A RAND NOTE

CAPTURING PIONEER PLANT EXPERIENCE: IMPLICATIONS FOR SYNFUEL PROJECTS

Christopher W. Myers, R. Yılmaz Argüden

January 1984

N-2063-SFC

Prepared for

The U.S. Synthetic Fuels Corporation

Rand
SANTA MONICA, CA. 90406

This publication was supported by Contract No. SFC-83-002-C, Task 1, from the U.S. Synthetic Fuels Corporation.

Published by The Rand Corporation

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PREFACE

This Note, prepared under The Rand Corporation's Energy Policy Program, is the first product of Rand's work for the United States Synthetic Fuels Corporation (SFC). It is based on the results of Task 1 under Contract SFC-83-002-C. The study assesses the capture and transfer of information generated by pioneer synthetic fuels projects that would be valuable to subsequent builders, identifies the kinds of information needed but not adequately collected and preserved by industry, and examines ways to improve the capture and transfer of pioneer synfuel project experience.

Although directed at pioneer synfuel projects supported by the SFC, the study holds implications for how industry keeps and uses information from innovative process plant projects generally. The results of the study should therefore be of interest to industry and government project planners and to other decisionmakers concerned with commercializing new technologies, as well as to those involved in designing and building follow-on plants.

SUMMARY

This study addresses the need for and benefits of information from pioneer synfuel projects. As first-of-a-kind commercial plants, the first set of synfuel technology projects will generate experience and information that will be valuable to firms contemplating investments in subsequent plants using these technologies.

This research drew upon Rand's earlier experience in the Pioneer Plants Study and assessed current industrial practices in project information-keeping through interviews with personnel at 19 major companies in the oil, chemical, and design-construction industries.

The following are the study's principal findings:

- Pioneer synfuel projects will probably yield experience and information that will be vital to firms deciding to invest in and build subsequent plants.
- The characteristics of pioneer synfuel projects make it likely that much information will be preserved, especially in the short term.
- However, not all valuable pioneer project information is routinely collected and maintained.
- Because of the way most firms collect and maintain project information, some information that is important for interpreting pioneer project experiences will be lost.
- A systematic information collection system can substantially increase the public and private value of the pioneer synfuel projects.
- Such a system does not require government access or centralized storage.
- The question of government or public access is a serious issue involving important policy tradeoffs.
- Keeping pioneer plants operating improves information retention and enhances its value, and can generate valuable new data.

ACKNOWLEDGMENTS

This study would not have been possible without the cooperation, time, and assistance of numerous industry representatives. Most have asked that they remain anonymous; nonetheless, we gratefully acknowledge their contributions to this research. We thank our Rand colleagues for their comments and guidance, including Ed Merrow, Ron Hess, Lee Johnson, Skip Horvath, Loretta Swanson, Robert Perry, Ken Phillips, John Birkler and Mary Vaiana. We especially thank our colleague Arthur Alexander for his review of this Note, and James Harlan and Robert Kidd, SFC project monitors, for their help through the course of the research. Special thanks are due to Gabrielle Wharton, Hester Palmquist and Janice Jones for their help in preparing this document and its precursors, and especially for their patience. Will Harriss deserves special credit for improving the Note through his skilled editorial efforts. The authors remain responsible for failing to accept the good advice of these individuals and for any resulting errors that remain.

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I. INTRODUCTION

Soaring world oil prices and the supply disruptions of the last decade demonstrated America's vulnerability to insecure foreign energy sources. Conversion of our vast coal and oil shale resources into synthetic fuels could provide alternative domestic energy supplies in the future. We still know little, however, about how "synfuel" technologies will perform in production facilities, nor are we certain how much they will ultimately cost. These uncertainties currently retard our ability to acquire the critical information needed to better assess potential synfuel technologies. In response to this concern, the federal government has established a national synfuels program to develop early commercial experience with synfuels technologies. In particular, the U.S. Synthetic Fuels Corporation (SFC) is encouraging private industry to build and operate pioneering domestic synfuel plants.

As first-of-a-kind plants, these pioneer synthetic fuel plants will generate information that should be extremely valuable to the nation and to other firms that might want to build later plants using these technologies. The pioneer commercial plants will establish realistic cost and performance baselines against which alternative technologies and policies can be evaluated. They will help demonstrate which technologies hold the highest potential for continued commercial development. They can also be used to improve the design, construction, and operation of later plants.

An important rationale for the federal government's subsidization of pioneer synfuel plants, then, is to generate information on feasibility, costs, processes, project execution, and other foreseen and unforeseen issues in the development of these new and uncertain technologies. This information can be used as a basis for later project planning and investment and as a tool for analytical interpretation and understanding of our ability to respond to long-term supply disruptions using synthetic fuels. Information is valuable both to individual companies and to the nation. In this sense, a policy of providing incentives to private industry to commercialize synfuel technologies sooner than they would have otherwise buys better information at an earlier stage. The benefit to the country as a whole lies in being able to reach more informed energy planning decisions sooner. The benefit to later builders lies in being able to select better technologies and build more efficient plants by capitalizing on the pioneer project experiences. Both the public and private sectors could then respond more efficiently to a long-term supply crisis.

Given the value of this information, it is important that it be there when needed. Earlier Rand research indicated that the information practices of process industry firms that build pioneer plants may not be adequate to this task; many companies do not collect and preserve all appropriate project experience.[1] Moreover, later plants may be designed and built many years after the pioneer plants were constructed; information may be destroyed or lost in the meantime. (The desire to learn from the German WWII synfuels experience has been frustrated by this problem: Retrospective project and technology evaluation is very difficult in the absence of good information retention.) Therefore, without explicit action to collect and preserve it, important information from pioneer synfuel projects may not be fully available to those who will subsequently need it.

OBJECTIVES

This study addresses two basic questions:

- What items of information about pioneer sythetic fuels projects will be most useful to subsequent decisionmakers?
- What is the most effective way to capture and preserve that information?

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[1] E. W. Merrow, K. E. Phillips, and C. W. Myers, *Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants*, The Rand Corporation, R-2569-DOE, September 1981.

Our objectives are to:

- Describe how information can be used and interpreted across pioneer projects.
- Describe how companies use past experience with pioneer projects in deciding whether to invest in new plants, and how to build them.
- Identify which pioneer project data are important for interpreting those project experiences, drawing both on our earlier experience with Rand's Pioneer Plants Study, and on industry interviews.
- Identify important pioneer synfuel project information that may not be available to subsequent firms.
- Develop a method for capturing and summarizing pioneer synfuel project experiences. The method should consider the burden on pioneering firms and its effect on their incentives for pioneering in the first place.

APPROACH

This research drew upon Rand's findings in the Pioneer Plants Study (PPS), and assessed current project information-keeping practices. The PPS retrospectively evaluated the cost, schedules, and performance of 44 major process plant projects built in the U.S. and Canada. In the present study, we looked to see what project information for our analysis was and was not available in the PPS database. We also compiled and examined the reasons why some information was missing and why some companies did not participate. This helped us to identify the information items that are valuable for evaluating subsequent projects, but are not always available later.

We then conducted detailed interviews with staff at 19 major companies to identify information they particularly find useful, how they use it, and how carefully they keep and transfer it. Their answers shed light on two concerns for future plant-builders: What would be the ideal set of information by which to evaluate pioneer projects retrospectively? And as a practical matter, how does one weigh the needs of future users against the proprietary rights of the pioneering firms?

We then applied our findings to define the specific items with the appropriate formats for collection, and reviewed alternative systems for collecting and transferring that information.

OUTLINE OF THE STUDY

Section II reviews the PPS and its implications for the kinds and availability of pioneer project information that can be used to evaluate future projects, and examines the kinds of information that firms were and were not able to supply. Section III discusses the results of extensive industry interviews: what information firms need and use to make subsequent decisions, what the best sources of the information are, and how well information survives over time. Section IV compiles a set of information items that could enhance the benefits of the pioneering synfuels program if captured and transferred. We then address several policy questions and options: Who collects the information, who will get access to it, and what the Synthetic Fuels Corporation might do in dealing with these issues.

CONCLUSIONS

Our principal findings may be summarized as follows:

- Pioneer synfuel projects could generate information vital to firms deciding to invest in and build subsequent plants.
- Because of the way most firms collect and maintain project information, some important information will be lost.
- A systematic information collection system can substantially increase the public and private value of the pioneer synfuel projects.
- Such a system does not require government access or centralized storage.

II. THE PIONEER PLANTS STUDY: METHODOLOGY AND IMPLICATIONS

We evaluated industry information-keeping patterns through an examination of the Pioneer Plants Study (PPS) database. We found patterns of missing data, many of which would have been valuable for retrospective project evaluations. This exercise also identified systematic reasons why some companies were not able to participate in the earlier study. By drawing on Rand's access to detailed proprietary project data, we were able to identify key information items that are useful for evaluating past and subsequent projects, but are not always available later.

BACKGROUND

Misestimation of the capital costs and performance of innovative energy process plants and other chemical process facilities creates fundamental problems for government and industry in planning the development and commercialization of advanced technologies. Misestimation erodes the rationality of R&D allocations, capital expenditure assessments, and comparisons between competing projects and systems. The past decade has witnessed continual upward revisions in the estimated costs of many synthetic fuels and other energy process plants--increases far beyond the effects of inflation. In addition, most of the few plants that have been completed have experienced reliability problems that adversely affected their economic viability.

With support from the U.S. Department of Energy in 1978, The Rand Corporation began the PPS to investigate these problems. This research sought to answer three salient questions:

- What factors are responsible for inaccurate cost estimates for process plants?
- How well do pioneer plants perform and what factors are responsible for poor plant performance?

- Can better methods be developed for predicting cost and performance?

Results

A total of 34 firms in the process industries provided data for the PPS, which arrived at three principal conclusions:

- Both performance problems and cost estimation error were common among the plants examined. Both phenomena are associated with characteristics of the project or technology that are knowable early in project development.
- Most of the variation in cost estimation error can be explained by (1) the extent to which the plant's technology departed from that of prior commercial plants, and (2) the degree to which the project's site and related characteristics were defined.
- Most of the variation in early plant performance is explained by the degree of innovation embodied, and by whether the plant processed solid materials (especially as feedstock).

The analytic methods developed in this research make it possible to compare technologies at different stages in their development, aid in screening projects for purposes of R&D allocation, and suggest promising areas for improving the economic viability of synthetic fuel technologies and of other process plants.

Rand's experience with the PPS furnished insights into what information is important in interpreting and evaluating pioneer project experience, both for individual projects--how well they did or did not work or meet expectations--and for comparisons across projects. Such evaluations are what investors in follow-on plants need to get a good understanding of which technology to choose and how to design the plant for the technology they do choose.

Nature of the PPS Database

The PPS is unique for the character, depth, and breadth of its database, which spans the process industries: oil, chemical, and minerals processing plants and companies. Data for each of 44 plants are highly detailed, enabling a depth of analysis previously unparalleled in cross-industry analyses.[1] The database is large enough (and currently is being expanded) to sustain a statistical analysis of cost estimation and performance problems, yet detailed enough to allow the adjustments necessary to present a realistic picture of the problems. In all, companies furnished some 1200 items of information on each of the plants. These data include:

- Detailed technical process information
- Cost-estimation histories and actual expenditures
- Project development histories
- Key problems encountered at each project stage
- Project management characteristics
- Planned and actual schedules
- Environmental and regulatory requirements
- Planned and actual plant performance

All information was collected under nondisclosure agreements, whereby we agreed not to reveal data about individual plants or projects or the names of the companies involved; however, 24 firms gave their consent to public acknowledgement.[2] Many of the major oil and chemical companies were represented, and many had been involved in synthetic fuels development.

Not all companies could participate, however. About 20 firms were not interested in the study, or felt that their data were too sensitive to release. But more than two dozen firms reported either that they did not keep data on projects that we were asking for, or that the data, if they did have them, were too hard to find or transfer. In other words,

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[1] Data were collected for a total of 50 plants; missing data problems eliminated six of them from the statistical analyses, however.

[2] See Merrow, Phillips, and Myers, p. ix, for a listing.

more than half the companies that did not participate *could not participate because they did not have the relevant data--even for a single project.*

We even encountered data availability problems for the companies that gave us reasonably complete data on at least one of their plants. Figure 1 displays some of the key categories of information that we collected, and the proportion of the 50 plants or 159 cost estimates that had complete information (more than one estimate is usually developed for a major project). Conceptual estimates provide a rough cost number for use during process development, while definitive estimates prepared during early construction are often used in cost control. Two, three, or four more estimates may be developed and updated from the early conceptual stage to the final estimate. But because they often dispose of data files after a few years, companies could not provide us with more than a single estimate for about 15 percent of the plants. Even then, some of the estimates were not usable because they bore no relationship to the final project that was built. A much smaller number--around half--gave us breakdowns; that is, they broke down estimated costs by engineering, materials and equipment, construction labor, and so on. But each firm retained a sense of how well the probject had been defined at the time of each estimate, at least across the nine items we measured.

