DOE/RA/50553-1233
Distribution Category UC-90c

DOE/RA/50553--1233

DE82 020556

EAST TEXAS

FEASIBILITY STUDY

FINAL REPORT

VOLUME 1

March 30, 1982

EAST TEXAS PROJECT

FINAL REPORT

(VOLUME I)

		PAGE
	EXECUTIVE SUMMARY	v
I.	INTRODUCTION	1
II.	OBJECTIVE	2
III.	CONCLUSIONS	3
IV.	RECOMMENDATIONS	5
V.	PROJECT BACKGROUND	7
VI.	PROGRAM DESIGN	12
VII.	PHASE I SYSTEM SCREENING	18
VIII.	PHASE II SYSTEM SELECTION	39
IX.	PHASE III BASE CASE DESIGN	55
X.	PHASE IV ECONOMIC EVALUATION	66
XI.	COMMERCIAL VIABILITY	71
XII.	REGULATORY COMPLIANCE SCHEDULE	72
XIII.	FIGURES	79
XIV.	TABLES	86

(VOLUME II)

APPENDIX

INDEX OF FIGURES

(VOLUME I)

FIGURE	TITLE	PAGE
1	PHASE IDENTIFICATION AND SCHEDULE	79
2	EAST TEXAS PROJECT SCHEDULE	80
3	PHASE I SYSTEM COMBINATION	81
4	SAARBERG-OTTO GASIFIER	82
5	PROCESS BLOCK DIAGRAM: SAARBERG-OTTO GASIFICATION	83
6	REGULATORY COMPLIANCE PLANNING SCHEDULE-BASELINE CASE	84
7	REGULATORY COMPLIANCE PLANNING SCHEDULE-PESSIMISTIC CASE	85

INDEX OF TABLES

(VOLUME I)

TABLE	TITLE	PAGE
A	PIPELINE COST ESTIMATES	86
B	PHASE I CAPITAL ESTIMATE--SOURCES & METHODS	87
C	PHASE I PROCESS/FEEDSTOCK RANKING	88
D	PHASE I PARAMETER RANKING	89
E	PHASE II RANKING	90
F	PHASE II CAPITAL COST SOURCES	91
G	PHASE II CAPITAL COST ESTIMATES	92
H	PHASE II SUBJECTIVE RANKING	93
I	PHASE II PROCESS DATA SAARBERG-OTTO PROCESS/LIGNITE	94
J	PHASE III CAPITAL ESTIMATE SUMMARY SAARBERG-OTTO (BASE CASE)	95
K	PHASE III OPERATING & MAINTENANCE COST SUMMARY SAARBERG-OTTO (BASE CASE)	96
L	PHASE IV ECONOMIC ANALYSIS INPUT DATA	97
M	PHASE IV SUMMARY OF ECONOMIC ANALYSIS	98
N	STATUS OF 2ND GENERATION GASIFICATION PROCESSES	99

APPENDICES

(VOLUME II)

APPENDIX	DESCRIPTION
I	LOGIC NETWORKS, ACTIVITIES, COSTS & SCHEDULES
II	WORK PLAN/SCHEDULE - RUST
III	WORK PLAN/SCHEDULE - COAL PROGRAM GROUP
IV	PROJECT FILE INDEX
V	DESIGN CRITERIA
VI	PHASE I PRELIMINARY PROCESS SCREENING STUDY
VII	PHASE I SITE SELECTION (BY COUNTY) METHODOLOGY
VIII	SUMMARY - PHASE I SITE SELECTION DATA
IX	PHASE II SITE SELECTION METHODOLOGY
X	PROCESS FLOW DIAGRAMS/MATERIAL & HEAT BALANCES
XI	SUBJECTIVE RANKING METHODOLOGY
XII	ECONOMIC ANALYSIS - ASSUMPTIONS
XIII	ECONOMIC ANALYSIS - INPUT DATA
XIV	COMMERCIAL STATUS - COAL GASIFICATION TECHNOLOGY

EXECUTIVE SUMMARY

The objective of the study was to develop a detailed, technical and financial analysis for conversion/expansion of the Clear Lake methanol plant from natural gas feed to coal (lignite) derived syngas as a basis for management decisions on future strategies.

In July, 1980 the management committee approved RFA 040-033 to perform the feasibility study. This effort was to be completed in 18 months.

Rust Engineering in Birmingham was selected as the engineering contractor. The scope of work was to include a plus or minus 30% capital estimate of the project, a study of technical feasibility and environment acceptability, flow diagrams, economic analyses, system specifications, layout, conceptual system drawings, and a project schedule showing both engineering and construction.

In order to assure the most efficient utilization of manpower, the first effort at the engineering house was to develop a complete work plan. The work plan was developed in four phases.

There were 48 systems studied during the Phase I effort. As a result of this exercise, six systems were selected for further refinement and analysis. In the Phase II effort these six systems were further studied to select one system or base case for a final effort. Phase III involved completing the technical and cost data on the selected process and Phase IV involved performing a complete economic evaluation on the study.

Unfortunately, the effort at Rust was terminated on October 31, 1981 at the end of Phase II, and the Phase III and IV efforts were completed in an abbreviated time frame by the limited personnel available on the coal program team in Dallas.

The base case, refined in Phase III, was the Saarberg-Otto process, located in Robertson County, utilizing Texas lignite.

The Saarberg-Otto process uses a pressurized, entrained bed, slag bath type gasifier, operating at 600 psig. Pulverized Texas lignite is fed to the gasifier and boiler requiring approximately 4MM tons/year of 6,700 Btu/lb lignite. The gasification complex would be on a 2500 acre site in Robertson County in East Texas. The site would be within 5 miles of the proposed mine. Syngas would be transported to Clear Lake via a 20-inch pipeline that is approximately 160 miles long. Facilities would be installed at Clear Lake to process the syngas into the necessary ratios of hydrogen and CO to feed the methanol synthesis and acetic acid units. The study was done at existing plant capacities. The capital cost for the base case was estimated to be million in mid-1981 $. These costs were reviewed and developed in conjunction with the Celanese

Estimating Department. Annual operating costs were approximately : million in mid-1981 dollars. These costs are based on coal program team cost estimates. Utlizing these capital and operating costs, economic analyses were performed in Phase IV.

The conclusions from the feasibility study are:

- o The gasification of coal and lignite and utilization of the syngas as a raw material for methanol is technically and environmentally feasible.
- o A program of this nature is economically unattractive in the time frame studied, as the DCF for the base case was % based on current Celanese economic evaluation standards and February, 1981 gas forecast.
- o It is felt that these economics are dependent on world and U.S. politics. Specifically, world politics is probably the most worrisome matter. The mid-East politics appear to be in a very delicately balanced position and with the slightest nudge could tremendously impact the cost of natural gas in the future.

The following recommendations are made as the results of the East Texas Feasibility study:

- o The active Celanese coal gasification project should be put on hold for the present.
- o Management's attention should be directed to developments in the gasification area in order to monitor

projects which may be instituted by utilities and/or major energy companies.

- A good data base is available for any future analyses and should be kept up-to-date as changes occur.

I. INTRODUCTION

This report presents the results of the East Texas feasibility study on utilizing coal or lignite based synthesis gas for the production of methanol in the Clear Lake plant. This study was conducted by the Coal Program team as a result of economic studies performed in conjunction with the 1981 Strategic Plan preparation. An RFA was approved on July 28, 1980. The study was primarily performed by Rust Engineering; however (through management direction) the project was terminated at Rust prior to completion. Final efforts were completed by the Coal Program team in the Dallas office. As a result of the termination, neither the technical effort nor the economic evaluation were refined as well as originally conceived. It is felt, however, that the design and cost elements presented here are adequate for the future evaluation of coal gasification opportunities.

This report will address the results obtained during the various phases of the study in summary form. Those interested in further details are referred to the East Texas Project files where all the detail data is stored.

II. OBJECTIVE

The objective of the East Texas Project was twofold. The primary objective was to determine the technical and economic feasibility of converting the methanol unit at Clear Lake to utilize syngas produced from coal instead of natural gas. The secondary objective was to develop a data base within Celanese for the evaluation of future strategies concerning the utilization of coal-based syngas for raw materials or as an energy source in existing or new plants.

III. CONCLUSIONS

Several conclusions resulted from the feasibility study. The first conclusion to be reached is that the use of coal based syngas as a raw material for methanol is technically and environmentally feasible. Several commercial operations have existed for years in South Africa, Great Britain, and Germany which produce a syngas suitable for methanol synthesis, and within a very few years a variety of new technologies will be available and demonstrated.

The second conclusion is that the newer (second generation) processes provide significant economic advantages over the older (first generation) processes for methanol production. (For example, the Lurgi systems ranked 39th to 48th in the ranking of 48 systems.)

Another conclusion is that Texas lignite and a mine-sited gasification system (within the areas studied) provide significant economic advantages over sub-bituminous coal transported to a coastal site. The newer processes can overcome the deficiencies of lower quality feeds more efficiently.

It can be further concluded that under current Celanese economic restraints and projected economic and political conditions, a coal gasification facility to retrofit the Clear Lake plant is not economically attractive in the time frame studied. Although not economically attractive under the currently forecasted and defined conditions, there are ways to enhance the attractiveness of the project. These methods were not thoroughly investigated during the study.

IV. RECOMMENDATIONS

As a result of the East Texas Feasibility Study the following recommendations are presented:

- The Celanese-sponsored coal gasification project should be put on hold for the present. As new and innovative financing options are developed; as potentially viable partners are identified; and more specifically, as the political and economic situations change over the next few years, it is probable that this project may be justified and reinstituted.
- Management attention to developments in the gasification area should be maintained in order to monitor projects which may be instituted by utilities and/or major energy companies. This recommendation is extremely important, as a side-stream syngas product off of a major installation could very economically be converted into methanol. This low cost methanol could bring new competition into the traditional methanol markets. This methanol could be produced at a significantly lower total cost than even Celanese variable cost.
- The existing records should be maintained. Although the time is not right for actively pursuing a gasification project in Celanese, it is almost a certainty that within a relatively short period of time there will be a major interest in utilizing coal-based syngas as a raw material. For this reason, it is recommended that the

data accumulated during this study be retained in a usable form and that someone be appointed to maintain and update the data for future studies, as required.

V. PROJECT BACKGROUND

MARCH, 1979 JOINT STUDY

In late 1978 and early 1979 Celanese participated in a joint study with several other interested parties. The study was conducted at the Radian Corporation, Austin, Texas and participants besides Celanese were: The Aluminum Company of America, E.I. Dupont DeNemours and Company, Houston Lighting & Power Company, Panhandle Eastern Pipeline Company, Sonoco Energy Development Company, and the Texas Eastern Transmission Corporation. This study had two objectives: 1) to assess the feasibility of converting lignite or coal to medium Btu gas for use as a fuel or feedstock in existing Texas Gulf Coast plants; 2) to determine the realistic cost of this gas to the consumer.

A key study feature was the use of the expertise of the sponsor companies in assembling the best possible information. This expertise was used in developing costs for mining, transportation, gasification, and product gas distribution, and in analyzing this cost data on a commercial basis. Input data was developed by teams of engineers and scientists from the sponsoring companies and Radian. Three different gasification processes at two different plant sites utilizing two different feedstocks were evaluated. Economic analysis included both utility financing methods and standard 100% equity discounted cash flow methods.

The conclusion reached in that study was that there were no apparent technological, environmental, or regulatory barriers which prevented the construction of a gasification plant in Texas. For the gasification systems evaluated, medium Btu gas costs exhibit little dependence on the type of processing technology. It was also determined that the use of Texas lignite was more economically attractive than the use of a non-Texas coal.

1980 METHANOL STRATEGY

During the development of the 1980 Methanol Strategy it became evident that the long-term availability of natural gas as an economical raw material for methanol was still a key issue. Long-range economic evaluations by the Planning Department, utilizing data from the March, 1979 joint study, confirmed that at some future date coal could become the preferred source of syngas for methanol manufacture.

Economics performed at that time concluded that in the 1989 time frame a coal-based expansion and an expansion in Canada to support projected sales would yield comparable economic returns.

As a result of this analysis, Celanese Chemical Company strategy recommended that a feasibility study to retrofit and expand the Clear Lake methanol facility to utilize coal-based syngas be completed by mid-1982.

About the same time the United States Department of Energy (DOE) began soliciting for proposals to participate in feasibility studies for the production of "alternate fuels." The emergence of methanol as an alternate motor fuel then became another element. The substitution of methanol for gasoline, even a small percentage, would drastically expand the methanol market. Although the new fuel market was recognized as a potential, planning analyzed only the projected growth in our traditional markets.

DOE PROPOSAL - APRIL 1980

A task force was formed in February, 1980 to prepare a proposal to the DOE. In order to meet the required proposal date, it was necessary to employ the services of Bechtel, Incorporated to assist. The proposal presented a plan to study the feasibility of utilizing Texas lignite to produce a syngas suitable for methanol synthesis to retrofit and expand the methanol unit at the Clear Lake plant.

During the preparation of this proposal a work plan was developed which was designed to develop sufficient knowledge of the state of the art on coal gasification to allow selection of the most economical gasification process, feedstock, and site for such a facility.

The proposal was presented to the DOE in April, 1980 to register Celanese as a potential participant in the synfuels industry. No funds were requested with this proposal as it was felt that the temporary loan of funds would involve governmental controls which would seriously hamper our efforts.

