower available. General industrial and social infrastructure already well established.

Economic Criteria

- Initial fixed capital cost of project $106,250,000 mid-1978 basis. This includes all engineering, procurement,

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construction and related costs, all materials delivered to site, an allowance for spares, first charge of all catalysts and chemicals for the onsite plant plus limited offsite facilities.

- Fixed capital expenditure phased over project implementation period according to normal industry S-curves. Base project schedule 33 months from contract award to initial commissioning.

- Allowance made for constant working capital required over life of project and recovered in year following close down of plant. Allowances for owner's project management and initial commissioning costs also included.

- Economic life of project 15 years from initial commissioning. Zero scrap value.

- Depreciation allowance 20% per year, declining balance method. Tax at 50% per year of taxable income paid in the year following that in which liability incurred. No selective investment grants.

- Production build up 80% first year, 90% second year, 100% succeeding years; 330 operating days per year.

- Zero inflation over life of project.

Economic model. Based on these assumptions, a general economic model was set up using the discounted cash flow format with the price of natural gas, the transfer price of ammonia product and the interest rate as principal variable. In this way, the project operating economics over the life of the plant was expressed as a set of equations relating the project net present value (NPV) to the principal variables defined above.

Putting NPV's equal to zero enabled these equations to be transformed to expressions relating the discounted cash flow rate of return (DCFRR) to the natural gas price and the transfer price of ammonia product. This relationship is illustrated in Figure 1 for the base case.

Further expressions were developed to study the effect of project schedule slippage on overall project profitability. Delays of three and six months were written into the model and the corresponding equation sets for project NPV calculated. Six months was considered the maximum delay in project implementation schedule which could be tolerated without seriously inflating the project capital cost and so masking the effect under special study here.

A rationale. To enable the several sets of project NPV equations to be more easily interpreted, the following rationale was proposed.

In general $N = f(G, A, i, d)$ .... (1)

Where
N = Overall project NPV
G = Price of natural gas
A = Transfer price of ammonia product
i = Interest rate
d = Schedule delay

Similarly, ΔN, the loss of NPV from the base case value caused by a schedule delay, d, may be expressed in the form:

$$\Delta N = f(G, A, i, d) \quad \text{.............. (2)}$$

Where the function is linear in G and A but not in i and d

When $N = 0$, $i = r$, the DCFRR and Equation 1 reduces to:

$$r = F(G, A, d) \quad \text{.............. (3)}$$

For any given value of G and when $d = 0$ (i.e., for the base case with no project schedule delay), as A is reduced, so the DCFRR falls until it reaches the project cutoff interest rate, i_{min}. At this point $r = i_{min}$ and the project is at the limit of economic viability. Thus we may postulate the existence of a minimum value of A, A_{min} which may be read from Figure 1 at $r = i_{min}$.

Any schedule delay when $A = A_{min}$ will drive the project into negative NPV. The magnitude of this negative profitability may be deduced from Equation 2 in the form.

$$\Delta N_{min} = f(G, i_{min}, d)$$

Note that this is the minimum value of ΔN corresponding to A_{min} and i_{min}.

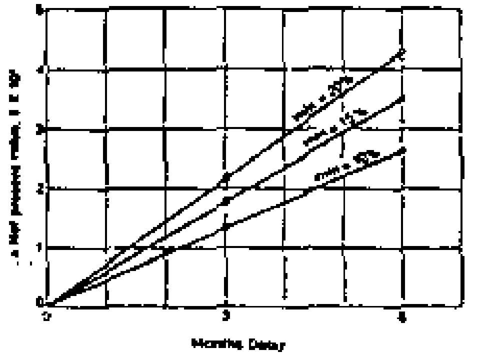

Fig. 2—The cost of schedule delay in terms of net present value is $1.4 million at the minimum ammonia transfer price.

Variables affecting loss size. As expected, the size of the loss of NPV introduced as a result of project schedule delays of up to six months is strongly affected by the price of natural gas and the transfer price of ammonia product as independent effects. For a given set of boundary conditions, however, the price of natural gas uniquely determines the minimum transfer price of ammonia product for a given project cutoff interest rate. The two effects compensate to such a degree that the value of ΔN_{min}—the minimum loss of profitability is essentially independent of the natural gas price and is a function of i_{min}—the project cut off interest rate and the schedule delay alone. This relationship is shown in Figure 2.

In interpreting this graph it must be noted that this

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gives the minimum loss in overall project profitability corresponding to the project cutoff interest rate. At ammonia transfer prices in excess of A_{min} the loss in profitability will be greater by approximately $10,000 per month per $1 per ton the anticipated ammonia transfer price is above A_{min}. An example will make this point clear.

An example. Consider an ammonia plant project as described above in which the price of natural gas is set at $2.5/GJ ($2.63/MM Btu) and the project cutoff interest rate 10%/year. Figure 1 indicates the minimum transfer price for ammonia product to be $150/ton. The cost of a three months schedule delay in terms of NPV is seen in Figure 2 to be $1,400,000 at this minimum ammonia transfer price.

If the actual anticipated transfer price of ammonia is, say, $170/ton, an additive correction factor of 10,000 × (170—150) × 3 = $420,000 is indicated resulting in a total loss in overall project profitability of $1,820,000 for this case.

APPLICATION TO FINANCING CONSTRAINTS

A calculation of the type outlined can be made for any capital project. The set of basic assumptions will be different in every case. They should reflect as closely as possible the anticipated economic environment of the project when construction has been completed.

In this context, as in all project appraisal work, absolute accuracy is neither obtainable nor essential. The effect of deviations from the basic assumptions can be readily explored by sensitivity analysis, or better still for those who accept the underlying philosophy, uncertainty analysis.

Many considerations. The important point is that predictions of project profitability constitute just one, albeit rational, source of input to the decision making process. There are always other considerations to take into account. And these may have greater influence than arguments based on straight economic principles. Nevertheless, in such an event a knowledge of overall project economics may still be used to establish the cost of decisions taken on non-economic grounds.

Their relative importance can be quantified.

In the case of schedule delays induced by project management constraints set by financial institutions, a knowledge of the potential loss in project profitability may be used in a number of ways.

Yield from loss potential knowledge.

- As an argument in the negotiations of a relaxation of the rules where there is significant risk of a loss of overall project profitability in excess of the potential equipment cost saving. Thus in the ammonia plant example, if the strict adherence to the rules in the case of a critical item of equipment would result in a three months schedule delay, the cost of applying that rule may be set at a minimum of $1,400,000 and the benefits accruing from it should be well in excess of this figure.

- As a basis for establishing incentive payments for counteracting the delay by alternative allocation of manpower resources. This can take a number of forms such as extra overtime working, shift working, switching personnel from one job to another, etc.

- As a basis for establishing extra quick delivery bonuses payable by the plant owner to vendors of critical equipment whose delivery is likely, otherwise, to delay the overall project schedule.

- As a way of forming a rational basis for estimating the value to the project as a whole of higher cost immediately available funds for early downpayment on critical equipment items.

- As a way of determining the true value to the plant owner of alternative sources of project finance.

Exceptions to the rule. The principles of discounted cash flow analysis, based essentially on the concept of market economics, will not necessarily apply in some of the developing countries whose industrialization is very dependent upon institutional financing. Where economic planning and industrial development is controlled wholly by government or government delegated agencies, any one of a number of different project appraisal methodologies may be used. These are sometimes cumbersome to apply, involving, typically, the quantitative assessment of social benefit in its widest sense.

But even so, there should still be an equivalence between alternative systems of project appraisal. A loss in overall project profitability as represented by a decrease of NPV in market economy terms should be related to an equivalent loss in overall project social benefit in non-market economy terms. The precise form of the equivalence is dependent upon the particular methodology utilized. And because this is private to the organization responsible for economic study, the translation from one frame of reference to the other must be carried out by that organization itself. Thus the overall cost to the project of schedule delays—and those caused by financial constraints in particular—should be calculable for all defined appraisal methods.

About the authors

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III.- C - 5

When engineers are on the team

Here's what technical professionals should know about how bankers size up a project for which a loan is sought. Goal: To bridge the communication gap and improve the decision-making process

G. R. Castle, Chemical Bank, New York City

A WELL-INFORMED ENGINEER should (1) have a clear definition of project financing, (2) know the major considerations a banker looks at in this unusual financing, (3) grasp why project financing has become so popular and (4) comprehend advantages of the method.

A definition. Project financing is a type of loan whereby the payout of the financing is anticipated from the project's revenue stream. Often the loan is structured so that it is not backed up by the full faith and credit of the owner or sponsor of the project. Thus leaders can only look to the *project* for a payout. In such a case the owner does not sign the note. It may be signed by a newly formed venture set up (by the sponsor) to construct and operate the project.

The borrower's assets are limited to that constructed from proceeds of the project financing plus any initial equity invested into the borrower.

Projection. The lender must often rely heavily on a projection. This is prepared by an engineer or is based on assumptions provided by him. For this reason, engineer and banker must work closely as a *team*. Members of this team must understand each other. There is an inherent equity risk in construction of any new venture and it is not appropriate for a bank to assume an equity risk. This is not a commercial bank role.

The bank must analyze various financing risks and considerations and determine which are acceptable. It must rely heavily on input from the engineer. After this determination is made, the bank will then apply the various project financing techniques to shift any unacceptable or equity risks to another party.

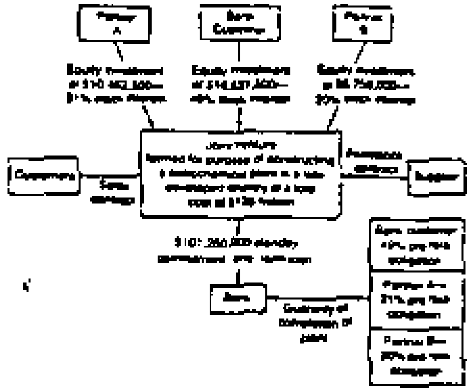

Fig. 1—Structure of an off balance sheet financing

THE BANKER'S VIEWPOINT

Some concerns and risks a banker considers:

1. Completion—This is the question of whether the project will be constructed for the cost originally projected and, if there are overruns, who will pay.

It also includes the questions will the project work according to the original design? Will it produce the product according to original specifications with operating costs in line with the original economics? This risk a bank will seldom assume.

2. Equity—How much equity cushion is in the project? How much money have stockholders invested in it? The amount of equity will usually vary depending on the strength of undertakings provided by the sponsors or other financially responsible parties.

3. Market—Is the output covered by sales contracts? If so, what are the terms of these contracts? How long do they run? What sales price is provided?

It is unusual for a bank to assume the market risk except for a readily marketable commodity such as oil.

4. Source of supply—Does the venture have a contract covering supply of feedstock? If so, what are the terms of that contract?

The supply risk, like the market risk, is not one a bank would usually assume.

5. Project risk—Will the project work over a continuous period of time and achieve expected levels of efficiency? How likely is it that an explosion or other force majeure might occur?

Banks assume some of this risk and part of it can be covered by insurance.

6. Political or country risk—In many international financings the political risk is important. This would usually include the risks of expropriation, inconvertibility and war and insurrection. Furthermore, many foreign investors are also concerned about gradual or subtle expropriation. Examples. Increases in taxes and renegotiation of contract terms by the government in the host country.

On a selective basis banks have made loans in developing countries where the financing is structured so that banks assume all or some of this political risk.

7. Operator—The ability of the operator is also a very basic consideration in all project loans where we rely on the project to pay us out.

Engineer's role. The question of completion and the project risk directly involve the engineer. For example, we need to know whether the project employs any new technology. Has it been built before? How difficult is it to operate?

Even if the financing is structured so that the completion risk is shifted to another party (through an undertaking to complete) we will need to consult with an engineer. Only he can say what shall be included in the definition of completion in such a completion undertaking. We also will rely on the engineer's opinion when we evaluate the operator. As we review market risk and supply risk, the banker will consider the likelihood of a new, more efficient process being introduced to compete with technology involved in our project.

Forecast. After review of factors such as those above, the banker will develop an economic forecast (Table 1).

Using this forecast, we will then determine a coverage on the loan (similar to the coverage ratios on the bottom of the table). We also analyze how sensitive the project is to changes in our original assumptions. For example, where is the breakeven level for this venture?

This forecast will be an important part of the banker's decision. We will rely on the engineer for many assumptions used in this economic forecast. In fact, the engineer might even prepare this forecast.

Technical assessment. The most obvious assumptions the engineer would help us with include:

- Levels of production and efficiency that can be achieved
- Reasonable assumptions for operating costs and expenses
- Assumptions regarding total initial capital costs for the project
- Construction period during which the project is assumed to be built
- Capital expenditures required each year to maintain the project
- Economic forecast analysis. This could include the determination of breakeven levels for the project or a forecast revision based on new assumptions.

TABLE 1—Hypothetical economic forecast for petrochemical plant to be constructed in developing country ([illegible])

	Years								[illegible]
	1	2	3	4	5	6	7	8	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cost of sales	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	$ 12,[illegible]	[illegible]	[illegible]	[illegible]	$ 12,656	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	1.63	1.70	1.75	[illegible]	[illegible]	[illegible]

NOTE: [illegible]

III.- D - 2

PROJECT FINANCING ADVANTAGES

Why do banks make these kinds of loans and assume these unusual risks? They provide many benefits to customers. We simply try to help our customers achieve these benefits.

1. The first advantage is that many project financings are either off balance sheet from the sponsor's standpoint or have a very limited impact on the owner's balance sheet. By off balance sheet I mean that the amount of the loan does not appear as a liability (or any other way) on the sponsor's balance sheet.

For example, let's assume that the project involves a petrochemical plant similar to the one in Table 1. Let's also assume that our customer plans to construct this plant for $135 million. If the customer borrows this from a bank to pay for construction, this $135-million direct borrowing will show up as a liability on our customer's balance sheet. There could be several adverse effects on the customer. For example, under certain circumstances this kind of added leverage (debt) might even reduce the owner's bond rating.

Joint venture. However, if our customer forms a joint venture with one or more other companies to build that same project, financing can be off balance sheet from the customer standpoint. In Fig. 1 I have described how such an off balance sheet financing might work. As shown, the customer joins two partners, A and B, in a joint venture. The bank makes a loan (the project financing) to the joint venture. Since the bank customer owns only 49 percent and does not guarantee payment of the loan, accountants have permitted the bank customer to carry its investment in the joint venture as an unconsolidated subsidiary. As a result, the customer only shows its $16,537,500 equity investment in the joint venture stock as an asset. None of the liabilities (including the project financing) are consolidated and show up as liabilities on the bank customer's balance sheet.

Concerns covered. Each of the seven concerns I discussed are covered in some way by Fig. 1. The risk of completion is covered by a pro rata completion guaranty from the bank customer and its partners. This completion undertaking is not a guaranty of the loan. It is an undertaking that the joint venture partners will cover (any) overrun expenses with additional equity. The undertaking would also typically include a covenant by the partners that they will operate the project for some specified test period at a level of efficiency that confirms project viability. However, after defined completion this undertaking falls off. Henceforth there are no undertakings by the partners to support the project financing.

Contracts. As a condition of the financing, some portion of the output is covered by sales contracts and some portion of the supply of feedstock is covered by feedstock contracts. The levels depend on our analysis of such things as project breakeven level.

Because this project financing is not covered by a continuing undertaking from the partners beyond completion, the bank would normally require an equity investment by the partners. This is to provide a cushion if the operation of the project does not meet forecast levels. The amount of this equity requirement would vary depending on strength of the undertakings by partners. In this case, I have provided for 25 percent equity because of what I view as the very limited undertaking which only covers completion.

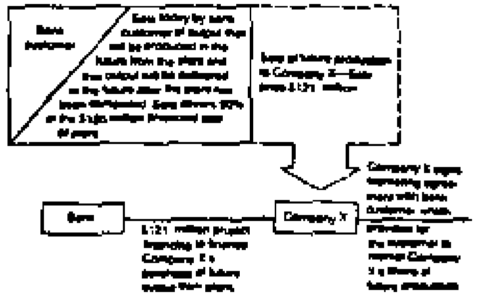

Fig. 2—Structure of a financing arranged so that it will not impact restrictions in the bank customer's existing loan agreements

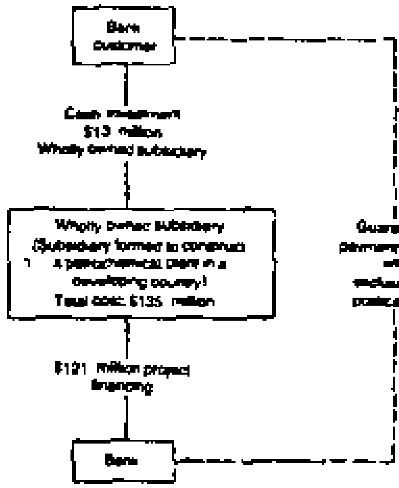

Fig. 3—Structure of a financing whereby the bank assumes the political risk but not the project risk

Risks. Project risk and political risk are two that a bank would typically assume in a financing such as the one described in Fig. 1. In fact, the guaranty of completion might even provide that if there is a political event (expropriation, inconvertibility or war and insurrection), then the obligation to complete will no longer be enforceable. Our customer is assumed to be an experienced operator of this kind of plant. However, if there were any question about the *ability* of the operator, this might have an effect on the way we would structure the financing. It might even impact on our decision to loan.

2. A second advantage could be that a project financing can sometimes fall outside the restrictions in a loan agreement or bond indenture. For example, assume that our customer borrows money from an insurance company. In connection with that loan, he signs a loan agreement with numerous financial restrictions on our customer. Let's further assume that these restrictions include covenants by the customer that he shall not borrow any more money. At the same time, the customer looks for a way to finance construction of the $135-million plant I described earlier.

Fig. 2 shows how such a financing might be arranged without violating terms of the insurance company loan agreement.

Advance payment. In Fig. 2 the bank customer builds the plant. He does not go into partnership with others. The project loan finances 90 percent of the cost. The concept involved here is sometimes referred to as an "advance payment" financing. Rather than borrow money the bank customer sells future production from the plant. Amount of the forward sale is $121.5 million. A newly formed Company X buys this future production (paying $121.5 million) and borrows it from a bank. The bank customer receives $121.5 million from the sale and uses these funds toward the construction of the plant.

The forward sale is created by a document called a Forward Purchase Agreement. In it, the bank customer would covenant to complete construction of the plant and operate it so long as it is economic. Company X (the borrower under the loan) would be a nominally capitalized company formed solely for the convenience of this transaction. Company X might be formed and owned by a charitable organization such as a school or hospital.

After the plant is completed and the production starts to accrue to Company X, there is another agreement (Marketing Agreement) between Company X and the bank customer. In it, the customer agrees to market Company X's share of the plant's output on behalf of Company X, as production is generated. The revenue that flows to Company X as a result of the Marketing Agreement is applied simultaneously against the retirement of both the advance payment and the loan.

Better for the bank. Although proceeds of the financing end up with the bank customer this is technically and legally not a loan to the customer. Thus, it sometimes will fall outside the limitations on borrowings in a loan agreement. From a banking standpoint, the undertakings in this second case are somewhat stronger than the one in Fig. 1. In this second financing concept, operating undertakings by the bank customer continue for the loan's life. In the first loan, after defined completion all undertakings by the partners fall away or no longer continue.

As a result of the stronger undertakings in this second plan, the bank is willing to loan 90 percent of the plant cost with only 10 percent equity rather than a 75 percent financing (25 percent equity) as in the first case. In fact, if it were not for political risk because the plant is in a developing country, the bank might finance 100 percent of cost based on this second financing concept.

Completion risk is covered by an undertaking (in the Forward Purchase Agreement) whereby the customer covenants to complete. Also the project risk in this second case is reduced somewhat by a covenant from the customer to operate the plant to its economic limit. This same covenant satisfies the bank that the plant will be operated properly.

As a condition to this second financing plan, the bank would probably require sales contracts and feedstock contracts similar to those described in the first plan.

3. The last advantage involves the shifting of political risk from owner or sponsor to the bank. In each of the first two cases the financing can be structured so that some portion of the political risk is shifted from the customer to the bank. In those cases, the project is located in a foreign country. So if there is a political event at a time when the bank does not have recourse to the owners, then—to the extent of the loan—the project owners reduce their exposure. However, occasionally the bank customer only wants to minimize its political risk in a project to be built in a developing country. Possibly this desire is because the customer already has a large investment there.

Minimizing political risk. See Fig. 3. In this third financing the customer assumes the economic risk. This shifts political risk to the bank by guaranteeing payment on the loan. Basis: If there is a political event (expropriation, inconvertibility or war or insurrection) then the guaranty is unenforceable.

Even in a financing such as this where the banks do not assume the economic risk, we would consider all seven items mentioned earlier. A political event might occur which would make the guaranty unenforceable. After the guaranty is no longer enforceable, the banks henceforth take the economic risk. This is because thereafter they can only look to the project.

Lower requirements. Depending on our evaluation of the political risk, our standards or requirements in connection with the seven points might not be as high as where we take the economic risk from the beginning. Also our requirements might vary depending on the structure of the financing. For example, the structure might permit the guaranty of payment to be unenforceable after a political event even though the project is not complete. Our standards might be higher for this type of structure than if the banks don't assume the political risk until after completion.

About the author

George B. Castle is a vice president of Chemical Bank, Energy and Minerals Division, New York City. He holds a M.B.A. degree from New York University (1960). Mr. Castle joined Chemical Bank in 1956, and was subsequently promoted to vice president in 1971. He is currently in charge of technical services for Energy and Minerals Division. This job involves the structuring and syndication of project financings for petroleum, mining and other energy related loans made throughout the bank. Mr. Castle has authored a number of published papers, including A banker's approach to project finance, March 1976 issue of HP. He has also served as an instructor in a short course for AIME on project financing.

III. - D - 4

How banks aided Brazil's HPI

A monetary "package" was put together by several banks, Inter-American Development Bank financed acquisition of technology and purchase of equipment to be bought through bidding

G. E. Montes, Inter-American Development Bank, Washington, D.C.

HOW DO REGIONAL BANKS (such as the Inter-American Development Bank) select and process HPI-related loan requests? How are a typical HPI project's finance arrangements handled after approval? In answering these questions, I'll begin by discussing bank authorities' interface with governments. This is followed by an actual case study from Brazil.

COPESUL: A financing challenge

The core of Brazil's third petrochemical center, under construction near Porto Alegre in Rio Grande do Sul, is a large ethylene plant owned by COPESUL, Companhia Petroquimica do Sul. COPESUL's equity is held 51 percent by PETROQUISA, a subsidiary of PETROBRAS, the national petroleum company and 49 percent by FIBASE, a subsidiary of Banco Nacional de Desenvolvimento Económico, the national development bank of Brazil. Principal raw material: naphtha from a petroleum refinery owned and operated by PETROBRAS. The transfer of the naphtha as well as return of some by-products not consumed by downstream industries will be by pipe line. At medium severity cracking, this plant is expected to have the following annual productive capacity, in metric tons:

polymer grade ethylene	420,000
polymer grade propylene	120,000
butadiene	65,500
benzene, toluene and xylenes, as three separate streams	158,500
heavy ends	51,000
crude LPG (propane/propylene)	211,000
pyrolysis gasoline	231,000
total	1,259,000

Annual meeting. On an annual basis, Bank authorities meet with the plant-site country's Ministry of Finance, National Planning Office or other equivalent groups. Projects of mutual interest are listed in priority for the current year or for the immediately following year. Additional possible projects, whose planning is not as advanced, are put in the pipeline for subsequent years.

The next step depends on the degree of planning already done and the urgency attached to the project. If planning is not sufficiently advanced, the country may request an *orientation mission* from the Bank.

Project committee. At this point, the borrower works out plans for information to be included in a feasibility study. Moreover, a Project Committee will be formed at the recommendation of the Bank's Loan Committee. This project group will later conduct an analysis mission and will prepare a project report for consideration by the bank's top management. The mission will study, analyze and report on physical, technical, financial, institutional, economic and legal aspects.

The "orientation mission" won't apply to all projects. Some projects may be sufficiently advanced and need no further orientation prior to analysis.

The information studied by an "analysis mission" is a reflection of the project report to be prepared by this group and subsequently reviewed at other levels of management. The report then serves as one of the bases for decision by the Board of Executive Directors.

Proposal report. A typical report on an industrial project contains the following:

1. An executive summary of the project.

2. A frame of reference for the project, to provide a picture of the magnitude, importance and history of growth of industry, current problems and opportunities, restraints or incentives under which it works, level of technological development and other similar factors. (Similar information, but in a more detailed fashion is studied with relation to the subsector of industry corresponding to the project).

3. Information on the borrower and executor, who may be the same or different entities: in the latter case, part of the information sought will be particularly applicable to one and part particularly applicable to the other. The goal here is to grasp a clear understanding of the legal, financial and managerial characteristics of the entities with whom the Bank is about to do business.

III.- E - 1

4. One or both entities are further studied with relation to past and present operations, products, and market, as well as the necessary projections.

5. Market prospects for the product or products which will result from the project (this includes past, present and projected views of production, consumption, export, and imports of the product(s) under consideration).

6. A detailed description of the project to be financed, including capital cost estimates, operating costs, and a financing plan.

7. A detailed description of the method of execution of the project.

8. Financial projections both of the project and of the executor or borrower, as applicable.

9. A socio-economic evaluation of the results expected from the project. Naturally, this kind of information must be required by development institutions, but not necessarily by commercial sources of financing.

Development loans. These loans, as the name indicates, are granted to support the social and economic development of a host country by financing needed projects. Although the division is not sharp, development loans for industrial plants are generally granted from the ordinary capital (OC) or from interregional funds (IC). Both imply medium term repayment times (12 to 18 years) and interest rates slightly lower than commercial rates. This rate is a reflection of the Bank's cost of obtaining the funds. It is reset twice a year. The rate prevailing for the second half of calendar year 1979 was 7.9% per year on balance owed. There is also a commitment fee on the undisbursed part of the loan, currently 1.25% per annum.

In many cases, the IDB loan has provided all of the foreign exchange requirements. The loan has thereby solved the corresponding problem of availability of foreign exchange. In other cases, notably in very large projects, IDB has not been able to provide all the foreign exchange requirements. So it has worked jointly with other sources of financing to solve the problem. A case study to be described later will show details of such a solution.

Global development loans. The administrative load required in the analysis of loan applications and the supervision of current loans is heavy. Thus, IDB must use some other means to reach the small borrower. Global or program loans are granted to local financial agents such as Central Banks, national development banks, and local development banks. They, in turn, can lend to smaller borrowers. The loan "workload" is carried by the initial borrower who is better suited than the IDB to handle it.

The initial borrower also contributes funds in local currency to help constitute a program consisting of foreign exchange and local currency in the proportions required. And the ultimate borrower or beneficiary contributes equity applicable to working capital and to local acquisitions, including land and buildings.

