

While this example is unreal, it illustrates that *time is a real factor* in forecasting costs and identifies the predominant areas of concern.

Combined Effect

We have looked in some detail at the way in which a remote location and a long project duration can each affect cost, and at some of the ways of reducing the risk of working under these conditions while still remaining competitive. The combined effect of these two groups of problems can, however, be far greater than the sum of the two separate effects. This can best be illustrated by considering the time and cost of correcting a mistake, an accident or an adverse trend:

- The cost of a spare part may be \$1000.
- The cost of flying the part to the site may be \$10,000.
- The cost of the delay caused by having to wait for the spare part can be \$100,000 — or \$1,000,000.

An adverse trend at home may take a week to diagnose and a week to correct; but in a remote location abroad, even if your management system is first class, this may take a month to diagnose, a month to analyze and three months to correct — If it is not too late by then to make any change at all. Management systems that work well adequately at home may be totally inadequate abroad.

Sources of Information

Another important consideration in

estimating construction costs abroad is the sources of information that are available, and the methods available for evaluating the conditions. Everyone tends to develop his own particular approach to this sort of evaluation, because at the end the individual must have a personal conviction that his assessment is correct, backed up by as much research and documented evidence as possible.

A basic source of information is government departments and agencies. They will provide the ground rules in the form of regulations and decrees and often generalized data, such as statistics on employment, prices and production; but they are unlikely to provide the specific experience that is needed for commercial operation. Commercial staff at the local embassy can usually provide reliable information and good local contacts in specific industries. In addition, multi-national corporations often have data of the same quality related to their own commercial needs and tempered by their own commercial experience. Branch office officials are often pleased to see a new face, and will willingly trade local information for views from the outside world. For specific, practical experience, contact with local commercial enterprises is necessary. Remember to treat advice from potential suppliers and subcontractors with as healthy a skepticism as that from potential competitors. They are promoting their own interest. A face-to-

face interview is worth ten written documents, because it is then possible to assess how much the other man believes what he is saying.

Cross-check every piece of data.

Observation of work in progress will yield a valuable insight into real industrial practice and cover the direct cost items — materials, labor and construction equipment.

There is one source, however, that is more important than any other and it is too often overlooked or not appreciated. It is virtually impossible to assess a new and remote environment in a week or a month unless the investigator is fully forearmed. This requires five qualities, without which his chances of success are significantly reduced:

- He must have experience with the type of problems and situations he is investigating, gained mainly by understudying a more experienced investigator.
- He must have a thorough understanding of the complex interplay of economic forces, and the particular economic system within which the project will be constructed.
- He must be a student of human nature.
- He must study the particular conditions and circumstances he is trying to evaluate thoroughly before he starts.
- He must be fully conversant with conditions and trends internationally, and especially as they apply to the particular locality and type of project, by continuing study of technical and economic affairs.

In addition, his effectiveness will be materially increased if his trip is planned in consultation, and carried out jointly with a local representative. Meetings need to be arranged with due consideration given to local protocol, and the itinerary arranged to ensure a balanced picture is obtained.

Analysis and Presentation of Results
Having collected as much relevant information as practicable, conclusions have to be drawn that can be applied to the basic "here and now" estimate.

Some items, such as unit costs, can be used directly, but most will require interpolation and interpretation. In doing this, a weighting must be applied to the various figures obtained to reflect the confidence the assessor has in the source of data, and the relevance of the source and the data
(continued on next page)

FIGURE 4
EFFECT OF TIME ON PROJECT COST
WILL BE EVALUATED UNDER THESE HEADINGS

VALUE OF MONEY	—INFLATION CURRENCY RATES OF EXCHANGE COST OF EQUIPMENT & MATERIALS COST OF LABOR & SERVICES
DURATION	—PLANS SCHEDULE
ECONOMIC SITUATION	—TAXES & DUTIES CRAFT LABOR PRODUCTIVITY WORKING RULES (UNION OR GOVERNMENT) GOVERNMENTAL LEGISLATION LICENSING, ENVIRONMENTAL OR SAFETY STANDARDS INTEREST RATES
PERSONNEL	—QUALITY OF MANAGEMENT & EXECUTION

Construction Costs (continued)

to the project under consideration.

After considering these two factors, the weighting may of course be anywhere between zero percent and 100 percent or, in other words, any information obtained may have to be either rejected or accepted to the exclusion of other conflicting data. The results of the analysis can be expressed in one of two ways depending on the detailed estimating method being used. They should be expressed either as a unit cost that can be applied directly to engineering quantities, or as a conversion factor, such as a productivity factor, that can be applied to the basic estimating cost/manhour data. However these conclusions are expressed, they form part of the estimate and should be carefully tabulated together with their supporting documentation. They are just as much part of the estimate as the quantity, specification, resource used, timing and resultant unit cost, and they must be able to be monitored in the same way.

The Future Outlook

Everything that has been described here is based on the hypothesis that financial and industrial affairs will be conducted in the future in a similar way to the conduct of affairs in the recent past and in accordance with the same rules.

This may be true in the very short run, say for the next five years, and it may be true in North America for rather longer, but good cost engineers will always be looking for evidence of trends that may cause the forecast to be modified. What evidence is there of change?

There is a quiet social and political revolution occurring throughout the world (and in some places it is not so quiet) which is altering slowly, but irreversibly, the rules by which commerce and industry are run. The day of laissez-faire capitalism is gone, to be replaced by political and commercial protectionism, by government regulations of prices, profits and incomes, government monopolies buying and selling essential goods and services, and governmental pressure on industry that in practice becomes a mandatory decree. Democratic party politics is being replaced by single party government, and legislation is becoming common-place that subjugates individual freedom to the collective good. The conservationist will

probably wield much greater power in the future. How much further will these changes go? How can a project that may not be completed for eight to ten years be evaluated, and the profitability of a scheme established under these new rules?

Part of the answer lies in going back to first principles. Man's needs are basically unaltered and means of fulfilling them are going to remain substantially the same — the same technology is available and the same resources are used; but the method of applying the technology and mobilizing the resources is new. No longer is the profit motive the sole, or even the final, measure of success. Profit was a valid measure only so long as it represented the added value or benefit to society of organizing resources at a given cost in such a way that a higher price could be obtained. That profit represented the surplus from the operation that could be applied, by reinvestment in one sense or another, to the benefit or enhancement of society. Once profit was arranged by other means such as by organizing cartels, and used for other purposes than to obtain an adequate return on an investment, then the forces of its destruction were set in motion. The results of this trend are there for us all to see around the world today.

Cost engineers must be aware of these changes in society, and sensitive to the new ways of applying technology, organizing resources and evaluating the acceptability of projects. Investigation of all the problems discussed earlier can be carried out with these new objectives clearly in our minds. The conclusions may well be different, but they will be equally valid, just so long as the investigations and researches are conducted in accordance with sound economic principles and do not rely too heavily on well proven, but historic, cost factors. Maybe maximum employment will become the criterion on which the success of a project is based, or exclusive use of local resources, or minimum disturbance of the ecology of the area — but whatever the new criteria will be, cost engineers will be more useful and more highly regarded if, as a profession, they can be a little more clear-sighted and a little more perceptive than the rest of their colleagues in industry.

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Chris Walker is manager of cost engineering for H.A. Simons (International) Limited in Vancouver, responsible for the development and direction of the cost engineering and engineering economics activities of the group. He holds a Masters Degree in Economics and Mechanical Science from Cambridge University. He is a Member of the Association of Professional Engineers of British Columbia and a Charter Mechanical Engineer (U.K.). He has been a Member of the American Association of Cost Engineers for 11 years and is currently Director of Education. He is a Member of the (British) Association of Cost Engineers for 17 years, and was their President from 1972-74. Walker was Chairman for two consecutive terms of the International Cost Engineering Council, which was formed in 1974 to coordinate and develop the function of cost engineering worldwide. He was a member of the Certification Board of AACE, and Past President of the Montreal Section.



Anghel Patrascu, C.C.E.
Head - Cost Engineering

B.P. Alaska, Inc. (British Petroleum)
100 Pine Street
San Francisco, California 94111

PRE-ESTIMATING SURVEY

Pre-estimating survey of factors that will influence the entire design, construction program and plant cost does not always receive the attention it deserves.

For a repetitive project into a known area, or for a very small one, one may not have to go very far; a few phone calls could suffice. Even in this case, however, it is recommended that a field survey be made to avoid costly surprises.

This paper will cover the survey of the area, climate, soil, accessibility, transportation, availability of labor and its cost, economic activities in the area now as well as in the future, union regulations, union contracts and their expirations, available utilities, and many others.

There is no substitute for first-hand information. Publications and other people's experience should be used as a supplemental source only. Care should be exercised when using any second-hand data. Discretion is required during the field survey, not to alert the competition.

The first item to be considered will be the geographical area.

GEOGRAPHICAL AREA

What must be known first is where will the plant be built. Will it be in the Midwest, the Gulf Coast, Alaska, the world's jungles or its deserts? Depending on the specific area, field costs, for example, could vary probably by as much as ten times the cost of a so-called "normal" area like the Gulf Coast.

CLIMATE

Climate goes with the geographical area, and it is a very decisive factor in the cost of building the plant. One should know if the plant will be built in a hot or cold place, what is the average snow or rain fall, and when does it fall. This will influence the design of the plant as well as the productivity of labor.

SITE ACCESS

The accessibility of any proposed site must be well known, both for the construction phase, as

well as for obtaining the raw materials for the plant, and shipping out its finished products. Is a railroad available nearby and who will build the required spur? What about roads: Who will build the approach, who will maintain them, will any bridges be required? What about water transportation? Is any dock available nearby and if so, what is its maximum handling capacity? Will dredging be required? In some countries roads and harbors could be adequate, but they may be so congested that extensive costs in demurrage and scheduling delays will result. What are the possibilities of using marshalling yards to consolidate shipments. Can lightering be used if the docks are not accessible?

On some construction sites the first field activities will be supported by helicopter. Later, during construction, a regular small jet airfield may have to be built as part of the project. Depending on the location, the method of transporting equipment and bulk to the site, and the effect on schedule will have to be estimated very carefully.

SOIL CONDITIONS

Now, one must take a look at the soil conditions. For an unknown site, or even if there are any doubts, soil borings will be a must. Will pilings be required, will cut and fill be acceptable, what about dewatering, clearing or demolitions of existing obstacles such as buildings or underground obstructions? How, and where, will the trash and surplus soil be disposed of? If there is need for fill where will it come from?

EARTHQUAKE FACTOR

Generally, earthquake charts are readily available, but they may not be 100% accurate. It is suggested that this be verified with local authorities for confirmation.

THE ENVIRONMENT

Many years ago this probably was not of any major concern, but today it could add millions to the plant construction, years to the schedule or it could simply stop any construction. Depending on the type of plant being considered, the owner should know what he can do, and what he cannot do.

CONSTRUCTION PERMITS

Not all proposed and economically feasible projects receive the green light. While many studies are made before the actual permits are obtained, it may not be advisable to go too far before knowing if the plant could be built in a particular location.

ATTITUDE OF THE COMMUNITY

Lately there have been projects that did not have the go-ahead because of the negative attitude of the community. Environment may be a concern, but a more important factor could be a simple human characteristic: We would like to have certain things, like roads or plants, provided they are installed somewhere else.

POLITICAL STABILITY

If the political climate is not favorable to business, investments may be slowed down or even completely halted. One will have to survey the history and the trend to make a reasonable forecast. Unfortunately, not all costs could be included in the estimate. Eliminating all the uncertainties may eliminate many overseas projects or for that matter, even domestic ones. However, the facts should be known and considered intelligently.

GENERAL ECONOMICAL STATUS

Now it is time to look into the area's general economical climate. Is it a booming or a depressed area? Are there other projects in the area now, during the construction of the proposed plant, or when its construction will be nearing completion?

If there are projects going on now, where did labor come from? If there will be other parallel projects there may be competition for the same labor force. This, however, may not be a problem if it happens to be in an area with a large labor pool.

REMOTE LOCATIONS

Nowadays plants are becoming larger and larger, with a good number of them being in the range of billions of dollars. Many of them are related to energy supply or processing raw minerals. Unfortunately, sources that were once located close to the market are becoming fewer and fewer. The only available sources are in far away places which most often are in foreign countries, the arctic, deserts, jungles, or remote mountain areas.

The task of developing those resources, and the plants for their processing in order to bring them to the market place, is enormous. Due to their scarcity some products could be sold even at very high prices, but others must be carefully evaluated. It is the duty of cost engineering together with the other disciplines to estimate the cost of the proposed facility accurately. The surveying team, and the entire engineering staff for that matter, must consider that raw materials may have to be brought to the plant for processing; the finished products sent to the market; harbors and roads will have to be constructed; power, steam,

and waste treatment plants built; a complete community erected; and complete and modern facilities provided.

The logistical aspect and the enormous problems of lodging and feeding thousands of people hundreds or thousands of miles from any major inhabited area will in themselves require excellent coordination and a lot of money.

GENERAL CONTRACTORS

If the survey is made by the owner, and if a general contractor or an engineering and construction firm has not been selected, the owner may look for a prime contractor that has adequate experience in the proposed geographical area. It may even be helpful if the owner makes the survey with the help of a potential engineering and construction firm. This firm may in turn rely on some local contractors for reliable local information. For some foreign projects there may be a requirement to use only local contractors—they must be contacted.

