SUMMARY

The objective of the work reported herein was to develop the capital costs and the product cost for a facility to produce methanol from coal using Texaco coal gasification technology and ICI methanol synthesis technology. Th design and cost estimating techniques are intended to be comparable to those employed in another EPRI study (1) carried out last year in which the same coal was used to produce a range of hydrocarbon products via direct coal liquefaction. Both studies employ identical coal feed analyses, coal feed rates, plant site conditions, field labor rates, and costing basis (mid-1979 pricing).

Fluor developed a cost estimate for the plant, with the exception of the Rectisol acid gas removal unit. On this unit a turnkey cost estimate was received from Lotepro, the U.S. affiliate of Linde AG of West Germany.

On this effort, Fluor has relied heavily on previous design studies for the basic cost data employed for some of the conventional process units as well as the utility and off-site systems. For the major process systems including gasification, shift conversion, methanol synthesis, and methanol refining, capital costs were individually determined for all major equipment items, with total selling price for each plant unit or section being determined by internal cost correlations. Capital costs are presented on both a site specific and a U.S. Gulf Coast basis. Total capital requirements, operating costs and product prices have been determined using EPRI's economic premises, all described in the report.

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1. Engineering Evaluation of Conceptual Coal Conversion Plant Using the H-Coal Liquefaction Process, EPRI AF-1297: Fluor Engineers and Constructors, Inc., December 1979

Some of the salient design characteristics are summarized below:

Table S-1

PLANT DESIGN CHARACTERISTICS

FEEDSTOCK	
Coal Feed Rate (Illinois No. 6), tpd (MF)	14,448
PRODUCT	
Methanol, tpd (0.74 percent H_2O)	10,927
BY-PRODUCT	
Elemental Sulfur, tpd	501
PLANT INVESTMENT - \$ MILLIONS	1,159
Product Cost, First Year of Operation (1985)	
\$/10^6 Btu (HHV)	4.71
¢/gallon	30.3
THERMAL EFFICIENCY - PERCENT	
(Calculated on HHV of Methanol Product)	57.86

The product methanol is intended for use by the electric power industry as either a turbine or a boiler fuel. The methanol contains a small amount of chemical impurities and does not meet the U.S. specification for chemical grade methanol.

Design data was solicited and received from Texaco on coal gasification and from Imperial Chemical Industries (ICI) on methanol synthesis. Lotepro provided the design for the Rectisol acid gas removal unit. The design of the remaining units including coal preparation, shift conversion, COS hydrolysis, air separation, methanol refining, and all the utility and off-site systems was developed by Fluor.

The process design involves coal preparation, air separation, coal gasification, shift conversion, Rectisol acid gas removal, COS hydrolysis, methanol synthesis, and methanol refining. Ancillary process units include Claus sulfur recovery, tail gas treating, and hydrogen recovery via pressure swing adsorption (PSA). In addition, all necessary off-site facilities are provided. All electric power needed for plant operation is generated onsite.

The process design developed in the course of this work appears noteworthy for a number of reasons as follows:

- Careful heat integration between the various sections of the plant has led to a relatively high overall thermal efficiency.
- The low inerts content characteristic of synthesis gas produced by the Texaco process combined with its ability to generate this gas at pressures in excess of 50 atmospheres made it possible to select a low-pressure methanol synthesis unit and eliminated the need for feed gas compression.
- A pressure swing adsorption (PSA) unit is employed to recover and recycle hydrogen from the synthesis loop purge gas.
- A Rectisol acid gas removal system was selected due to its successful history of protecting sulfur sensitive catalytic systems in commercial operations. The Rectisol process utilizes methanol as absorbant for the acid gases, H_2S and CO_2.
- A novel process design for the methanol refining system has been developed as a means of reducing heat needed for fractionation. This contributes significantly to the high thermal efficiency achieved in the design.

Section 2

BASIS OF DESIGN AND ASSUMPTIONS

The yields associated with gasifying Illinois No. 6 were furnished by the Texaco Development Company upon request by EPRI. Texaco considers the design basis they have provided, including the slurry feed concentration of 60 percent coal, to be representative of current technology that has been demonstrated in their test facilities. Some previous EPRI gasification studies (such as AF-642) assumed a slurry concentration of 66.5 percent for a very similar Illinois No. 6 coal. The 66.5 percent slurry concentration design basis was considered by both Texaco and EPRI to represent a projection of technology. Note that certain aspects of the Texaco unit are considered proprietary and are not described in this report.