In general, performance data were more available than cost data. About 80 percent gave us performance information: both the issues resolved during plant design, and plant performance for at least the first 18 months. Of the plants that had problems with start-up, however, only about a third could describe them and list the causes. And only about a third could give us process development information--that is, the testing facilities that were built, the pilot plants, bench-scale tests, and so on. *In sum, the information that firms keep from pioneer projects is by no means complete, even among firms that wish to be reasonablely thorough about it.*

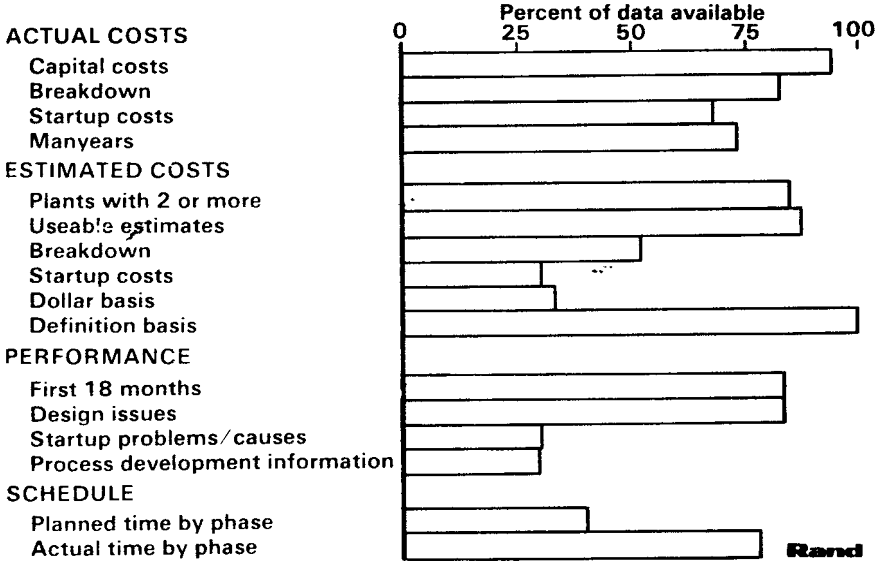

Fig. 1 -- Data-Availability Problems in the PPS

PROJECT INFORMATION FOR RETROSPECTIVE EVALUATION

The types of data needed for cross-project statistical analyses may not be identical to those any one firm might use to make decisions about building later plants. In general, of course, past project experience is helpful in making these decisions. The PPS sought to understand why many pioneer plants cost more and perform worse than expected. In doing so, the PPS developed tools for evaluating past as well as proposed projects. In this sense, the information requirements are closely parallel.

The PPS points to how first-of-a-kind projects can be compared. Retrospective evaluation requires two steps: "normalizing" data across projects and then evaluating and comparing specific projects. Data are normalized by comparing different technologies and projects on as common a basis as possible, differentiating project-specific versus technology-specific outcomes. That is, the analyst/investor asks whether problems in the project were due to the technology choice itself or to other conditions relating to how the project was managed or executed. To some extent every project or technology is unique. Differences in site or market conditions, owners, contractors, etc. may appear overwhelming and tend to inhibit cross-technology and cross-project comparisons. One goal is to be able to abstract from the specific project details in order to draw general lessons about how later projects should be managed and executed. A second goal is to provide information that allows decisionmakers to separate promising new technologies from unpromising ones.

For each project, the nonrepeating costs and the problems are isolated and pulled out--force majeure events, for example, or overdesign for reliability.

Normalizing Pioneer Project Data

From our experience in the PPS, we derived several methods for normalizing project data. First, all costs, both estimated and actual, should be compared in constant dollars. Second, the effects of external factors must be removed. (These methods will be discussed in greater detail below.) All probable nonrecurrent costs should be identified, such as those entailed in deliberate overdesign (e.g., putting in extra pumps, valving, and so on to ensure reliability for the first plant). Costs of start-up problems must be identified, especially if they have to do with improving plant design. In a follow-on project, R&D costs are largely irrelevant. If they are charged to capital cost of the project, they too need to be removed.

Sometimes the product market falls off after a plant is built and the plant therefore does not operate to full capacity. This sort of poor performance is a far different matter from technical failure, of course.

Again to avoid confusion, the analyst should compare equipment costs separately--look at what the major equipment costs were, separate them from the installed costs and offsites, and so on. One should also look at man-hours by project phase--engineering, construction, and start-up. Where were the contingencies in the estimates? How did they get used up, or were they?

Companies vary in how they charge costs to start-up--whether they capitalize or expense them. We concluded that the particular accounting practice is much less important than knowing the total cost to start the plant up; that is, the sum of the capitalized and expensed categories.

Finally, it is difficult to analyze productivity in detail, and each firm does it in its own way; but again, whatever the analytic approach, the important task is to conclude, from a project's cost and schedule, whether productivity was significantly better or worse than expected.

Normalizing Estimated and Actual Costs

Normalizing all costs is essential for evaluating how much cost growth occurred and why it occurred. Errors in forecasting inflation that were included in the estimates need to be removed. Often, that is not done and inflation is wrongly blamed as a consequence. Several information items for each cost estimate are needed to normalize costs: first, the amount of money spent prior to the date of the estimate, and when it was spent; second, the amount of escalation that was included. Lacking a specified dollar amount, a much more complicated set of information is needed: the inflation rate assumed, the time frame over which it was included, the rate of expenditure assumed over that time frame, and how the inflation was included. Then for actual costs, the rate and timing of expenditures are needed. Finally, a good inflation index is needed that reflects accurately the true changes in the value of the dollar. A computer program is useful for this purpose because the calculations are arithmetically complex.[3]

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[3] The specific information items needed are provided on p. 68 of Appendix B.

Normalizing for External Factors

External factors are certain nonreplicating events beyond the control of an estimator: *force majeure* events, new regulatory standards, changes in the design output of the plant, and the like. These factors usually do not have a major effect on most projects, but they can greatly distort cost, schedule, and performance comparisons between projects where they did and did not occur. They are often blamed as major culprits in cost growth and schedule slippage, but the blame is usually inappropriate.[4] For each item identified, its effect on the cost or schedule, and when the effect occurred, are needed. Armed with this information, the effect can be converted to constant dollars, removed from actual costs or from the schedule, or both, and from all estimates made after the event.[5]

LESSONS FROM THE PIONEER PLANTS STUDY

Several lessons from the PPS are important to information from pioneer synfuel projects. First, many firms were unable to join or participate in the PPS because they lacked the appropriate data, or what data they had were simply inaccessible (perhaps buried in someone's dusty files, or a key person was gone).

Second, it is not difficult or expensive to collect project information if a simple, complete, and consistent format is provided, and if the information is collected during the project or shortly after its completion, not several years later.

Third, most companies keep a tight hold on what project information they do save. They tend to regard every project detail as sensitive or proprietary. Rand obtained some data under strict, long-term secrecy agreements, but a few companies could not see their way to release any data. Rand obtained information only when a company was persuaded that the results of the analysis would be useful to it--that the PPS was not merely an academic study, for example--that other companies were participating, and that the information would be kept confidential from

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[4] *Ibid.*, p. 47.

[5] The items needed are listed in App. B, p. 78.

their competitors, the public, and the government. The government was paying for the study and therefore was entitled to see the results, but it was not to see information about specific plants, for two basic reasons. First, the government *is* the public in a sense, and in any event is notorious for not maintaining confidentiality. And second, the government may be the research sponsor but it is also the regulator, and some project-specific information is sensitive in that respect.

Finally, and most importantly, companies do not routinely retain all data that are important to project evaluation and retrospection, and the data are often not in a usable form. It takes some effort to normalize and interpret the data for each project and across the projects.

The implication for a synfuels information program is that the pioneer synfuels program would benefit substantially from an active program that captures project information in a form that is transferable to other companies. We will return to this issue in the final section.

III. HOW COMPANIES USE AND KEEP PROJECT INFORMATION

To aid their investment decision on a non-pioneer plant, firms require information to estimate project profitability. This calculation will depend on expected capital costs, startup costs and and time, operating costs, and technology performance. Such estimates for more than one project are often made and compared as part of the decision to build a new plant. The experience of the pioneer plants can provide information on these items if they are collected, preserved and retrievable. Discussions with industry specialists and our own experience in related data collection efforts point to specific data required for this profit calculation and to the means of making these available to decisionmakers.

APPROACH

We augmented the results of our PPS analysis with exhaustive interviews, through which we sought to answer four basic questions:

- How is the pioneer project important to those investing in, designing, and building follow-on projects using the same technologies?
- What information does industry need for this purpose and why?
- Where does industry get this information? Why are some sources more valuable than others?
- How well is the needed information captured and transferred, and how well does it survive over time?

We relied heavily on our earlier research in the PPS to identify important project information that may not always be collected and kept. We have also continued to expand the PPS database by adding clarifying data on project schedule and startup for the plants already in the database. We are adding new plants and companies as well. By integrating the present study with our PPS follow-up research, and drawing upon Rand's access to proprietary data, we have been able to assess how well company information policies match actual practice in specific projects. (We also interviewed firms that had not been asked to participate in the PPS.)

Figure 2 shows the kinds of companies and people that were interviewed. Half of the 19 firms were oil companies; the rest were divided between chemical companies and architect-engineer-construction firms. The firms range from medium size to industry giants. Most have expressed interest in synfuel projects, either as pioneers or followers. We conducted confidential two-hour interviews with more than 40 people, who ranged from fairly high-level estimating and engineering staff to senior corporate planners and executives. Because many of the responses we received varied a great deal, in some cases we interviewed at a

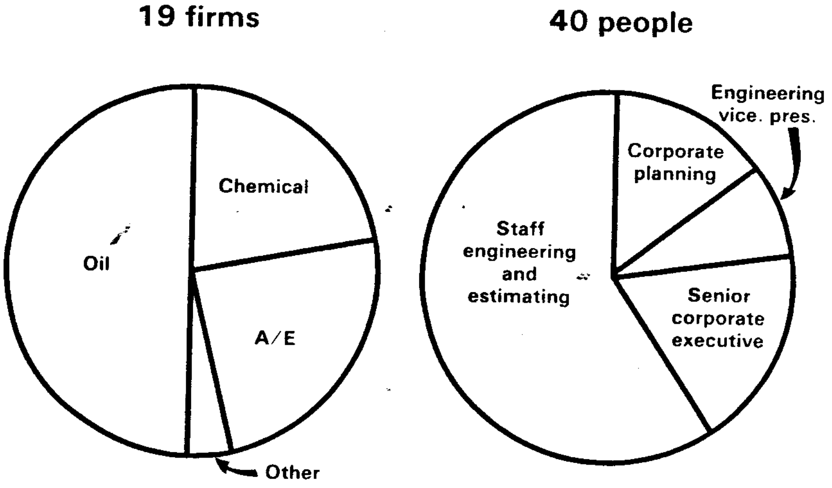

Fig. 2 -- Firms and people interviewed

second level within a firm; this gave us a sense of how information needs and uses differ across firms and between levels within a firm.

Our approach in the interviews was to identify the important information that is needed and used in making project development decisions. These decisions may be considered as having three major phases: initial screening, feasibility study, and design/build. The focus was on follow-on projects--those pursued after a pioneer plant has been built and a company may be interested in developing the second, third, or fourth facility using a technology already pioneered. The interviews covered the full range of information that is needed, from project-specific information--the site, permits, markets, and so on--to the firm's experience with conventional plants. This experience is also important because first-of-a-kind plants always embody a good deal of conventional technology as well. For example, major portions of most synfuel plants resemble standard upgrading or refining facilities. We talked about how process design information, conducted in-house or by contractor, fits into these decisions. Finally, we solicited interviewees' opinions on the most important lessons to be gained from pioneer projects that their firms had built or that they knew about.[1]

INFORMATION NEEDED FROM PIONEER PROJECTS

As one would expect, pioneer synfuel project information proved to be very important. In a summary form, Fig. 3 shows the kinds of questions that companies routinely ask about the pioneer project. They particularly want to know what it cost, how long it took, how well it worked, and what problems occurred. Companies can then proceed to ask themselves: Can it be done better? How can the design of the next plant be improved--to make startup, for example, much smoother? What uncertainties remain? Firms turn to the experiences of the pioneer plants to help answer these questions.