Other loans. IDB will also fund technical assistance projects and pre-investment loans. The corresponding projects may serve to:

- Identify or quantify raw material resources
- Identify and/or develop projects to the point where they can use the more substantial amounts of financing to transform them into commercial operations
- Develop feasibility studies to plan future courses of action and to help a prospective borrower prepare a loan request for a commercial project
- Reduce or eliminate a technical, marketing or administrative weakness of an operating organization.

Some of these loans are direct loans. Others are for programs which end up including numerous subloans.

Complementary financing. The Bank may help the borrower to locate "complementary" financing in addition to that which IDB can provide. Naturally, this kind of assistance is not always necessary or applicable. Basic objectives of the Bank's complementary financing program with international private sources of funding are:

- First, to assist borrowing member countries to gain access to capital markets, or to improve and diversify such access
- Second, to reduce the risk factor of the credit operations, and by so doing improve the terms for the prospective borrowers.
- Finally, to contribute to enhancing the economic effectiveness and the financial soundness of the external borrowing programs of member countries.

The mechanism is similar, but not identical, to a participation agreement. Here one lending institution serves as the leader for a group of lenders. After negotiating a loan with the borrower, the leader sells a participation to other institutions.

Agreement in principle. The complementary financing process starts with an agreement in principle. The prospective borrower will negotiate such a loan with a lender or groups of lenders to be found by the process to be described.

In the course of IDB's analysis of the loan request, there will be enough information to permit preparation of a prospectus which describes the lending opportunity to prospective lenders.

To assure competition, the Bank invites financial in-

The development bank plays a central role in getting the project owner together with the right "mix" of lending institutions

III.- E - 2

stitutions to submit offers of financing for the full amount of the complementary loan. These offers are requested on a firm basis. The Bank expects the terms and conditions of such offers to be more favorable than those applicable under similar financing, without the Bank's participation, to borrowers of comparable credit standing. Why? In the first place, the financial institution receives the benefit of the Bank's analysis of the loan request. Moreover, the Bank is willing, subject to approval by the Board of Directors, to provide its previously defined part of the required financing. Should this final approval not be given, the financial institution has incurred no obligation to go ahead with its part of the financing. Secondly, the detail work during disbursement and during the subsequent repayment is carried out by the IDB.

The prospective borrower often is able to obtain better terms: (a) because of the confidence provided to the lenders by the intermediary presence of IDB; (b) because the borrower knows there is competition among prospective lenders.

AN HPI CASE

IDB has participated in major petrochemical developments in Latin America. Examples: Petroquimica Bahia Blanca in Argentina, and the second and third petrochemical centers of Brazil in Bahia and Rio Grande do Sul, respectively. The latter provides a wide variety of characteristics not always found together in petrochemical projects of any size. This project brings forth important considerations such as:

- Large-scale production of major intermediates, in a single plant, for consumption by several downstream industries
- A well-planned case of technology transfer
- A proper care for preservation of the quality of the air and of nearby water streams
- Providing for the needs of human and physical infrastructure
- A long-range view to the development of the chemical industry in Brazil
- Financing by multiple sources.

The Box on page 89 gives the basic details of the petrochemical facility being built at Porto Alegre in Rio Grande do Sul.

Multiple financing sources. A manufacturing complex the size of the COPESUL core plant presents correspondingly large financing challenges. Because of the large investment, about $845 million for the core plant, many sources of financing were tapped.

The equity portion of the investment has been provided by two entities prominent in the Brazilian economy: 51 percent by PETROQUISA (the petrochemical subsidiary of PETROBRAS the national oil company) and 49 percent by BNDE, (Banco Nacional de Desenvolvimento Econômico, the national development bank, through its subsidiary FIBASE—Insumos Básicos, S. A. Financiamento e Participações)

Many sources of capital were tapped to build the huge $845-million COPESUL facility. The financing "package" was complicated but worthwhile

Downstream. Both PETROQUISA and FIBASE also participate in equity of several of the downstream plants. In addition to its equity participation in COPESUL, BNDE is providing a long-term loan in local currency. The foreign exchange financing requirements are being met by medium and long-term loans from a variety of sources.

In addition to an IDB loan for acquisition of ethylene technology, a long-term loan was granted for the purchase of equipment to be acquired by international competitive bidding. The World Bank granted a long-term loan for similar purposes. In addition, a consortium of French financial institutions headed by Credit Lyonnais has granted a credit line to be used to buy goods and services in France.

Since each type of financing provides both constraints and opportunities, the formation and the use of the financing package entail some complications. But such complications are worthwhile, considering the expected results.

Chemical markets. To date, prices of chemical intermediates and final market products in Brazil have been fixed by regulation. This is to permit a reasonable rate of return at the various stages of manufacturing and marketing. This arrangement is administered by CIP, the inter-ministerial council of prices.

At the time the Bank was considering the loan application, only the São Paulo petrochemical center was in operation. The second center at Camacari, Bahia, was near completion. As a result, there were few sources of intermediates of various kinds. And there were few complications from fixing one sales price for one producer and a different one for another.

Unwieldy method. With the advent of second and now third national petrochemical manufacturing centers, and the probability that some buyers will buy from two or more suppliers, the traditional method of setting prices becomes unwieldy. Investments per unit of production will vary widely. The depreciation charges will be affected not only by these investment requirements, but also by differing ages of plants and differing schedules of depreciation.

There will be many more products manufactured than up to now. There will be the additional complications of interchange of intermediate materials among the geographic and commercial areas associated with each of the three petrochemical centers.

To cope permanently with the new pricing problems which stem from the existence of two or more manufacturing centers, Brazil will develop a dynamic quantitative model of the economy's petrochemical sector.

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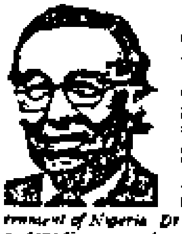
About the author



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Expansion; sales. At high severity cracking, ethylene production can be increased to about 472,000 tons per year, with simultaneous increases in production of butadiene, aromatics, heavy ends, and decreases in LPG and pyrolysis gasoline.

This central plant also will generate steam for its own use and for downstream plants. It will purchase electrical energy in bulk for the other plants.

Most of the main products will be sold to second stage petrochemical plants. These will produce low and high density polyethylene, polypropylene, synthetic rubber, mono and polyvinyl chloride, styrene, polystyrene and propylene oxide. Some of the aromatics not consumed in the area will go to other markets in and out of the country.

Beyond the area set aside for the core plant and the second-generation processing plants, is an area for the formation of an industrial park to accommodate third-generation plants.

Acquisition of technology. The COPESUL plant is an outgrowth of a gradual and steady accumulation of operating experience. In Brazil, ethylene manufacture started as a refinery by-product. This was about 1958 when a petroleum refinery in the São Paulo area was modified to recover by-product ethylene. The operation was followed by propylene recovery about two years later. By natural development more than by master plan, the petrochemical operations of the area grew and led to the establishment of a 340,000 ton/year ethylene plant by Petroquímica União, which started operations in 1972. The area has grown as a petrochemical center. Investment in petrochemical plants is now in excess of $2 billion.

The continued growth of the Brazilian economy and the attendant growth of petrochemical markets led to the planning and construction of the second petrochemical complex, near Camacari, Bahia. This complex includes a plant for the manufacture of 380,000 tons/year of ethylene and a variety of by-products. There are more than 25 downstream units, some based totally on the locally produced intermediates and others on these plus materials brought in from other locations in Brazil or imported.

Financing, downstream plants. Foreign exchange needs of five of the downstream plants plus two located elsewhere in Brazil were financed in part by an IDB loan granted to Banco Nacional de Desenvolvimento Econômico.

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The development of the two national petrochemical complexes had, as one result, the effect of building an ever growing group of personnel with expertise in the design, construction and operation of olefin manufacturing plants. But it was realized that the skills in the area could be improved and should be more widespread. This led to the development of a detailed, carefully designed plan for the acquisition of ethylene manufacturing technology from abroad for use not only in the third national petrochemical complex, but also in future ones. This transfer of technology includes the training of personnel working for COPESUL, others working for the R & D Department of PETROBRAS and still others working for two major Brazilian engineering firms.

Design methods including manuals and computer programs will be or have been transferred. Brazilian personnel will work closely with designers of the new ethylene plant. In addition, the technology transfer will continue as an up-dating process for ten years. Acquisition of the technology was financed in part by an IDB loan.

Environmental protection. Environmental protection stems from close cooperation between the management of the core plant company, COPESUL, and the state authorities, plus clear understandings with the downstream plants about the distribution of responsibilities. This interest in environmental protection is shared by the international financing sources, as evidenced by suitable clauses in the loan contract between IDB and COPESUL.

Primary treatment of any potentially troublesome liquid discharges will be undertaken by the corresponding plant, be it the core plant or one of the second-stage processing plants. The resulting treated effluents must conform to federal and state regulations before they can be sent to the central treating plant, to be operated by COPESUL. The details of this plant have not been fully developed, nor is it necessary that they be fixed at this time. The design will respond to the nature of the treated wastes received from the various plants. It is anticipated, in any case, that besides the treatment for sanitary wastes and prudent precautionary measures to cope with any malfunctions upstream, this treating plant will include a series of oxidation ponds.

Atmospheric pollution? Each plant will assure its own compliance with state and federal regulations. In addition to this, the entire complex will be surrounded by a green belt.

Infrastructure. The State of Rio Grande do Sul is to coordinate development of the necessary infrastructure. Physical aspects will include roads, railroad connections, waste treatment, and housing in nearby towns.

The human side calls for, among other things, the training of large numbers of construction and operating personnel. For example, during the years 1978 through 1981, there will be a need to train about 6,000 skilled personnel such as welders, electricians and mechanics. Later, at least 1,800 trained persons will be needed for maintenance and the direct work of operations. ■

[1] Adapted from a paper presented at American Chemical Society Symposium on Chemistry and Economic Growth in Developing Countries, 1979).

Major factors to consider in project financing

For a general understanding of project finance issues, consider these observations from various authors who have dealt with the subject

C. H. Vervalin, Hydrocarbon Processing Staff

PROJECT FINANCING—broadly defined—is any financing based on the project's viability rather than on the general funds or credit of the equity participants. In other words, the cash flow and credit worthiness of the project are sufficient to induce lenders to loan money . . . The project must meet the cost/risk/return analysis of all parties—owners and lenders.[1]

In the process of seeking lenders, the borrower must consider a number of factors that the lender will fully assess before participating in financing arrangements (See Table 1). Banks ordinarily require a detailed appraisal of such elements. Moreover, technical professionals involved in the financing aspects of project development or management should be fully familiar with terms and concepts used by banks and other lending institutions (See Table 2).

The contracts. How do lenders assess credit risk? The project credit structure attempted most frequently incorporates a number of key contracts between sponsors, lenders, suppliers of raw materials, and purchasers of end products designed to address the principal risk.[2] Key contracts that make up this package include:

1. **The Joint Venture Formation Agreement** between the various partners establishes the percentage ownership, rights and obligations of each party. It spells out the way decisions will be reached and disputes settled. It must be equitable to all parties particularly in the event of changed or adverse circumstances.

2. **The Completion Agreement** requires the partners to put general credit behind the funds borrowed by the Joint Venture until predetermined operating and financial criteria have been met. Such obligation is generally satisfied by a financial guarantee of principal and interest or a purchase of assets agreement. This covers the risk that the investors for unseen circumstances may wish to abandon the project. This would leave the

TABLE 1—International financing of HPI projects: Major factors to consider

Initial product marketing research
- □ Locating the market
- □ Selecting product to fill the market
- □ Selecting product form to fill the market
- □ Export-domestic market ratio to justify project
- □ Marketing assistance when product becomes available
- □ Test marketing studies in areas selected
- □ Nontariff trade barriers important in product marketing
- □ Terminals necessary for successful product marketing

Financing for process evaluation and process selection
- □ Locally available materials—quality, quantity, price—which affect process selection
- □ Locally available skills—quality, quantity, price—which affect process selection
- □ Locally available equipment—quality, quantity, price—which affect process selection
- □ Tariff barriers for imported materials, equipment, skilled labor and process technology
- □ National and political policies affecting imports
- □ Currency transfer restrictions affecting available financing
- □ Currency restrictions affecting export of products
- □ Technology uses that affect export of products

Financing construction of the process plant
- □ When technology is imported
- □ When equipment is imported
- □ When materials are imported
- □ Original catalysts and materials charge to process
- □ Spare equipment, parts and supplies
- □ Initial operation of the project

Purchasing and expediting project equipment, materials and skilled labor
- □ Third country purchases
- □ Technology-equipment exchanges
- □ Raw materials-product exchanges
- □ Investment insurance
- □ Post products exports for equipment supplied (imported)
- □ Barter of products for credits

Eventual ownership of project as determined by financing
- □ Ownership retained by engineer-contractor
- □ Finance source retains ownership
- □ Liens on production held by equipment and/or materials suppliers
- □ Governmental ownership—partial or total
- □ Ownership retained by third party

Cost Control
- □ Initial studies
- □ Engineering and design
- □ Construction, and initial operation
- □ Continuing maintenance and operation

Selection of appropriate engineering construction company
- □ Experience in project type under consideration
- □ Evaluation of personnel
- □ Assessment of over-all performance record
- □ Evaluation of E/C's size and scope

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TABLE 2—Glossary of project financing terms

- Balance sheet items—amounts explicitly listed on a company's balance sheet in either the assets or the liabilities column.
- Cash flow—for lending purposes, net profit before taxes plus depreciation, amortization and interest due.
- Central Bank undertakings—usually a guarantee to convert local currency into freely convertible currencies either at fixed exchange rates or at the free market rate.
- Completion delays—delays in completion of construction and/or acceptance testing of a facility beyond the originally specified target date.
- Commitment fees—fees paid to lenders for firmly agreeing to make loans at a future date. Usually stated as a percent per annum applicable on the undrawn amount of the loans.
- Contingent liability—a possible, as opposed to a certain, future liability normally listed in the explanatory footnotes accompanying a corporate balance sheet.
- Cost overrun—cost incurred to complete a facility in excess of the originally specified price.
- Deliver-it-or-pay—term supply agreements which are a financial commitment to pay cash instead if the supplies are not forthcoming in accordance with contract specifications.
- Demand loans—loans payable immediately at the option of the lender on any date.
- Drawing on L/Cs—getting paid from a letter of credit by presenting to the advising bank your draft plus the supporting documentation specified in the L/C.
- Drawing unilaterally—L/Cs that do not specify that and/or all the supporting documentation accompanying your draft has to be countersigned by the opening party or its representatives.
- First demand provisions—a clause in performance standby L/Cs enabling the beneficiary to get paid immediately at any time against his simple written statement that he is drawing on the L/C.
- Fixed price contracts—suppliers or contractors agree to provide equipment or an entire facility at a stated fixed price. A fixed price contract is often in effect a cost reimbursable contract if it includes clauses allowing for cost escalation, reopening because of changes in scope, etc.
- Fixed rate loans—loans at a stated fixed interest rate.
- Floating rate loans—loans at an interest rate equivalent to a fixed margin above a variable base interest rate such as the U.S. bankers prime loan rate or the six month London Interbank Eurodollar Deposit Offered Rate (LIBOR).
- Footnote item—assets or contingent liabilities listed in the explanatory footnotes accompanying a corporate balance sheet.
- Foreign currency translation adjustments (FASB rule 8)—nominal foreign exchange losses resulting from exchange fluctuations on items valued in foreign currencies included in US corporate consolidated balance sheets now have to be charged off against quarterly consolidated earnings
- Formula prices—variable prices for supplies or products determined by a formula including such factors as cost of production, international market prices, loan agreement operating margin provisions, etc.
- Full recourse—direct or indirect guarantee of a financial obligation.
- Lead commercial bank—the bank which acts as coordinator for the financing package for a project, including acting as manager for any lenders' syndicates that may have to be assembled.
- Letter of credit documentation—the supporting documentation (invoices, shipping documents, etc.) that in order to get paid must accompany your drafts as specified in the L/C.
- Loan disbursement procedure—procedure to get the loan proceeds transferred to the account of the borrower or into an L/C from which the beneficiaries get paid.
- Lump sum contract—see fixed price contracts.
- Offtakers—purchasers of the output of a plant.
- Offtake agreements—product purchasing agreements
- Operating profit margin—profits from operations, generally net sales less cost of sales before general overhead charges, interest, etc.
- Performance bonds—a promise to pay issued by an insurance company or commercial bank guaranteeing the performance of a contractor or supplier in accordance with contract specifications.
- Permanent financing—financing with a maturity schedule that can be repaid from the cashflow of the facility.
- Price/earnings ratio—market price of a company's common shares divided by annual earnings per share.
- Progress payments—partial payments to a supplier or contractor against work progress certificates.
- Segregation of export revenues—proceeds from exports flow directly from purchasers into a special account at the lending bank rather than into the Central Bank's general foreign currency reserves
- Sponsors—parties such as suppliers or purchasers who are not necessarily shareholders in a project.
- Standby L/C—guarantee from a commercial bank to pay if the bank's client does not pay.
- Take-and-pay agreement—a simple term purchasing agreement promising to pay against delivery of products.
- Take-or-pay agreement—term purchasing agreements which are financial commitments to pay whether the products are or are not delivered.
- Take-out commitment—undertaking to repay lenders by a certain date, usually from the proceeds of other financing.
- Vendors—suppliers of materials and equipment.
- Working capital balance—current assets less current liabilities

lender with a half complete plant, and no way to get his money back.

3. **The Raw Material Supply Contract** assures that the raw materials for operation are available to the Joint Venture and in sufficient quantity and quality. The risk of facilities remaining idle is not one lenders are anxious to assume.

4. **The Plant Operation/Management Contract,** generally exists between the new joint venture and the principal commercial joint venturer who has both the experience and the technology to manage and operate the f[illegible]ies within projected cost parameters. Without this [illegible]overed, the lenders would have no assurance the facilities would continue to be run and operated by experienced and trained personnel.

5. **The Product Sale and Purchase Agreement** is to assure that the end product will be sold. It generally involves the various commercial joint venture sponsors buying their pro-rata share from the Joint Venture at market or formula price, whichever is higher. Aim: to assure economic viability and meet debt service requirements. Without such assurance, the lenders will face adverse market conditions which could limit debt service ability.

6. **The Loan Agreement** is between the Joint Venture as borrower and the lenders. It follows the pattern of domestic term credits and establishes interest rate, repayment terms, borrower covenants as well as events of default.

The risks. Mention was made that the above contracts are to deal with the issue of risks. Three fundamental risks are associated with a major HPI capital project investment:[3]

(Continued page 193)

• **Commercial risks**—Price and supply/demand relationships of the feedstocks and products as projected for the life of the project may fail to follow the projections. This may result in the forecast cash flows being inadequate to pay off the loan.

• **Political/economic risks**—The Iranian revolution makes these risks easy to understand. However, don't assume that these risks are confined to less developed countries. Any country can cause difficulties for a project. Examples: currency devaluations, raising tariff barriers, changing environmental regulations or nationalizing a whole industry.

• **Technical risks**—These risks are associated with the physical plant itself. In the absence of the other two risks, they determine whether or not the project can generate income by producing product at a competitive price throughout its whole life.

Project financing lenders are not risk takers. They seek to protect themselves from non-repayment of their loans by suitable contracts and insurances.

Unfortunately, contractual arrangements are not guarantees against project failure. They must be combined with sound planning and skillful implementation to reduce lender exposure to unforeseen, unpleasant surprises.

Technical risks. Lenders look carefully at a project's technical and economic viability. Major factors examined include (1) selection of a competitive process, (2) estimation of capital requirements, (3) contractor selection, (4) engineering and construction practices and procedures and (5) plant startup factors, such as potential for delays.

Engineer/constructor's role. Today, there is a premium on the contractor's ability to locate capital investors and match them with client requirements for construction of large HPI projects.[4] This market has become so competitive, particularly for foreign projects, that the contractor who can offer the best financing often gets the job. A potential contractor for a major project enters the financing picture at two stages.

1. Preparation of bid packages
2. Providing financial assistance to the client.

Contractor responsibility. The contractor has various financial responsibilities. Initially, he must often help his client obtain financing to get the project "off the ground". Then, during the entire construction program, there must be a continuous effort to assure that the contractor's working capital position is not weakened. The tools for this are cash management, letters of credit, and foreign exchange control.

Project loan structure. How does a lender expect a project loan to be structured? A project loan is a credit to a capital intensive facility having no historical operating record itself. The lender seeks repayment from operations of the project after it is built. Such a credit is divided into two phases:[5]

1. **The Construction Loan Period** during which time the plant is built by funds advanced from the lender and operations commence.

2. **The Permanent Loan Period** during which time the plant operates, generating cash flow to retire the debt to the lender and return equity to the sponsors.

This division is helpful because the risks involved in each stage are different. In many cases, the lender during construction is different from the long term lender. A loan for the construction phase must be repaid from permanent financing.

Multiple parties. Apart from the "mechanics" of project financing discussed thus far is the matter of parties involved—their contribution and their knowhow. Projects have become so large and so complex that mutual understanding of the over-all picture is needed by bankers (lenders), lawyers, economists, engineers, financial analysts and even politicians, legislators and government bureaucrats. A broad-brush comprehension is necessary for all of these.[6]

Project cash flow. Technical professionals concerned with project financing matters should understand the ramifications of project cash flow. This includes comprehending a description and interpretation of the concept, the refinancing of existing plants, how bankers view cash flow matters, and how money is managed from project concept to completion. HP has produced a special report to cover this important subject.[7]

New energy sources. Finally, a new dimension has been added to international finance matters—the synthetic fuel facility. In the U.S., especially, which has new legislation relevant to creation of a synfuels industry, financing alternatives must be understood.

Financing options to be considered include (1) municipal financing (of coal gasification plants), (2) utility financing, and (3) industrial financing. Financial analysts who are looking closely at development of solid fuels say that to offset the effects of inflation these sources must get into operation. Once the capital has been spent, escalation on that element of the energy price is established for the life of the project.[8]

Money availability. What about the capital "crunch" we have heard about in some quarters? The best thinking is that credit needs for the equity portion of the private sector will be met by the market mechanisms of today. The market mechanism of cash flow and equity and debt offerings will grow at a rate sufficient to meet HPI needs in the future. On an absolute basis, there will be a capital shortage, although the interface of market dynamics will dictate higher returns due to the continuing inflationary spiral.[9]

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World money resources for project finance

International sources of financing should be known by operating company and engineering/construction company managements. Mega-projects of the future will call for large and wide-ranging capital resources

H. S. Kohli, The World Bank, Washington, D.C.

INTERNATIONAL PROJECTS comprise a big part of activities by companies involved in the design, engineering, supply, construction and operation of hydrocarbon processing plants. Financing of projects overseas, particularly in developing countries, involves special considerations. This is partly due to the difference in ...tes of financing such projects.

...r most large projects, governments provide or guarantee financial resources. They often participate in equity ownership. In addition, to overcome capital shortage (and freely convertible foreign exchange) in most developing countries, large projects frequently also require external financial resources. In recent years, major international commercial banks have met a major part of this need. However, due to country creditworthiness or portfolio reasons, commercial banks cannot meet these needs fully, at least on long-maturity loan terms needed to make these projects with long gestation periods financially viable.

Filling a gap. To fill this financing gap, developed countries (led by the U.S. and in recent years joined by OPEC countries) organized bilateral and international institutions. Examples: USAID and The World Bank. They provide long-term fin...ng. In 1975, they provided abo... 17 billion in medium and long-term financing to developing countries. This amount is now about $31 billion.

In recent years there has been a large expansion in the number and composition of multilateral, bilateral and commercial financing sources for international projects. Many of these official and non-official sources are also increasingly co-financing, together, large projects in developing countries. The role which more experienced agencies (such as The World Bank) play in co-financing may vary considerably. Variances depend on factors like the borrower's wishes, the capacity and experience of co-lenders, and the type and source of co-financing. The lead lender, such as the World Bank, may solicit co-lenders for a project prepared with the bank's technical assistance and fully appraised by the Bank on behalf of all co-lenders. The Bank may also fully assume responsibility for negotiation and supervision on behalf of the co-lenders. There can also be much lesser degrees of Bank (or lead lender) initiative and responsibility.

There are important differences in the criteria used, and depth of analysis employed, by different sources of financing in determining project suitability.

About more information . . .

For more information on project financing relevant to the HPI, see the special report in the December 1979 issue, pages 71-92, and the article by C. H. Vervalin in the January 1980 issue, page 189. For other HPI-related papers on the subject, not published by HP, note literature citations at the end of the Vervalin article.

Commercial banks, as in domestic financing requests, are concerned primarily with determining management capabilities and borrower financial creditworthiness. However, where the project is large relative to the borrower's operations, the commercial lenders must confirm that the project would not have an adverse impact on borrower's future financial viability.

Export credit agencies are concerned primarily with the source of equipment and services purchased by the project from the credit extending country, and with the borrower's ability to repay their loan. However, many export credit agencies are now required to ensure that the projects do not adversely impact on their own home industry.

International development institutions—bilateral, regional and multilateral—are generally much more comprehensive in their analysis of projects submitted. This analysis includes detailed technical evaluation of all technical, organizational, economic and financial aspects. It is to confirm that the project is economically desirable from the country's point of view. Is it soundly conceived? Will it be implemented and operated soundly?

Therefore, while appraising the proposal for financing, an international development institution such as The World Bank not only reviews in detail all aspects of the plant facilities but also their impact on—and the need for—all related physical and social infrastructure in the country. Examples: housing, environmental control, railway, port, road, power and water facilities.

Long-term relationships. Partly due to the above approach to project analysis and partly due to the inexperience of many borrowers in developing countries, the interna-

TABLE 1—Major export credit financing institutions

Austria	Oesterreichische Kontrollbank A.G. Vienna
Canada	Export Development Corporation Ottawa
France	Compagnie Française d'Assurance pour le Commerce Extérieur (COFACE), Paris
Germany	Kreditanstalt für Wiederaufbau (KFW), Frankfurt Ausfuhrkredit-Gesellschaft (AKA) Frankfurt
Japan	Export Import Bank of Japan Tokyo
Portugal	Banco de Fomento Nacional Lisbon
United Kingdom	Export Credits Guarantee Department (ECGD) London
United States	US Export Import Bank Washington, D.C.

Most of these loans go to middle income developing countries.

Bilateral and Multilateral. These include three groups:

1. Bilateral aid agencies. See Table 2. Loans are made at concessionary terms and are aimed at the poorest developing countries. Most of these loans are for non-industrial use. Legal aid agencies (example: USAID) also provide substantial technical assistance.

2. Regional development banks and funds. See Table 3. Most of these are owned by their governments. Financing is provided on both concessional and market terms. They collaborate closely with other regional and international development institutions. Co-financing is common, in which case project analysis is usually done by the larger institution.

