TECHNICAL EVALUATION SERVICES. FINAL REPORT. RESEARCH AND DEVELOPMENT REPORT NO. 82

PARSONS (RALPH M.) CO., WASHINGTON, D.C

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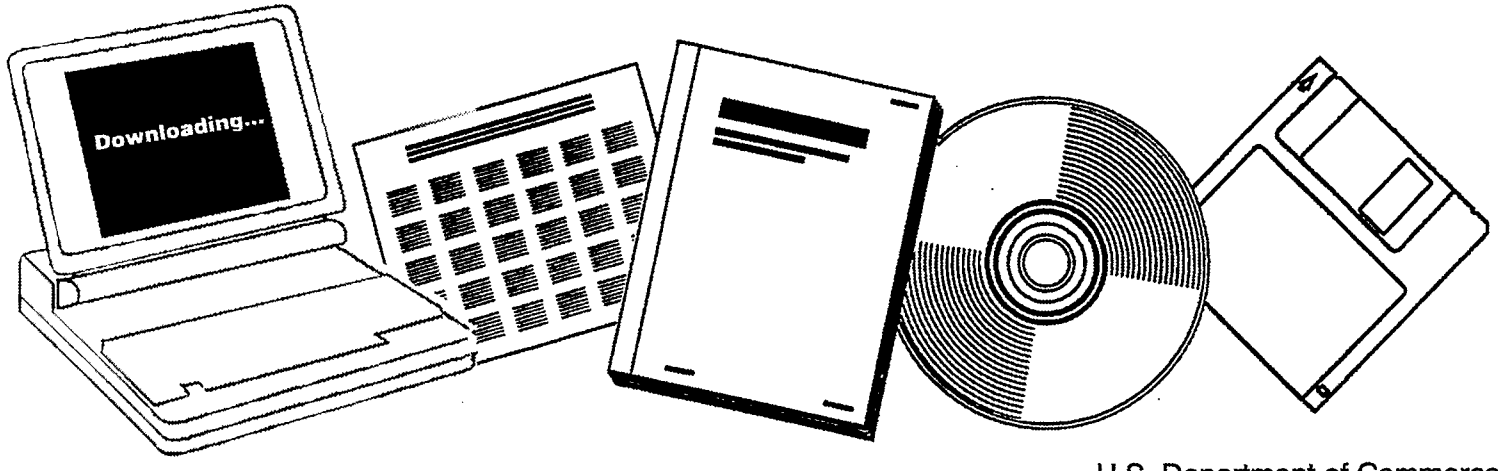

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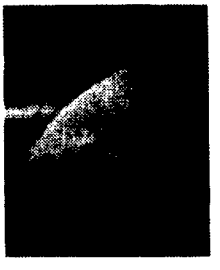

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TECHNICAL EVALUATION SERVICES

FINAL REPORT

RESEARCH AND DEVELOPMENT REPORT NO. 82

Prepared by:

THE RALPH M. PARSONS COMPANY

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Pasadena, California 91124

November 1977

Prepared for

DEPARTMENT OF ENERGY

OFFICE OF ASSISTANT SECRETARY FOR ENERGY TECHNOLOGY

DIVISION OF COAL CONVERSION

Washington, D.C. 20545

Contract No. EX-76-C-01-1234

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TABLES

FIGURES

ABBREVIATIONS

bbl	barrels
bbl/d	barrels/day
Btu	British thermal unit
COED	Coal-Oil-Energy-Development
COG	Coal-Oil-Gas
DCF	discounted cash flow
DOE	Department of Energy
ERDA	Energy Research and Development Administration
GOCO	government ownership - company operated
HDS	hydrodesulfurization
LCDC	Liquefaction Coal Development Corporation
MM and mm	million
MW	megawatt
OCR	Office of Coal Research
OSHA	Occupational Safety and Health Administration
PDU	process development unit
P & I	piping and instrumentation
P & M	Pittsburg and Midway Coal Mining Company
ROM	run-of-mine
SNG	substitute natural gas
SRC	solvent refined coal
SRL	solvent refined lignite
T/D	tons per day
UND	University of North Dakota

SECTION 1

INTRODUCTION

On October 31, 1972, the U. S. Department of Interior's Office of Coal Research (OCR) later to become a part of Energy Research and Development Administration (ERDA) and then the Department of Energy (DOE), and The Ralph M. Parsons Company entered into a four-year contract; the objective of the contract was "to have performed technical evaluation services relative to clean liquid and/or solid fuels from coal, directed toward the development of a design for a commercial plant which will reliably produce clean liquid and/or solid fuels from coal at a cost which is competitive with alternate sources of equivalent fuels."

The contract scope was expanded and period of performance was extended by twelve modifications; the contract was extended to August 31, 1977. Also, an additional Contract, E(49-18)-1775 was executed with OCR on December 31, 1974; the bulk of the conceptual design/economic evaluation work was transferred to Contract -1775 at that time.

A number of task assignments were completed under Contract E(49-18)-1234. Some of these were major, long duration, efforts and some were brief response efforts. All were intended to assist OCR and ERDA to achieve their objective of defining and developing effective coal conversion technology. General categories of work performed included:

- Development of Conceptual Designs/Economic Evaluations
- Assessment of performance and potential for certain development programs
- Supply of construction support services
- Proposal Reviews
- Presentation and publication of results of our work
- General response items

Completion of this wide range of activities required the broad expertise provided by several hundred people over the course of the contract work. As required, process engineers, project engineers, discipline engineers, environmental engineers, economists, and many other skills were applied. Of particular importance is the balance of technical and economic skills for prediction of constructed value of large coal conversion plants; as a major international contractor who is daily buying major equipment items and installing them, realistic and current economic estimates are developed.

Reports have been transmitted and accepted for all major task assignments under this contract. This final report provides a summary of the results accomplished and a list of references for the reports which have been prepared under this contract and which contain detailed designs, data, conclusions and recommendations.

Acceptance of this report completes the contractual obligations of The Ralph M. Parsons Company.

SECTION 2

SUMMARY

The tasks assigned under Contract No. E(49-18)-1234 have been completed and the reports describing the results of the separate task efforts have been accepted. The work was completed on schedule and within budget.

The technical evaluation contractor assignments included work in the following areas:

- Development of conceptional design and economic evaluations for commercial scale plants.
- Assessment of performance of pilot plants and other experimental operations; also the potential economics to be expected from successful development of the separate technologies.
- Construction support services.
- Proposal reviews.
- Publication and dissemination of the results of the work.
- General response items.

To successfully complete these assignments, expertise was made available in such fields as coal mining and preparation, coal conversion technology, petroleum technology, power plant design, nuclear energy applications, systems engineering, economics, environmental analysis, and energy conversion.

Specific task assignments completed include the following major items:

2.1 CONCEPTUAL DESIGNS

2.1.1 CLEAN BOILER FUEL

The results were reported in a planning document[1] and the final R & D report which consisted of three volumes.[2,3,4]

The objectives of this design were:

- To establish a preliminary demonstration plant design to effectively produce clean boiler fuels from coal.

- To estimate the budget for fixed capital investment requirement for the design, engineering, procurement, and construction of the coal conversion plant.

- To estimate the earliest date at which the coal conversion plant could be mechanically complete and ready to begin operations.

- To estimate the required fund drawdown schedule; i.e., the amounts of money that would be expended during each semi-annual period over the life of the project.