Fluor obtained necessary design criteria from Imperial Chemical Industries (ICI) of Great Britain for the methanol synthesis unit and developed the process design. Many of the design features of the ICI process are proprietary and are not included in the report.

A design and cost estimate of a Rectisol unit for removal of acid gases from the methanol synthesis gas was obtained from Lotepro, the U.S. affiliate of Linde AG of West Germany.

The plant size selected for this study was 14,468 tons per day of coal expressed on a dry basis. This is the same feed rate as used in EPRI Research Project 411-4 to which the results of this study may be compared.

Most of the equipment items for this plant were specified as shop fabricated items. However, the shift converters and methanol synthesis reactors are too large to be shipped from a fabricator's shop to the jobsite by rail. These reactors were priced as field fabricated vessels of monobloc construction using in-house cost data. Several vessel fabricators were contacted to determine the alternative cost of these reactors when constructed as field fabricated vessels using layered construction techniques. The costs reported for layered construction vessels was slightly higher than that of monobloc construction vessels for these specifications, and monobloc construction was chosen. It was noted that for vessels of increased size, wall thickness, and especially weight, state-of-the-art layered construction techniques will show a cost savings over monobloc construction.

Site conditions selected for this study are generally representative of a rural Illinois location. It was assumed that feed coal would be received by rail and that product methanol would be shipped by rail or truck. Plant elevation is assumed to be 500 feet MSL and design air temperature is 85°F. The electric power needed for operation of the facility is generated on-site.

Coal analysis of the Illinois No. 6 used is as follows:

Ultimate Analysis	Weight Percent
Carbon	69.76
Hydrogen	4.91
Nitrogen	1.47
Sulfur	3.47
Oxygen	8.88
Chlorine	0.07
Ash	11.44
	100.00

EPRI furnished the following specification for the product methanol, primarily directed towards use as turbine fuel.

Item	Weight Percent
Methanol	99.0 Minimum
Heavy Ends	0.25 Maximum
Water	0.75 Maximum

Section 3

PLANT CONFIGURATION

The selection of the Texaco process for coal gasification and the ICI process for methanol synthesis was made by EPRI before the start of Fluor's work.

The selection of the Rectisol process for acid gas removal was based upon the need for a process which has the demonstrated capability of reducing residual sulfur concentration to extremely low levels to protect the methanol synthesis catalyst from poisoning. The Rectisol process satisfies this requirement.

The overall energy balance, including electric power and steam, is dictated by the large amount of high-level process heat that is recovered as 1500 psig steam in both the gasification and the shift units. These sources furnish about 88 percent of the total steam requirement needed for electric power generation and for mechanical drive of the process equipment including the air, oxygen, and methanol synthesis unit recirculation compressors. The remainder of the prime steam is raised in gas-fired boilers, utilizing purge gas from the methanol synthesis unit as fuel. Schemes involving gas turbines proved unattractive in this study.

For this design, the waste heat boilers in the Texaco unit are specified as the superheating type. If all the high-level heat in the gasifier effluent had been used to generate saturated steam, an externally fired superheater would be required. Total steam generation would then be substantially greater and would exceed the amount needed for in-plant purposes. Therefore, surplus electric power would have to be generated and exported, but this would not have conformed with the requirements for this study.

This design calls for a Texaco gasification system that will produce two gaseous effluents:

- a quenched water-saturated gas stream containing sufficient water vapor for shift conversion
- a high-temperature gas stream from which a large amount of high-level process heat can be recovered.

A portion of the cooled second stream is commingled with the first stream prior to shift conversion. The remainder of the second stream is mixed with the shift effluent to produce a gas with the proper H_2:CO ratio for methanol synthesis. One of the principal objectives in the development of this scheme is to maximize heat recovery, while at the same time providing for a practical shift conversion scheme. In actual operation, control of the overall scheme must be achieved by varying the bypass flow around the shift converter to compensate for process variables such as catalyst aging and fluctuations in gasifier effluent composition.

Overall environmental considerations have led to the inclusion of a COS hydrolysis operation on the gas bypassing the shift converter. Although the Rectisol process is capable of COS removal, it appears that a more expensive Rectisol unit will result if it must be designed in such a manner that a high percentage of the COS reports with the H_2S-rich gas going to the Claus unit. Hydrolysis of carbonyl sulfide occurs in the shift converter so that a separate COS hydrolysis step on that stream is unnecessary.

