PHASE A REPORT
on
CONVERTING THE CRESAP TEST FACILITY
TO A TWO-STAGE
COAL HYDROLIQUEFACTION PROCESS

by

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REMARKS
The cover of this report
contains a misspelled word
(i.e., "hydroliquefaction").
However, the title is correct on
the title page. We have informed
Scientific Design of this error.
Thanks,
Martha Stewart

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ABSTRACT

This report contains a preliminary process design and cost estimate for the addition of a new coal extraction system to the Cresap, W. Va. pilot plant. The new facilities being considered would provide for direct contact of the coal slurry with a recirculating stream of hydrogen-rich gas at pressures in the range of 1350-2500 psig. Preliminary process flowsheets and planning drawings are included.

Also included in this report is a discussion of the possibilities for continued component testing in the existing Cresap pilot plant.

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I. SUMMARY

The DOE has considered the addition of a new front-end coal extraction unit to the Cresap, W. Va., pilot plant. The new extraction unit would operate at a higher coal conversion than the existing extraction system and would be able to process a wider variety of coals. Integration of the new unit with the existing pilot plant facilities would form a two-stage hydroliquefaction process having the features of donor solvent recycle and addition of molecular hydrogen within the coal extraction step followed by upgrading of the coal extract in a hydrogenation unit. With minor changes in the Extract Hydrogenation section, the integrated facility would then produce a low sulfur boiler fuel.

If increased nitrogen removal and greater conversion of extract to a higher grade liquid fuel is desired, substantial modifications to the Extract Hydrogenation section would be required. Operation at reduced throughput would limit the extent of these modifications. In this case the design capacity would be correspondingly reduced.

This report presents the result of the first phase only (preliminary engineering) of a two-phase program to incorporate these modifications into the Cresap pilot plant.

A. Proposed New Front End Extraction

The preliminary process design provides for contacting coal/solvent slurry with recirculating hydrogen at pressures ranging from 1350 to 2500 psig. Initial conversion of coal takes place in the coil of the gas-fired Slurry Preheater. Maximum coil outlet temperature is 860°F. Further reaction may be achieved, if desired, by directing the gas/slurry mixture through all or part of the adiabatic Dissolver. After separation from the slurry, gases flow to the Gas Absorber for removal of light hydrocarbons, CO₂ and H₂S. The remaining hydrogen-rich gas stream is recompressed combined with make-up hydrogen and recycled to the Slurry Preheater. The hot slurry is reduced in pressure, cooled to 650°F, and sent to the existing solids separation section for removal of mineral matter and unconverted coal from coal extract and coal-derived solvents.

Preliminary process flowsheets, estimated material balances and equipment sizes are based on the present rated pilot plant feed capacity of 20 tons per day (TPD) of moisture-free coal. Design yields and operating conditions are based on test runs at the Wilsonville, Ala., and Ft. Lewis, Wash. SRC I pilot plants.

The capacity of the integrated facility may be substantially less than 20 TPD if deeper hydrocracking is required in Section 600 to improve the quality of the fuel oil product. A final design of the new extraction unit should therefore be based on the reduced capacity of the integrated pilot plant. Although this report does not include a comprehensive review of capacity limitations in sections downstream of coal extraction, a general discussion does direct attention to certain restrictions.

The proposed new facilities would best be located in open areas close to the existing facilities. The reaction and gas/slurry separation equipment would be located in the area designated "Section 2000" next to Section 600. The Gas Absorber, its auxiliaries and the Recycle Compressors would be located on the far side of the existing compressor house. Construction would be planned to minimize interruptions to the existing operation. The new facilities would be connected in parallel with the existing extraction section so that either the new or old system could be used. Preliminary plant layout drawing are included in the Appendix.

Estimated cost for the new extraction facilities based on a coal throughput of 20 TPD is 3.8 million dollars (1978 dollars). An allowance of 25 percent above this base figure is required in recognition of the preliminary nature of the work done so far on the new sections. Estimated maximum total cost for revamping the extraction section is therefore 4.8 million dollars.

In order to establish the effect of design capacity on the cost of the new front-end facilities, a preliminary estimate was also prepared for an assumed capacity of 10 TPD (moisture-free basis). The estimated cost is 3.5 million dollars (1978 dollars); and thus this 50% reduction in capacity lowered the capital cost by only a little over 7%.

B. Component Testing Program

A brief review of the component testing program at Cresap is included. No major modifications are proposed; however some suggestions are included concerning the valve testing program.

II. STATEMENT OF WORK

This report is submitted to fulfill the requirements of "Phase A" as described in the Statement of Work contained in SD's proposal¹ to DOE and ORNL. Pertinent portions of that Statement, which was approved in its entirety by DOE and ORNL, are summarized below.

The DOE wishes to use the DOE facility at Cresap, West Virginia, either for (1) development of two-stage coal hydroliquefaction or (2) testing of various coal liquefaction components while operating all or part of the existing facilities.

If the facility is modified to develop two-stage coal hydroliquefaction, the following criteria shall apply:

- Minimum equipment additions and revisions to existing equipment.
- Minimum disruption to the current operating program.
- Avoidance of equipment changes solely for the sake of maintaining the current nominal coal feed rate of 20 TPD.

In evaluating the facility for testing of various coal liquefaction process components, the following criteria shall apply:

- The modification or additions to the facility shall be capable of accomplishment with minimal expenditure.
- Integrated operation is not mandatory.

- Sustained operation with accumulation of significant experience relative to equipment reliability, on-stream efficiency, etc. is a primary consideration.

The work is to be accomplished in two phases. Phase A is the preparation of preliminary engineering information and an evaluation of the existing plant as a test facility. After a review of Phase A the DOE will decide whether the detailed engineering, Phase B, should be carried out.

III. PRELIMINARY PROCESS DESIGN OF PROPOSED NEW EXTRACTION FACILITIES

A. Description of Flow Sheets

Two preliminary process flowsheets for the new front-end facilities are presented here. Both flowsheets show the same equipment arrangement and design. They differ only with respect to the yield structure incorporated into the material balance which appears at the top of each flowsheet. The material balance for Flowsheet No. 2005-X-101A is based on operation with a full Dissolver. The material balance for Flowsheet No. 2005-X-101B is based on by-passing the Dissolver. Differences in the yield structures are discussed in sub-section B.

Pulverized coal from the existing bin in the Coal Feed Preparation section is blended with recycled solvent streams in the existing Slurry Mix Tanks. The major recycle stream is solvent recovered from the bottom of the Vacuum Column in Section 500. Donor solvent, which is separated as Fractionator bottoms in Section 700 and then stored in tanks in Section 1100, comprises the remainder of the recycled solvent. New Slurry Circulation Pumps are needed to recirculate the coal/solvent slurry to the Mix Tanks and to feed the net slurry forward to the suction of the new Preheater Charge Pumps. Triplex plunger pumps have been selected for the Preheater charge service because of the high discharge pressure required.

ABBREVIATIONS:

A	HEAT TRANSFER AREA
CW	COOLING WATER
DPHE	DOUBLE PIPE HEAT EXCHANGER
M&F	MOISTURE AND ASH FREE
MF	MOISTURE FREE
NNF	NO NORMAL FLOW

NOTES:

- YIELD ARE BASED ON DATA FROM E.T.E. #15 AND WILSONVILLE PILOT PLANTS FOR WESTERN KENTON COUNTY.
- CAPACITY: 20 TPD W.E. COAL.
- HYDROGEN CONSUMPTION IN PREHEATER: 4.0 DISSOLVER IS SHOWN AT 2.5% WT% OF MOISTURE AND ASH IN COAL. FEED: 100% COAL (CONVERSION: 2% H₂ AT 95% RECYCLE GAS RATE IS SHOWN AT DESIGN RATE OF 25,000 GCF PER TON OF MOISTURE FREE COAL AT 100% GAS RATE. 10,000 GCF PER TON IN 10% RECYCLE RATIO.
- MATERIAL BALANCE IS BASED ON 1,500 PPM MOISTURE PRESSURE (CONSIDERED AS TYPICAL). ACTUAL OPERATION MAY RANGE FROM 1,000 TO 2,500 PPM.
- STREAM 1-2 IS CORRESPOND TO STREAMS 1-4 ON FLOW DIAG. 44-101-04-01-0200-01
- COIL SPACE RATE IN PORTION OF THE BLUERY PREHEAT COIL WHERE TEMPERATURE IS ABOVE 600°F IS 15% OF TOTAL COIL SPACE RATE.
- COIL SPACE RATE IN THE FULL DISSOLVER IS 15% OF TOTAL COIL SPACE RATE.

