TRI-STATE SYNFUELS COMPANY
Indirect Coal Liquefaction Plant
Western Kentucky

FLUOR ENGINEERS AND CONSTRUCTORS, INC.
Contract 835504

August 27, 1981

PROCESS DEVELOPMENT STUDY NO. 2

MENTHOL/SNG PRODUCTION

DRAFT COPY
FOR
REVIEW AND COMMENT

Comments must be received by Fluor no later than September 28, 1981 to preclude adverse impact of schedule.

PROCESS DEVELOPMENT STUDY NO. 2

METHANOL/SNG PRODUCTION

TABLE OF CONTENTS

PROCESS DEVELOPMENT STUDY NO. 2

Methanol/SNG Production

I. INTRODUCTION

The past Tri-State studies have been directed towards adapting a Sasol-type plant to produce transport fuels from coal. The Sasol plants utilize the Synthol (Fischer-Tropsch Synthesis) process to produce liquid fuels and a variety of by-product chemicals. The Tri-State Feasibility Study utilized a configuration that incorporated the processing steps identical to those used by Sasol except for minor adjustments to allow for different coal, different product specifications and different environmental constraints.

The current study investigates two alternate processing routes and the resultant product slates. The first alternate uses the synthesis gas to produce a fuel grade methanol product. The second case examines a process configuration that would futher convert the methanol to gasoline using the Mobil MTG process.

Fluor prepared conceptual designs, and capital and operating cost estimates for the two alternate cases using in-house data. This data along with the data developed for the Synthol case, prepared during the Feasibility Study, are presented here.

II. SUMMARY

Presented in this section is a summary of data developed for the three alternate processing schemes to produce liquid fuels from coal. The data for the Synthol case are extracted from the earlier Feasibility Study while the data for the two alternate cases were prepared as a part of this study. The Synthol case, as presented in the Feasibility Study, utilized processing steps identical to those used in Sasol plants except for minor modifications that are necessary to allow for different feed coal, different product specifications, and different environmental constraints. One significant deviation from the Sasol processing scheme is that the methane separated from the Synthol tail gas is not reformed to maximize liquid fuels but is instead further processed to produce SNG. The plant size is roughly the same as the Sasol II plant.

The plant utilizes Lurgi Mark IV gasifiers to gasify coal. Raw gas from the gasifiers is cooled and purified before being fed to the Synthol unit. Gas cooling and purification produces liquid streams which are further treated to extract useful products. The heavy tars are upgraded through Tar Distillation and Oil Workup units to produce useful transport fuels. The gas liquor stream is treated in Phenosolvan/Ammonia Recovery units to produce ammonia and phenol by-products. Naphtha recovered from these liquids is hydrogenated and used as gasoline blending stock.

The cooled gas that has been purified in a Rectisol unit is fed to the Synthol unit. The liquids produced in the Synthol unit are upgraded in the Oil Workup and Chemical Workup facilities to produce LPG, gasoline, jet fuel, diesel fuels, medium fuel oil, and a variety of alcohols and ketone chemicals. The gas stream from Synthol is treated to recover an ethylene product. A hydrogen-rich gas and a methane-rich gas are separated from the tail gas. The hydrogen-rich gas is recycled back to Synthol while the CH_4-rich gas is further processed to produce an SNG product. The Rectisol unit produces a CO_2/H_2S stream, which is further treated in the Sulfur Recovery Unit to produce sulfur.

The first alternate processing scheme (Methanol Case) proposes to produce fuel grade methanol. This scheme synthesizes the purfied gasification gases to methanol. This will result in the deletion of the Synthol and the downstream processing units such as the Oil Workup, Chemical Workup, C_2 Recovery, and the Ethylene plant. The Lurgi gasification units, the associated gas cooling and purification units as well as the gasification liquids processing units remain the same as in the Synthol case. The liquid products from the plant are limited to fuel grade methanol and the phenols and creosotes produced from Lurgi gasifiers rather than a wide range of liquid fuels produced in the Synthol case.

In this methanol case the methane contained in the gasification gases leaves the Methanol Synthesis unit in the form of a purge gas. This purge gas is further treated by methanation and purification to produce an SNG product.

The second alternate processing scheme (MTG Case) proposes to produce methanol as in the methanol case and further convert it to gasoline using the Mobil "Methanol-to-Gasoline" (MTG) process. The MTG product is fractionated to yield a stabilized gasoline blending stock, LPG, isobutane (iC_4), and a mixed C_4/C_5 stream. The mixed C_4/C_5 stream is alkylated with some of the iC_4's to produce alkylate. The remaining iC_4's will be sold as product while the stabilized MTG gasoline, alkylate and the nC_4/iC_5 from the Alkylation unit are blended together. This blend does not appear to meet gasoline specifications and it is suggested that it be marketed as a gasoline blend stock. The hydrogenated Lurgi naphtha is not blended into the gasoline pool as it may be feasible to use it as feedstock for benzene extraction.

In all three cases, the plant is self-sufficient in steam generation. In-plant boilers produce steam at 1500 psig which is let down to 600 psig through turbogenerators to meet the plant steam demands. The plant power demands are met by the power generated by the turbogenerators with an deficiencies being made up by purchased power.

Table 1 and Table 2 present a summary of an overall feed/product slate and the capital and operating costs for the three processing schemes. The coal feed to the plant boilers varies due to different steam demands for the different schemes. As seen in the table, the Synthol case results in the lowest thermal efficiency (useful thermal energy output as a precentage of energy input) and the methanol case the highest.

The methanol case eliminates the Synthol and the downstream processing units and replaces them with a Methanol Synthesis unit. Deletion of the

Synthol and associated units saves capital investment, and reduced processing saves energy, making this scheme more thermally efficient. As this scheme involves a smaller number of processing units, the catalyst and chemical requirements are reduced as are the operating manpower requirements. The fuel grade methanol produced in this scheme could possibly be marketed as turbine fuel or as an extender to gasoline.

In the MTG case the methanol is converted to gasoline using the Mobil MTG process that converts methanol to dimethyl ether which is further converted to gasoline. This additional processing step increases the capital investment over the methanol case. The additional processing also requires additional energy making this case slightly less thermally efficient than the methanol case. Additional processing also results in an increase in the catalyst and chemicals consumption as well as the operating manpower requirements.

A gasoline product produced by blending the stabilized gasoline, alkylate, hydrogenated Lurgi naphtha, isobutane and the nC_4/iC_5 appears to meet the summer specifications but fails to meet the volatility (V/L) specification for the winter conditions. Additionally, the gasoline produced in this scheme is stated to contain 4 to 6 wt. percent durene. Durene is these concentrations can cause carburetor icing problems in colder climates. To avoid such problems and to meet the gasoline specifications, it is suggested that the gasoline so produced be used as a blending stock. However, for the purpose of this study, it is proposed to produce Lurgi naphtha and isobutane as separate products and blend together the stabilized MTG gasoline, alkylate and nC_4/iC_5's to be marketed as a gasoline blending stock.