Figure 4 summarizes our results and presents a ranking of the information needed from the pioneer project. An information category is ranked as *critical* if at least three quarters of the companies called it

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[1] An outline of question topics covered during the interviews is included as Appendix A.

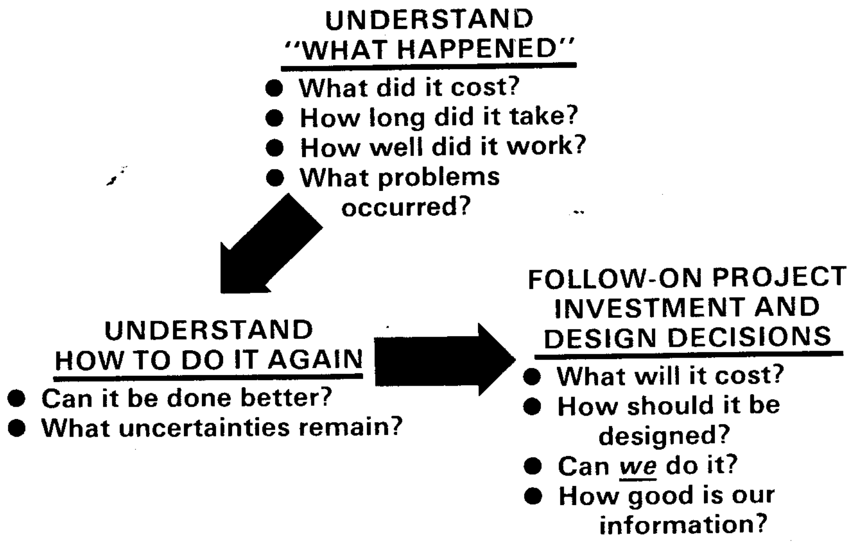

Fig. 3 -- Importance of pioneer synfuel project information

so and said they could not make good decisions without it. It is ranked as *important* if half or more of the companies called it critical, but some said it was important and useful but not absolutely essential. It is ranked as *secondary* if the companies regarded it as only somewhat important or useful.

In the critical category are details on the processes, the product-yields, quality, heat and material balances, and so on. Such information is obtained through licenses, of course; otherwise, the licensor is not in the business of selling that process.

There are several critical cost questions: What was the total capital cost? Of that total, what was the particular cost of the pioneer or first-of-a-kind unit? In a shale plant, for example, what

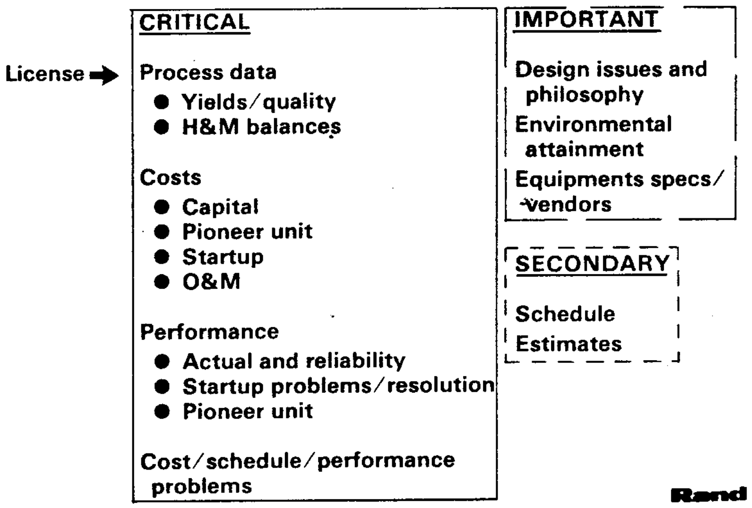

Fig. 4 -- Information needed from pioneer projects

did the retort cost? How much did it cost to start the plant up? How much does it cost to operate and maintain the plant?

Information on the plant's performance and reliability is equally essential. What were the startup problems? How were they resolved? How well did the new technology process steps work?

The last item on the critical list is *problems* in cost, schedule, and performance. This information is important to interpret *what happened* with the pioneer project: if it differed in cost, schedule, or performance from what they expected would happen, why the problems occurred, how they dealt with those problems and what they cost. This information is essential to *interpret* what happened and to understand what to do next time.[2]

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[2] A major focus of the data collection formats included in Appendix B helps in this interpretation (e.g., questions 12 & 13, Sec. I; 7 & 8, Sec. II; and 8-10, Sec. III).

All of the information listed under "important" is performance-related in a general sense. For example, what issues had to be dealt with in the process development and engineering design of the plant, and what philosophy was employed? That is, was the plant "overdesigned" to maximize reliability, or was it more "bare-bones" to minimize capital cost? How well did it meet environmental standards? What were the equipment specifications? Who supplied the equipment?

The project schedule and the cost estimates are ranked as *secondary*, because many people felt that they become outdated. Even so, both are essential to *understanding* the cost, schedule, and performance outcomes of the project, and so in a sense are not secondary. They help interpret the experience of the pioneer project.

Cost Data Needed

The cost information needed includes the total capital investment by major categories: engineering, bulk equipment, construction labor, battery limits and offsites, and so on. Of those investments, it is also helpful to know what it cost to erect the pioneer or new units. Other items include startup costs, operating and maintenance costs, and costs imposed by such external factors as labor strikes, bad weather, and unanticipated new regulations.

Some information on project cost is needed after mechanical completion (see Fig. 5). Two kinds of costs are incurred at that point: capital costs of startup, and then the expensed costs for starting up and for operating and maintaining the plant. A knowledge of total startup costs imparts a sense of how problematical the project was, and whether the follow-on project can reduce those costs. It is not necessary to know what portion was capitalized and which was expensed--only the total. Because, for corporate and tax reasons, companies vary in how they account for startup costs, it is rather meaningless to compile breakdowns across different firms' projects.

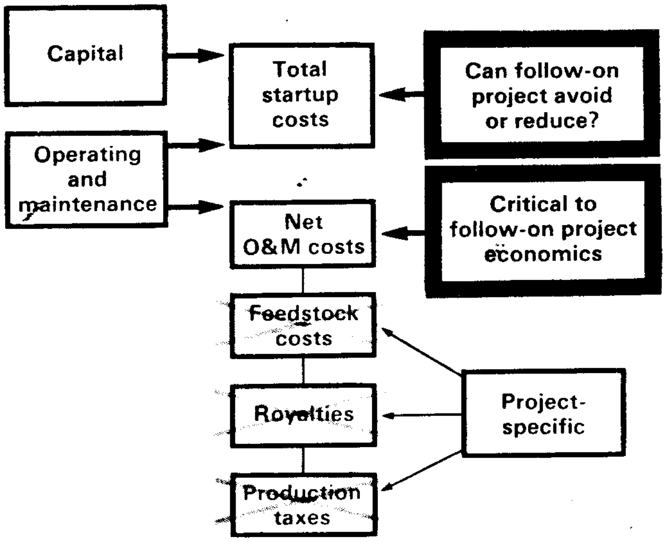

Fig. 5 -- Cost data needed after mechanical completion

Despite the capital-intensive nature of synfuel projects, many companies reported that net operating and maintenance (O&M) costs are at least as important as the total capital cost. In some firms' economic analyses, the projected O&M costs alone made a proposed project uneconomical. Project-specific information is not needed from the pioneer plant, however. These include the costs of feedstock, which can overwhelm the O&M costs; royalties for the technology; and production taxes. Those are all site-, project-, and market-specific costs. They are calculated by each company for specific projects, but need to be deducted from operating and maintenance accounts to yield a picture of net O&M costs.

Performance and Start-Up Data Needed

The planners of follow-on projects will need to know planned versus actual design capacity, planned versus actual production, and information on reliability and performance of the pioneer unit. Any market constraints, either in availability of feedstock or in ability to sell the product, can also be very important.

Startup and early operations provide extremely important information because they involve both cost and performance. In fact startup, more than anything else, was reported to us as providing the key information that enables the analyst to distinguish technology problems from problems with project execution.

The first one to three years of initial operations--the numbers commonly reported to us--appears to be long enough to provide a reasonable handle on how well the technology performs, how reliable it is, and what the operating and maintenance costs are.

The implications for synfuel project data collection are two-fold: Firstly, for any kind of information program, intensive data collection should continue for two to three years after mechanical completion; it does not end with startup. Secondly, to maximize design improvements, the startup of the first plant should finish before the second plant is designed.

Schedule Data Used Less Often

Information on the pioneer project's schedule is less frequently relied upon. The schedule information as reported to us is often site- or owner-specific and can become quickly outdated. If something went wrong with the schedule, however, it is important to understand the reasons why. For example, was the project delayed because of site-specific, labor, procurement or permitting difficulties which later projects could avoid?

RANKING OF DATA SOURCES BY VALUE

The interviewees concur that it is easy to rank information sources according to the value of their information or the confidence companies have in it, in this order: (1) The operating pioneer plant (including the owner-operator). The people involved in the design, building, and operation of the pioneer plant are very important sources. (2) The next three are also of about equal value: the licensor, the architect-engineering or design/construction firm, and the vendors, especially for specialty items. (3) A good step below that is the public record--conferences, journals, and so on. (4) Another major step below that is the government.

These interview results mirror our own experience in the Pioneer Plants Study. That is, we got our best information when there was an operating plant, when the people who were involved in the project and plant were still there, and when we went to the owner/operator.

Key People and Operating Plant Enhance Data Value

Figure 6 illustrates the relationship among the plant, the people, and the owner/operator. The continued presence of project personnel ensures a corporate memory, and encourages the transference of learning to others. Aside from manuals, computer files, and ledger sheets, these experienced people are a repository of useful information--call it folklore--that often goes unrecorded, such as how the as-built plant differs from the as-designed, and how the process has evolved over time. As valuable as these people are to follow-on builders, they often scatter when the pioneer facility shuts down, however.

An operating pioneer facility, of course, is a veritable technical college for a potential investor. The investor can get a close look at the works, and perhaps even try it out with different feedstocks, as the sponsors of the Great Plains Project did when they shipped 12,000 tons of coal to the SASOL project in South Africa to test their feedstock with the Lurgi technology.[3] Keeping the plant operating allows technical

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[3] According to one project executive, these tests provided "important data ranging from physical coal properties, gasification rates, tar/oil compositions, steam and oxygen ratios, composition of waste streams including ammonia and phenols content, ash properties,

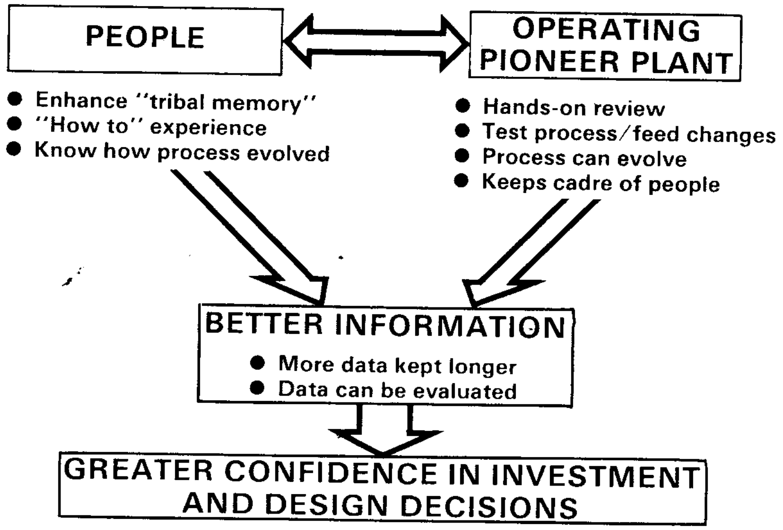

Fig. 6 -- Key people and operating plant enhance data value

improvements to be made as operating experience is gained. Thus technologies can evolve over time in a commercial rather than bench-scale setting. Having an operating plant enables a company to retain a cadre of key experienced individuals, and it also implies better recordkeeping.

These two factors interact. Having both the people and the operating plant gives the investor much greater confidence and more valuable information than having only one or the other. Without an operating plant and people for reference, firms may tend to avoid that technology.

CO-shift requirements, and other invaluable data that provided the basis for both conceptual process and detailed mechanical design." (*Energy Technology VI*, p. 726.

Process Licensor as Information Source

It was widely reported to us that a company usually obtains a process license by paying for it in stages: paying a little bit at the outset to get the information necessary for a screening decision; a little more at the feasibility study level; and the full balance when it is decided to build.