As a result of the effort involved in preparing this proposal, an RFA was prepared for approval of funds to employ an outside engineering firm to perform the feasibility study.

RFA 040-033

RFA 040-033 was presented to company management and approved by the management committee on July 28, 1980 for million expense. The RFA objective was: "Develop a detailed technical and financial analysis for conversion and expansion of the Clear Lake methanol plant from natural gas feed to coal (lignite) derived syngas feed as a basis for management decisions on future strategies".

To implement the RFA (along with a companion RFA for a similar study for the Bishop plant), company management decided to establish a Coal Program group. During the mobilization of this group it became apparent that only limited manpower could be made available to staff the study projects. A "Core Group" was established to support the resource development, technical, operations, and financial areas.

After extensive analysis of the capabilities and costs of various engineering houses, Rust Engineering in Birmingham, Alabama was selected as the prime contractor for the basic feasibility study.

One Celanese project engineer was available to direct the activities in Birmingham. This was not adequate staffing to provide control over this complex study; therefore a management contractor was employed. Extensive effort was devoted to locating a firm with qualified personnel to support our efforts. Voss International of Houston, Texas was selected as the project management contractor.

Voss supplied a project manager and two engineers to complete the Celanese team. This arrangement (a first in the Celanese Chemical Company) was very successful and instrumental in the quality of the data developed.

VI. PROGRAM DESIGN

MAJOR EFFORT BREAKDOWN AND SCHEDULE

Rust Engineering developed a work plan and logic network to eliminate wasted effort and provide a "road map" for direction of the study. The East Texas Project was divided into four phases which would be completed in eighteen months or less. See Figure 1.

The system (feedstock, gasification process, site) to be used in the final detailed study and economic evaluation was to be determined as part of the following overall selection procedures:

<u>Phase I:</u> Prominent gasification technologies were to be identified, studied, and screened according to their commercial status. The most promising of these technologies were to be selected for further evaluation. Three feedstocks were to be identified by Celanese. An economic analysis of the capital and operating costs would be made to rank the various systems and four systems selected for further evaluation.

<u>Phase II:</u> A more detailed technical and economic evaluation of the four systems selected in Phase I were to be made, in order to rank the systems, and the "best" system was to be selected for further study.

Phase III: The system selected in Phase II would be analyzed in depth. Sufficient detail design was to be done to produce a $\pm30\%$ capital cost estimate. Operating costs were to be refined.

Phase IV: Economic studies were to be made to analyze the financial sensitivities of the selected systems. The results obtained in these studies were to be presented in a Final Report.

Through management direction early in September, 1981 the feasibility study activities performed and directed by Rust Engineering were terminated effective October 31, 1981.

- o Phase I activities had been completed and Phase II activities were under way.

- o A revised Work Plan and Schedule were developed by Rust to orderly shutdown the study and to provide the maximum, meaningful data through Phase II activities.

- o Revised Bar Chart, Logic Diagrams and Activity Manhour Estimates were prepared by Rust. Examples are included in Appendix II.

Due to the short time frame remaining, the decision was made to use the same selection method outlined for Phase II in the original Work Plan but to reduce the level of detail.

Additional data could not be obtained from the process licensors. Thus, capital costs were not always supported by equipment lists, layouts and P & I diagrams. Vendor and process-licensor quotations were used, and no special effort made to confirm these costs. The subjective ranking was not based on visits to the process licensors and their pilot plants. A joint Celanese-Rust task force subjectively ranked the four systems, based on the process knowledge possessed by the individuals on the task force.

The Coal Project group in the Dallas office completed the remaining activities.

- The Phase III and IV activities in the Work Plan were revised by the Celanese Coal Program group.
- The remaining activities were divided into tasks. Areas of responsibility were defined and a work schedule prepared.
- The tasks consisted of: select a base case; review and refine the process design; develop alternatives; prepare cost estimates; provide economic analysis; and issue a final project report. A brief description of each task is included in Appendix III.

WORK PLAN AND SCHEDULES

The work plan for performing the feasibility study at Rust Engineering was developed to accomplish the project objective. It was developed as follows:

- o An overall time frame was established for the major divisions of work. See the attached bar chart schedule (Figure 2).
- o Detailed activities to be performed were determined and used to establish the interaction sequence of these activities. See logic networks included in Appendix I.
- o Specific objectives, tasks and results associated with the individual work activities were defined and the activity descriptions produced.
- o Typical details included in each writeup are included in Activity No. 120. See Appendix I.
- o A detailed effort analysis was made for each activity. Activity manhour estimates were compiled for each phase by engineering discipline and summarized by phase and division. Examples are included in Appendix I.
- o Based on the effort analysis, the detailed activity schedule was refined for optimum manpower utilization, and the logic network was time-scaled.
- o Cost estimates for both manpower and expenses were estimated, and a detailed budget was established. Forecast schedules for project costs and manhour utilization were developed. The schedules were updated monthly. See forecast schedules in Appendix I.

p

- o A procedure was established to cover changes in the work plan. A "Work Plan Variation Notice" (WPVN) had to be prepared by Rust for Celanese approval. The WPVN included the type of variance (add, delete or change activity, logic, schedule or other changes) and ultimately their impact on project schedule and cost.
- o A glossary was provided to define the terms utilized in the Work Plan.

PROJECT ADMINISTRATION & CONTROL

The Celanese Project team in house at Rust Engineering provided daily guidance, liaison and control.

A project instruction manual was prepared to assure proper administration and control. The major items of the manual were:

- o Formal requirements for reporting and distribution of project documents
- o Organizational charts to define areas of responsibility.
- o Drafting standards for uniformity in drawings.
- o Equipment and drawing number systems for continuity and control.
- o Time coding system for tracking manhours for control and comparison to original defined budgets.
- o Change order system for documenting changes and their impact on project costs and schedule.
- o Project file system providing a permanent and adequate data base for future reference.

The file index is included in Appendix IV of this report for general information and reference.

DESIGN CRITERIA

The design criteria was a document developed to provide guidance and background data to insure continuity and to permit all phases of engineering to proceed at the same time. The design guidelines were reviewed to be consistent with current Celanese philosophy, engineering standards and practices.

The document provided all disciplines with the same base point for design of the facility. The document included such data as: product volume required, product quality, stream factors, feed characteristics, utility requirements, environmental control, etc. The design criteria is included in Appendix V.

VII. PHASE I SYSTEM SCREENING

INTRODUCTION

The objective of Phase I was to select four systems to produce synthesis gas for detailed study in Phase II. A system was defined as the entire complex, including the feed (coal or lignite); site of plant; gasification process; gas cleanup and tailoring processes; transportation of the gas; and retrofit and conversion at the Clear Lake plant.

The screening method employed was based on an economic comparison of the operating and capital costs for each system.

Eight gasification technologies were selected in the preliminary screening effort. Delays in vendor response eliminated two from consideration in Phase I. The data on these processes was developed later and is on file.

Three typical feedstocks were identified and cost estimates developed by the Resource Manager and Morrison-Knudsen.

Two different scenarios were developed for site selection: a mine site for Texas lignite feed and a coastal site near Clear Lake for either lignite or coal feed. Twelve potential counties were reviewed and four selected. Specific sites within a county were developed in Phase II.

Process and utility designs were possible after the process and feedstocks were identified. Capital and operating costs were estimated for each design.

By design, all gasification schemes produced the same quality syngas; therefore, Clear Lake retrofit costs were equal for all systems and were deleted for evaluation impact in Phase I screening.

Ford, Bacon and Davis developed pipeline designs, routings, and capital and operating costs. Their effort was from the geographical center of a county on a straight line to the Clear Lake plant. Detailed investigation from specific sites was developed in Phase II.

Phase I effort evaluated six processes with three different feedstocks located in four counties, resulting in forty-eight (48) systems. Figure 3 demonstrates the combinations.

PRELIMINARY SCREENING

Rust Engineering reviewed more than one hundred gasification processes identified in a study prepared for Celanese by the Radian Corporation. A workable number of viable processes were selected for inclusion in the East Texas feasibility study. The criteria used in selecting the processes were as follows:

1) The existence of a commercial facility of more than 400 tons/day coal feed per gasifier, or

2) Plans for a commercial facility capable of offering commercial design guarantees by 1985 and presently meeting the following requirements:

   A. An existing pilot plant with up to 10 tons/days of coal feed that has successfully operated to produce syngas, and

   B. Plans for a prototype facility with 250 tons/day of coal feed to be operational by 1985.

Using the criteria defined above, the following gasification processes were selected for further study:

- o Shell Koppers
- o Lurgi, conventional
- o Koppers-Totzek (GKT)
- o Texaco
- o High Temperature Winkler (HTW)
- o U-Gas (Institute of Gas Technology, IGT)
- o Slagging Lurgi (British Gas Corporation)

After initial review, the Westinghouse process and the Saarberg-Otto process were added for further consideration. The Shell-Koppers process was deleted, since Shell is not pursuing a path of licensing their technology. A summary of the preliminary screening is included in Appendix VI.

RESOURCE

As a result of the resource studies by Morrison-Knudsen, three feedstocks were identified: Texas lignite, a New Mexico coal and an Illinois coal. Typical analyses and delivered costs were provided for each feedstock.

Feedstock analyses were used in the process and utility design to ultimately determine the tonnage requirement. This tonnage in conjunction with delivered cost provided the annual feed cost input for system selection.

SITE SELECTION

According to Phase I logic diagram and work plan, only counties with potential for siting a gasification complex were investigated. A specific site within a county was selected in Phase II.

Environmental and socio-economic restraints made it apparent that a gasification complex could not be located at the Clear Lake plant site. A 75-mile radius was chosen to provide the easiest access to water delivery and a minimum distance for syngas pipeline delivery. A coastal location would allow coal/lignite to be delivered by barge in addition to rail.

The second possibility was to construct a gasification complex at a minesite and transport syngas to Clear Lake via a longer pipeline. Counties were identified in two general areas in Texas: "coastal counties" in the vicinity of Clear Lake and "lignite counties" with lignite resources. The objective was to select one coastal and two lignite counties for evaluation.

Five coastal counties are environmentally acceptable for siting either a coal or a lignite gasification complex. Seven counties in the east-central region of Texas were identified based on identified sources of lignite for a mine-sited lignite gasification complex.

The screening method was based on an environmental fatal flaw analysis, an economic analysis, and a set of potential penalties to be applied in the event economic analysis did not permit distinction between counties. The coastal and lignite counties were evaluated separately to assure that both cases were included in the final analysis.

Preliminary environmental site screening studies were performed by Radian Corporation. No environmental fatal flaw constraints were identified in the counties selected for study.

Economic evaluations were based on the net present values of selected capital and operating costs occurring over the project life. Counties with the lowest net present values are preferred for siting the gasification complex.

The net present values used in this report were generated by a Rust-developed computer program. This program combined initial costs and weighted future costs, computed depreciation and investment tax credits, discounted all cash flows to a "zero point" and calculated the net present value of all of the cash flows associated with each alternative.

In the coastal counties the capital cost for the syngas pipeline plus the operating costs for purchased water and the pipeline were used for the economic ranking. This ranking demonstrated Brazoria to be the most favorably ranked county, and that county was recommended for further study and identification of potential plant sites. Fort Bend County w[illegible]ed second and, having less severe environment[illegible]en Brazoria County, was also recommended for [illegible]n Phase II.

In the lignite counties the capital cost for the syngas pipeline and the water supply system plus the operating costs for purchased feedstock, water, and operating the pipeline were used in the economic ranking. The economic analysis of the lignite counties demonstrated the superiority of Robertson and Shelby Counties. These counties were recommended for further study and location of potential plant sites in Phase II.

Since selection of counties by economic analysis was successful, the potential environmental and socio-economic penalties were not applied.

The methodology used and a summary of the Phase I site selection results can be found in Appendices VII and VIII.

PIPELINE

Ford, Bacon and Davis (FB&D) was retained to provide preliminary route selections and order of magnitude estimates for proposed pipelines from twelve potential fossil-fuel gasification sites in Texas to the Clear Lake plant.

Preliminary route selections for comparative cost purposes were originated from the approximately geographical center of the counties under review. Individual routes were laid out on a straight line from the county centers to selected convergence points in the Houston metroplex and around the prime real estate areas.

Two convergence points were selected during the investigation: one for the northern, and one for the southwestern counties. The northern route would cross the Houston ship channel. Both routes would come to the same point and follow a common route into the Clear Lake plant.

Consideration was given to bypass topographical, historic or man-made obstacles. Costs were included for railroad, road and major river crossings.

No permitting requirement impacts were assessed.

The pipeline basic design parameters were:

- 200MM SCFD flow of syngas.
- Delivery pressure of 800 psig at Clear Lake.

Order of magnitude estimates were developed from historical data for material and construction costs, right-of-way, and operating costs.

Pipeline capital operating cost estimates are shown in Table A, the total capital costs varied from . . . for a thirty-six mile, 24-inch pipeline from Brazoria County to ..... for a two hundred thirty-eight mile, 34-inch pipeline from Wood County.

Costs were influenced by cost of right-of-way, major river crossings, size of pipe, terrain characteristics, and other construction considerations. Costs were included for communication and remote control system for the pipeline.

FB&D's overall evaluation was that based on current cumulative knowledge of the project, no serious obstacle could be seen which would excessively hinder or prohibit the successful completion of the proposed pipeline and the related facilities.

The syngas pipeline capital and operating costs developed were used in the system selection procedures.