Table 1

Overall Feed/Product Slate

	Synthol	Methanol	MTG
Feeds			
Coal Feed			
Gasifiers, ST/D	21,895	21,895	21,895
Boilers, ST/D	8,772	7,341	7,881
Raw Water, GPM	18,685	16,800	17,700
Electric Power (Purchased), MW	83.2	43.9	44.0
Products			
SNG, MM SCF/D	155.7	155.3	151.5
Methanol, ST/D	(2)	9,673	-
Gasoline, BPD	17,411	-	-
Gasoline, Blend Stock, BPD	-	-	28,423
Treated Lurgi Naphtha, BPD	(3)	2,541	2,541
C_3 LPG, BPD	1,219.5	-	2,113
Isobutane, BPD	-	-	2,811
Jet Fuel, BPD	4,629	-	-
Diesel, 1-D, BPD	3,349	-	-
Diesel, 2-D, BPD	267	-	-
Fuel Oil, BPD	506	-	-
Ethylene, ST/D	481	-	-

Table 1

Continued

	Synthol	Methanol	MTG
Products (Continued)			
MEK, ST/D	18.6	-	-
Acetone, ST/D	57.0	-	-
Higher Ketones, ST/D	0.7	-	-
Ethanol, ST/D	128.4	-	-
Propanol, ST/D	37.0	-	-
Butanol, ST/D	19.3	-	-
Pentanol Plus, ST/D	18.4	-	-
Phenols, ST/D	44.5	44.5	44.5
Cresols, ST/D	54.4	54.4	54.4
Cresotes, ST/D	404.1	404.1	404.1
Sulfur, ST/D	565.5	565.5	565.5
Ammonia, ST/D	217.5	217.5	217.5

(1) Rates are based on a stream day basis. An on-stream operation of 340 days per year is assumed.

(2) Methanol produced in the chemical workup facilities is consumed as makeup in the Rectisol unit.

(3) Lurgi naphtha is blended into gasoline in this case.

III. Capital Cost Estimate

The Tri-State Synfuels Project Feasibility Study served as the primary data base for this study. The feasibility study scope was adjusted as necessary by unit to reflect the scope of the study using factored type cost estimates. Additional Direct Field Cost Estimates were developed for units included in this study that were not included in the feasibility study. These cost estimates were prepared using either capacity factored or 400 account type cost estimates. Estimates for each case are given in Table 2.

The cost estimates are January 1980 dollars and include a 10% contingency.

Table 2

Capital and Operating Cost

	Synthol	Methanol	MTG
Capital Cost, $MM	3,304	2,588	2,785
Catalysts and Chemicals			
Initial, $MM	22.0	12.4	19.5
Annual, $MM/Yr	36.2	21.0	22.9
Maintenance			
Labor, $MM/Yr	39.6	31.1	33.4
Materials, $MM/Yr	59.5	46.6	50.1
Operating Labor			
Manpower	1,100	866	954
Annual Cost @ $29,000/man, $MM/Yr	31.9	25.1	27.7

IV. Schedule

The Project Master Schedule (Attached) indicates a first of December 1987 mechanical completion. This is some two weeks earlier than the Synthol case. While it is ture that the me-hanol plant contains less units, it is the critical path units which set the schedule and they remain essentially the same in both cases (Lurgi gasification, steam and power generation, etc.).

The Project Master Schedule is based on two major assumptions:

1. A decision to change to either of these two plants by mid-September 1981.
2. No delays in the start of Phase 2 due to delays in environmental approvals.

V. Process Description

Brief process descriptions of the three different schemes are presented in this section. Also presented are simplified process block flow diagrams and plot plans. Table 3 presents a list of the process units required. The Offsites and Utilities systems in each scheme remain the same, though the size of the various systems change.

The front end of the plant, where the coal is gasified, the coal gas is purified to prepare synthesis gas, and the gasification liquids are procrssed, is identical in all three schemes. The only difference appears in the oxygen purtiy for gasification. The synthol case used an oxygen purity of 98.5% while the two alternate schemes use 99% pure oxygen. The higher purity oxygen is required for the two alternate schemes to keep the inerts in the methanol synthesis purge gas at the level that will permit SNG specifications to be met. Each scheme requires 36 Lurgi Mark IV gasifiers to gasify coal at a rate of 21,895 short tons per day. The gasifiers produce raw synthesis gas by partial oxidation of coal in the presence of steam and oxygen.

The raw gas from Lurgi gasifiers contains reaction water and some heavy hydrocarbons that are condensed as the gas is cooled. The condensed material is then separated into aqueous and hydrocarbon phases in the Gas Liquor Separation Unit. The aqueous phase is further treated in the Phenosolvan unit for recovery of phenols and cresols. The ammonia-contaminated water from Phenosolvan is treated in the Ammonia Recovery unit to produce an ammonia product. The hydrocarbon phase from the Gas Liquor Separation unit is fractionated in a Tar Distillation unit to recover naphtha, creosotes and pitch. Naphtha is combined from naphtha recovered in Rectisol unit and processed in the Naphtha Hydrogenation unit, while the pitch is used as in-plant fuel. The cooled raw gas is further purified in a Rectisol unit that uses a cold methanol wash system to remove sulfur compounds and CO_2 from the raw gas. The sulfur-contaminated CO_2 from Rectisol is treated in a Stretford unit to recover sulfur.

The purified gases from Rectisol are processed to yield hydrocarbon liquids. The three schemes presented in this study differ in the process steps used to produce hydrocarbon liquids as well as the end products themselves. Brief descriptions of the processing steps used in the three different schemes follow this discussion.

In all schemes, the plant is self-sufficient in steam generation. Steam is generated at 1500 psig by boilers that use coal fines as fuel. The 1500 psig steam is let down to 600 psig through turbogenerators to provide electrical power and provide the in-plant steam requirements. Any deficiency in the electricity used in-plant is made up by purchased power. In all schemes, the purchased power requirements are below the 100 megawatt limit specified in the Feasibility Study. Contaminated liquid effluents are treated for resue or disposed of on-site. There is no effulent discharge of hazardous materials from the plant.

See the Feasibility Study for a more complete description of the front end units as well as the offsites and utilities systems.

Synthol Case (Dwg. 835504-00-4-012)

Purified gas from Rectisol is fed to the Fischer-Tropsch based Synthol unit which converts the H_2, CO and CO_2 contained in the pure gas to a wide spectrum of products that include hydrocarbons and oxygenated compounds such as alcohols, aldehydes, ketones and organic acids. Principal reactions occurring in the Synthol reactors are:

$n\ CO + 2nH_2$	$(CH_2)_n + n\ H_2O$
$n\ CO + (2n+1)\ H_2$	$C_n\ H_{2n+2} + nH_2O$
$2nH_2 + n\ CO$	$C_n\ H_{2n+1}\ OH + (n-1)\ H_2O$
$(2n-1)\ H_2 + n\ CO$	$C_n\ H_{2n}O + (n-1)\ H_2O$
$(2n-2)\ H_2 + n\ CO$	$C_n\ H_{2n}\ O_2 + (n-2)\ H_2O$
$CO + H_2O$	$CO_2 + H_2$

The effluent gas leaving the Synthol reactors is cooled to condense hydrocarbon liquids. These liquids consist of higher molecular weight hydrocarbons, decant oil, and lower molecular weight hydrocarbons and light oil. Water soluble chemicals in the reactor effluent are dissolved in a water scrubber. The water stream containing acid and non-acid chemicals is sent to the Chemical Workup facilities for further processing for recovery of alcohols and ketones.