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**PROPOSED ADDITION TO CRESAP COAL LIQUEFACTION
PILOT PLANT, FIRST STAGE HYDROGENATION**

**U.S. DEPARTMENT OF ENERGY/
OAK RIDGE NATIONAL LABORATORY**

PREPARED BY SVS DATE 08/79 DRAWN BY MEM
CHECKED BY SVS DATE 08/79
APPROVED BY J.M.K. DATE 08/79 No. 2005-X-101A

STREAM 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Recycle hydrogen (which already has been replenished with the required amount of make-up hydrogen) is added to the high pressure slurry upstream of the Slurry Preheater. The gas/slurry mixture is heated from an inlet temperature of approximately 100°F to an outlet temperature of approximately 800°F (860°F is the design value) as it flows upward through the helical coil of this gas-fired furnace. In the range of 500°F-600°F, the slurry passes through a gel-like state. This high viscosity condition corresponds to the initial (pyrolitic) break-up of the coal structure to form high molecular weight organic compounds and some light gases. As the conversion proceeds, highly reactive intermediates (free radicals) are produced. These intermediates are stabilized by the transfer of labile hydrogen atoms from the donor solvent². Coal space velocity in the Preheater coil is approximately 100 lb/hr-ft³ at 20 TPD coal throughput. Since it is estimated (based on Wilsonville data) that conversion of the coal occurs primarily in about the last third of the coil, the effective coal space velocity is approximately 300 lb/hr-ft³ at 20 TPD.

The effluent from the Slurry Preheater may either flow through the Dissolver for further hydrogenation to liquids and to gases or it may by-pass the Dissolver and flow directly to the Reactor Effluent Separator. The Dissolver is an empty cylindrical vessel provided with alternate outlets at approximately one-third, two-thirds and full working Dissolver height. The coal slurry/gas mixture flows upwards and leaves through one of these outlets. At 20 TPD coal throughput, the coal space velocity in the full Dissolver is 50 lb/hr-ft³. Maximum Dissolver operating pressure is 2500 psig. (When the Dissolver is by-passed, this

is the maximum pressure at the outlet of the Slurry Preheater). Most test runs will probably be at lower pressures with a minimum estimated operating pressure of 1350 psig. (Recent work by Mobil for short residence time conversion has indicated that a pressure of 1375 psig is satisfactory³.) Recycle hydrogen may be added to the Dissolver inlet pipe to serve as quench gas or, if a future gas sparger is installed, fed directly into this reactor. A small bleed can be taken from the bottom of the Dissolver to control solids accumulation.

The Dissolver effluent is a complex mixture containing excess hydrogen, product gases, distillate vapors, distillates boiling over a wide range of temperatures, extract, unconverted coal, and polymerized material and mineral matter from the coal. This mixture flows to the Reactor Effluent Separator where gases and hot vapors are separated from the slurry. The hot gases and vapors flow to a two-stage overhead condensation system. This staging of two partial condensers was selected in order to avoid possible formation of a heavy oil/water emulsion. In Vapor Cooler No. 1, the gas stream is cooled to 400°F in a small steam generator. After separation and removal of the condensed heavy oil in the Overhead Separator, the gas stream is further cooled to 110°F in the water-cooled Vapor Cooler No. 2. Condensed lighter solvent and water phases are separated from the gas stream and decanted in the Overhead Decanter. The heavy and light condensed solvents from the Separator and Decanter are combined and fed to the Economizer Surge Drum in Section 700. The aqueous condensate, which contains dissolved hydrogen sulfide and may contain small quantities of ammonium salts, is sent to the Sour Water Stripper. The cooled gases leaving the Overhead Decanter consist mainly

of excess hydrogen, along with light paraffins (mostly methane), hydrogen sulfide, carbon monoxide and carbon dioxide. These gases flow to the Gas Absorber for removal of light hydrocarbons and acid gases.

The slurry from the Reactor Effluent Separator is depressurized in the Intermediate Pressure Flash Drum. Disengaged hydrogen and solvent vapors are sent to the Stabilizer in Section 700. The remaining slurry is cooled to 650°F in a small steam generator and then flows to the Primary Feed tank in the solids separation area (Section 300.)

The cooled gases from the Overhead Decanter are contacted with a recirculating lean oil in the Gas Absorber for simultaneous absorption of hydrocarbon and acid gases (carbon dioxide and hydrogen sulfide). Lean oil feed is Vacuum Column bottoms; i.e., "solvent" having a boiling range of 500°F to 850°F. The rich oil leaving the bottom of the Gas Absorber is flashed at approximately 5 atmospheres to release absorbed hydrogen, acid gases and light hydrocarbons. These gases are sent to the Stretford unit for removal of hydrogen sulfide. (No investigation of the capabilities of the Stretford Unit was made, as it was not included in SD's Scope of Work.)

Hydrogen-rich recycle gas leaving the top of the Gas Absorber flows to the Recycle Compressors via the Recycle Compressor Knock-out Drum. Two full-sized compressors are suggested so that a spare will be available at all times. Compressor capacity was based on a total hydrogen feed rate to the Slurry Preheater of 25,000 SCF of 90 vol% per ton of moisture free coal. (Wilsonville and Ft. Lewis generally operated with gas feed rates

in the range of 12,000-20,000 SCF/ton.) Either a reciprocating machine or a diaphragm compressor may be used. A diaphragm machine is recommended because it is well suited for the small flows and offers the advantage of minimum maintenance since there is no packing or packing rings. Moreover, the construction of the diaphragm compressor minimizes the possibility of any leakage to the atmosphere. A by-pass cooler is provided for any gas recirculated to the suction of the machine.

Fresh hydrogen from the Hydrogen Make-up Compressor in Section 900 is added to the discharge from the Recycle Compressor. Based on data from the Wilsonville and Ft. Lewis pilot plants, the expected range of hydrogen consumption is 0.8 - 2.5 weight per cent of the moisture and ash free (MAF) coal. Total hydrogen usage in the new extraction facilities, including solubility losses, is estimated to range from 1.6 to 3.2 weight per cent of the MAF coal.

B. Yield Structure and Hydrogen Consumption

Two yield structures were estimated (Table 1) which form the bases for the material balances shown on the two process flowsheets. These projected yields approximate the range of product distributions for the proposed new extraction facilities.

The first yield structure (Case 1) is a prediction of the maximum extent of liquefaction that could be attained in the new reaction section when operating with a full Dissolver. Hydrogen consumption is estimated at 2.5 weight percent of the MAF coal. It is estimated that approximately

TABLE 1

ESTIMATED YIELD STRUCTURE FOR PROPOSED
NEW EXTRACTION UNIT

Units: Weight Percent
Basis: Moisture & Ash-free Coal

	<u>Case 1</u>		<u>Case 2</u>
Hydrogen	-2.5		-0.8
Methane	2.4	} 5.9% HC Gases	0.4
Ethane	1.4		0.2
Propane	1.2		0.2
Butane	0.9		0.1
CO	0.1		0.0
CO ₂	1.3		0.8
H ₂ S	2.2		0.3
H ₂ O	5.4		2.8
Light Oil (C ₅ -400°F BP)	10.2	} 22.6% Liquids	1.0
Middle Distillate (400-500°F BP)	12.4		3.4
Solvent (500-850°F BP)	0		3.0
Extract (850°F+BP, pyridine-sol.)	60.0		76.6
Unconverted Coal	5.0		12.0
TOTAL	100.0		100.0

NOTES:

1. In Case 1, the coal extraction takes place in the Slurry Preheater and in the full Dissolver. (At 20 TPD coal throughput, coal space velocities in the Slurry Preheater and in the full Dissolver are 100 lb/hr-ft³ and 50 lb/hr-ft³, respectively.)
2. In Case 2, the Dissolver is by-passed. Coal extraction takes place in the Slurry Preheater.