3. International development banks and funds. See Table 4. This
tional development institutions tend to be closely associated with the projects for a long period—sometimes 10 years—during their identification, preparation, appraisal and subsequent implementation. Such close collaboration between the lenders and borrower is essential to ensure most efficient use of the country's resources.

FINANCING SOURCES

There are four major sources of foreign funds available to developing countries to finance large developmental projects: (1) commercial banks and private sources, (2) official grants from governments, (3) official export credits, and (4) bilateral and multi-lateral agencies.

Commercial. Sources: international commercial banks, Eurodollars, export credits by private sources and individuals, and equity investments by private sources. These represent about half of all net capital flows to developing countries. They are increasingly involved in co-financing with multilateral development institutions such as the World Bank.

Most commercial loans are not tied to purchases from any one country. And they are relatively quick to arrange. But they are available only to the most credit-worthy of the developing countries and borrowers. Also, except in periods of excess liquidity they carry shorter repayment terms and higher interest terms than other sources.

Official grants. These funds are available on a government-to-government level. They carry no marginal interest and repayment obligations. Main sources are members of OECD and some OPEC countries such as Kuwait and Saudi Arabia. These grant funds are increasingly earmarked for social, infrastructure and agriculture-related projects or for general non-project assistance. Except for the least-developed countries, they are not an important source for industrial projects.

Official export credits. Sources: Government owned institutions such as U.S. Export Import Bank. (See Table 1.) Interest rate and repayment period terms are the best, in market terms. Financing is tied to purchase of goods and services from the country of the institution.

TABLE 2—Major bilateral (official) sources of financing

Belgium	Société Belge d'Investissement International Brussels
Canada	Canadian International Development Agency (CIDA) Ottawa
Denmark	Industrialization Fund for Developing Countries (IFU) Copenhagen
France	Caisse Centrale de Coopération Economique (CCCE) Paris Fonds d'Aide et de Coopération (FAC) Paris
Germany	Deutsche Gesellschaft für Wirtschaftliche Zusammenarbeit mbH Cologne Kreditanstalt für Wiederaufbau Frankfurt
Japan	Overseas Economic Cooperation Fund (OECF) Tokyo
Iraq	Iraqi Fund Baghdad
Libya	Libyan Arab Foreign Bank Tripoli
Kuwait	Kuwait Fund for Arab Economic Development Kuwait
Netherlands	De Nederlandse Investeringsbank voor Ontwikkelingslanden NV The Hague
Norway	Norwegian Agency for International Development (NORAD) Oslo
Saudi Arabia	Saudi Fund, Jeddah Islamic Development Bank, Jeddah
Sweden	Swedish International Development Association (SIDA) Stockholm
United Kingdom	Ministry of Overseas Development (ODM) London Commonwealth Development Corporation (CDC) London
United States	US Agency for International Development (USAID) Washington, D.C. Overseas Private Investment Corporation Washington, D.C.
Venezuela	Venezuelan Investment Fund (FIV) Caracas

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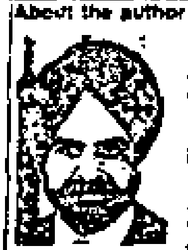
group of institutions is more broad based both in ownership (World Bank has 139 shareholder countries) and in operations (World Bank has some 80 active borrowing countries). In addition to project analysis and lending, they also analyze broader developmental issues on national and international levels. Financing provided carries long maturity terms (10-50 years). Funds are available on both concessionary interest terms (for the very poor countries) and on market terms (for middle income countries). However, these agencies do not normally finance full cost of projects. They require that the borrower also contribute a significant portion of costs. International lenders offer funds up to the foreign exchange cost of industrial projects, with the country financing the local costs. Some of these local financing needs are met by the governments themselves. The rest are met either by the project entity or local development banks set up to provide long term financing for developmental project.

For larger projects, other foreign sources are sought for cofinancing. Institutions like The World Bank often put together the financing plan for a large complex project to match the project needs with different commercial, export credit, bilateral and multilateral sources of financing potentially available to the project. Such "co-financing" efforts are becoming increasingly important.

About the author



[illegible] S. Kohli is *deputy division chief, Chemicals and Fertilizer Division, Industrial Projects Department of The World Bank, Washington, D.C., where he has worked for seven years. From 1970-72, he attended Harvard University, where he received his M.B.A. degree, with high distinction (Baker Scholar). Mr. Kohli also holds a mechanical engineering degree (with honors) from Punjab University, India. He has held positions with Pechiney Group, Paris; Union Carbide, New Delhi; and Premalite of India.*

The views and interpretations in this article are those of the author and should not be attributed to The World Bank or to its affiliated organizations, or to any individual acting in their behalf.

CO-FINANCING BETWEEN INTERNATIONAL SOURCES

Funding is done between two or more international sources. Objectives are to increase the flow of capital to developing countries and to promote more effective use of available assistance. Interactions may occur between any of the following: aid agencies, multilateral institutions, export credit agencies, commercial banks and official sources.

Growing trend. Co-financing will remain a significant source of funds for projects financed by The World Bank and other international institutions. As newly established official agencies are able to process more of their own operations, new sources of funds are likely to develop. They will rely for a time on the Bank's pipe line of projects.

Private institutions may contribute more to Bank operations, especially in the middle-income developing countries. As more borrowers gain experience in obtaining money on reasonable terms from export credit agencies, this should also become a more ample source for cofinancing.

FINANCING CRITERIA

There are important differences in criteria used, and the depth of analysis, by different sources of financing in determining suitability of projects.

Commercial banks. They are concerned primarily with management capabilities and borrower's financial creditworthiness. Where the project is large relative to the borrower's existing operations, commercial lenders must be assured that the project would not have an adverse impact on borrower's future financial viability. Their basic concern, in this balance sheet lending approach, had been about the borrower's financial viability and its continued ability to repay their loans, as distinct from the economic and technical viability of the projects themselves. Historically, most commercial bank loans had short or medium term maturity (e.g. 1-6 years). Thus, their analysis focussed on the borrower's financial performance over a relatively short time horizon. But this approach is changing with the increased exposure of most commercial banks in developing countries, with longer loan terms and with the increasing costs and complexity of projects. Most commercial banks are becoming aware of the need to check the basic, long term viability of projects financed by them. Some have already set up small-project analysis units.

Export credit agencies. They are concerned primarily with the amount and source of equipment and services purchased by the project from the credit-extending country. Like commercial banks, they have traditionally not been very concerned about basic justification of the projects from the host country point of view. However in their case also, criteria for screening projects for financing have changed. Products manufactured in projects financed by export credit agencies in other countries increasingly compete with industries in their home country. So, many export credit agencies are now required by their governments to ensure that the projects financed by them do not adversely impact on their home industry. Export credit agencies thus check at least the market justification, if not the overall economic justification, of projects they support.

International development institutions. The international development institutions—bilateral, regional and multilateral—are generally much more comprehensive in their analysis of projects. This analysis includes detailed evaluation of all technical, organizational, economic and financial aspects. It is to confirm that the project is economically desirable from the country's point of view, that it is soundly conceived, and that it would be implemented and operated soundly.

Whether large or small, every project financed by the international development institutions is considered in the light of the country's total needs, capabilities, and economic priorities to ensure the most efficient use of scarce resources. Therefore, in addition to the usual financial analysis of the project which measures the impact

TABLE 3—Regional development banks and funds

1. African Development Bank
   P.O. Box 1387
   Abidjan, Ivory Coast
2. Asian Development Bank
   P.O. Box 789
   Manila, Philippines
3. Arab Bank for Economic Development in Africa
   Khartoum
   Sudan
4. Arab Fund for Economic and Social Development
   P.O. Box 21923
   Kuwait, Kuwait
5. Arab International Bank
   P.O. Box 1563
   Cairo, Egypt
6. Abu Dhabi Fund for Arab Economic Development
   P.O. Box 814
   Abu Dhabi
7. Caribbean Development Bank
   P.O. Box 408
   Wildey, St. Michael
   Barbados
8. Central American Bank for Economic Integration
   Apartado Postal No. 772
   Tegucigalpa, Honduras
9. Islamic Development Bank
   P.O. Box 5925
   Jeddah, Saudi Arabia
10. Inter-American Development Bank
    808 17th Street, N.W.
    Washington, D.C.
11. Libyan Arab Foreign Bank
    Tripoli, Libya
12. Kuwait Fund for Arab Economic Development
    P.O. Box 2921
    Kuwait, Kuwait
13. West African Development Bank
    P.O. Box 1172
    Lome, Togo
14. International Investment Bank
    17 Presnenski Val 123557
    Moscow, USSR

TABLE 4—International development banks and funds

1. European Investment Bank
   P.O. Box 2005
   Luxembourg
2. OPEC Special Fund
   P.O. Box 995
   Vienna
3. United Nations Capital Development Fund
   (UNCDF)
   One United Nations Plaza
   New York, N.Y.
4. The World Bank
   1818 H Street, N.W.
   Washington, D.C.
5. International Development Association
   1818 H Street, N.W.
   Washington, D.C.
6. International Finance Corporation
   1818 H Street, N.W.
   Washington, D.C.
7. United Nations Development Programme
   (UNDP)
   One United Nations Plaza
   New York, N.Y.
8. International Fund for Agriculture Development (IFAD)
   Rome, Italy

* A partial list of development banks within the developing countries has been prepared by the author. For a copy, write to C. Vervalin, P.O. Box 2608, Houston, Texas 77001. Offer expires June 1, 1980.

of its financial costs and benefits on the financial health of the project sponsor, these lenders also carry out a rigorous economic analysis. They measure the costs and benefits of the project to the country after disregarding any internal transfers in the economy (e.g., taxes, duties, etc.). And they make adjustments for any price distortions in the domestic markets due to national price, trade or currency regulations.

For the purposes of such evaluation, the international institutions' definition of a project is often much different and wider than that used by commercial lenders. For example, while appraising the proposal for financing of a chemical plant, the World Bank not only reviews the technical, financial and economic viability of the plant facilities themselves but also their impact on and the need for all related physical and social infrastructure in the country. This project analysis is supported by periodic, comprehensive country economic studies. These studies are supplemented as necessary by more detailed analysis of individual sectors of the economy and relationships between them.

Long relationship. International development institutions are closely associated with the projects for a long period. Active involvement of commercial banks and export credit agencies is mainly during the period when the project financing arrangements are being finalized. But the established international development institutions are closely involved for as much as 10 years.

This approach is possible because, despite their recent rapid growth, development institutions still deal with few large projects. (In fiscal 1979, the average loan size was about $40 million for an average World Bank project investment of $120 million.) Size and the importance of individual projects in most countries requires development institutions to take a very hard-nosed, detailed look at projects before throwing their technical and financial support behind them.

Project lending work runs through four principal stages: (1) identification; (2) preparation; (3) appraisal—including evaluation of industry and sector, market and marketing, technology, management, financing plan, financial analysis, and economic analysis; and (4) supervision of project, by the lenders, during implementation.

While the formal and final responsibility for project preparation, implementation and operations rests with the project sponsors and owners, international development institutions often provide substantial technical assistance to their borrowers during all four stages of project cycle. ■

Trends - Construction Activities

These data are confined to the Hydrocarbon Processing Industry (HPI). This is defined as new capital investment for planning and construction of: refining units, petrochemical units, natural gas processing units and other units which include environmental control, dedicated utility systems and solids fuels processing units.

They are considered 'activities' since any single confirmed entry into our data bank may consist of a complete 'grass roots' refinery, a complete petrochemical facility or only an addition or a single refinery processing unit. However, each activity must reflect a capital investment of at least $500,000.00 U.S.

These worldwide data have been collected and confirmed in writing since 1947. We will discuss data from October 1977 through October 1980--a total of 16 data points.

In Plot No. 1 you will notice that total worldwide activities remain in the 3000 range. However, we have noticed a rapid increase in 1980 to an all time peak of 3470--and still climbing. Within the next five years as solid fuels and biomass conversion facilities begin emerging we expect a continuing increase in HPI construction activities. The engineering and construction companies, equipment suppliers and other service groups are all currently expanding to meet this expected demand in construction and engineering activities.

Another problem area we are beginning to encounter which is also indicated in Plot No. 1 is the restraint imposed upon capital construction by the capacity of the service and supply industries capabilities.

Engineering, design and fabrication capacity--worldwide--has been level between the 3000 and 3300 activities which appears to be the upper limit of worldwide capability.

Also notice the nice increase in U. S. activities since February 1979 and now a slight increase in Outside U. S. activities. The ratio is beginning to shift in favor of U. S. activities.

Status. All activities in our HPI Boxscore are reported as Planning, Engineering, Underconstruction or Completing. Once shown as Completing they are deleted from the active data bank. In Plot No. 2 we show the status of the activities from Plot No. 1.

Because most HPI projects are rather complex, Planning is rather constant taking into consideration normal worldwide business cycles.

Engineering is slightly more erratic, but again seems to hover around one-third of the total activities.

Construction shows the most variation and corresponds

MORE

closely to the Completing line.

By following any single activity through its history in our Boxscore, one can determine a 'residence' time of or activity life. We have compiled these on a rather crude basis and found that a U. S. activity sustained a 'residence' time of about 22 months while an Outside U.S. activity was about 53 months on average. Many Outside U. S. activities require longer planning, engineering and construction time due to many reasons.

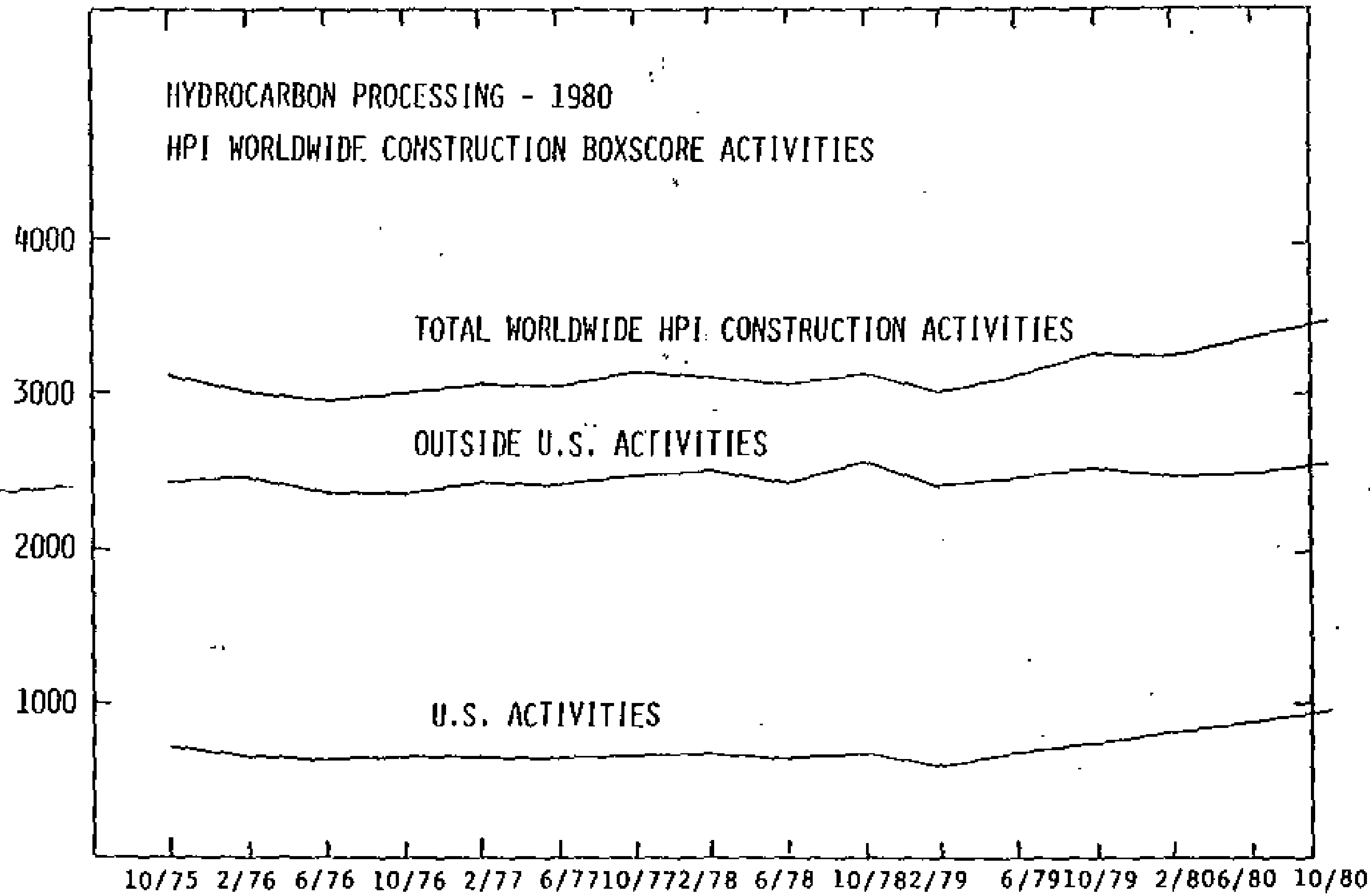
Types of activities. In Plots No. 3, 4, 5 and 6 are shown the worldwide activities by type--Refining, Petrochemicals, Natural Gas Processing and Others.

In Plot No. 3 notice that while Refining activities have been up since Feb. 1979 in the U. S. we are now seeing a nice upturn for Outside U. S. activities.

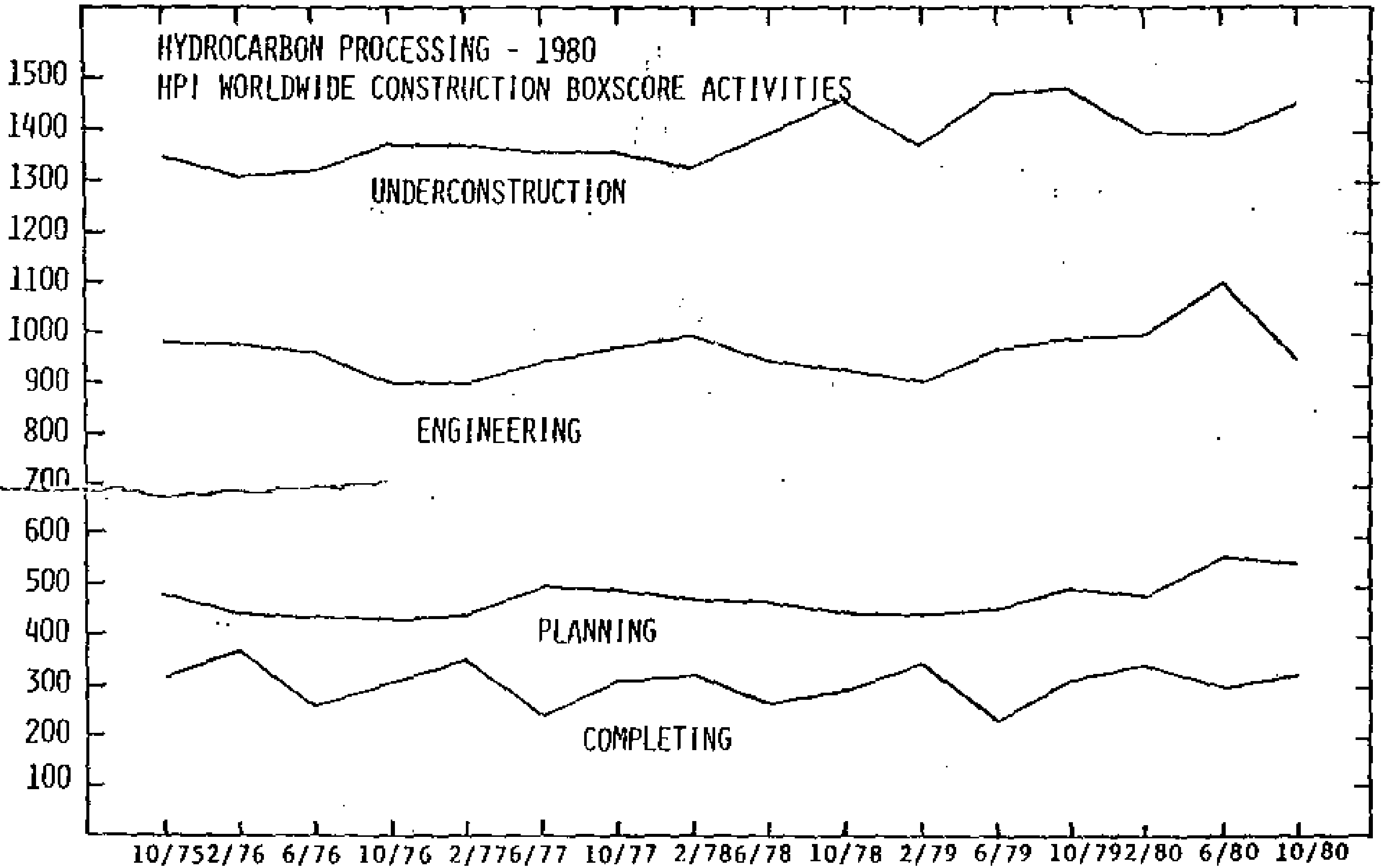
Petrochemical activities in Plot No. 4 may appear to be level for the U. S. but keep in mind that these 200 or so have all been rather large projects. As you would suspect, Outside U. S. petrochemical activities are more than six times those of the U. S. and follow a slightly more erratic pattern.

Natural Gas Processing activities in the U. S. have declined until Feb. 1980 and are now increasing. Correspondingly, we see a decline in Outside U. S. activities as the large Arabian Gulf and African projects are completed (Plot No. 5).

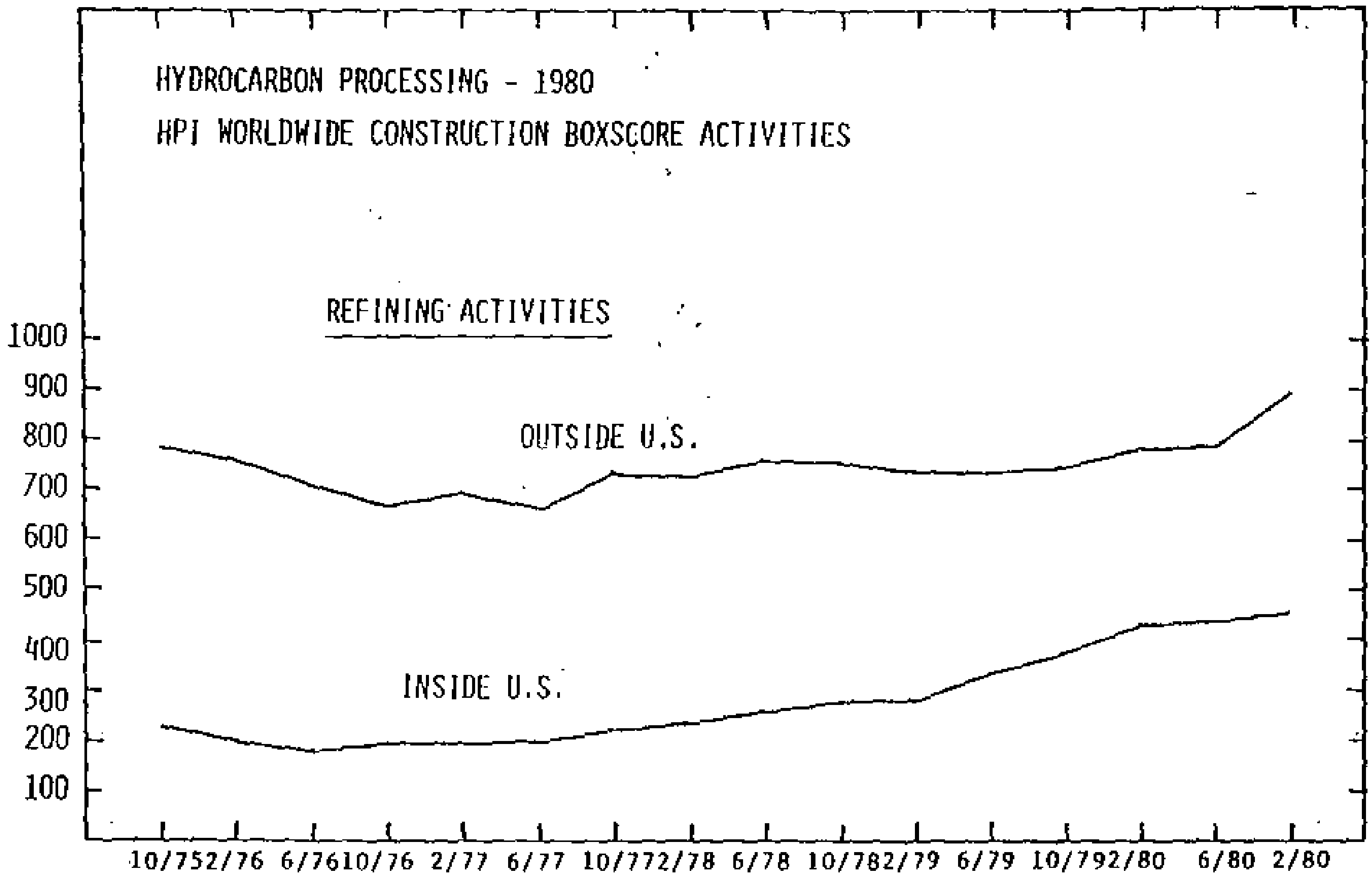
Other activities have always been low with U. S. around 100 and Outside around 200. However, with current developments in alternate fuels and feedstocks projects this could become a very important area of capital investment.