The condensed hydrocarbons are further processed in the Oil Workup facilities.

These facilities also process the hydrocarbon liquids returned from the C_2 Recovery and the Ethylene Plant. The Oil Workup facilities separate the various feed streams into different fractions and subsequently process them to saleble products. The products from Oil Workup consist of LPG, gasoline, jet fuel, diesel and fuel oil. Synthol tail gas containing unconverted H_2, CO and CO_2 along with light product gases that do not condense are treated to remove CO_2 prior to being fed to C_2 Recovery. In the C_2 Recovery unit the tail gas is separated into a Hydrogen-rich gas for recycle to Synthol, a methane-rich gas which is upgraded to produce SNG, C_2's for feed to the Ethylene plant, and C_3 and heavier hydrocarbons which are fed to the Oil Workup system.

A portion of the Hydrogen-rich gas separated in the C_2 Recovery is fed to a pressure swing adsoption (PSA) unit to supply the pure hydrogen needed in the plant. The Ethylene plant takes the ethylene/ethane ($C_2^=/C_2$) as feed and cracks the ethane to produce additional ethylene. Ethylene product is separated from the cracked product gas with the heavier hydrocarbons being fed to the Oil Workup facilities.

This is the scheme used in the Feasibility Study and represents an adaptation of the technology that has been well demonstrated on a commercial scale in the Sasol plants in South Africa. The product quality information for this case was included in the Feasibility Study.

<u>Methanol Case</u> (Dwg. 835504-00-4-009)

This scheme proposes to eliminate the production of a wide range of liquid fuels and chemicals and alternately produce fuel grade methanol as a final product. This results in the deletion of the following units from the Synthol case:

20	Synthol
21	CO_2 Removal
23	C_2 Recovery
24	Ethylene Plant
27,29-35,60-65	Oil Workup
36-38	Chemical Workup

And the addition of the following unit:

20 A	Methanol Synthesis

The purified gas from Rectisol is fed to the Methanol Synthesis unit where the gas is compressed to about 1175 psia and then synthesized to methanol. Lurgi technology has been used for the preparation of this study as previous work has indicated that Lurgi and ICI are very close on an evaluated basis. Copper catalyst is used to promote the exothermic synthesis reactions:

$$CO + 2H_2 \qquad CH_3OH$$

$$CO_2 + 3H_2 \qquad CH_3OH + H_2O$$

The reaction heat is recovered by generating steam. The methanol reactor effluent is cooled by a combination of feed-effluent exchangers plus cooling water. The methanol product is separated from the cooled reactor effluent and the unconverted gases recycled back to the methanol reactor. A purge is removed from the recycle gas to control the inerts buildup in the methanol synthesis loop.

A portion of this purge gas is processed to supply hydrogen for the Naphtha Hydrogenation unit. The purge gas is first fed to a shift unit to convert

CO to CO_2 and hydrogen. This gas is then fed to a PSA unit. Purified hydrogen is sent to the Naphtha Hydrogenation unit and the CH_4-rich stream from the PSA unit combined with the remainder of the synthesis loop purge gas.

The combined purge gas is converted to SNG in the Methanation unit according to the following reations.

$$CO + 3H_2 \qquad CH_4 + H_2O$$

$$CO_2 + 4H_2 \qquad CH_4 + 2H_2O$$

These reactions are carried out in two reactors operating in series. The reactions are highly exothermic and the temperature in the first reactor is controlled by adding large amounts of SNG recycle to the fresh feed.

The effluent from the first reactor is cooled by generating steam and heating the feed to the second reactor. The effluent from the second reactor is cooled by preheating the feed to the first reactor. The effluent from the second reactor is chilled prior to being scrubbed in the Rectisol unit to remove residual carbon dioxide and water vapor. The resultant SNG product leaves the plant via pipeline at about 1100 psia without additional drying and compression.

For the methanol case, the product qualities for the gasification products (phenols, cresols, creosotes, sulfur and ammonia) are the same as those produced for the Feasibility Study. The product qualities for methanol, hydrogenated naphtha and SNG are presented in Table 4.

<u>MTG Case</u> (Dwg. No. 835504-00-4-007)

For MTG case the crude methanol (from the Methanol Synthesis unit) is converted to gasoline using the Mobil MTG process. The remainder of the processing scheme remains the same as in the methanol case. This will result in the addition of the following process units to the methanol case:

22A	MTG
23A	MTG Fractionation
24A	Alkylation

The crude methanol from the methanol synthesis is first catalytically converted to dimethyl ether. The dimethyl ether is further reacted catalytically in fixed bed conversion reactors to yield a hydrocarbon mixture. The two major reactions can be represented as follows:

$$\underset{\text{Methanol}}{2CH_3OH} \xrightarrow{-H_2O} \underset{\text{DME}}{CH_3OCH_3} \xrightarrow{-H_2O} \begin{array}{l}\text{Olefins}\\ \text{Paraffins}\\ \text{Aromatics}\\ \text{Cycloparaffins}\end{array}$$

The reaction is highly exothermic and the temperature is controlled by a recycle stream to the conversion reactors.

The reactor effluent is cooled by exchanging against feed methanol, by steam generation and finally cooling with air coolers. The cooled product is separated from the vapor and sent to the fractionation unit. Unconverted vapor is recycled to the feed. Water produced in large quantity, from the reaction, is separated and sent to Effluent Treatment.

In the Fractionation Unit the liquid hydrocarbon product from the Mobil MTG unit is separated into stabilized gasoline, propane LPG, isobutane and a mixed C_4/C_5 stream. The Mixed C_4/C_5 stream is further processed with some isobutanes to produce a C_8/C_9 alkylate blending stock in a HF Alkylation unit. The alkylation reaction links an olefinic hydrocarbon with an isobutane molecule to form a branched chain paraffinic hydrocarbon suitable for gasoline blending. The reactor effluent is fractionated into HF and isobutane for recycle, alkylate for gasoline blending and a nC_4/iC_5 product.

Blending calculations indicate that a blended gasoline product that utilized stabilized MTG gasoline, hydrogenated Lurgi naphtha, alkylate, nC_4/iC_5 and isobutane as blending components will meet the summer gasoline specifications, however, it fails to meet the volatility (V/L) specifications, for the winter conditions. Additionally it is stated that this gasoline product contains 4-6 wt. percent durene. Durene in these concentrations can cause carburetor icing problems in colder climates. This indicates that this product be used as a blending stock rather than an end product. If such a gasoline were to be produced, the expected specifications will be as shown in Table 5A.

The blending calculations indicate that it is doubtful that the plant can produce a specification gasoline product. A parallel study is currently being performed by Fluor to determine the feasibility of benzene extraction from Lurgi naphtha, therefore, for the purpose of this study, the Lurgi naphtha and isobutane are produced as separate products. The remaining components (stabilized MTG gasoline, alkyline, alkylate and nC_4/iC_5's) are blended and must be marketed as a gasoline blend stock. Expected specifications for these products are presented in Table 5B.