CONSULTANTS AND JOINT VENTURES

So far, many foreign governments have not interfered, but now they start demanding that joint ventures with local firms be established, and construction drawings made there. This may reduce the cost only if the respective country has experienced engineering organizations. Otherwise, training of local personnel will be required. It may be that drawings for civil or other simpler disciplines will be done overseas, and the more sophisticated disciplines, such as controls and process, be done in the home office, but costs will not be the same.

UNIONS

The next very important parts of our pre-estimating survey are unions and labor cost. For larger projects, a labor relation representative must be part of the survey team. Knowing if the site is in a union region, is a basic requirement. Can pre-assembled or completely assembled systems or machines be brought to the site, or will the union insist the assembly be done in the field? Can unions be convinced that bringing in pre-fabricated assemblies is part of the economics of building the plant?

UNION REGULATIONS

It is recommended that a copy of the regulations of the most important unions be obtained and studied. Any provisions that will result in higher costs should be evaluated.

One may think that in many foreign countries there are no union problems, but this is not always the case. While in some countries unions may not be as well organized, or maybe non-existent, in others they may be ever better organized and more influential than in this country.

QUALIFIED LABOR POOL

If the proposed plant will be built in a fairly industrial area, one may expect to find an adequate labor pool. Care should be taken only if a very specialized trade is required. Building a

plant in a less industrialized area, in the Arctic, or in a developing nation, not to mention an underdeveloped one, the availability of an experienced labor pool will be a serious and costly problem.

Importing foreign labor and training local manpower will be required. In this country the labor force is relatively mobile, but this will not be the case in many others.

One problem that will be faced by the project management will be staffing: Office as well as field personnel. The cost of recruiting, relocation, traveling, training, and loss of initial productivity during training must be considered and priced. It was mentioned previously that in some countries there are not too many trained construction workers, and that thousands will be needed. Some could be imported, but this will very often be discouraged by the host country.

If the respective foreign country is in the developing stage, there may already be some trained people—it will be very helpful to inquire about the experience of other contractors, or better yet, have a list of people previously trained and employed by one's own organization. Some companies may not be willing to share their knowledge of the local talent with a possible competitor, but local authorities could help.

TRAINING

Training will not be a requirement in an industrial nation, but it will be a basic requirement in many others. In some, training may be extended almost to the entire work force and to all the disciplines. Training facilities, instructors, their wages during training and transportation will be all part of the capital investment.

WORK PERMITS

The amount of expatriates sent overseas by the American firm may be limited by local work permits. This may not influence the engineering personnel too much, but it may control the desired quality of the field supervision. There is a tendency for some countries to impose restrictions on work done outside their borders or the personnel that can be "imported".

LABOR PRODUCTIVITY

This is a highly controversial issue, not always easy to determine, difficult to obtain, and expensive during construction if not well estimated and monitored. Basically, it comes down to how much actual work one worker does as compared to a base. The base most often used is the Gulf Coast area, but it may be any. The problem with actual productivity is that most companies consider their knowledge and data to be highly classified. If the respective company does not have any data, it can consult published data (scarce and unreliable), or it can obtain some from local contractors or unions. This last approach could be easy for an owner, but not for an out-of-town contractor. Experience in the area, data obtained from other contractors, published data, and a lot of judgement will be required in determining the productivity factors to be used. The importance of this subject is enormous. For a large project, it will influence schedule,

direct costs, indirect costs, working space, and the economics of the project. For a remote location it will affect the size of the camps, cost of catering, recreational facilities, and many others.

LABOR CONTRACTS

As part of the survey of labor unions, one should see when the existing labor contracts were signed, when will they expire and what could happen at their expiration. Estimating a project during whose life some labor contracts could be negotiated several times would present a special problem.

LABOR COST

A review of the latest union contract would indicate the cost per manhour, per trade. This will include base pay, special allowances, taxes, union dues, and benefits.

Labor costs would also include family living allowances, liberal severance pay, extra vacation time, social taxes, health insurance, pension, perfect attendance record bonus, and many more.

OVERTIME

It is best if the plant is built without any use of overtime. This, however, may not always be possible. Some projects may have scheduled overtime for the entire duration, while others may have only spot overtime. Overtime is an expensive substitute for lack of planning. One must consider the loss of productivity with the increased use of overtime. It is best if the estimated cost of scheduled overtime is shown separately.

SPECIFICATIONS

When the owner is using an outside engineering and construction company, it must be established whose specifications will be used.

LOCAL CODES

A knowledge of national codes alone is not sufficient—state and local codes must be compiled as well. A copy must be obtained and carefully studied, for this may mean redesigning some facilities and spending additional funds. Unfortunately, some cities may have some regulations which may be referred to as "unwritten codes", and some research is recommended. Again, for some foreign projects, American codes may be accepted, but a copy of local codes, if any, must be obtained. In addition, the measuring system will be metric.

PROCUREMENT

Again, no particular problems with domestic projects. For foreign projects, however, local specifications and sizes of local materials such as structural steel shapes should be well known for design/engineering purposes. It is recommended that detailed engineering be done at a place close to the construction site, or the main source of construction material. This will not be applicable to the process equipment which will be purchased worldwide.

MATERIAL MIX

When one deals with foreign projects, it is important to establish from where will most of the equipment and bulks be purchased. This may be dictated by availability, proximity or special import restrictions. This mix is important for calculating how much of different currencies will be required, for calculating escalation rates, freight, import duties, expediting and inspection, marshalling, and other related costs.

ORIGIN OF THE CONSTRUCTION MATERIALS

The origin of the bulk materials such as lumber, cement, aggregates, steel, piping, hardware, etc., must be established. For domestic projects, this may not be a problem other than for calculating freight, access for inspection, and for shortages in case of emergency. For foreign projects, however, this could cause a considerable problem. First, standards and measures will not be the same as in this country. Second, material may not be readily available and ample supply may have to be ordered well in advance. Beware of restrictions on importing materials, the costs of bringing them to the site, and the storage costs.

EVALUATING BIDS

The process of evaluating worldwide bids must be considered. Distances, shipping time, exchange rates, escalation, economic stability, and other monetary and non-monetary aspects must be considered to arrive at the right decision of from where to purchase. In most countries the inflation rate is higher than in the United States, and it must be considered. Worldwide procurement necessitates worldwide expediting, inspection and shipping. This will be against a background of various languages, business practices, and cultures.

EXPORT PACKING

Packing of equipment will vary if its destination is the jungle, the desert or the Arctic; whether it will go on the deck of the ship or below deck; how long it will stay on the site before it is erected; and the adequacy of site storage facilities. Packing is even more important if one considers that the fabricator may be thousands of miles away, equipment cannot be sent back for repairs, and local repair facilities may not be adequate. Proper identification is important, so that valuable time will not be wasted in the field to find what is needed.

UTILITIES

During the field survey, one must look into what utilities are available, where, how much and at what cost. What electric power is available, who will bring it to the plant, who will build the primary transformers, etc. Does power have to be produced by the plant? Is natural gas available, in what volume, what pressure? Who will bring it to the plant? Is there a need for a pipeline? Will the process require steam, and if so, will it be produced on the site or will it be purchased? If steam is purchased, who will bring it to the fence line and who will provide meters? What about process and drinking water? Is it available; in

what quantities? What treatment must be provided, and how will it be returned to the river or ocean?

HOUSING

If the site is near a city, the problem of housing may not be too acute, but considering the case of a grass root complex in the middle of nowhere, it may be a very serious problem indeed. Camps for the manual work force must be built with separate facilities for the staff. In some cases separate quarters may have to be provided for male and female personnel, and separate quarters for families.

WAREHOUSING

One of the many requirements, during construction is adequate storage space—outdoor and indoor. Some of the plant equipment and bulk materials may require a large outdoor laydown and storage area. For overseas projects, where boatloads of material may arrive at one time, storage space is very critical.

GUARD SERVICE

Another consideration in warehousing is security. If the equipment is not properly protected, it may invite theft. Theft, in turn, will be expensive, not only in terms of replacement costs, but schedule, if its disappearance is discovered only when the item is needed. A permanent guard service and adequate fences will be a must.

SITE FABRICATION FACILITIES

The possibility of onsite fabrication facilities should be considered. The most common facility will be a pipe spool shop, due to the bulk nature of shipping pre-fabricated piping. Another major advantage in the site pre-fabrication is that assembly could be scheduled to suite site erection—providing piping, valves and fittings are available.

CONSTRUCTION EQUIPMENT

First, from the scope of work and the schedule, the cost engineer should know what equipment will be necessary, when, and for what period of time. Second, it should be known where the equipment will be coming from. What about operators, maintenance and maintenance facilities? Can some of the work, like earth moving, be subcontracted to a local contractor and have him supply his own equipment, maintenance and camps? What about the fuel? Who will supply it? Who will store it?

Maintenance is as important if one considered that equipment which is not used is expensive and it does not help the schedule. Maintenance facilities and expert mechanics, together with adequate spare parts, are a must.

SCHOOL

School should be provided for the children of the construction personnel if family status is accepted. This will include the facilities and the teachers. The school could be a temporary construction, but if a community is planned, it is best to build a permanent one.

MEDICAL FACILITIES

Regardless of plant location, if thousands of people will be working on the site, adequate medical facilities must be provided. If a city is nearby, those medical facilities may only be for first aid. If others, however, are further away or not adequate, a hospital will have to be built, staffed and operated. If the facilities are small, it may be required to have emergency transportation to major nearby facilities twenty-four hours a day.

FOOD AND CATERING

Now that shelters and medical facilities for personnel at the site are provided for, what about food? The surveying team must know where will food supplies come from, how will it be served, by whom, and how much will it cost.

Adequate kitchens, supply rooms and mess halls must be provided; also, American as well as local food will have to be served. A commissary may be a part of the facilities if there are families on the site. In remote locations most food may be flown in, thus increasing the transportation cost. In addition to food, other services such as laundry and housekeeping must also be provided.

SANITARY FACILITIES

The surveying team must consider whether there are any existing sanitary facilities that may be used, or whether new ones will have to be constructed. The team should keep in mind that there will be thousands of people on the site during this construction period.

RECREATIONAL FACILITIES

Rest and recreation facilities are required for working people as well as for their families. What to provide will depend on the location, but the management must keep in mind that morale is a very important factor. Recreational facilities will help combat boredom, will reduce turnover, and it will also be helpful in improving productivity.

SCHEDULE

Plant completion in a foreign country will take longer than in the United States. This will be due to the many problems that will be encountered there; the slower rate of doing things, a lack of urgency, probably an attitude of mañana, communications, deliveries, and many others. All those factors and others must be considered when estimating the cost of field construction.

CURRENCIES

For projects that will involve worldwide purchasing and use of labor from more than one country, it would be preferable to have the estimate prepared in U.S. dollars. It should be known where money will be expended, how much and in what currency. The estimate should be prepared in current exchange rates, and contingencies for possible unfavorable fluctuations provided for. Knowledge of what currencies will be used, and how much will be required, is also needed for cash flow forecasts.

In international projects it may not be uncommon to deal with a dozen currencies. Considering the fact that they may be evaluated or devaluated several times during the life of the project, that makes for a difficult forecasting.

FINANCING

Financing could effect the estimating of a foreign project. More often than not, the financial institutions may require a mountain of paper before releasing funds to pay a major invoice, and some invoices could be returned for insufficient back-up. Some bankers may request to be consulted before a major commitment is made: All will mean time and money.

The client, the contractor or the engineering and construction company may have to finance some activities with their own money for many months. This will all involve some interest, but it will be interest that may not be reimbursed.

Knowing who will finance the project and what will their requirements be will help. Would there be any restriction on how much could be purchased where? Some of those requirements may be costly and time consuming.

COST OF TRAVELING

Traveling, including cost of hotels, food and transportation, could be an important part of the engineering and construction costs. The estimate could be calculated based on past data, location, what work will be done where, what coordination will be required, how many people will be traveling and for how long.

COST OF LIVING

Providing everything for those that will be working at the jobsite is not all. What about those that will be staying in that foreign city where the engineering will be done, and from where the overall coordination will be handled? Some of them will be there with their families. There are a few places on earth where life will be cheaper than in the United States, but there will be many where the cost of living will be much higher.

EDUCATION ALLOWANCE

This may not apply to families that are stationed at the construction site if a school is provided, but the jobsite school will go only to a certain grade. Assuming again that this is a remote location, the worst case, children above the given grades must be sent to other schools. This may also be applicable to those living in the city if adequate English speaking schools are not available.

OVERSEAS PREMIUM

An important incentive for the home office personnel working overseas is additional income. This, combined with the high cost of keeping this personnel overseas, adds to an important premium that must be included in the estimate. The schedule must be consulted, the mix of expatriates

to locals must be calculated, and the additional indirect cost estimated. The percentage of married to single people must be established.

TAXES

Domestic or foreign, large or small, taxes are on items that will be applicable to them all. This will take the form of sales tax, turnover tax, use tax, value added tax, real estate tax, etc.

IMPORT DUTIES AND PERMITS

Assuming that the required equipment and other materials can be imported, it must be known what the applicable import duties will be. This will vary with the shipment's description and its country of origin. Some goods may not be imported at all, and domestic products must be used. A good survey is very important for it may change some of the plant economics, schedules, and design. Use of brokerage firms is recommended.

GOVERNMENTAL AGENCIES

In this country one has to deal more and more with governmental agencies. For almost any construction in foreign countries, the dealings may have to be exclusively with the foreign government or with some of their agencies. Sometimes the "red" tape could be monumental.