Sometimes the information obtained at the first stage is general, and may differ from the more decisive information obtained at a later stage. In a few cases, it was reported to us that a company was encouraged by first-stage information to proceed with a technology, only to back out of the project when more detailed information revealed that the economics and technology were not feasible for the company.

Obviously, process information is even more valuable if the potential builder can get access to the owner/operator and the plant. That is not always the case, especially when the owner/operator is not the process licensor. If the would-be builder is dealing with the licensor alone, and no plant is operating, it is still harder to evaluate the information. A number of cases were reported to us in which licensors withheld some information or masked poor performance or startup problems. Finally, a licensor who is not the owner/operator normally does not have startup and operating experience--which can be the key decision information.

Design/Constructor as Information Source

Design/constructors, or AE&C's (architect-engineer-constructors) as they are frequently called, are often relied on, especially by medium to smaller-sized companies, to do a great deal of the screening and feasibility work. In fact, they are a common source for early, rather "scrubbed down," information about the process itself, because the AE&C has access to licensors. That is, a potential investor can avoid paying the money at the early stages to the licensor by paying an AE&C to do some screening work. Design/ constructors are of course all the more valuable if they built the pioneer plant, and especially if they still employ the key people in that project. In fact, a company deciding to hire that AE&C will usually name such people as part of the contractual agreement. AE&C's are not always the best source of detailed information, however, because they turn over some of it to the owner/operator who paid for it, and they are usually not involved in startup or operations.

Public Record as Information Source

No company reported relying on information obtained from public sources in deciding to invest in and build a follow-on plant. The public record can be useful for other purposes, however. Journals and the like help keep people abreast of their technical fields, but the information they contain is usually too general or too academic to be useful in making project decisions. Similarly, journal accounts of what happened on a project are often incomplete or inexact.

Government as Information Source

Industry considered the government to be the poorest information source. (One firm did cite a contrary example, however, concerning the value of some of DOE's components-testing research.) The reasons are fairly straightforward and understandable, but they have important implications for a Synthetic Fuels Corporation information program. The first reason frequently cited was that the information is not well kept--that government fails to keep good information, or it keeps too much and there is an information overload problem, or the information is so poorly organized as to be inaccessible. In several instances the Morgantown library was cited as an example. People from industry, and Rand researchers as well, have tried to use Morgantown, only to be confronted with unindexed boxes of documents. (This problem is not uncommon in industry archives, also.) Other common complaints are that because government is so poor at keeping secrets, firms will not give it information that is worth much anyway. Besides, the data are less valuable detached from the people involved in the pioneer project; consequently, if information is available from some other source, that source is to be preferred over the government. Any synfuel project information program should try to avoid these problems.

FACTORS INFLUENCING INFORMATION SURVIVAL

Who Keeps What?

Large owner/operators and large architect/engineer-constructors tend to keep a great deal of information, but to keep different kinds in different ways. Smaller firms tend to keep spottier records, but even the records of the larger firms and the AE&C's have gaps from project to project. Not all these gaps are necessarily due to carelessness. Firms vary in their need for and use of data. Also, the licensor and the AE&C usually do not have startup data and data from operating experience. Finally, across all companies, the retention of project information decreases over time; early cost histories of a project may disappear as they are updated, and as the project itself fades into history the information fades with it.

General Impressions

Our interviews of industry representatives yielded many explanations of why the kinds of retrospective data we have identified are not always available. The following paragraphs summarize a few of the comments and observations of our interviewees.

"Every project is different." That is, there being no such thing as a duplicate plant, information from a prior unit will not be useful. Pioneer projects have unique problems; it is not prudent to store copious information on atypical problems. Early cost estimates are soon outdated; later ones are more accurate (which is true, but finding where the inaccuracies were and how they have been updated is important to understanding cost growth and final cost, especially of a pioneer unit.) Many companies, especially the smaller ones, do not build enough plants to enable any kind of sophisticated statistical work or to warrant keeping a cost file of any kind. Even if people agreed that they should hold onto information, they may all have different opinions on what should be kept. Since the firm cannot save everything, they often end up saving little or nothing.

Data are often not tracked very well during a project because it is often hard to know what data will be useful or marketable later. Moreover, technology can evolve so rapidly that extensive record-keeping is a waste. In these cases, firms tend to depend on people's memories. Every single company relies heavily on certain people to keep and interpret the information. When they leave, the information can lose its usefulness.

Many interviewees reported that corporate management is not sufficiently committed to the idea of keeping good information, even though it wants and uses it.

Sometimes information is routinely purged after five to seven years. When a plant is shut down, many companies have a rule that all records of the plant are destroyed within one to three years.

Finally, to our great fascination, we were often told that the data "wandered off somewhere and were never seen again." The words varied, but the story was repeated many times.

How Information Survival Varies By Company

We found that information capture and survival is a function of the firm's capability for estimating and engineering. Where there is only a small estimating shop or no centralized engineering, very little information is kept or retained, and the firm relies heavily on contractors or other people. Where there are extensive in-house estimating and engineering capabilities, the firm retains and uses far more data in-house. Such firms are also better able to interpret the data, because they are the ones who build the plants. The resources devoted to record-keeping vary widely, in both money and effort. End-of-project reports are common, but for the same size project, writing one may entail anywhere from half a day to six months of a manager's time. They may be tucked away in a file drawer somewhere; some companies have rather sophisticated or complex cost and process files, but most do not, and hence there is little systematic collection of information. But even expensive data retention systems do not always capture and keep data that the company itself needs and could use. Needs and uses also vary. If the company does a great deal of engineering, it has an engineering standards "manual" with process and mechanical design lessons from major projects, especially pioneer projects, incorporated into them routinely.

Information Survival Varies By Project

Information survival also varies considerably by project even within the same company. For high-visibility projects where there is a major company stake or high-level sponsor--say, a member of the board is pushing it--the information tends to be kept more readily. The data also tend to be better kept if the purpose of the project is to test a process or demonstrate a process to be licensed, as opposed to a refinery or a more standard plant; if the project plays an important role in a new business or long-term business strategy for the company--perhaps because it wants to diversify into a new market, for example, and it appears likely that a follow-on plant will be built; and if the pioneer plant is still operating. (When a plant is shut down, plant records are often purged and the experienced people dispersed, and with them the ability to interpret what happened is lost.)

Information Survival Varies by Method

The capture and survival of information also varies by the method of retaining the information. Three factors are primarily important: ease of use, accessibility, and completeness. If it is easy to use, firms tend to collect, keep, and use it. Ease implies standard, convenient formats with data recorded in common units. Accessibility is important whether the information is contained in a cardboard box or in a computer. Finally, information that is complete is more likely to survive because people find it more consistently useful. Completeness implies more than masses of raw data, of course. An important component is the presence of the information necessary to normalize the cost, schedule, and performance outcomes across projects.

Table 1 summarizes our discussion of the factors that influence the capture and survival of information.

Information Kept Varies--Even for Critical Data

Returning to our *critical, important, and secondary* categories of information for evaluating pioneer projects: In Figure 7 we have taken the set of information gathered in the interviews and classed each category of information according to whether it is almost always kept

Table 1

FACTORS INFLUENCING INFORMATION SURVIVAL: SUMMARY

COMPANY CHARACTERISTICS	● **In-house estimating & engineering** ● **Resources devoted** ● **Need and use for data** ● **Only owners usually have startup/ operating data**
PROJECT CHARACTERISTICS	● **Visibility** ● **Project purpose** ● **Plant still operating**
METHOD OF STORAGE	● **Ease of use** ● **Acessibility** ● **Completeness**
PEOPLE	● **Management commitment** ● **Needs of collectors** ● **Availability of project personnel**

across companies and across projects over at least some period of time; whether it is usually kept, that is, it is kept for some projects, or by some companies, but not all; and whether it is sometimes or only rarely kept. It is plain to see that the information kept varies tremendously, *even for the critical data*. Firms almost always preserve critical information and some of the very important information. They usually keep some of the interpretive information, especially the startup costs of the pioneer unit, design issues, and so on. But few firms keep records on problems that occurred in startup, how they were resolved, and important information relevant to *understanding cost, schedule, and*

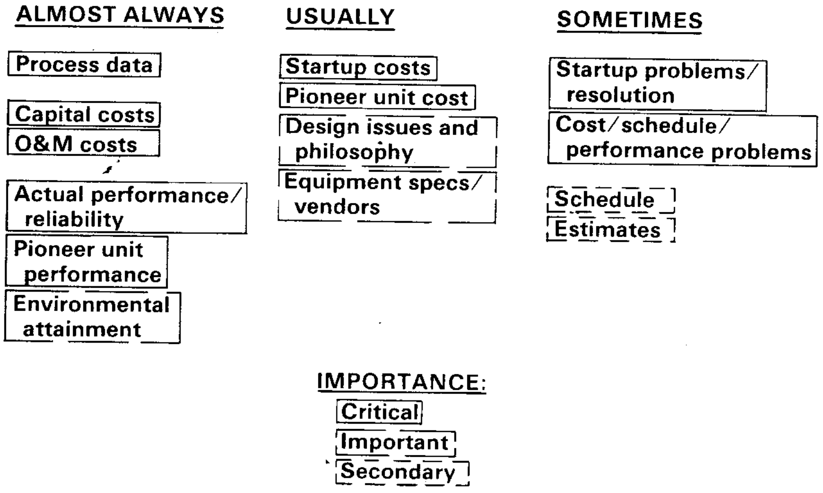

Fig. 7 -- Information kept varies--even for critical data

performance problems. It is somewhat understandable that schedule and estimates are only sometimes kept because they are not used much, *except* in helping *interpret* the pioneer project experience. Understanding how the pioneer projects' actual cost, schedule, and performance *varied* from their expected baselines is critical to good retrospective evaluation and investment decisions.

IV. CONCLUSIONS

WILL PIONEER SYNFUEL PROJECT INFORMATION SURVIVE?

The central question in this discussion is whether the information from the first pioneer synthetic fuel projects supported by the SFC, or by the Energy Security Act more generally, will be available for future projects--and if not, what should be done. Much information will be routinely available through the licensing system, of course--not merely process data, but some of the basics, such as capital cost information. We are talking here primarily about raw data. Some of the data are potentially available through the existing SFC monitoring program, although in what form, if any, the data can be released is a matter of some uncertainty.

Some characteristics of pioneer synfuel projects make it likely that the information will survive: They are highly visible, they represent major commitments by large companies, and some information is valuable to the pioneering firms, either in helping them decide whether they want to build a follow-on plant or to sell the information to others. There is never any guarantee that information will be preserved, however.

The most critical factor in the survival and utility of this information will be the length of any hiatus before further synfuel projects are launched. (A continual decline--or no real increase--in oil prices, for example, could encourage a hiatus.) The longer any such hiatus lasts, the greater will be the decay in the availability and the value of the information. For that reason, the benefits of an information program are manifest. A hiatus means that people with first-hand experience will gradually disperse, the plant may shut down, and the data may be lost if they were collected at all.

Focus of an Information System

Figure 8 lists the categories that an information program might provide, and notes the importance of the various items. Each item is flagged as to whether it is almost always available with the licensing or business-as-usual system, or whether it is potentially available through the SFC project monitoring system. The remaining gaps point to priorities for a program information system.

As we can see by looking down the first column, the existing system will almost certainly embody process data, capital costs, operating and maintenance costs, reliability and performance of the plant and the pioneering unit, and the environmental attainment record. Some of that information may also be available through the monitoring system, such as the capital cost and the environmental attainment. Some information about cost, schedule, and performance problems will also be available as well as some understanding of schedule and estimates. Still uncertain, however, is the level of detail at which some data on cost and performance will be available because the data given to the SFC are protected by secrecy agreements.

The final column of Figure 8 identifies the priorities for a program information system that will enhance the benefits of a pioneering synthetic fuels program: the cost of the pioneer unit, costs of startup, the problems in startup and how they were resolved, the issues that were dealt with in the design of the plant, and the philosophy of how the plant was designed are not always available from any other source. The kinds of data represented in the priorities list are characteristically interpretive information; identifying and explaining cost, schedule, and performance problems and solutions provide the critical understanding of what happened. Raw data will be abundantly available under the business-as-usual system and perhaps under the SFC monitoring system, but interpretive information will by and large not always be there--and therein lie the priorities for this system.