The Mobil MTG process proposed in this scheme has been piloted in samll scale. Reliable scale-up of the plant is expected to be feasible from the pilot plant data. The first commercial plant, located in New Zealand, is currently believed to be in design phases. The operating conditions in the MTG unit are similar to those currently practiced on a wide scale in the refining industry.

Table 3 - Process Units

Unit No.	Process Units	Synthol	Methanol	MTG
1,2	Coal Handling and Screening	X	X	X
3	Ash Handling	X	X	X
10	Gasification	X	X	X
11	Gas Cooling	X	X	X
12	Rectisol	X	X	X
13	Gas Liquor Separation	X	X	X
14	Tar Distillation	X	X	X
15	Naphtha Hydrogenation	X	X	X
16	Phensolvan	X	X	X
17	Ammonia Recovery	X	X	X
18	Stretford	X	X	X
20	Synthol Unit	X	-	-
21	CO_2 Removal	X	-	-
23	C_2 Recovery	X	-	-
24	Ethylene Plant	X	-	-
25	H_2 Purification (PSA)	X	X	X
25A	CO Shift	-	X	X
27				
29-35	Oil Workup	X	-	-
60-65				
66	SNG (Methanation, Rectisol, CO_2 Removal)	X	X	X
36-38	Chemical Workup	X	-	-
20A	Methanol Synthesis	-	X	X
22A	MTG	-	-	X
23A	MTG Fractionation	-	-	X
24A	Alkylation	-	-	X

X - Indicates inclusion of the process unit in the subject processing scheme.

Table 4

Product Quality - Methanol Case

Methanol

Purity	95%
H_2O	5%
CO_2	Traces

Hydrogenated Lurgi Naphtha

RON (clear)	91
MON (clear)	77
RVP, psia	2.2
Sp. Gr.	0.823
Distillation (ASTM D86), °F % Distilled	
0	172
10	192
30	207
50	223
70	252
90	300
End Point	372

SNG

HHV, Btu/SCF	979.8
Methane Purity, Vol%	96.6
Impurities	
CO_2, vol%	0.5
CO, vol%	0.01
H_2, vol%	0.3
N_2+Ar, vol%	2.6
H_2O, lb/million SCF	5.7
Interchangeability Indices	
Lifting	1.053
Flashback	1.014
Yellow Tip	1.075
Specific Gravity	0.5684

Table 5A

Gasoline (1)

In case the hydrogenated Lurgi naphtha and isobutane are also blended with stabilized MTG gasoline, Alkylate and nC_4/iC_5's from the alkylation to produce an end use gasoline product, the expected quality will be:

	Summer		Winter	
	Spec.	Calc.	Spec.	Calc.
Test Temperature, °F				
@ V/L = 20	133 (Mine)	136	116 (Min)	110
RvP, psia	9.5	9.5	13.5	13.5
RON	93.0	93.0	93.0	93.2
MON	84.0	84.5	84.0	85.0
(RON + MON)/2	88.5	88.7	88.5	89.1
Olefins, wt%	20.0 (Max)	10	20.0 (Max)	10
Durene, wt%		4-6		4-6
Distillation (ASTM D 86), °F				
% Distilled				
0		87		74
10	149 (Max)	129	131 (Max)	90
50	170-245	204	170-235	196
90	374 (Max)	327	365 (Max)	326
EP	437 (Max)	387	437 (Max)	386

(1) As this gasoline does not meet specifications, the MTG case, for the purpose of this study, produces Lurgi naphtha and isobutane as separate products and blends the other components (stabilized MTG gasoline, alkylate and nC_4/iC_5's) to be marketed as a gasoline blend stock.

Table 5B

Product Quality - MTG Case

Gasoline Blend Stock

RON (Clear)	92.8
MON (Clear)	84.8
Rvp, sia	7.4
Sp. Gr.	0.722

Distillation (ASTM D86), °F
Vol% Distilled

0	101
10	134
30	165
50	208
70	267
90	336
End Point	388

Hydrogenated Lurgi Naphtha

Same as in Methanol Case

C_3LPG

C_3H_6, mol%	4.1
C_3H_8, mol%	94.7
C_4's, mol%	1.1

Isobutanes

C_3, mol%	0.7
iC_4, mol%	86.9
nC_4, mol%	11.2
iC_5, mol%	1.2

Table 5B

Product Quality - MTG Case

Continued

SNG

HHV, Btu/SCF	979.2
Methane Purity, Vol%	96.5
Impurities	
CO_2, vol%	0.5
CO, vol%	0.01
H_2, vol%	0.3
N_2+Ar, vol%	2.6
H_2O, lb/million SCF	5.8
Interchangeability indices	
Lifting	1.054
Flashback	1.015
Yellow Tip	1.74
Specific Gravity	0.5687

APPENDIX 1

Scope of Study

March 24, 1981

PROCESS STUDY
EVALUATE THE PRODUCTION OF
METHANOL IN LIEU OF SYNTHOL PRODUCTS

1.0 GENERAL

Maintaining the same coal feed rate to the gasifiers, produce fuel grade methanol in lieu of the products produced from the synthol reaction. Estimate the additional costs associated with installing the necessary Mobil 'MTG' facilities at some future undefined date.

2.0 WORK DEFINITION

2.1 Composition of Pure Gas from Rectisol is proprietary with the process developer.

2.2 Fuel grade methanol specification.

(Fluor will assume that fuel grade methanol is the same as MTG grade methanol).

2.3 Methanol synthesis will be based on Lurgi technology for the purpose of this study.

2.4 Methanol purification will be based upon Fluor's technology.

2.5 Methanol storage and shipping facilities

(To be supplied by Tri-State eight weeks after Tri-State releases Fluor to commence work).

PROCESS STUDY (Continued)