CLEAR LAKE RETROFIT

Phase I gasification plant design was based on a process design which would produce approximately the same composition gas for all cases. This created an identical cost basis for the Clear Lake plant (CLP) retrofit. This being the case, a decision was made to omit any CLP retrofit costs from the Phase I system selection study.

PROCESS DESIGN

The process design began when acceptable gasification processes and feedstocks were determined. The design effort resulted in block flow diagrams and material balances in the following areas:

- Gasification
- Waste heat boiler, particulate removal and quench
- Sour shift
- Raw syngas compression
- Acid gas removal
- Molecular sieves
- Cryogenic methane separation
- Oxygen plant
- Sulfur plant

The steps required at Clear Lake were:

- CO/H_2 separation
- High temperature shift
- CO_2 removal

H_2/CO ratio adjustment was performed at the gasification site; therefore, the syngas entering the pipeline was the same for all systems, except for the small 3% difference in methane content. This allowed the Clear Lake retrofit portion to be deleted for Phase I evaluation because it was the same for all systems.

The process design blocks were developed as follows:

- Gasification.

  The material and energy balances were based on requested assessment data from each licensor. Licensors specified operating pressure, feedstock flows, moisture content, outlet gas conditions, and the suggested number of gasifiers for the required syngas production.

- Waste Heat Boiler, Particulate Removal and Quench.

  The design for these units came from the licensors. The original request specified superheated steam to be generated, but some licensors said this was not possible with conventional materials. For the purpose of Phase I evaluation, it was assumed that some of the waste heat boiler (WHB) systems would generate steam at approximately 1600 psig, with the other waste heat boiler systems generating 900 psig saturated steam. After the WHB, the syngas was wet scrubbed to saturate it and remove all particulates.

- Sour Shift.

  In the sour shift unit, a portion of the syngas was shifted to adjust the overall H_2/CO ratio of the syngas into the pipeline. A H_2/CO ratio (1 [illegible]) was selected to provide the quantity of feed for the methanol synthesis and acetic acid units at Clear Lake. The catalyst volumes and vessel sizes calculated were confirmed by vendors.

- Raw Syngas Compression.

  The raw gas was compressed to approximately 975 psig to compensate for pressure drop in the pipeline and arrive at Clear Lake at 800 psig. The syngas compression horsepower requirements were calculated and included pipeline and recycle gas compression.

- Acid Gas Removal.

  A Rectisol unit was chosen and the design information supplied by Lotepro. The unit has three gas outlets: the clean product gas; the sulfur rich stream; and the CO_2 stream. The unit was designed to concentrate the sulfur gases (H_2S and COS) sufficiently to feed to a Claus sulfur plant, even with the low sulfur New Mexico coal. The CO_2 stream containing hydrocarbons was incinerated before discharge to the atmosphere.

- Cryogenic Methane Separation.

  In methanol production, methane in the feed gas is inert, and the level of inerts in the feed gas must be minimized. Westinghouse, U-Gas, and Lurgi generate more methane than is acceptable, which must be removed in a cold box. Design information was supplied by Lotepro.

  With the Lurgi gasifier the methane recovered along with the tars and oils from gas cooling are converted to CO and H_2 in a partial oxidation reactor.

  For Westinghouse and U-Gas the methane is reformed to generate additional H_2 and CO. In all cases 200MM SCFD of H_2 + CO must be produced.

- Molecular Sieves.

  Molecular sieves were provided to remove the trace impurity components in the syngas before entering the pipeline or cryogenic methane separation.

- Oxygen Plant.

  Oxygen plant design was provided by Lotepro to supply oxygen @ 25 psia. Horsepower was calculated for compression to the required gasifier inlet pressure.

- Sulfur Plant.

  Sulfur plant design was provided by Hannon-Western, Inc. of Dallas, Texas.

UTILITIES DESIGN

A separate design of the entire utility system for each gasifier/feedstock combination was not possible within the allotted time. For this reason, a "base case" utility design was developed for the Texaco gasifier using New Mexico coal. A preliminary set of material and energy balances for each gasification technology was developed. The following variables were calculated:

- Water usage
- Utility usage
- Land requirements
- Cost estimate

Once the utility requirements for other gasification combinations were calculated, the designs and cost for utilities would be factored from the "base case" design. Individual systems are discussed below.

- Raw Water Supply and Treatment.

  A well system for water supply was proposed and a treatment system based on a "typical" raw water analysis defined. A potable water system was also defined.

- Wastewater Treatment.

  The wastewater treatment system for the Texaco process wastewater was designed utilizing Texaco suggestions as a guide. The system also handled wastes from raw water treating, boiler feedwater preparation, cooling tower blowdown, and sanitary wastes. The design assumed a zero discharge concept.

- Cooling Towers.

  The cooling water requirement was based on the total gasification complex. For Phase I only evaporative cooling towers were considered. Other options such as air cooling or system integration to improve efficiency were not considered.

- Coal Handling.

  For all cases, coal was assumed to arrive by unit train, sized to 2"x 0". The coal handling system included unloading, active and dead storage, conveying, grinding for gasifiers and boilers, and storage silos.

- Ash Handling.

  Ash handling included collection at the boilers and gasifiers and transport via conveyors to on-site disposal. Dewatering of gasifier ash was included as required.

- Coal Drying.

  No drying system was designed for Phase I; however, a value was included for capital and operating costs. If the licensor required the feed be dried, the energy required to remove the specified amount of moisture was calculated. This energy requirement was converted to an equivalent amount of fuel and considered as an additional raw material input.

- Steam and Power.
  For each case a steam and electrical balance around the plant was generated. Large drivers were steam-driven, and all electricity was generated by steam turbines. The saturated steam from the gasifier waste heat boiler was superheated in separate fired boilers to match the steam system conditions. Some preheating of boiler feedwater with gasifier waste heat was done, but most of the low level process waste heat was not utilized at this time. The boiler design included fuel gas particulate and sulfur removal. For each case the steam levels were chosen for efficiency and operational control with no electricity sales.

SYSTEM SCREENING METHOD

The screening method was based on an economic comparison of the operating costs, capital costs and tax shield for each system. The operating costs over an assumed 350 day/year, 20-year life of the project, and the capital costs of each process unit, the syngas pipeline, and the water supply systems were summed for each year. Tax shields were combined with the operating and capital costs to obtain an annual cost. These costs were discounted at 15% to obtain a net present value. The sum of these net present values was used to rank the systems. The systems were ranked in inverse order of increasing overall costs (lowest cost equals highest rank).

Discussion follows in the development of operating and capital costs, tax shields and net present value for a system.

OPERATING COSTS

The operating costs included those costs for purchase of feedstock and water, as well as those costs for maintaining and operating the syngas pipeline and water supply systems.

Feedstock costs were determined from the fuel quantities required for the process and utility facilities times the unit costs for each selected feedstock. The unit water costs utilized were those costs established in the preliminary site selection procedures. Railroad freight costs were added to coal/lignite prices to establish the delivered unit cost to the coastal county areas.

Pipeline operating costs were the operating and maintenance costs developed by Ford, Bacon and Davis as part of their preliminary pipeline design and estimate.

Water operating costs included the cost of purchasing the raw water and the costs to operate and maintain the required water supply system. Water purchase costs for all counties considered in the study were developed by Radian Corporation as part of their preliminary environmental study work. The operating and maintenance costs for the water supply system included the water pipeline and a well field operation (if required).

CAPITAL COSTS

Capital costs used in the evaluation included the gasification complex, the syngas pipeline and water supply system. Capital costs for facilities at Clear Lake were not included because these costs were considered constant in all cases.

The capital costs associated with the gasification complex were developed from three general sources.

- Rust estimates based on in-house file data and/or order-of-magnitude estimates.
- Cost figures based on Celanese historical data.
- Cost data received from process licensors.

Using the information from these sources, costs were estimated for those process operations whose costs were known. Ratio factors between the known and unknown process operations were developed based on throughput, horsepower requirements, waste heat recovery requirements or waste disposal requirements.

Table B describes the sources and methods of developing the capital estimate for the gasification complex.

The pipeline capital costs used in the evaluation were those developed by Ford, Bacon and Davis as part of their preliminary pipeline and estimate.

The capital costs for water supply were those for the water supply systems associated with the four counties selected in the initial site-screening procedure. The capital costs included the water supply pipeline and wells: Rust estimated the water supply pipeline capital costs; Radian estimated the capital costs for the wells and associated equipment required in Robertson County.

TAX SHIELD

In the case where a particular project does not generate a revenue, credit may be taken for the operating expenses, depreciation and investment tax credit associated with that project within the corporation's overall accounting procedure. In the screening methodology, tax shield was considered to be a positive cash flow into the project, so its value was added algebraically to the capital and operating costs (negative cash flows to the project) to derive an overall project cash flow. Tax shield was used in a computer program which evaluates projects in terms of net present value.

SYSTEM COST

Annual operating costs, capital costs, and tax shield were combined to give an annual cash flow (negative). These cash flows were then discounted at 15% to obtain a net value in 1987 dollars. These costs were summed over 20 years and the sums used to rank the systems.

RESULTS

A ranking of the forty-eight (48) systems was made in inverse order of increasing net present value (lowest cost equals highest rank).

Inspection of the ranking data presented in Table C shows that only a 3.3% difference in net present value exists between the first and tenth-ranked systems. This difference was well within the accuracy of the economic analysis.

The results were reviewed from other perspectives to identify which combinations would yield the best gasification technology, feedstock and location. The order of appearance of either a process arrangement, a feedstock and/or a location implies that some degree of superiority was being exhibited by that parameter. A parameter ranking is summarized in Table D.

A brief discussion follows for selecting the four systems:

- o High Temperature Winkler - Texas Lignite - Robertson County
- o Texaco - Illinois No. 6 Coal - Brazoria County
- o Saarberg-Otto - Texas Lignite - Robertson County
- o Texaco - Texas Lignite - Robertson County

The High Temperature Winkler process arrangement, operating with lignite in a Robertson County location, ranked first among the forty-eight systems studied, so more study of this system is obviously justified.

The Texaco process arrangement, operating with Illinois coal in a Brazoria County location, ranked third overall in the forty-eight systems studied. A detailed evaluation of this system will allow a comparison of not only a different gasification process, but also a different feedstock.

Although the Saarberg-Otto process arrangement, operating with lignite in a Robertson County location, ranked lower than the U-Gas process arrangement with the same feedstock and location, Saarberg-Otto appeared to be a better selection for further study. First, the commercial status of the Saarberg-Otto was more advanced; this process was currently being studied in a 290 TPD feedstock operating pilot plant; and, additionally, the commercial status of the U-Gas process by 1985 seemed heavily dependent on U.S. Government funding. Second, the process was very similar to another promising technology

(Shell-Krupp) which was not evaluated in this study, so tentative conclusions about Shell-Krupp may also be obtained.

Finally, a detailed study of one gasifier operating on two different feedstocks would permit the maximum amount of information to be derived. The Texaco process with lignite in Robertson County was selected as the candidate for this possibility. Conclusions about feedstock performance should be positive because the gasification process is constant. The performance of the gasifier studied in detail would provide data that could be extrapolated to predict performance with different feedstocks. The High Temperature Winkler process, operating with Illinois coal in a coastal county, had a high system ranking, but was not selected because there was a serious concern as to whether the Winkler process could accommodate a coal which has a high swelling index.

Comparison of these four systems would produce an overall review of the following:

- Economics of coal gasification
- The status of commercial grade technology in the mid-1980's
- The comparison of mine-mouth plants versus plants with rail delivered feedstocks
- The comparison of coal versus lignite feedstocks

VIII. PHASE II SYSTEM SELECTION

INTRODUCTION

The objective of Phase II was to select a base case system from the systems selected in Phase I for detail study in Phases III and IV.

The work plan for the feasibility study outlined Phase II screening effort of the four systems to include system optimization, economic analysis, and technical subjective ranking of the optimized systems. When the scope and time frame of the feasibility study were curtailed by Celanese management, the amount of detail included in the economic and subjective analysis was reduced.

Phase II ranking of the four systems was based on a two-part approach: an economic analysis based on site specific operating costs and improved capital cost estimates, and a subjective ranking of categories of technical concern.

RESOURCE

As a result of the Phase II site study, specific sites were selected. Morrison-Knudsen then furnished delivered coal/lignite costs and quality for the specific sites to be studied.

SITE SELECTION

The purpose of the Phase II site selection study was to identify one specific site in each of the two lignite counties (Robertson and Shelby) and one in the coastal area (Fort Bend or Brazoria County). These sites had to be large enough to accommodate the gasification complex and be environmentally acceptable.

The study was designed as follows:

- o Establish site criteria.
- o Search for specific site which met those criteria.
- o Rank sites, by county, on the basis of economics and environmental acceptability.
- o Select one coastal county and two lignite county sites based on the above rankings.

Air quality is the primary environmental/regulatory concern which may preclude construction of a gasification complex in an area. For that reason, an air quality analysis was performed to determine if portions of the selected counties were acceptable.

The economic evaluation was based on the net present values of selected capital and operating costs occurring over the project life. In this evaluation sites with the lowest combined net present values were preferred for siting the gasification complex.

The capital cost items considered in evaluating the sites were the syngas pipeline, plus costs for the water supply system. In addition, capital costs were included to accommodate certain environmental and infrastructure requirements, where applicable.

The operating costs associated with each site were those costs required to purchase feed stock and water, operate the water supply system, and operate the syngas pipeline. Taxes were also included as an operating cost.