HYDROCARBON PROCESSING - 1980
HPI WORLDWIDE CONSTRUCTION BOXSCORE ACTIVITIES
4000
3000
2000
1000
TOTAL WORLDWIDE HPI CONSTRUCTION ACTIVITIES
OUTSIDE U.S. ACTIVITIES
U.S. ACTIVITIES
10/75 2/76 6/76 10/76 2/77 6/77 10/77 2/78 6/78 10/78 2/79 6/79 10/79 2/80 6/80 10/80

Plot No. IV.A-1

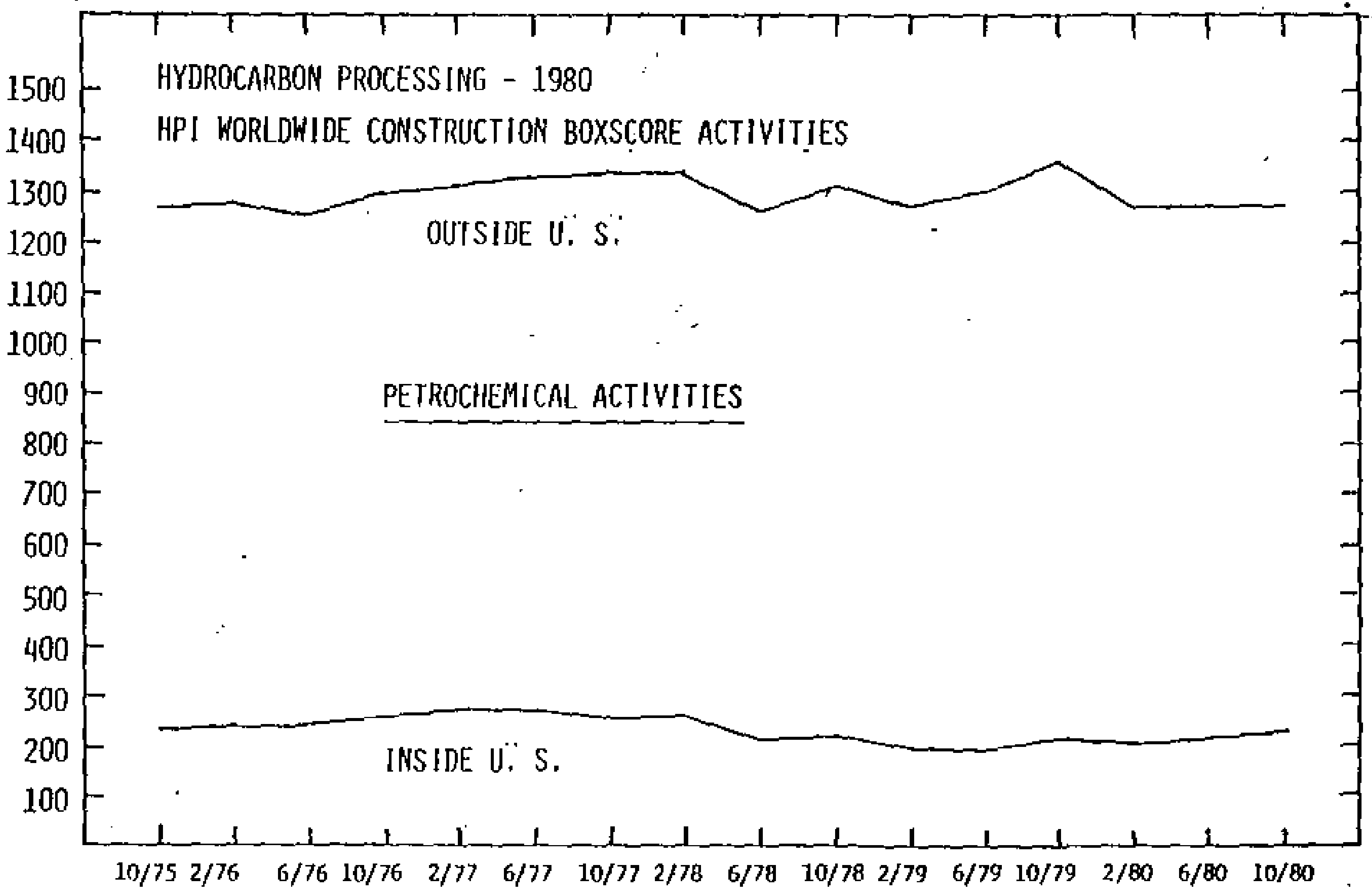

HYDROCARBON PROCESSING - 1980
HPI WORLDWIDE CONSTRUCTION BOXSCORE ACTIVITIES
UNDERCONSTRUCTION
ENGINEERING
PLANNING
COMPLETING
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
10/75
2/76
6/76
10/76
2/77
6/77
10/77
2/78
6/78
10/78
2/79
6/79
10/79
2/80
6/80
10/80

Plot No. IV.A-2



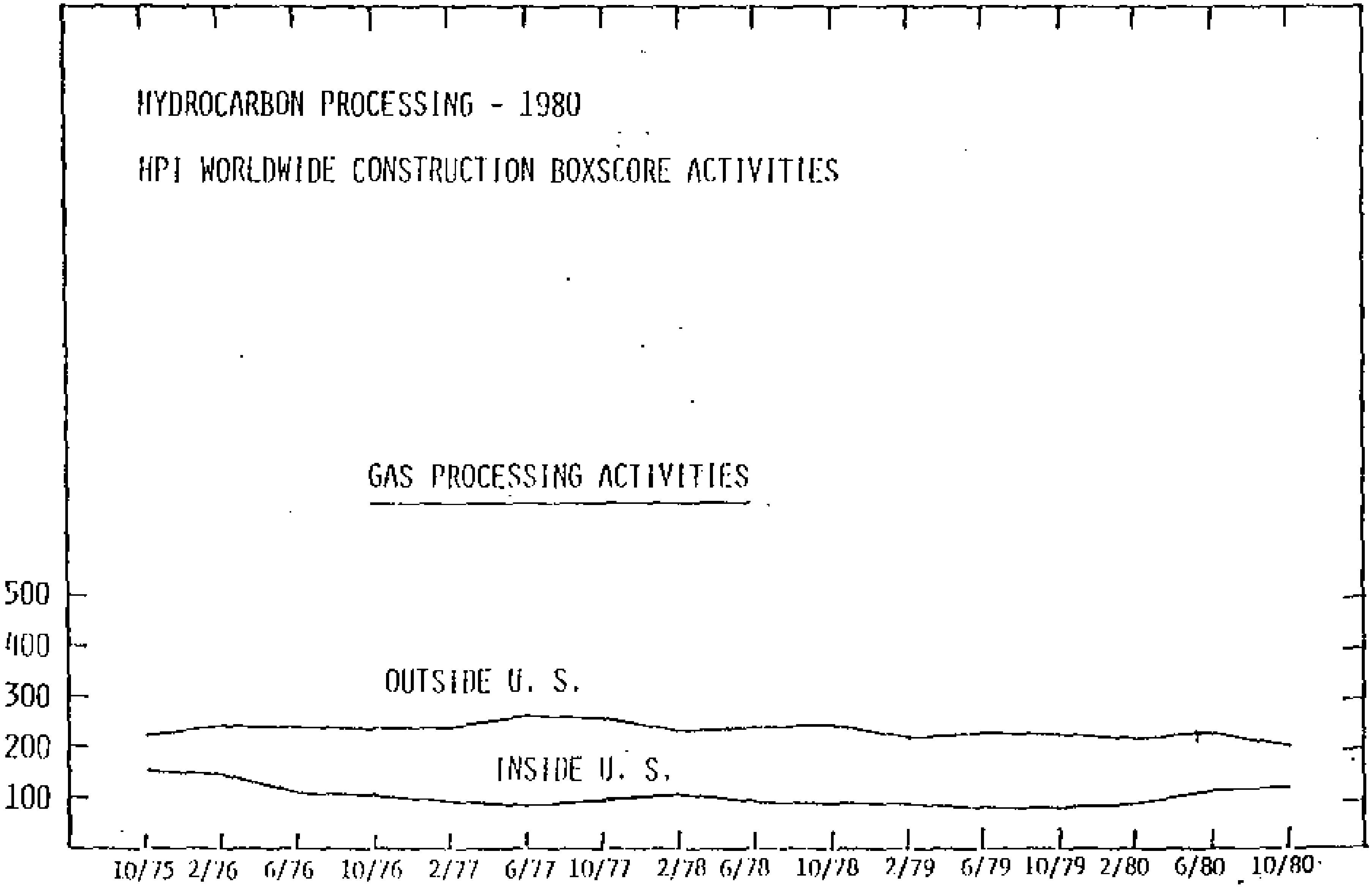
Plot No. IV.A-3

DO 1 13

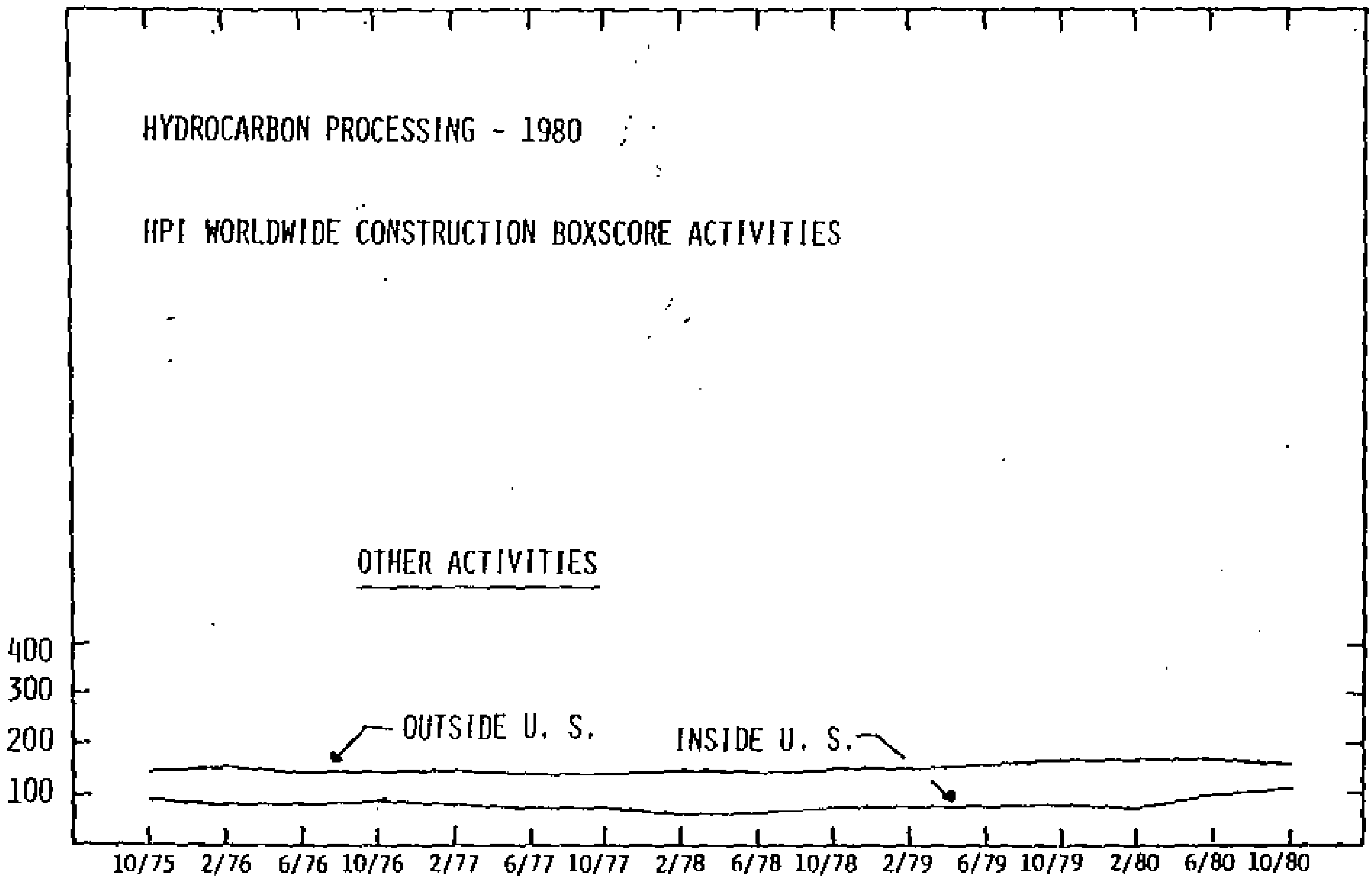


Plot No. IV.A-4

Pe.1 A4


HYDROCARBON PROCESSING - 1980
HPI WORLDWIDE CONSTRUCTION BOXSCORE ACTIVITIES
GAS PROCESSING ACTIVITIES
OUTSIDE U. S.
INSIDE U. S.
500
400
300
200
100
10/75 2/76 6/76 10/76 2/77 6/77 10/77 2/78 6/78 10/78 2/79 6/79 10/79 2/80 6/80 10/80

Plot No. IV.A-5


HYDROCARBON PROCESSING - 1980
HPI WORLDWIDE CONSTRUCTION BOXSCORE ACTIVITIES
OTHER ACTIVITIES
400
300
200
100
OUTSIDE U. S.
INSIDE U. S.
10/75
2/76
6/76
10/76
2/77
6/77
10/77
2/78
6/78
10/78
2/79
6/79
10/79
2/80
6/80
10/80

Plot No. IV.A-6

Trends

Energy. Cost of energy is projected to continue rising. Plot No. IV-A-7 shows the average refiner crude oil acquisition cost in current $ U.S. Notice the phase out of U. S. price controls in 1982 which will place all consumers on an equal basis.

However, since most crude oil is purchased with $ U.S. we should have some idea of the effect of currency exchange rates. As seen on Plot No. IV-A-8 are projected exchange rates for the West German Mark and the Japanese Yen versus $ U.S. While the DM continues strengthening and also the Yen, there appears to be a break after 1983. Currency exchange rates must be carefully considered in any market evaluation.

Considering these projections on crude oil and currency exchange effects, notice in Plot No. IV-A-9 how these are expected to influence ethylene prices in the U. S., Western Europe and Japan. The strengthening of the $ U.S. beginning in late 1982 will have a noticable effect on Western Europe and Japan ethylene prices.

Potential growth areas. First look at ammo nia demand as shown on Plot No. IV-A-10. Notice how the demand is shifting from the developed countries to the developing areas. This represents opportunities for industrialization to supply local demand.

Benzene is another important indicator as a rather complex projection is shown in Plot No. IV-A-11. In this case 'MOVEMENTS' are transfer of product to fill do mestic and trading demands. Perhaps an example is in order. Mexico has considerable benzene production but until 1984 will be importing benzene to meet local demand. Canada has excess benzene and will export quite heavily. The same applies to Japan, East Europe and the U.S.S.R. This presents opportunities for developing countries to enter this market--either as a consumer or as an exporter.

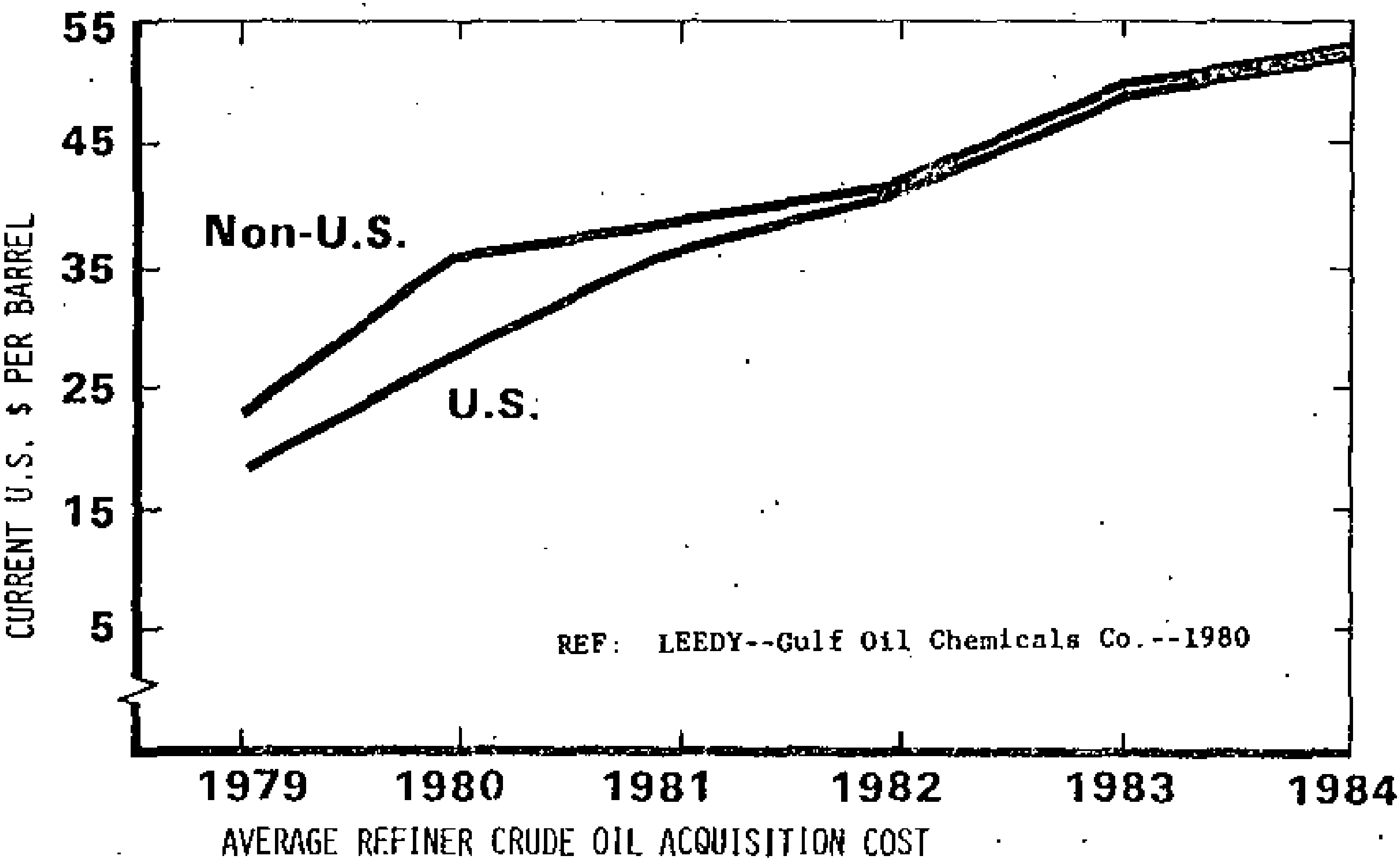
The basic petrochemical--ethylene--indicates industrialization at high technology levels. Plot No. IV-A-12 shows a 15 year forecast of production by geographical regions. It is interesting to notice that while production should increase three times in 15 years, the industrial countries show good growth rates. However, the opportunities lie in the developing areas and you will notice that Latin America has the second highest annual growth rate. Plot No. IV-A-13 shows these data in bar chart form.

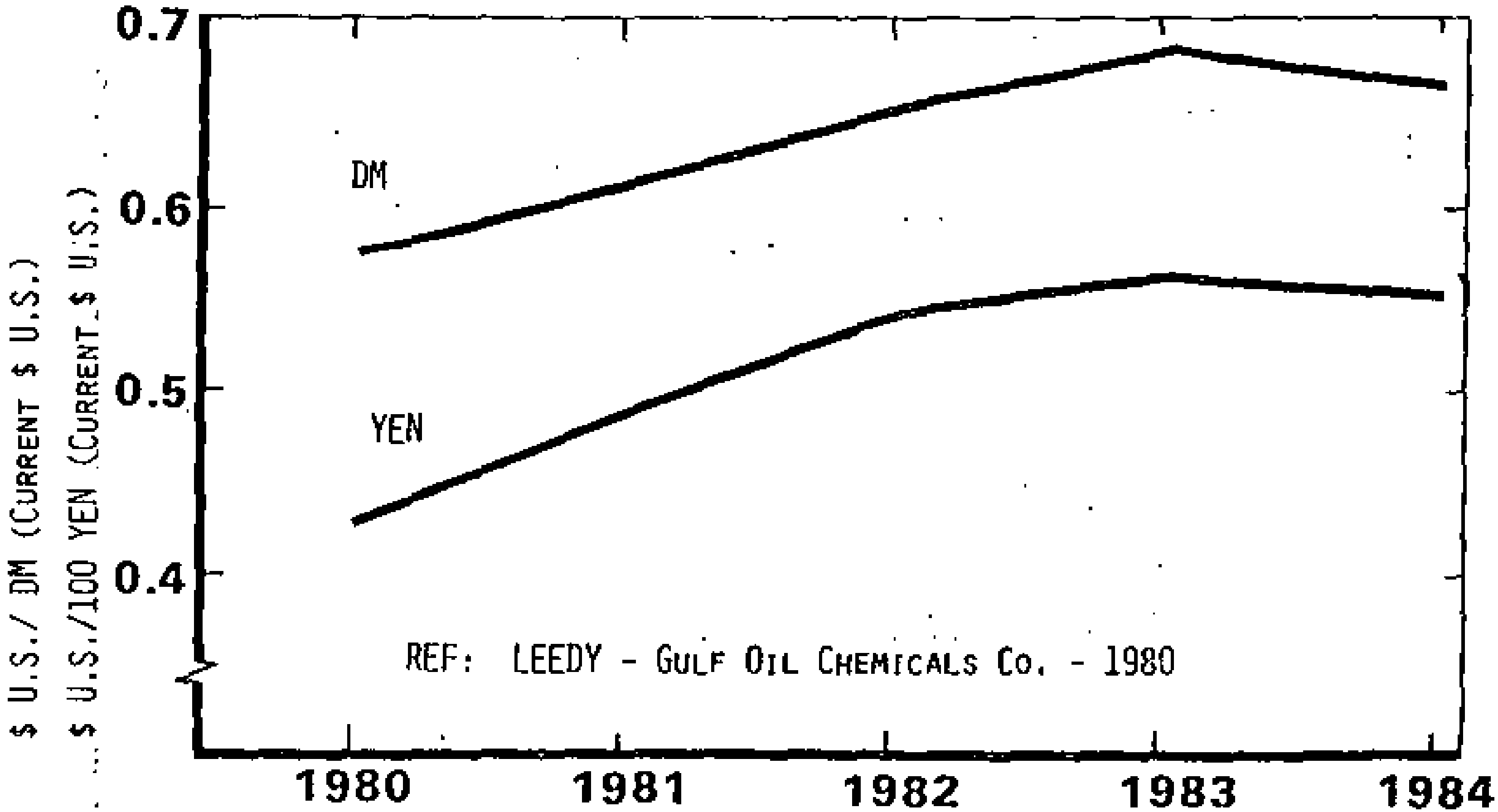
As discussed in the section on PLANNING, feedstock selection can be very important. Depending upon availability and overall complex production plans, a feedstock can be selected to produce a single product or a broad spectrum of coproducts. This is shown for various ethylene feedstocks

MORE

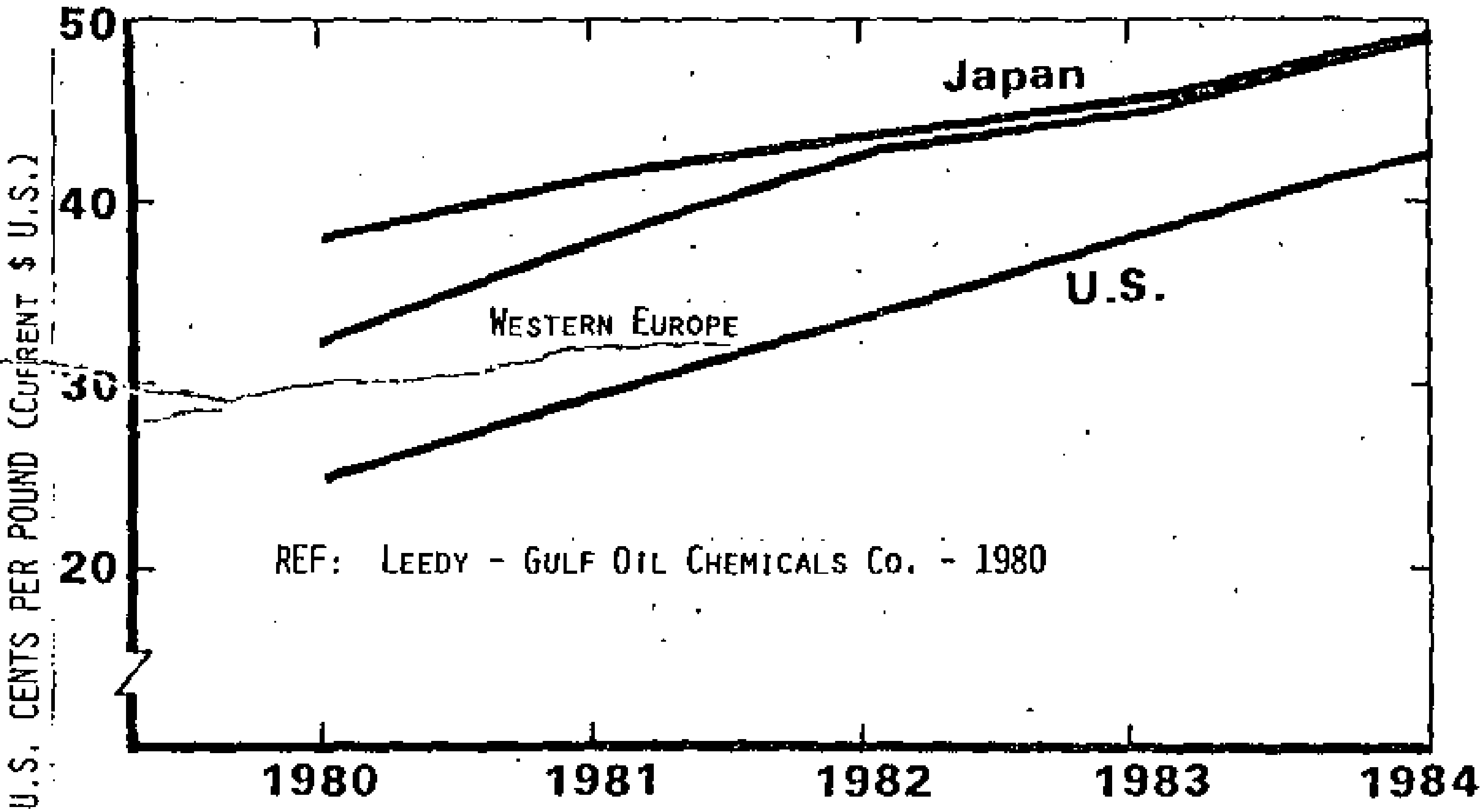
in Plot No. IV-A-14. Feedstock requirements also vary as shown in Plot No. IV-A-15. Notice the increasing amounts required as the feedstock becomes heavier. It should be noted that plants using heavier feedstocks are more complex and require larger investments. However, if there is a market for the coproducts then ethylene unit costs can be competitive. This is referred to as coproduct credit.

Plot No. IV-A-16 presents one projection of polyethylene demand growth.