LANGUAGE PROBLEM

The English language is very well accepted as the international engineering language. In most foreign countries, and especially in their large cities, there are many English speaking people. But going overseas, especially with a family, one is not interested in the engineering language alone. Organizations which do a lot of work overseas and send their home office personnel there should give mandatory courses in the respective language before and during the assignment.

While on the subject of the language, it must be established in what language will the construction documents be, and provide for cost of translation.

LOCAL CULTURES

This aspect cannot be over-emphasized. While it does not really belong in the estimating stage, familiarization, or the lack of it, could save or

cost a lot of money. Language is a way of communicating, but people cannot communicate by language alone. One should know how people think, how they react and what their attitude is toward foreigners. Some things that Americans will take for granted may be taboo in other countries. Teaching those that may go overseas how the hosts will behave, the basics of their culture, religion, food, and other habits, is essential. Understanding people in the country where the plant will be constructed may be the most important cost control tool. Cultural shocks are expensive. Sending people overseas costs money.

LOCAL CUSTOMS

For people going overseas, it will be desirable to have some basic knowledge of local customs. Knowing local customs and cultures is helpful in understanding the people in the host country, but also for the estimating and scheduling aspect. In the lands of Islam, time must be provided for the regular daily prayers, and some are during working hours. This, incidentally, means building a mosque on the site if one is not available. Local customs and work habits must be known for they mean additional money and time. Also, the holiday schedule. Time does not always mean money.

COORDINATION

It should be established at an early stage how this will be achieved.

Good coordination will save money, but there will be some direct costs associated with it. The most obvious will be to station people at strategic locations, their salaries, the living allowances and traveling costs. Coordination, however, does not apply only to the cost and schedule. Good coordination is just as important for engineering, procurement, expediting, quality assurance, financing, etc. This could involve many trips by many people at a high direct cost. Considering the international aspect of some projects, fluctuating economics, language problems, varied philosophies and terminology, cost estimating, cost control and forecasting is complex and requires constant direction for uniformity.

This article lists only about 120 items that must be surveyed before estimating. For some projects only part of the list will apply, for others most of the list and more.

Soil Conditions (other than those covered in BEDD Spec. 102)

Soil Investigation and Report for Plot Area **or**

Soil Investigation and Reports for Area **Near** Plot Area (existing facilities)

Site Access

Site Clearing and Grubbing

Site Fill and/or Removal to Rough Grade

Rock Problems

Compacting

Soil Replacement

If Piling, Type, Depth, Load Per Pile Used in Area

Excavation Material Suitable for Backfill

Availability of Burrow Pit

Availability of Backfill and Cost Delivered to Job Site

Available Dump Site for Excavation Materials

Disposal of Ground Water

Cathodic Protection Requirements

Boundary Regulations

Contractor Philosophy of Design

Type of Construction Contract

Plot Plan Layout

Piping Expansion

Percent Shop Versus Field Fabrication of Pipe

Pipe Shop Fabrication in Two or Three Dimensions for Shipping

Shop Versus Field Fabrication of Vessels and Fired Heaters

Steel Structure Design Including Pipe Racks

Civil Foundation Design

Use of Mat Concrete

Electrical Design for Cable Layout and Cables Per Conduit

Building Design – Type of Architecture

Equipment and Material Handling

Location of Storage Area (laydown and warehouse(s)) in reference to job site

Access to Job Site, Clearances, Turns

Condition of Haul Roads, Capacity of Any Bridges

Plot Plan of Existing Facilities (photos, if available)

Railroad Facilities Location Relative to the Job Site

Contractor Work Methods

General Approach of Traditional Versus Modern Techniques

Material Handling

Control Systems

Quality of Supervision

Use of Construction Equipment

Labor Logistics at Job Site

Use of Field Prefabrication for Pipe, Pipe Supports, Rebar, Fireproofing, Sandblasting and Painting

Reusable Versus Wooden Forms

Vessel Dressing

Field Labor

Number and Size of Other Jobs in Refinery, in Area, That Could Effect Availability and Quality of Labor

Average Number of Days of Rain Per Year

Average Total Snowfall Per Year

Number of Days Over 90 °F, Over 100 °F Per Year, Below 0 °F, Below -20 °F

Other Adverse Climatic Conditions That Could Effect Construction Progress Such as Wind, Dust, Insects

Project Location is Remote or Near Metropolitan Area

Availability of Local Labor: Skilled, Semi-skilled and Unskilled – Quantity and Quality

Requirements for Expatriate Labor, Quantity, Quality and Nationality

Work Crew Mixes of Crafts by Nationality and Skill

Requirements for Camp and Catering

Requirements for Supervision Ratio to Direct Labor

Determine Job Site Productivity Factor Based on Above

Determine Manpower Loading (restraints)

Build-up Rate

Peak Manpower Number and Duration of Peak

Work Space Density

Use of Overtime Hours Per Day, Number of Days Per Week

Run Down Rate

Realistic Construction Completion Date

Availability of Labor

Fast Track (double shift)

Available Construction Utilities

Use of Subcontracting

Logic Sequence and Timing of Work

Availability of Construction Equipment

Labor Cost

Payroll Burden on Labor by Percentage

Social Insurance – Employer (and employee if not base wage)

Workman's Compensation

Unemployment Insurance

General Labor Liability Insurance

Labor Fringe Benefits

Holidays Per Year

Vacation/Annual Leave, Paid Days Per Year

Pension/Retirement Allowance

Notice Pay (number of days)

Apprentice Training Allowance

Off Day Pay

Other Local Requirements

Premium Pay

Overtime Factor on Base Rate

Second Shift Premium

Contract Labor Broker's Fee

Basis of Charges (base wage, total labor cost, other)

Overseas Bonus for Expatriate Labor

Percentage on Base Wage for Each Nationality

Historic Escalation on Local Construction Labor

Past 3 years:

- 1.
- 2.
- 3.

Normal Date of General (or union) Increases

Local **Base** Wage Per Hour (**without** burden, benefits, premium, broker's fee or bonus) local currency or U. S. \$

Direct Labor	High	Average	Low
Foreman			
Welder			
Pipe Fitter			
Iron Worker			
Rigger			
Mechanic			
Insulation Worker			
Mill Wrights			
Painter			
Boiler Maker			
Pipe Fitter Welder			
Boiler Maker Welder			
Sheet Metal Worker			
Rebar Worker			
Carpenter			
Mason/Bricklayer			
Plaster			
Electrician			
Instrument Technician			
Inspection Technician			
Heavy Equipment Operator			
Truck Driver			
HVAC/Buildings			
Common Labor			

Indirect Labor	High	Average	Low
Typist			
Key Puncher			
Office Boy			
Clerk			
Guard			
Timekeeper			
Interpreter			
Printer			
Maintenance Mechanic			
Maintenance Electrician			
Store Keeper			
Fork Lift Driver			
Crane Operator			
Rigger			
Car/Light Truck Driver			
Cook			
Cook Helper			
Laundry Boy			
Camp Boy			
Nurses Aid			

Local Supervision Wage/Salary (if available)

Give basis, i.e., per hour, day, month, if base only or with burden, benefits, premium, broker's fee or bonus

Supervisor (above crew foremen)

Wage Rates for Expatriate Direct Labor (above) in Local Area

By Nationality

Identify Basis

Absenteeism and Turnover Rate (historical)

Average Local Constructor Labor Absenteeism Rate; Average Local Turnover Rate

Is Local Labor Paid for Time Off Job

Required Amenities Such as Hard Hats, Shoes, Gloves, Goggles, are Provided by Worker or Contractor

Subcontracting

Types of Subcontracting Available Locally for Materials and/or Erection

Types of Shop Fabrication Available Locally

Owners Recommended Local Subcontractors List

Material Costs

Local Procurement

Basis Must Indicate Measurement Unit, i.e., Metric Tons or Cubic Meters, etc.

Basis Must Indicate if Transportation to the Job Site is Included or not

Cost Can Be in Local Currency. If US\$, Indicate Exchange Rate

Indicate Availability of Materials if Limited

	High	Average	Low
Concrete, 2000 lb/in ²			
Concrete, 2500 lb/in ²			
Concrete, 3000 lb/in ²			
Screened Sand			
Blasting Sand			
Gravel			
Crushed Stone			
Rough Stone			
Concrete Block			
Paving Asphalt			
Asphalt Spray			
Plywood			
Rebar			
Anchor Bolts			
Construction Lumber			
Cement, Type V			

Equipment and Material Supply

Owner's Recommended Suppliers List:

Local

World Wide

List of Materials and Equipment Available Locally

PHASE II – INDIRECT FIELD COSTS

Construction Equipment

Is Full Range of Construction Equipment Available for Rental Locally

Obtain Rental Costs for the Following Equipment:

Indicate Sizes and Rental Period, Per Week, Per Month

Indicate if Cost is Delivered at Site and Assembled With Operators

Equipment	High	Average	Low
Gin Poles (Sizes)			
Crane 500 ton			
Crane 350 ton			
Crane 100 ton			
Crane 75 ton			
Crane 50 ton			
Crane 25 ton			
Bulldozer			
Back Hoe			
Loader (Cherry Picker)			
Graders			
Rollers			
Mixers, Concrete			
Asphalt Finisher			
Asphalt Distributor			
Compactors, Concrete			
Compactors, Earth			
Vibrators			
Cutters, Rebar			
Benders, Rebar			
Fork Lifts			

Dump Trucks			
Equipment	High	Average	Low
Flat Bed Truck			
Pickup Truck			
Van Truck			
Tractor/Trailer			
Ambulance			
De-water Pump			
Low Boy Truck			
Electric Generator			
Portable Air Compressor			
Water Test Pump			
Welding Machine			

Construction Equipment Services

Are Fuels (Gasoline And Diesel), Greases, Oils Available From The Refinery

At What Cost

If Not Available, Is There A Recommended Supplier

At What Cost If Supplied By Recommended Supplier

Are Repair Services Available Locally For Major Construction Equipment

Are Spare Parts Available Locally For All Construction Equipment

Temporary Construction Facilities

Are Existing Buildings Available for Contractor Use

If Available, What Kind of Building, Size and Distance to Job Site (show on a plot plan)

Are Temporary Prefab Buildings Available Locally

Name(s) of Supplier(s)

New and/or Used

Cost Delivered to Site for Various Types and Sizes

What Area Will Be Used for Temporary Facilities

Plot Size and Location in Reference to Job Site (include temporary parking area)

What Area Will Be Used for Equipment Laydown Area

Plot Size and Location in Reference to Job Site

Will Temporary Fences Be Required

If Required, Show on a Plot Plan

Will Concrete Batch Plant Be Required and/or Will Rock Crusher Be Required

Will All Utilities Be Available for Temporary Facilities Including Potable Water, Electric, Sewage, Dry Air, Refuse Pickup, and Steam

Are Telephone and Telex Connection Available

Mark Plot Plan Where Tie-ins Are for All Temporary Services

Will All Temporary Facilities Be Dismantled and Demolished After Construction

Will Some Facilities Be Retained by Refinery

Construction Consumables

Is Full Range of Consumables Available Locally

Obtain cost for the Following Consumables Purchased Locally. Indicate Quantity of Unit Price.

	High	Average	Low
Welding Rod			
Oxygen			
Acetylene			
Rope			
Hoses, Air			
Hoses, Water			
Scaffolding			
Radiograph Film			
Annealing Kits			
Riggers Fittings			
Canvas			
Plastic Sheets			
Cable			

Small Tools

Are Craftsmen's Tools Available Locally

Historical Area Loss Rate of Small Tools on Construction Projects

Field Office Supplies

Are "normal" office supplies available locally

Typewriters, Electric

Calculators

Copy Machines

Printing Machines

Stationery Supplies

Small Computers and Software, Rental or Lease Basis

Construction Insurance and Bonding

Is There a Recommended Carrier for Erection All Risk Insurance, Comprehensive General Liability, Construction Equipment Floater, Marine Cargo Insurance

Is There a Recommended or Required Bonding Agent for the Contractor's Bonds

If Yes to Either of the Above, What Rates Will Be Used

Safety

What Local Job Safety Procedures Are Required

What Medical Facilities Are Available, Ambulances, Doctors, Hospitals

At Job Site

Locally

Will Refinery Provide Fire Protection at Job Site

What Permit Procedures Will Be Required for Burning, Welding and Personnel Smoking at Job Site

Will Contractor Be Required to Have a Safety Engineer

Construction Utilities

Will Refinery Provide Construction Utilities

Potable Water

Test and Construction Water – Indicate Quality

Utility Air (wet)

Electrical (voltage and amps)

Steam (low pressures)

What Are Maximum Supply Rates

Will There Be a Cost Charged – To Whom

If Refinery Cannot Supply, Are There Other Utility Sources Available

At What Supply Rate and Cost

Show Tie-in Points for Refinery or Other Supplier Utilities on a Plot Plan

Camp and Catering

Will a Camp Be Required For This Project – If Yes:

For Whom – Nationality

Minimum Requirements for Quality of Camp

Location of Camp Relative to Job Site

Are Any Camp Facilities Available Now

Will There Be Charges For Its Use

Ocean Transportation and Local Inland Transportation

Location of Closest Port

Capacity of Port Facilities

Maximum Lift

Depth of Water

Storage Facilities

What Are Port Charges or Custom Clearance Expenses

Distance to Job Site

Hauling Conditions of Roads, Bridges and Restrictions

Rail Service Available

What are Shipping Times and Rates From:

Europe

United States

Japan

Other

Is There a Recommended Shipper's List

What Import/Export Duties Will Be Charged and Who Will Pay

Contractor's Home Office Expenses

Will Owner Have Staff and/or Project Manager Located in Contractor's Home Office –
If Yes:

How Many Men and How Long Will They Stay

Mobilization/Demobilization

Closest International Airport

Distance to Job Location

Is Local Transportation Available to Job Site; What Kind and Cost

Cost of First Class Hotel Per Day

Near Airport

Near Job Site

Rental Cars Available at What Cost

Entrance Requirements for Labor Force

Field Supervision

Requirements for Type of Supervision

Ratio to Direct Labor

Control Systems

Indirect Labor

Will Refinery Provide Security Services for Construction

Will Contractor Have Separate Gate

Distances to Job Site From Gate

Refinery Guard at Contractor Gate

Fire Protection Provided by Refinery

Maintaining Roads in Refinery

What Parking Area Will Be Provided

Are Services Available for Testing Locally

Concrete Samples

Welding Xray

Welder Qualification

PHASE III – ADDITIONAL PROJECT COSTS

Land/Right-of-Way Cost, Buy or Lease

Soil Investigation and Analysis

Contractor's Engineering, Procurement, Project Team, Home Office Expenses and Fees

Project Management

Basic Engineering Design (Schedule A)

Owner's Project Staff

Change Orders

Spare Parts for Operations

Catalyst, Chemicals and Lubricants

Royalties and Know-how Fees

Local Taxes, Duties, Permits and Agent's Fee

UOP Start-up Crew

Contractor Commissioning Stand-by Crew

Vendors for Commissioning Activities

Operation's Staff Recruiting

Operator, Engineering and Maintenance Training and Manuals

Working Capital for Inventory, Salaries, Wages and Expenses

Utilities Provided to Contractor

Commissioning and Start-up Insurance

New Laboratory Test Equipment and Supplies

New and/or Changes to Existing Computer System

Bank Charges and Commissions

New Maintenance Equipment

PHASE IV – CONTINGENCY

Changes in Scope of Project

Charge Stock, Project Specifications, By-products

Process Background

Schedule A Design Status

Site Work Required (unforeseen soil problems)

Detail Design Status (contractor)

Variations in Effectiveness of Management

Project Manager

Contractor's Management and Field Supervision

Forecast of Escalation

Equipment and Materials

Labor Wage/Salary Rate

Additional Work/Rework

Climatic Conditions

Accidents

Extended Construction Schedule

Climatic Conditions

Accidents

Labor Disruptions

Equipment and Materials Delivery and/or Availability

Owner's Directives

Changes in Economic Conditions

Currency Exchange Rate(s)

Estimating Techniques

Estimating Errors and Omissions

ENGINEERING DESIGN SEMINAR

SEPTEMBER 6, 1994 – NOVEMBER 11, 1994

COST ENGINEERING

by Mr. Don Kinsh

SEMINAR AGENDA

Introduction to Cost Engineering

Types of Cost Estimates and Their Use

Order of Magnitude Estimate

Curve Type Estimate

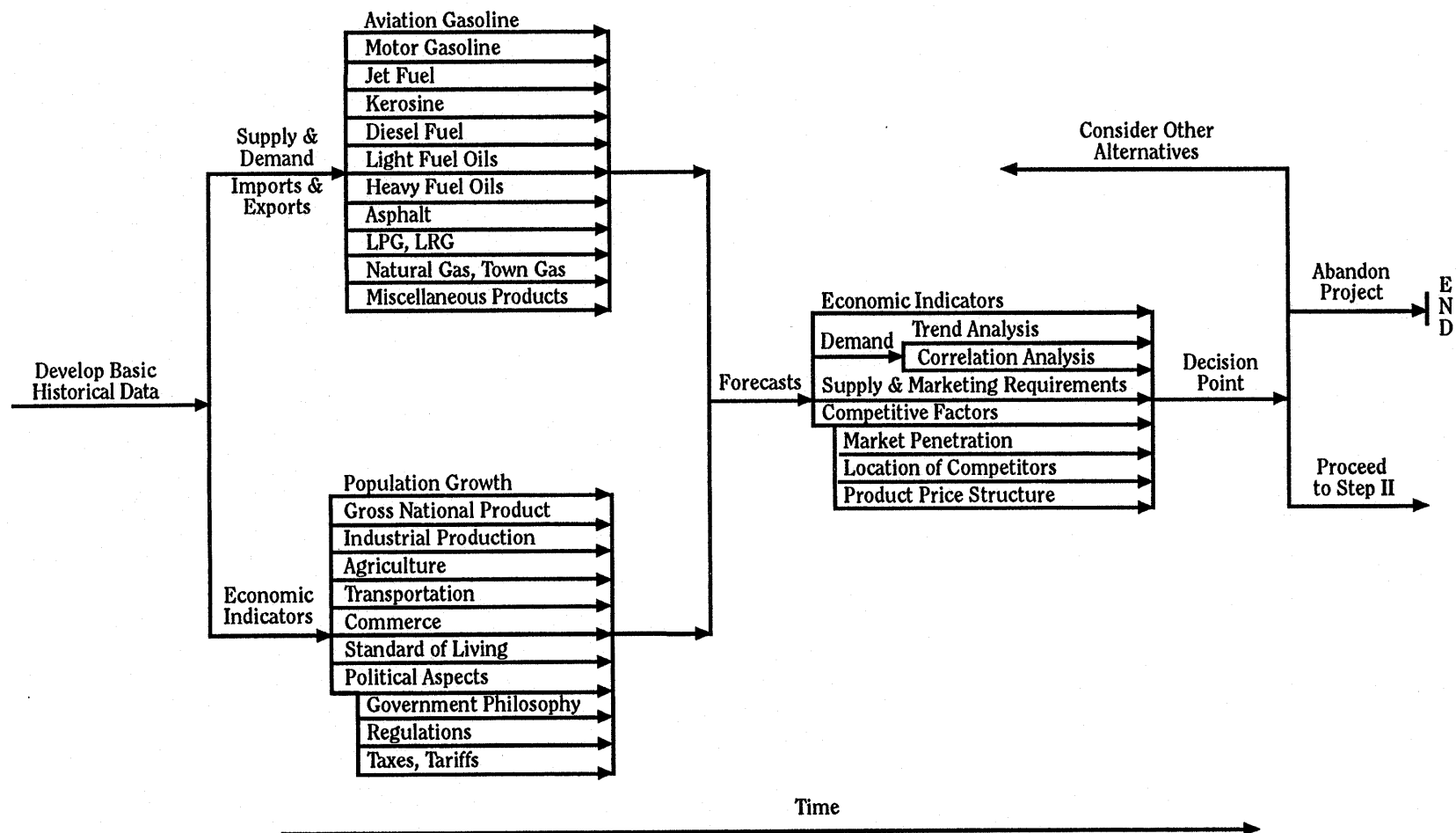
Factored Estimate

Cost Indices

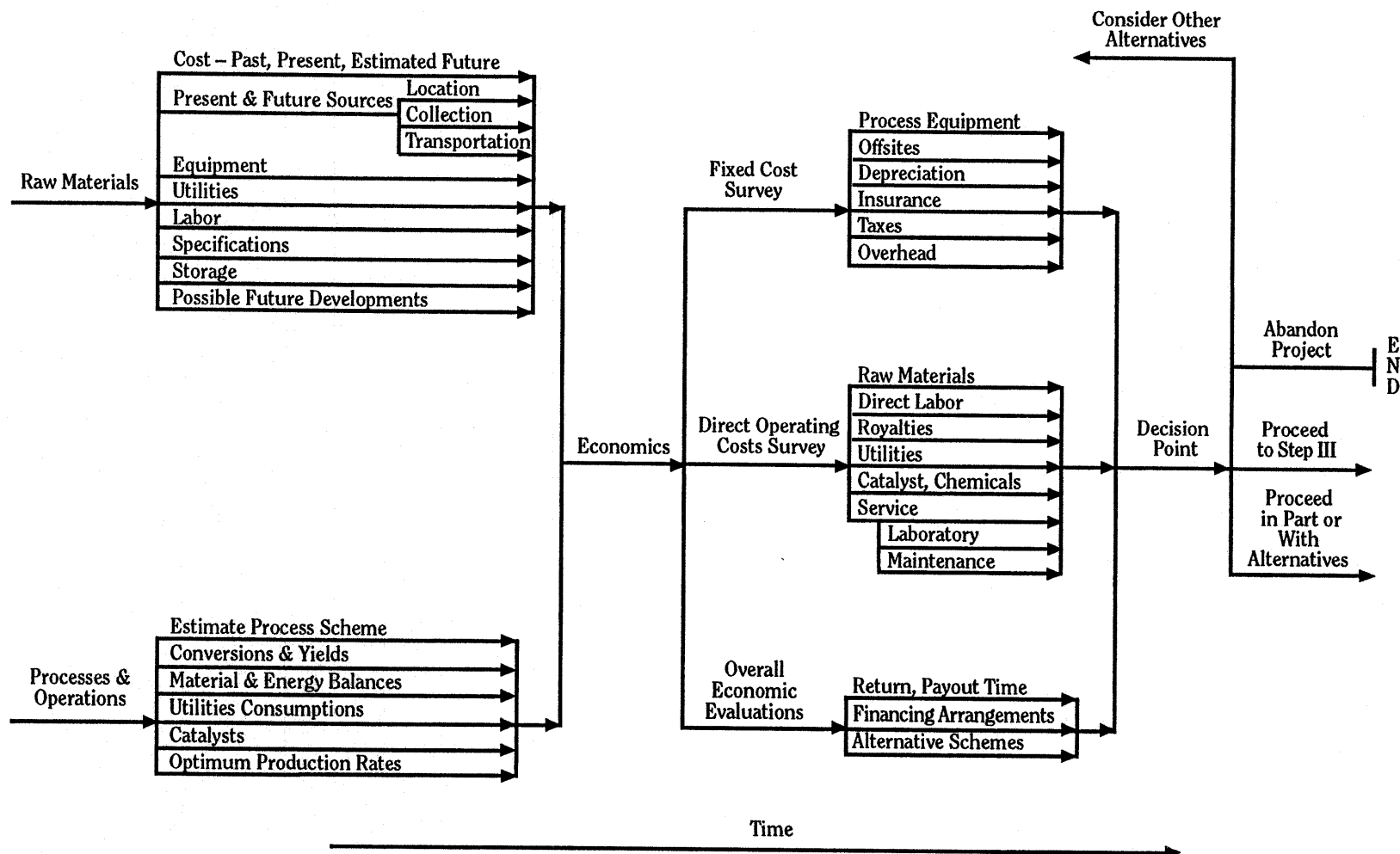
Escalation

Solving Problems in Economic Choice

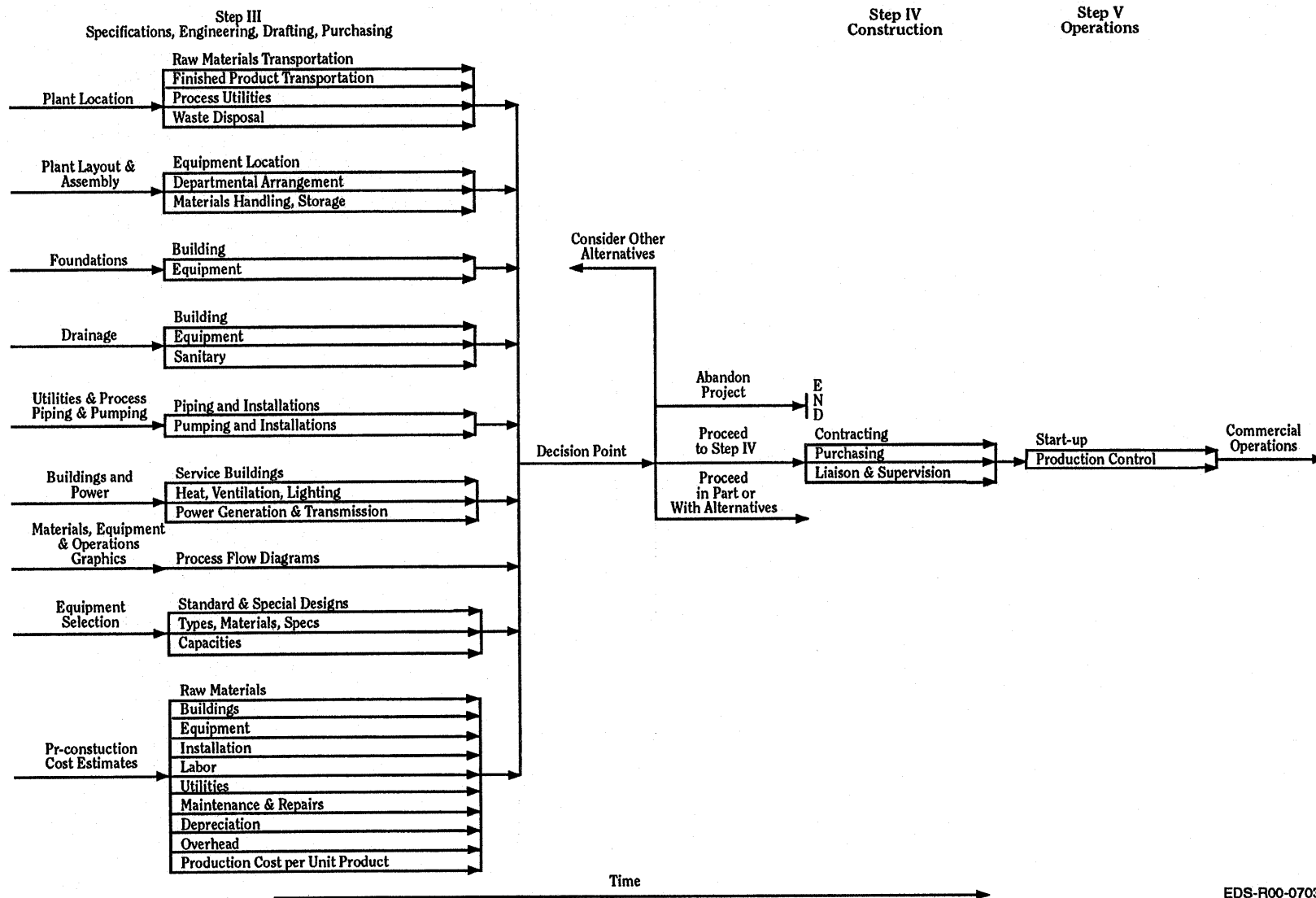
*Checklist Diagram
Step I – Market Study*