INFORMATION CATEGORY	POTENTIAL SOURCE		
	Normal licensing system	SFC monitoring system	Priorities for program information system
Process data	■		
Costs			
● Capital	■	■	
● Pioneer unit	?	?	■
● Startup	?	?	■
● O&M	■		
Performance			
● Actual & reliability	■	?	
● Startup problems/resolution		?	■
● Pioneer unit	■	?	
● Design issues and philosophy	?		■
● Environmental attainment	■	■	
● Equipment specs/vendors	?		■
Costs/schedule/performance problems		?	■
Schedule > Variance		?	■
Estimates > Variance		?	■

Critical Important Secondary

Fig. 8 -- Likely sources and availability of synfuel project data

Program Information System Attributes

The program information system should focus on capturing critical, absolutely essential interpretive information, especially about startup and initial operations. To avoid redundance, it could be coordinated in some way with the existing SFC project monitoring system, and the information should be collected selectively to avoid the problem of information overload. The information should be well organized and accessible, with a consistent format. The system should also be sensitive to real proprietary concerns, particularly technical process information. Failure to do so could create strong disincentives for firms pioneering the technologies. Finally, because information is most valuable in conjunction with people and with operating plants, the system might well keep track of key individuals in each project.

Serious consideration should be given to encouraging firms to keep the plants operating during any hiatus. This measure would greatly enhance the value of the pioneer synfuel projects. Second only to capturing the project information in the first place, this is the most effective means of preserving information. Operating plants allow the technologies to continue to develop and improve. They provide potential investors with the opportunity to evaluate feedstock alternatives--an opportunity critical to the Great Plains plant design. The presence of operating synfuel plants, then, enables new information to be created, as well as helping to preserve the pioneering project experiences. And because no single data collection instrument can capture *all* information that might be useful to someone else later, an operating facility with its cadre of experienced personnel is the most effective way to preserve the information and experiences for later use.

POSSIBLE SFC OPTIONS

We perceive four possible SFC options, each with its advantages and disadvantages. First, the SFC could take on the entire task of gathering and disseminating information. Second, the SFC could let the companies collect it, and merely audit it to make sure it is being collected and preserved. Third, the responsibility for either gathering and disseminating or for auditing only could be placed with an independent third party, such as a synfuels industry group. Finally, the SFC could do nothing. We take up each option below.

First, the SFC could collect and openly disseminate the information. If the SFC were to do that, abundant data would probably be available, especially the critical interpretive information. But to the extent it touches on sensitive or proprietary information, the SFC may inhibit companies from pioneering in the first place because they do not want to give that information up. Or if they do build pioneer plants, they may not give the SFC complete information or the best information; in that case, builders of subsequent projects would have good reason not to trust the information fully. But without some action, follow-on builders probably will not get adequate information. The question is, is it better than nothing?

The second option is simply to audit. In that case, information would probably be available from the company, and other firms could purchase it as part of the licensing process. Mere auditing by the SFC should not inhibit the incentives of pioneering companies, and the data would probably be more credible to future users. On the other hand, the SFC, Congress, and the Executive branch may thus be denied access to information they need for informing policy judgments or future negotiations.

The option of delegating a third party to collect, disseminate, and/or merely audit the information would probably ensure its availability. There would also be even less disincentive to pioneer, because the SFC and the government would not be involved at all, and the data would probably be more credible. An advantage of this option, then, is that there is no major role for the SFC to play once it is established. The disadvantage is the SFC's being somewhat of a captive to the third party, which will have great power over how they use the information or make it available. The SFC probably would have no access to the raw data--the same problem as with the audit--although much data are available through their project monitoring system.

Finally, the SFC's taking no action is easy and cheap, and it does not affect pioneering incentives. But some data may be lost, especially the critical interpretive information about what happened in the pioneering projects; information may not be available to subsequent investors, especially after a hiatus; and the SFC will lack some data useful for policymaking judgments--except as they are provided through the project monitoring system.

Industry Comments

Most of the industry representatives we interviewed expressed a preference for option two, and some for option four. Most of them supported the general principle of an information system and agreed that some important information is likely to be lost otherwise. All agreed that the government, including the SFC, should *not* be directly involved in handling the data, however. Instead, the most frequent suggestion was that the SFC should identify the information commonly needed and provide consistent (or "cookbook") forms for collecting and storing it. The collection and retention of this information would become a condition of SFC support. A corollary condition would require that project sponsors provide this information at reasonable cost to other companies requesting it.

SUMMARY OBSERVATIONS

Despite the difficulties involved in balancing these tradeoffs, several conclusions can be drawn about what the Synthetic Fuels Corporation might do to enhance pioneer synfuel program benefits. Consider the case under the fourth option. Companies seeking pioneer synfuel project information will pay the owner-operator, process licensor, and/or architect-engineer-construction firms involved in the first-of-a-kind projects for whatever information those firms can supply. Those firms will not necessarily have all the important information, however, especially if considerable time has elapsed.

The benefits of the pioneering synfuel program are increased significantly when all relevant experience gained from the initial projects is transferable to subsequent sponsors. Substantial progress toward this goal can be made by simply requiring that the pioneering firms collect this information, keep it, and make it available (for a reasonable fee) to others requesting it. Although we believe the costs of collecting and retaining the information are not high if done appropriately during the projects, the SFC might consider paying project sponsors for doing so. The SFC should also consider ways to keep the pioneer facilities operating during any hiatus when the plants might be shut down otherwise.

The SFC can further promote that goal by providing project sponsors with a convenient data collection format and requiring that they complete and retain it. This format should be developed with industry consultation, standardized, and then provided to sponsors early to avoid imposing undue costs on them. This format should be publicly available so that other potential sponsors will be aware of the types of information being collected.[1]

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[1] See Appendix B.

To meet the needs of industry sponsors, there is therefore no need for a centralized data source to which each subsequent developer would turn for project information. In fact, even if such a central repository existed, it would not be the most desirable information source. Firms would still turn directly to the pioneering firms for the original data, in which they would repose greater confidence. This is so for two reasons. First, only the pioneer firms have the experienced people and operating facilities. No amount of record-keeping can substitute entirely for their value. Second, centralized information banks established by a third party such as the SFC may well suffer from a lack of credibility, as noted in Sec. III. Moreover, a centralized information system is likely to be perceived as being less protective of the information than if the data were collected and retained by the pioneering firms.

Information systems such as the one discussed above, and that suggested by many industry representatives, would not permit public access to the raw data, however. Some information potentially valuable to SFC or government policy decisions would therefore be denied to public decisionmakers. Yet to allow government access to the information might well compromise its value, and even its collection. Still, government access for policymaking purposes does not require a centralized data source. A disinterested third party might be employed to synthesize and analyze the raw data. This party could then provide the SFC and other public policymakers with aggregated project results in "scrubbed down" form.

The issue of public access to detailed proprietary project information is a question beyond the scope of this study. Settling this question requires that policy judgments be made. We have identified many of the important tradeoffs that should be weighed in making those judgments.

The analysis presented here suggests that the benefits of the pioneering synfuel program can be enhanced through the systematic collection of project information. This can be accomplished simply by requiring that firms collect it and make it available. The benefits represent substantial gains over the existing business-as-usual system.

They do not require data centralization or public access. Moreover, realizing these benefits does not depend on resolving public-policy questions about access to the information.

APPENDIX A: INTERVIEW QUESTIONS

This Appendix lists the topic areas discussed during our interviews with industry represenatives.

1. Broadly outline how major venture decisions are made in this firm.

2. How is experience from prior projects used for making subsequent major venture decisions using similar technology?

    (a) What are the primary characteristics used to distinguish successful projects from unsuccessful ones?

    (b) How do you tell whether a project was unsuccessful because of the technology employed, as opposed to the way the project was executed (e.g., unique scheduling or management problems)?

3. What do you do to ensure that meaningful comparisons can be made between two or more projects (e.g., how are site-specific factors or as-spent dollars "normalized"?)?

4. What kinds of information or experiences from prior pioneering projects are useful for later venture decisions (e.g., what aspects are likely to be repeated)?

    (a) Under current company procedures?

    (b) Ideally?

5. When is this information useful?

    (a) For project screening.

(b) For feasibility study authorization (or project definition).

(c) For detailed engineering authorization.

6. To what extent does the level of detail required (or desired) vary at different decision points?

7. Where does this information come from? How is the relevant experience transferred? What is the relative importance of each?

   (a) Personal (and personnel) experience

   (b) Written documents from pioneer projcts

   (c) (Other) owner-operators

   (d) Process licensors (gratis)

   (e) Process licensing agreements (fee)

   (f) Architect-Engineering firms

   (g) Industry research organizations (e.g., GRI, EPRI)

   (h) Conferences/trade journals

   (i) Equipment vendors

8. To what extent does this company rely on outside contractors in making major venture decisions?

   (a) At each decision point (screening, feasibility, detailed engineering)?

   (b) Why (e.g., in-house capability, second opinion/additional information)?

9. Can (or is) another company's experience in building or operating a pioneer plant be useful to your company's decision to build and operate a similar follow-on plant?

    (a) What kinds of experience?

    (b) At what level of detail?

    (c) From what kinds of companies?

10. How well do existing procedures and practices provide all relevant information? What information is lost or attenuated?

11. What would improve the quality and quantity of useful information?

    (a) In what form should the information be collected and stored?

    (b) What units of measurement are appropriate?

    (c) Would a project historian be useful? What qualifications should he/she have?

12. What are the costs and benefits associated with collecting and using information from previous projects for later investment decisions?

    (a) Under current company procedures and practices

    (b) In an ideal system

13. How much effort (such as manyears) does this company spend in collecting and maintaining project information and experience?

    (a) What kinds of data are kept (e.g., cost, technical, management information, other indicators of "what happened")?

(b) At what level of detail (e.g., total costs only versus detailed equipment cost breakdowns)?

(c) How is it kept (e.g., archives, special library, computer files)?

(d) How is it accessed and used (please walk through an example)?

14. If there is a delay between the pioneering project and a second similar project, what are the problems in using information from the pioneer plant?

    (a) Are there special problems caused by a delay? For example, does the information become less useful or less valuable?

    (b) What specific information items and/or transfer mechanisms are especially affected by delay?

    (c) Does the nature of these problems change according to the length of the delay between the first project and the subsequent projct decision?

APPENDIX B: DATA COLLECTION FORMATS

This Appendix contains data collection formats for specific information items identified in the accompanying report. These suggested formats represent a subset of the items contained in Rand's basic process plant information worksheet. As such, they reflect over five years of Rand experience in collecting and evaluating similar pioneer plant information, and have been revised several times based on industry feedback.

Most of the questions focus on information needed to *interpret* what happened in a project, and why. Thus, some questions identify the areas of new technology in the plant, while others focus on design and/or startup difficulties. Still others are useful to normalize project data. No detailed technical or process data are requested.

The worksheet should be filled out shortly after the completion of startup, although some sections could be completed earlier. Monthly performance data should be tracked and plotted throught the first 30 months. The worksheet should be completed by someone closely connected with the project, such as the project manager.

I. GENERAL INFORMATION

1. NAME OF PLANT ______________________________

LOCATION ______________________________
City State

2. NAME OF PERSON COMPLETING WORKSHEET: ______________

TITLE: ____________ DATE COMPLETED: ____________

3. PROJECT PARTICIPANTS

a. Project Sponsors ______________________________

____

b. Owner/Operator ______________________________

c. Prime Contractor(s) ______________________________

d. Project Manager ____________ Company ____________

4. a. **Major products** of the plant:

____

____

b. Major products **output rates** (i.e., nameplate capacity):

____________ (mm lbs/yr)

____________ (mm lbs/yr)

____________ (mm lbs/yr)

5. a. **Raw materials** used:

____

____

b. Raw material **consumption rates**:

________________ (mm lbs/yr)

________________ (mm lbs/yr)

________________ (mm lbs/yr)

6. What is the status of the plant location? CHECK ONE.

Colocated	____	Expansion	____	Revamp	___
Grassroots/ greenfield	____	Add-on	____	Other	___
				What?	________

7. Please describe the **recent commercial history** of this process:

LARGEST CAPACITY BUILT: ____________ (mm lbs/yr)

LOCATION: ____________________

COMPANY: ____________________

8. Please provide a copy of the **BLOCK DIAGRAM** for this plant. This is the diagram of major functional subsystems. Examples are provided in Figs. 1 and 2.

These questions involve information about the number and cost of the process steps in this plant **according to the block diagram**. *Process steps are defined as the points in the plant where chemical or physical conversion occurs.* A chemical conversion step involves changes in the molecular form of a material, while physical steps physically alter material. Parallel operations are counted as a single step. Some examples of items (or major equipment groupings) to be counted as process steps and items not to be included appear below.