Based upon a recommendation made by ICI, plus previous Fluor studies, a nominal 50 atmosphere methanol synthesis unit was selected so that the methanol synthesis loop will operate at essentially the same pressure as the gasifiers with no need for feed gas compression. Accordingly, the pressure level for the facility was established primarily by limitations on the oxygen compressors. The decision was reached to employ only centrifugal compressors for this service, and that discharge pressure would be limited to those that have either been commercially demonstrated or pressures which the manufacturers indicate can be reached with existing product lines. Fluor's evaluation indicated that an oxygen discharge pressure of 1050 psig is feasible under these conditions. Allowing for the pressure drop considered necessary by Texaco for control of the gasification operation, gasifier pressure was established at 915 psig. Making allowance for pressure drop through the remainder of the gas processing train, the operating pressure of the methanol synthesis reactors was set at a nominal 800 psig or about 54 atmospheres.

The amount of gas purged from the methanol synthesis loop exceeds that needed for the boiler. Therefore, a Pressure Swing Adsorption (PSA) unit is provided to recover hydrogen from the purge gas. The recovered hydrogen is recycled to the methanol synthesis loop, while residual gases, depleted in hydrogen but containing significant amounts of CO and methane, are utilized as boiler fuel.

Section 4

OVERALL PLANT DESIGN

OVERALL DESCRIPTION

The overall processing sequence is depicted in Drawing No. 4-001, Overall Block Flow Diagram.

The overall facility consists of a coal-to-methanol plant along with the required support, utility, and off-site facilities to comprise a self-sufficient operation. Coal is gasified via Texaco partial oxidation technology using oxygen as the oxidant. The gasifier effluent stream is then processed by shift conversion, COS hydrolysis, and Rectisol acid gas removal to produce a methanol synthesis gas. This gas is then processed, via the ICI low-pressure process, to produce methanol. Water formed during methanol synthesis is removed from the product by distillation. Purge gas from the methanol synthesis loop furnishes the fuel needs of the entire facility. The primary product is a stabilized methanol stream suitable for use by the electric power industry as either turbine or boiler fuel.

Support units, in addition to coal receiving, include the air separation plant, a sulfur recovery plant, and product storage and shipping facilities.

Utility services include all systems necessary for operation of the plant such as steam, electric power, fuel gas distribution, cooling water, instrument air, boiler feedwater treating, potable water, fire water, storm and waste water facilities, and sanitary water treating. Electric power in sufficient amount to satisfy the in-plant requirements is generated in turbogenerators. Steam is generated in gas-fired boilers and by recovery of process heat.

Off-site requirements include items such as administration building, laboratory, change and guard houses, maintenance building and equipment, warehouse, firehouse, roads, fencing, on-site railroad trackage, and like items.

LISTING OF UNITS

The facility has been subdivided as shown below. Also indicated is the number of trains of equipment within each process unit.

Table 4-1

LIST OF UNITS

Unit No.	Description	Number of Trains
01	Coal Preparation	1
11	Air Separation	6
21	Coal Gasification	*
31	Gas Processing and Cooling	
	COS Hydrolysis	2
	Shift Conversion	2
32	Acid Gas Removal (Rectisol)	4
41	Methanol	
	Methanol Synthesis	4
	Methanol Refining	4
51	Emissions Control	
	Claus Sulfur Plant	2
	Tail Gas Treating	2
61	Steam and Power Generation	
	Boiler Plant	3
	Turbogenerators	2
71	Product Storage and Shipping	
81	Utilities	
91	Off-sites	

*Proprietary information

FEED AND PRODUCTS

Table 4-2 presents a tabulation of the feed and product flow rates for the facility and Table 4-3 gives the expected analyses for coal and the the methanol product.

Table 4-2

FEED AND PRODUCT FLOW RATES

	TPD	Lb/hr
FEED STREAMS		
Coal (MF Basis)	14,448	1,204,000
Oxygen (as 100 percent)	13,853	1,154,400
PRODUCT STREAMS		
Methanol	10,927	910,601
Sulfur	501	41,737
Ash to Disposal (dry basis)	1,666	138,814

Table 4-3

FEED AND PRODUCT INSPECTIONS

FEED STREAM

Coal (Illinois No. 6)

Ultimate Analysis (Dry)	Weight Percent
Carbon	69.76
Hydrogen	4.91
Nitrogen	1.47
Sulfur	3.47
Oxygen	8.88
Chlorine	0.07
Ash	11.44
	100.00
Moisture Content, Wt.%	11.00

PRODUCT STREAM

Methanol (Fuel Grade)