The process design bases and yields for this plant were supplied by OCR, and its process development contractors; they were based on the OCR process design concept which was considered to have the greatest potential for converting a typical coal into low sulfur liquid fuels at a cost to be competitive with alternative fuel sources.

A brief summary description of the proposed demonstration plant to produce clean boiler fuels from coal follows.

The design uses purchased coal feed. The coal conversion process plants consist of a coal liquefaction unit and a gasifier unit to produce synthesis gas (syngas) from coal-derived materials. Ten thousand tons of coal per day are fed to the liquefaction unit, which is a modified SRC plant; it uses SRC II processing with recycle of unfiltered coal dissolver effluent to slurry the coal feed. This dissolver unit will dissolve the majority of the feed coal in a coal-derived solvent in the presence of reducing gases at elevated temperatures and pressures. The lighter clean boiler fuel, containing 0.2% sulfur, is produced by hydrodesulfurization (HDS) of a portion of de-ashed solvent refined coal. The filter cake, produced by separation of undissolved coal plus coal ash from liquid products, is fed to the gasifier unit where it reacts with steam and oxygen at elevated temperature and pressure to produce the hydrogen-containing reducing syngas required for the coal dissolving step. By-product light hydrocarbons produced are burned captively as fuel to produce the necessary steam and electrical energy required to operate the complex.

An artist's conception of the plant is presented as Figure 1 at the end of this section. We estimated that the facilities would occupy approximately 350 acres; a site containing 600-plus acres is recommended.

A fixed capital investment was developed for use in planning future budgets; the estimate is preliminary and is targeted to be within the -5 to +20% accuracy range, based upon the process selected. The estimating procedure used included determination of the costs of major equipment items plus historical in-house costs and factors to determine final plant constructed costs.

The estimated fixed capital investment was $270 million in mid-1973 dollars.

Economic projections were based on use of the discounted cash flow (DCF) rate of return method of determining return on invested capital. The product selling price required to provide a specified DCF was estimated for a number of financial parameters. All economics were mid-1973 based. Sensitivities of required product selling prices to investment cost, cost of coal, other operating costs and profitability were presented. The economics are summarized in Section 3 of this report.

The environmental factors were assessed and the results of this assessment published.[5]

2.1.2 COED PLANT DESIGN

A conceptual design/economic evaluation was ninety percent completed for a coal conversion complex consisting of a captive coal mine; a process plant to convert 25,000 tons of clean washed coal to synfuels plus fuel gas, and a power plant to produce up to 1,000 megawatts of electrical power. The process plant used COED-based technology.

In predesign work, we reviewed the data generated at the COED pilot plant in Princeton, New Jersey. Reaction rate, heat transfer and mass transfer principals were applied to accomplish a 750-to-one scale-up ratio from pilot plant operations to the commercial plant design.

Interim progress on this design was reported under this contract[6] and the final R & D report was completed and issued under Contract No. E(49-18)-1775.[7]

2.1.3 OIL/GAS PLANT DESIGN

A process concept and very preliminary economic evaluation was developed at the request of OCR in support of the Project Independence Blueprint effort. The term Oil/Gas was coined during this Project Independence work for a concept of a large coal conversion complex to use SRC II technology to produce low sulfur fuel oils plus significant substitute natural gas (SNG).

This conceptual plant produced 100,000 barrels per day of liquid fuels plus 500 million standard cubic feet per day of SNG. The concept and its projected economics have been summarized.[8]

2.1.4 FISCHER-TROPSCH PLANT DESIGN

Two concepts of Fischer-Tropsch plants to be responsive to U. S. requirements were developed. The first, a small unit, was developed in response to the question posed by OCR: Should there be a place for Fischer-Tropsch plants in future U. S. synfuels plans; if the answer is yes, what role should Fischer-Tropsch technology play? The second concept/economic evaluation was developed under a tight deadline schedule for the Project Independence Blueprint effort. The results of these two conceptual design/evaluation efforts have been published.[8,9]

2.1.5 COAL MINES

As part of the total conceptual design effort, we developed conceptual designs/economic evaluations for coal mines.

The initial objective was to develop a conceptual design and economic evaluation for facilities to (1) mine a minimum of 12 million tons per year of Illinois No. 6 seam coal and, (2) prepare it in a form suitable for use as feed to coal-conversion process plants. The initial mine conceptual design/economic evaluation was used for the COED process conceptual design/economic evaluation.

The long-range objective was development of conceptual designs and economic evaluations for mines in additional geographic areas. These mines were to supply coal to conceptual coal conversion plants.

Conceptual surface coal mine design was developed for the mid-western U.S.A. area and the results were reported in detail.

2.2 TECHNICAL EVALUATION, EXPERIMENTAL OPERATIONS

Four comprehensive development programs were reviewed in detail.

2.2.1 SOLVENT REFINED COAL (SRC)

The SRC development program was reviewed, including the development of data for use in design of the 50 ton per day pilot plant located at Fort Lewis (Tacoma), Washington, design of the pilot plant, operation of the pilot plant, probability test the program would develop information adequate for design of a demonstration plant, and the data which could be expected to be produced during the following six months of operation. A report, presenting opinions on each of these points, plus recommendations, has been published.[10]

2.2.2 CLEAN COKE

The Clean Coke program was reviewed in detail. Clean Coke is a proposed coal conversion technology to convert high sulfur marginal quality coal to metallurgical grade coke plus numerous commodity chemicals. Key process steps were being tested in process development units at the U. S. Steel research facilities located at Monroeville, Pennsylvania.

A report summarizing the status of the development, progress on the PDU work, and projected economics for a commercial scale plant has been published.[11]

2.2.3 PROJECT LIGNITE

Project Lignite is a program to define preferred technology to convert lignite to gaseous, liquid and solid fuels. The technology was being

investigated in a PDU operated by the University of North Dakota at Grand Forks, North Dakota. We reviewed the program and progress in the PDU in detail.

A report describing the results of our program review as well as a review of the potential economics has been published.[12]

2.2.4 COED

The COED pilot plant used low pressure pyrolysis technology. It was operated by FMC Corporation at Princeton, New Jersey under OCR funding. We reviewed the pilot plant program in detail.

The primary objective was to assess the status of the pilot plant development program and to determine if adequate data were present for a commercial plant design; if data were inadequate, to then define additional development programs required to be carried out using the pilot plant facilities. The results were to be used to develop a conceptional design and cost estimate for a commercial plant facility utilizing the COED process design concept.

A review of existing laboratory and pilot plant data was completed with emphasis being placed upon the adequacy and completeness of these data for preparation of a commercial plant design and a further definition of any deficiencies and additional required data. The results were incorporated into our conceptual design.[7]

2.3 CONSTRUCTION SUPPORT SERVICES

We provided construction support services to OCR/ERDA for the SRC pilot plant and for the Cresap pilot plant reactivation.

2.3.1 SRC PILOT PLANT

The primary objective was to review the design/construction and planned operation of the SRC pilot plant; to define any problems, and to recommend corrective action to OCR. Additionally, the objective was to review construction progress for the SRC pilot plant and to make appropriate recommendations to OCR and ERDA.

2.3.1.1 Design Review

Parsons reviewed the process data, material balances, P&IDs, overall process design, and three possible alternate modes of SRC pilot plant operation and the effect on the capacities of critical process equipment. The philosophy of process control was reviewed and a study was made of the Data Logging Computer to evaluate its performance in data procurement, process calculations, data interpretation, and printout records.