2.6 Purchase a maximum of 100 MW of power.

2.7 No methane reforming - design for pipeline gas per SNG specification used in existing study.

2.8 Other basis used in the preparation of the feasibility study shall remain constant.

3.0 DELIVERABLES TO TRI-STATE

3.1 Block flow diagrams.

3.2 Total coal and raw water requirements.

3.3 Catalyst and chemical summaries.

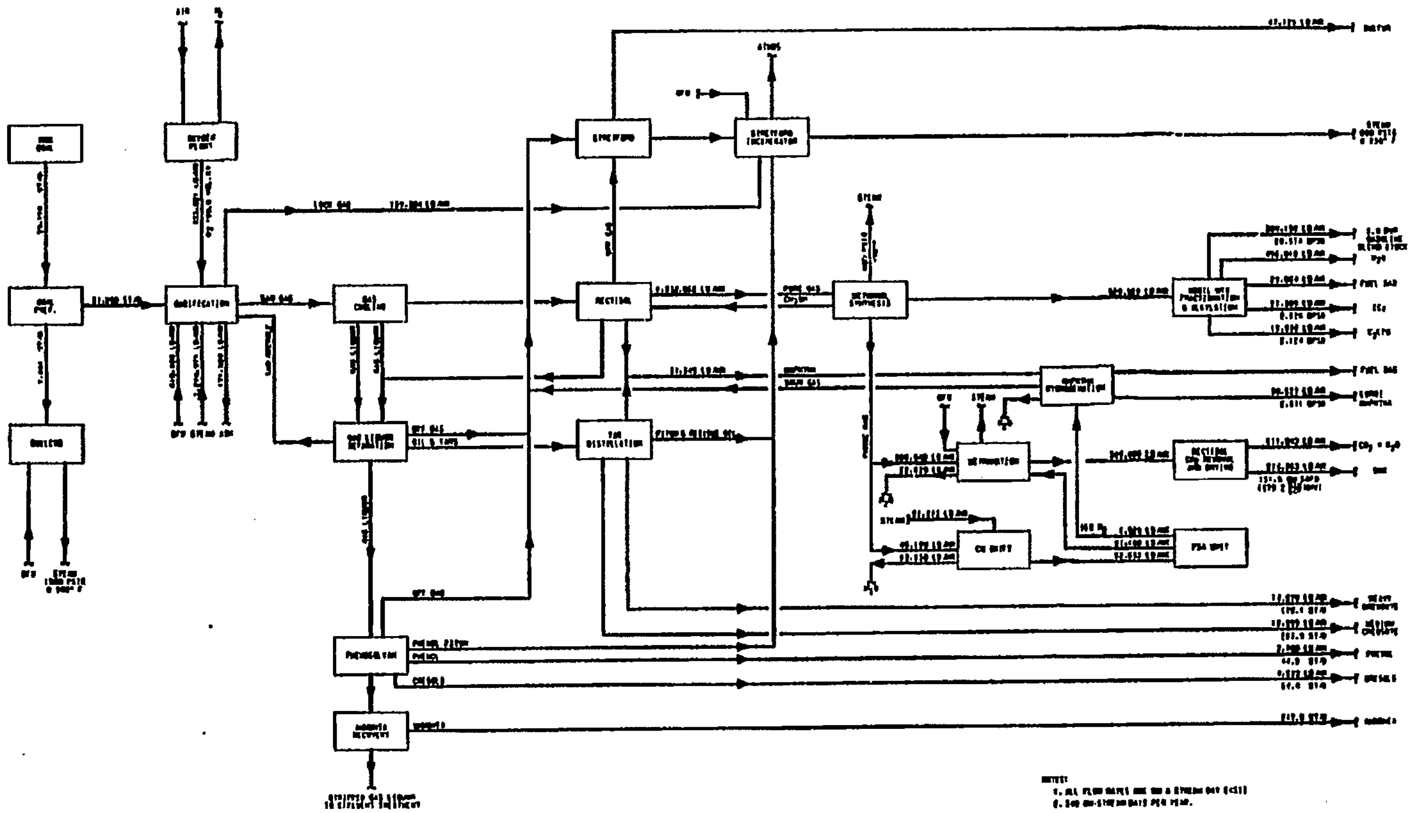
3.4 Operating costs.

3.5 Cost estimates, both stand alone methanol and a second estimate for converting the methanol to Mobil 'MTG' facilities.

3.6 Thermal efficiency calculation.

4.0 SCHEDULE

It is estimated that the above work will be completed about 18 weeks after Tri-States releases Fluor to commence with this work, assuming Tri-States provides the noted information in a timely manner.