Methanol	99.09
Heavy Ends	0.08
Light Ends	0.09
Water	0.74
	100.00

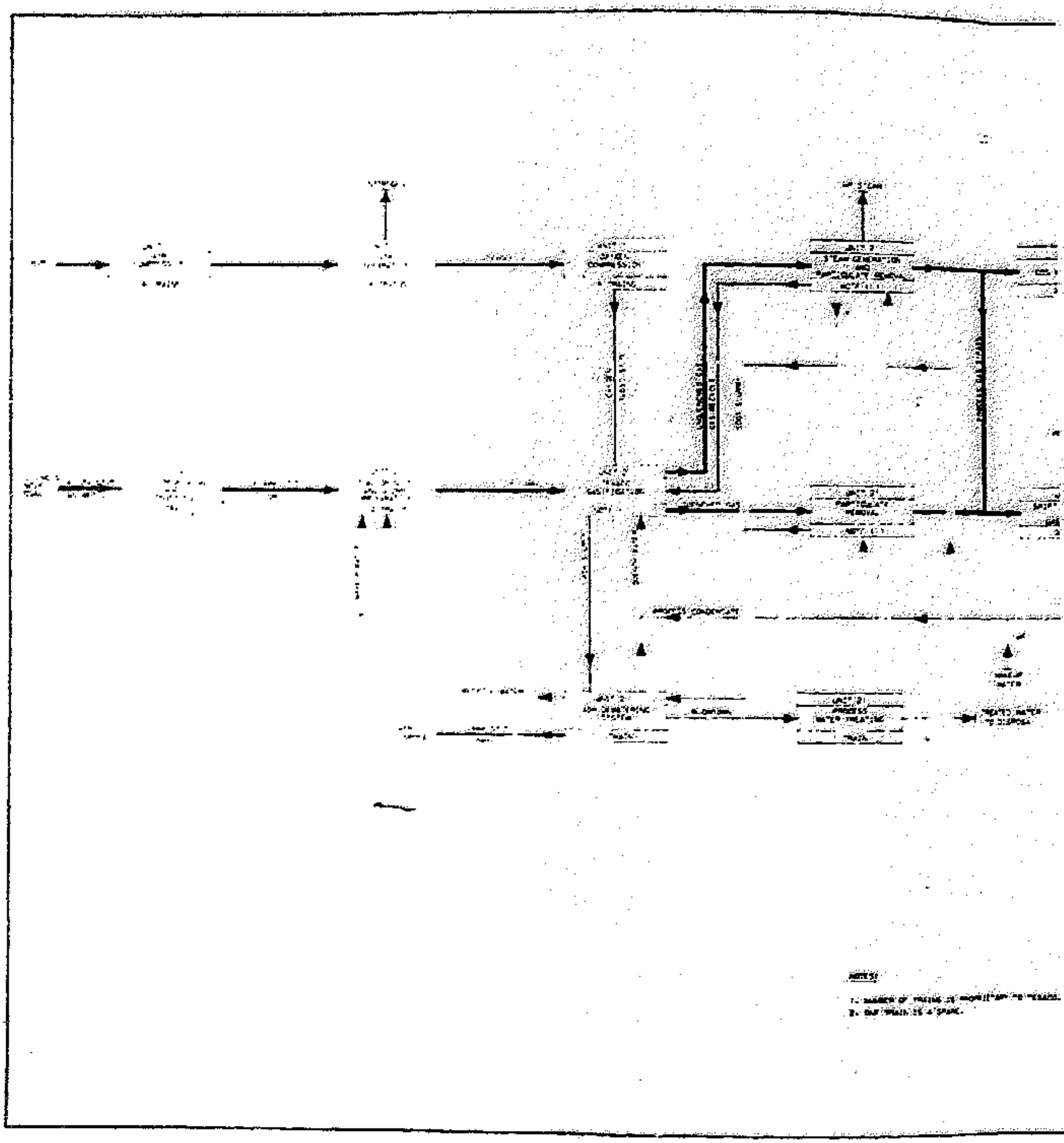
THERMAL EFFICIENCY

Overall thermal efficiency of the facility is calculated to be 58.95 percent on an HHV basis as shown in Table 4-4. Also shown in this table is the efficiency calculation based on LHV of coal and products.