Checklist Diagram
Step II – Feasibility/Economics Study



Checklist Diagram *Step III, IV, and V – Design, Construction, and Operation*



Use and Type of Cost Estimates

Use	Suitable Type	UOP Class
Selection of Project Preliminary Feasibility Studies	Order of Magnitude	E
Refined Feasibility Studies Go-No Go Economic Studies Select Licensor of a Process	Curve Type Factored Type	C or D
Refined Economic Studies Establish Project Budget Check Lump Sum Bids	Curve Type Factored Type Detailed Type	C – A or B
Selection of General Contractor for Reimbursable Contract	Detailed Type	A
General Contractor May Use for Lump Sum Bid	Detailed Type	A+
Cost Control Estimate	Definitive Type	–

Reva-P

How

F
greater than
± 50%

None
Available

None
AVAILABLE

B
± 20 to 25%

A
± 15%

A+

± 15%

Type	UOP Class	Information Available	Data Used	Project Stage
Order of Magnitude	E ± 50 percent	Capacity of unit or plant.	Capacity curves or power factors and judgement	Very early conceptual stage
Curve Type	D ± 40 percent	Capacity of individual units. Process design data. Operating conditions. Yield estimates. Major tower size, driver types, cooler types.	In-house curves of units somewhat similar but questionable due to process design, age, or other reasons.	Planning Stage
Curve Type	C ± 25 percent	Same as above. process design some equipment size	In-house curve data for sections of the units, developed from directly comparable projects.	Feasibility Studies
Detailed Type EFCEST Type	B ± 15 percent	EFCEST data for all equipment. Process flow drawing with line sized, or marked up P & I from similar unit.	In-house equipment sizing and pricing with a few key vendor quotations. In-house plot plan made by Cost Estimating group. In-house conceptual bulk material take-off techniques.	Feasibility study when curve costs not available
Detailed Type	A ± 10 percent	UOP Schedule A equipment specifications. P & I drawings. UOP proposed plot plan	In-house equipment sizing and pricing with a few key vendor quotations. In-house conceptual bulk material take-off techniques.	After UOP Schedule A is complete.
Detailed Type	A+ Better than ± 10 percent	UOP Schedule A equipment specifications. Contractors plot plan, piping layout, and electrical design. Preliminary foundation design. Proposed construction equipment lists. Temporary facilities plans.	Vendors equipment quotations. Take-off of bulk materials from preliminary layouts and designs.	After contractor has received quotations on most equipment and has done preliminary layout and structural design.
Definitive Type	- Better than ± 10 percent	Equipment purchase orders, final plot plan, piping spool drawings, structural drawings, concrete drawings.	Purchase order for equipment and subcontracts. Detailed take-off from construction drawings.	After contractor has done much purchasing and most of detail design.

COST CONTROL.

ITEMS NOT INCLUDED IN UOP COST ESTIMATES OF BATTERY LIMIT COSTS UNLESS SPECIFIED

Owner's
Cost

Cost of land, site preparation, and soil investigation

Piling or any unusual foundation requirements

o Docks, marine terminals, or jetties

offsites

o Access roads to site

o Home office administration building

— Worker's transportation allowance, employee housing, workers' barracks, canteens, and recreation facilities

Overtime pay during construction

Know-how fees and royalties on licensed processes

Owner's expenses in developing the project

Local permits, taxes and fees, or specified costs of doing business in the area

— Items concerned with export shipments, such as ocean freight, export crating, marine insurance, import taxes and customs

Operating capital and investment in goods in the process

Miscell.
Exclusion

— Escalation on materials and labor due to price fluctuation or economic conditions

— Contingencies

— Site preparation and soil investigation

Cost of start-up including testing, manpower, utilities, operating manuals and training programs

- Spare parts, special tools or maintenance equipment
- Catalyst, chemicals and raw materials including initial fills or inventories
- Customer or national standards or codes
- Special pollution or noise control facilities
 - o Electrical main substations
 - o Power generation
 - o Water or hydrocarbon pipelines
 - o Additions or extensions to utilities systems or offsites
 - o Laboratory facilities or supplies
- Special communications or computer systems

The following assumptions are normally made regarding economic conditions at the time the job is bid.

There will be an adequate supply of skilled labor available for construction

There will be a reimbursable contract with a fixed cost for home office services

The plant will be constructed in the U. S. Gulf Coast.

There is no lost time due to climatic conditions.

Material and labor prices are based on the date of the estimate.

AMERICAN NATIONAL STANDARD – COST ENGINEERING – GLOSSARY OF TERMS

Accounts Payable is the value of goods and services available for use on which payment has not yet been made. (See Taxes Payable).

Accounts Receivable is the value of goods shipped or services rendered to a customer on which payment has not yet been received. Usually includes an allowance for bad debts.

Administrative Expense is the overhead cost due to general direction of the company, above the plant manager level. Generally includes top management salaries and the costs of legal, central purchasing, traffic, accounting, and other staff functions.

Average Annual Cost is the conversion, by an interest rate and present worth technique, of all capital and operating costs to a series of equivalent equal annual costs. As a system for comparing proposal investments, it requires assumption of a specific minimum acceptable interest rate.

Battery Limit comprises one or more geographic boundaries, imaginary or real, enclosing a plant or unit being engineered and/or erected, established for the purpose of providing a means of specifically identifying certain portions of work as being related groups of individual items or associated facilities. Generally refers to the processing area and includes all process equipment, and excludes such other facilities as storage, utilities, administration buildings or auxiliary facilities, unless so specified.

Book Value (Net) is the current investment value on the books calculated as original value less depreciation accruals. New asset value for accounting use. Also, the value of an outstanding share of stock of a corporation at any one time, determined by adding the par (or stated) value of the stock outstanding to the surplus applicable to that class of stock and dividing by the number of shares of that class outstanding.

Break-even Point is the percentage of capacity at which incomes of a company or facility just cover all fixed and variable costs. Depreciation normally included. (See Shutdown Point.)

Burden is the percentage of cost used for maintaining, staffing and furnishing of an office with staff other than operating personnel. In contracts with some governmental agencies, these items are included in indirect cost.

Capital Budgeting is a systematic procedure for classifying, evaluating, and ranking proposed capital expenditures for the purpose of comparison and selection, combined with the analysis of the financing requirements.

Capital, Cost of is the weighted average of (1) the after-tax cost of long-term debt, (2) the yield on any outstanding preferred stock, and (3) the cost of common equity capital.

Capital, Fixed is the total original value of physical facilities which are not carried as a current expense on the books of account and for which depreciation is allowed by the Federal Government. It includes plant equipment, building, furniture and fixtures, transportation equipment used directly in the production of a product or service. It includes all costs incident to getting the property in place and in operating condition, including legal cost, purchased patents, and paid-up licenses. Land, which is not depreciable, is often included. Characteristically it cannot be converted readily into cash.

Capital, Sustaining is the fixed capital requirements to (1) maintain the competitive position of a project throughout its commercial life by improving product quality, related services, safety, or economy, or (2) required to replace facilities which wear out before the end of the project life.

Capital, Working are the funds, in addition to fixed capital and land investment, which a company must contribute to the project (excluding start-up expense) to get the project started and meet subsequent obligations as they come due. Consists of the difference between current assets (cash, receivables, and inventories) and current liabilities (accounts, notes, and taxes payable). Characteristically, these funds can be

converted readily into cash. Working capital is normally assumed recovered at the end of the project without loss.

Capitalized Costs is the present worth of the cost of renewing and operating a facility perpetually. As a system for comparing proposed investments, it requires assumption of a specific minimum acceptable interest rate.

Cash Flow is the net flow of dollars into or out of the proposed project. The algebraic sum, in any time period, of all cash receipts, expenses, and investments. Also called cash proceeds or cash generated.

Cash Return, Percent of Total Capital is the ratio of average depreciation plus average profit, to total fixed and working capital, for a year capacity sales. Under certain limited conditions, this figure closely approximates that calculated by profitability index techniques where it is defined as the difference, in any time period, between revenues and all cash expenses, including taxes. The sum of net profit after tax and the depreciation deduction used in calculating net profit.

Contingencies are specific provisions for unforeseeable elements of cost within the defined project scope. This is particularly important where previous experience relating estimates and actual costs has shown that, statistically, unforeseeable events which will increase costs are likely to occur. It may or may not include allowance for escalation.

Contracts are legal agreements between two or more parties, which may be of the type listed below.

In Cost Plus contracts, the contractor agrees to furnish to the client services and material at actual cost, plus an agreed upon fee for his services. This type of contract is employed most often when the scope of services to be provided is not well defined.

Cost Plus Percentage Burden* and Fee – The client will pay all costs as defined in the terms of the contract, plus "burden and fee" at a specified

percent of the labor costs which he is paying for directly. This type of contract generally is used for engineering services.

*In contracts with some governmental agencies, these items are included in indirect cost.

Cost Plus Fixed Fee – The client pays costs as defined in the contract document. In this case, Burden on Reimbursable Technical Labor Cost is considered part of cost. In addition to the costs and Burden, the client also pays a fixed amount as the contractor's "fee."

Cost Plus Fixed Sum – The client will pay costs defined by contract plus a fixed sum which will cover "non-reimbursable" costs and provide for a fee. This type of contract is used in lieu of Cost Plus Fixed Fee contract where the client wishes to have the contractor assume some of the risk for items which would be reimbursable under a Cost Plus Fixed Fee type of contract.

Cost Plus Percentage Fee – The client pays all costs, plus a percentage for the use of the contractor's organization.

Fixed Price types of contract are ones wherein a contractor agrees to furnish services and material at a specified price, possibly with a mutually agreed-upon escalation clause. This type of contract is most often employed when the scope of services to be provided is well defined.

Lump Sum – Contractor agrees to perform all services as specified by the contract for a fixed amount. A variation of this type may include a Turn-Key arrangement where the contractor guarantees quality, quantity and yield on a process plant or other installation.

Unit Price – Contractor will be paid at an agreed-upon unit rate for services performed. For example, technical man-hours will be paid for at the unit price agreed upon. Often field work is assigned to a subcontractor by the prime contractor on a unit price basis.

Guaranteed-Maximum (Target Price) – A contractor agrees to perform all services as defined in the contract document guaranteeing that the total cost to the client will not exceed a stipulated maximum figure. Quite often, these types of contracts will contain special share-of-the-saving arrangements to provide incentive to the contractor to minimize costs below the stipulated maximum.

Bonus-Penalty – A special contractual arrangement usually between a client and a contractor wherein the contractor is guaranteed a bonus, usually a fixed sum of money, for each day the project is completed ahead of a specified schedule or below a specified cost or both, and agrees to pay a similar penalty for each day of completion after the scheduled date or over the specified cost up to a specified maximum either way. The penalty situation is sometimes referred to as liquidated damages.

Construction Cost is the sum of all cost, direct or indirect, inherent in converting a design plan for material and equipment into a project ready for operation, i.e., sum of field labor, supervision, administration, tools, field office expense and field purchased material cost.

Cost Engineer is the engineer whose judgement and experience are utilized in the application of scientific principles and techniques to problems of cost estimation, cost control, business planning and management science.

Cost Control is the application of procedures to follow the progress of design and construction projects as well as manufacturing operations in order to minimize cost with the objective of increasing profitability and assuring efficient operations. There are three essential elements of control: (1) establish the optimum condition; (2) measure variation from the optimum; and (3) take corrective action in order to minimize this variation. The application of these procedures attempts to limit costs to those authorized for capital projects or cost standards, focuses control efforts where they will be most effective, and achieves maximum control at minimum operating cost.

Cost Index (Price Index) is a number which relates the cost of an item at a specific time to the corresponding cost at some arbitrarily specified time in the past.

Depletion is the allocation of the value of the quantity of natural resources extracted from a deposit (applying to resources not replaceable by human beings). A non-cash expense, but allowed tax deduction. (see Depreciation).

Depreciation is the allocation of the cost of fixed capital assets less salvage (if any) over the estimated useful life of the unit, in systematic and rational manner (straight line, sum of the digits, double declining balance, etc.). A noncash flow tabulation used in various profitability measures, depreciation is important only as an allowed deduction from income taxes.