95% of the organic portion of the coal is converted to pyridine-soluble material. Although a large portion of the converted coal forms extract (pyridine-soluble material boiling above 850°F), there is significant formation of light hydrocarbon gases, light oil (IBP - 400°F BP) and middle distillate (400°F-500°F BP). Yields were based on SRC I test Run No. 8 carried out at the Wilsonville, Ala.⁴ and on SRC-I Test No. 1 at the Ft. Lewis, Wash.⁵ pilot plants at a similar coal space velocity within the Dissolver, but with a Western Kentucky coal feed. Screening studies carried out at the Merriam Laboratory in 1977 indicate that Ireland Mine Pittseam coal is more reactive than Western Kentucky No. 9 and 14 coal¹⁴. The Ireland Mine coal tested at Merriam, however, contained more ash than the Ireland Mine coal used at Cresap (13.9% versus typically 10% at Cresap). Since the ash contains the catalytic material which increases coal reactivity, it was judged that the reactivity of the Cresap feed coal would be lower than that of the Ireland Mine coal tested at Merriam and similar to the reactivity of Western Kentucky coal. (The Merriam laboratory helps to develop the test program for the Ft. Lewis pilot plant.)

The second yield structure (Case 2) corresponds to by-passing the Dissolver. Coal conversion in the Slurry Preheater (and within the hot transfer line from the Preheater to the Reactor Effluent Separator) is estimated at 88%. Most of the converted coal forms extract. Production of distillates and light hydrocarbons is quite low. Hydrogen consumption is estimated at 0.8 wt. % of the MAF coal. Yields were based on preliminary data gathered at Wilsonville⁶, with a Western Kentucky coal.

C. Design Capacity of New Facilities

Production of a higher grade fuel oil at Cresap requires complete - or nearly complete - conversion of extract to lighter materials in the Extract Hydrogenation unit (Section 600). It is estimated that, with some modifications, this unit could process an extract feed at a rate equivalent to a front-end coal throughput which lies in the range of nine to thirteen tons per day of moisture-free coal. Design capacity of the proposed new front-end should be set accordingly.

Limitations and required modifications to Section 600 are discussed briefly below. Capacity limitations in the hydrogen generating and separation facilities are also discussed.

1. Capacity Limitation in Extract Hydrogenation (Section 600)

If it is desired to increase conversion of extract to lighter materials, process modifications and equipment changes would be required in this section. Moreover, a reduction in throughput would be required. A very rough estimate is that 500-600 lbs./hr. of extract could be completely converted at 50% extract concentration in the feed by using two reactors in series and recycling unconverted extract from the Fractionator Reboiler to the first reactor. (This rough estimate is based on once-through data from the Cities Service reports on hydroprocessing of SRC extract⁷. Conversions of 55% and 50% were assumed for the first and second reactors, respectively. Total feedrate was set at 1375 lb./hr. based on CRESAP test run data cited in the August, 1978 Monthly Technical Progress Report⁸.) Since the new front-end facilities would produce 900-1150 lb/hr of extract at 20 TPD coal

feed, the matching front-end capacity appears to be in the range of 9-13 TPD of moisture free coal.

Additional feed preheat capability would have to be provided in order to use two Hydrogenation Reactors. During operation in August, 1978, catalyst was not added to the first reactor. This vessel had to be used as part of a feed preheat loop.

A bleed may have to be taken from the recycle stream containing unconverted extract; otherwise, refractory materials might buildup. The bleed would probably be sent to the Low Temperature Carbonization unit, Section 800.

2. Capacity Limitation in Hydrogen Generation (Section 900)

The Hydrogen Generation facilities at Cresap were oversized for the original mild hydrogenation conditions. It is estimated that the design production capacity of 21,000 SCFH of 98% hydrogen is sufficient to process approximately 14-15 TPD of MF coal with complete conversion of extract in Section 600. This estimate assumes a total hydrogen consumption in Section 600 of 5 wt% based on the feed of 50/50 extract/solvent feed mixture. Hydrogen usage in the proposed new front-end facilities was set at extreme values 1.6 and 3.2 per cent of the MAF coal with corresponding extract yields of 76 and 60 weight per cent.

3. Capacity Limitation in Solids Separation

A recent study by Kleinpeter et al⁹ indicates that an overflow rate of approximately one-half the Cresap design value is required to achieve satisfactory deashing of SRC extract. The extract to be produced in the proposed new front-end facility would be quite similar to that from SRC I and similar performance would therefore be expected. Anti-solvent was used in these studies. Effectiveness of the anti-solvent was considerably reduced when contaminated by coal solvents of similar boiling range (see sub-section D.5 following).

D. Other Considerations

1. Vapor-Liquid Equilibrium Data

Complete correlations of V-L-E data for the complex mixtures that exist in coal liquefaction systems are not available. Chao et al¹⁰ have reported binary data for hydrogen with particular high boiling aromatic compounds characteristic of coal-derived solvents (e.g. methylnapthalene and diphenylethane). Chao has also reported binary data for methane with some of these same solvents¹¹.

Using these binary data as a basis, along with data reported for aromatic petroleum fractions, K-values were estimated and used in the preparation of the two material balances shown on the process flowsheets. K-values for hydrogen sulfide and carbon dioxide were approximated based on information given by Grayson and Streed¹² and atmospheric data reported by Prausnitz and Temper¹³.

2. Slurry Preheater Design

The design considered for this estimate is a bottom-fired vertical furnace with a helical coil, similar to the units which have operated successfully at Ft. Lewis and at Wilsonville. This simple design is consistent with the objective of evaluating the performance of a two-stage hydrogenation process at Cresap. The radiant design does not lend itself to measurement of heat transfer data. Such an activity is judged to be outside the main objective of the proposed revamp.

Coil dimensions were based on a coal space velocity of approximately 100 lb/hr-ft³ (similar to Wilsonville and Ft. Lewis) and on an inlet superficial velocity of 5.5ft/sec at design rates. This corresponds to an internal volume of 15.1 ft³. The heat flux is calculated to be approximately 4974 BTU/hr-ft² based on the external surface.

Before specifying a final design, consideration should be given to a zoned (electrical or other) heating system. Such a design offers the possibility of controlling effective contact time by heating one or more zones.

3. Dissolver Design

The internal volume of 33.4 ft³ is based on a coal space velocity of 50 lb./hr.-ft³ at a capacity of 20 TPD coal feed. The length-to-diameter ratio is similar to the L/D ratios of the reactors at the Ft. Lewis and Wilsonville pilot plants. Alternate withdrawal points are recommended at one-third and two-thirds of the full working height. These locations correspond to coal space velocities of 150 lb./hr.-ft³ and 75 lb./hr-ft³, respectively.

Special features include:

- a nozzle for withdrawal of accumulated solids via a line to a blowdown tank,
- a support ring for future installation of a distribution plate,
- flanged construction for ease of access.

Materials of construction are an overlay of 347SS on 3 chrome/1 moly steel. Design pressure is 2750 psig.

4. Gas Absorption

Design of the Gas Absorber and its auxiliary equipment was based on maintaining at least 90 vol% hydrogen in the feed gas to the Slurry Preheater. This determined the required absorption of hydrocarbon gases. No special requirement was set for the removal of acid gases. Maximum concentrations of these gases in the feed gas to the Slurry Preheater were calculated at 1.0 vol% hydrogen sulfide and 0.8% carbon dioxide (based on Case I conditions as shown on the material balance for process flowsheet 2005-X-101A).