Twenty-three (23) sites in the four counties were identified for initial consideration. Six sites were eliminated from detailed evaluation because of their failure to satisfy the established criteria. The remaining seventeen sites were found environmentally acceptable, therefore, included in the final evaluation and ranking.

Brazoria and Fort Bend Counties were combined for the ranking process. Three sites in Brazoria County were considered to have the lowest identical net present value. Based on the evaluation of subjective factors, one of these sites, located near the town of Danbury, was recommended as the potential site for a coastal complex.

In the lignite counties, one site in the northwest corner of Robertson County was found to be the better of two sites considered in that county. In Shelby County, two of the six sites considered proved to be nearly identical in both economic and subjective evaluation. One site, near the town of Center, was recommended as a potential site for a lignite gasification complex, because of its more favorable geographical location.

The methodology used for the site selection and a summary of the results can be found in Appendix IX.

PIPELINE

The pipeline design was again provided by Ford, Bacon and Davis. Their Phase II effort was to design the pipeline from the specific sites selected in Robertson County and Brazoria County to Clear Lake. The gas flow, as well as battery limit gas conditions at the gasifier and Clear Lake, remained unchanged, but it was found more economical to reduce the pipeline size and add gas compression.

CLEAR LAKE RETROFIT

The Phase II evaluation incorporated the required facilities at Clear Lake. The process design concepts from Phase I were reviewed and refined in Phase II. The facilities designed were complicated by the operating flexibility desired by Clear Lake. The overall design provided a pure CO stream for acetic acid production and a specified stream of H_2, CO, and CO_2 for methanol production. The equipment required to achieve the composition of these two major streams from the syngas in the pipeline are discussed below.

- Guard beds were installed to remove trace residuals of sulfur and chlorine compounds which would poison the methanol synthesis catalyst.

- A cryogenic system (Cold Box) was provided for separating CO and H_2. The system was designed to produce a high purity CO stream, a CO + CH_4 stream, and two H_2 + CO streams. The CO stream is for the acetic acid unit. The two H_2 + CO streams are compressed and combined with the gas which bypassed the Cold Box. The CO + CH_4 stream was used as fuel for the new steam boiler.

- A portion of the syngas was reacted in a shift reactor either for H_2/CO ratio adjustment or for CO_2 generation. The vessel sizes and catalyst volumes calculated were confirmed by vendors.

- CO_2 removal design information was provided by Union Carbide. A portion of the syngas from the shift reaction was processed further to remove CO_2. The CO_2-free syngas portion was mixed with the main syngas for control of CO_2 in the methanol feed.

PROCESS DESIGN

The basic material and energy balances generated during Phase I remained valid for Phase II. The data was reviewed and refined with no major changes being made to the gasification and gas process designs. The design for the steam and power system also remained valid, but a more accurate cost estimate was developed.

Minor changes included:

- A system was added for oxidation of the hydrocarbons in the CO_2 vent from Rectisol.
- Refinements were made in the water preparation and waste water treatment systems from the Phase I utility work.
- Water consumption for the boiler Flue Gas Desulfurization system and for the Texaco slurry feed were included.

A brief description of the four gasification technology and feedstock combinations studied in Phase II follows:

HIGH TEMPERATURE WINKLER - TEXAS LIGNITE

High Temperature Winkler (HTW) process uses a pressurized, fluidized bed gasifier. Dried and sized lignite is fed to the gasifier through a lock hopper and a screw conveyor system. The lignite reacts with oxygen and steam to produce a gas primarily composed of carbon monoxide and hydrogen. The fluidized bed gasifier which maintains a relatively large inventory of feed is operated at a lower temperature than an entrained bed gasifier. Gasification temperatures are high enough to avoid the production of tars and oils, but some quantity of methane is produced. Bottom ash is removed from the gasifier by a cooled screw-conveyor and lock hopper system. The major portion of ash in the syngas is removed in cyclone - type separators external to the gasifier. Ash collected in the cyclone separators is reinjected into the gasifier. From the cyclones the gas passes through a waste heat recovery boiler which produces high pressure saturated steam. A separate coal fired boiler is used to superheat the steam. A water jacket on the gasifier is used to preheat boiler feedwater. The final syngas ash removal and cooling is accomplished by a water quench and scrubber system. From this point, the syngas is processed through gas shifting, compression, acid gas separation, and trace component removal.

Heat recovery from the syngas provides only a portion of the steam required for the total gasification plant. A separate large capacity fossil fuel boiler will supply the remaining plant steam. A start-up boiler was not required.

The syngas prepared at the gasification plant would be pipelined to the Clear Lake plant and further prepared to feed the methanol and acetic acid units.

SAARBERG-OTTO - TEXAS LIGNITE

The Saarberg-Otto gasifier is a pressurized, entrained bed slag bath gasifier. The pulverized lignite feed to the gasifier is reacted with oxygen to produce a crude syngas containing hydrogen and carbon monoxide. Gasification conditions are such that only a small amount of methane and no tars and phenols are produced. The hot gases in the top of the gasifier are cooled by injecting recycled cooled syngas to solidify any entrained slag. Processing steps of waste heat recovery, particulate removal, gas shifting, compression, gas separation, and trace component removal are incorporated in the process to prepare the syngas for pipelining to the Clear Lake plant.

TEXACO - ILLINOIS COAL/TEXAS LIGNITE

The Texaco Process uses a pressurized, entrained bed, downflow gasifier. The coal is pulverized and water slurried before being fed to the gasifier. The coal mixture is reacted with oxygen to produce a gas primarily composed of carbon monoxide and hydrogen. Gasification conditions are maintained to produce only a small amount of methane with no tars and phenols produced. Heat from the syngas produced is recovered by a radiant tube section in the gasifier and a convective tube section attached to the gasifier. The recovered waste heat produces high pressure saturated steam. A portion of molten ash in the syngas solidifies on the radiant tubes and falls into the bottom water quench area for removal. Additional syngas ash is solidified and removed in the convection section. The final ash in the syngas is removed in a water quench scrubber that also cools and saturates the gas. From this point, the syngas is processed through gas shifting, compression, acid gas separation, and trace component removal.

Heat recovery from the syngas provides a large portion of the total steam requirement. The recovered saturated steam is superheated in separate fired superheater boilers. A separate small capacity fossil-fuel fired boiler provides the remaining gasification plant steam required and serves as the start-up boiler.

The syngas prepared at the gasification plant would be pipelined to the Clear Lake plant and further prepared to feed the methanol and acetic acid units.

Process flowsheets and material balances for the four systems studied in Phase II are shown in Appendix X.

SYSTEM SCREENING METHOD

The overall work plan developed for the feasibility study outlined the method to be used in Phase II to select one system for detailed analysis. This method included two separate procedures to be used in ranking the four systems identified in Phase I. The first involved determining the capital and operating costs of the systems and ranking them in order of their net present values. The second involved subjectively ranking each system in those areas where cost numbers were not adequate descriptors. The results of both procedures were utilized to select the best system.

When the scope of the study was curtailed, it was decided to use the same method as in Phase I but to apply each procedure in less detail than originally conceived. Thus, capital costs were not always supported by equipment lists, layouts and P & I drawings. Vendor and process-licensor quotations were used with no additional effort made to refine these costs. The subjective ranking was not based on visits to the process licensors or their pilot plants. A Celanese-Rust group subjectively ranked the four systems based on the process knowledge acquired by the individuals working on the project.

The economic-analysis method used for the Phase I system selection was also used in this ranking. Operating costs, capital costs and tax shields were combined and expressed as a net present value in mid-1987 dollars.

OPERATING COSTS

The operating costs considered in this process included those tor feedstock, the syngas pipeline, and water system.

Feedstock costs were determined from the fuel quantities required for the process and utility facilities times the unit costs for each selected feedstock.

The other operating costs shown in the comparison are those derived for the specific sites in Robertson and Brazoria Counties in Phase II of the site selection process. The water costs utilized were those costs established in the Phase II site selection procedures. Syngas pipeline operating costs were those estimated by Ford, Bacon and Davis in their Phase II study.

The operating costs for each of the four systems are shown in Table E.

CAPITAL COSTS

Equipment costs for each processing step in each of the four cases were estimated using vendor quotes, process licensor estimates and total installed costs from Rust-prepared equipment lists. Table F shows the source ot the capital costs tor each process area within each system. Syngas pipeline capital costs were estimated by Ford, Bacon and Davis, and water system capital costs were estimated by Rust. These costs were not obtained by factoring as was done for the Phase I effort. A new total capital cost was developed for each system. The basis for each capital cost is described in support documents in the project file. Table E lists the summary of the capital cost for each system. Table G lists the gasification complex capital costs by major process areas for each system.

TAX SHIELD

The same method was used to calculate the effects of depreciation expenses, and investment tax credit as in Phase I. The value of the tax shield for the four systems is shown in Table E.

SUBJECTIVE ANALYSIS

Subjective ranking covers categories which could not be described in monetary terms. These categories are:

- o Process maturity
- o Process operability
- o Process flexibility
- o Environmental impacts of the process

Process maturity covers the development status of the process, including: the existence and size of a pilot plant; commercial status; and design experience with this type of equipment. Operability covers the reliability and complexity of a processing system. Flexibility includes the turndown capabilities and the adaptability of a system to a range of feedstocks. Environmental impacts include the difficulty of disposing of the by-products produced by a processing system. The methodology is explained in Appendix XI.

The data of the subjective analysis is shown on Table H. This data was developed by a joint Celanese-Rust task force effort.

RESULTS

The data in Table E shows that the High Temperature Winkler Process using lignite in Robertson County has the lowest net present value, therefore, the highest economic ranking. The net present value of the Saarberg-Otto process using Texas lignite in Robertson County was next lowest, therefore was ranked second. The High Temperature Winkler and Saarberg-Otto systems were essentially equivalent in net present value. Both Texaco systems were significantly higher in net present value so these systems were ranked third and fourth.

Table H presents the results of the subjective rankings. These results indicate that the Saarberg-Otto process operated with lignite in Robertson County had the highest overall ranking. The Texaco-Illinois No. 6 Brazoria County system was second; High Temperature Winkler - Robertson lignite system was third; and the Texaco-Robertson lignite system was last.

The subjective rankings indicated that the Saarberg-Otto system would be preferred over the Texaco or High Temperature Winkler system. The economic analysis actually indicated the High Temperature Winkler was better than the Saarberg-Otto system. However, this economic difference was fairly small and it was felt desirable to get a direct comparison on a subjective basis between the Saarberg-Otto and High Temperature Winkler system. The salient features of this comparison are described below:

Saarberg-Otto

Favorable features of this gasifier are:

- simplicity of design, including few moving parts and an internal water wall (which is cheaper to install and which precludes refractory-life problems),
- potential for accommodating at least a partial radiant waste heat boiler, and
- the large size of the pilot plant which means that the system components are within the size limits of present-day manufacturing.

Some of the drawbacks are:

- the pilot plant has only been operated with coal, not lignite (although its atmospheric predecessor, the Otto-Rommel, has gasified lignite),

- the pilot-plant unit has only operated at 300 psig,

- sustained operation of the pilot plant has not been demonstrated, and

- commercialization not imminent within next 3-4 years.

<u>High Temperature Winkler</u>

The most favorable feature of this gasifier is that it has been designed for lignite. Some of the drawbacks of the process are:

- it is limited to operation at low pressure because of the shaft seals on the screw conveyors,

- the feed system is composed of multiple lock hoppers and valves,

- the gasifier is of a jacketed design, (which could lead to fabrication problems and is more expensive),

- operation with a swelling coal is marginal, maybe impossible, and

- the methane concentration in the syngas produced by a unit of commercial size is unknown.

Based on the results of the subjective analysis, the Saarberg-Otto process using lignite in Robertson County was recommended for the Phase III and IV evaluation.

IX. PHASE III BASE CASE DESIGN

INTRODUCTION

The objective of Phase III was to refine the data generated on the base case selected in Phase II for economical analysis in Phase IV.

Refinements were accomplished in the process design, capital, and operating cost areas.

The base case includes Saarberg-Otto coal gasification technology with a plant site in the northwest corner of Robertson County and near a mine providing feedstock from the Texas lignite Wilcox seam. Syngas was compressed and transported to Clear Lake via a pipeline. Gas conditioning facilities were installed at Clear Lake to prepare the necessary ratios of H_2 and CO to feed the existing methanol and acetic acid units.

BASE CASE DESCRIPTION

The Saarberg-Otto gasifier is a pressurized, entrained bed slag bath gasifier (see Figure 4). The pulverized lignite feed to the gasifier is reacted with oxygen to produce a crude syngas containing hydrogen and carbon monoxide. Gasification conditions are such that only a small amount of methane is produced with no tars and phenols produced. The hot gases in the top of the gasifier are cooled by injecting recycled cooled syngas to solidify any entrained slag. Processing steps of waste heat recovery, particulate removal, gas shifting, compression, gas separation, and trace component removal are incorporated in the process to prepare the syngas for pipelining to the Clear Lake plant. A process block diagram of these steps is attached (Figure 5).

Heat recovery generates a low pressure steam from the gasifier walls and a high pressure steam from a separate syngas waste heat boiler. This steam, combined with additional superheated steam from a separate fossil fuel boiler, provides the steam requirements for the process and mechanical drivers.