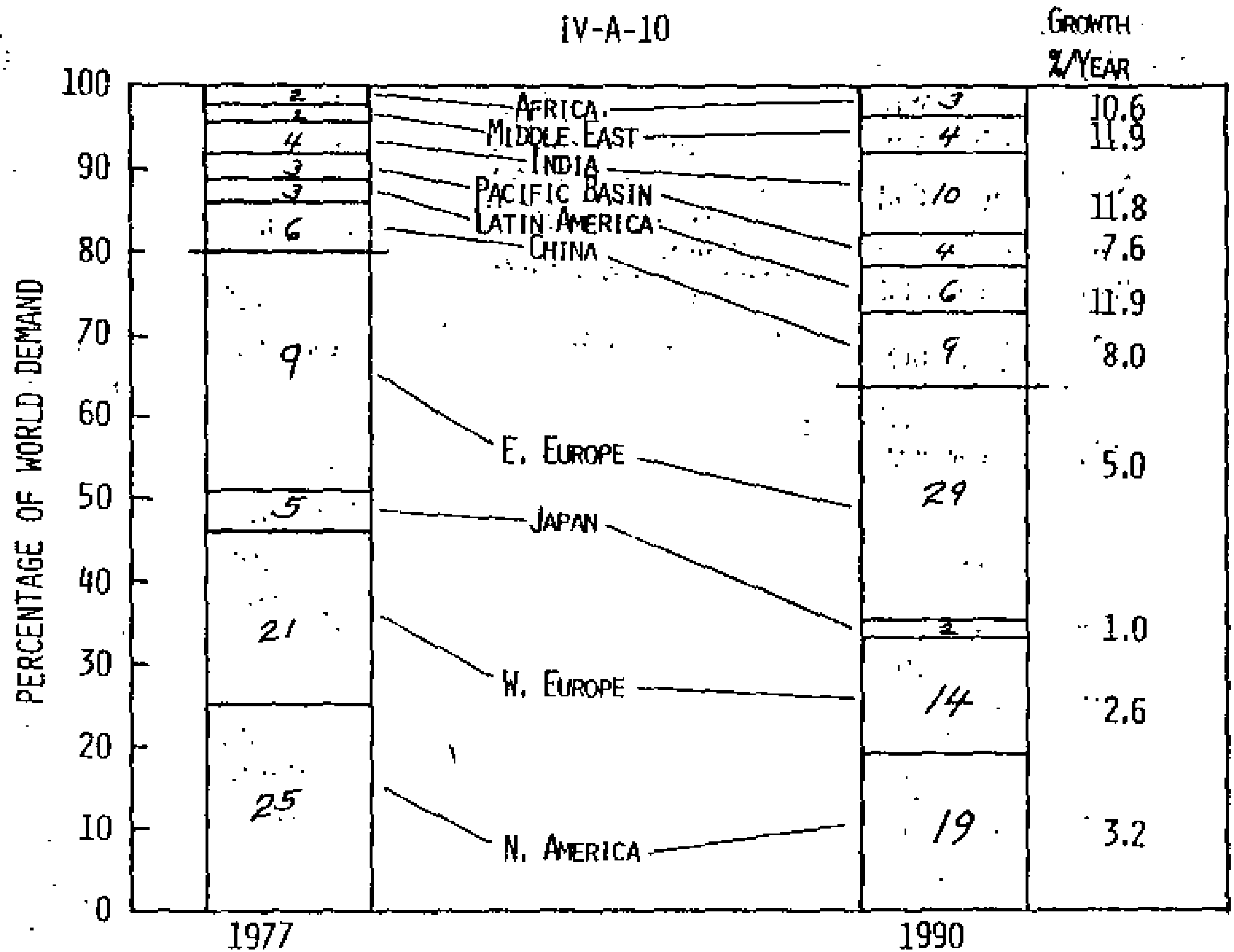

55
45
35
25
15
5
CURRENT U.S. $ PER BARREL
Non-U.S.
U.S.
REF: LEEDY--Gulf Oil Chemicals Co.--1980
1979
1980
1981
1982
1983
1984
AVERAGE REFINER CRUDE OIL ACQUISITION COST



FORECASTED VALUE OF $ U.S. VERSUS GERMAN MARK & JAPANESE YEN



ETHYLENE PRICING FORECAST (CURRENT $ U.S.)

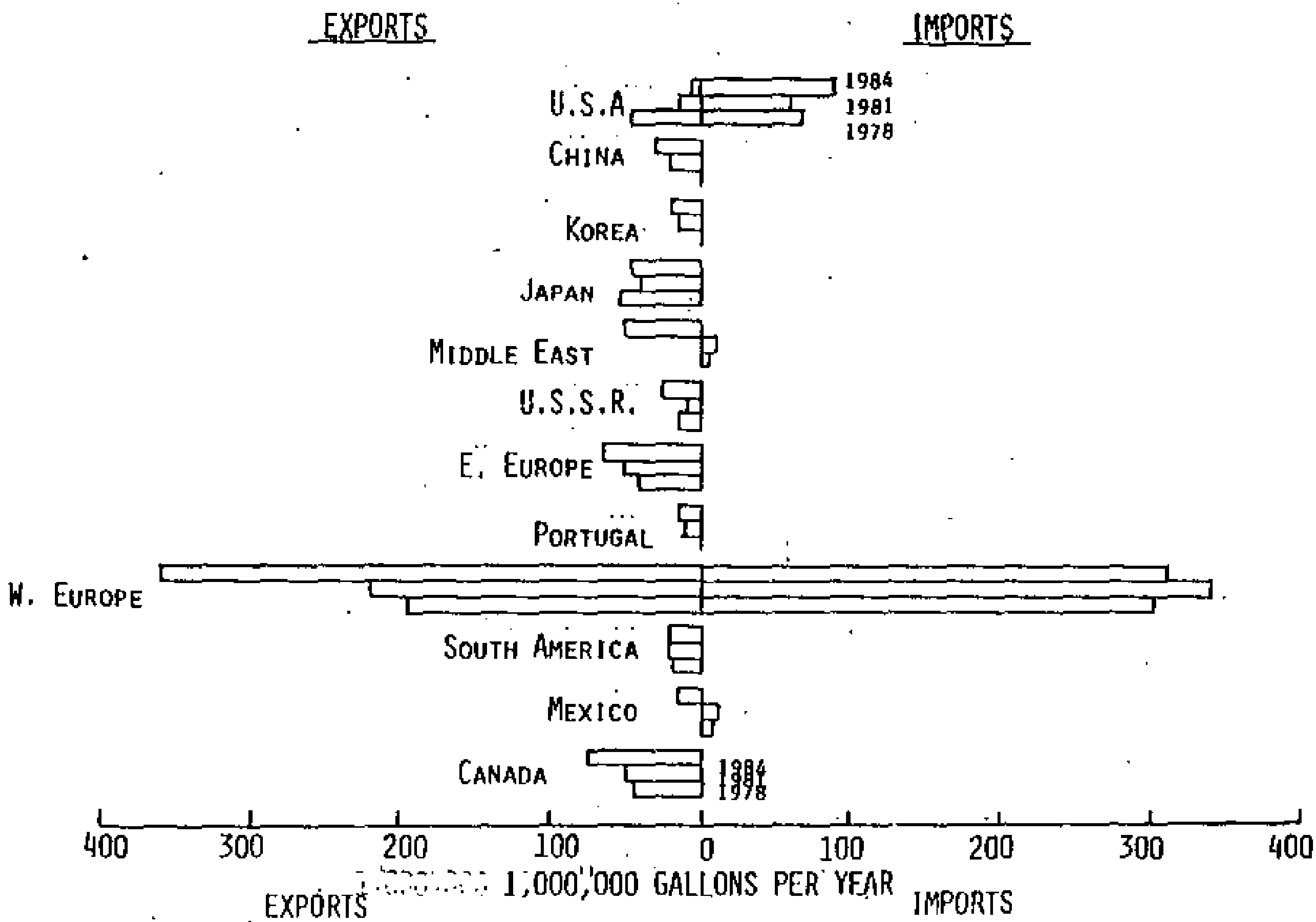


REGIONAL DEVELOPMENT OF AMMONIA DEMAND

Ref: CHEM SYSTEMS

BENZENE MOVEMENTS - 1978, 1981, 1984

REF: LEEDY, GULF OIL CHEMICALS CO.-1980

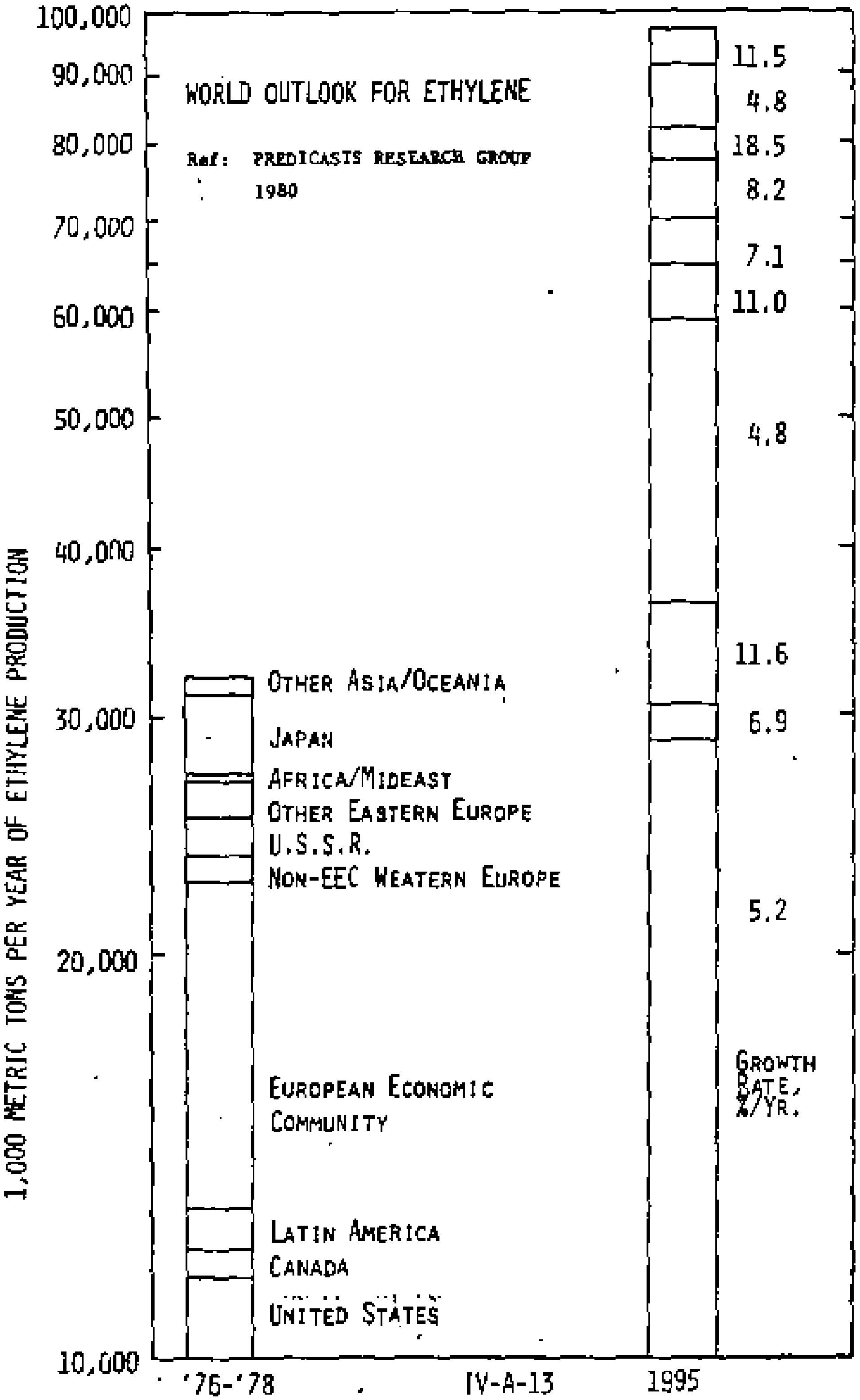


THE WORLD OUTLOOK FOR PETROCHEMICAL SUPPLY

ETHYLENE PRODUCTION BY REGION, 1,000 METRIC TONS PER YEAR

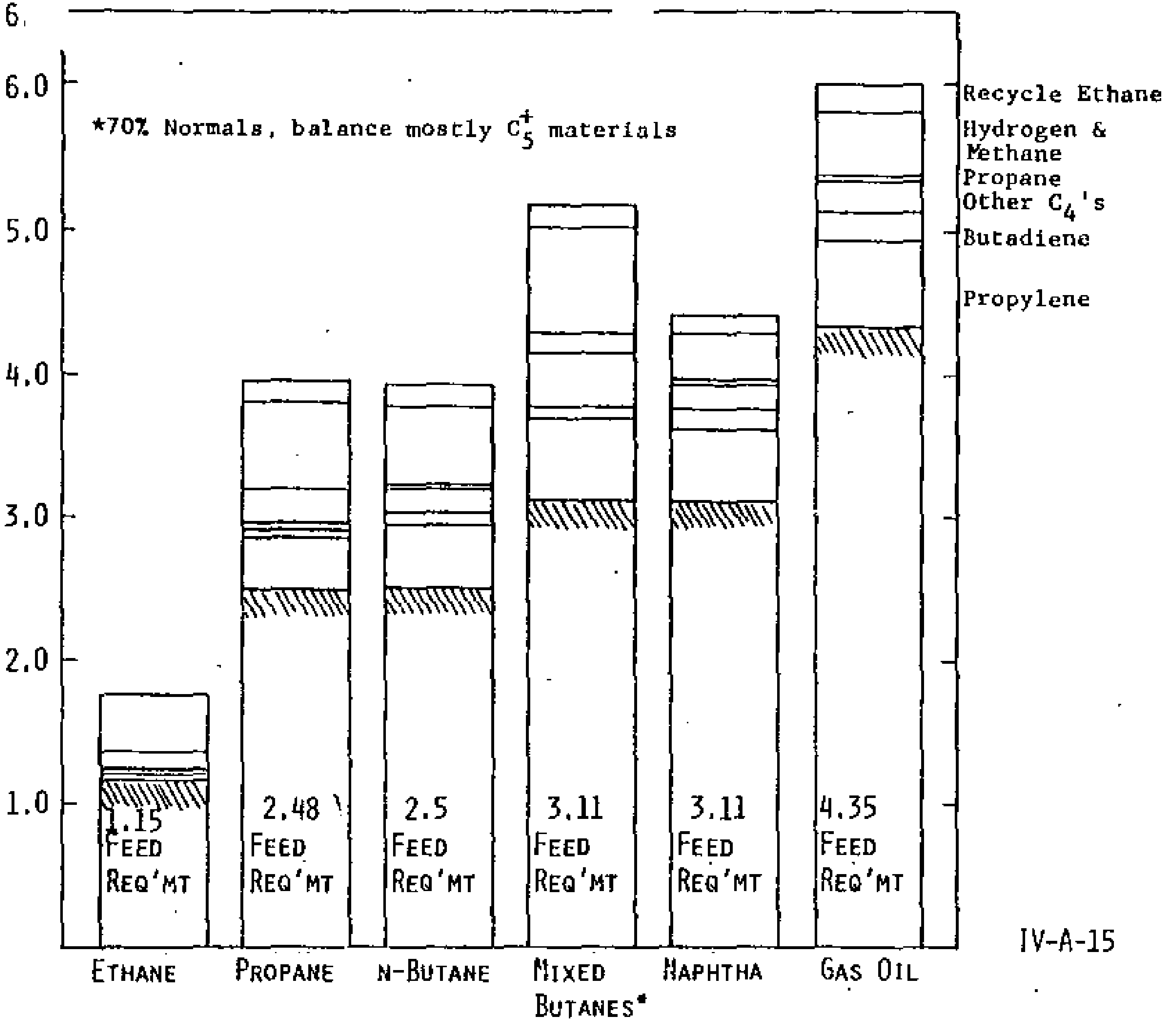
REGION	1976-1978 AVERAGE	1995	GROWTH RATE %/YR
UNITED STATES	11,506	28,750	6.4
CANADA	634	1,925	6.4
LATIN AMERICA	769	5,550	11.6
EUROPEAN ECONOMIC COMMUNITY	9,807	22,875	4.8
NON-EEC WESTERN EUROPE	869	5,650	11.0
U.S.S.R.	1,700	5,825	7.1
OTHER EASTERN EUROPE	1,690	6,975	8.2
AFRICA/MIDEAST	196	4,150	18.5
JAPAN	4,049	9,450	4.8
OTHER ASIA/OCEANIA	832	5,950	11.5
TOTAL	32,052	97,100	6.4

Ref: Predicasts Research Group, 1980


WORLD OUTLOOK FOR ETHYLENE
Ref: PREDICASTS RESEARCH GROUP 1980
1,000 METRIC TONS PER YEAR OF ETHYLENE PRODUCTION
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
OTHER ASIA/OCEANIA
JAPAN
AFRICA/MIDEAST
OTHER EASTERN EUROPE
U.S.S.R.
NON-EEC WESTERN EUROPE
EUROPEAN ECONOMIC COMMUNITY
LATIN AMERICA
CANADA
UNITED STATES
11.5
4.8
18.5
8.2
7.1
11.0
4.8
11.6
6.9
5.2
GROWTH RATE, %/YR.
'76-'78
1995

OLEFIN PLANT PRODUCT YIELDS BASED ON FEEDSTOCK TO PRODUCE 1,000,000,000 POUNDS OF ETHYLENE

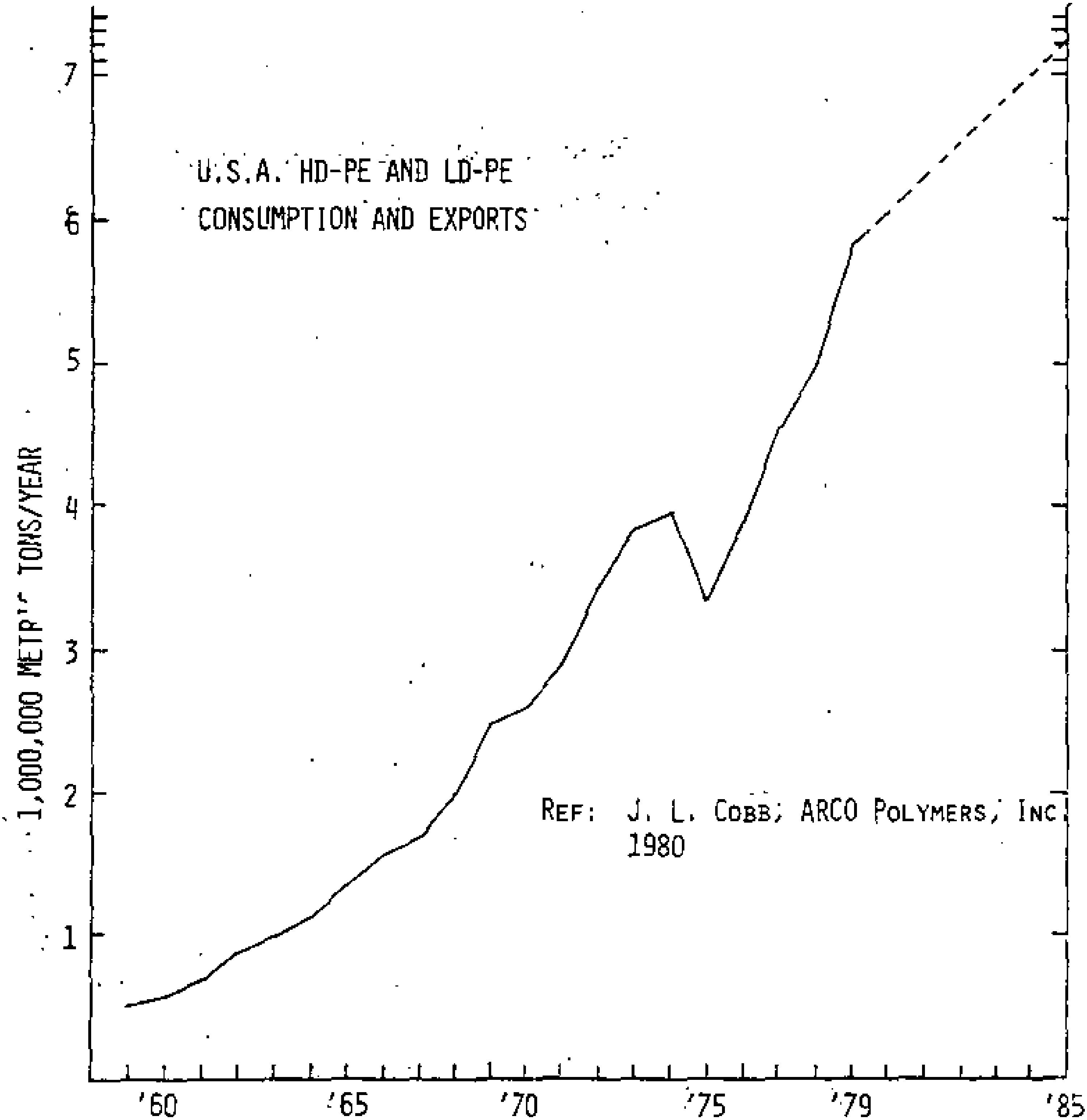
	PRODUCTS, 1,000,000 POUNDS					
FEEDSTOCK	ETHYLENE	PROPYLENE	BUTADIENE	BENZENE	MOTOR FUEL	HEATING FUEL
ETHANE	1,000	40	30	10	25	235
PROPANE	1,000	90	55	45	140	660
N-BUTANE	1,000	630	85	50	225	660
LT. NAPHTHA	1,000	620	170	125	825	540
KEROSINE	1,000	580	175	140	1,170	995
GAS OIL	1,000	680	220	150	1,380	1,270



Typical Ethylene Feed and Co-Product Ratios with Differing Feeds

(Tons/Ton ethylene, assuming ethane recycle to extinction)

Ref: Turner, Louis - Royal Institute of International Affairs, London, April 1980



U.S.A. HD-PE AND LD-PE
CONSUMPTION AND EXPORTS
1,000,000 METR'' TONS/YEAR
7
6
5
4
3
2
1
REF: J. L. COBB, ARCO POLYMERS, INC
1980
'60
'65
'70
'75
'79
'85

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Transactions, "Fifth International Cost Engineering Congress, ICEC, 1978, Utrecht, The Netherlands

FORECASTING HPI PLANT COST

HPI Plant Cost apparently correlates well with total worldwide historical construction activities. Based upon recent historical construction activities—1970-1978—various fluctuations for major equipment and bulk materials as well as total project cost track quite well for major geographical areas.

Therefore, forecasting short-term future cost should be possible—at least for budget estimates—using these historical as well as announced plans for future HPI activities.

This paper is divided into two parts:
1. Data from HYDROCARBON PROCESSING's Worldwide HPI Construction Boxscore is sorted into activities for ten geographical areas. These HPI activities are further classified into four general classifications—(P) Planning, (E) Engineering, (U) Construction and (C) Completing. This data bank—which has been maintained since 1943—was described at an early AACE meeting.[1]

Use of these data in Management Science have been presented and published.[2,3] A previous[4] presentation discussed use of these data to project HPI expenditures in developing countries. Its use in projecting short-term demand for major equipment in ethylene and ammonia plants was the subject of a recent presentation.[5]

2. Will develop a means of forecasting HPI plant cost for the period 1978-1983 by geographical area using data from Part I. Demand for major equipment and bulk materials when correlated with the influence of all HPI plant activities can provide a useful tool to enable the Cost Engineer to better ascertain plant cost trends.

HPI Activities

Although AACE members are familiar with the HPI Construction Boxscore from previous presentations,[1,3] a brief description is in order. Since 1943, HYDROCARBON PROCESSING has surveyed—on a continuous basis—some 1,500 operating companies, engineering firms, construction firms, and licensing groups. These data are stored in an electronic data processing system so that they can be retrieved in a variety of sorts. Each activity stored represents a capital expenditure of at least $1 MM. These data are currently published and distributed "free" in February, June and October of each year. Special sorts are available through the Sales Division of Gulf Publishing Company.

The period June 1970 through February 1978 is used in this presentation. Space and time restricts us to trend lines. However, we will point out several interesting time/track data points. Also, the influence of capacity and actual production for several products in the geographical areas analyzed upon these activities and total activities could be demonstrated but must be omitted here. Suffice to state, there is a definite correlation.

Geographical areas. For this paper, the world has been classified into ten geographical areas: United States, Canada, Other Western Hemisphere (Latin America), Europe, COMECON, Africa, Middle East, Far East, China (P.R.C.) and Australasia.

Activity status. Each HPI activity, when reported and confirmed in writing, is assigned a status classification as mentioned above. The status is updated three times each year and changes made upon confirmation. Activities are reported only once upon Completion and removed and stored on the Master Tape. Therefore, historical data can be retrieved chronologically for background and historical studies.

In-house application. Each year, HYDROCARBON PROCESSING supplies data to the Gulf Publishing Company's Sales Division, based in part on the HPI Construction Boxscore data, which is published each September as a "free" booklet. This "free" booklet, called HPI Market Data Booklet projects HPI capital expenditures for the coming year. The HPI, as used here, includes refining, gas processing, petrochemicals and solid fuels processing. Areas of interest include capital expenditures for new projects, maintenance, environmental control, as well as fire and safety material and equipment.

Forecasting Data Base

Total activities

Fig. 1 shows the historical pattern of Total Worldwide HPI activities. Notice the dip from the 1973 war followed by the rapid recovery. The maximum was less than 500 activities off a steady ...rn of around 3,000. We see no reason for another significant deviation from a history of almost four years of 3,000 plus activities.

Geographical distribution

Figs. 2, 3 and 4 show our ten geographical areas with total HPI activities over the period October 1970-February 1978. Fig. 2 shows the U.S., O.W.H. and Canada--the Western Hemisphere. For the U.S., maximum rate of change has been about 9 percent for any reporting period. After the 1973 dip, the U.S. has held around 700 activities. O.W.H. has shown the least deviation rate and has regained to a steady 400 activities. Canada appears to be rather erratic; however, this is a semilog plot and rate of change has actually been less than those of the U.S. for identical periods. Canada should continue at around 90-100 constant total activities.

Fig. 3 shows Europe, the COMECON and Africa. Europe has held steady and had a steady decline. However, we now notice a slight recovery and holding around 650. Depending upon COMECON activities, which appear back on their steady rate begun in 1974, European activities may decline for such activities as we call HPI. Africa appears on an upturn and we expect this to hold.

Fig. 4 shows the Far East, the Mideast, the P.R.C. and Australasia. As the Far East was declining, the Mideast began to rise. Our data from the P.R.C. on' ...became reliable in 1973. There was a rapid g... rate followed by a decline, probably due to ha... currency problems, which seems to have stabilized at around 70 activities. Australasia has always been up and down and presently appears in a steady decline.

Status tracking. The problem with electronic data banks is protecting oneself from the paper "flood." Therefore, we have selected data shown in Figs. 5 and 6 by carefully asking the machine for only a bit of its fantastic memory. The period October 1975 and February 1978 are well within normal human recall. Also, these have been placed in one well-known geographical area and one rather broad area. This selection was made in order to better understand certain trend lines we shall discuss below.

Again, we find the familiar P, C, E and U status plotted for the U.S. in Fig. 5. Notice how E and U track very closely if one slides E to the left to account for normal engineering time and U to the right to account for prolonged construction periods. Completing, while appearing rather "saw-toothed," tracks quite well when the two earlier factors are moved to their approximate position.

Notice the rather sudden decline and virtual flattening of the P line after June 1978. This is important in analyzing U.S. data as it pertains to a lack of an energy policy and reliable government leadership. Actually, most of these activities are "world scale" and engineering time and construction perio... may extend. This shows a very flat activity for ...U.S. for at least five years ahead. This mig... ...ve been ascertained from Fig. 2; however, it is emphasized here. One key to future cost may well lie in reported planning activities. Without burdening you with the entire data bank, permit a statement that "There is a definite correlation between planning activities and the others."