Absorbed gases are removed by flashing the rich oil at low pressure. A heater and cooler are specified for the rich and lean oil streams respectively for use during start-up. There is a noticeable build-up of light oil (C₅-400°F BP) in the circulating solvent. Final design should allow for a continuous bleed in case this proves to be needed.

5. Light Oil Content in the Hydrogenated Slurry

The concentration of light boiling solvents in the hydrogenated slurry leaving the new reaction section should be kept as low as possible in order to avoid a buildup of these coal-derived distillates in the paraffinic anti-solvent.

Kleinpeter's study⁹ indicates that the "Solvent Deashing" quality of the paraffinic anti-solvent used in the solids separation step is severely reduced by only a few percent of coal-derived solvents. The anti-solvent typically has a boiling range of 350-400°F.

Since the recirculated anti-solvent is distillate from the Vacuum Column, any light oil contained in the slurry which boils in the same range will concentrate in the anti-solvent and a purge will be required.

Concentration of light oil in the hydrogenated slurry leaving the new reaction section is approximately 0.02 wt% (0.2 lb./hr) for low severity (Case 2) operation and 0.10 wt% (4.3 lb./hr.) for high severity (Case 1) operation. Typical relationships between the equilibrium concentration of light oil in the anti-solvent and anti-solvent purge rate for Cases 1 and 2 are shown in Figure 1. The cases correspond to the two extremes of front end reaction conditions. For purposes of this illustration, an anti-solvent circulation rate of approximately 1200 lb./hr. has been assumed.

FIGURE 1

PURGE RATE OF RECIRCULATION ANTI-SOLVENT

vs.

CONCENTRATION OF LIGHT OIL IN RECIRCULATION ANTI-SOLVENT

BASIS: 1210 lb/hr. RECIRCULATION RATE

IV. PRELIMINARY PLANT LAYOUT OF NEW EXTRACTION FACILITIES

Three preliminary plant layout drawings were prepared for the proposed new extraction unit. These are included in the Appendix. The reaction and separation systems of this new unit have been designated Section 250. The recommended location, agreed upon both by SD and Cresap plant supervision, is in an empty corner of Section 600, now designated as "2000 Test Future" on Fluor E. & C. Drawing No. 448404-R-TC-00-050 (Rev. 13-11/9/77). The gas absorption and recompression systems of the new unit, designated Section 260, would best be located on the far (north) side of the hydrogen compression building.

Drawing 2005-C-200 shows the agreed upon location for new Sections 250 and 260 and the new recirculation pumps required to transfer coal/solvent slurry from the existing slurry mixing system to new Section 250. Drawing 2005-D-201 portrays new Section 250 in plan and elevation view; 2005-D-202 shows new section 260 in plan view only.

It is indeed fortunate that the location chosen for new Section 250 is available because this space has much to recommend it and only a few minor disadvantages. The advantages of this location are as follows:

1. It is large enough to accommodate the new equipment.
2. It is as close to existing upstream and downstream units (Sections 200 and 300) as it is possible to get without some dismantling which would severely interfere with operation of the existing facilities.
3. Transfer of coal/solvent slurry stream is facilitated by such close coupling.
4. Interconnections of piping, instrumentation and electrical service to the existing plant sections as well as the Main Control Room and to new Section 260 can be readily accomplished on existing pipe racks and sleepers (with straight forward modifications and some additions).
5. It is so situated that it appears to be possible to locate the fired heater with due regard for the safety aspects involved; however, see the second disadvantage cited subsequently.
6. It is reasonably close to the Main Control Room, the operating center for the complex.
7. It is readily accessible from existing roads for equipment delivery and erection and for other construction purposes.
8. With careful planning and scheduling construction can be accomplished with a low level of interference with the operation of the existing facilities.

The disadvantages are:

1. The foundations left over from the dismantling of Section 400 and buried at present under a rough concrete slab might be troublesome.

2. Though advantage was taken of the buffer space provided by the N-S main road and the short E-W spur off it in locating the fired heater, the clearances to other processing areas are not overly generous so that careful consideration of this aspect will be necessary in reaching a final design.

The location selected for new Section 260 has the following advantages:

1. It places the new hydrogen compressors in close proximity to the existing hydrogen compression system thereby facilitating integrated operation and maintenance activities.
2. Interconnections with new Section 250 can use the route of the existing sleepers running N-S on the east side of the compressor building.
3. It is reasonably close to the Main Control Room, which is the operating center for the complex.
4. It is readily accessible from existing roads for equipment delivery and erection and for other construction purposes.
5. With careful planning and scheduling construction can be accomplished with a low level of interference with the operation of the existing facilities.

The only real disadvantage of this location for new Section 260 is that it puts the existing compressor house between it and new Section 250. Were sufficient space available one would obviously not separate the two new sections in such a way.

3
1-10-79

REFERENCE DWGS.
NEW REACTION SECTION 250 --- 2005-D-201
NEW GAS TREATMENT SECTION 260 --- 2005-D-202

CRESAP 2 STAGE ADDITIONS

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SCIENTIFIC DESIGN COMPANY INC. DESIGN - TWO PARK AVENUE - CONSTRUCTION NEW YORK				
PARTIAL PLOT PLAN COAL LIQUEFACTION PILOT PLANT FOR CRESAP, WEST VIRGINIA				
NO.	DESCRIPTION	DATE	BY	CHECKED
DRAWN BY <u>880</u> DATE <u>8/1/79</u> SCALE <u>1" = 40'</u> CHECKED BY _____ DATE _____ APPROVED BY _____ DATE _____ NO. 2005-C-200				

ON
TO/FROM EXISTING
SECTION 200

PLAN @ GRADE & EL. 109.0'

PLAN @ EL. 137.0'

PLAN @ EL. 130.0'

PLAN @ EL. 119.0'

SCHEMATIC ELEVATION

NOTE: THE NEW SLURRY RECIRCULATING PUMPS, J-C251A/B ARE TO BE LOCATED IN THE EXISTING SECTION 200, SEE DWG. 2005-D-200 FOR GENERAL LOCATION.

3
1-10-79

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SCIENTIFIC DESIGN COMPANY INC.	
DESIGN	TWO PARK AVENUE NEW YORK
EQUIPMENT ARRANGEMENT	
NEW REACTION SECTION 250	
FOR	
CRESAP 2 STAGE LIQUEFACTION PLANT	
CRESAP WEST VIRGINIA	
DRAWN BY	DATE
CHECKED BY	DATE
APPROVED BY	DATE
REVISIONS	
APPROVED FOR CONSTRUCTION BY	

No. 2005-D-201

V. PRELIMINARY CAPITAL COST ESTIMATES

A. Summary

A base estimate was prepared for the new front-end extraction facilities for a coal throughput of 20 TPD. Subsequently, an estimate for 10 TPD coal throughput was prepared. Estimated costs are summarized in the following table.

PRELIMINARY COST ESTIMATES FOR NEW FRONT-END REACTION SYSTEM

THOUSANDS OF DOLLARS (1978)

Design Coal Throughput, Tons per Day, moisture-free basis	20 (Base <u>Estimate</u>)	10 (Reduced <u>Capacity</u>)
Major Equipment	735	580
Materials and Construction	1,802	1,679
Construction Supervision	173	173
Engineering	1,070	1,070
Local Taxes	<u>40</u>	<u>40</u>
TOTAL	3,820	3,542

It is apparent that the final design capacity of the proposed new facilities has only a minor effect on overall cost. Additional details are listed on the two attached "Cost Estimate Sheets". The procedures used in obtaining the cost estimates are outlined in a discussion which follows the summary sheets.

SCIENTIFIC DESIGN COMPANY, INC.