Table 4-4

THERMAL EFFICIENCY CALCULATION

	Flow Rate Lb/hr	Heat of Combustion Btu/lb	Total Heat 10^6 Btu/hr	Efficiency Percent
HIGHER HEATING VALUES (HHV)				
Heat Input				
Coal (MF)	1,204,000	12,669.5	15,254.1	100.00
Heat Output				
Methanol	910,601	9,692.4	8,825.9	57.86
Sulfur	41,737	3,983.0	166.2	1.09
Total			8,992.1	58.95
LOWER HEATING VALUES (LHV)				
Heat Input				
Coal (MF)	1,204,000	12,214.3	14,706.0	100.00
Heat Output				
Methanol	910,601	8,501.5	7,741.5	52.64
Sulfur	41,737	3,983.0	166.2	1.13
Total			7,907.7	53.77


STEAM GENERATION
AND
PROCESS CONDENSATE
PROCESS
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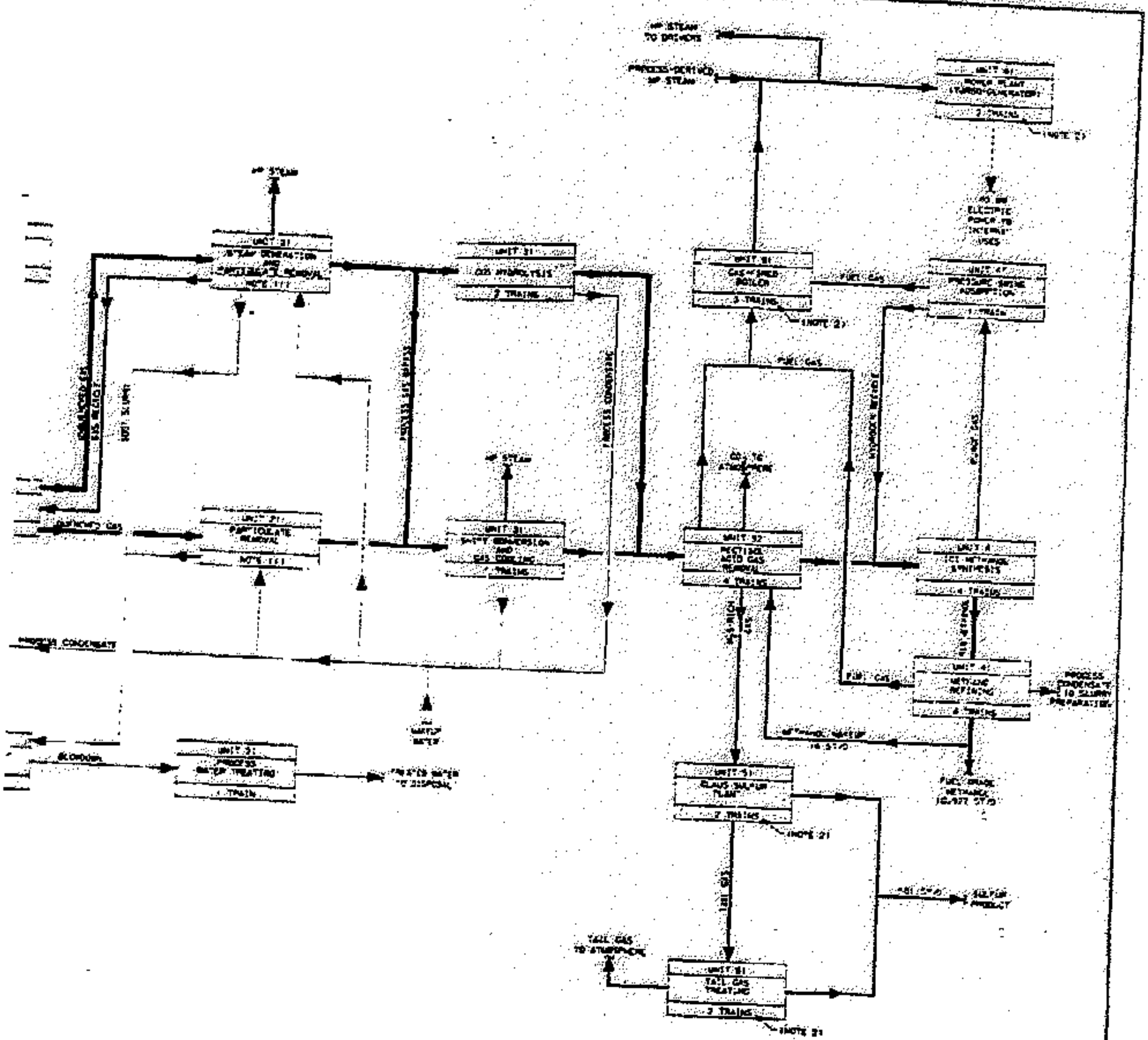

NOTES:

1. NUMBER OF TRAINS IS PROPRIETARY TO TEXACO.
2. ONE TRAIN IS A SPARE.

OVERALL BLOCK FLOW DIAGRAM
COAL TO METHANOL PROJECT

NONE

475004-4-001

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