Development Costs are costs specific to a project, either capital or expense items, which occur prior to commercial sales found necessary to evolve the potentialities of that project for consideration and eventual promotion. Major cost areas include process, product, market research, and development.

Direct Cost is dollar per unit of time for the manufacturing expenses which may be affected by production rate. Direct costs are generally assignable to a specific product or process area. Usually included are:

Input Materials

Operating, Supervision, and Clerical Payroll

Fringe Benefits

Maintenance (Payroll and Benefits; Materials and Supplies)

Utilities

Catalysts, Chemicals and Operating Supplies

Miscellaneous (Royalties, Services, etc.)

Detailed descriptions of the above classifications are:

Input Material Costs

Raw materials which appear in some form as a product. For example, water added to resin formulation is an input material, but sulfuric acid catalyst, consumed in manufacturing high octane alkylate, is not. Input materials are frequently the largest item of direct costs, ranging as high as 80 percent in some chemical industries, and should be estimated as accurately as possible, using material balances and applicable prices.

Operating, Supervision and Clerical Payroll Costs

Wages paid personnel who operate the production facilities. Detailed estimates require an analysis of such personnel and the associated wage rate. For such detail, Manning Tables are usually developed. Such tables include the number of personnel for each craft and the schedule of man-hours. These data and the hourly wage rate are combined to yield an accurate labor cost.

Where supervisory and clerical costs cannot be calculated for a specific product or process area because of overlapping responsibilities, they may be estimated as a percentage of operating labor. The range is from 5–30 percent; 25 percent is an average for the chemical process industries.

Fringe Benefits*

Payroll costs other than wages not paid directly to the employee. They include costs for:

- Holidays, Vacation, Sick Leave
- Federal Old Age Insurance
- Pensions, Life Insurance, Savings Plans, etc.

Benefits normally range from 25–30 percent of all payrolls, including maintenance. A short-cut method of estimating payroll cost, including benefits involves multiplying the number of plant operators (estimated for some convenient unit of time, such as a shift or a day) by a wage rate which includes a correction for supervision, technical payroll, and benefits.

*In contracts with some governmental agencies, these items are included in indirect cost.

Maintenance Cost

Expense incurred to keep manufacturing facilities operational. It is frequently estimated as a percentage of investment based on accounting records or a knowledge of the equipment or manufacturing process. Total Maintenance, defined as materials plus labor (not including maintenance overhead) usually ranges from 3 percent of investment, for inactive, long-lived equipment like buildings or storage tanks, to 10 percent for a process using corrosive materials. More accurate estimates of maintenance require analysis of the material and labor components.

Maintenance payroll cost may be estimated:

- As 1/2–2/3 of total maintenance (includes payroll benefits).

- As a function of operating cost.

- As a percent of investment.

- As a function of utility consumption.

- On the basis of cost records.

- By detailed manpower requirements.

Contract maintenance is frequently used where heavy maintenance demands occur intermittently or where they may be prescheduled, as for plant "turnaround." Detailed analysis, beyond the scope of this summary, is required to justify maintenance contracts.

Maintenance materials cost may be estimated:

As 1/2–1/3 of total maintenance.

On the basis of cost records.

By detailed analysis of equipment life.

As a percent of investment.

Maintenance materials which have a life of more than one year are usually considered capital investment in detailed cash flow accounting.

Utilities

The fuel, steam, air, power and water which must be purchased or generated to support the plant operation. Utility requirements must be estimated or calculated. When utilities are purchased, as from a local utility or an adjacent plant, unit "total" costs are available from the supplier.

Cost for utilities generated within the limits of the manufacturing facility are estimated as part of the overall cost estimate. For short-cut estimates for these situations, purchased costs can be used, but all other costs related to utilities (including return of investment) must be excluded.

Catalysts, Chemicals, and Operating Supplies

Materials consumed in the manufacturing operation, but not appearing as a product. Consumption must be calculated or estimated. Operating supplies are a minor cost in process industries and are sometimes assumed to be in the maintenance materials estimate. In many industries, such as mining, they are a significant proportion of direct cost and must be estimated in detail.

Miscellaneous

Costs paid to others for the use of a proprietary process. Both paid-up and "running" royalties are used. Cost of paid-up royalties are usually on the basis of production rate. Royalties vary widely, however, and are specific for the situation under consideration.

Although the direct costs described above are typical and in general use, each industry has unique costs which fall into the "direct cost" category. Examples include equipment rental, waste disposal, contracts, etc. Such items must be analyzed for each specific situation.

Discounted Cash Flow (see Profitability Index)

Escalation is the provision in actual or estimated costs for an increase in the cost of equipment, material, labor, etc., over those specified in the contract due to continuing price level changes over time.

Estimate is an evaluation of all costs of the elements of a project or effort as defined by an agreed-upon scope. Three specific types based on degree of definition of a process industry plant are:

Order of Magnitude Estimate

An approximate estimate made without detailed engineering data. Some examples are an estimate from cost-capacity curves, an estimate using scale up or down factors, and an approximate ratio estimate. It is normally expected that an estimate of this type would be accurate within plus 50 percent or minus 30 percent.

Budget Estimate

In this case, budget applies to the owner's budget and not to the budget as a project control document. A budget estimate is prepared with the use of flow sheets, layouts and equipment details. It is normally expected

that an estimate of this type would be accurate within plus 30 percent or minus 15 percent.

Definitive Estimate

As the name implies, this is an estimate prepared from very defined engineering data. Engineering data includes fairly complete plot plans and elevations, piping and instrument diagrams, one line electrical diagrams, equipment data sheets and quotations, structural sketches, soil data, sketches of major foundations, building sketches, and a complete set of specifications.

This category of estimate covers all types from the minimum described above to the maximum definitive type which would be made from "Approved for Construction" drawings and specifications.

It is expected that an estimate of this type would be accurate within plus 15 percent and minus 5 percent.

Expansion is any increase in the capacity of a plant facility or unit, usually by added investment. Scope of its possible application extends from the elimination of problem areas to the complete replacement of an existing facility with a larger one.

Fee is the charge for the use of the contractor's organization for the period and to the extend specified in the contract.

Field Costs are those costs, other than direct labor, such as field administration, direct supervision, capital tools, etc., involved in producing a finished project.

Fixed Costs are the costs independent of short-term variations in output of the system under consideration. This includes labor, maintenance, technical service, laboratory expense, taxes, insurance, plant overhead, administrative, selling, and research expense. For the purpose of cash flow calculation, depreciation is excluded (except in income tax calculations).

Fringe Benefits are employee welfare benefits including expenses of employment not paid directly to the employee such as holidays, sick leave, social security, insurance, etc.

Home Office Costs are necessary costs involved in the conduct of everyday business which can be directly assigned to specific projects, processes or end products, such as engineering, procurement, expediting, inspection, estimating, reproduction, telephone, telegraph, etc.

Incremental Costs (Revenues) are the cost and revenue differences between two alternate courses of action. These should be based on changes which can actually be foreseen as occurring rather than having accounting conventions to approximate overheads, etc. Costs refer both to investment and annual operating costs. In a narrower sense, the cost of the last unit produced at a given level of production.

Indirect Costs** include all costs included in a project, other than direct costs, such as material and labor, which do not become a final part of the installation, but are required for the orderly completion of the installation and may include, but not limited to, starting costs, contractor's fees, insurance, taxes, etc. In manufacturing, those costs not directly assignable to the end product or process and which may include plant overhead, material handling and maintenance charges, etc.

**In government contracts, it is often calculated as a fixed percent of direct payroll costs.

Interest, Compound is the rate earned by money expressed as a constant percentage of the unpaid balance at the end of the previous accounting period. Typical time periods are yearly, semiannually, monthly, and instantaneous.

Interest Rate of Return (see Profitability Index)

Inventory is the value of raw materials, products in process, and finished products required for plant operation. Inventory also includes other supplies used for maintenance, catalyst, chemicals, and spare parts.

Labor Cost is the salary plus all fringe benefits of construction craftsmen and general labor on construction projects, and labor crews in manufacturing or processing areas which can be definitely assigned to one product or process area or cost center.

Leverage (Trading on Equity) is the use of borrowed funds or preferred stock in the intent of employing these "senior" funds at a rate of return higher than their cost in order to increase the return upon the investment of the residual owners.

Maintenance is the expense, both for labor and materials, required to keep equipment or other installations in suitably operable condition. Maintenance does not usually include those items which cannot be expended within the year purchased and that must be considered fixed capital.

Manufacturing Cost is the total of operating costs chargeable to productions of a given product, usually expressed in cents or dollars per unit of production. This includes direct expenses, such as ingredients, labor, and utilities, and also fixed or allocated charges such as maintenance, depreciation (a non-cash expense), insurance, and property taxes. Overheads within the plant are usually considered within manufacturing cost. Sales, administrative and research overheads, and freight are usually not included.

Mapi Method is a system of analysis based fundamentally on the discounted cash flow procedure. By formula approach, it compares making an investment now with going on without investing for one more year. This method is easy to apply, but should not be used where the assumptions built into the formula do not fit a particular situation.

Material Cost is the cost of everything of a substantial nature that is essential to the construction or operation of a facility, both of a direct or indirect nature. This generally includes all manufactured equipment as a basic part.

Maximum Out-of-Pocket Cash is the highest year-end negative cash balance during project life.

Net Profit is earnings after all operating expenses (cash or accrued non-cash) have been deducted from net operating revenues for a given time period.

Net Profit, Percent of Sales (Profit Margin) is the ratio of annual profits to total sales for a representative year of capacity operations. An incomplete measure of profitability, but a useful guidepost for comparing similar products and companies.

Operating Costs are charges for labor, material and contracted services which can be assigned or allocated to a specific manufacturing operation.

Opportunity Costs are profits from alternative ventures that are foregone by using limited facilities for a particular purpose.

Optimum Plant Size is the plant capacity which represents the best balance between the economics of size and the cost of carrying excess capacity during the initial years of sales.

Overhead is a cost or expense inherent in the performing of an operation, such as engineering, construction, operating or manufacturing, which cannot be charged to or identified with a part of the work, product or asset and, therefore, must be allocated on some arbitrary basis believed to be equitable or handled as a business expense independent of the volume of production.

Payout Time is the time required to recover the original fixed investment from profit and depreciation, usually, after taxes and based on capacity operations. The most recent practice is to base payout time on an actual sales projection. Also called pay-off or payback period. It is simple to calculate and can be used for evaluating many projects. It is not satisfactory for comparing projects with different lives or patterns of cost and earnings.

Plant Overhead (Factory Expense) are plant costs which are not directly attributable to any one product or processing unit and, therefore, can be allocated on some arbitrary basis believed to be equitable. This includes plant management salaries, payroll department, local purchasing, and accounting.

Present Value (Present Worth) is the discounted value of a series of cash flows at any arbitrary point in time. It is also the system of comparing proposed investments which involves discounting at a known interest rate (representing a cost of capital or a minimum acceptable rate of return) in order to choose the alternative having the highest present value per unit of investment. This technique eliminates the occasional difficulty with Profitability Index of multiple solutions, but has the troublesome problem of choosing or calculating a "cost of capital" or minimum rate of return.

Productivity is a relative measure of labor efficiency, either good or bad, when compared to an established base or norm as determined from an area of great experience which may be either an increase or decrease in cost.

Profitability is a measure of the excess of income over expenditure during a given period of time.

Profitability Index (PI) is the rate of compound interest at which the company's outstanding investment is repaid by proceeds for the project. All proceeds from the project, beyond that required for interest, are credited by the method of solution toward repayment of investment by this calculation. It is also called discounted cash flow, interest rate of return, investor's method, and internal rate of return. Although frequently requiring more time to calculate than other valid yardsticks, Profitability Index reflects both dollar and time values of all money involved in a project in a single number. In some cases, such as multiple changes of sign in cumulative cash position, false and multiple solutions can be obtained by this technique.

Project Life (Economic Life) is the total years of operation for any facility, sometimes, but not necessarily, equal to depreciable life.

Rate of Return on Investment is the efficiency ratio relating profit or cash flow incomes to investments. Several different measures of this ratio are in common use. (See Return on Average Investment, Return on Original Investment, Profitability Index).

Replacement is a facility proposed to take the place of an existing facility without increasing its capacity, caused either by obsolescence or physical deterioration.

Research Expense are those continuing expenses required to provide and maintain the facilities to develop new products and improve present products.

Return on Average Investment is the ratio of annual profits to the average book value of fixed capital, with or without working capital. This method has some advantages over the Return-on-Original-Investment method. Depreciation is always considered, and terminal recoveries are accounted for. However, the method does not account for the timing of cash flow and yields answers that are considerably higher than those obtained by the Return-on-Original-Investment and Profitability Index methods. Results may be deceiving when compared, for example, against the company's cost of capital.

Return on Original Investment is the ratio of expected average annual after tax profit (during the earning life) to total investment (working capital generally included). Similar in usefulness and limitations to payout.

Risk is the degree of dispersion or variability around the expected or "best" value which is estimated to exist for the economic variable in question. Also a quantitative measure of upper and lower limits which are considered reasonable for the factor being estimated.

Sales Price is the revenue received for a unit of product. Gross sales price is the total amount paid. Net sales are gross sales less returns, discounts, freight, and allowances. Plant netbacks are net sales less selling, administrative and research expenses.