Another trend seen from Fig. 5 is the sharp increase in engineering activities. This further emphasizes the importance of the transition from planning to engineering. These are already beginning to show in construction activities and will eventually be reflected in completing.

Perhaps a word of caution is in order. The old axiom about computers--garbage in, garbage out--does not prevail here. For example, this data bank is scrubbed quarterly for cancellations and bad data. In the February 1978 "scrubbing," only ten of 3,000 activities were removed for "bad data." By means of this constant surveillance, current reports are within tenths of a percent of actual reported and confirmed inputs. While it is not our purpose to authenticate these data (and we have nothing to sell), it is important that you understand the surveillance exercised in maintaining this data bank.

Keep in mind, Fig. 5 is a somewhat detailed analysis of approximately 700 HPI activities. Notice the corresponding percentage relationship for the various activity status conditions for each reporting period. For example, in February 1978, approximately 58 P's, 140 C's, 170 E's and 285 U's were reported for the U.S. This is about 9 percent Planning, 26 percent Engineering, 44 percent Under construction and 21 percent Completing. Thus, for short-term forecasting, e.g., five years, E and U with careful watch on C would suffice. However, for longer range forecasting, e.g., ten years plus, a careful study of historical, current and future P data must be used.

Turning to Fig. 6, which is for Outside the U.S. (a rather large grouping of activities), notice first the effect of a large data bank. Smoothness and close tracking of P, E and U are quite obvious. As you would expect, Completing can be easily understood considering the large number of activities in rather harsh climates. Again, this is reflected in the rather constant (or flat) U and E plots. It just takes more engineering and construction time for the large O.U.S. activities as well as some of the smaller ones.

Cost Engineers realize the difficulties of Completing an activity in certain harsh and hostile climates where much of our activities are occurring today—and most likely will continue in the near term.

Therefore, I would suggest that these data are useful in all phases of Cost Engineering and especially in the Management Science Area.

WORLDWIDE MATERIAL COST INDICES

General

The world is steadily evolving into a single world economy with cycles that affect trade and commerce occurring more or less simultaneously around the world. Currently, the Western World and Japan operate on closely interrelated cycles. The current recovery in the United States is slowly spreading to Western Europe. The economic activity in the nations that supply raw materials depends ultimately on the vitality of the consuming nations.

With a modern, efficient steelmaking plant, Japan has developed a competitive edge over domestic steelmakers in some industrialized nations in the Free World. Japan has demonstrated some farsighted vision in its actions to restrict its imports into the United States and Western Europe. Some Oil producers, like Saudi Arabia, have supported restraints on oil prices in recent years. These restraints have helped hold the line on energy costs and have allowed the industrialized nations to proceed along the path of economic recovery.

United States Direct Material Indices

Pullman Kellogg has developed correlations for many BLS indices covering the various classes of equipment and bulk materials used in our process plants. For example, piping includes pipe, flanges, fittings, valves and shop labor. We ascertain the current status of specific commodities from monthly meetings with our Procurement Department. Covered are such factors as demand, shop loadings, delivery lead times, increase or decrease in number of acceptable vendors and the general feeling of where the market is heading by the vendors of these direct materials.

We have had a measure of success in developing these correlations for the United States. Fig. 7 shows a plot of a weighted multicommodity BLS plant index utilizing 1971 as base 100. We recognize that the BLS indices, when compared to Pullman Kellogg's actual direct material cost experience in which we measure what we paid in the market place for our materials at that point and time, tend to understate the full magnitude of price increases during rapidly rising cost periods, such as occurred during 1973-75. A prime factor is the inability of the BLS system to recognize changes in the quantity discounts obtained by contractors who buy large quantities from specific vendors and manufacturers. During times of relative stability, there is a general tendency for the BLS indices, at least for certain commodities, to somewhat overstate the projected cost when compared to actual marketplace transactions as indicated by our experience. For example, in Fig. 7, the actual market showed a decrease during 1976 as compared to most BLS indices which showed a small increase.

Outside the United States

In order to develop new tools to assist in forecasting worldwide direct material price trends, we [illegible]parated the world into ten geographical areas as discussed previously. We plan to develop forecasts and then track them for the period 1978 through 1985 based on worldwide HPI activities.

Our original plan was to look at process plants only in the ethylene and ammonia sectors, with particular emphasis on (P) Planning and (E) Engineering classifications. We found a good correlation for the United States when all HPI activities, regardless of state of completion and type of plant, were utilized. In hindsight, this would seem to make sense since the demand for bulk materials and equipment really does not depend on the type of process plant, but more likely on the volume of process plants required to be built.

One major factor that needs to be accounted for is the effect of location of suppliers of worldwide direct materials in relationship to the countries where these plants will be built. Many of the ten geographical areas are essentially developing nation areas with minimum capabilities relative to the supply of direct materials. Therefore, need to monitor cost trends may of necessity be limited to those industrial centers such as the United States, Canada, Japan and the EEC (European Economic Community), rather than all of the ten geographical areas. This approach would require grouping process plant facilities based on the prime source of vendor materials. Unfortunately, many offshore U.S. projects will have suppliers of direct materials from several of the major developed nations. Therefore, the [illegible]lation forecasts, although related to total HPI [illegible]vities, will have to be closely examined in order to develop a tool that fits the real world.

Figs. 8 and 9 utilize data published in Engineering and Process Economics (EPE) by John Cran.[6] Those curves when plotted seemed to have little correlation with the HPI activities.

These indices, based on BLS or other published information, record past history only. What is of vital interest is the future. Most important are the inflection points when changes in the price trends occur. To ascertain these points, it is absolutely essential to know precisely where, from a tracking point of view, we are at any given point in time.

Pullman Kellogg utilizes econometric models to make projections from various BLS indices for the United States. Through geographical economic relationships, we plan to monitor and adjust our forecasting mechanism.

We hope through utilization of proper evaluation techniques to utilize the HPI Construction Boxscore to assist in making accurate forecasts, recognizing the critical factors that affect the cost of direct materials in the worldwide Hydrocarbon Processing Industries.

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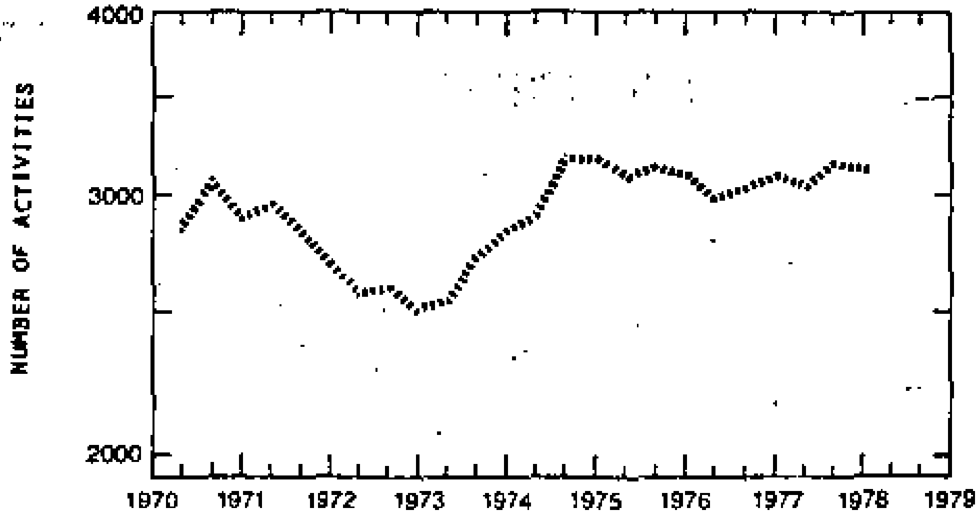
Acknowledgments

The speakers wish to especially acknowledge the data analysis so carefully prepared by Ms. Riddle and the Gulf Publishing Company for being permitted to present this "in-house" analysis publicly.

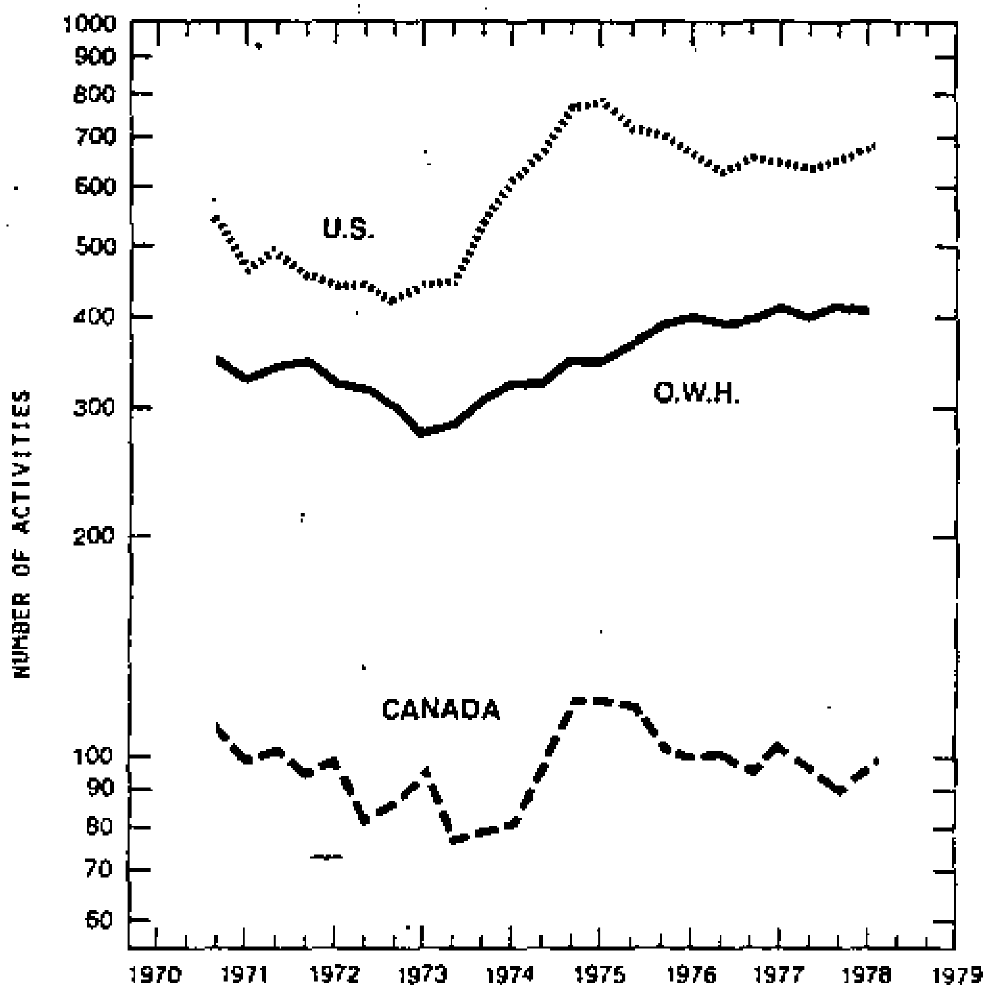
TOTAL WORLDWIDE HPI ACTIVITIES



HYDROCARBON PROCESSING – 1978

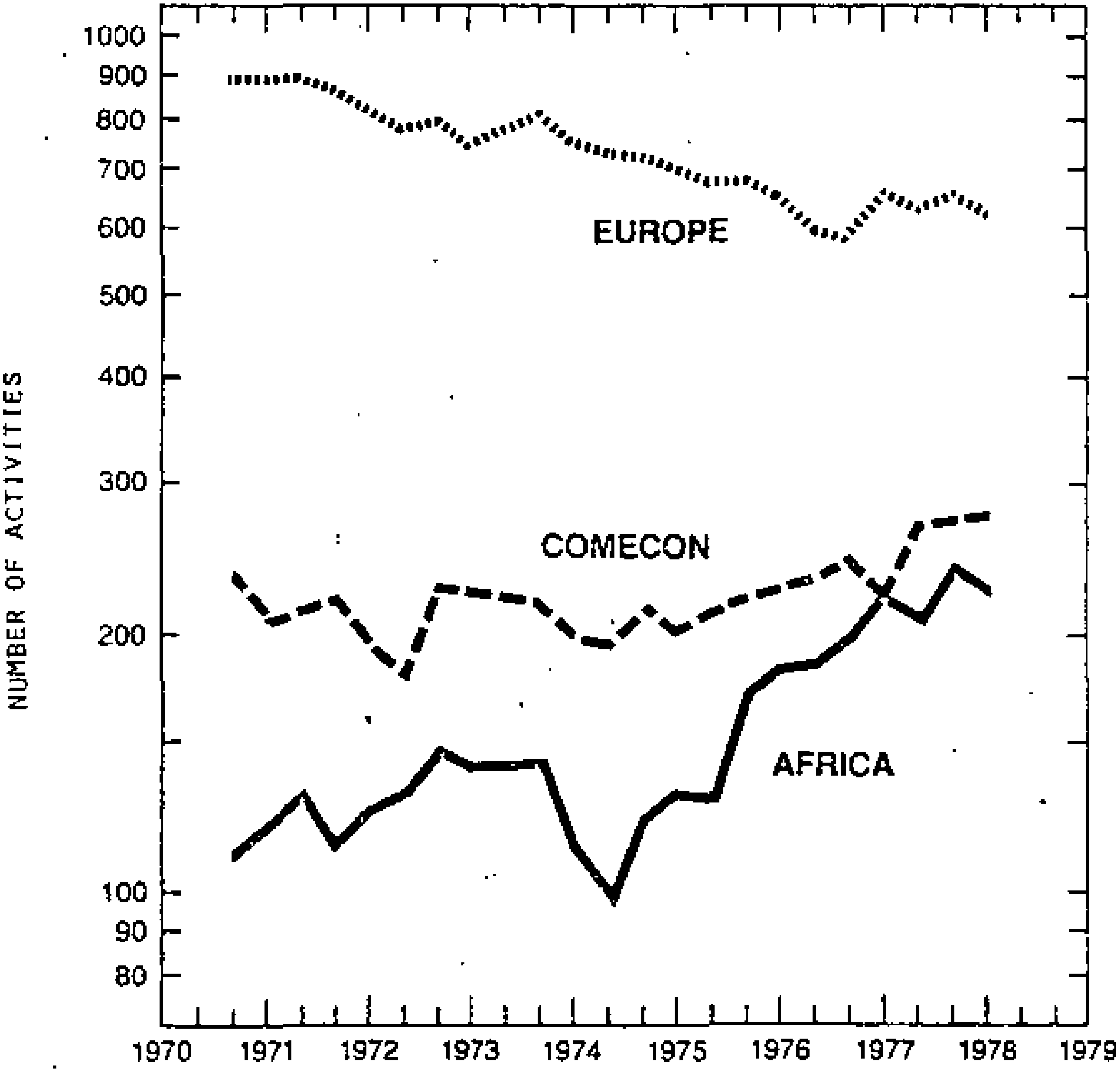
FIGURE 1

GEOGRAPHICAL DISTRIBUTION OF WORLDWIDE HPI ACTIVITIES



HYDROCARBON PROCESSING – 1978

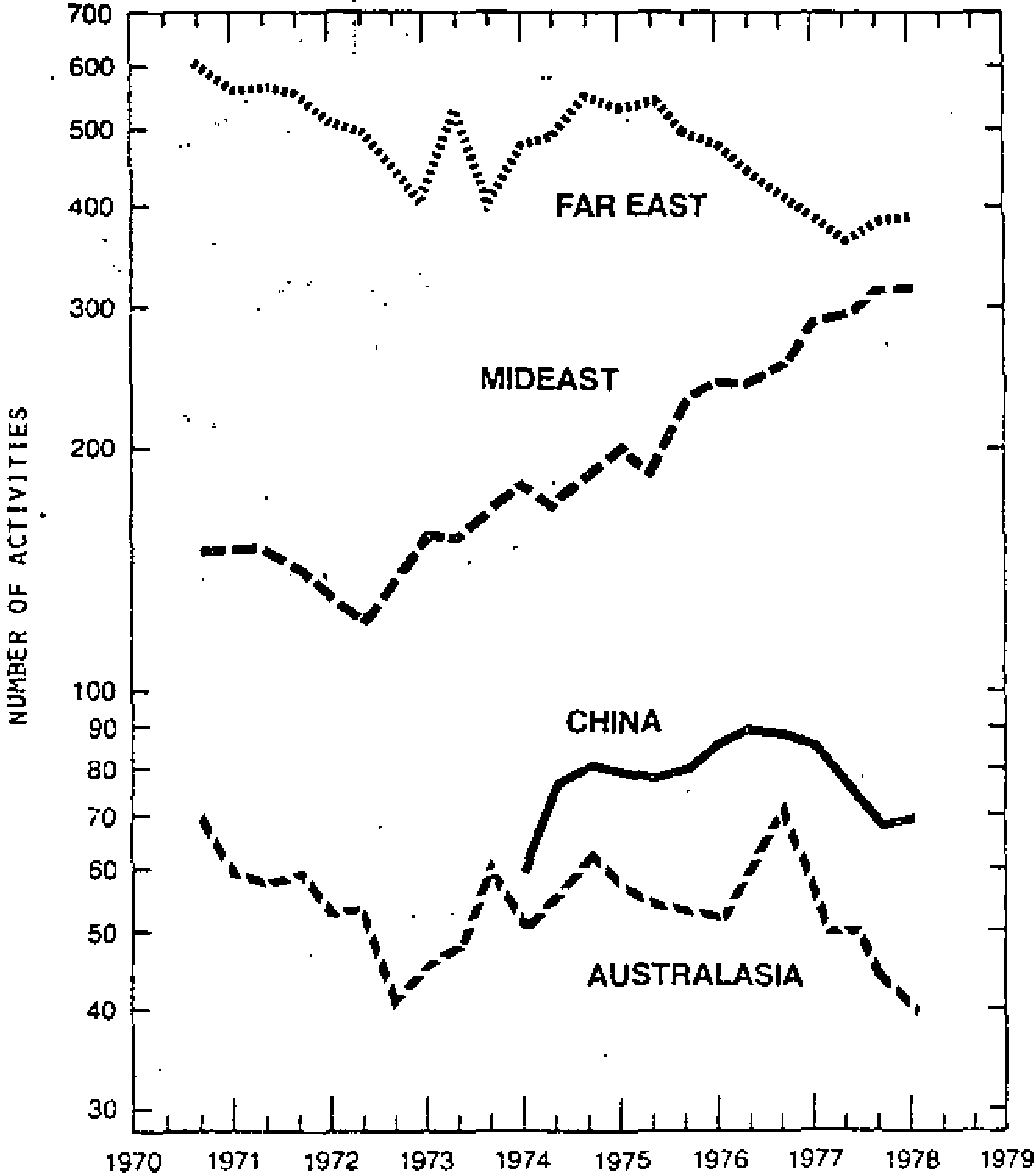
GEOGRAPHICAL DISTRIBUTION OF WORLDWIDE HPI ACTIVITIES



HYDROCARBON PROCESSING – 1978

FIGURE 3

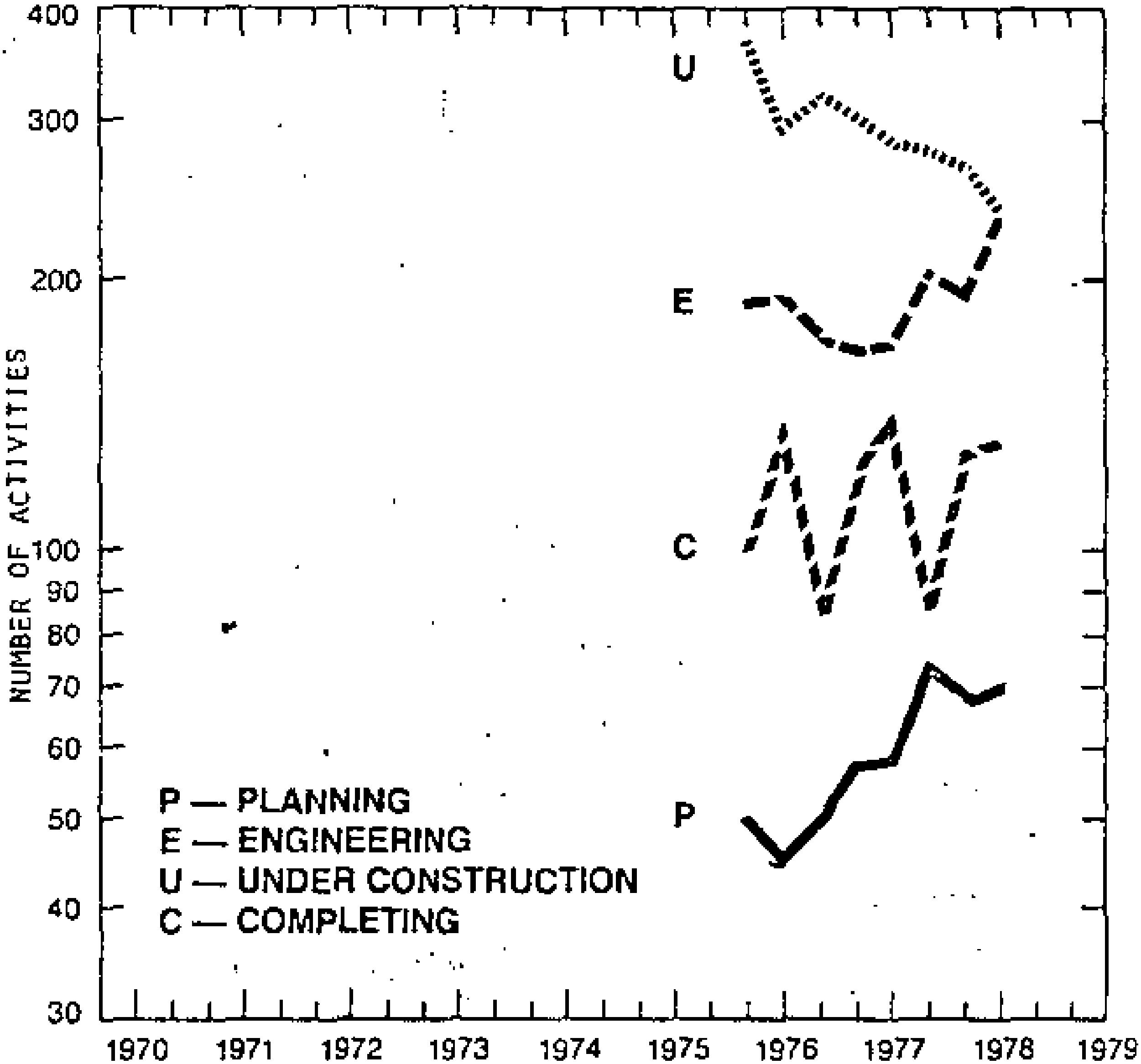
GEOGRAPHICAL DISTRIBUTION OF WORLDWIDE HPI ACTIVITIES



HYDROCARBON PROCESSING – 1978

FIGURE 4

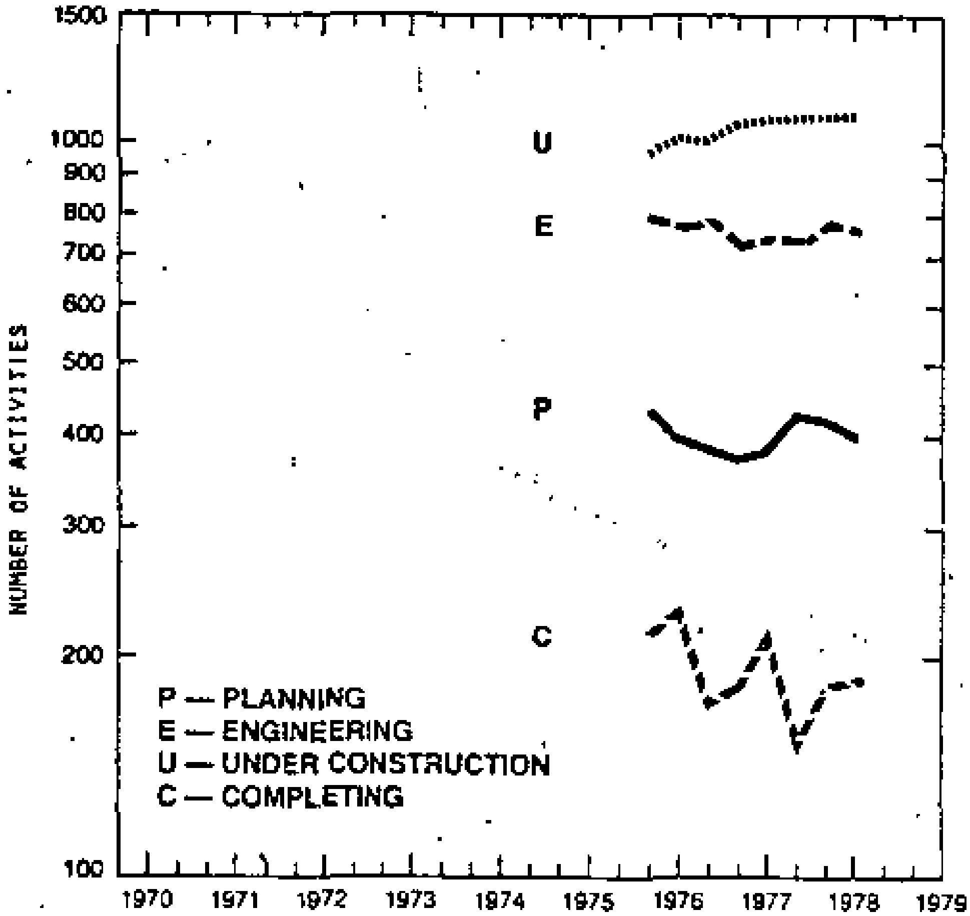
TOTAL U.S. HPI ACTIVITIES
PROJECT STAGE



HYDROCARBON PROCESSING – 1978

FIGURE 5

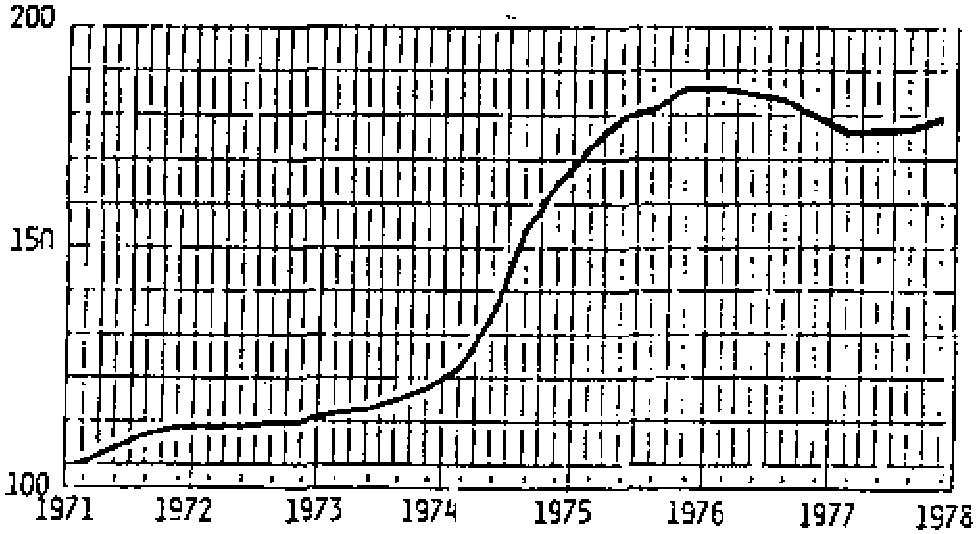
TOTAL O.U.S. HPI ACTIVITIES PROJECT STAGE