2.3.1.2 Mechanical Review

A complete review was made of critical equipment specifications for completeness of design, safety, operability and maintainability. A cursory review was made of structural, civil, piping, electrical, and instrument control drawings to evaluate the capability and operability of the process units. An environmental review was made to ensure adequacy of plant design to control effluent streams.

2.3.1.3 Construction Review

We made monthly job site inspections to establish construction job progress and to advise OCR and ERDA of any problems and recommend possible appropriate corrective action. The detailed supporting calculations for contractor job progress were reviewed and recommendations made to OCR and ERDA.

2.3.2 CRESAP PILOT PLANT REACTIVATION

We supplied Acceptance and Inspection services to ERDA for the reactivation of the donor solvent coal liquefaction pilot plant located at Cresap, West Virginia. The assignment was restricted to the review of code conformance and agreement of the installations with the Engineers' (Fluor Engineers and Constructors, Inc.) design, mainly as presented in the Engineers' mechanical flow diagrams. Quality of workmanship such as piping weld quality and accuracy of instrument connections (loop checks) were not included in our scope of work; responsibilities for these resided with the construction crafts.

Construction was more than 50% complete when we started our work.

Elements of our work included:

- Certification of Vessels
- Proper construction with defined scope of work exceptions as noted above.
  - installed equipment was inspected for conformity with mechanical flowsheets.
  - capacity limiting equipment such as tanks, compressors, pumps, and rotative equipment were checked against equipment specifications.
  - piping, instrumentation and control valves were checked for proper hook-up in accordance with appropriate diagrams. Equipment and pipelines were checked for materials of construction as specified. Several defined scope of work exceptions have been noted in the introductory portion of this section.

- Safety
  - review defined portions of the plant and plant operating procedures.

The results of this work have been reported.[13]

2.4 PROPOSAL REVIEW

Approximately 60 proposals to OCR/ERDA for support of new or continuing development programs were reviewed and reports transmitted to OCR/ERDA. Each report contained substantiated recommendations, in many cases based on preliminary economic analyses. The transmittals were in the form of letter reports.

2.5 PAPERS AND PRESENTATIONS

We responded to invitations to present summaries of our work plus opinions to a U. S. Senate Committee and technical societies; also, to publish summaries of our work for rapid and effective distribution of the results. Six such presentations/publications were completed in addition to the formal reporting to OCR and ERDA.

2.6 GENERAL

We completed a number of shorter duration response assignments and reports during the course of the contract work. The results are contained in our letters P-1 through P-317 to OCR/ERDA dated September 13, 1972 through August 31, 1977.

2.7 FOLLOWING REPORT SECTIONS

Additional detail describing the work accomplished is presented in Sections 3 through 8 of this report.

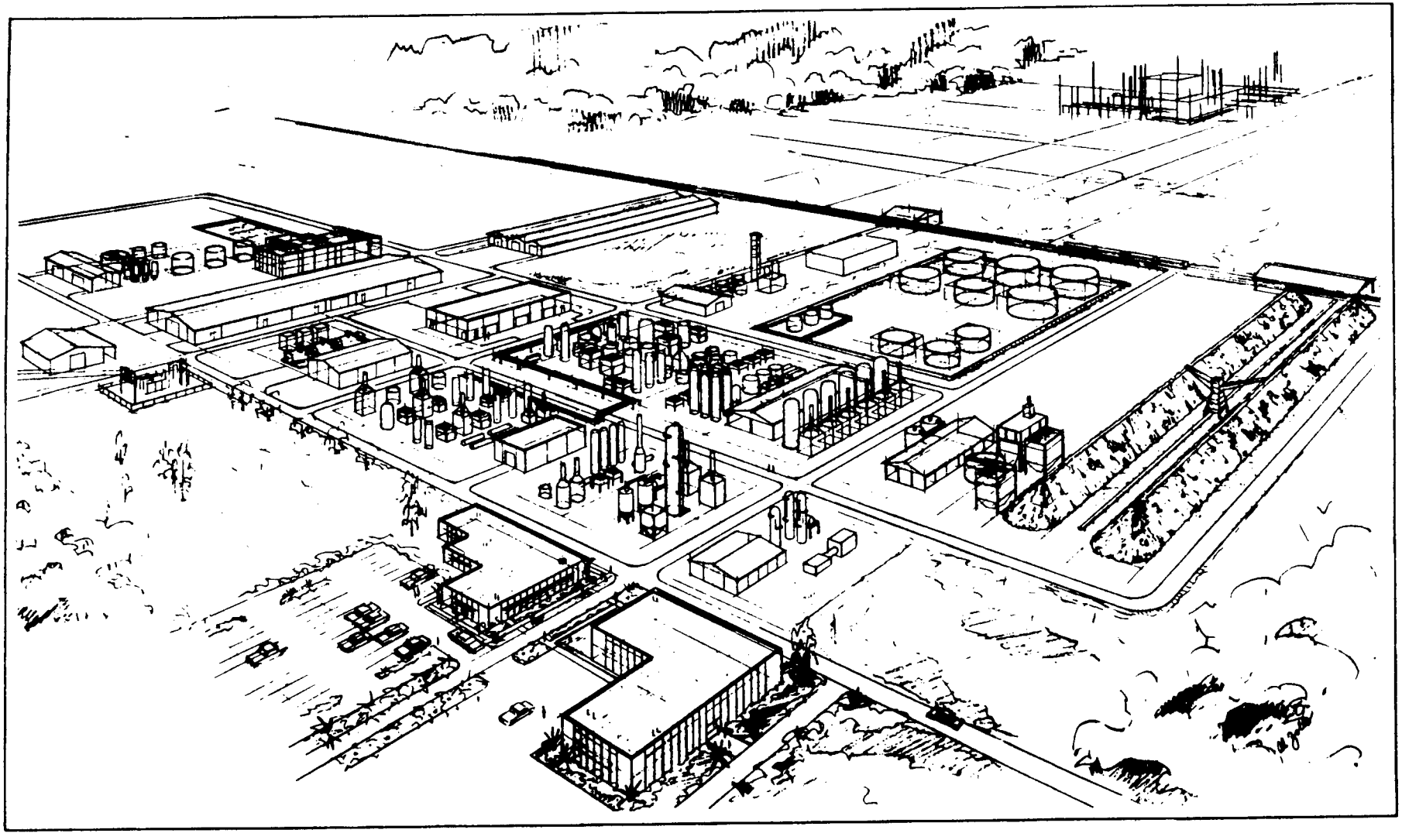

Figure 1 - Artist's Concept of Demonstration Plant

SECTION 3

CONCEPTUAL DESIGNS

3.1 CLEAN BOILER FUEL DEMONSTRATION PLANT

We responded in the fourth quarter of 1972 to requests by OCR to assist them in their planning; to do this by developing a proposed process configuration, probable fixed capital investment, and schedule of fund requirements for a demonstration scale plant to produce "clean" boiler fuels from coal. Following this planning effort, we were authorized by OCR to develop a conceptual design and economic evaluation for this type of demonstration scale facility. This work was completed and the results were published in 1973.[2,3,4] A summary of the design and economic characteristics follows.