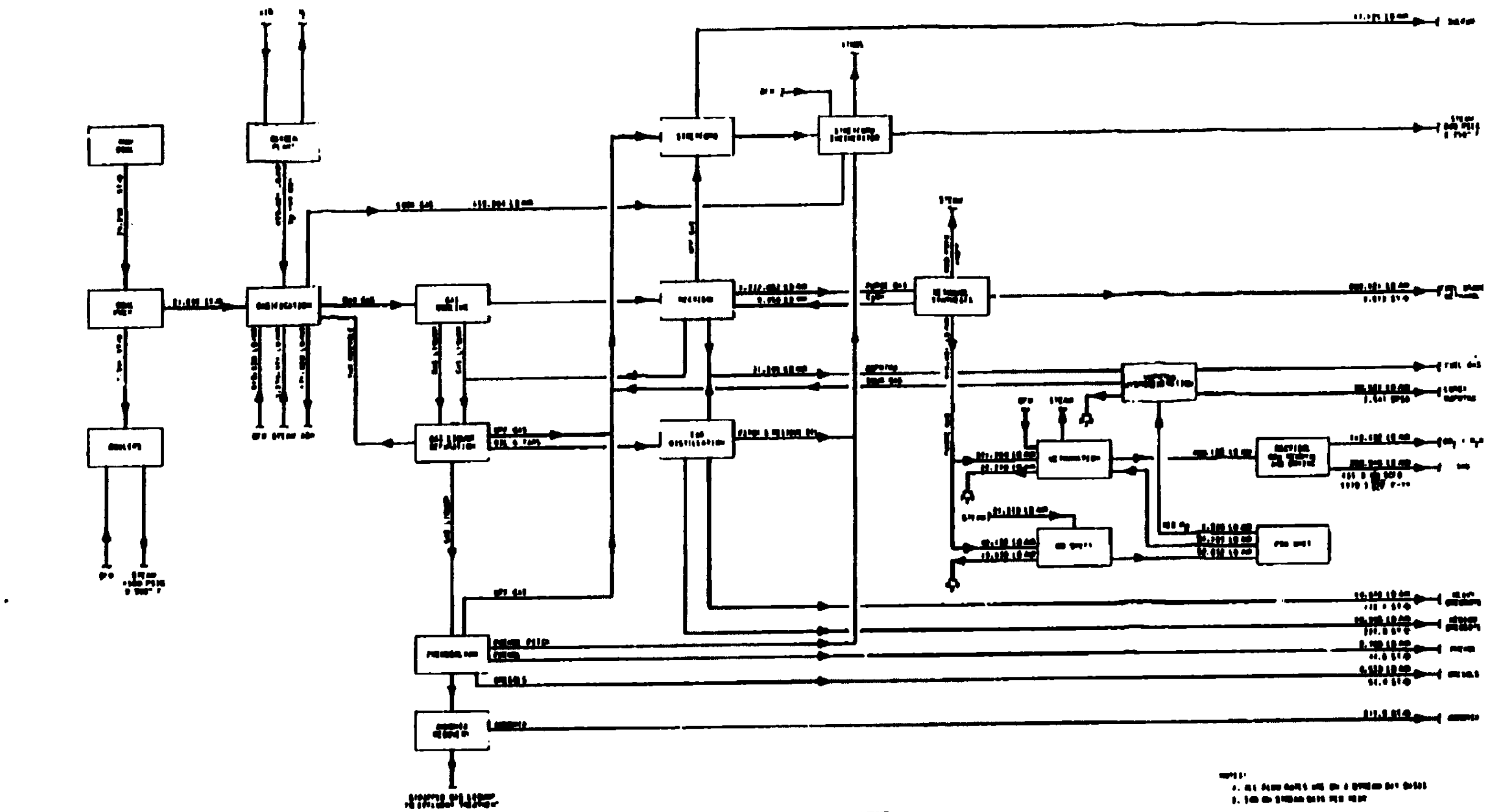


USE OR DISCLOSURE OF REPORT DATA
IS SUBJECT TO THE RESTRICTION ON THE
NOTICE PAGE AT THE FRONT OF THIS REPORT

FLUOR

BLOCK FLOW DIAGRAM
MATERIAL BALANCE
METHANOL PLUS MOBIL MTG CASE

NONE | 835504-00-4-007 | D

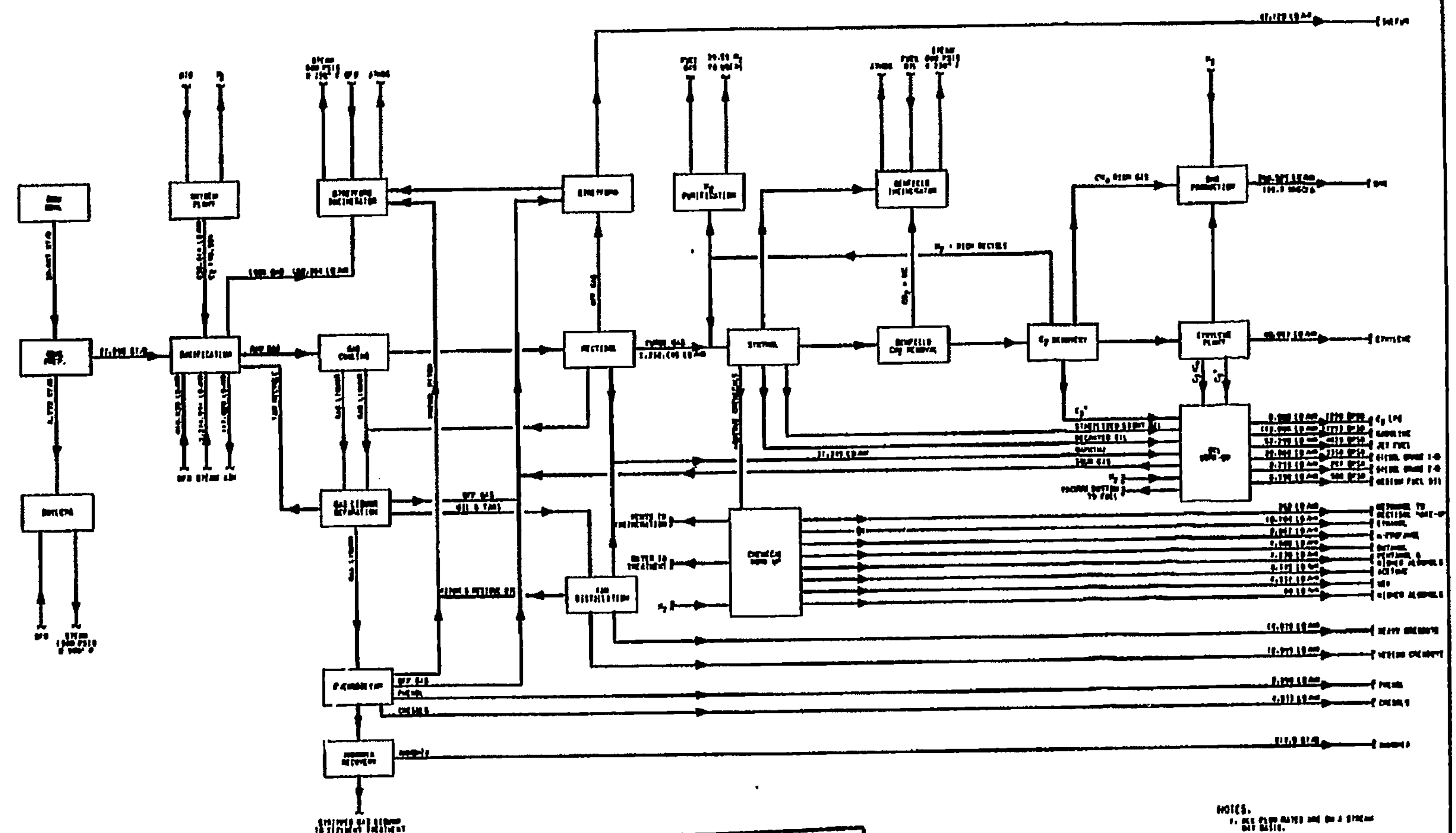


USE OR DISCLOSURE OF REPORT DATA
IS SUBJECT TO THE RESTRICTION ON THE
NOTICE PAGE AT THE FRONT OF THIS REPORT

FLUOR

BLOCK FLOW DIAGRAM
MATERIAL BALANCE
METHANOL CASE

NONE | 835504-00-4-009 | D

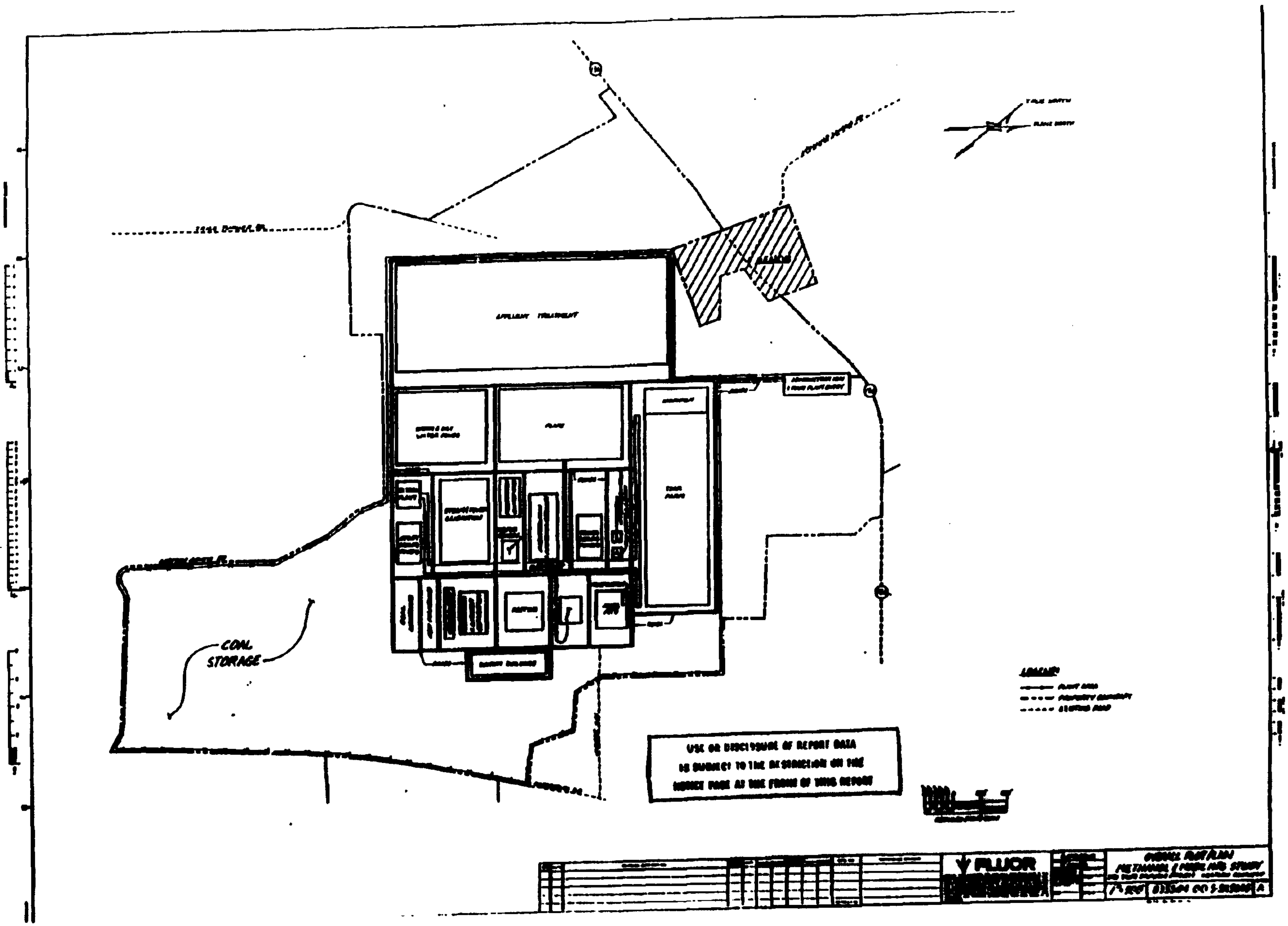


USE OR DISCLOSURE OF REPORT DATA
IS SUBJECT TO THE RESTRICTION ON THE
NOTICE PAGE AT THE FRONT OF THIS REPORT

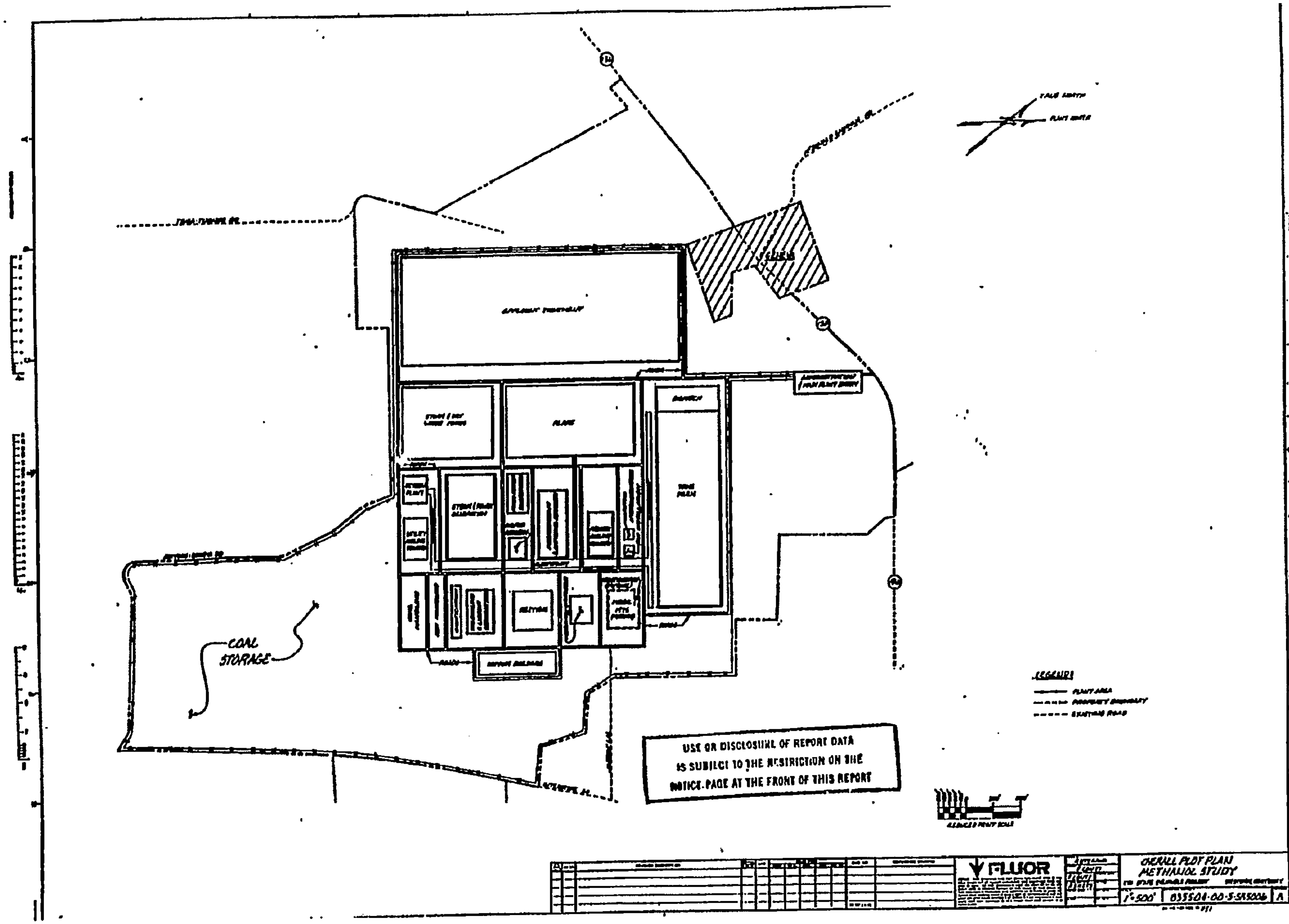
FLUOR

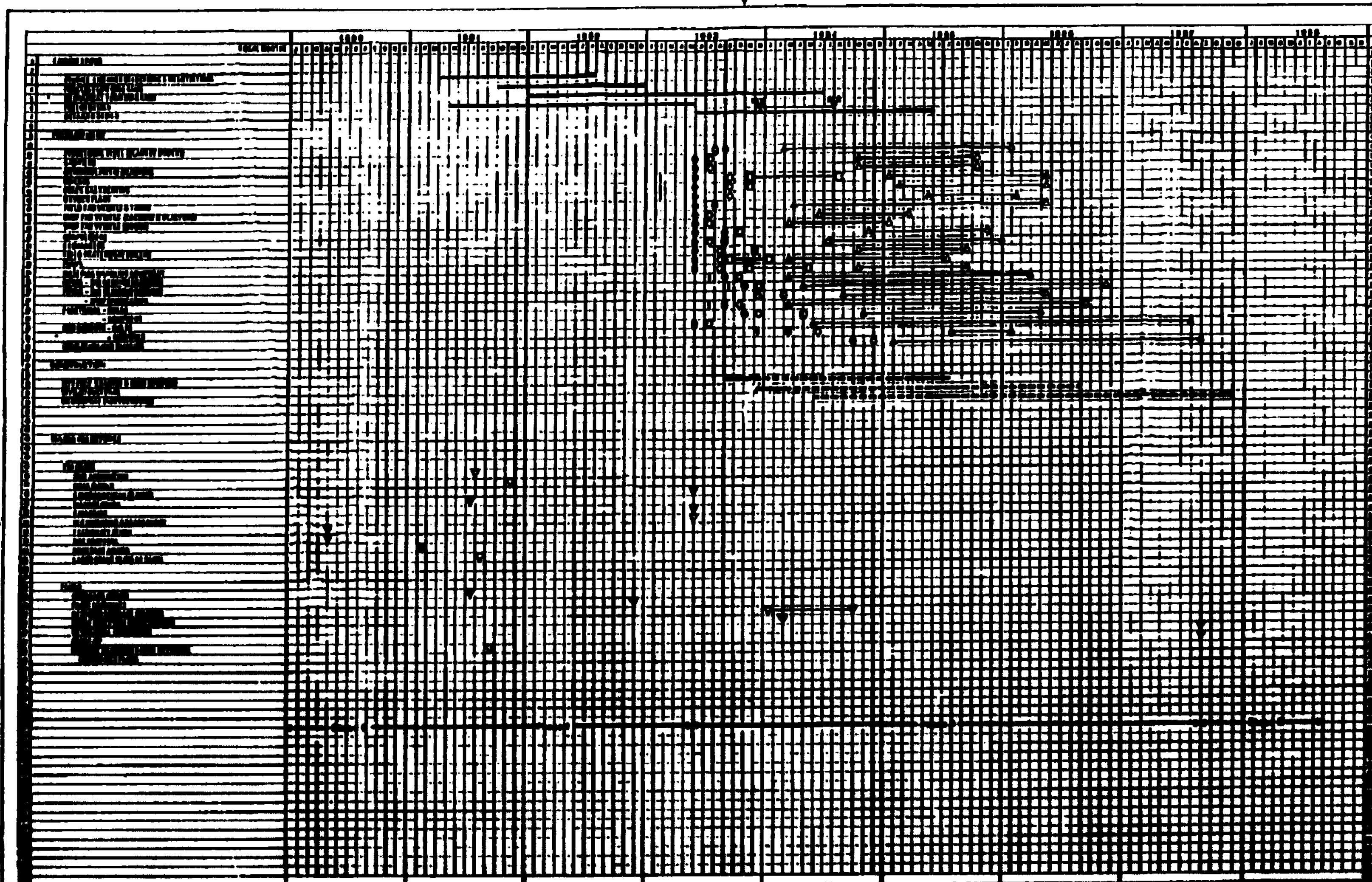
BLOCK FLOW DIAGRAM
MATERIAL BALANCE
SYNTHOIL CASE

NONE | 835504-00-4-012 | B



COAL STORAGE
USE OR DISCLOSURE OF REPORT DATA
IS SUBJECT TO THE RESTRICTION ON THE
NOTICE PAGE AT THE FRONT OF THIS REPORT
FLUOR


COAL STORAGE
LEGEND
USE OR DISCLOSURE OF REPORT DATA
IS SUBJECT TO THE RESTRICTION ON THE
NOTICE PAGE AT THE FRONT OF THIS REPORT
FLUOR
OVERALL PLOT PLAN
METHANOL STUDY
1"=500'
835504-00-5-SK5006
A



NOTES:

USE OR DISCLOSURE OF REPORT DATA IS SUBJECT TO THE RESTRICTION ON THE NOTICE PAGE AT THE FRONT OF THIS REPORT

FLUOR

TRI-STATE SYNFUELS PROJECT

PROJECT MASTER SCHEDULE

METHANOL/METHANOL & MTG PLANT STUDY

COST ESTIMATE

CLIENT: TRI-STATE SYNFUELS CO.
DESCRIPTION: METHANOL STUDY CASE WITH METHANOL SYNTHESIS, MTG CONVERSION FRACTIONATION, & ALKYLATION