CUSTOMER: DOE/ORNL

PROJECT NO.: 2005

ESTIMATE NO.:

PLANT: Addition of First Stage

LOCATION: Cresap, West Virginia

Hydrogenation Facilities

DATE: 1/23/79 PREPARED BY: GEH CHKD. BY:

COST ESTIMATE BASIS: Preliminary Process Design For 20TPD Moisture-Free Coal (1978 Dollars)

		Material Labor Total		
I. MAJOR EQUIPMENT	B. Fired Heaters	106,000		
	C. Compressors and Fans	119,300		
	D. Drums - Vessels	76,300		
	E. Heat Exchangers	41,900		
	F. Tanks	-0-		
	G. Pumps	206,000		
	M. Separating and Drying Equip.			
	P. Materials Handling Equipment			
	Q. Fire and Safety Equipment			
	R. Converters and Reactors	147,000		
	S. Size Reduction Equipment			
	T. Towers	38,500		
	U. Auxiliary Equipment			
	V. Maintenance & Shop Equipment			
	X. Special Equipment			
	Z. Refrigeration Equipment			
	TOTAL MAJOR EQUIPMENT	735,000		735,000
II. MATERIALS AND CONSTR.	A. Foundations	17,000	54,000	
	H. Piping	210,000	494,400	
	L. Buildings	-0-	-0-	-0-
	J. Structural Steel	64,000	33,000	
	K. Instrumentation	356,000	203,000	
	L. Insulation and Fireproofing	28,000	71,700	
	N. Electrical	49,000	147,000	
	W. Equipment Erection	-0-	54,200	
	Y. Painting	5,000	15,700	
	TOTAL MAT'L'S AND CONST.	729,000	1,073,000	1,802,000
III	CONST. SUPERVISION COSTS SD	-0-	173,000	173,000

IV. ENG'G. COSTS	Engineering	29,875 M/H	1,015,000		
	Purchasing				
	Res. Eng.	700 M/H	35,000		
	Miscellaneous Costs	Const. HO 500 M/H	-0-	20,000	
	TOTAL ENGINEERING COSTS	31,075 M/H	1,050,000	20,000	1,070,000
V. OTHER COSTS	Local Taxes 3%		40,000	-0-	40,000
	Duties				
	Export Freight				
	Field Modification				
	Escalation		Not Incl.	Not Incl.	Not Incl.
TOTAL OTHER COSTS					
VI	SUB-TOTAL BARE PLANT COST		2,554,000	1,266,000	3,820,000
VII	CONTINGENCIES AND FEES				
	Contingency		-0-	-0-	-0-
	Engineering Overhead & Profit		Incl.	Incl.	Incl.
	Construction Overhead & Profit		Incl.	Incl.	Incl.

2,554,000 1,266,000 3,820,000

SCIENTIFIC DESIGN COMPANY, INC. *6/1/79*

CUSTOMER: DOE/ORNL PROJECT NO.: 2005 ESTIMATE NO.:
 PLANT: Addition of First Stage LOCATION: Cresap, West Virginia
Hydrogenation Facilities DATE: 2/1/79 PREPARED BY: GEH CHKD. BY:
 COST ESTIMATE BASIS: Preliminary Process Design for 10TPD Moisture-Free Coal (1978 Dollars)

		Material	Labor	Total
I. MAJOR EQUIPMENT	B. Fired Heaters	84,500		
	C. Compressors and Fans	84,000		
	D. Drums - Vessels	65,000		
	E. Heat Exchangers	38,000		
	F. Tanks	-0-		
	G. Pumps	158,500		
	M. Separating and Drying Equip.			
	P. Materials Handling Equipment			
	Q. Fire and Safety Equipment			
	R. Converters and Reactors	116,000		
	S. Size Reduction Equipment			
	T. Towers	34,000		
	U. Auxiliary Equipment			
	V. Maintenance & Shop Equipment			
	X. Special Equipment			
	Z. Refrigeration Equipment			
	TOTAL MAJOR EQUIPMENT	580,000		580,000
II. MATERIALS AND CONSTR.	A. Foundations	17,000	54,000	
	H. Piping	189,000	445,000	
	L. Buildings	-0-	-0-	-0-
	J. Structural Steel	64,000	33,000	
	K. Instrumentation	356,000	203,000	
	L. Insulation and Fireproofing	25,000	65,100	
	N. Electrical	38,000	115,000	
	W. Equipment Erection	-0-	54,200	
	Y. Painting	5,000	15,700	
	TOTAL MAT'L'S AND CONST.	694,000	985,000	1,679,000
III	CONST. SUPERVISION COSTS	-0-	173,000	173,000
IV. ENG'G. COSTS	Engineering	} 29,875 M/H	1,015,000	
	Purchasing			
	Res. Eng. & Start-Up	700 M/H	35,000	
	Miscellaneous Costs	Const. H.O. 500 M/H	-0-	20,000
	TOTAL ENGINEERING COSTS	31,075 M/H	1,050,000	20,000
V. OTHER COSTS	Local Taxes 3%		40,000	40,000
	Duties			
	Export Freight			
	Field Modification			
	Escalation	Not Incl.	Not Incl.	Not Incl.
TOTAL OTHER COSTS				
VI	SUB-TOTAL BARE PLANT COST		2,364,000	1,178,000
VII	CONTINGENCIES AND FEES			
	Contingency		-0-	-0-
	Engineering Overhead & Profit		Incl.	Incl.
	Construction Overhead & Profit		Incl.	Incl.
			2,364,000	1,178,000
				3,542,000

The costs shown above do not cover modifications that may be required in the existing sections of the plant. As previously noted, additional feed preheat capacity and extract recycle and bleed handling capability must be incorporated into Sections 600 and 700 in order to effect high extract conversions, even at reduced capacities. Other modifications may be required elsewhere in the existing facilities.

The estimated costs for new sections 250 and 260, including tie-ins to the existing facilities, are of a caliber such that the actual costs should not exceed them by more than 25%. Thus, the total cost of just the new front end should not exceed 4.8 million dollars for the base case involving 20 TPD coal throughput and 4.4 million dollars for the 10 TPD alternate.

On the assumption that authorization to begin definitive design engineering would be given on or about July 1, 1979, it is estimated that start-up of the revamped facilities could be realized by the end of calendar year 1981.

B. Discussion of Estimating Procedures

1. Base Estimate (20 TPD Coal)

The cost estimate was based on the preliminary process design and layout studies contained in this report. The estimating procedure used was as follows:

a. Major Equipment

Preliminary quotations were obtained for the Slurry Preheater, Preheater Charge Pumps, and Recycle Compressors. The Slurry Preheater price obtained was based on a 316 SS coil, which was

later modified by SD for the more conservative choice of Inconel 800. The price for the horizontal triplex plunger charge pumps was obtained from Wilson Snyder. The compressor price was based on the preferred choice of a diaphragm machine.

All other equipment was estimated from in-house data; i.e., cost correlations based on recently received quotes for similar equipment.

b. Materials and Construction

Basic material requirements were estimated according to the procedures indicated below. Labor and indirect construction costs were then estimated from these material requirements, using correlations developed by SD from recently completed projects. Labor productivity was assumed to be 90% of U.S. Gulf Coast.

(i) Foundations

Concrete foundation designs were based on 1800 pounds per square foot at two feet below grade. Quantities of concrete were estimated from preliminary equipment sizes and weights and from the preliminary plant layout drawings.

(ii) Piping

A preliminary piping take-off was prepared based on the process flowsheets and plant layout drawings. Material of construction for process piping was specified as 304SS from the outlet of the Slurry Preheater to the Vapor Cooler No. 2 (for gases) and to the Intermediate Pressure Flash Drum (for

the slurry. All other process pipe was specified as carbon steel. Average process pipe diameter was assumed to be two inches (nominal). Pressure ratings were based on design pressures of the related major equipment. Valving requirements and utility and service piping were estimated from the process flowsheets and based on experience accumulated within SD for projects of similar scope.