We completed a detailed preliminary process design, capital investment estimate, and projected economics for a project to design, engineer, procure, construct, and start up a demonstration scale plant to produce clean boiler fuels from coal. The design used purchased coal. The results of this work are summarized below.

The project plan was based on construction of a demonstration plant in the Eastern Region of the Interior Coal Province. This region consists primarily of the states of Illinois, Indiana and Kentucky. This location meets the criteria of availability of large resources of high-sulfur coal and a large potential utility/industrial market that has ecological restrictions for high-sulfur coal use.

The design basis was provided by consultation with OCR and its process development contractors The demonstration plant had the capacity to process 10,000 tons of coal per day and produce approximately 25,000 barrels of low sulfur liquid products. The primary products consist of two grades of clean boiler fuels; secondary products are a high-grade naphtha and sulfur. The liquid boiler fuels will have an energy content of approximately 145 billion Btu per day, which can generate 620 megawatts of electrical energy based on a 35% efficiency in the power generation step.

The largest quantity boiler fuel was roughly equivalent to a No. 6 fuel oil, contained 0.5% sulfur, and provided 65% of the boiler fuel energy produced. The second boiler fuel approximated a No. 4 fuel oil with 0.2% sulfur content and amounted to about 35% of the fuel product.

All utilities required to operate the plant were captively produced. The only fuel feed was coal.

The coal conversion process units consisted of a coal liquefaction unit and a gasifier unit to produce synthesis gas (syngas) from coal-derived materials. Ten thousand tons of coal per day were fed to the liquefaction unit, which is essentially an SRC II type plant. This was the first SRC II design published. The liquefaction unit will dissolve the majority of the feed coal in a coal-derived solvent in the presence of reducing gases at elevated temperatures and pressures. The lighter clean boiler fuel, containing 0.2% sulfur, was produced by hydrosulfurization of a portion of the liquid fuel produced in this process unit. The filter cake, produced during the process of separation of residual coal and liquid products, was fed to the gasifier unit where it was reacted with steam and oxygen at elevated temperature and pressure to produce the hydrogen-containing reducing syngas required to operate the complex.

An artist's conception of the plant is presented in Figure 1, located at the end of the SUMMARY section. The preliminary estimate is that the facilities will occupy approximately 350 acres; a site containing 600-plus acres is recommended.

A block flow diagram, preliminary process flow diagram, complete with heat and material balances, a complete equipment list, and projected economics were developed.

A fixed-capital investment estimate was developed for use in planning future budgets; the estimate is preliminary and is targeted to be within the -5 to +20% accuracy range, based upon the process design and equipment as published, utilizing historical in-house costs and factors to determine final plant constructed costs.

The estimated fixed capital investment is $270 million expressed in mid-1973 dollars; all economics summarized here are in mid-1973 dollars.

Included in the $270-million estimate are the necessary ancillary facilities such as administration, laboratory, cafeteria, maintenance, warehouse, and other related buildings and equipment, maintenance equipment, road paving, fire prevention, and utilities distribution systems required to efficiently operate this grass roots complex in Southern Illinois.

In addition to the fixed capital investment for these physical facilities, it is estimated that an additional investment of $40 million would be required to carry the project through the startup period. These additional funds are for such items as initial charge of catalysts and chemicals, plant startup expenses, and initial working capital. The total budget project capital estimate, excluding interest during construction, therefore, is approximately $310 million for the period through startup. Depending on the financing arrangements used, the interest during construction is expected to be in the range of zero to $50 million.

There were a number of uncertainties in this design, which was based on immature technology and preceded the availability of experimental results from pilot plant operations for the two primary coal conversion steps of liquefaction and production of syngas by an entrained two-stage slagging type gasifier. We recommended that the future development program include data input from the total coal conversion program laboratory and pilot plant work to confirm and substantiate the design. Recommendations for a program to develop the required data and performance inputs were presented in the report.

The Tacoma SRC pilot plant was subsequently modified to test the SRC II mode of operation defined in this design.

The economic evaluation results are summarized below.

Investment and economic estimates are based on mid-1973 prices. The average product selling prices were projected to be $11.23 per barrel (bbl) per million Btu (MM Btu), based on private ownership, 65/35 debt/equity ratio, 7.5% interest rate, run-of-mine coal purchased at $5.75/ton, and a 10% discounted cash flow rate of return (DCF) on equity. These were economic parameters defined for the project in mid-1973.

If government ownership and operation (GOCO) of the demonstration plant were used, the break even point over a 10-year operating period (return invested capital but without interest), would occur at an average product selling price of $8.84/bbl or $1.40/MM Btu.

Other cases studied are summarized in Table 3-1 which follows:

Table 3-1 - Summary of Average Product Selling Prices Based on Coal at $5.75/ton Run-of-Mine

Ownership	10-year Project Life, 0% DCF ($MM Btu)	Average Product Required Selling Price[a]		
		DCF = 0% ($/MM Btu)	DCF = 10% ($/MM Btu)	DCF = 20% ($/MM Btu)
Government (not taxed)	1.40	1.08		
Private (100% equity)	1.60	1.21	2.12	3.63
Private (65% debt, 7-1/2% interest)	1.75	1.40	1.78	2.44
Private (65% debt, 9% interest)	1.79	1.45	1.85	2.51

[a] 20-year project life

Sensitivity analyses of required product prices to variation in coal costs, investment cost and profitability levels were calculated and were reported in Vol. III of R&D Report No. 82 - Interim Report No. 1.[4]

3.2 COED CONCEPTUAL COMMERCIAL PLANT

A conceptual design/economic analysis of a commercial coal pyrolysis based plant was begun under Contract No.E(49-18)-1234 and completed under Contract No. E(49-18)-1775. A summary of the design characteristics and projected economics for this design follows.

The objectives of the work described in this report were to:

- Review the experience obtained during the successful operation of the OCR/ERDA supported COED pilot plant operated by FMC Corporation at Princeton, New Jersey, over the period 1970 through 1974.
- Develop a conceptual design for a commercial COED-based industrial complex including all operations required to mine coal, prepare it by cleaning and washing it, convert it to ecologically clean liquid and gaseous fuels, and convert the gaseous fuels to electrical energy for sale.
- Estimate the economics for the facility to serve as a guide in making decisions regarding future commercial applications of this technology.
- Provide recommendations regarding additional development effort to foster commercial exploitation of the technology.
- Define probable project and financial parameters for design, engineering, procurement, construction, and startup of the complex.

Work was completed on a preliminary design and economic evaluation for a commercial complex to mine high sulfur coal and produce low-sulfur synthetic crude oil (syncrude), electrical energy, and sulfur using COED-based pyrolysis technology for the coal conversion portion of the complex and the results reported.[7] Approximately ninety percent of the design was completed under this contract and the remainder under Contract No. E(49-18)-1775.

The industrial complex consists of a large captive coal mine supplying the feed material to a coal preparation plant, which in turn supplies approximately 25,000 tons per day of clean, washed coal to a COED-based pyrolysis coal conversion plant. In a typical case, a COED facility produces approximately 28,000 bbl/d of 25°API, 0.1% sulfur syncrude plus low-sulfur fuel gases, as well as by-product sulfur. Fuel gases are fed to a close-coupled electrical power generation plant that produces electricity for in-plant use plus 830 Mw for export. It also produces steam for captive use in the complex.