JAN 1980 INSTANTANEOUS
PROP. NO.:
W.O. NO.:
CONT. NO.: 835504
MADE BY: BSC
APPROVED:
LOCATION: HENDERSON, KY.
PROJECT: TRI-STATE SYNFUELS PROJECT

A/C NO.	ITEM & DESCRIPTION	MANHOURS X 1000	ESTIMATED COST $ X 1000 LABOR	SUB-CONTRACTS	MATERIALS	TOTAL
00-00	Excavation					
10-00	Concrete					
20-00	Structural Steel					
30-00	Buildings					
40-00	Machinery & Equipment					
50-00	Piping					
60-00	Electrical					
70-00	Instruments					
80-00	Painting & Scaffolding					
85-00	Insulation					
	DIRECT FIELD COSTS	45,493	545,914	4,264	981,393	1,531,571
90-00	International Expense					
91-00	Temporary Construction Facilities					
92-00	Constr. Services, Supplies & Expense					
93-00	Field Staff, Subsistence & Expense					
94-00	Craft Benefits, Payroll Burdens & Insur.					
95-10	Equipment Rental					
95-50	Small Tools					
99-40	Field Staff Overhead Costs					
	INDIRECT FIELD COSTS					728,117
	TOTAL FIELD COSTS					2,259,688
96-00	Home Office Construction					
	Project Engineering					
	Process Engineering					
	Design					
	Purchasing					
	Business Services					
97-00	Office Expense					
98-00	Office Payroll Burdens					
99-50	Office Overhead Costs					
	TOTAL OFFICE COSTS					277,440
	TOTAL FIELD & OFFICE COSTS					2,537,128
99-30	Sales Tax					
99-10	Escalation					
99-20	Contingency					247,525
	TOTAL					
99-60	Fee					
	TOTAL PROJECT					2,784,653

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______

PRINTED IN U.S.

COST ESTIMATE