DO INCLUDE AS PROCESS STEPS:	*DO NOT INCLUDE AS* PROCESS STEPS:
Reactors, distillers, dryers, gasifiers, ion exchangers, gas absorbers, choppers, grinders, mixers, aerators, filters	Pumps, on-line heaters, storage and surge tanks, offsites, duplicate or parallel trains

A. *Based on the block diagram*, how many **total process steps** are linked in this plant?

Total number of process steps: ____________

Please *NUMBER these steps on the diagram* and LIST them below:

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
10. ____________________
11. ____________________
12. ____________________

EXAMPLES OF *BLOCK DIAGRAMS*

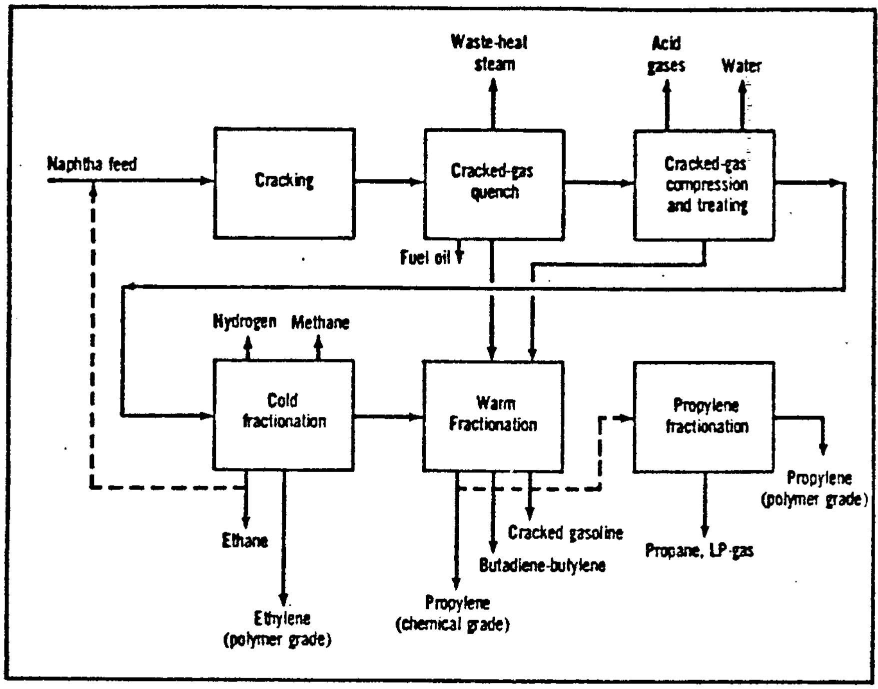


FIG. 1 Typical ethylene plant

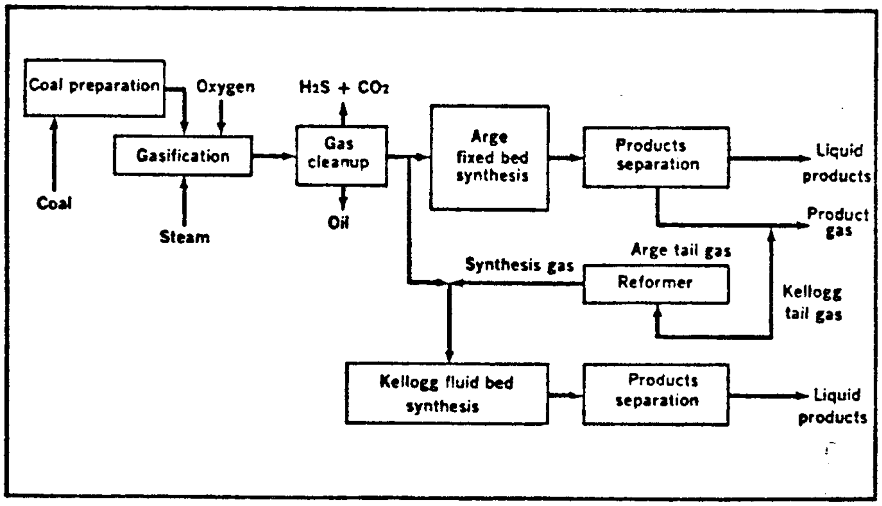


FIG. 2 Fischer-Tropsch process[1]

Source: Brownstein, Arthur M. Trends in Petrochemical Technology: Impact of the Energy Crisis, Petroleum Publishing Company, Tulsa, Oklahoma. 1976.

B. How many of these process steps incorporate **technology unproven (or new) in commercial use**?

NOTE: A process step is said to be unproven in commercial use if *one or more of the following pertain*:
(1) Employs chemistry that has not been commercially employed before;
(2) Incorporates major equipment that has not been commercially used;
(3) Represents a new match of feed and equipment.

Number of NEW process steps: ____________

Please *CIRCLE these steps on the diagram.*

Please *LIST these steps below* and the *REASON for the newness* (e.g., new chemistry, new feed, new materials, newly designed equipment)

	NEW STEP	REASON
(a)	__________________	________________________________
(b)	__________________	________________________________
(c)	__________________	________________________________
(d)	__________________	________________________________
(e)	__________________	________________________________
(f)	__________________	________________________________
(g)	__________________	________________________________

C. How many **new integrations** of steps used commercially in other plants were involved in this plant?

Number of new integrations ____________

Please LIST these new integrations:

(a) ____________________
(b) ____________________
(c) ____________________
(d) ____________________
(e) ____________________
(f) ____________________

9. Did the development of this plant require that **new process equipment** be designed?

YES ___ --> ANSWER Q9A-B.

NO ___ --> SKIP TO Q10 BELOW.

A. *If new process equipment was required*: WHAT EQUIPMENT?

(1) ______________________ (4) ______________________

(2) ______________________ (5) ______________________

(3) ______________________ (6) ______________________

B. At what point(s) in the development process was the need for new design recognized?

(1) ______________________ (4) ______________________

(2) ______________________ (5) ______________________

(3) ______________________ (6) ______________________

10. Is this plant, or any unit in this plant, a **scale-up** from another plant?

Yes ___ ANSWER Q.10A-B

No ___ SKIP TO Q.11

A. Which **units** are scaled-up?	B. What is the **scale-up ratio** ? (Ratio=new plant capacity divided by old plant capacity)
(1) ______________________	Ratio: ______________________
(2) ______________________	Ratio: ______________________
(3) ______________________	Ratio: ______________________

11. Were any type of **process development or testing facilities** built or relied upon in the development and design of this plant?

YES ___ --> DESCRIBE BELOW.

NO ___ --> SKIP TO NEXT PAGE.

A. If any type of *testing, process development, pilot, or demonstration facilities* were built or relied upon, please describe each below:

TYPE OF FACILITY	PROCESS UNIT(S) INVOLVED	CAPACITY	SCALE FACTOR TO COMMERCIAL UNIT*	OPERATING SCHEDULE (For Facility) START DATE (mo/yr)	SHUT-DOWN DATE (mo/yr)
Bench scale	________	________	________	__/__	__/__
	________	________	________	__/__	__/__
Process Development Unit	________	________	________	__/__	__/__
	________	________	________	__/__	__/__
Commercial Scale Components Testing Facility	________	________	________	__/__	__/__
	________	________	________	__/__	__/__
Integrated Pilot	________	________	________	__/__	__/__
	________	________	________	__/__	__/__
Semiworks or Demonstration Facility	________	________	________	__/__	__/__
	________	________	________	__/__	__/__

*Test unit capacity / commercial unit capacity.

12. Below are some of the fundamental reasons why there may have been significant technical problems that had to be solved during the development effort. Please indicate the extent that each item was a source of development and design problems. Ignore problems that appeared only after the initiation of startup.

PROBLEM AREA	EXTENT OF PROBLEMS (Circle number)						Please explain the nature of the difficulty.
	No Problem	Minor				Major	
A. Uncertainties in process chemistry	0	1	2	3	4	5	________
B. Uncertainties in reactor design	0	1	2	3	4	5	________
C. Uncertainty of feedstock composition	0	1	2	3	4	5	________
D. Process impurities (e.g., recycle, catalyst deactivation product impurities)	0	1	2	3	4	5	________
E. Peak temperatures	0	1	2	3	4	5	________
F. Temperature tolerances	0	1	2	3	4	5	________
G. High pressures	0	1	2	3	4	5	________
H. Pressure tolerances	0	1	2	3	4	5	________
I. Corrosive materials	0	1	2	3	4	5	________

(Continued on following page)

PROBLEM AREA	EXTENT OF DIFFICULTY (Circle number)					Please explain the nature of the difficulty.
J. Abrasive materials	No Problem 0	Minor 1	2	3	4	Major 5	______
K. Liquids handling	No Problem 0	Minor 1	2	3	4	Major 5	______
L. Gases handling	No Problem 0	Minor 1	2	3	4	Major 5	______
M. Waste handling	No Problem 0	Minor 1	2	3	4	Major 5	______
N. Solids handling OR DOES NOT APPLY ____	No Problem 0	Minor 1	2	3	4	Major 5	______
O. Solids preparation and feed OR DOES NOT APPLY ____	No Problem 0	Minor 1	2	3	4	Major 5	______
P. Solids processing OR DOES NOT APPLY ____	No Problem 0	Minor 1	2	3	4	Major 5	______
Q. Instrumentation and process diagnostics	No Problem 0	Minor 1	2	3	4	Major 5	______
R. Other (Please identify) ______	No Problem 0	Minor 1	2	3	4	Major 5	______

2. Please identify the TWO MOST DIFFICULT problem areas listed above:

(1) ______

(2) ______

13. Below is a list of technical problems which may have been encountered after the initiation of startup. Please indicate the extent to which they were a source of startup or early operational difficulty for this plant.

PROBLEM AREA	EXTENT OF DIFFICULTY (Circle number)						Please explain the nature of the difficulty.
A. Uncertainties in process chemistry	No Problem 0	Minor 1	2	3	4	Major 5	____________
B. Uncertainties in reactor design	No Problem 0	Minor 1	2	3	4	Major 5	____________
C. Uncertainty of feedstock composition	No Problem 0	Minor 1	2	3	4	Major 5	____________
D. Process impurities (e.g., recycle, catalyst deactivation product impurities)	No Problem 0	Minor 1	2	3	4	Major 5	____________
E. Peak temperatures	No Problem 0	Minor 1	2	3	4	Major 5	____________
F. Temperature tolerances	No Problem 0	Minor 1	2	3	4	Major 5	____________
G. High pressures	No Problem 0	Minor 1	2	3	4	Major 5	____________
H. Pressure tolerances	No Problem 0	Minor 1	2	3	4	Major 5	____________
I. Corrosive materials	No Problem 0	Minor 1	2	3	4	Major 5	____________

(Continued on following page)

PROBLEM AREA	EXTENT OF DIFFICULTY (Circle number)						Please explain the nature of the difficulty.
J. Abrasive materials	No Problem 0	Minor 1	2	3	4	Major 5	____
K. Liquids handling	No Problem 0	Minor 1	2	3	4	Major 5	____
L. Gases handling	No Problem 0	Minor 1	2	3	4	Major 5	____
M. Waste handling	No Problem 0	Minor 1	2	3	4	Major 5	____
N. Solids handling OR DOES NOT APPLY ____	No Problem 0	Minor 1	2	3	4	Major 5	____
O. Solids preparation and feed OR DOES NOT APPLY ____	No Problem 0	Minor 1	2	3	4	Major 5	____
P. Solids processing OR DOES NOT APPLY ____	No Problem 0	Minor 1	2	3	4	Major 5	____
Q. Instrumentation and process diagnostics	No Problem 0	Minor 1	2	3	4	Major 5	____
R. Other (Please identify) ____	No Problem 0	Minor 1	2	3	4	Major 5	____

2. Please identify the TWO MOST DIFFICULT problem areas listed above:

(1) ____

(2) ____

II. PLANT PERFORMANCE

1. Using the graph provided in Fig. 3, please plot the **planned** and **actual plant production rates** as a *percent of the design* (nameplate) *capacity*. These plant production rates should incorporate both through-put and on-stream (system availability) factors.[1]

2. Using the graph provided in Fig. 4, please plot the **planned** and **actual availability** factors as a *percent of time*.