The design provides operating flexibility to process coal showing a range of analyses which might be expected over the course of a 20-year operating life. This distinguished the design from others that have been based on a single typical coal analysis and that might be called single feed source or "point" designs. The use of a fixed coal feed rate and variable coal characteristics requires higher fixed capital investment to provide the necessary flexibility. It also results in variable product rates.

A block flow diagram, preliminary process flow diagrams with heat and material balances, complete equipment list, artist's conceptual drawing, thermal efficiencies, and model of the plant were developed and delivered.

To the best of our knowledge, this is the only OCR/ERDA/DOE plant design that recognizes the design requirements and economic implications of providing the required flexibility to accommodate variable feed composition.

The estimated fixed capital investment for the complex is $1 billion in first-quarter 1974 dollars. The total capital investment is estimated to be $1.125 billion; this includes the cost of initial raw materials, catalysts and chemicals, allowance for startup and land acquisition, and initial capital. Typical required product selling prices for the mixed syncrude plus electrical power product slate at 10% discounted cash flow rate of return (DCF), after by-product sulfur credit, are as follows:

Syncrude ($/bbl)	Electricity (mils/kWh)
10	32
15	25
18	20
26	10

Sensitivities of required selling prices to profitability and to key economic parameters were reported. An artist's concept and simplified block flow diagram for COED is illustrated.

3.3 OIL/GAS PLANT DESIGN

At the request of OCR in support of the Project Independence Program, Parsons developed the concepts/economic projections for the two coal liquefaction plants cited, namely the Oil/Gas and Fischer-Tropsch.

The Oil/Gas concept recognizes that methane and other light hydrocarbons are produced during coal liquefaction and that some methane is made during the coal gasification step used to produce synthesis gas for ultimate use in the hydroliquefaction step. To further develop this concept, we developed a process concept and very preliminary economics. A conceptual design and economic evaluation was prepared for a large complex to convert coal to low-sulfur liquid/solid products plus substitute natural gas (SNG). This was done at the request of OCR

and in support of the Project Independence Blueprint effort in 1974. The results were summarized at a public hearing.[8]

The projected complex would process about 60,000 tons per day of high sulfur coal and produce 1,000,000 barres per day of clean boiler fuel plus 580 million standard cubic feet per day of SNG; the boiler fuel would have a sulfur content of approximately 0.4%. The projected fixed capital investment, mid-1973 basis, was about one billion dollars. Economic parameters for evaluation were supplied by Project Independence; they included a coal price of $7.25/ton, delivered, a debt equity ratio of 75/25, a 5-year design/construction schedule, and a 9% interest rate. Based on a 12% discounted cash flow rate of return (DCF) and using the low $7.25 coal price, a required product selling price of $1.22 per million Btu, mid-1973 basis, was projected. Escalation to current dollars and increase of coal cost would significantly increase this value.

3.4 FISCHER-TROPSCH CONCEPTUAL COMMERCIAL PLANT

The development of a conceptual design and economic evaluation of a small Fischer-Tropsch plant to be responsive to U.S. energy needs was completed and the results have been summarized.[9] Subsequently, we responded to a request to prepare a concept and economic projection for a large complex to produce 100,000 bbl/day liquids in support of the Project Independence Blueprint program; these results were summarized.[8]

Key points in the Project Independence effort were a Fischer-Tropsch plant to process about 140,000 tons per day of coal to produce 100,000 barrels per day of fuel oil and 1,660 million standard cubic feet per day of SNG. The judgemental fixed capital investment, mid-1973 basis, was about $2 billion. Again, using the economic parameters supplied by Project Independence, the projected required average product selling price at a 12% DCF was $1.37 per million Btu. As in the case of the Oil/Gas figures previously cited, escalation to current dollars and increase of coal cost would significantly increase this selling price requirement.

SECTION 4

TECHNICAL EVALUATION SERVICES

4.1 INTRODUCTION

Parsons supplied technical evaluation services for a number of programs and efforts. These varied from opinions regarding feasibility and expected costs for single unit operations to review of major development programs. The results of four of this type assignment are summarized in the following paragraphs of this section.

4.2 SOLVENT REFINED COAL (SRC) DEVELOPMENT PROGRAM

At the request of ERDA, we reviewed the SRC development program; this included the results developed at the Merriam, Kansas laboratories, as well as the design, construction and operation of the 50 ton per day pilot plant located at Fort Lewis (Tacoma), Washington. Emphasis was placed on the assessment of whether the program would provide adequate data to permit design and operation of a demonstration scale plant. The results were summarized in a report titled "Solvent Refined Coal."[10]

The pilot plant is operated under ERDA Contract E(49-18)-496 by the Pittsburg and Midway Coal Mining Company (P&M), a subsidiary of Gulf Oil Company. This evaluation was performed under Modification No. 6 of ERDA Contract E(49-18)-1234.

The report summarizes plant performance to the date of report preparation, a prediction of output for the subsequent six months, and recommendations regarding future activities and programs to obtain suitable data for process evaluations, technical feasibility, and demonstration plant design.

We strongly recommended in 1973 that priority be given to large scale functional product testing by representative potential customers. The report therefore recognizes the importance of producing enough synfuels to permit product functional testing by intended customers. The pilot plant at that time was in the process of producing 3,000 tons of solid SRC for testing in a 22 megawatt power plant. It was being operated in the SRC-I mode.

At the time of the program review, the pilot plant was in the early days of conversion to permit operation in the SRC-II mode. The SRC-II process can produce greatly increased quantities of coal-derived liquids and reduced quantities of SRC solid product. Process evaluations indicated advantages for the flexibility and product compositions possible with the SRC-II process.

Recommendations were presented regarding the pilot plant activities to provide data for use in process evaluation and plant design. The recommendations include additional data for the SRC-I process, the SRC-II process, process and mechanical development, central data file procedures, analytical data, correlation work, and metals loss program.

4.3 CLEAN COKE

A report titled "Clean Coke Process (PDU-Stage)"[11] was published in 1976. The report summarizes the results of a review of the Clean Coke program being developed by U.S.S. Engineers and Consultants, Inc., at the Monroeville, Pennsylvania Research Laboratory of the United States Steel Corporation.

The program was initiated by U.S. Steel in 1968 and has been under ERDA sponsorship since 1972. The primary goal was to produce metallurgical grade coke from high sulfur marginal quality coal. Other products include fuel and chemical products. The principal coal conversion steps are hydroliquefaction to product liquids including a high boiling coal-derived binder, a carbonization step to produce char, and a coking operation using char and binder produced in the carbonization and liquefaction steps, respectively. Other process steps include coal preparation, intermediate gas purification, hydrogen production, and liquid product recovery/purification. It represented one of the most complex of the process concepts for coal conversion under development in the OCR/ERDA program.

The principal significance of successful development of this technology would be to provide the United States with the capability of using coal not now considered satisfactory coking coals to produce metallurgical coke usable in steel manufacture. The economic justification for development of the process as currently conceived is significantly dependent on successful production, recovery, purification and marketing of a number of chemical and fuel products.

Experimental facilities in operation at that time include analytical laboratory, bench scale units, and five separate process development units (PDU) which together will test the major steps required to successfully practice the Clean Coke Process. The objective of the PDU program is to provide a firm basis for improved prediction of commercial plant economic potential and pilot plant design.