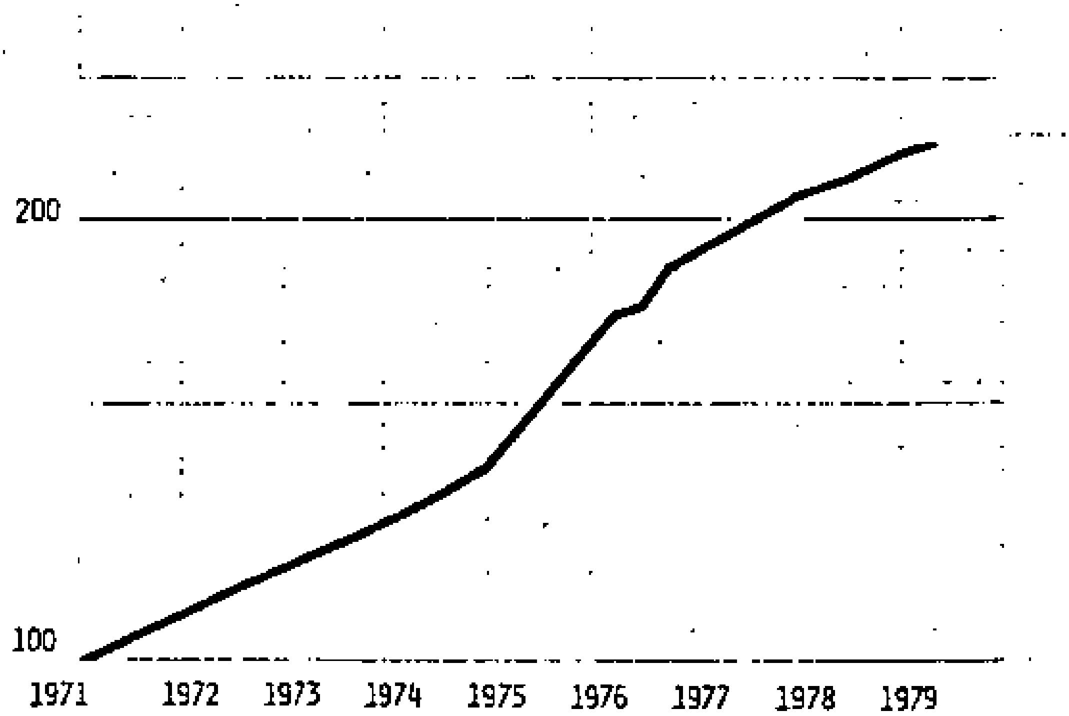
HYDROCARBON PROCESSING – 1978

FIGURE 6

BUREAU OF LABOR STATISTICS INDEX
26 SELECTED COMMODITIES WEIGHTED FOR NH_3 PLANT
ESCALATION ANALYSIS



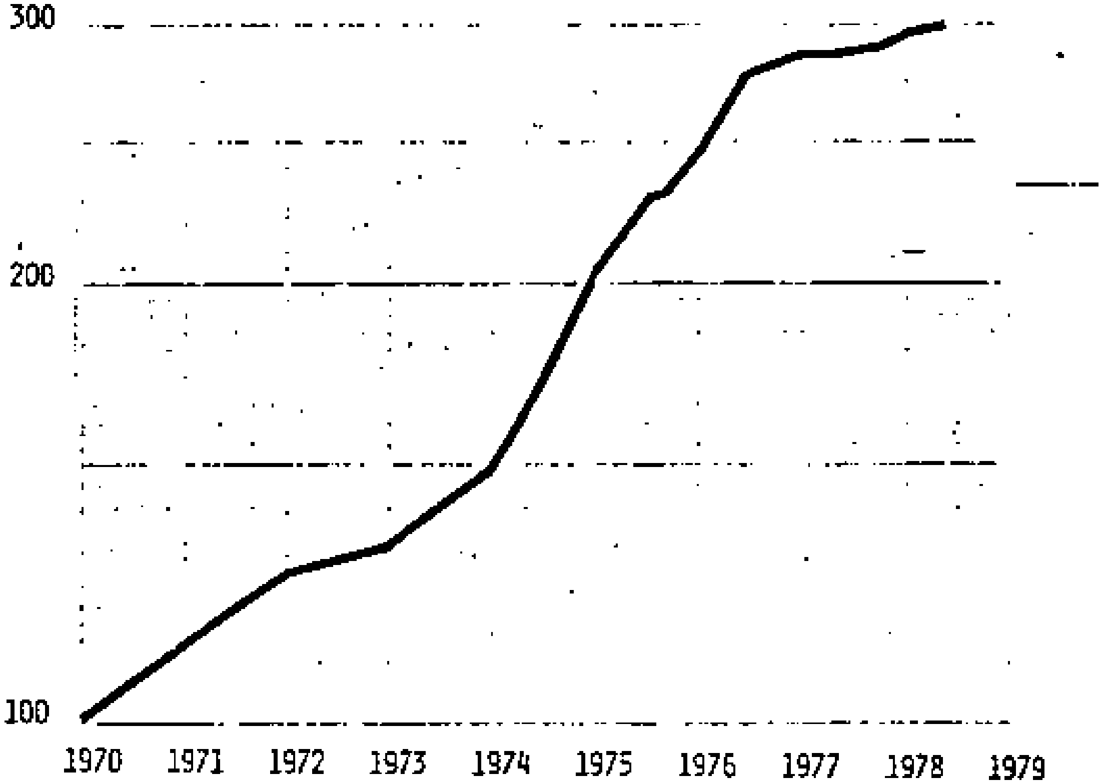
SOURCE: U.S. DEPARTMENT OF LABOR



SOURCE: ENGINEERING AND PROCESS ECONOMICS

FIGURE 8

UNITED KINGDOM



SOURCE: ENGINEERING AND PROCESS EOCNOMICS

FIGURE 9

Increase your plant's productivity

The key is to establish a formal program, with top management support. It should have realistic, measurable goals, and a system to evaluate and report improvement

Richard F. Baker, American Productivity Center, Houston

PLANT MANAGERS can get good results from what may be termed a "total productivity" concept. This pertains to the efficient use of *all* company resources. It is a coordinated methodology for managing the many complex ·tors which affect plant productivity. By incorporating ᵢ concept as an integral part of the plant's management process, managers can ensure that the proper resource trade-offs are being made for maximum plant productivity improvement. A coordinated productivity improvement program will provide the organization and the processes by which productivity gains can be achieved.

Low growth of productivity. Later, I'll cover some of the "how to" aspects of implementing a *total productivity* program in an HPI plant. But first, a word about the rationale for *why* such a program is needed. To start with, the recent declining rate of productivity growth in the United States emphasizes the critical need for plant managers to strengthen their productivity improvement performance.

In the past, U.S. productivity increases contributed to high employment levels, low inflation and the highest standard of living in the world. The superior level of U.S. manufacturing productivity enabled the nation to establish itself as the dominant industrial nation in world markets. In recent years, however, this position of strength and dominance has begun to erode. Compared with other major industrialized countries, the United States is now last in terms of productivity growth. (See Fig. 1.)

The United States is rapidly losing its competitive lead in the world economy. Foreign trade balances are nega- contributing to the steady decline in the value of the dollar. Domestically, inflation and unemployment are undesirably high, while the average standard of living is improving minimally.

Manager's performance. To regain lost ground, the private sector, and particularly individual plant managers, must take the lead in managing for productivity growth. A manager who incorporates productivity improvement into his short and long-term operations helps to alleviate inflationary cost increases. He thereby contributes to an improved competitive position and increased profits for his company.

The ability to hold down costs and increase profits is an important measure of a plant manager's performance. Managing a plant's total productivity is a valuable technique for achieving these objectives.

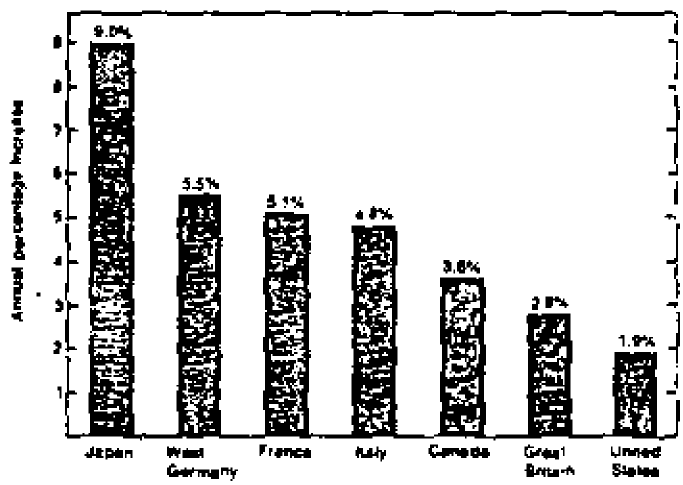


Fig. 1—Average productivity growth percentage (output per hours worked), 1965-1976.

Total productivity concept. Productivity is the efficiency with which resources are used to produce goods and services. It is generally expressed as a ratio of outputs to inputs. The most common productivity ratios in use are those published regularly by the Bureau of Labor Statistics: *Output per Employe and Output per Employe-Hour.* However, these ratios only consider the efficiency of using human resources and thus are partial productivity measures. (See Fig. 2.)

Hydrocarbon processing industry (HPI) operations are very capital and energy intensive, while feedstocks are a major portion of total costs. Consequently, partial productivity ratios pertaining to the efficiency of capital, energy and feedstock use provide important additional measures of plant performance. What is needed to

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Partial productivity

$$\frac{\text{Output}}{\text{Labor input}} \qquad \frac{\text{Output}}{\text{Capital input}}$$

$$\frac{\text{Output}}{\text{Feedstock input}} \qquad \frac{\text{Output}}{\text{Energy input}}$$

$$\frac{\text{Output}}{\text{Materials input}}$$

Total productivity

$$\frac{\text{Output}}{\text{Total inputs}}$$

$$\frac{\text{Output}}{\text{Labor} + \text{Capital} + \text{Feedstocks} + \text{Energy} + \text{Materials}}$$

Fig. 2—Partial and total productivity ratios.

properly evaluate plant productivity, therefore, is a family of productivity ratios relating plant output to each of the various resources used in the plant process.

Making trade-offs. During the normal course of daily operations, HPI plant managers frequently make trade-off decisions between various factors of production (e.g., capital investment vs. energy consumption, or maintenance down time vs. plant production). The result of such decisions may cause a particular partial productivity ratio to decline. But if the proper business decisions are made, the total productivity ratio (total output over total inputs) should improve. For example, an energy conservation capital investment will increase energy productivity while decreasing capital productivity (assuming no effect on output). If the investment was properly made, the net effect on total productivity should be positive. In the total productivity ratio, as in the family of partial productivity ratios, the outputs and inputs must all be measured in physical units or in constant dollar terms to remove the effects of inflation.

The *total productivity* concept is a management philosophy in which all plant resources—human, capital, energy, materials, feedstocks—are used in such a manner as to optimize total plant productivity. This philosophy leads directly to maximizing cost reduction and profitability objectives.

FACTORS AFFECTING TOTAL PLANT PRODUCTIVITY

Total plant productivity is affected by a complex interrelationship of technical and human factors involving nearly all aspects of plant management. Effective plant productivity improvement requires that all of these factors be managed as an integral socio-technical system.

Technical factors. Plant and equipment, inventories, feedstocks, energy and materials are the physical inputs of an HPI plant. The relationships among the technical factors affecting the efficiency of processing these inputs into the plant's products are illustrated in Fig. 3.

Plant productivity is a primary function of plant thruput (or product production), product yields and the quantities of resources consumed in the process. Each of these primary factors are, in turn, affected by various secondary, organizational and external factors. The organizational factors pertain to the plant's organization structure, policies and management performance. External factors are those which normally fall outside the operational control of plant management. Variations of this diagram will occur to account for individual company circumstances.

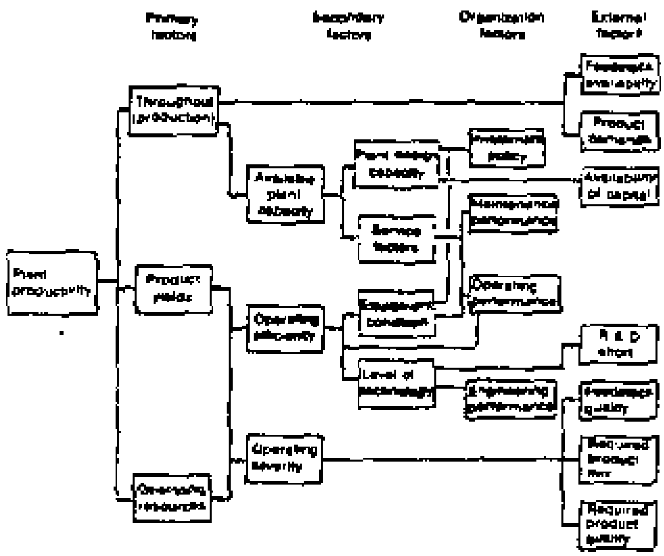

Fig. 3—Relationship of technical factors influencing productivity of an HPI plant.

Energy: an example. As an example of the manner in which these factors affect productivity, consider plant energy productivity. As an output/input ratio, energy productivity can be stated in such terms as Barrels Processed/Btu Energy Consumed or Pounds Produced/Mcf Gas Burned. The total volume of plant thruput (or production) is controlled by one of three factors: feedstock availability, product demand or available plant capacity. The yield of plant products

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can be affected by many factors including: feedstock quality, the required mix and quality of products and the operating efficiency of the plant. These factors all influence the final output—the numerator of the productivity ratio.

Energy consumption—the denominator—is determined by the level of plant thruput (or production) and by the efficiency and severity of the plant operation. The condition of equipment and catalysts, the level of plant technology (automation, energy conservation equipment, etc.) and performance of the operating, maintenance and engineering functions all influence the plant's energy efficiency. The relationship of plant output to energy consumption is the desired energy productivity ratio. Similar partial productivity relationships can be evaluated from Fig. 3 for each of the plant's primary resources.

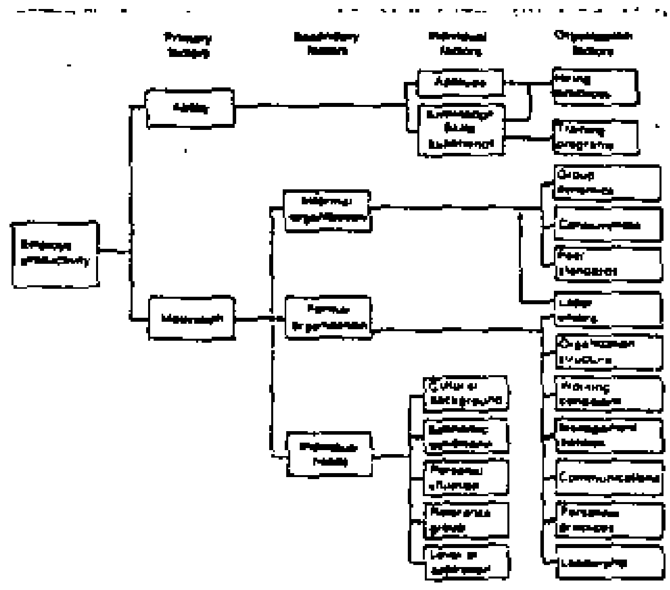

Fig. 4—Relationship of factors influencing employe productivity.

Employe factors. As vital to the operation of any HPI plant as the technical systems are the employes and their individual contributions to plant productivity. Equipment makes production possible, but people make it happen.

Fig. 4 illustrates the relationships among many of the factors affecting employe productivity. Those factors related to employe ability can generally be controlled with effective recruiting, hiring and training programs. The primary key to improving employe productivity involves strengthening employe motivation through satisfaction of the various individual and organizational needs indicated in Fig. 4.

The emphasis on employe motivation should be to encourage employes to work smarter rather than harder. Obviously, reduction of employe idle time, such as may exist due to maintenance work scheduling problems, will have a positive effect on productivity. But with the highly automated, capital intensive nature of most HPI plants, more important gains can be realized by enhancing the employes' contributions toward more efficient use of the plant's physical resources—feedstocks, energy, materials and capital. For example, the productivity contribution of process unit operators relates much more closely to the effect which the operators have on unit yields, energy consumption and equipment maintenance than it relates to the physical effort of the operators.

Total plant productivity. The technical factors and employe factors affecting plant productivity are not independent systems. They necessarily operate together to form the total socio-technical system within which the plant's total productivity is determined. The common relationships between the systems shown in Figs. 3 and 4 are the organizational factors.

Management policies directly affect the productivity of both the plant and employes. In addition, the collective

AMERICAN PRODUCTIVITY CENTER

American Productivity Center (APC) is a privately funded, non-profit organization dedicated to improvement of productivity and the quality of working life in U.S. industry. APC was conceived by Dr. C. Jackson Grayson, Jr., former business school dean at SMU and chairman of the U.S. Price Commission from 1971-73.

Dr. Grayson realized that while most U.S. firms agree that productivity is important, most do not have coordinated, ongoing productivity improvement programs. With approximately $13 million of pledged financial support and loaned executive talent from over 100 U.S. corporations, APC began operations during 1977.

Services include seminars, workshops, consultation, manuals and information services. Products being developed include:

- **Productivity awareness programs**—publications, films, slides, tapes, speech materials and posters related to productivity
- **Productivity information services**—books, periodicals, reference services, data bases, research sources and case studies
- **Productivity appraisal methods**—briefings and seminars on how to identify the most productive areas in which to direct improvement efforts
- **Company productivity programs**—special briefings on how to plan, implement and manage productivity improvement programs
- **Productivity measurement methods**—briefings and seminars on how to measure productivity at the company or plant level
- **Multi-firm comparisons of productivity data**—confidential collection and analysis of productivity data in conjunction with industry trade associations
- **Inflation and Unemployment: The Productivity Solution**—a special conference of top business, government and labor leaders, emphasizing the need for mutual cooperation to reduce inflation and unemployment through productivity improvement.

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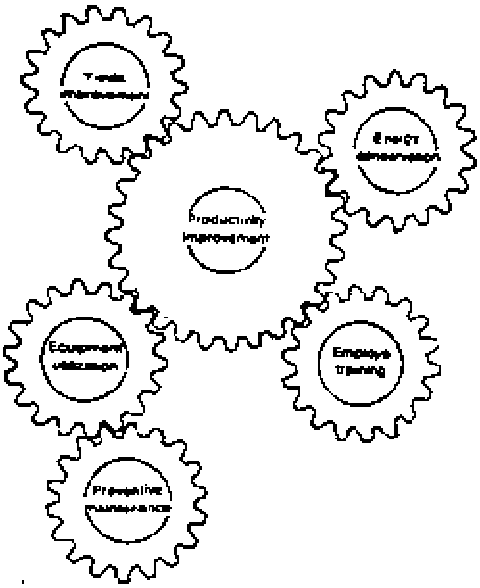

Fig. 5—A productivity improvement program coordinates other special programs. They are interdependent.

productivity of the employes establishes the operating, maintenance and engineering performance factors which have a major impact on total plant productivity.

Three primary conclusions can be drawn from this analysis:

1. Total plant productivity is influenced by a complex interrelationship of technical and human factors.

2. Plant managers must approach productivity improvement efforts on a total systems basis, evaluating all relevant factors and trade-offs between resources.

3. Apart from efficient operating and maintenance practices, the key to improving total productivity lies in motivating employes to increase their contribution to greater plant efficiency and resource utilization.

PRODUCTIVITY IMPROVEMENT PROGRAMS

The nature and importance of productivity may be clearly understood by plant management. And yet, there may be a natural reluctance to initiate a comprehensive productivity improvement program at the plant. Typically, managers and supervisors are already overburdened with special programs—energy conservation, health and safety, preventative maintenance, employe training, cost reduction, environmental, EEO, etc.

A typical harried foreman's comment is, "I'm already spending so much time on special committees and programs that I hardly have enough time for my primary responsibilities. The last thing we need is another special program." How can the proposal for a productivity improvement program be approached in such a situation?

Coordinating program. Most of the special programs which plant managers have established are specific efforts to improve some aspect of plant productivity. Energy conservation, for example, is a direct effort to improve energy productivity. A preventative maintenance program is an indirect attempt to increase output and all plant productivity ratios, especially capital productivity.

On the other hand, portions of some programs must be implemented to comply with various governmental regulations (environmental, OSHA, etc.) despite possible negative effects on plant productivity.

The potential problem with managing such an array of special programs is that, while they all affect plant productivity in some manner, there may not be any coordinating effort to ensure that all programs are working together for maximum total productivity of the plant. Consider the illustration in Fig. 5. Each of the programs, indicated by the smaller gears, affects plant productivity improvement performance. Note that if each program is administered independently, conflicts can occur in the plant's productivity improvement efforts, just as attempts to drive each small gear independently would cause mechanical conflicts. However, if a productivity improvement program operates as the primary driving force for all other special programs (except government mandated requirements), a coordinated systematic effort to maximize plant productivity will result.

Program organization. The organizational structures of HPI plants vary considerably from plant to plant to satisfy the unique requirements of each location and operation. Likewise, the most appropriate organization for managing a productivity improvement program will differ to some extent at each plant.

Several principal features of the program organization are recommended:

1. Productivity improvement should be an integral part of the plant management process. Consequently, primary responsibility for productivity improvement should follow the existing line organization, from the plant manager down to the first line supervisors.

2. A productivity committee or council should be established to provide coordination among departmental and special program productivity improvement efforts. If a variety of committees or task forces presently exists for various special programs, they could be combined into a productivity committee. Alternatively, they could continue to function as separate sub-committees of the productivity council.

3. A plant productivity coordinator, part time or full time, should be established to provide day-to-day administration and coordination of all productivity improvement efforts.

Key program elements. In addition to a productivity organization, the following key elements are recommended for an effective productivity improvement program:

1. The most obvious and essential is top management support. Managers must be dedicated to the total pro-

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ductivity concept of plant performance improvement. They must be willing to challenge traditional policies, accept innovative changes and commit the necessary resources to make productivity improvement possible.

2. Effective top-down communications are necessary › stimulate an awareness and concern for productivity throughout the organization. This involves the important area of motivation, essential to all attempts to improve employe productivity. Employes must understand the importance of productivity both to the viability of the company and to their future job security and standard of living. Training programs, company publications and employe meetings frequently are used to enhance communications.

3. Participation of all employes generally yields the best improvement results. Motivation must come from the top, but often the best knowledge of specific productivity problems and the most practical solutions to those problems come from the people actually performing the jobs. Bottom-up communications, therefore, are equally as important as top-down. Employe surveys, suggestion programs, labor-management productivity committees and incentive plans are various approaches being used to increase employe involvement.

4. Realistic goals and objectives should be established for productivity performance. The simplest procedure is to incorporate productivity planning directly into the normal business planning and budgeting process. In this way, productivity improvement objectives and their effects on plant performance are built directly into the ·rating budget, and the resources (capital, materials, manpower, etc.) necessary to achieve those objectives are provided for in the business plan.

5. A system for measuring, evaluating and reporting productivity improvement results logically follows the establishment of objectives. Such a system provides for analysis of the plant's productivity strengths and weaknesses, evaluation of productivity performance relative to the established objectives and reporting to company management the results of productivity improvement efforts. Also, employe involvement can be reinforced by communicating productivity results to them on a regular basis. Measurement systems vary from simple ratios to comprehensive total productivity analysis. The best approach is to keep the system sufficiently simple to provide meaningful results to those people managing the productivity improvement program. ■

About the author

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Can engineer/constructors cope with tomorrow's challenge?

Yes, says this author, but only by maintaining awareness of the changing market, willingness to adapt the company structure, motivation to develop new roles, and technological excellence

R. Pascoli, TechniPetrol S.p.A., Rome, Italy

ENGINEERING-CONSTRUCTION (E/C) companies must now operate in an environment quite different from the conventional one (see Box) to which they have been accustomed. The changing scene is due to the synergy of several decisive factors:

1. Sudden industrial and social development of oil-exporting countries. This brought huge investments in the HPI and in other industrial fields, as well as in general infrastructures (transportation, civil construction, education, health, telecommunications, defense), particularly since the 1973-74 events.

2. Decline of HPI investments in Europe and, to a lesser extent, in other industrialized areas, because of (1) a "mature" market and GNP situation, and (2) a decline in expected market trends following the 1973-74 crisis (not to mention the present one) in energy and raw materials availability and costs.

3. Development of basic national oil/chemical/fertilizer industry in Third World countries became independent in the '60s and early '70s as well as in other regions such as Latin America, India, South-East Asia.

4. Growing importance of COMECON-area market, specially for European and Japanese contractors.

Consider also possible sudden changes in market opportunities on

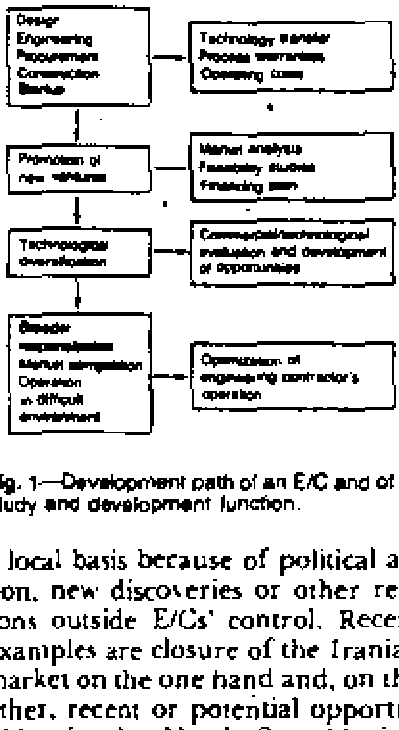

Fig. 1—Development path of an E/C and of its study and development function.

a local basis because of political action, new discoveries or other reasons outside E/Cs' control. Recent examples are closure of the Iranian market on the one hand and, on the other, recent or potential opportunities in the North Sea, Mexico, China.