CLIENT: TRI-STATE SYNFUELS CO.
DESCRIPTION: METHANOL STUDY CASE WITH METHANOL SYNTHESIS ONLY
PROP. NO.:
W.O. NO.:
LOCATION: HENDERSON, KY.
CONT. NO.: 835504
MADE BY: BSC
PROJECT: TRI-STATE SYNFUELS PROJECT
APPROVED:

JAN. 1980 INSTANTANEOUS

A/C NO.	ITEM & DESCRIPTION	MANHOURS X 10^3	ESTIMATED COST X 10^3 LABOR	SUB-CONTRACTS	MATERIALS	TOTAL
00-00	Excavation					
10-00	Concrete					
20-00	Structural Steel					
30-00	Buildings					
40-00	Machinery & Equipment					
50-00	Piping					
60-00	Electrical					
70-00	Instruments					
80-00	Painting & Scaffolding					
85-00	Insulation					
	DIRECT FIELD COSTS	43,116	517 394	4 264	895 371	1417 029
90-00	International Expense					
91-00	Temporary Construction Facilities					
92-00	Constr. Services, Supplies & Expense					
93-00	Field Staff, Subsistence & Expense					
94-00	Craft Benefits, Payroll Burdens & Insur.					
95-10	Equipment Rental					
95-50	Small Tools					
99-40	Field Staff Overhead Costs					
	INDIRECT FIELD COSTS					684 583
	TOTAL FIELD COSTS					2,101 612
96-00	Home Office Construction					
	Project Engineering					
	Process Engineering					
	Design					
	Purchasing					
	Business Services					
97-00	Office Expense					
98-00	Office Payroll Burdens					
99-50	Office Overhead Costs					
	TOTAL OFFICE COSTS					256 575
	TOTAL FIELD & OFFICE COSTS					2,358 187
99-30	Sales Tax					
99-10	Escalation					
99-20	Contingency					230 067
	TOTAL					
99-60	Fee					
	TOTAL PROJECT					2,588 254

PRINTED IN U.S.A.