The syngas composition of hydrogen and carbon monoxide is altered in the sour shift processing step. The tailored and compressed gas is then fed to a Rectisol process to remove the carbon dioxide and hydrogen sulfide gases. The carbon dioxide stream containing some carbon monoxide is thermally oxidized and vented. The hydrogen sulfide stream is processed in a Claus sulfur recovery unit to produce elemental sulfur. Syngas finally passes through molecular sieves to remove trace syngas impurities before entering the pipeline to the Clear Lake plant.

The supporting systems and processes contained at the gasification plant are:

- Lignite delivery, unloading, storing, reclaiming, grinding, sizing, feeding

- o Pure oxygen preparation and compression
- o Gasifier and steam boiler ash handling, land filling
- o Steam boiler flue gas desulfurization, particulate removal
- o Raw water delivery, purification, demineralization, distribution
- o Waste liquid collecting, storing, filtering, purifying, separating, reclaiming
- o Waste solid handling, land filling
- o Cooling tower
- o Building, support facilities

The gasification process data is presented in Table I.

At the Clear Lake plant additional gas separation and blending is done to achieve the desired syngas feed composition for the existing methanol unit. Pure carbon monoxide is separated in the cold box for feed to the existing acetic acid unit. Supplemental carbon dioxide, available from other Clear

Lake plant processes, is used in the methanol unit feed stream. Syngas to methanol is fed to the suction of the existing recycle compressor. Carbon monoxide for acetic acid is fed to the existing CO unit compressor.

Steam requirements resulting from shutdown of the existing methanol reformer and CO unit and from the addition of new gas tailoring equipment at the plant are provided by a new high pressure steam boiler. Fuels for the new boiler would be pipeline syngas, byproduct methane from the cold box, and purge gas from the methanol unit reaction loop. The design process data presented in Table I includes syngas for the new boiler.

The new supporting systems at the Clear Lake plant are:

- o High pressure steam boiler
- o Block preparation, drainage
- o Pipeway extension
- o Cooling tower

GASIFICATION PROCESS DESIGN

Process flow sheets, material balances and heat balances for Saarberg-Otto gasification with syngas cleanup and tailoring and Clear Lake retrofit are presented in Appendix X. These balances were based only on the syngas requirements for the methanol and acetic acid units.

Vendors provided data for the various processing sections

sections and Rust calculations were used to generate a heat balance. Major process steam consumptions and waste heat recovery were incorporated in the heat balance. Steam turbines were used for the large mechanical drivers. The heat balance generated by Rust is shown in Appendix X.

A new high pressure steam boiler was specified to meet the steam balance needs at the Clear Lake plant. Methanol purge gas and by-product methane were utilized as fuels for the boiler. The additional fuel for the boiler was pipeline syngas produced by the gasification plant. The Rust material and heat balances were not updated to reflect the additional syngas for the Clear Lake plant boiler. For economic analysis purposes the lignite feed to the gasification plant was increased fifteen percent (15%) to provide the needed syngas boiler fuel.

UTILITY DESIGN

Water preparation for the gasification complex consisted of the basic process steps to clean up river water and provide the required quality for potable, process, and boiler makeup water uses.

Raw water is pumped through a pipeline to the gasification plant site storage reservoir.

Potable water quality from the storage reservoir is prepared for the plant by a flocculating clarifier and sand filter system including storage.

Process water quality is prepared for cooling tower makeup and general water uses. The raw water turbidity is removed in a clarifier followed by a filter system before entering the storage tank.

Demineralized water quality for boiler makeup is produced in an ion exchange system. Ions are removed from the process quality water in cation and anion resin beds. Surge storage of demineralized water is provided. A flow sheet is presented in Appendix X.

The waste water treatment plant cleans and purifies the sanitary and process waste waters for recycle back into the process. A "zero" discharge concept is used for the waste water treatment facilities.

Sanitary wastes are collected separately and treated. After gross solids removal by a screen and grit chamber, aerobic biological oxidation is used to remove organics and a clarifier for final solids removal. The effluent water is chlorine treated for bacteria and used as cooling tower makeup.

The process sour water is processed to remove ammonia and destroy the cyanide compounds. The water passes through an ammonia stripping tower followed by contact tanks. Chlorine and sulfuric acid are added in the contact tanks for cyanide destruction. The effluent from the sour water treatment is combined with cooling tower blowdown, boiler blowdown, and demineralizer waste streams and forwarded to a clarifier for solids removal. The clarifier overflow passes through activated carbon filters to remove organics. A reverse osmosis unit is used to remove the dissolved solids in the water before returning as makeup to the cooling tower and the boiler flue gas desulfurization system. The reject water, high in dissolved solids, is processed through a brine evaporator with steam. High quality evaporation water is recycled to the demineralization system. Concentrated evaporator waste after chemical fixation is landfilled on the plant site. Solids removed in other waste water treatment steps, after dewatering, will be disposed of in the landfill area on the plant site. A flow sheet of the waste water treatment is presented in Appendix X.

TECHNICAL QUESTIONS

The process work completed by Rust Engineering was reviewed by the Dallas Coal Program Group. The following comments are directed toward the potential improvements that may be possible in the process steps or refinements in the data, should the project be reactivated in the future:

- The lignite requirement stated in Phase I and Phase II for the Saarberg-Otto gasifier is understated by 286 tons per day.

- Hydrogen and oxygen component accountability discrepancies exist in the Saarberg-Otto gasifier material balance. The syngas recycle flow to the gasifier is suspected. An increased recycle flow would improve the material and heat balances around the gasifier and would increase the waste heat recovery steam generation.
- An unclear recycle gas temperature is specified by Rust in the Saarberg-Otto lignite case. The lower temperature of 104°F before compression (recommended in the Saarberg-Otto proposal) should be used.
- Several optimization possibilities exist for the Clear Lake plant retrofit facilities, such as:
  - Do not recover the existing plant CO_2 stream into the syngas; consider incineration. Recovery of this stream increases the CO_2 removal system requirements of the new facilities, therefore, capital costs.
  - Reduce or eliminate the syngas shift requirements to reduce capital costs and steam requirements.
  - The existing plant boilers (650 psig) could provide the retrofitted plant and the new syngas facility steam requirements (thus eliminating the need for a new 900 psig boiler), if the high pressure steam need for gas shifting is eliminated, a new MS recycle compressor turbine (now 900 psig) is installed, and a new CO compressor turbine (now 900 psig) is installed.

- A biological waste water system incorporated in the waste water treatment plant in addition to the carbon bed would be a stronger design.
- The demineralized water system approach is good. A more specific design will optimize this system. The high waste water generated versus demineralized water produced is questionable.
- Storing a larger quantity of clear turbidity - tree water versus the raw (as is) water provides for a more flexible and reliable water preparation system.
- Additional detail work is essential to refine the "total complex" water balances.
- No overall Clear Lake plant utility estimates (except steam) were established for the retrofit portion at this time. No major utility supply problems are envisioned with incorporating this project into the existing plant.

EQUIPMENT LISTS

Fairly detailed equipment lists were developed. These equipment lists provided the basis for estimating those portions of the gasification plant that were not provided in the vendor packages. Extensive equipment lists were generated for such utility sections as fossil boiler, fired superheaters, power turbine generator, and condensers for the mechanical drive turbines. Additional equipment lists were prepared for condensate polishing, chemical feed systems, demineralizers, raw water preparation (process/potable), and waste treatment (liquid/solid). Plant sections to include oxygen plant, sulfur recovery, gasifiers, gas separation, acid gas removal, and pipeline that were supplied as vendor package estimates were not disassembled into separate equipment lists.

Equipment lists were developed for the Clear Lake plant retrofit portion of the project. This work included the new gasification tailoring equipment and the modifications needed to interface the syngas project into the existing Clear Lake plant.

The specific equipment list details are contained in the East Texas Project files.

CAPITAL ESTIMATE

The base case Saarberg-Otto capital estimate was developed by Rust Engineering in Phase II of the project work. An estimate was prepared for each process section in the gasification plant with the pipeline estimate prepared by Ford, Bacon and Davis. Vendor quotes, detail equipment lists, Rust estimates, and factored estimates for the support systems were all utilized for this Rust screening phase.

In the Phase III Dallas work, adjustments and additions were made to the Rust estimate to prepare a complete project capital cost. Celanese estimating personnel were utilized to be consistent in preparing the estimate. A capital estimate was included for the new processing equipment and modifications at the Clear Lake plant.

The capital estimate details are contained in the East Texas Project files with a summary presented in Table J.

OPERATING AND MAINTENANCE COST ESTIMATE

The operating costs were developed by the Coal Program Team using various inputs from the Rust Engineering work. A detailed review of operating costs items for the gasification plant and pipeline was made with annual costs established. A complete new plant manpower estimate was developed and costed. Maintenance materials were estimated as a factor to the total installed capital.

The operating and maintenance cost estimate details are contained in the East Texas files with a summary presented in Table K.

X. PHASE IV - ECONOMIC EVALUATION

INTRODUCTION

The objective of Phase IV was to evaluate the economics of the East Texas Project. The financial model utilized was adapted from the model developed for the National Methanol Company study.

Financial assumptions were developed in conjunction with the Financial Analysis Department and covered such items as:

- Depreciation schedules
- Investment tax credits
- Financing methods
- Interest rates

Basic cost data developed during Phase III included:

- Capital costs
- Feed costs
- Operating costs

- o Working capital

- o Gas savings

Income to the project was developed from the natural gas savings based on the February, 1981 Hydrocarbons Planning Department forecast.

A complete list of economic analysis assumptions can be found in Appendix XII.

CASE DESCRIPTIONS

Four cases were subjected to an economic analysis. Several sensitivities and variations were also developed; however due to management direction, these were not completed. The cases studied were:

Case I (Base case)

The base case developed fully in Phase III was based on the Saarberg-Otto process, feeding Texas lignite from a mine in Robertson County, a plant site near the mine, a pipeline to the Clear Lake plant and retrofit of the existing methanol and acetic acid units at Clear Lake.

Case 2

Case 2 is the same as the base case (Saarberg-Otto) design; however, syngas production is increased to provide for an additional 250MM gallons/year of methanol. This was the size case described in the approved RFA.

Case 3

Case 3 was based on the Texaco gasification process, feeding Illinois coal, a plant site in Brazoria County, retrofit of the existing methanol and acetic acid units at the Clear Lake plant.

Case 4

Case 4 was the same as Case 1, except the process was High Temperature Winkler.

DATA SUMMARY

A summary of the design basis and key economic input data for all four cases are shown in Table L. The base case data was taken from Phase III work. Detailed capital and operating costs estimates were made for the base case. A capital estimate was prepared for each of the alternate case designs. In Case 2 a capacity factor of 1.85 was applied to the base case design for the increased syngas production. Individual sections of the total complex were reviewed with factored capital estimates prepared.

The capital estimated for Case 3 and 4 were factored from the base case design based on ratios established in Phase II. The pipeline estimate to Clear Lake was modified for the non-mine mouth Texaco process case.

An operating and maintenance cost estimate was prepared for each of the alternate cases. Operating and maintenance costs were included for chemicals, catalyst, water, fuel transportation, operating supplies, operating and maintenance labor, maintenance materials, and pipeline operations. Each cost area was reviewed for the alternative cases. Varying cost estimating factors were used to adjust the base case costs for the specific case differences, such as, production rates, chemical consumptions, amount of equipment to maintain, etc.

Data input sheets for each case are included in Appendix XIII.

RESULT

A summary of the estimate returns on the four cases is shown in Table M. The best return was a project DCFROI of . % on Case 2, as compared to % for the base case. This indicates that there is some economy of scale. The other results (% on Case 3 and % on Case 4) merely confirmed the ranking developed in the Phase II study. Preliminary assessment of sensitivities was not finalized and will not be reported.

The only conclusion that can be reached is that in the time frame studied and under the current conditions this project is not economically attractive.

XI. COMMERCIAL VIABILITY

The gasification process for the East Texas Project will be chosen to ensure that it will be commercially demonstrated prior to startup. Of the leading processes (Saarberg-Otto, Texaco, Westinghouse, and High Temperature Winkler), one or more should be developed in time to permit installation on the East Texas Project (see Table N). The choice of one over the other in this study does not significantly affect the project economics. See Appendix XIV for the commercialization status of various coal gasification processes.

The support units for coal gasification are commercially proven.

XII. REGULATORY COMPLIANCE SCHEDULE

BACKGROUND

This section describes a project management tool to be used in support of regulatory compliance activities associated with the licensing of a coal gasification facility in Texas.

Although gasification processes have been commercially applied in foreign countries, their introduction in the United States will be carefully reviewed by federal and state regulatory authorities; therefore, environmental regulations that would impact these projects will be of major significance to their successful completion. To assist Celanese in understanding these regulatory requirements and their schedule considerations, Radian Corporation was asked to prepare a Regulatory Compliance Schedule.

The objective of this study was to provide an overview of individual environmental compliance program requirements and to provide planning guidance for the acquisition of needed project approvals. The elements of the document presented are as follows:

- o Identification and description of permit programs;

- Identification of environmental information needed in order to prepare permit applications and compliance programs; and

- Development of an integrated schedule for regulatory compliance which can be used as a guide by Celanese and contractor personnel.

The primary emphasis in this regulatory analysis is on issues related to on-site construction activities associated with the gasification plant, plus disposal of solid and liquid wastes. Regulatory requirements associated with coal mining and plant operation are identified but are given less attention than construction permits. Not included in this analysis are regulatory programs that are not expected to impact the overall schedule (spill prevention control and countermeasure, transportation permits related to highway and pipeline relocations, occupational safety and health program, noise control, and aircraft navigation requirements).