3. At what point were the planned **product quality specifications** met?

_______/_____
(month/year)

4. Were product quality specifications changed at any point?

YES ___ ANSWER Q.2A-B

NO ___ SKIP TO Q.3 BELOW

A. What changes were made? For what reasons?

	CHANGE	REASON
(1)		
(2)		

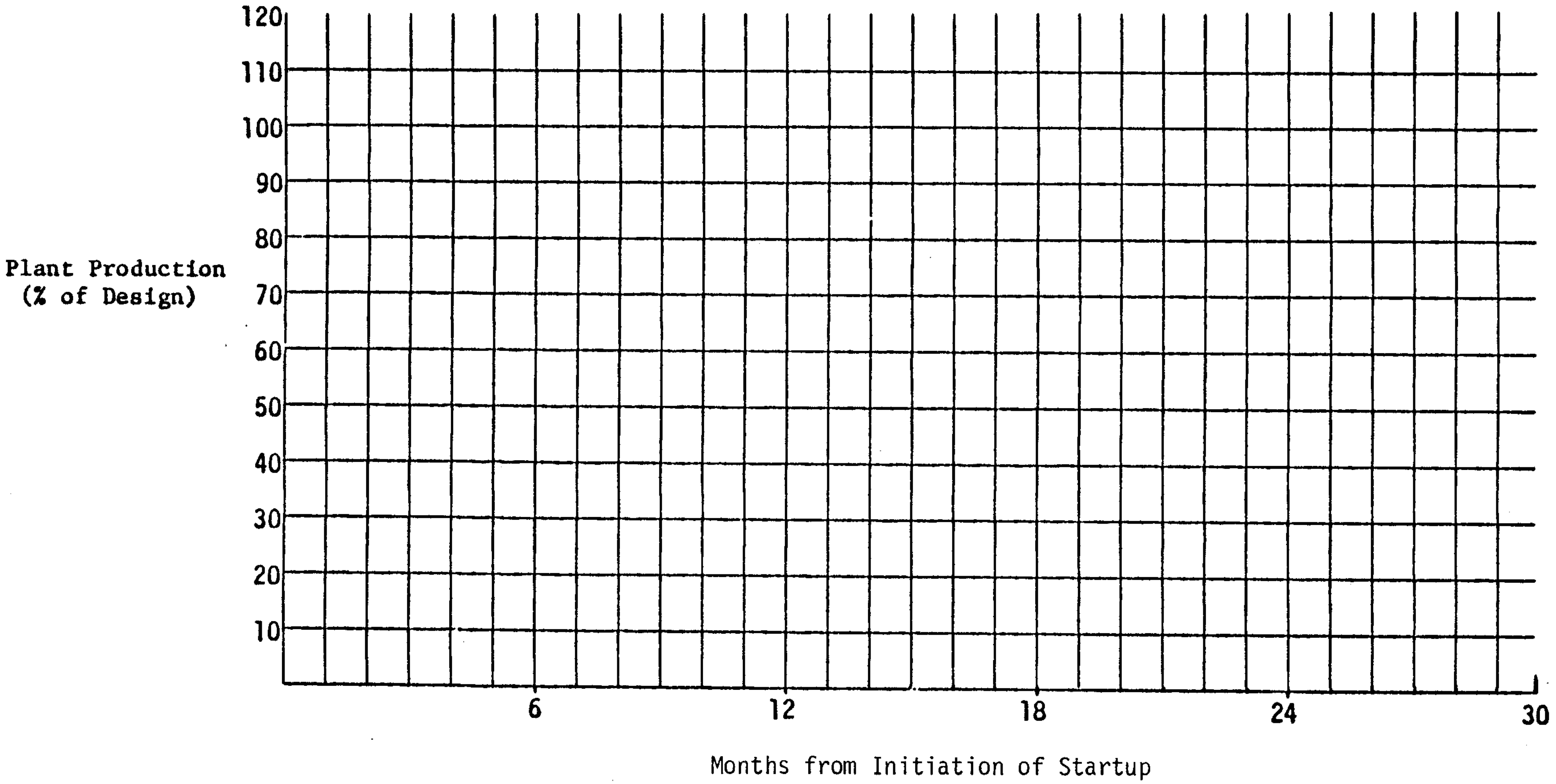
B. How did these changes affect cost or performance?

(1) ______________________________

(2) ______________________________

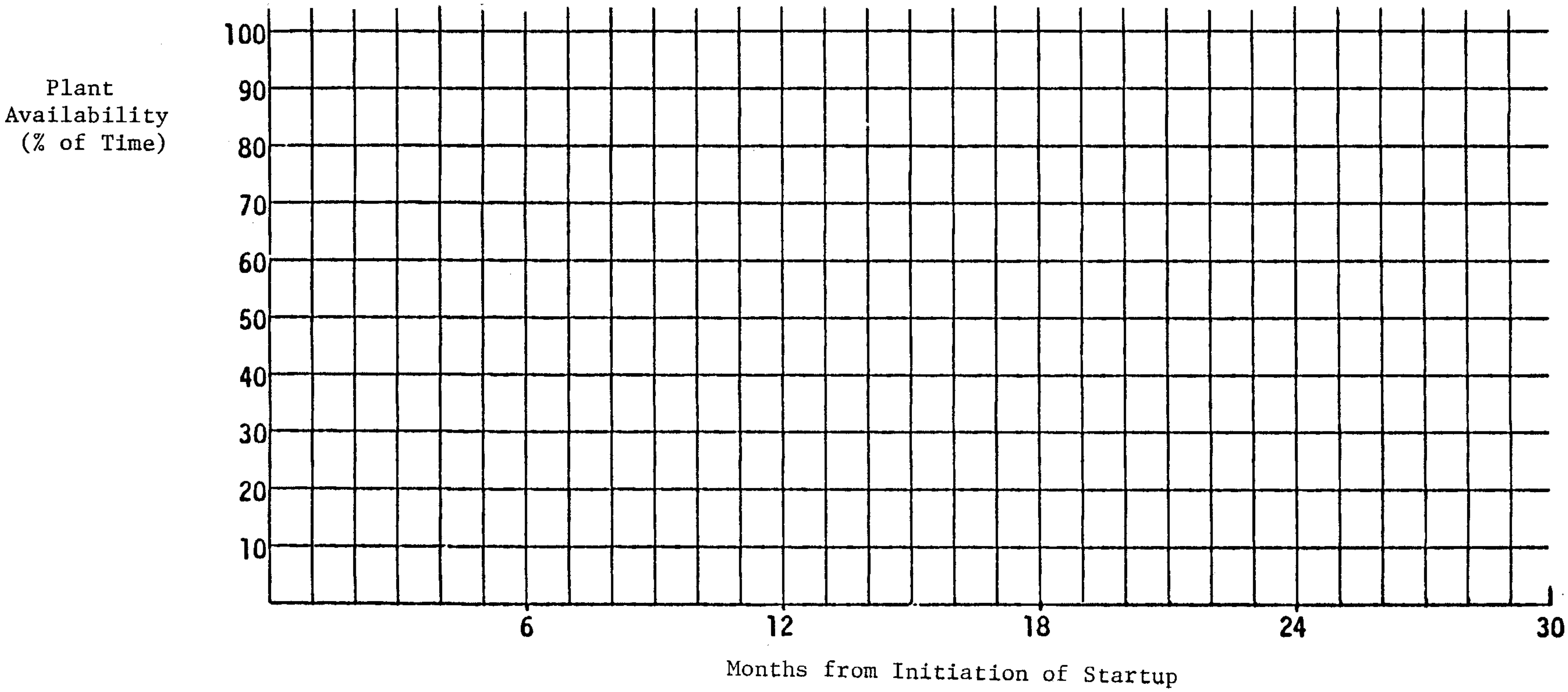
---

[1] For example, if for some period the plant was available for operation 70% of the time, but during that period the plant operated at only 60% of design capacity, then the overall plant production rate would have been 42%.



PLEASE: **Use solid lines (———) for <u>actual</u> production.**
Use broken lines (------) for <u>expected</u> production.

Fig. 3--Plant production over time



PLEASE: Use solid lines (———) for actual availability
Use broken lines (-----) for expected availability

Fig. 4--Plant availability over time

5. Did a **change in market conditions** after startup ever require that plant production be reduced?

YES ___ ANSWER Q.5A-F

NO ___ SKIP TO Q.6 BELOW

A. How much was production cut back because of this factor?

____

B. Briefly explain the circumstances surrounding the market change:

____

____

____

C. When did this cutback begin? DATE: __________ (month/year)

D. How long was production cut back? MONTHS: __________

E. Was the design (nameplate) production rate demonstrated at any time?

YES ___ --> For how long? ______

NO ___

6. To this point in time (even if beyond the 30 months shown), what has been the **maximum monthly production rate achieved** as a percent of design capacity, and in what month did it occur? (List first occurrance if it happened more than once.)

____% of design capacity; ____ months after initiation of startup

7. Please provide the four major contributors to *plant downtime* **during startup**:

	Equipment Type	Nature of Problem	When Occurred	Action Taken	Cost of Action Taken
a.			__/__		
b.			__/__		
c.			__/__		
d.			__/__		

8. Please provide the four major contributors to *plant downtime* **after the completion of startup**:

	Equipment Type	Nature of Problem	When Occurred	Action Taken	Cost of Action Taken
a.			__/__		
b.			__/__		
c.			__/__		
d.			__/__		

III. PROJECT SCHEDULE

1. a. Please complete the project development history matrix on the next page.

   b. Please attach a copy of the Project Master Schedule with major milestones noted.

2. What was the total **planned schedule** from the beginning of engineering through the end of start-up (in months)?

   ______________ months

3. When was this schedule plan developed (e.g., during project definition, or at the beginning of engineering)?

   ____

4. Briefly describe the **basis for the schedule plan** (i.e., how it was developed).

   ____

   ____

   ____

   ____

5. What was the **planned overlap** (or concurrency) between:

   o Project Definition and Detailed Engineering ? __________ months

   o Detailed Engineering and Construction? __________ months

   o Construction and Startup? __________ months

6. What was the total **actual schedule** from the beginning of engineering through the end of start-up (in months)?

   ______________ months

1. Please complete this table on the history of the project development.

Development Tasks	PLANNED Time (months)	PLANNED Manyears (approx.)	Date Started (mo/yr)	Date Completed (mo/yr)	Actual Time (months)	Manyears Expended (approx.)	Company or Division with major responsibility for Task	Type of Contract Used*	Did Any Major Problems Occur** (yes/no)	Were Major Design Changes Required?** (yes/no)
Research and Development	______	______	___/___	___/___	______	______	______	______	______	______
Project Definition	______	______	___/___	___/___	______	______	______	______	______	______
Engineering Design	______	______	___/___	___/___	______	______	______	______	______	______
Construction	______	______	___/___	___/___	______	______	______	______	______	______
Startup	______	______	___/___	___/___	______	______	______	______	______	______
Production			___/___	___/___						

---

*Please use the following codes:
F = firm fixed price (lump sum) contract
FF = firm fixed price with incentive fee
CI = cost plus incentive fee
A = an award contract
TM = time and materials
O = other (please explain)

**Please describe the nature of any major problems that occured or design changes that were required and indicate when they took place.

____

____

____

____

____

7. What *definition of each project phase was used* (i.e., when does it begin and when does it end)?

   a. Project Definition: ____________________

   ____

   b. Engineering: ____________________

   ____

   c. Construction: ____________________

   ____

   d. Startup: ____________________

   ____

8. What were the reasons for schedule delays or slippages (if any)?

   ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

9. Please comment on the general *management strategy* regarding the schedule. For example, to what extent was the project "schedule-driven"--by market competition, anticipated new regulations, etc.? Were any extraordinary measures taken to expedite the project? Was the schedule purposely extended for cash flow, manpower, or other reasons?

10. *Other Comments.* We are interested in any other insights you can offer to help us understand the project's schedule. Please feel free to comment in detail. For example, in what ways was the actual schedule different from what you believe an *optimal* schedule would have been? What could have been improved upon? Was anything *unique* about the schedule for this project, and why? How was the schedule different from a typical one for this size project?

IV. ACTUAL COST OF PROJECT

1. What was the **total capital cost** of the project in "as spent" dollars?

TOTAL COST $ ______________

2. Does that figure include any *startup* costs?

Yes ____

No ____

3. **STARTUP COSTS**

A. What were the **total startup costs** (in "as spent $")?

TOTAL STARTUP COSTS $ _________ (includes capital and expensed costs)

B. What do these startup costs include? ______________________________

____

____

C. *After the completion of start-up,* what were the "typical" operating and feedstock costs *per month*?

- Monthly **operating costs** $ __________ (*excluding* feedstock)
- Monthly **feedstock costs** $ __________
- Other costs (production taxes, royalties, etc.) $ ____________

4. Please allocate the total capital cost of the project (*excluding startup*) by activities.

ACTIVITY	COST (in thousands)
Development	
A. Applied research and development	$ ________
B. Process design through design specification preparation, i.e., project definition	$ ________
C. **TOTAL DEVELOPMENT COST**	$ ________
Design and Construction	
D. Detailed engineering	$ ________
E. Major equipment	$ ________
F. Bulk materials	$ ________
G. Construction labor	$ ________
H. Other costs	$ ________
I. **TOTAL DESIGN AND CONSTRUCTION**	$ ________

5. Did *development costs* reported in Question 4 above *include* any costs for development and testing facilities reported in Q.10, p. 6?