(iii) Structural Steel

Weights of the ladders and platforms for both Section 250 and Section 260 and of the structure and pipe rack for Section 250 were estimated with the aid of experience for projects of similar scope.

(iv) Instruments

Instrument take-offs were prepared from the process flowsheets, with reference made to the plant layout drawings. The necessary piping and wiring were included in this take-off.

(v) Insulation and Fireproofing

Preliminary take-offs were prepared for insulation of equipment and piping and priced according to the required thickness. The steel structure for Section 250 was assumed to be fireproofed to the elevation of the first platform.

(vi) Equipment Erection

Direct labor manhours were computed from the preliminary equipment sizes and weights with reference made to the plant layout drawings.

(vii) Electrical

The electrical estimate was prepared from the plot plan, equipment arrangement and estimated motor horsepower.

Electrical runs were assumed to be overhead and mostly on existing structural racks. Pricing, labor manhours, and indirect costs for construction were prepared from in-house data.

(viii) Painting

Areas in square feet were calculated for equipment, structural steel, and pipe. Material costs, labor manhours, and construction indirect costs were prepared from in-house data.

(ix) Construction Equipment Rentals

Overall costs, prepared from the equipment list and estimating sheets showing size and weights, plot plan and elevations, were then allocated appropriately to the various codes of accounts.

c. Construction Supervision/Temporary Facilities

The approach taken in estimating these costs is one used successfully by SD in the past for small projects. This approach involves keeping the time in the field as short as possible and the number

of people as small as it can be. The latter is accomplished by using craft supervisors who have multiple skills such that one man can cover for example Civil, Mechanical, Piping and Welding while a second man can cover Instrumentation, Electrical and Insulation. The construction superintendent completes the direct supervisory personnel for the field work.

The costs of temporary facilities are kept to the minimum by the use of office trailers and second-hand truck vans for warehousing.

d. Engineering

The assumption was made that, after the completion of process and project engineering for which manhours have been given in the SD's proposal, detailed engineering would be accomplished following competitive bidding for same. The manhours for this work, were estimated without contingency based on the major equipment list included in the Appendix Section of this report. The overall contingency of 25% includes an appropriate allowance for engineering.

Resident Engineering hours were allowed for on the basis of a single man for a little over four months overlapping the final phases of construction, complete pre-operational testing and startup.

2. Reduced Capacity Estimate

Major equipment sizes were scaled down to those required for 10 TPD coal throughput and re-estimated. Materials and Construction costs were reduced appropriately where possible. For example in the Piping account, the average line size was assumed to be 1 1/2 inches instead of the 2 inches used originally. Other accounts such as Construction Supervision and Engineering are not affected by the reduction in capacity.

The net result is a reduction in the estimated capital cost of a little over 7% indicating that within the accuracy of the estimating being done at this time, the uncertainty regarding the design capacity to be used for the proposed new front-end is not a significant factor.

VI. USE OF EXISTING FACILITIES FOR COMPONENT TESTING

SD was requested to consider the potential of the Cresap pilot plant for use as a component testing facility. In this context, "component" is to be taken to mean any system smaller than the entire pilot plant operating in an integral mode with recycle. The pilot plant at Cresap contains a number of "test loops" designed for performance studies of pumps, valves, heat exchangers, fired heaters and for corrosion/erosion studies in various sections of the plant. Many of the test loops are for slurry service. These test loops were reviewed as well as the general potential at Cresap for either process or equipment tests which would have common features with other coal liquefaction processes. Sketches of the test loops appear on the various mechanical flow diagrams prepared by Fluor E & C for the refurbished pilot plant. An index of these sketches is included in the Appendix of this report.

A. Process Considerations

It is not practical to test the process performance of individual sections or sub-sections of the existing Cresap pilot plant without addition of a new front-end extraction system. The existing front-end extraction system, which operates under mild conditions of the CSF process, produces a much different extract product than does the SRC I, H-Coal or EDS process. Testing of the extract would not yield results that can be applied to those processes. For example, performance of the solids separation system (Section 300) depends strongly on the nature and

quantities of the liquid and the solids fed to that unit process (i.e. viscosity of the liquid, particle size distribution and quantity of the solids). Similarly, performance in extract hydrogenation depends strongly on the nature of the extract fed (pre-asphaltene content of CSF is much higher than that in SRC extract.)

Importing SRC I and solvent could be considered to simulate the Cities Service/Lummus work for hydro-processing SRC extract⁵ on a larger scale in Section 600; however, it would seem more useful to test an integrated pilot plant simulating the new two stage hydroliquefaction process proposed by DOE.

B. Mechanical Considerations

The following items were among those considered in reviewing the planned performance tests at Cresap and also in formulating suggestions for possible new tests:

- suitability for the intended service of the materials, equipment, instruments or valves being tested.
- applicability of pilot plant data to be acquired in a given test to design of a large scale demonstration plant.
- possibility of vendors supplying prototype equipment for testing.

Comments were solicited from various Engineering Divisions within the SD organization. These are summarized below.

1. Piping Valves

(For this discipline use was made of the report by Fluor designated FE - 1517-24 and entitled "Evaluation of Valves for Cresap Testing"). It has been SD's experience and it is SD's position that the most suitable valve types for slurry services are plug and ball valves.

The basis for favoring these types is that the ideal valve design for slurries should have the following features:

- a clear unobstructed path in the open position so that no surface including seating surfaces will be impinged upon directly and there-by suffer erosion and damage by abrasion.
- no, or minimal, stagnant pockets alongside the flow path where the slurry material may lodge itself and eventually form a hardened mass, especially if a buildup can develop and protrude into the flow path.

This approach is the basis for some of the comments made in the following discussion of the test loops. In each case where a different valve is recommended to be added or substituted for the valve specified in FE-1517-24, its selection was based on the possibility that the recommended item may be better suited to meet the criteria discussed above.

It is duly recognized that knife-gates and eccentric plug valves have also been used extensively and with success in handling slurries, particularly in the pulp and paper industry, ash handling and for suspended solids in waste treatment plants.

Specific comments in the following discussion are keyed to the appropriate Test Plan numbers. For descriptions of the various tests reference can be made to the index of test sketches in the Appendix and to the sketches themselves on the Fluor Mechanical Flow Diagrams.

a. Test 1601

The specified valve is a 2-inch, 150 lb stainless steel Stockham Slurry Angle valve, Model S-15A. An angle valve is the valve type which probaby lends itself the least to favorable operation in slurry service. With a vertically upward flow, the face and seating surface of the disc is directly in line with flow and thereby can experience abrasion. These surfaces as well as the seat are also vulnerable to incrustation of solidified materials which may render the seating surfaces incapable of fully closing. Considering that this is a low slurry concentration service, these conditions may not develop to the point where the valve is seriously impaired.

The application of and experience with this valve were discussed with the representatives of Stockham Valves. They indicated that this valve is extensively used in alumina slurries in which it often experiences incrustation on the seating surfaces. For this condition, it is necessary to crack off the solidified material with a mallet or chipping device and regrind the seating surfaces. This is apparently a bothersome and time-consuming maintenance procedure.

The specified valve has a stainless steel body and stainless steel internal parts. The vendor recommends the use of stellite seat and disc rings to provide maximum wear since stainless steel is much too soft to resist abrasive wear. This valve is available in sizes up to 24 inch.