REGULATORY COMPLIANCE SCHEDULE

Figures 6 and 7 present the overall project time schedules for all major permits and identify critical path activities associated with the Baseline Case and Pessimistic Case, respectively. In addition to the expectation of lengthier application review, public hearing, and permit issuance times, the Pessimistic Case also assumes that: 1) separate

Environmental Impacts Statements (EIS) will be required by EPA for the NPDES program and by the Corps of Engineers (COE) under the Section 404 Dredge-and-Fill Program as opposed to a single EIS; and 2) mine permitting will be delayed by the filing of a petition to Declare Lands Unsuitable for Mining. Critical path network diagrams for the Base Case and Pessimistic Case are contained in the project files.

In the Baseline Case, total project permitting time is roughly 32 months and is determined by activities associated with the permitting of the mine. Critical to this analysis is the assumption that technical studies to support an application for a mining permit and associated water use related permits will be completed 12 months after project start. Depending on the actual mine site, substantially more time may be required to complete these technical studies. If mine permitting is not associated with the project or if mine-related technical studies are completed at the time of project start-up, total project permitting time can be reduced to approximately 26 months and is determined by the time associated with EIS preparation and approval.

In the Pessimistic Case total project permitting time is estimated at 45 months. The critical path activity is completion of the NEPA process, including development of a supplemental EIS by the Corps of Engineers for 404 permit. Assuming a supplement EIS can be avoided through advance coordination with the Corps or that a 404 permit is not needed, the project schedule is reduced to roughly 34 months. The critical activity in this abbreviated schedule is the technical study associated with the mine. If mine-related permitting time can be reduced or is not required, a schedule of 32 months results with completion of the gasification plant EIS as the critical activity.

A major consideration in both scheduling cases, especially if mine permitting is not involved, is the time required for completion of an Environmental Impact Statement under EPA's NPDES water quality program. Under the assumptions used in this analysis, it is assumed that responsibility for administration of this program is retained by EPA. However, it is possible that within the next one to two years, responsibility for administration of the NPDES program in Texas may be delegated to the Texas Department of Water Resources. Should this delegation occur, the need for development on an EIS would be reduced, if not eliminated.

Under both scheduling cases, timely completion of technical studies is critical. As discussed above, mine-related studies are the most significant of these studies and should be started as early as possible. Technical studies associated with wastewater management, air quality, and solid waste disposal analysis may also have a major impact on actual project scheduling.

EAST TEXAS CONSIDERATIONS

Three sites in Robertson, Shelby, and Brazoria Counties were considered in the East Texas Gasification Feasibility Study. Although site-specific investigations were not accomplished at these sites, regional environmental factors developed by Radian during the site selection process suggest some regulatory implications unique to each of the prospective sites.

The EIS preparation process will most likely be initiated by EPA Region VI following a request for New Source Determination for a NPDES permit. (This was the route taken by Exxon's East Texas Synthetics Project.) For a mine-mouth gasification facility in Texas, it is probable that the EIS will cover both the gasification facility and the mine. Therefore, in Robertson and Shelby Counties the preparation of mine and reclamation plans, the TRC mining permit process, and the inclusion of the mine impacts into the EIS process would most likely have to be integrated into the permitting schedule. The proximity of the mine to the plant may offer some solid waste disposal advantages in terms of costs; however, it remains to be seen whether this option will increase or decrease the permitting complexity.

Robertson County may face some future permitting congestion if one or more of several proposed energy facilities in that county precede Celanese in the permitting process. These other projects could conceivably consume available PSD increments, water resources, or generate the potential for large cumulative socio-economic impacts in this region, thus make permitting more difficult.

The Brazoria County site would differ from the two lignite county sites in that coal would be supplied by rail potentially from a variety of sources (possibly already permitted) rather than from one nearby lignite mine. This would make it least likely, although still a possibility if a new lignite mine is the source of coal, that mine permitting would have to be tied to the permitting schedule of the gasification facility in Brazoria County.

Brazoria County also is classified in a non-attainment status for ozone. This would represent some constraint on the design requirements for air pollution control technology for volatile organic compounds (VOC). However, the additional costs involved are judged to be minimal, consisting probably of increased monitoring of future emissions. As Brazoria County is classified a rural rather than urban non-attainment area for ozone, emission offsets for ozone may not be required.

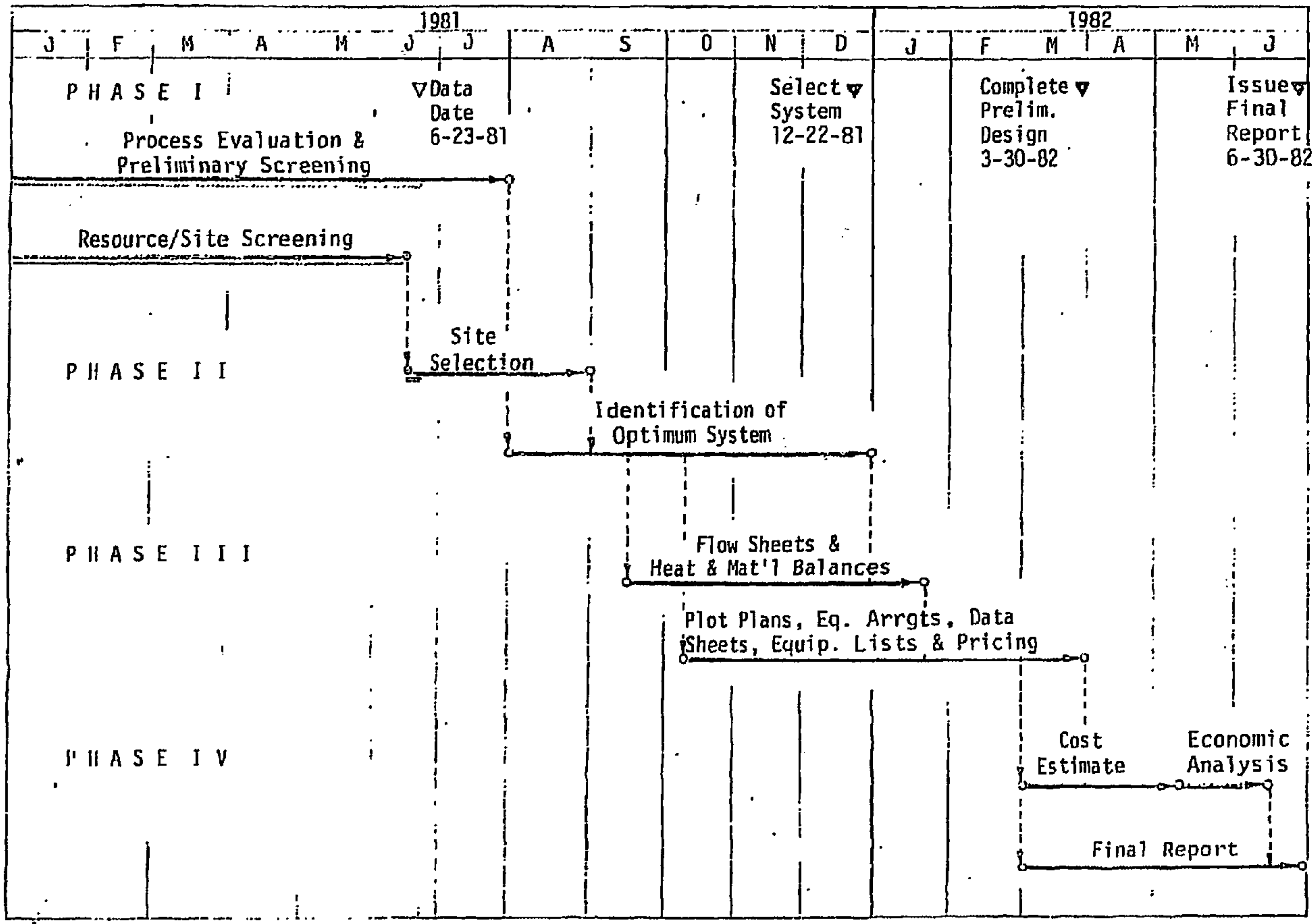
Another difference between the lignite and coastal sites is in the likelihood of obtaining an Underground Injection Control (UIC) permit which depends upon the suitability of subsurface geology. The distribution of saline aquifiers is generally more widespread and shallower near the Gulf Coast than in the lignite belt of Texas. A suitable aquifier would enable disposal of difficult-to-treat waste waters (containing brines, scale, and heavy metals) by deep-well injection. Therefore, permitting under the UIC program may be less difficult at the Brazoria site although not entirely ruled out for the lignite sites.

FIGURE 1

PHASE IDENTIFICATION AND SCHEDULE

CELANESE CHEMICAL COMPANY

EAST TEXAS PROJECT



CELANESE CHEMICAL COMPANY

EAST TEXAS PROJECT

FIGURE 2

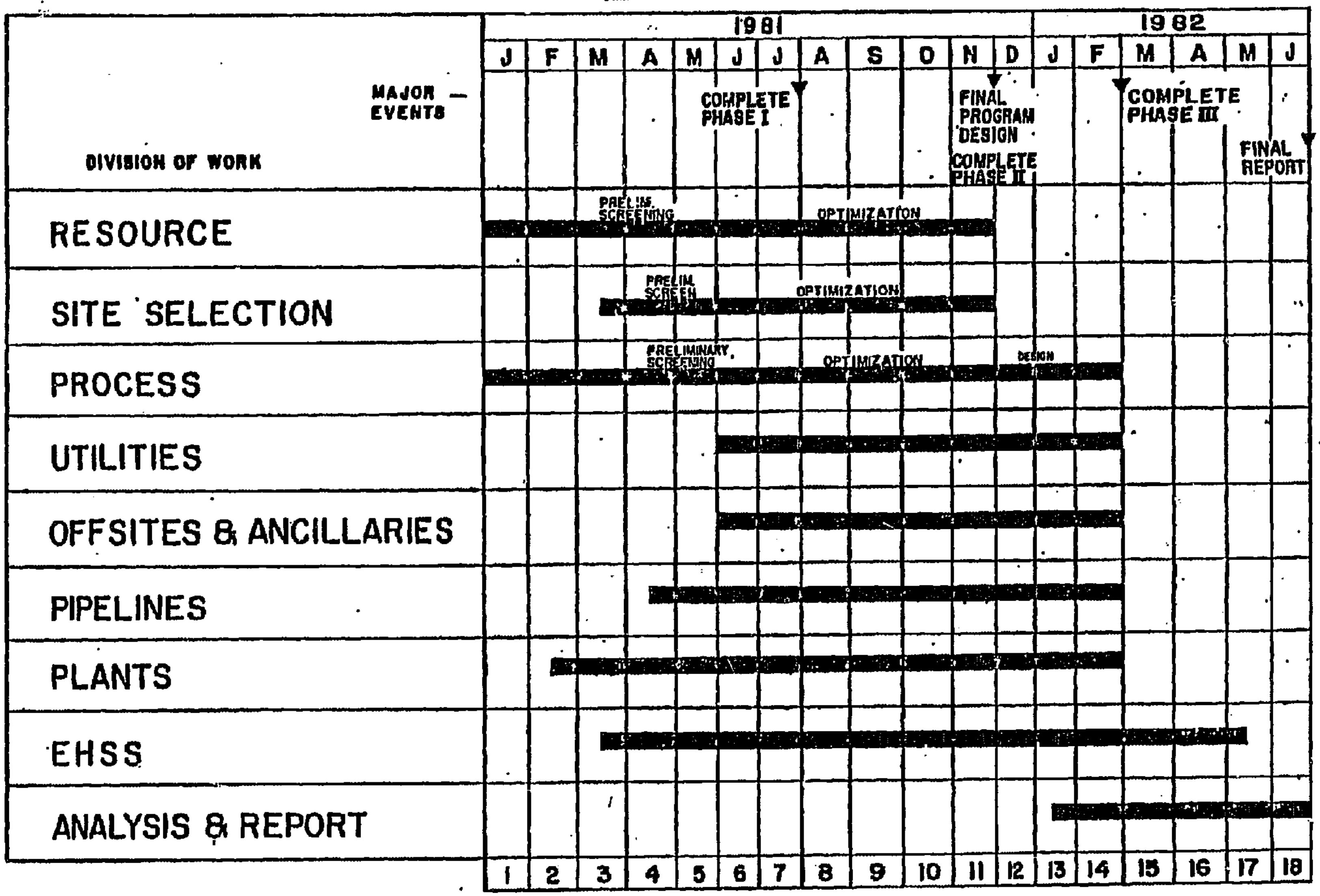
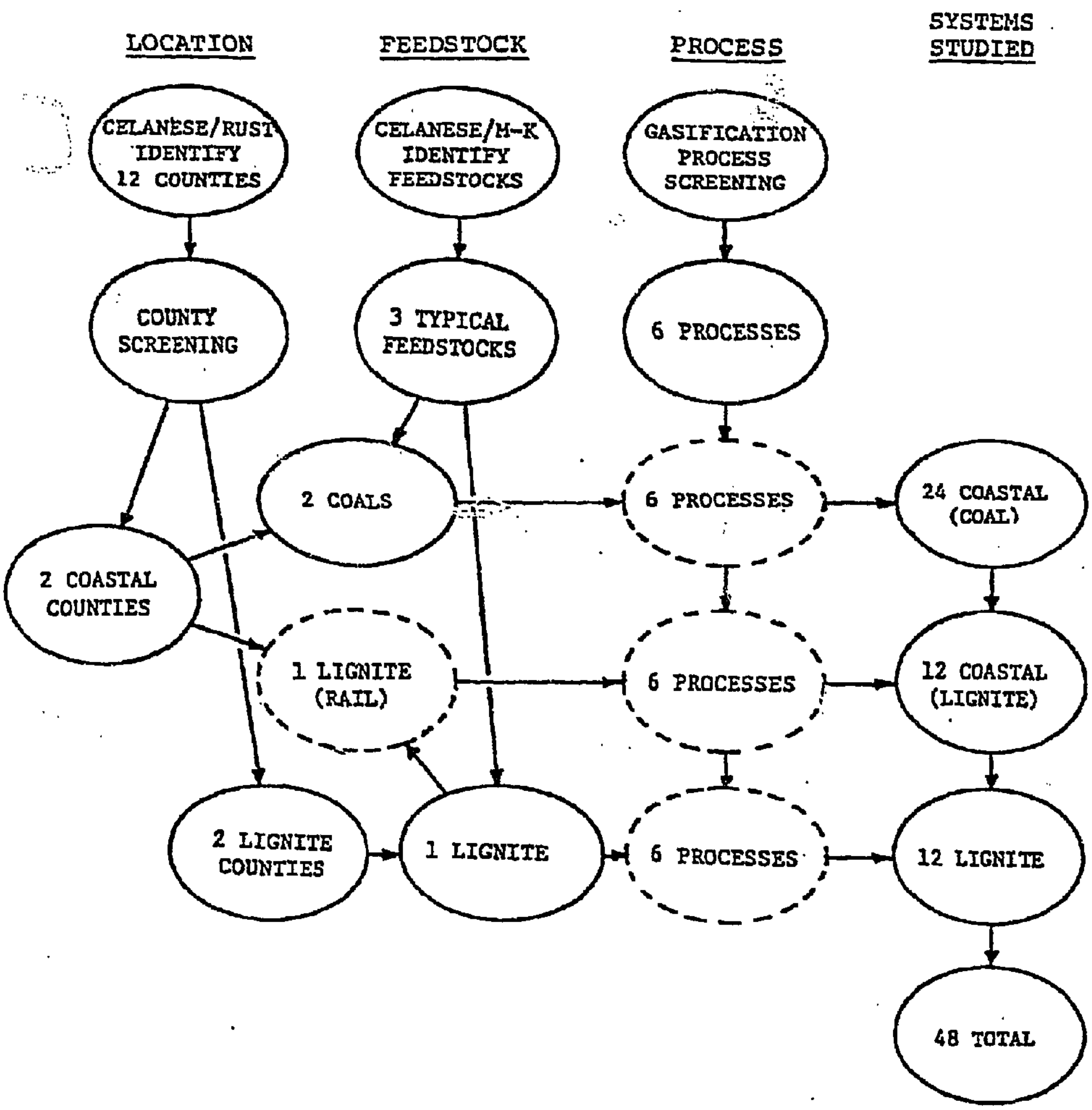