The objectives of the evaluation were to:

- Review the operation of the Clean Coke Process Development Units (PDU's) operated by U.S. Steel Corporation.
- Review and evaluate the data generated to date in the PDU's and supporting laboratory scale work. Issue an evaluation report.
- Review and critique economic estimates made by U.S. Steel for OCR/ERDA dated September 1974, entitled "Revised Preliminary Economics" and based upon the Preliminary Process Design Report dated August 1972. Evaluate the "by-product chemicals" values used and check the market penetration required to obtain the credits for each major by-product.

The evaluation was based upon review of published reports and visits to the Monroeville Research Laboratory.

4.3.1 PROCESS DEVELOPMENT UNIT (PDU) STATUS

There were five PDU's associated with the program. These units were:

- Coal Preparation
- Carbonization
- Hydroliquefaction
- Coke Preparation
- Liquid Treatment

PDU's to produce finished chemicals were not scheduled to be built under the then-existing ERDA contract.

We concluded that a firm design basis for a Clean Coke Pilot Plant could not be established by the project objective date of January 1, 1977. The design of certain units (Carbonization, Coke Preparation and Coal Preparation) could probably begin by the project objective date.

Based on available information, we concluded that the required selling price for metallurgical grade coke was higher than presently obtained in integrated coal mining coke making operations by large steel producers. We recommended that concerted efforts be made to improve the economics of the process. We suggested candidate procedures for improving the economics.

Specific recommendations for process improvements were presented.[11]

4.4 PROJECT LIGNITE

A report titled "Project Lignite (PDU Stage)"[12] was published in 1976. Project Lignite was aimed at achieving successful operation of a process development unit (PDU) to convert lignite to synfuels using SRC-type processing. The product, using SRC-I mode of operation, was termed SRL for Solvent Refined Lignite. Our work was performed under Modification No. 6 to ERDA Contract E(49-18)-1234, Technical Evaluation Services.

Major objectives of our work were:

- Summarize work required as defined by tasks and schedule in the University of North Dakota (UND) contract.
- List the work accomplished and in progress; by task.
- Summarize conclusions from existing data generated on the UND contract.
- Evaluate the Solvent Refined Lignite (SRL) process from both technical and economic standpoints.
- Outline the future work planned and recommend the most effective experimental program to provide adequate data to scale-up the SRL process and evaluate the economic potential of the process. Include comments regarding additional data required to determine operability and scale-up feasibility.

- Comment on prospects for practical commercial operability.
- Comment on the assumptions made and results obtained by the UND Economics Department in its evaluation of a commercial SRL plant.

The PDU, located in Grand Forks, ND, was designed to process 50 lbs/hr of lignite at 30% moisture to produce SRL. It has been described in detail in ERDA Report FE-1224-T-1 dated September 1974.

During 1975, numerous PDU mechanical equipment problems were encountered and corrected. The major problem area during this period was repeated failure of stainless steel components. For example, the preheater coil failed on three separate occasions and was replaced with a new one each time. Metallurgical tests performed, under Parsons direction, indicated that the failure mechanism was due to chloride stress corrosion of the stainless steel. We recommended that, for the benefit of continuity of PDU operations and until the failure mechanism was fully understood, all high pressure components subjected to the chloride attack be replaced by Incoloy 800. New components fabricated of this material were installed in January of 1976. Since that time, to the best of our knowledge, no equipment failures due to chloride attack have been observed. In general, the PDU at the completion of our review work, was considered mechanically sound.

4.4.1 DATA ANALYSIS; PDU

The PDU as designed is capable of processing 50 lbs/hr of lignite through the liquefaction train, producing about 55 to 50 wt.% SRL on a MAF basis. This is similar to the design basis as selected from laboratory data and Pittsburg & Midway Coal Mining Company (P&M) recommendations. At baseline conditions of 2,500 psig, 750°F preheater outlet, 1.4 liquid and 334 gaseous hourly space velocities, respectively, and 1.9/1 solvent to coal weight ratio, the PDU is reportedly able to achieve solvent balance. Detailed material balance data was not yet available but was reportedly currently being compiled by Project Lignite for publication. These conditions were intended to be used for generating sufficient vacuum bottoms for shakedown operations for the solid-liquid separations units.

4.4.2 ECONOMICS

An evaluation of preliminary economics developed by UND for a 30,000 T/D SRL plant was completed. As a result of the evaluation we concluded that the fixed capital costs estimated by the process developers for Unit 12 - Coal Liquefaction and Filtration, should be increased by about 10 percent based on mid-1975 major equipment costs.

Our evaluation also indicated that if the UND estimate of oxygen requirements is correct, the oxygen plant cost should be increased by about 50 percent.

Regarding the plant total cost, we recommended an escalation factor for the period from mid-1973 to mid-1975 which was 20 percent greater than that used by the process developer. This would increase the total plant cost from $460 million to approximately $615 million, including the increases estimated for Unit 12 and the oxygen plant.

In the development of average required product selling price we estimated, for planning purposes, about $1.90/MM Btu for mid-1975 in contrast to the $1.53/MM Btu by the process developer UND, based on a 12 percent discounted cash flow rate of return (DCF). In addition to the increase in total plant cost, the selling price increase was a result of other economic factors. For example, for this preliminary evaluation, we recommended a four-year construction schedule.

4.4.3 RECOMMENDATIONS

A number of recommendations were made regarding design of experiments, project evaluation check points, and future pilot planting.

SECTION 5

CONSTRUCTION SUPPORT SERVICES

5.1 SOLVENT REFINED COAL PILOT PLANT

Design and construction progress review services were supplied for the 50-ton-per-day Solvent Refined Coal (SRC) pilot plant located at Fort Lewis (Tacoma), Washington. This section briefly summarizes key elements of this portion of the contract performance.

At the direction of OCR we began, in December 1972, to review the SRC pilot plant design. This included review of the process design, mechanical design, key equipment specifications and effluent treatment facilities. A number of specific recommendations were made. Examples include:

- To revise the procedure and equipment used to cool the vapors generated in the pressure letdown system which follows the high pressure coal dissolving section.

- Major modification of the hydrogen production unit.

Other specific recommendations were contained in our letters P-5 to P-178 over the period October 6, 1972 to June 24, 1974.

Beginning in March, 1973, we made monthly visits to the pilot plant site. The objective of these visits was to review the construction progress reports with representatives of OCR, the plant operator (Pittsburg & Midway Coal Mining Company), and the constructor, Rust Engineering. The plant site was toured to independently assess construction progress status. Following the site tour, detailed discussions were held with the representatives of OCR, P&M, and Rust. We then presented our recommendation regarding percent completion and recommended actions regarding the total construction schedule and program; the recommendations were subsequently confirmed in the form of a written report.

In October, 1973, it became apparent that there would be a significant slippage in the construction schedule and this was reported. The pilot plant was mechanically complete about July , 1974.

We continued regular visits to the pilot plant during startup and operations. During these visits the operational status, data development, and mechanical performance were reviewed with representatives of OCR and P&M. Written reports were transmitted for each of the visits; each report contained recommendations. An early recommendation was production of material for use in functional product testing by potential customers. During this

period, we were deeply involved in development of conceptual designs for commercial scale plants using SRC technology and communicated to OCR and P&M quantitative opinions regarding effects of process variables, separate units operations performance such as filtration, and economic sensitivities to plant performance factors.

The SRC pilot plant has subsequently been operated successfully in both the SRC I and SRC II mode. It has produced 3,000 tons of solid SRC product which has been tested for performance in a 22-megawatt power plant. It has operated up to 61 consecutive days in the SRC II mode.