An alternate valve which is probably more suitable for the service is the Rockwell-Nordstrom Multiport Valve, Figure 3865, Arrg't No. 1. This is a 3-way, 2-port valve which can be adapted for the purpose by including a "Stop" so that flow can be directed through any one port or shut off. This valve is available in stainless steel, and if required, can be provided with hard faced body and/or seat. It does require a lubricant which must be selected for compatibility with the flowing medium. It is available in sizes up to 12 inch.

b. Test 1602 (i)

The specified valve is a 3-inch, carbon steel DeZurik Eccentric Plug Valve, Model 198. This valve was developed for and is successfully used in low slurry concentrations where the Neoprene Rubber lining is expected to resist abrasion by the flowing fluid. Since the service is a low concentration slurry at low temperatures, this seems to be a proper selection. The valve is available in sizes up to 36 inch.

c. Test Plan 1602 (ii)

The specified valve is a 2-inch carbon steel Fabri Knife Gate; no model number is given in the report. From the description of details and discussion held with the representatives of Fabri Valves, it is assumed that the Fig. 37 is intended. The standard valve, however is stainless steel up through 6-inch and carbon steel lined with stainless steel in the 8-inch size and larger. For this low concentration slurry at low temperatures, this seems to be a proper selection. This valve is available in sizes up to 24 inch.

d. Test 1604

A 4-inch stainless steel spring loaded Marlin Wafer Check Valve is specified. Attempts to locate the Marlin Company and obtain its literature were unsuccessful. However, from the drawing in the report, we assume that the valve is identical or very similar to the Mission Duo-Chek valve. For this service, which is inert gas plus air and in lines which may only fill with dry solids during shutdown periods, the selection appears to be appropriate. The Mission valve is available up through 54 inch size.

e. Test 1605

Three lubricated plug valves are specified; namely,

- Rockwell Model 143 - 125 lb Cast Iron
- Rockwell Model 2045 - 150 lb Carbon Steel Hypreseal with
Hard Faced Plug
- Rockwell Model 2045 - 150 lb Carbon Steel Hypreseal with
Hard Faced Plug and Body Seat

However, it is not clear why the Hypreseal design was selected. This variation of the plug valve was specifically developed for application having temperatures above 350°F. It seems needlessly expensive to apply a specially designed valve to a service less severe than that for which it was intended.

Consideration should be given to substitute the Rockwell Dynamic Balance Plug Valve. This design provides for the application of the line pressure above and below the plug, so that there is no net torque required to operate the valve. This feature eliminates the need for regular lubrication maintenance;

however, a fitting is provided for the injection of a sealant to grooves on the body surrounding the plug in order to maintain tight shut off if the clearance between plug and body increases due to wear. The sealant must be selected to be compatible with the flowing medium. Also, a flush connection can be provided for removing solids lodged above and below the plug. Rockwell representatives indicate that the Hypreseal Valve will be phased out within the next two years in favor of the Dynamic Balance Valve. These valves are available in sizes up to 16 inch.

A top entry type ball valve should also be considered. This is discussed in more detail under Test Plan 1607.

f. Test Plan 1606

The specified valve is a 3-inch, 300 lb stainless steel Stockham Slurry Angle valve, Model S-30A for a high slurry concentration service. All comments made under Test Plan 1601 apply, and to a greater degree since this service is more severe.

g. Test Plan 1607

A 2-inch DeZurik Knife Gate Valve Series C is specified. The service is a heavy concentrated coal slurry with 40% of coal fines. The valve is available with metal-to-metal seats or with resilient seats (elastomers or Teflon). The report does not indicate the seat material but a resilient seat is assumed in order to obtain tight shut-off. Although this valve apparently has been used successfully for heavy slurries in the paper and

pulp industry, it appears that it may have a number of weaknesses.

A study of the drawing of the valve indicates that the knife gate sits in a groove when closed. If the slurry is capable of solidifying, particles may lodge themselves in the groove. On attempting to close the valve, the gate may push the particles into the groove and thus prevent full closure. In addition since the seat material is fully exposed to the flow, scoring may develop on its surface.

For this type of service, it is recommended that a ball valve, such as the Hills-McCanna top entry "McCannaseal" be considered. For the two problems mentioned above, it is quite likely that if the slurry tends to cake on the sides of the port, it will be cracked off by rotating the ball, and the Teflon seats are removed out of the flow path so that scoring is quite unlikely. In any case, the top-entry provides maximum accessibility for servicing.

The DeZurik knife-gate is available in sizes up to 24 inch. The ball valve is available in sizes up to 10 inch.

h. Test Plan 1608

This Test Plan is similar to Test Plan 1605 except that the service is a high concentration slurry. All comments made under Test Plan 1605 apply.

2. Vessels and Tanks

The Fluor report designated FE-1517-26, dated April, 1976 and entitled "Evaluation of the Use of Existing Cresap Pilot Plant Vessels for Development Testing" was reviewed. This report, which is on the main vessels in the plant, concludes that no worthwhile testing program could be developed using the existing vessels. SD substantially agree with Fluor's conclusions for the following reasons:

- Vessels in a commercial size plant will be of different size, shape and layout.
- Whatever the new shape and arrangement would be, they probably will be amenable to a standard vessel design approach so there probably would be no need for a "prototype" solely for the purpose of getting data on mechanical stability.
- Fluor's report indicates that whatever vessel damage there was, was primarily caused by malfunction or wear of ancillary mechanical equipment, i.e., agitators. Although vessels can be designed to allow for this, there is doubt that any test duplicating these failures on the existing equipment would develop any more information of value in the design of the commercial sized plant.

The idea was put forward that there might be some benefit from corrosion/erosion studies using the existing vessels as test subjects. From the information available, corrosion per se does not seem a major problem; however, erosion is severe. In general, again for corrosion only, the basic materials of construction specified seem fairly clearcut. Attempting

additional research as to material resistance to hydrogen attack would be going over already well explored ground and, in any case, such a testing program would need expert guidance and time which is not available.

A more productive area would be a continuing study on erosion resisting materials suitable for the abrasive ash. This would not only be of great benefit in a commercial sized plant for this process, but also in other competing processes. A great number of sophisticated materials have been already tried or suggested for further testing at Cresap. These tests should be completed if possible and the data completely reported.

3. Pumps, Compressors and Fired Heaters

The following information outlining the test program provisions at the Cresap facility was reviewed.

a. Pump Specifications for:

J-A 202 A/B	J-A 313 A/B/C/D
J-B 202	J-A 314 A/B/C/D
J-B 206	J-B 607
J-C 303	J-A 608 C/D

b. Schedule of Materials to be tested in reciprocating pumps

c. Schedule of Materials to be tested in centrifugal pumps

e. Fired Heater Specifications for:

B-A 201
B-A 501

d. Test Loop Diagrams for Fired Heaters

1311 - B-A 201
1316 - B-A 501

SD's comments are as follows:

- The materials and coatings scheduled for testing at Cresap appear to be suitable for the services.
- The only other material that can be suggested at this time is silicon carbide.
- The vendors supplying equipment for the pilot plant can build the same type equipment for a commercial scale plant.
- There are other manufacturers who build similar equipment but nothing with particularly unique features that would justify testing.
- The only mechanical design feature that might be studied is the use of flushed wear rings and throat bushings on centrifugal pumps. This feature is commonly used in refinery coking services.

4. Heat Exchangers

The Fluor report designated respectively FE-1517-28 (dated April, 1976) and FE-1517-25 (dated May, 1976) and entitled respectively "Evaluation of Heat Exchangers for Cresap Testing" and "Evaluation of Fired Heaters for Cresap Testing" were reviewed in conjunction with the plans embodied in Test Element Series 1200 and 1300 respectively. It was concluded that the carrying out of these test programs would provide useful information and that augmenting the programs would not be feasible in the time available. Moreover, limited inquiries indicated that it is not likely that heat exchanger manufacturers will donate prototypes for testing at Cresap.

5. Instruments

The "1700" series test elements details presented in Fluor report designated FE-1517-34 dated June, 1976 and entitled "Flow Measuring and Control Valve Applications for Coal Liquefaction Process Streams for Cresap Testing" were reviewed. It was concluded that the carrying out of the test program outlined there would provide significant information concerning flow measuring devices and control valves for the very difficult services involved and that to go beyond this program would not be feasible in the time available.