FIGURE 3

PHASE I SYSTEM COMBINATION



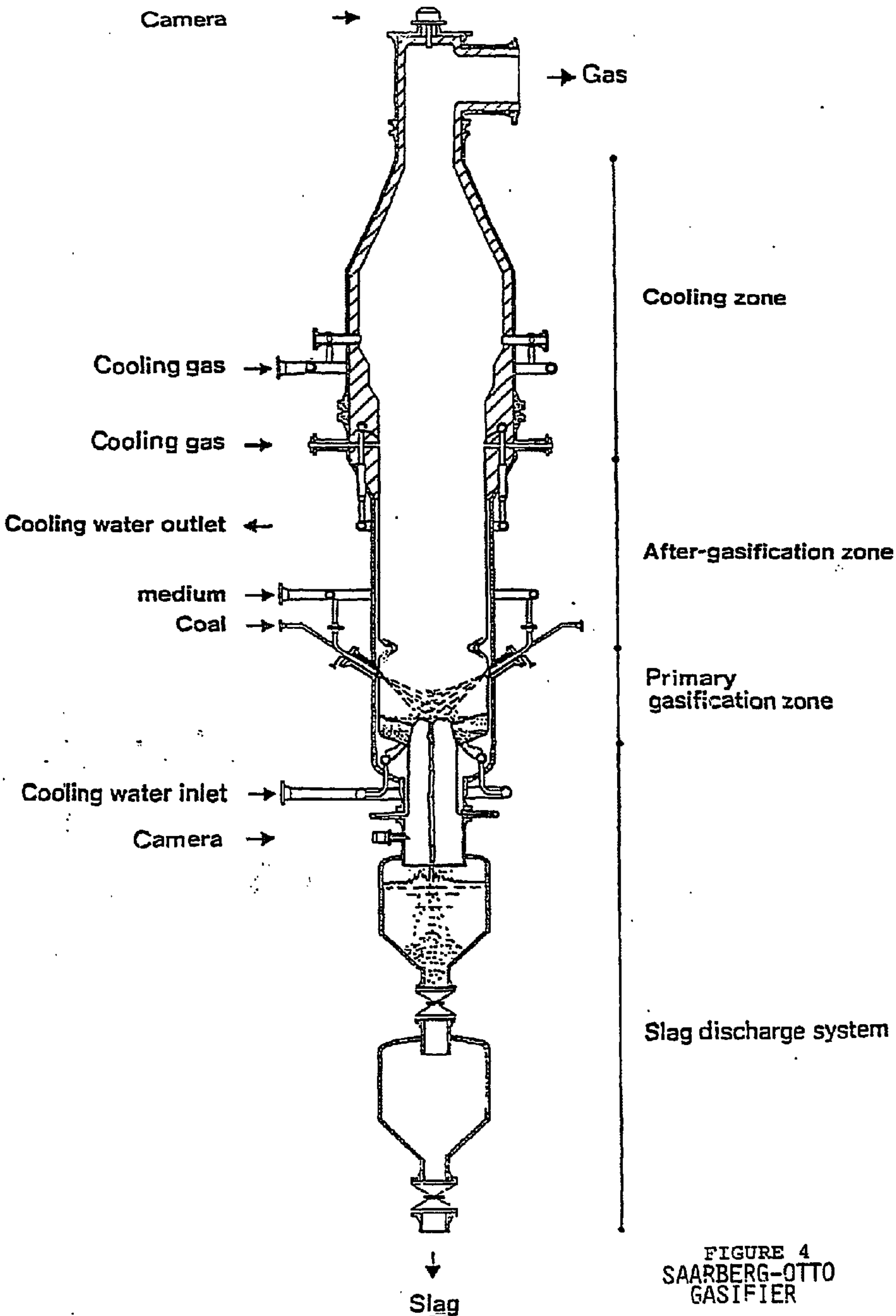


FIGURE 4
SAARBERG-OTTO
GASIFIER

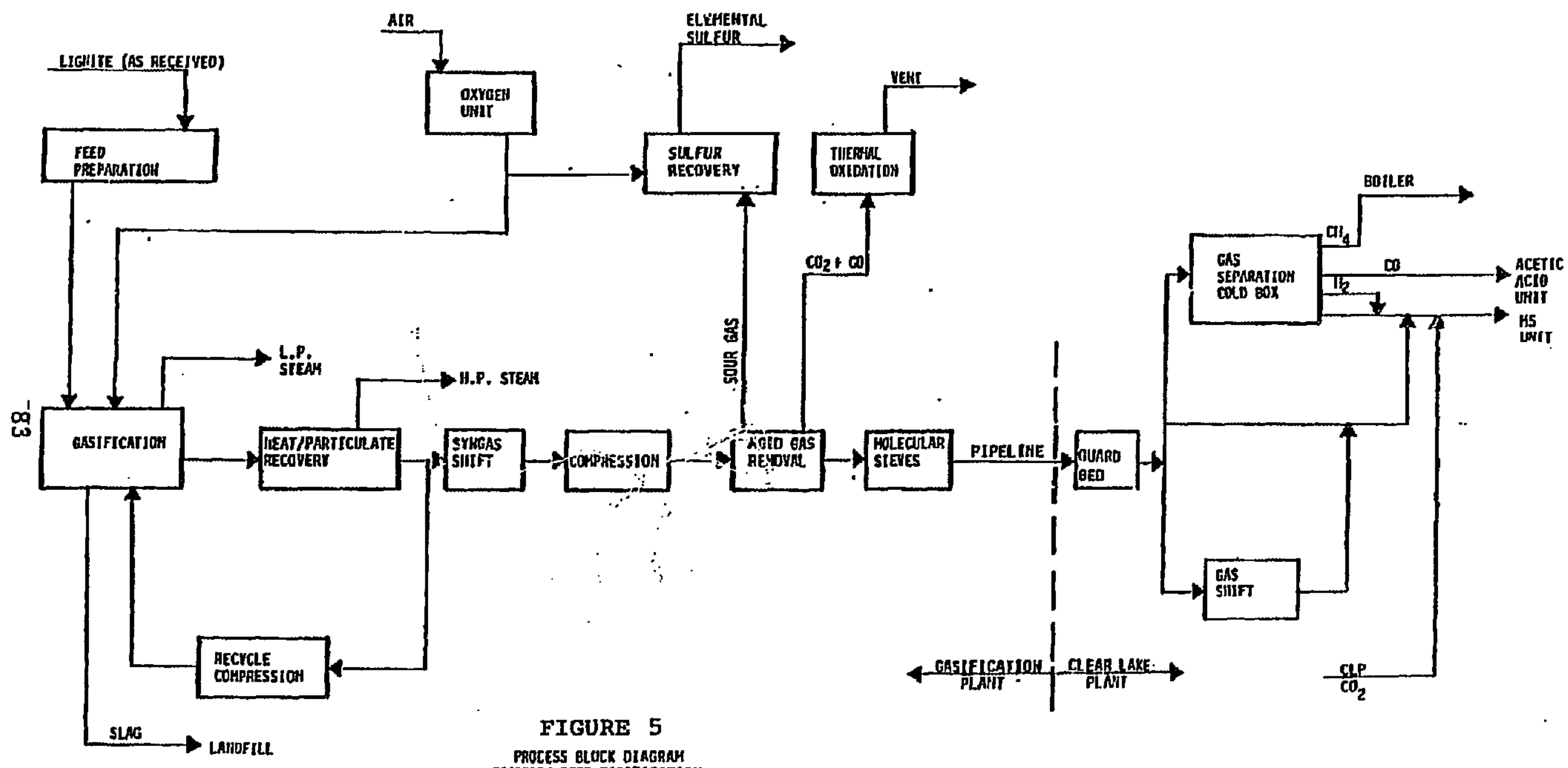
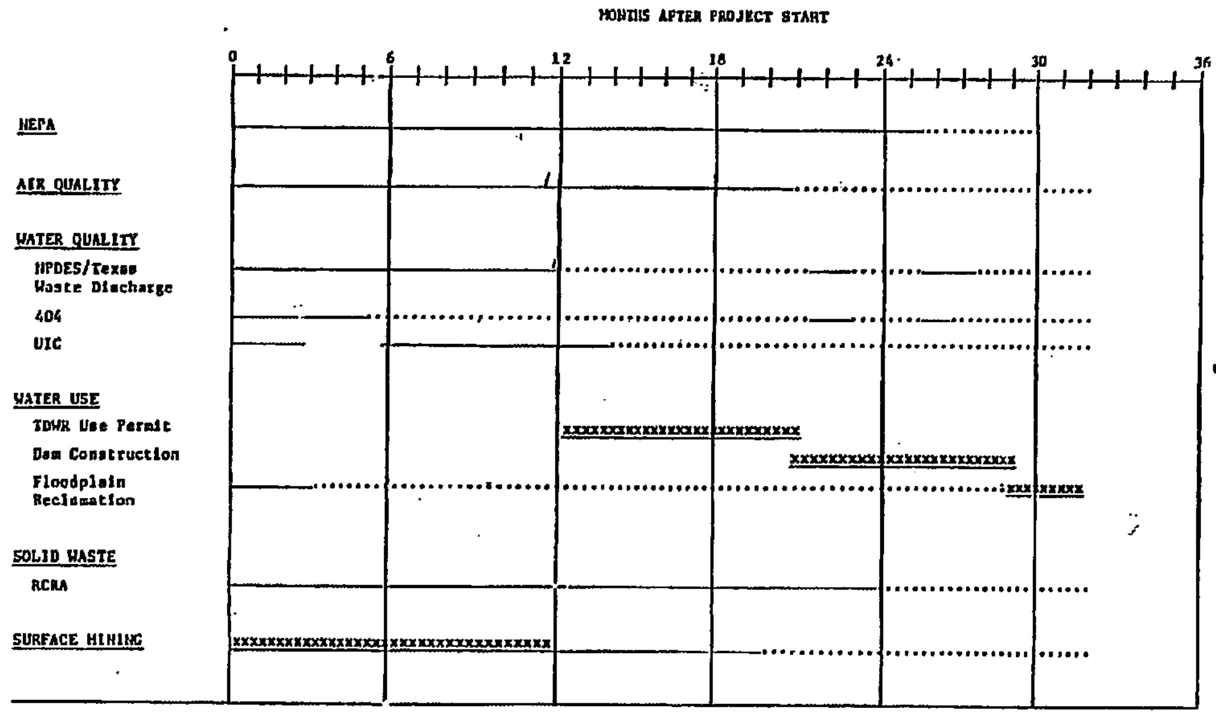