5.2 CRESAP TEST CENTER - INSPECTION AND ACCEPTANCE SERVICES

R&D Report No. 82 - Interim Report No. 8 [13] was transmitted to ERDA in August, 1977; this report summarized the results of Inspection and Acceptance services supplied in support of the ERDA program to reactivate the Cresap Test Center Facility.

Modification No. 9 of Contract E(49-18)-1234 was executed by ERDA (DOE) and Parsons Company on July 30, 1976. The contract provided for Parsons to furnish the following services to ERDA:

> The completed Cresap Test Center at Cresap, West Virginia will consist of facilities for coal handling and pulverization, solvent extraction of coal, separation of extract from residual solids, carbonization of heavy ends, solvent recovery by vacuum distillation, catalytic hydrogenation of coal extract, fractionation of product, auxiliary facilities for utilities, off-gas and waste water treatment and hydrogen generation.

The effort involved in the inspection to be performed hereunder is generally categorized as follows; a further description of the responsibility and scope restrictions follows item 5.2.4 - Miscellaneous.

5.2.1 CERTIFICATION OF VESSELS

Many of the vessels in the liquefaction process will be subjected to elevated temperatures and pressures in the course of operation. These vessels are designed to operate safely under such process conditions, and they should have been tested and certified in accordance with recognized codes and procedures for operation under these conditions. Inspection must establish that these vessels have been so tested and certified.

5.2.2 PROPER CONSTRUCTION

The following areas are to be inspected for proper construction:

- Installed equipment to be checked for conformity with mechanical flowsheets.
- Capacity limiting equipment such as tanks, pumps, compressors and rotative equipment are to be checked against equipment specifications.
- Piping, instrumentation and control valves are to be checked for proper hookup in accordance with the appropriate diagrams. Equipment and lines are to be verified for the materials of construction as specified. Because of Liquefaction Coal Development Corporation's (LCDC) on-site location, its inspection will very likely precede ERDA's inspection. Consequently ERDA will have available the results of the LCDC inspection for use wherever possible. All piping, instrumentation lines, control valves and motor hookups and all items shown in P&I diagrams will be field checked for conformance with the P&I diagrams. Checks will be based on the assumption that the metallurgy of installed piping systems conforms to that specified in the P&I diagrams. The suitability of the specified metallurgy for the intended service will be reviewed and comments submitted to ERDA.

5.2.3 SAFETY

Safe operation is of paramount importance and all aspects of safety are to be carefully scrutinized in the inspection task; each of the following areas are to be reviewed for safety:

- High pressure reaction vessels, piping, connections for conformity with the prevailing codes.
- Protection of personnel during operation.
- Location and adequacy of fire-fighting equipment fire blankets and medical assistance supplies.
- Full compliance with OSHA regulations.
- Proper plant safety in the event of failure of process units or instrumentation, such as:
  - All pneumatically actuated valves are to fail into a safe or nonhazardous position on the loss of the pneumatic system.

- Containment or evacuation of disposal of reactants without danger of conflagration or explosion.

- Plant operation procedures including procedures for startups, shutdowns, upsets, tailures, and emergencies with the obective of anticipating and nullifying any hazardous conditions arising during these operations.

5.2.4 MISCELLANEOUS

Establish that all operation permits, envronmental permits and state permits have been obtained, and are current and valid.

The assignment was restricted to the review of code conformance and agreement of the installations with the Engineer's design, mainly as presented in the Engineer's mechanical flow diagrams. Quality of workmanship such as piping weld quality (except as proven by hydrotests per code) as well as quality and accuracy of instrument connections (loop checks) were not included in the scope of the contract; these activities were the province of construction crafts. Another factor was that construction was more than 50% complete at the onset of our activities.

The kickoff meeting was held at Cresap on August 5, 1976, when Parsons project management team met with the ERDA representative and with representatives of the Engineer(Fluor Engineers and Constructors, Inc.) and LCDC to agree upon the ground rules for the accomplishment of the work.

On August 18, 1976, our key personnel, including a resident engineer, arrived at the jobsite to set up a Parsons field office and to start the inspection work. We issued a Job Procedure on September 2, 1976.

Between September 14 and September 22, 1976, Parsons conducted a jobsite inspection of installation conformance with mechanical flow diagrams covering Unit 100 and Offsite (utilities) Units. Reports to ERDA covering discrepancies found in these areas were transmitted in October, 1976.

The Support Units Training Manual was received by Parsons on August 26, 1976. The manual was subsequently reviewed and comments were transmitted to ERDA in October 1976.

In October 1976 it was agreed that the detailed review of code conformance of vessels be restricted to vessels classified "Lethal" by the engineer. This activity was completed following receipt of the last code papers in January 1977; results of the review were transmitted to ERDA in February 1977.

During October and November 1976 we reviewed the materials of construction specified for piping and equipment. The materials review was

based on heat and material balance information furnished by the Engineer. We reported our conclusions in December 1976.

For reference, a description of the units, by unit number is shown in Table 5-1.

Table 5-1 - Description of Units

Unit No.	Description
100	Coal Preparation
200	Extraction
300	Solids Separation
500	Solvent Recovery
600	Hydrogenation
700	Fractionation
800	Low Temperature Carbonization
850	Buildings
900	Hydrogen Generation
1000	Utilities
1200	Environmental Systems
1300	Interconnecting Pipeway

Between November 9 and November 24, 1976, we conducted a field review of:

- Unit 200 for mechanical flow diagram conformance
- Unit 800 for mechanical flow diagram conformance
- All installed electrical equipment for code conformance
- All installations for conformance with OSHA rules.

Reports to ERDA listing discrepancies and code variances, for corrective actions were issued after this field inspection with a letter report issued in February 1977.

We reviewed the pressure relief devices and the blowdown system for process safety during November and December 1976; the review was based on information supplied by the engineer regarding specified, maximum operating conditions. Provisions for relief during fire conditions were also checked. We reported the results to ERDA in February 1977.

Between December 7 and December 10, we conducted a field review of piping metallurgy as installed. A portable elemental analyzer was used with the assistance of a Texas Nuclear Company operator to determine speci-

fication conformance of a significant sample of alloy pipe and fittings. The review served to augment ongoing observations of pipe fabrications conducted by Parsons field engineer starting in September 1976; observations and reviews included fabrications in the shop, as well as in the field prior to installation. A letter report containing the results of this review was transmitted to ERDA in April 1977.

The work of the Resident Engineer was completed on December 18, 1976.

Between January 7 and January 28, 1977, Parsons conducted a field review of:

- Unit 500 for mechanical flow diagram conformance
- Unit 700 for mechanical flow diagram conformance
- Main control panel for conformance with design.

Inspection of other units and other planned activities were delayed due to extremely cold winter weather. Reports summarizing the completed reviews were transmitted to ERDA in January and February 1977.

Between March 6 and March 18, 1977, Parsons conducted a field inspection of:

- Unit 300
- Unit 600
- Unit 900 (partial)
  - Electrical installations not previously completed
  - Fire protection provisions
  - Personnel protection and safety provisions
  - Overhead piping obstructions
  - Practical aspects of plant operating procedures.

Reports covering the results of this review were transmitted to ERDA in April and May 1977.