Opportunities. In addition, E/Cs' market environment is likely to be substantially affected in the coming years by forecast developments and/or strengthening of present trends in the following fields:

- Gas
- "Poor" and/or expensive oil sources
- Coal
- Nuclear
- Energy saving (both in the HPI and in other industries)
- Shift (mainly in Europe) of refinery operation toward higher conversion of residues into lighter products, in accordance with declining trends of fuel oil demand
- Industrial uses of alternative energies, such as solar and geothermal
- Recycling and upgrading materials recoverable from wastes and/or by-products
- Emerging of alternative fuels/raw materials (alcohol, methanol)
- Possible medium/long term development of opportunities connected with a more "industrial" approach to agricultural and livestock operations and to optimal upgrading of agro-animal products/by-products/wastes.

Gone . . . perhaps forever

- Plenty of large projects, both grass-roots plants and substantial expansions, concentrated mostly in the developed countries (where the most promising markets for end-use products were located).
- Clients consisting mainly of major oil and chemical firms, characterized by strong management, financial, technological and marketing capabilities.
- An E/C role that is generally limited to basic design (sometimes); engineering; procurement; erection; commissioning; assistance to startup (not always)
- Upstream and downstream activities performed directly by the owner, who held in his hands the overall project control as well as full responsibility (risks and profit).
- An E/C role, even in turn-key projects, not far from the mere execution of specialized services under close control of the client's supervisors and procedures.

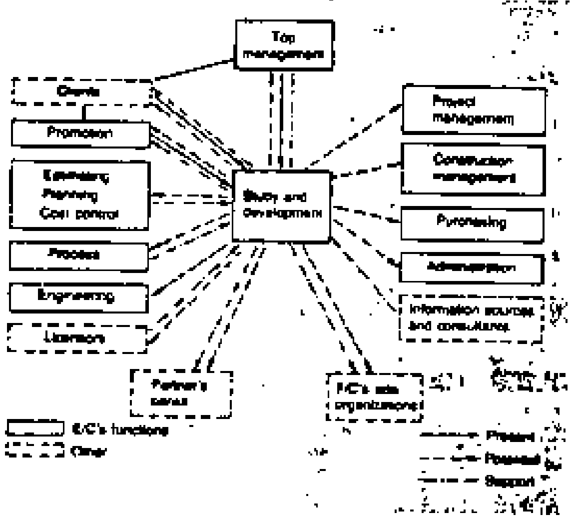

Fig. 2—Functional connections of a study and development group.

NEW ROLE FOR E/Cs

E/Cs' market was heavily affected in the 1970s—particularly second half—by the changes outlined in points 1-4 in this article's opening paragraphs. These have forced most E/Cs to enhance their capabilities, structure, work procedures and commercial strategy, in order to survive and compete. E/Cs have developed strong capabilities in areas upstream and downstream of their original fields (design, procurement, erection). This includes wide responsibilities in the following critical aspects of venture management:

- Market research and analysis
- Definition of optimum products slate and specifications
- Technology evaluation and selection
- Location study
- Feasibility study
- Financing (often a most critical item)
- Owner's personnel training program
- Direct plant operation for the first 1-2 years
- Marketing of products, up to buy-back arrangements.

Taking on these diversified responsibilities stems in part from new business with the Third World clients. These clients generally have lower technical and marketing capabilities when compared with major Western hydrocarbon processing firms. Moreover, E/Cs have to cope with a local environment characterized by a generally poor industrial background.

Third World. Clients in developing countries, conscious of the situation in which they are operating, often do not even try to control the engineering/construction process. Their project management is wisely focused mainly on a careful control of *critical* activities such as:

- Price
- Schedule
- Personnel training
- Test runs (plant capacity and products quality)
- Marketing agreements (when applicable), in accordance with contract terms

The E/C is therefore forced into a sort of "partnership" with the client. Here, the E/C's risks are higher than in "classical" engineering practice. The contractor has poor technical control and assistance from the owner. So the possibility of correcting errors during project development is lower.

Difficult logistics. All the risks of managing a project in a developing country are borne by the E/C from transport to customs, from use of local manpower and subcontractors to materials supply from local sources.

Projects frequently go beyond the original schedule. And this means additional field and home-office costs, escalation, and maybe penalties.

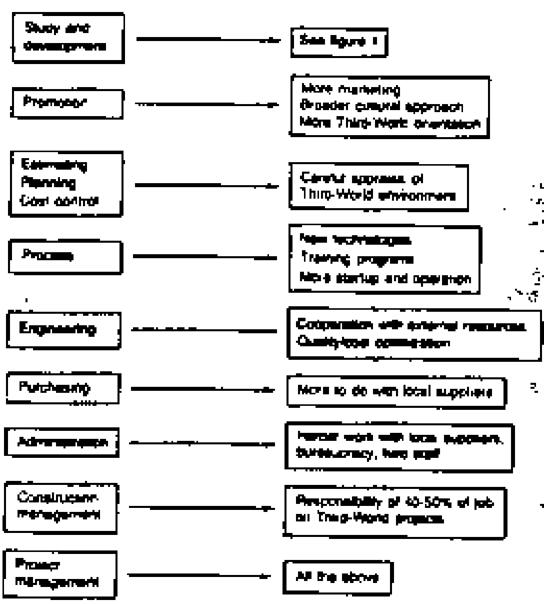

Fig. 3—Development of an E/C's functions.

The costs and risks of promotional activities and proposal preparation are higher than in a more conventional environment, too.

These additional risks and costs must be carefully evaluated in definition of contract price; the item "contingencies" now has a more vital role in the proposal price book. This item cannot be too high, or it will cause the E/C to lose the contract. But neither can it be lower than reasonable. Much better to lose a contract than to lose money on a contract awarded.

Opportunity. Conversely, profit opportunities for prepared, flexible, careful E/Cs are now higher than ever.

The E/Cs' role is much closer than in previous years to that of the entrepreneur. The role is characterized by a wide range of capabilities and responsibilities, deep involvement in venture success, high risks and high profit opportunities.

Expect an evolution/revolution in E/Cs' commercial strategy, technological approach, structure, and work procedures.

STRUCTURE MUST CHANGE

The wide and complex market environment and the "entrepreneurial" expectations in the E/Cs' role require deep changes in structure. Only with such change can they develop new capabilities and strengthen existing ones.

Study and development is a function already part of major E/Cs. This function is likely to grow further in the future. Historically, it involves:

1. Technology evaluation and acquisition
2. Process warranties (consumptions and yields)
3. Personnel requirements
4. Budget cost estimates
5. Total running costs
6. Profitability analysis and evaluation
7. Market analysis and assessment, and coordination of external market research capabilities
8. Location study
9. Feasibility study
10. Financing plan
11. Overall evaluation of venture
12. Appraisal of industrial companies and of their expansion program (usually for financing purposes)
13. Evaluation of possible technological and commercial diversification strategies, either for external clients or for the contractor itself.
14. Evaluation of possible developments in E/C's operation: a true "revamping" or "expansion" of E/C's structure and capabilities.

Areas of responsibility. Items 1-3 above are usually the responsibility of the Process Department. Item 4 requires Estimating Department's capabilities. The remaining items represent the present and potential field in which the Study and Development Department is called to operate. In these areas, S&D gives top management essential support, helping them to validate information on which decisions are based.

Items 5-9 include the already established field of action for "Study and Development Department" (or whatever it is named in various companies).

Items 10-14 are developing just now in most E/Cs. Probably some companies hesitate to assign such a delicate and complex role to a function frequently belonging, at least for historical reasons, to the Process Department.

The need for item 14, *study and development of E/C's structure*, is probably not yet identified by most engineering contractors. Or, at least, their senior management believes it safer to handle the matter directly itself or through external consultants. External consultants are useful to manufacturing companies. But for service-oriented industries such as E/Cs the "inside" view is critical. In the service-oriented operation, in fact, functions cannot be considered separately from the people performing them. In fact, applying theory to practice may be inadequate without appreciation of "personalized" details.

An "internal consultant" is necessary to optimize an E/C's structure and operation. Possible subjects of analysis, evaluation and development are:

- Definition of technological sectors most promising for E/C's future operations.
- Definition of geographical areas worth deep commercial effort.
- Choice of best technological/commercial/financial partners.
- Evaluation of most suitable commercial and cultural tools for factual penetration in chosen commercial/technological areas.
- Evaluation and development of new tools suitable for development of the E/C's operation in new geographical, social, political environments.
- Improvement of E/C's procedures and capabilities in its full range of activities:

... from telephone/telex to expediting

... from quick mailing through direct couriers to administrative operations

... from cooperation agreements to organization of seminars

... from relations with local agents to computerized financing programs

... from connection with external marketing consultants to optimal support to its own people working abroad

... from connection with international data bank systems to sizing of process equipment

... from programming of personnel requirements to project cost control

... from detailed engineering (piping, electricals, mechanicals, civil work, PV & HE) to optimization of subcontracting and field work procedures.

A multi-disciplinary approach is essential in this type of organizational scenario.

Marketing approach. The *promotion* of new opportunities is gradually shifting from a "sales" function to a broader "marketing" activity, in accordance to the shift of markets from major Western clients to state-controlled companies in developing countries.

Promotion people have to be more Third-World-oriented than before. They need a broader professional and cultural background. A more extended use of "native" promotion people and local agents is advisable.

New requirements also include

the development and diffusion of a strong, reliable, qualified "image of the company". The officials of key ministries in developing countries cannot, in fact, be asked to compromise themselves with poorly known, doubtfully qualified, "second class" E/Cs.

Estimating, planning, cost control have, and will have, a leading position in the challenge.

Careful quotations and optimized project control require, in a Third World environment, an accurate analysis of local conditions and an improvement of general skills. The goal here is to limit as much as possible uncertainties about costs, schedule and work quality.

Process Department should become familiar with a broader slate of technologies, as required by technological diversification. An additional duty is represented by the training programs for client personnel. Also the heavier responsibilities for commissioning and startup of plants in a Third World environment must be carefully taken into account.

Engineering Department would at first appear to be less involved in the change. On the contrary, it *also* requires a careful optimization (through both computerization and use of external resources, including local ones). Only then can it optimize the efficiency/cost ratio of its performance. It will thus contribute to success of the overall operation in a competitive environment.

Purchasing and administrative operation requires a considerable improvement of skills, too. They will more and more have to operate in a complex and unfavorable environment. And they have to maximize skills and performance.

Most Third World clients require purchase of materials from local firms. They also call for cooperation with local engineering firms. This limits the E/C's degrees of freedom and complicates work of the Purchasing and Administrative departments.

Construction management is perhaps the most critical function in the new E/C world. Erection can require as much as 40 or 50 percent of investment for grass-roots projects in remote locations. To be considered: local and foreign subcontractors, direct-hiring opportunities, custom and transport problems, raw materials quality availability and costs, and local regulations.

Much of the profit of turn-key projects in developing countries come from extremely good management of construction activities.

Project manager's job is nothing but control and optimization of the E/C's performance on its contract. Nothing is changing from the "classic" project management role, except the need for broader, deeper skills in the financial, technical, organizational and cultural areas.

The "winner" E/C of tomorrow will also organize to handle atypical projects such as:

- Agro-industrial projects
- Integrated projects for regional development
- General infrastructures
- Projects for manufacturing industry
- Cooperation with state agencies in development of public interest projects (such as exploitation of new raw materials/energy sources, energy saving, waste recycle, renewable energies)

The most successful E/Cs of tomorrow will be those that match a high level of professional skills to opportunity for creativity, blended into a broad and diverse organization with cultural sensitivity.

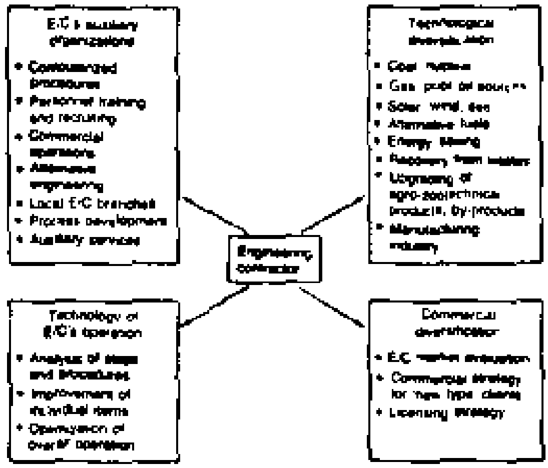

Fig. 4—Development trends for engineering contractors.

SUCCESS THROUGH TECHNOLOGY

A creative approach and careful attention to development of E/C technology is critical to survival. A major step in this is development of specialized organizations specifically tailored to some of the new E/C's competitive needs. Examples:

- Management of all computer procedures connected with E/C's activities,

. . . from personnel salaries to material takeoff

. . . from civil work design to bidding procedures

. . . from automatized drafting of

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P&I drawings to handling of data banks.

This organization could also offer its services in the open market.

• **Training programs for client's personnel;** commissioning, startup, and first-period operation of plants, recruitment of local or foreign manpower for direct-hiring construction projects. In the future, organizations of this type will include:

— consulting services for development agencies or ministries, and even health or education organizations in developing countries

— training programs and consulting services for engineering personnel and for other service-oriented organizations.

• **Commercial activities connected with buy-back or countertrading** agreements, expandable to other import-export operations when feasible and convenient.

• **"Specialized" engineering organizations,** tailored to specific technological or geographical situations:

— particular technological sectors, such as mechanical goods manufacturing or food processing, do not require high-level engineering skills (and cannot bear relevant costs). The simpler project management required imposes the use of "ad hoc" organizations.

— small and flexible organizations on local basis, sometimes required because of the political climate, both contribute to development of local engineering resources and create useful connections for local business opportunities;

• **Typing, drafting and other auxiliary services.** This could apply also to employee bus service, express mailing through couriers, etc. These services also could be offered on the market.

• **Specialized consulting activities and/or process development** (even from laboratory scale) could be offered through separate companies.

Optimized operation. Another group of "E/C Technology" developments includes the careful analysis and optimization of all the steps and procedures of the E/C's operations. This would begin with selection of commercial opportunities, and be operative clear down to the internal mailing service within company's building. The precise type of organization system required to accomplish this is contingent on the needs and goals of each particular company.

Technological/commercial diversification. The term "technology" is used here in the classical sense. Diversity, flexibility and creativity are musts for the successful E/C of tomorrow. It is easy to forecast that past levels of investment in traditional refining/petrochemical activities will not be maintained in coming years. Market trends have definitely been lowered by high energy/raw materials prices.

It is impractical for each E/C to launch its own diversification program without a careful analysis of its "personal" situation and opportunities. The experiences, capabilities, technology availability, structure, and commercial situation of each E/C push it toward a definite form or type of technological development.

Broader services. The competitive E/C of tomorrow will offer services and an *operational style* extending well beyond those required in past construction of HPI plants. The new E/C will be able to handle a variety of projects—large and small alike—in widely diverse fields. Examples are synfuels, biomass, waste recovery, public transportation, health services, heavy industry construction and services, etc.

Such a company will be characterized by its ability to apply highly sophisticated engineering methodology to many aspects of a nation's technical/economic needs. Such a company can ill afford to confine its operations to the HPI. Rather, it must use its talents, gleaned from experience with this complicated industry, in a greatly expanded scope of activities. ■

MANAGEMENT GUIDELINES

Control project costs effectively

Give proper attention to the estimate, basic engineering, equipment, commodities, home office relationships, construction, field subcontracts, schedule, and project changes

A. E. Kerridge, C-E Lummus, Houston

THE FIRST STEP in cost control is to prepare a good estimate. Cost cannot be controlled if there is an inadequate, incomplete, or unrealistic estimate. Fig. 1 illustrates the increasing probability of improved accuracy as estimates are made at progressive stages of project execution.

THE ESTIMATE

An **order of magnitude estimate** is derived from curves or return costs from previous projects and is prepared in the conceptual stage.

A **preliminary control estimate** is prepared when the process design is complete and equipment data and sizes are available.

A **definitive estimate** is prepared when basic engineering is complete and preliminary bulk material takeoffs have been prepared.

A **detailed or check estimate** is prepared on completion of design engineering when production drawings, final material quantities and prices are known.

Variations. The last two stages shown in Fig. 1 illustrate that the final cost of a project is not known until financial completion, when all commitments and invoices have been paid. Prior to that time there is always the possibility of variation from an estimate no matter how detailed.

Normally, three levels of estimate are prepared during project execution.

- Order of Magnitude
- Preliminary Control
- Definitive

Cost control can only be applied at a level corresponding to the quality and detail of the estimate available.

Project cost control starts on the wrong base if there is a poor estimate. Estimates may be arbitrarily reduced or an estimating accuracy may be claimed which is not supported by the project scope definition available. Poor project execution may be blamed for cost overrun when an unrealistic or over optimistic project estimate is the problem.

Procedures. An essential requirement for the production of quality estimates is good estimating procedures. Detailed formalized procedures, consistency of method, feedback of previous cost data, and a standard code of accounts are the prime requisites for project estimating. Project costs must be reported under the same code of accounts to match the estimate to ensure good feedback for comparison.

TABLE 1—Elements of capital cost in a project

	% of total		
	Low	Typical	High
Home office	2	10	12
Equipment	20	30	40
Commodities	25	31	40
Direct labor	15	20	25
Construction indirects	6	9	12
Total		100	

Table 1 shows the major elements of capital cost in a project. Although cost control procedures should be applied to all areas of cost, a knowledge of the cost elements will allow additional vigilance to be applied to cost sensitive areas.

No matter how thorough the estimate, there may be errors, omissions, and unforseen events. To allow for this, on completion of the estimate, a contingency and risk analysis should be performed. An

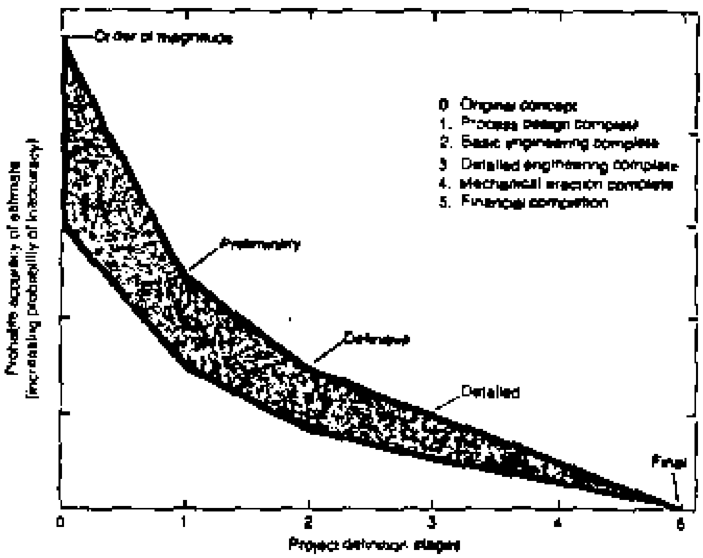

Fig. 1—Project estimates and their accuracy improve as estimates are made at progressive stages of project execution.

VII.-B-1

appropriate contingency is included as an integral part of the estimate.

BASIC ENGINEERING

The intrinsic cost of a project is set in the basic engineering phase, during which the following major project definition documents are produced:

- Project Scope definition and coordination procedures
- Process design package
- General engineering specifications
- Equipment list and equipment data
- Piping and instrument diagrams (process and utility)
- Site and plot plans
- Single line electrical diagrams
- Construction plan
- Master project schedule.

Cost influence. Basic engineering fixes the quality and content of the project which in turn fixes the basic cost. Such things as the equipment, the material and design specifications, philosophies regarding reliability, spares, safety, environmental protection, automation and controls, extent of buildings and structures, etc., are fixed. After basic engineering has been fixed, the only opportunities for cost savings are by improved project execution efficiency and productivity in engineering and construction or by more competitive equipment and material purchasing.

Significant costs are saved only by reducing the scope of the project by removing equipment items or using less stringent design and material specifications.

Because the project costs are committed when basic engineering is approved, there should be a thorough cost review prior to approval. It should be a separate exercise from the technical review, to insure that extra cost has not been built in unnecessarily.

EQUIPMENT

Equipment items are normally estimated with close accuracy provided the basic capacity, duty, materials, and type have been defined. Often there may be large price differences between bids. Careful commercial and technical analysis must be made to insure that acceptable quality is selected at the lowest price to take advantage of specific market conditions.

A major problem controlling equipment costs is to stop price additions after the purchase order has been placed. Changes, such as nozzle sizes, ratings, orientations, attachments, instrument and electrical connections, etc., provide the vendor with an opportunity to increase his price unless fixed unit prices for additions have been established during the competitive bidding stage.

Control equipment costs. The following general rules should be part of the project procedures to control equipment costs:

- **Do not issue inquiries prematurely.** Wait until equipment definition is firm so that vendors can bid on information which will not change.
- **Obtain competitive bids** from at least three vendors. Search the market ahead of time to determine which vendor shops are hungry for work.
- **Obtain firm price quotations.** If escalation clauses are unavoidable, specify an escalation formula which can be monitored and relates to the required delivery.
- **If nozzles or other attachments may be added or changed, obtain fixed unit prices for these additions** prior to the placement of the purchase order.
- **If spares are required, obtain firm price quotations** with the bid or before placement of the purchase order.

COMMODITIES

Commodities or bulk materials include:

- Civil, structural and building materials
- Piping, valves, fittings, and associated materials
- Electrical equipment and materials
- Instruments and instrument materials
- Insulation, fireproofing, painting

The cost of commodities is set by quality and quantity. Quality is set by the specifications developed during basic engineering. Quantity is also set during basic engineering by the size, type, and number of pieces of equipment, the piping and instrument diagrams, the size of the plot plan, and the plant arrangement. When basic engineering is complete, the base cost for commodities has also been irreversibly established, even though at that point in the project execution the exact commodity quantities may not be known. Thereafter it is only possible to reduce excesses, wastage, or inefficiencies by good control during design engineering, procurement, and construction.

Document review. To reduce the base cost of commodities would require returning to basic engineering to reduce the quality of specifications, remove equipment items, or remove piping and instrumentation. This reinforces the importance of a specific cost review of the key basic engineering documents prior to the start of production design. Approval is a commitment for the quality and quantity of commodities required by the approved basic engineering documents.

Control commodity quantities. The following general rules should be observed to achieve effective control of commodity quantities:

- **Prepare a detailed commodity material estimate** and make this available to those responsible for final design drawings and bills of materials.
- **Estimate takeoff quantities must** be referenced to specific equipment items, P&ID's, pipeline numbers, plot plan area numbers, or other suitable identification so that it is possible to make comparisons during the progress of design engineering. The drawings used for takeoff should be retained.
- **Since the estimate takeoffs are based upon designs which are not final, appropriate allowances must be added** to the estimate takeoff to cover final design, construction and maintenance spares. Allowances must be identified. Unit prices used in the estimate must also be recorded.

As design proceeds, final takeoff quantities by area or system should be compared against the takeoff quantities for the same area or system in the estimate.

Figure 2 illustrates a typical trend curve which should be maintained

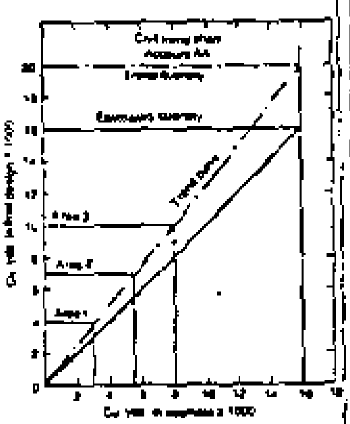

Fig. 2—Commodity material trend curve.

for each major commodity material category.

Commodity price control. Commodity price control can be achieved by the following:

• Obtain at least three competitive quotes. Review the market ahead of time to determine which suppliers need work.

• Do not issue inquiries until specifications and quantities are firm so there is no chance for a bidder to change his price after the purchase order has been placed.

• Attempt to obtain fixed price quotes or fixed unit prices. Do not accept escalation clauses or other price adjustment clauses which cannot be easily monitored.

• Do not place orders which are open ended or where the fabricator can invoice according to his measurement. This particularly applies to pipe fabrication.

HOME OFFICE

Home office costs include the following:

• Salaries and benefits of home office personnel (engineering, procurement, and supporting services)

• Home office overheads for accommodation, facilities, and non chargeable support staff.

• Home office expenses such as reproduction, communications, travel, business expenses, and computer time.

Of the above, the major cost is the salaries of the home office personnel. This cost can be controlled if the hours charged to the project can be controlled.

The first step towards control is to prepare a manhour estimate for each discipline. These manhour estimates must identify the number of activities to be performed in terms of number of equipment items, requisitions, drawings, model tables, etc. The better the quality of the manhour estimate, the better the opportunity for comparing physical progress and manhours expended against the original plan and budget.

During project execution there should be continuous monitoring of manhour expenditure, relating this to the progress achieved and the budget. A particular problem is the "90% syndrome" where progress and expenditure reports are favorable until 90% completion is reached, at which time the last 10% creates a considerable overrun in manhours and schedule time.

Avoid 90% syndrome. The likelihood of the 90 percent syndrome occurring can be reduced by the following actions:

• Use realistic manhour budgets and realistic schedule periods. Unrealistic schedules and budgets tend to create unrealistic and distorted reports.

• Ensure that methods of measuring physical progress are factual. This requires that the schedule activities are given weightings by proper allocation of the manhour budget and that progress is measured against fixed yardsticks and does not reflect inexperience or optimism.

• Recognize that the meeting of a schedule date does not mean that no further hours will be charged. There is always followup work, removal of "holds," replies to queries, and other liaison and finalization work which carries on in engineering even though purchase orders may be placed and drawings issued for construction.

Reduce H.O. manhours. The following are some general guidelines for controlling or reducing home office manhours:

• Do not allow work to start in the office until all the necessary information required is available. An early start without information does not gain schedule time and merely consumes extra hours when the work must eventually be done again.

• Complete each stage of the project work with reviews and approvals before the next stage starts. Examples are:

Process design
Basic engineering
Engineering design model

In each case subsequent activities should not be started until the preceding activity has been finalized, approved, and frozen.

• Control review and approval procedures. Do not submit documents for approval until they are complete and do not release them for further action until formal approval has been received.

Do not accept comments or second thoughts after formal approval has been given.

Do not submit documents for approval in a piecemeal manner and ensure that approvals are complete or that approvals with qualifications are clear.

• Make every effort to minimize the products of engineering (specifications, requisitions, and drawings). Do not do more than is needed by the Procurement and Construction organizations. Every item eliminated is a reduction in manhours. Use standard drawings and drawing forms to the maximum extent.

• Do not do work out of sequence and avoid recycle. Aggressively oppose project changes which are matters of opinion or improvements which are only marginal.

• Maintain individual trend curves as illustrated in figure 4 for each of the major disciplines show-