FIGURE 5

PROCESS BLOCK DIAGRAM
SAARBERG-OTTO GASIFICATION

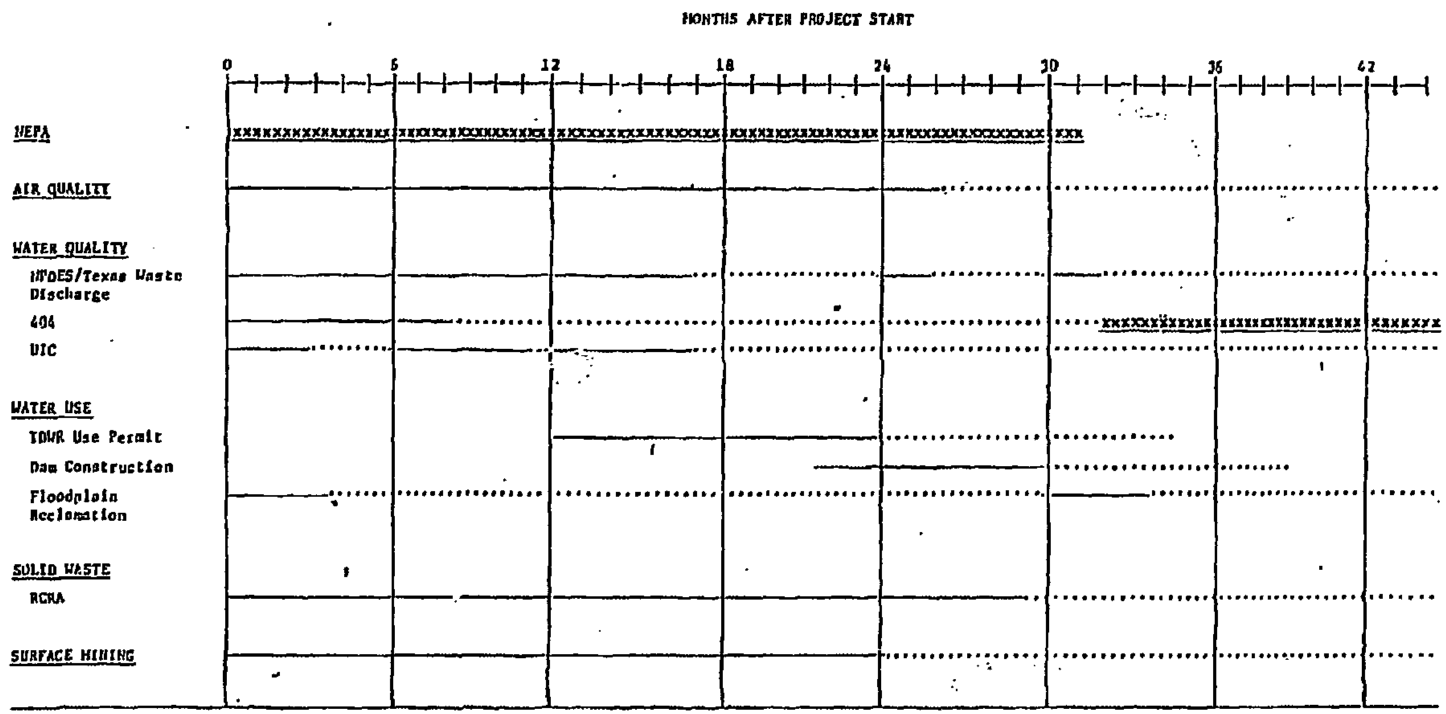


Explanation: Scheduled Work Float ..... Critical Path xxxxxxxxxxxx

Notes: 1. Scheduled work for major programs often represents a composite of several activities; see Table 3 for detailed and itemized program schedules.

2. Periods of float between scheduled work activities within a major program may represent regulatory reviews and decisions. Refer to CPM network diagram (baseline case).

Figure 6 REGULATORY COMPLIANCE PLANNING SCHEDULE - PESSIMISTIC CASE



Explanation: Scheduled Work Float ••••• Critical Path XXXXXXXXXXXX

Notes: 1. Scheduled work for major programs often represents a composite of several activities; see Table 3 for detailed and itemized program schedules.
2. Periods of float between scheduled work activities within a major program may represent regulatory reviews and decisions. Refer to CPM network diagram (pessimistic case).

Figure 7 REGULATORY COMPLIANCE PLANNING SCHEDULE - BASELINE CASE

TABLE B

PHASE I CAPITAL ESTIMATE -- SOURCES AND METHODS
GASIFICATION COMPLEX

Unit Operation	Estimate[a]	Data Source	Basis of Ratio Factor
Gasification	(V) (F)	Texaco	Throughput and waste heat recovery
POX	(C) (F)	Celanese	Throughput
Sour Shift	(R) (V)	Rust/Haldor-Topsoe	-
Autothermal Reforming	(V) (F)	Lurgi	Throughput
Compression	(C) (F)	Celanese	Horsepower
Acid Gas Removal	(C) (F)	Celanese	Throughput
Sulfur Recovery	(V) (F)	Hannon-Western	Throughput
Methane Separation	(C) (F)	Celanese	Throughput
Air Separation	(V) (F)	Linde A.G.	Throughput or hp
Steam Generation-FGD	(R)	Rust	-
Power Generation	(R)	Rust	-
Material Handling	(R) (F)	Rust	Throughput
Waste Treatment	(R) (F)	Rust	Throughput and waste pond area
Miscellaneous [b]	(R)	Rust	-

a. Rust Estimate (R), Celanese Estimate (C), Vendor Estimate (V), Ratio Factor (F) of R, C, or V.

b. Sitework, roads, railroads, pipeways, fire protection, buildings, tankage, foundations, interconnects, etc.

TABLE .D

PHASE I PARAMETER RANKING

TECHNOLOGY RANKING

Ranking	Process	Gasifier Type	Highest Economic Ranking
1	HTW	Fluidized Bed	1
2	Texaco	Entrained Bed	3
3	U-Gas	Fluidized Bed	4
4	Saarberg-Otto	Entrained Bed	7
5	Westinghouse	Fluidized Bed	18
6	Lurgi	Fixed Bed	39

FEEDSTOCK RANKING

Ranking	Feedstock	Highest Economic Ranking
1	Lignite	1
2	Illinois No. 6	3
3	New Mexico	13

LOCATION RANKING

Ranking	County	Highest Economic Ranking
1	Robertson	1
2	Shelby	2
3	Brazoria	3
4	Fort Bend	5

TABLE F

PHASE II CAPITAL COST SOURCES

Process Area	HTW Robertson Lignite	S-O Robertson Lignite	Texaco Robertson Lignite	Texaco Brazoria Ill. # 6
I. GASIFICATION	Rust Est. Scaled from U-Gas. Memphis, Telecon 9/2/81.	From Process Package	Scaled from Coastal Bend Texaco "B" Package dated 8/14/81.	
II. SOUR SHIFT	Rust Estimate and Haldor-Topsoe Quote dated 7/7/81.			
III. COMPRESSION	Scaled from Process and Power Equipment Sales (Elliott) quotation dated 10/7/81.			
IV. ACID GAS REMOVAL	Scaled from Lotepro Estimate. (undated)			
V. SULFUR RECOVERY	Scaled from Hannon Western quotation dated 7/9/81.			
VI. OXYGEN PLANT	Scaled from Lotepro Estimate dated 6/19/81.			
VII. ASH HANDLING	Rust Estimate - See Rust Interoffice Memo dated 10/14/81.			
VIII. MATERIAL HANDLING	Rust Estimate - See Rust Interoffice Memo dated 10/14/81.			
IX. BOILER	Rust Estimate - See Rust Interoffice Memo dated 9/22/81.			
X. FGD SYSTEM	Rust Estimate - See Rust Interoffice Memo dated 10/14/81.			
XI. TURBINE GENERATOR	Rust Estimate - See Rust Interoffice Memo dated 9/22/81.			
XII. WASTE TREATMENT	Rust Estimate - See Rust Interoffice Memo dated 10/14/81.			
XIII. MISCELLANEOUS	Rust Estimate - Identical for all cases.			
XIV. WATER SYSTEM	Rust Estimate (3)			
XV. SYNGAS PIPELINE	Ford, Bacon and Davis Estimate (8)			

TABLE II

PHASE II SUBJECTIVE RANKING

FACTORS	Weighting Factors	KRW Lignite		Saarberg-Otto Lignite		Texaco Lignite		Texaco Illinois #6	
I. PROCESS MATURITY									
A. Process Design Experience	0.9	34.7	31.23	36.9	33.21	33	29.7	38.4	34.56
B. Mechanical Design Experience	0.9	37.3	33.57	37.3	33.57	33.7	30.33	37.1	33.39
C. Pilot Plant Experience	0.8	34	27.2	31.6	25.28	24.2	27.36	36.0	28.8
D. Commercial Experience	1.0	23.4	23.4	23.4	23.4	22.2	22.2	23.8	23.8
E. Scale - Up Requirements	1.0	36.8	36.8	41.2	41.2	38	38	43.4	43.4
II. OPERABILITY	Subtotal I	#3	152.2	#2	156.66	#4	147.59	#1	163.95
A. Reliability	0.9	35.7	32.13	36.9	33.21	33.5	30.15	33.7	30.33
B. Complexity	0.5	35.2	17.6	38.6	19.3	35.7	17.85	36.3	18.15
C. Frequency of Maintenance	0.1	33	3.3	34.2	3.42	30.3	3.03	30.5	3.05
D. Cost of Maintenance	0.1	32.6	3.26	34	3.4	30.3	3.03	30.5	3.05
E. Sparing Requirements	0.1	33.8	3.38	38	3.8	32.1	3.21	32.3	3.23
III. FLEXIBILITY	Subtotal II	#2	59.67	#1	63.13	#4	57.27	#3	57.81
A. Turndown Capability	0.2	42.4	8.48	39.4	7.88	40.9	8.18	39.9	7.98
B. Environmental Impacts	1.0	33.6	33.6	35.2	35.2	35.9	35.9	34.8	34.8
C. Retrofit Impact on Clear Lake	0.1	43.2	4.32	39.8	3.98	41.4	4.14	40.8	4.08
D. Feedstock Ranges	0.5	37.7	18.85	37.1	18.55	34.9	17.45	36.8	18.4
IV. ENVIRONMENTAL	Subtotal III	#4	65.25	#2	65.61	#1	65.67	#3	65.26
A. Emission Allowable	1.0	33.7	33.7	35.3	35.3	37.3	37.3	33	33
B. Disposal of Ash	0.2	40.2	8.04	44.4	8.88	42.4	8.48	43	8.6
C. Disposal of Wastewater	0.3	34.8	10.44	38.8	11.64	35.6	10.68	35	10.5
TOTAL	Subtotal IV	#3	52.18	#2	55.82	#1	56.46	#4	52.1
			329.3		341.2		326.99		339.12
			#3		#1		#4		#2

TABLE I

PROCESS DATA
SAARBERG/OTTO PROCESS-LIGNITE

At Gasification Plant [1]	
Fuel Preparations	
Lignite Feed - Dryers (AR)	429 TPD
Gasifier	
Lignite Feed (AR)	8707 TPD
Oxygen Feed	4485 TPD
Quenched Outlet Temperature	1470°F
Pressure	600 PSIG
Numbers Operating/Spare	2/1
Fuel Size	$<$ 3 mm
H.P. Steam Generation	518 M PPH
Boiler/Fired Superheaters	
Lignite Feed (AR)	3066 TPD
Total Steam Generated	1.84 MM PPH (900 PSIG-850°F)
Water	
Raw Water Intake	4.8 MM GPD
Cooling Tower Make-up	2400 GPM
Cooling Tower Circulation	175 M GPM
Boiler Make-up	~ 620 GPM
Waste Products	
Gasifier Slag	1438 TPD
Boiler Ash (Fly + Bottom)	497 TPD
FGD Sludge	115 TPD
Sulfur	61 TPD
At Clear Lake Plant	
Syngas Usage	
Methanol Production	208.3 MM SCFD H_2 + CO
Acetic Acid Production	19.2 MM SCFD CO
Boiler	
Steam Generated	600 M PPH (900 PSIG - 850°F)
Fuels: Syngas	34 MM SCFD H_2 + CO
Methane from cold box	.2 MM SCFD
MS Purge Gas	36 MM SCFD

(1) Quantities presented are 15% greater than Rust material balances for Clear Lake Plant boiler syngas fuel.

(AR) is as received

TABLE N

STATUS OF 2ND GENERATION GASIFICATION PROCESSES

GASIFIER	LARGEST OPERATIONAL (T/D)	PLANS SIZE (T/D)	LOCATION	TIMING
ENTRAINED BED				
Texaco	400	900	Kingsport, TN	1983/1984
		1000	Coolwater, CA	1984
Shell	150	1000-2000	Germany and/or	1985+
		1000-2000	Holland	1985+
S/O	290	-	-	1985+
FLUIDIZED BED				
HTW	39	660 (12% Moisture)	Germany	1984
U-Gas	24	1100	Memphis, TN	1985+
Westinghouse	35	1200	South Africa	1983/1984
FIXED BED				
Slagging Lurgi	300	600-800	Scotland	1982/1983