In March 1977, copies of all operating permits were received. These were reviewed and comments were transmitted to ERDA in April 1977.

Copies of field hydrotest reports were received in March 1977. The reports covering process piping were reviewed, and comments were transmitted to ERDA in April 1977.

In April 1977, a field review was made of:

- Unit 900 Panel Instruments
- Unit 1230 Instrumentation.

Results of this review were transmitted to ERDA in April.

A review of the Unit 100 pulverizing and ground coal transfer system was started in October 1976. This task was completed and we transmitted the findings to ERDA in May 1977.

In July 1977, Parsons was advised that the compressor installation was completed. The details of the installation of Unit 600 and of 900 compressors were reviewed, and the results were reported in August 1977.

We understand that ERDA and the Engineer intended to take action to correct deficiencies disclosed by our Inspection and Acceptance Services reports.

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SECTION 6

PROPOSAL REVIEWS

An important contribution was the review of proposals plus presentation of substantiated recommendations for acceptance, rejection or modification of the proposals. Approximately 61 proposals were reviewed during the term of the contract. A brief summary of the procedures used and the scope of the effort follows.

Upon receipt of a proposal from OCR/ERDA with a request to review it, a senior staff member, performing as proposal coordinator, carefully reviewed the proposal. Then, in consultation with the Project Manager, the disciplines required to effectively review the proposal were defined. The proposal was then transmitted to multiple senior personnel with the proper defined discipline background and experience to provide an effective review. A schedule was established and guidelines for the review transmitted. The multiple individual reviewers then completed their analysis and wrote an appropriate report, including recommendations to conform to the review schedule.

Upon receipt of the multiple review reports from the separate discipline participants, the senior proposal coordinator prepared a report summarizing the consensus recommendation. If significant differences occurred between reviewers, these were resolved in conference. The senior staff proposal coordinator and Project Manager then reviewed the final report and it was transmitted to OCR/ERDA. In each case, substantiations for the recommendations were included.

A wide range of project objectives and scope were included. The estimated costs for the projects ranged from $50,000 to about $80 million. The general categories, and approximate number of proposals in each category are shown in Table 6-1.

Obligations under the proposal review portion of contract performance were completed and the appropriate reports transmitted to OCR/ERDA.

Table 6-1 - Proposal Reviews

Proposal Category	Number of Proposals
Process Development	34
Product Recovery, Characterization and Refining	10
Equipment Development	10
Systems Analysis	3
Environmental, Socio-Economic Studies	2
Coal Mining	1
Economics	1
Total	61

SECTION 7

PAPERS AND PRESENTATIONS

In addition to the reports transmitted to OCR/ERDA to discharge obligations for specific task assignments, a number of invited presentations were made and publications resulted; these were intended to quickly publicize key results of the work done under this contract.

A list of six presentations and publications resulting from our contract performance is presented in Table 7-1 which follows; these are in addition to the major reports to OCR/ERDA summarizing the results of work under this contract. The presentation/publication efforts continued past 1975, with the bulk of this type activity then falling under Contract No. E(49-18)-1775 because of the nature of the assignment which was development of multiple conceptual designs/economic evaluations.

Table 7-1 - Papers and Publications

1. O'Hara, J. B., Jentz, N. E., Rippee, S. N., and Mills, E. A., "Preliminary Design of a Plant to Produce Clean Boiler Fuels from Coal," Presented at the 66th Annual Meeting of the American Institute of Chemical Engineers (AIChE), Philadelphia, PA, November 15, 1973.

2. O'Hara, J. B., Jentz, N. E., Rippee, S. N., and Mills, E. A., "Producing Clean Boiler Fuels from Coal," CEP Capsule, Chemical Engineering Progress, Vol. 70, No. 6, Page 70, June 1974.

3. O'Hara, J. B., Jentz, N. E., Rippee, S. N., and Mills, E. A., "Clean Boiler Fuels from Coal," Coal Processing Technology Manual, Vol. 1, Pages 41-52, Prepared by the Editors of Chemical Engineering Progress, June 1974.

4. O'Hara, J. B., Jentz, N. E., Rippee, S. N., and Mills, E. A., "Design of a Demonstration Plant to Produce Clean Oils from Coal," Published Proceedings of the Synthetic Hydrocarbon Conference Annual Meeting of American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME), Dallas, TX, February 24, 1974.

5. O'Hara, J. B., Rippee, S. N., Loran, B. I., and Mindheim, W. J., "Environmental Factors in Coal Liquefaction Plant Design," Presented at EPA Symposium on Environmental Aspects of Fuel Conversion Technology, St. Louis, MO, May 14, 1974.

6. O'Hara, J. B., "Coal Conversion," Presented to the United States Senate Committee on Interior and Insular Affairs Subcommittee on Energy Research and Water Resources, Washington, D.C., March 3, 1975.

SECTION 8

GENERAL

During the course of the work, there were a number of additional response activities and reporting exchanges. These are documented in our letters P-1 through P-317 which were issued over the time period of September 13, 1972 through August 31, 1977.

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SECTION 9

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5. O'Hara, J. B., Rippee, S. N., Loran, B. I., Mindheim, W. J., "Environmental Factors in Coal Liquefaction Plant Design," R&D Report No. 82, Interim Report No. 3. Prepared for the United States Department of the Interior, Office of Coal Research, May 1974.

6. O'Hara, J. B. et al, "Interim Technical Progress Report." Technical Evaluation Services, Clean Liquid and/or Solid Fuels from Coal - Interim Report No. 4 (for period October 1972 - August 1974).

7. O'Hara, J. B., Crawford, C. L., Hincks, H. F., and Mills, E. A., "Commercial Complex, Conceptual Design/Economic Analysis, Oil and Power by COED-Based Coal Conversion," R&D Report No. 114, Interim Report No. 1, FE-1775-1. Prepared for the Energy Research and Development Administration, September 1975.

8. O'Hara, J. B., "Projected Characteristics of Large Coal Liquefaction Complexes." Presented at the Project Independence Blueprint Public Hearings, Chicago, September 11, 1974.

9. O'Hara, J. B., Cumare, F. E., and Rippee, S. N., "Synthetic Fuels from Coal by Fischer-Tropsch," Coal Processing Technology Manual, Vol. II. Prepared by the Editors of Chemical Engineering Progress, August 1975.

10. O'Hara, J. B., et al, "Technical Evaluation Services: Coal Conversion and Utilization - Liquefaction, Solvent Refined Coal," R&D Report No. 82, Interim Report No. 6, FE-1234-6. Prepared for the Energy Research and Development Administration, May 1976.

11. O'Hara, J. B., Howell, R. D., and Papso, J. E., "Coal Conversion and Utilization - Liquefaction, Clean Coke Process (PDU-Stage)," R&D Report No. 82, Interim Report No. 7, FE-1234-7. Prepared for the Energy Research and Development Administration, November 1976.

12. O'Hara, J. B., et al, "Technical Evaluation Services: Coal Conversion and Utilization - Liquefaction, Project Lignite (PDU-Stage)," R&D Report No. 82, Interim Report No. 5, FE-1234-5. Prepared for the Energy Research and Development Administration, July 1976.

13. O'Hara, J. B., Hervey, G. H., "Cresap Test Center, Inspection and Acceptance Services," R&D Report No. 82, Interim Report No. 8, FE-1234-8. Prepared for the Energy Research and Development Administration, September 1977.

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