Sales Profile is the growth or decline of historical or forecast sales volume by years.

Selling Expense is the total expense involved in marketing the products in question. This normally includes direct selling costs, advertising, and customer service.

Shutdown Point is the production level at which it becomes less expensive to close the plant and pay remaining fixed expenses out-of-pocket rather than continue operations, that is, the plant cannot meet its variable expense (see Break-even Point).

Site Preparation is an act involving grading, landscaping, installation of roads and siding of an area of ground upon which anything previously located has been cleared to make the area free of obstructions, entanglements, or possible collisions with the positioning or placing of anything new or planned.

Start-up Costs are presale operating costs to bring the plant on stream. This includes employee training, equipment tests, process adjustment, as well as the usual manufacturing costs. It is generally assumed that no revenue is obtained from products made during this period. Frequently, part of this start-up cost is capitalized.

Sunk Cost is money which was spent before today and cannot be recovered.

Taxes Payable are tax accruals due within one year.

Turnover Ratio is the ratio of annual sales to investment. Inclusion of working capital is preferable, but not always done. This ratio is considered to be a reasonable basis for an estimate of facilities cost and for new products similar to existing products. The ratio ranges around 1.0 for many chemical plants. The product of turnover ratio and profit margin on sales gives a return-on-investment measure.

Uncertainty is unknown future events which cannot be predicted quantitatively within useful limits such as accidents, which destroy invested facilities, a major strike, or a competitor's innovation which makes the new product obsolete, etc.

Unit Cost is dollars per unit of production. This is usually the total cost divided by units of production, but a major cost divided by units of production is frequently referred to as a unit cost. The total unit cost is frequently subdivided into the unit cost for labor, chemicals, etc.

Variable Costs are raw material costs, by-product credits, and those processing costs which vary with plant output, such as utilities, catalysts, chemicals, packaging, and labor for batch operations).

Wageestimate is an estimate completely lacking or devoid of any form of valid support data.

COST ESTIMATE BASED UPON TIME

Cost Estimate in 30 Minutes

$$\text{Estimate} = \$XXX,XXX \pm 50 \text{ pct Accuracy}$$

Cost Estimate in 24 Hours

$$\text{Estimate} = \$XXX,XXX \pm 30 \text{ pct Accuracy}$$

Cost Estimate in 1 Week

$$\text{Estimate} = \$XXX,XXX \pm 15 \text{ pct Accuracy}$$

Cost Estimate in 1 Month

$$\text{Estimate} = \$XXX,XXX \pm 10 \text{ pct Accuracy}$$

WILLIAMS 0.6 FACTOR

$$(C_1/C_2)^{0.6} = (\$/\$_2)$$

where:

C_1 = Capacity of proposed plant

C_2 = Capacity at known cost

$\$_1$ = Unknown cost

$\$_2$ = Known cost

Example

$$(20,000 \text{ bpsd}/10,000 \text{ bpsd}) = (\$/\$1,000,000)$$

$$\$_1 = (\$1,000,000)(1.515) = \$1,500,000$$

LANGE FACTORS

$$\text{Cost} = f_L \sum \text{Equipment Cost}$$

f_L depends on nature of plant.

That is:

Fluids

Solids

Solids/Fluids Combination

MULTIPLYING FACTORS FOR EQUIPMENT INSTALLED COSTS

Fractionating Columns	4
Pressure Vessels	4
Heat Exchangers	3.5
Fired Heaters	2
Pumps	4
Compressors	2.5
Instruments	4
Miscellaneous Equipment	2.5

UOP COST ESTIMATE SUMMARY

CUSTOMER _____

EST. NO. 3635-A

LOCATION _____

PROJ. NO. 6349

UNIT UOP HC UNIBON PROCESS UNIT 40,000 bpsd

DATE _____

ESTIMATE BASIS U.S. GULF COAST

BASE RATE _____

Item	Material	Man Hours	Labor Cost	Subcontract	Total
Fired Heaters	\$1,720,000	25,400			
Vessels and Internals	4,787,800	11,011			
Heat Exchangers	2,495,900	18,984			
Pumps and Drivers	446,200	4,855			
Compressors and Drivers	2,438,000	7,600			
Misc. Equipment	39,000	892			
Instruments	1,158,700	13,230			
Electrical	-	-		888,000	
Piping	3,507,200	144,640			
Insulation	-	-		348,400	
Fireproofing	43,400	13,624			
Steelwork	290,400	6,855			
Concrete	169,000	37,406			
Paving	47,600	7,125			
Painting	18,300	26,672			
Buildings	102,500	14,257			
Piling	-	-	-		
		332,551	2,460,900		
Location Factor			481,700		
DIRECT FIELD COST	17,264,000		2,942,600	1,236,400	21,443,000
Indirect Field Costs	568,000		920,400	729,600	2,218,000
Labor Benefits			1,270,000		1,270,000
TOTAL FIELD COST	17,832,000		5,133,000	1,966,000	24,931,000
Des. Engr., Cont. Exp. & Fee					3,669,000
Overtime and Premium Pay					
Sales Tax					
Escalation					
Suggested Contingency					
Estimated ERECTED COST					\$28,600,000

of the Hydrocracking Process

Summary by Sections

Estimate No. 3635-A

Description	Material	Labor	Subcontract	Total
Reactor Section – Train "A"	4,037,000	483,600	181,200	4,701,800
Reactor Section – Train "B" (Duplicate of Above)	4,037,000	483,600	181,200	4,701,800
Reactor Section – Common Equipment	1,501,000	255,400	115,000	1,871,400
Recycle Gas Scrubber Section	870,000	126,700	78,000	1,074,700
Recycle Gas Compressor Section	1,253,000	275,200	81,000	1,609,200
Makeup Gas Compressor Section	2,483,000	321,100	146,000	2,950,100
Debutanizer Section	1,221,000	382,600	124,000	1,727,600
Product Fractionator Section	1,812,000	564,400	330,000	2,706,400
Control House	50,000	50,000	–	100,000
Direct Field Cost	17,264,000	2,942,600	1,236,400	21,443,000

40 000 BPSD

By use of the following method, we can greatly simplify the problem.

Plot reactor section **without reactor's cost** versus reactor effluent mass flow at various pressures.

Plot reactor volume versus cost at various pressures.

Plot makeup gas and recycle compressor horsepower versus cost at the different compressor driver possibilities.

Plot the various costs of fractionators or fractionation schemes versus the column diameter or other appropriate correlating variable.

Now, given a unit to estimate and the process variables, we can calculate the appropriate correlating factors and sum up the various sections in the following manner.

Reactor section without reactors

- + Reactors
- + Makeup gas compressor section
- + Recycle gas compressor section
- + Fractionation section
- = Total process unit cost

MAJOR INDEXES

Nelson (Oil & Gas Journal)

ENR (Engineering News Record)

Chemical Engineering (McGraw-Hill Publication)

BLS (Bureau of Labor Statistics)

Example

Year	Index
1975	121
1981	221

Therefore:

$221/121 = 1.83$ factor to escalate 1975 estimate to 1981

Four main indexes are used extensively in the process industries. A summary of the pertinent features of each is given in the following table.

	ENGINEERING NEWS RECORD CONSTRUCTION INDEX	NELSON REFINERY CONSTRUCTION INDEX	CHEMICAL ENGINEERING	MARSHALL AND SWIFT (ii)
Publisher	Engineering News Record McGraw Hill	Oil and Gas Journal	Chemical Engineering McGraw Hill	Marshall and Swift
Index for complete chemical plants	No	Yes	Yes	Yes (excluding buildings)
Index for general process equipment	No	Yes	Yes	No
Specific classes of equipment	No	Yes	Yes	No
Separate index for buildings	Yes	No	Yes	Yes
Index for large civil projects high in unskilled labor	Yes	No	No	No
Correction for labor productivity	No	No (i)	2-1/2 percent per year	Yes (Details not divulged)
Correction for technical improvement	No	No (i)	No	No

(i) Oil and Gas Journal has published various other indexes and articles on the subject of productivity and technological improvements which require considerable study in order to apply them with any confidence.

(ii) Name Marshall and Stevens recently changed to Marshall and Swift.

ESCALATION

Escalation Rate = (Current Prices/Last Years Prices - 1.00)100

Compounding is included through the use of last years prices which include last years escalation.

Compounded:

Years = 5

$$(\$1,000,000)(1.10)^5 = \$1,611,000$$

Not Compounded:

$$(\$1,000,000)[1 + (0.10)(5)] = \$1,500,000$$

Rate

12 percent:

$$(\$1,000,000)(1.12)^5 = \$1,762,000$$

4 percent:

$$(\$1,000,000)(1.04)^5 = \$1,217,000$$

Years

6:

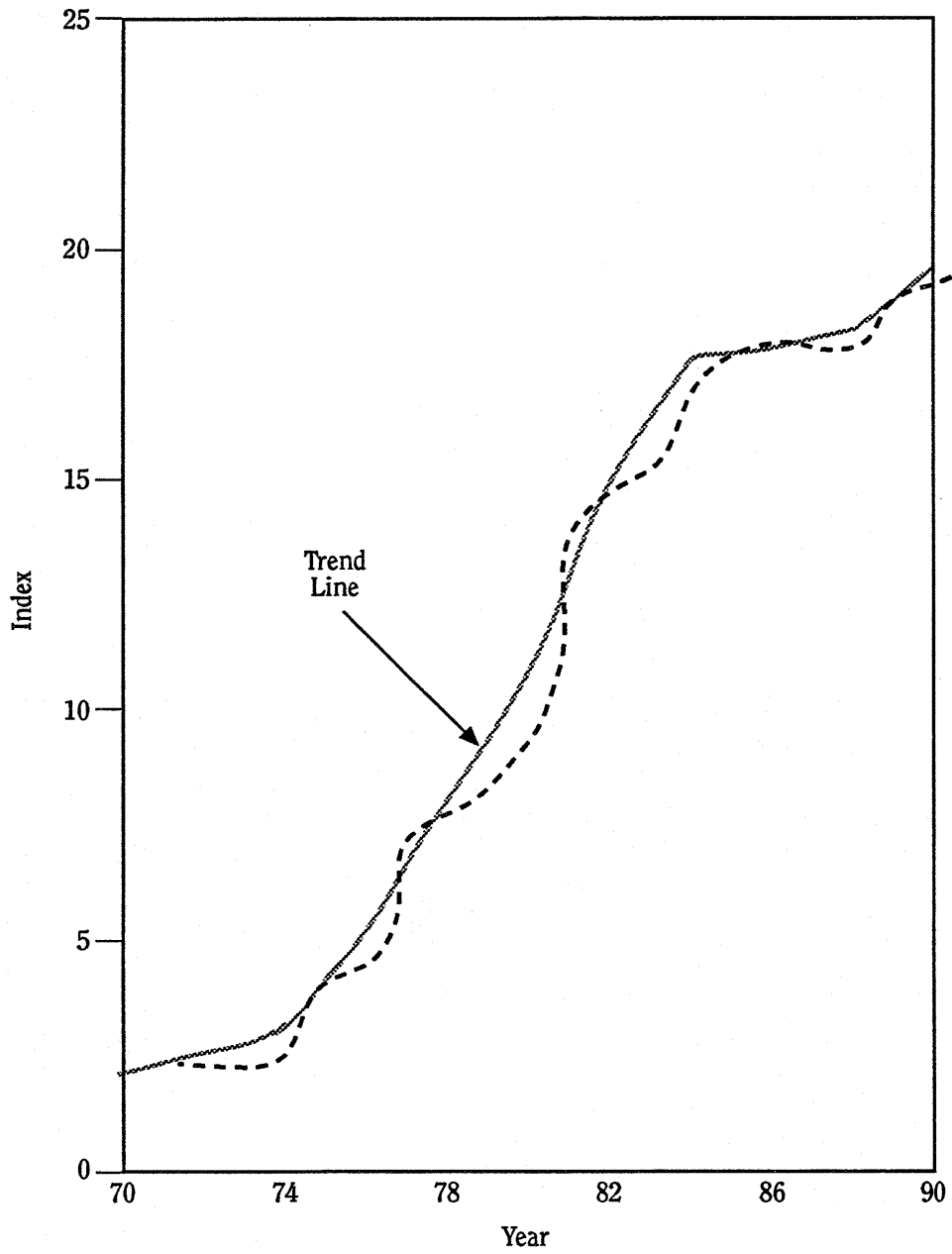
$$(\$1,000,000)(1.10)^6 = \$1,772,000$$

4:

$$(\$1,000,000)(1.10)^4 = \$1,464,000$$

Figure 1

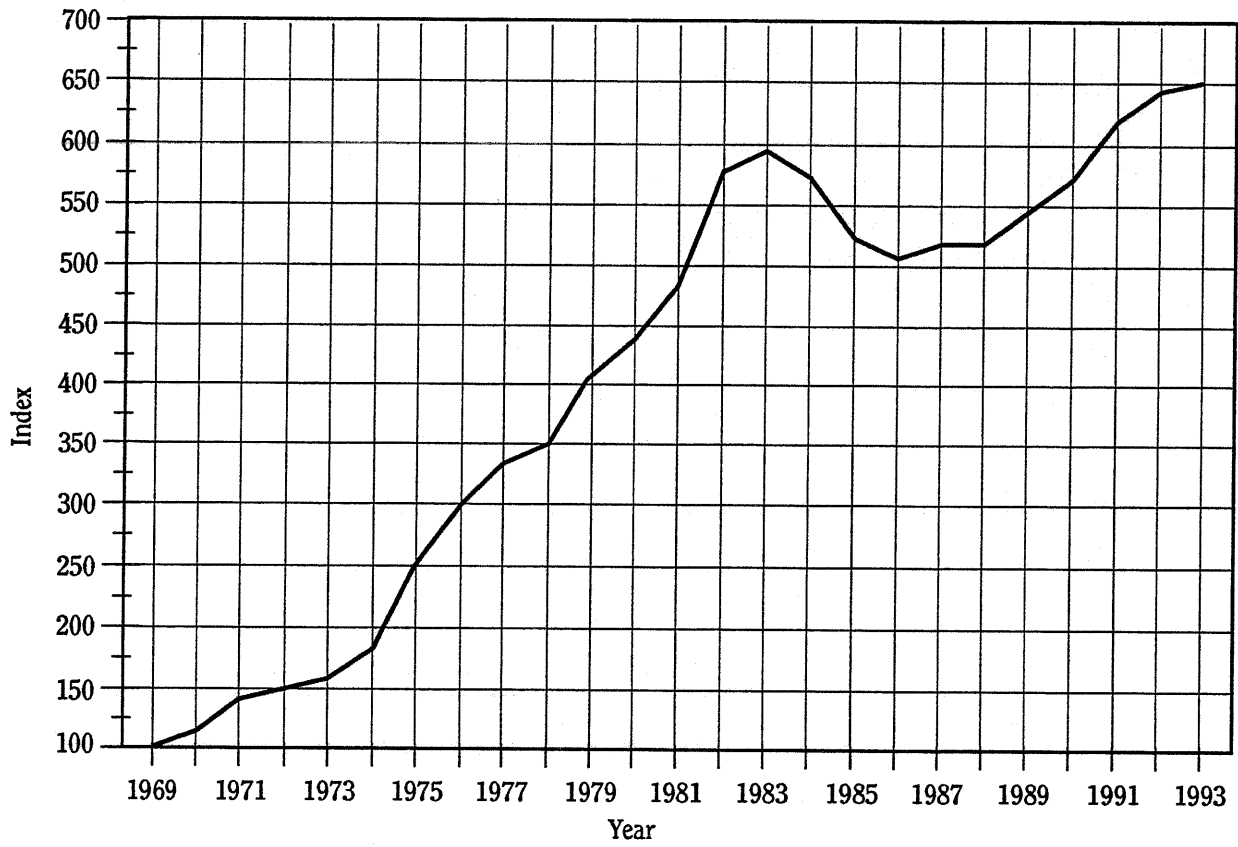
Escalation



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Figure 2

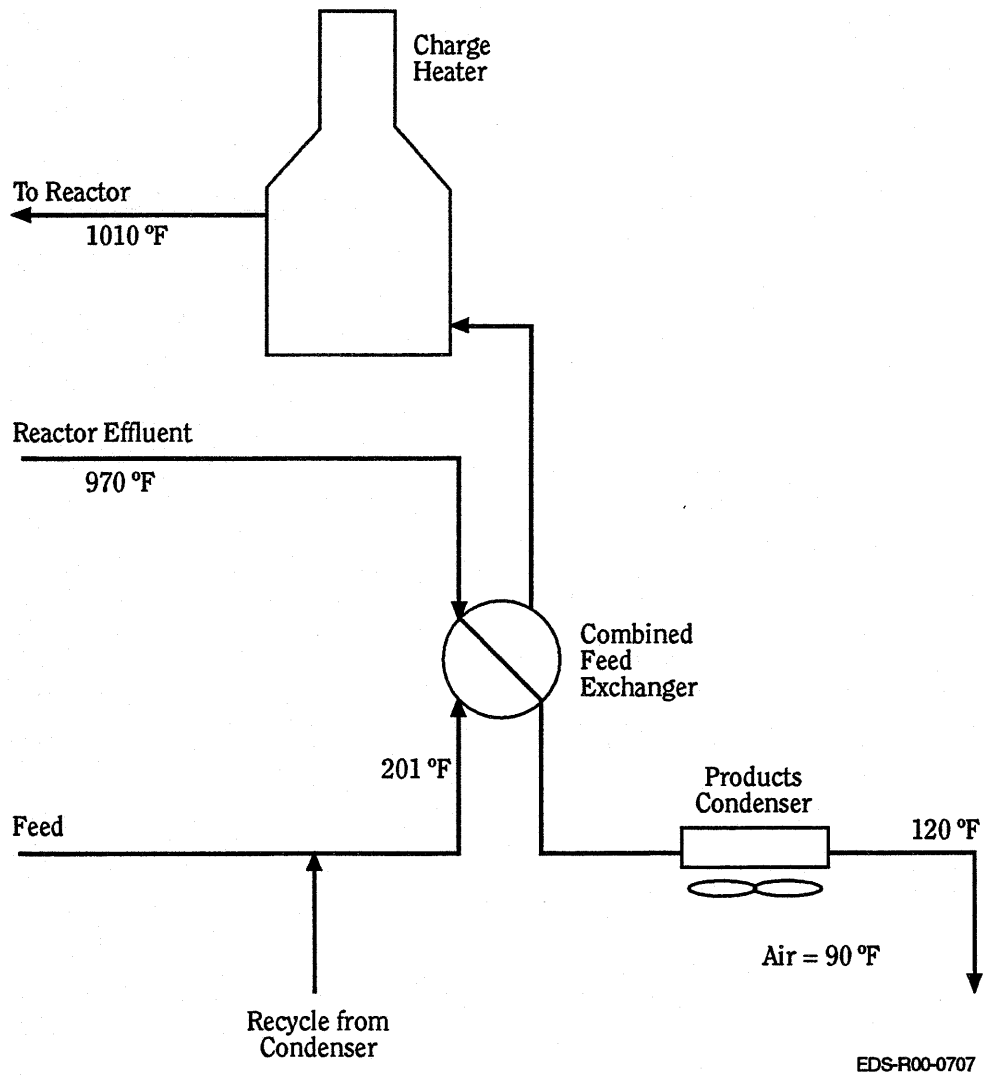
Curve Cost Escalation Index



EDS-R00-0706

Figure 3

Combined Feed Exchanger Study



COMBINED FEED EXCHANGER STUDY

Trials

Case I	75° Approach $970 \rightarrow 276$ $\frac{864}{106} \leftarrow \frac{201}{75}$	Condenser $276 \rightarrow 120$
Case II	60° Approach $970 \rightarrow 261$ $\frac{884}{86} \leftarrow \frac{201}{60}$	Condenser $261 \rightarrow 120$
Case III	50° Approach $970 \rightarrow 251$ $\frac{901}{69} \leftarrow \frac{201}{50}$	Condenser $251 \rightarrow 120$
Case IV	35° Approach $970 \rightarrow 236$ $\frac{920}{50} \leftarrow \frac{201}{35}$	Condenser $236 \rightarrow 120$
Case V	20° Approach $970 \rightarrow 221$ $\frac{941}{29} \leftarrow \frac{201}{20}$	Condenser $221 \rightarrow 120$

Payout of Various Approaches

	Case I	Case II	Case III	Case IV	Case V
Exchanger Cost	\$ 484,000	\$ 617,000	\$ 770,000	\$1,128,000	\$2,025,000
Condenser Cost	174,000	163,000	156,000	137,000	108,000
Heater Cost	345,000	294,000	260,000	202,000	138,000
Compressor Cost	800,000	800,000	800,000	800,000	800,000
Δ Foundation, Struct. Piping, Insulation, Etc.	—	—	—	564,000	1,215,000
Total Equipment	\$1,803,000	\$1,874,000	\$1,986,000	\$2,831,000	\$4,286,000
Flue Gas Cost	\$2,424,000	\$2,064,000	\$1,827,000	\$1,419,000	\$ 966,400
Electrical Cost	19,000	16,000	16,000	16,000	13,000
Total Utilities	\$2,443,000	\$2,080,000	\$1,843,000	\$1,435,000	\$ 979,400
Investment Cost	—	\$ 71,000	\$ 112,000	\$ 845,000	\$1,455,000
Δ Utilities Savings	—	\$ 363,000	\$ 237,000	\$ 408,000	\$ 456,000
Payout – Years	—	0.2	0.5	2.1	3.2

*Based on fuel cost of \$4 per million Btu and electrical cost of \$0.03 per kh.

Annual Cost of Various Approaches

Annual cost of equipment equal investment times capital recovery factor

Annual cost of utilities calculated on yearly basis

Therefore, using 13 year life and interest rate of 50 percent (equivalent to 2 year payout):

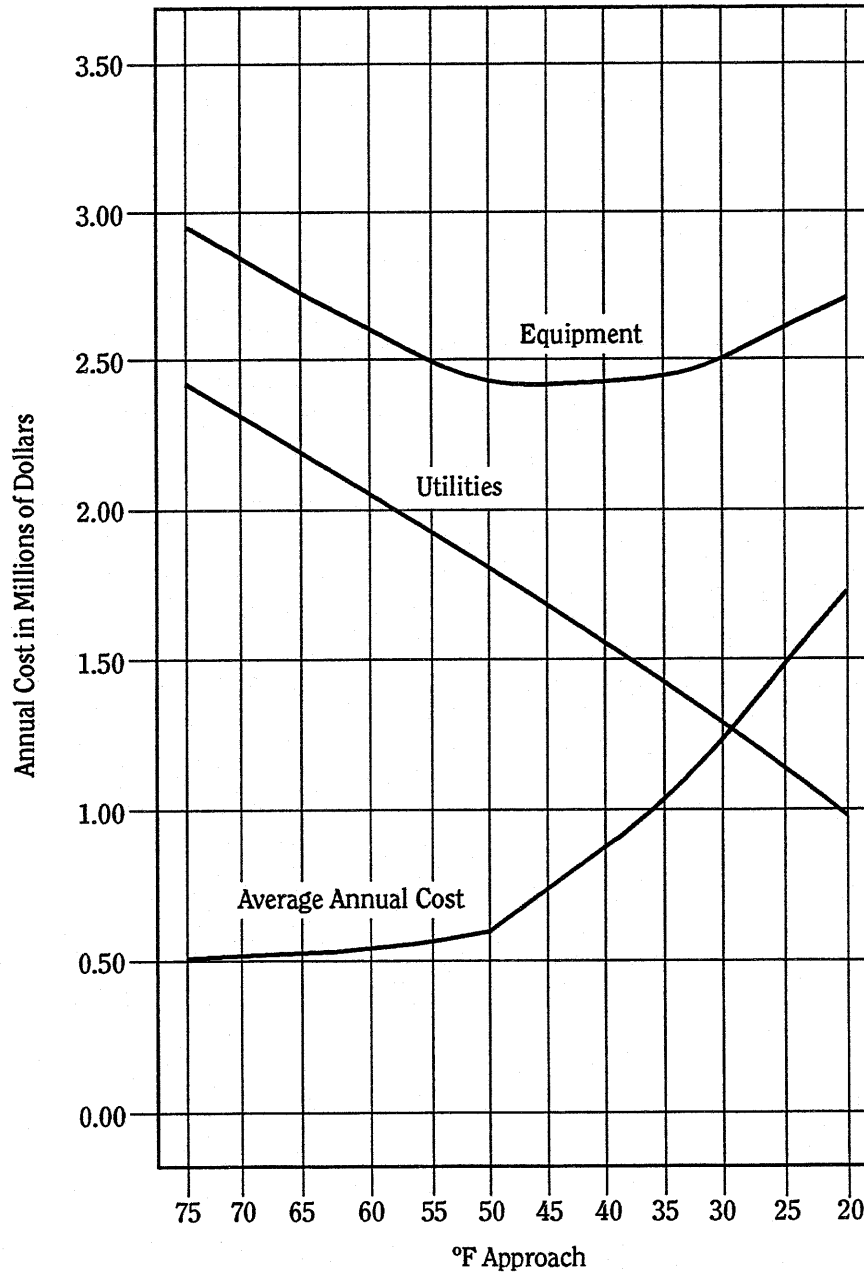
Capital Recovery

$$C.R. \text{ Factor} = 0.50258$$

	Case I	Case II	Case III	Case IV	Case V
Equipment	\$ 504,000	\$ 540,000	\$ 596,000	\$1,021,000	\$1,752,000
Utilities	2,443,000	2,080,000	1,843,000	1,435,000	979,000
Average Annual Cost	\$2,947,000	\$2,620,000	\$2,439,000	\$2,456,000	\$2,731,000
<i>If n = 13 years, i = 40 pct, then C.R. = 0.40510</i>					
Equipment	\$406,000	\$435,000	\$481,000	\$823,000	\$1,412,000
Utilities	2,443,000	2,080,000	1,843,000	1,435,000	979,000
Average Annual Cost	\$2,849,000	\$2,515,000	\$2,324,000	\$2,258,000	\$2,391,000
<i>Or if n = 13 Years, i = 30 pct</i>					
Equipment	\$ 311,000	\$ 333,000	\$ 368,000	\$ 630,000	\$1,082,000
Utilities	\$2,443,000	\$2,080,000	\$1,843,000	\$1,435,000	\$ 979,000
Average Annual Cost	\$2,754,000	\$2,413,000	\$2,211,000	\$2,065,000	\$2,061,000

Figure 4

Annual Cost of Various Approaches



EDS-R00-0708