Yes ____ ANSWER Q.5A.

No ____ SKIP TO Q.6.

5A. *If costs were included*: For which facilities?

____

____

6. Please provide a breakdown of the actual design and construction costs which is oriented to the plant's major functional areas, or process steps. Also indicate when the costs were incurred, or the dollar basis of the costs. (Cost elements that are not normally allocated--such as home office costs, indirects, site preparation, etc.--should be identified as separate blocks.)

PROCESS STEP	ACTUAL COST	YEAR SPENT OR DOLLAR BASIS
(1) ________	$ ________	________
(2) ________	$ ________	________
(3) ________	$ ________	________
(4) ________	$ ________	________
(5) ________	$ ________	________
(6) ________	$ ________	________
(7) ________	$ ________	________
(8) ________	$ ________	________
(9) ________	$ ________	________
(10) ________	$ ________	________
(11) ________	$ ________	________
(12) ________	$ ________	________
(13) ________	$ ________	________

8. Please check whether each item *was* or *was not* included in the *actual design and construction capital cost.*

ITEM	INCLUDED IN ACTUAL COST? Yes	No	Does Not Apply
A. Direct materials	___	___	___
B. Direct construction labor	___	___	___
C. Prime contractor's field labor overhead and fee	___	___	___
D. Prime contractor's detailed engineering and fee	___	___	___
E. Specialty subcontracts	___	___	___
F. Materials sales tax and importation costs	___	___	___
G. Project management services	___	___	___
H. Land purchases/leases/property rentals	___	___	___
I. Property or municipal taxes	___	___	___
J. Insurance	___	___	___
K. Research and development costs ..	___	___	___
L. Process design and design specification preparation	___	___	___
M. Initial plant inventory/warehouse parts/spares/catalysts	___	___	___
N. Owner's organization costs	___	___	___
O. Project financing costs	___	___	___
P. Temporary/permanent owner's administration facilities	___	___	___
Q. Pre-operating personnel costs ...	___	___	___
R. Site preparation	___	___	___
S. Government development grants, investment tax credits	___	___	___
T. Start-up costs	___	___	___
U. Instrument calibration, line flushing, etc.	___	___	___

8A. If any items *do not apply:* Please explain briefly below.

ITEM	REASON DOES NOT APPLY
(1) ____________________	______________________________
(2) ____________________	______________________________
(3) ____________________	______________________________

V. INITIAL ESTIMATE OF PROJECT COST

1. Estimates of project costs are often made at several times during the development of the project. How many *separate, major cost estimates* were made for this project?

   Number of estimates ______________

   This section asks about the first major estimate made for the project. Section XII asks about subsequent estimates.

Please answer these questions **as of the time the estimate was prepared.**

2. Date of this estimate: ___/___ mo yr

3. Total capital cost estimate: $ _________

4. What is the *dollar basis* for this estimate?

   Build Today/Operate Today (no escalation) _________ SKIP TO Q.5.

   Estimate includes escalation _________ ANSWER Q.4A-4F.

   4A. IF ESTIMATE *INCLUDES* ESCALATION: What annual escalation rate is assumed?

   _________%

   4B. What is the *dollar amount* of the escalation included in the estimate?

   $ _______

   4C. Through what *date* is escalation projected?

   _____/____ mo yr

   4D. Through what *execution phase* is escalation projected?

   PLANNED END OF CONSTRUCTION _____

   PLANNED MIDPOINT OF CONSTRUCTION _____

   OTHER PROJECT PHASE _____

   Explain: ____

4E. What *method* of including escalation was used?

ASSUMED EXPENDITURE CURVE ______

LINEAR EXTRAPOLATION ______

4F. Briefly explain how you applied the method you used.

____

____

____

5. Planned end of construction date: ___/___
mo yr

6. Plant design output capacity: __________ (mm lbs/yr)

7. Please provide a *breakdown* of the total capital cost estimate by activity:

	Estimated Cost ($)
Design and Construction	
Engineering	__________________
Major equipment	__________________
Bulk materials	__________________
Construction labor	__________________
Other construction-related costs	__________________
Contingency	__________________
Escalation	__________________
Total Design and Construction	__________________
Startup	__________________
Total Design, Construction, & Startup	__________________

8. Please provide a breakdown of the estimated design and construction costs which is oriented to the plant's major functional areas, or process steps. Costs which are not normally allocated (e.g., contingency, escalation, home office, site preparation) should be identified separately.

	PROCESS STEP	ESTIMATED COST
(1)	____________________	$ ________________
(2)	____________________	$ ________________
(3)	____________________	$ ________________
(4)	____________________	$ ________________
(5)	____________________	$ ________________
(6)	____________________	$ ________________
(7)	____________________	$ ________________
(8)	____________________	$ ________________
(9)	____________________	$ ________________
(10)	____________________	$ ________________
(11)	____________________	$ ________________
(12)	____________________	$ ________________
(13)	____________________	$ ________________

9. Please check whether each item *was* or *was not* included in the estimate.

ITEM	INCLUDED IN ESTIMATE Yes	No	Does Not Apply
A. Direct materials	___	___	___
B. Direct construction labor	___	___	___
C. Prime contractor's field labor overhead and fee	___	___	___
D. Prime contractor's detailed engineering and fee	___	___	___
E. Specialty subcontracts	___	___	___
F. Materials sales tax and importation costs	___	___	___
G. Project management services	___	___	___
H. Land purchases/leases/property rentals	___	___	___
I. Property or municipal taxes	___	___	___
J. Insurance	___	___	___
K. Research and development costs	___	___	___
L. Process design and design specification preparation	___	___	___
M. Initial plant inventory/warehouse parts/spares/catalysts	___	___	___
N. Owner's organization costs	___	___	___
O. Project financing costs	___	___	___
P. Temporary/permanent owner's administration facilities	___	___	___
Q. Pre-operating personnel costs	___	___	___
R. Site preparation	___	___	___
S. Government development grants, investment tax credits	___	___	___
T. Start-up costs	___	___	___
U. Instrument calibration, line flushing, etc.	___	___	___

9A. IF ANY ITEMS IN Q.9 DID NOT APPLY: Please explain briefly below.

ITEM	REASON DID NOT APPLY
___	___
___	___
___	___

10. Were there any major changes in process steps which occurred between this estimate and the completion of startup (e.g., because of the addition or deletion of one or more steps)?

Yes ___ ANSWER Q.10A.

No ___ SKIP TO NEXT SECTION.

11A. What were the changes? ______________________________

____

____

____

____

VI. SECOND AND SUBSEQUENT ESTIMATES OF PROJECT COSTS

This section asks about estimates made subsequent to the initial estimate. It should be duplicated and completed for each major estimate.

1. ____________________ cost estimate
   (second, third, etc.)

Please answer these questions **as of the time the estimate was prepared.**

2. Date of this estimate: ___/___
   mo yr

3. Total capital cost estimate: $ ________

4. What is the *dollar basis* for this estimate?

Build Today/Operate Today _________ SKIP TO Q.5.
(no escalation)

Estimate includes escalation _________ ANSWER Q.4A-4F.

4A. IF ESTIMATE *INCLUDES* ESCALATION: What annual escalation rate is assumed?

_________%

4B. What is the *dollar amount* of the escalation included in the estimate?

$ ________

4C. Through what *date* is escalation projected?

_____/____
mo yr

4D. Through what *execution phase* is escalation projected?

PLANNED END OF CONSTRUCTION _____

PLANNED MIDPOINT OF CONSTRUCTION _____

OTHER PROJECT PHASE _____

Explain: ____

4E. What *method* of including escalation was used?

ASSUMED EXPENDITURE CURVE _____

LINEAR EXTRAPOLATION _____

4F. *Briefly* explain how you applied the method you used.

____

____

____

5. Planned end of construction date: ___/___ (mo yr)

6. Plant design output capacity: _________ (mm lbs/yr)

7. Please provide a *breakdown* of the total capital cost estimate by activity:

	Estimated Cost ($)
Design and Construction	
Engineering	______________
Major equipment	______________
Bulk materials	______________
Construction labor	______________
Other construction-related costs	______________
Contingency	______________
Escalation	______________
Total Design and Construction	______________
Startup	______________
Total Design, Construction, & Startup	______________

8. Please provide a breakdown of the estimated design and construction costs which is oriented to the plant's major functional areas, or process steps. Costs which are not normally allocated (e.g., contingency, escalation, home office, site preparation) should be identified separately.

PROCESS STEP	ESTIMATED COST
(1) ________________	$ ______________
(2) ________________	$ ______________
(3) ________________	$ ______________
(4) ________________	$ ______________
(5) ________________	$ ______________
(6) ________________	$ ______________
(7) ________________	$ ______________
(8) ________________	$ ______________
(9) ________________	$ ______________
(10) ________________	$ ______________
(11) ________________	$ ______________
(12) ________________	$ ______________
(13) ________________	$ ______________

9. Please check whether each item *was* or *was not* included in the estimate.

	INCLUDED IN ESTIMATE?		
ITEM	Yes	No	Does Not Apply
A. Direct materials	___	___	___
B. Direct construction labor	___	___	___
C. Prime contractor's field labor overhead and fee	___	___	___
D. Prime contractor's detailed engineering and fee	___	___	___
E. Specialty subcontracts	___	___	___
F. Materials sales tax and importation costs	___	___	___
G. Project management services	___	___	___
H. Land purchases/leases/property rentals	___	___	___
I. Property or municipal taxes	___	___	___
J. Insurance	___	___	___
K. Research and development costs ..	___	___	___
L. Process design and design specification preparation	___	___	___
M. Initial plant inventory/warehouse parts/spares/catalysts	___	___	___
N. Owner's organization costs	___	___	___
O. Project financing costs	___	___	___
P. Temporary/permanent owner's administration facilities	___	___	___
Q. Pre-operating personnel costs ...	___	___	___
R. Site preparation	___	___	___
S. Government development grants, investment tax credits	___	___	___
T. Start-up costs	___	___	___
U. Instrument calibration, line flushing, etc.	___	___	___

9A. IF ANY ITEMS IN Q.9 DID NOT APPLY: Please explain briefly below.

ITEM	REASON DID NOT APPLY
______________________	________________________________
______________________	________________________________
______________________	________________________________

10. Changes in external conditions can change cost estimates during the project. For each area listed below, indicate whether or not a change had any effect on the project cost or schedule since the previous estimate was made.

EXTERNAL CONDITION	WAS THERE CHANGE THAT AFFECTED COST OR SCHEDULE?		CHANGE IN COST (+/-) (in dollars)	CHANGE IN SCHEDULE (+/-) (in months)	DATE OCCURRED (mo/yr)	DESCRIBE EVENT	HOW WAS EFFECT CALCULATED?
Environmental Regulation							
Air	NO___	YES___	$________	________	___/___	________________	________________
Water	NO___	YES___	$________	________	___/___	________________	________________
Waste	NO___	YES___	$________	________	___/___	________________	________________
Safety Standards							
Worker safety	NO___	YES___	$________	________	___/___	________________	________________
Product safety	NO___	YES___	$________	________	___/___	________________	________________
Equipment & Materials							
Price changes	NO___	YES___	$________	________	___/___	________________	________________
Shortages	NO___	YES___	$________	________	___/___	________________	________________
Labor							
Wage changes	NO___	YES___	$________	________	___/___	________________	________________
Shortages--Engineering staff	NO___	YES___	$________	________	___/___	________________	________________
Shortages--Skilled craft	NO___	YES___	$________	________	___/___	________________	________________
Shortages--General Construction	NO___	YES___	$________	________	___/___	________________	________________
Strikes	NO___	YES___	$________	________	___/___	________________	________________
Severe productivity problem	NO___	YES___	$________	________	___/___	________________	________________
Other factors							
Unusually inclement weather	NO___	YES___	$________	________	___/___	________________	________________
Other (Specify)							
____________	NO___	YES___	$________	________	___/___	________________	________________
____________	NO___	YES___	$________	________	___/___	________________	________________

11. Were there any changes in external conditions listed on the previous page which affected the plant's *performance* (e.g., new waste regulations)?

Yes ____ ANSWER Q11A.

No ____ SKIP TO Q12.

11A. Please describe the changes and their effect on plant performance.

____

____

____

12. Were there any major changes in process steps which occurred between the previous estimate and this one (e.g., because of the addition or deletion of one or more steps)?

Yes ___ ANSWER Q.12A.

No ___ SKIP TO NEXT ESTIMATE.

12A. What were the changes? ________________________

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