MAJOR EQUIPMENT LIST

PROPOSED ADDITION OF NEW EXTRACTION FACILITIES TO THE

CRESAP, W. VA. COAL LIQUEFACTION PILOT PLANT

SECTION 250 Extraction

<u>ITEM NO.</u>	<u>DESCRIPTION</u>
B-C251	Slurry Preheater
C-C252	Vapor Cooler No. 1
C-C253	Vapor Cooler No. 2
C-C254	Primary Slurry Trim Cooler
D-C251	Dissolver
F-C251	Reactor Effluent Separator
F-C252	Overhead Separator
F-C253	Overhead Decanter
F-C254	Intermediate Pressure Flash Drum
F-C255	Dissolver Blowdown Pump
J-C251A&B	Preheater Charge Pumps
J-C252A&B	Slurry Recirculation Pumps
J-C253	Dissolver Blowdown Pump

SECTION 260 Recycle Gas Treatment

C-C261	Solvent Heater
C-C262	Solvent Cooler
C-C263	Recycle Compressor Bypass Cooler
D-C261	Gas Absorber
F-C261	Gas Absorber Flash Drum
F-C262	Recycle Compressor Knock-out Drum
J-C261A&B	Solvent Circulation Pumps
JC-C261A&B	Recycle Compressors

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<u>Test Element Number</u>	<u>Test Element Title</u>	<u>Fluor Test Sketch Number</u>	<u>Test Sketch Description</u>	<u>Fluor Mechanical Diagram No. 448404-R</u>
1000	Solvent Deashing	1011	Solvent Supply System	1110 - 010
		1012	Extract Recovery System	0500 - 010
1100	Pumps	1115	J-A202A/B, J-B202	0200 - 010
		1125	J-B607A/B	0600 - 010
		1130	J-B303A/B, J-C303	0300 - 010
1200	Heat Exchangers	1204	C-A601	0600 - 010
		1208	C-A802	0800 - 010
		1211	C-A602	0600 - 010
		1212	C-A603	0600 - 010
1300	Fired Heaters	1311	B-A201	0200 - 011
		1316	B-A501	0500 - 010
		1317	B-A602A/B	0600 - 010
1600	Piping Valves	1601	Lunkenheimer, Stockham Valves in Low Slurry Concentration	0500 - 010
		1602	DeZurik Valves	0800 - 010
		1603	Bailey Rod-Out Valve	0500 - 010
		1604	Spring-Loaded Wafer Check Valve	0800 - 010
		1605	Rockwell Valves	0800 - 010
		1606	Lunkenheimer, Stockham Valves in high slurry concentration	0300 - 010
		1607	DeZurik Valves in high slurry concentration	0200 - 010
		1608	Rockwell Valves in high slurry concentration	0200 - 010
		1621	Grayloc High Pressure Connector	0600 - 010

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<u>Test Element Number</u>	<u>Test Element Title</u>	<u>Fluor Test Sketch Number</u>	<u>Test Sketch Description</u>	<u>Fluor Mechanical Diagram No. 448404-R</u>
1650	Piping Erosion	1660	Cold Slurry	0200 - 010
		1670	Hot Slurry	0300 - 010
1700	Instrumentation	1702	Flow Meters, Unit 300	0300 - 010
		1703	Flow Meters, Unit 500	0500 - 010
1750	Control Valves	1751	Control Valves, Unit 200	0200 - 011
1780	Let-Down Valves	1780	High Pressure Let-Down Valves Expansion Chambers	0600 - 010
1800	Extractor Improvement	1800	Extractor Improvement	0200 - 011
1850	Alternate Extractors	1850	Alt. Extractor Tie-ins	0200 - 011
1900	Corrosion	1911	F-A203A Inlet	0200 - 011
		1921	B-A201 Outlet	0200 - 011
		1922	C-A202 Outlet	0200 - 011
		1923	D-A201 Outlet	0200 - 011
		1931	B-A302 Inlet	0300 - 010
		1941	B-A501 Outlet	0500 - 010
		1951	J-A608 B Discharge	0600 - 010
		1961	J-A706A & B Suction	0700 - 011
		1971	J-A806A & B Discharge	0800 - 011

BRIEF HISTORY AND DESCRIPTION OF THE CRESAP FACILITY

Under contract with the Office of Coal Research, Consolidation Coal Co. developed the CSF process on a bench-scale and then prepared a design for the Cresap pilot plant based on that process. Detailed engineering design of the original pilot plant was carried out by C. W. Nofsinger Co. Construction was completed in 1967 by Dravo Corporation. Portions of the plant were operated intermittently from 1968 until shutdown in April, 1970. During this period numerous mechanical deficiencies were encountered. Toward the end of this period, however, runs of up to ten days were carried out for portions of the plant including extraction, solids separation and carbonization. Operation of the extract conversion facilities was not as successful.

In 1974, the Office of Coal Research awarded Fluor Engineers a contract to (1) refurbish the pilot plant; (2) add facilities for testing equipment, valves, instruments, and for conducting corrosion/erosion studies; (3) make necessary modifications to meet new environmental and OSHA standards; and (4) start-up and operate the refurbished pilot plant. Operation was resumed in late 1977. In August, 1978, sustained operation of the entire pilot plant, including extract conversion, over a six day period was achieved for the first time.

The CSF process as it is currently operated at Cresap produces a low-sulfur heavy fuel oil. In addition, some lighter boiling distillate material is produced, as well as small quantities of gases and a char which contains mineral matter, unconverted coal, polymerized material and unrecovered coal extract.

The conversion of coal to heavy fuel oil takes place in two steps:

1. Extraction of the coal at 400 psig and 750°F. Hydrogenation of pulverized coal is achieved by transfer of hydrogen from a donor solvent stream. Coal conversion on the order of 70% is achieved in this step.
2. Partial conversion of the coal extract in a high pressure hydrogenation step to form low-sulfur distillate products and to further remove sulfur from the coal-derived materials. Hydrogenation occurs in an ebullated bed in the presence of a catalyst. A donor solvent cut is separated from the distillate products for recycle to the extraction step.

The attached block diagram outlines the main steps in the process. After extraction of the coal with recycle and donor solvents, solids are removed from the hydrogenated slurry by one of several methods; i.e., (1) gravity separation, (2) a variation of gravity separation called "solvent deashing," in which a paraffinic solvent is added to enhance settling, (3) hydroclones, or (4) filtration. The separated solids are fed to a Low Temperature Carbonization Unit where a char containing mineral matter and unconverted coal is produced. In a commercial plant the hydrogen required for extract hydrogenation would be produced from this char. Extract and solvent is recovered within the carbonization unit and recycled to the solids separation step.

BLOCK DIAGRAM OF PROCESS AREA

CRESAP, W. VA.-COAL LIQUEFACTION TEST FACILITY

The extract/solvent stream that remains after solids removal flows to a vacuum distillation system where light oil and recycle solvent are separated from the extract. Light oil is sent to storage. The recycle solvent stream is required in the coal extraction step to form a pumpable coal slurry.

Partial conversion to distillates is achieved in the hydrogenation section. Originally four series hydrogenation reactors were installed. Currently, only two reactors are fully piped up. The first reactor has, however, been used as part of a feed preheat loop so that only one reaction stage was used during 1977-1978.

The effluents from hydrogenation are a gas stream (which is fed to a Stretford Unit for removal of H_2S) and several liquid streams which are fractionated to yield a light oil, middle distillate, donor solvent and heavy flash bottoms stream containing unconverted extract and some of the heavier distillate material. The light oil is sent to storage. Middle distillate is added to the flash bottoms to form the fuel oil product and donor solvent is recycled to the coal extraction section.

A more detailed description of the CSF Process is given in a paper by D. G. Chapel entitled "Initial Operation at the Cresap Test Facility," presented at the Fifth Annual Conference on Coal Gasification, Liquefaction and Conversion to Electricity, U. of Pittsburgh, August 1978.

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