ECONOMIC FEASIBILITY STUDY
CFR ADVANCED DIRECT COAL LIQUEFACTION PROCESS

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PREPARED FOR
CANADIAN ENERGY DEVELOPMENTS INC.
&
ALBERTA RESEARCH COUNCIL

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KILBORN INC.

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Kilborn has followed standard procedures in preparing the evaluation in the report but the Report is based in part on details, information and assumptions provided by others and Kilborn, therefore, cannot guarantee the correctness of the Report; but to the extent of its investigation and within the scope of the work delegated to it, Kilborn believes that the Report is substantially correct.

1.0 SUMMARY

This preliminary economic feasibility study has been prepared by Kilborn Inc. for Canadian Energy Developments Inc. and Alberta Research Council as part of their US Department of Energy contract under the DOE Advanced Coal-Liquefaction Program. This report provides preliminary technical and economic data on the CFR Advanced Direct Coal Liquefaction Process.

Technical

The conceptual CFR advanced coal liquefaction project was configured similar to the Improved Baseline Design developed by Bechtel Corporation and AMOCO Oil Company under the DOE Advanced Coal Liquefaction Program using the HRI two stage coal liquefaction process. The study was based on the production of 75,000 BPD of C_4^+ synthetic crude oil for subsequent processing in a conventional petroleum refinery from Black Thunder (Wyoming) sub-bituminous coal.

Figure 1.1 presents an overall block flow diagram of the conceptual coal liquefaction process. The coal is slurried in process derived recycle oils; solubilized in the first stage coal liquefaction reactors in the presence of carbon monoxide, hydrogen and an aluminate catalyst; hydrogenated in the second stage reactors in the presence of hydrogen and a molybdate catalyst; and hydrotreated for heteroatom removal and hydrogen addition in secondary hydrotreating facilities. Carbon monoxide and hydrogen required in the liquefaction process and hydrotreater are produced by steam reforming of natural gas followed by carbon dioxide removal and separation of the synthesis gas stream into high purity hydrogen and carbon monoxide-rich synthesis gas streams. By recycling the CO_2 to the reformer, the ratio of hydrogen to carbon monoxide in the synthesis gas can be controlled.

FIGURE 1.1

OVERALL FLOW DIAGRAM
 FOR ADVANCED COAL LIQUEFACTION PROCESS
 DOE ADVANCED COAL LIQUEFACTION PROJECT

Unique features of the CFR advanced coal liquefaction process are the use of carbon monoxide in the first stage liquefaction reactors, the use of counterflow reactors in both stages and close coupling of the mixed feed hydrotreater and second stage liquefaction reactors, thereby avoiding a product recovery system on the second stage reactor system, a feed system on the hydrotreater and permitting a common hydrogen recycle system to be used.

Raw material requirements and product and by-product quantities for the conceptual plant are listed below:

Raw materials

Coal	15,970	tonnes/day (MAF)
Natural Gas	161,370	MMBTU/day

Products

Synthetic Crude Oil	75,000	BPD
Sulphur	107	tonnes/day
Ammonia	217	tonnes/day
Propane	6,030	BPD

Synthetic crude oil yield is 4.70 barrels per tonne of MAF coal (Black Thunder).

Financial

Capital and operating costs were developed for an Nth plant design, as given in Tables 1.1 and 1.2 respectively. The Nth plant design is defined as the Nth commercial plant built when the technology basis, plant design and operation are well established, resulting in the following characteristics:

- Lowest reasonable plant cost contingency.
- No spare trains.
- Lowest reasonable engineering cost.

TABLE 1.1
CAPITAL COST INVESTMENT – COAL LIQUEFACTION PLANT

PLANT NO.	DESCRIPTION	BASIS	TOTAL RATE	NO. OF OPER UNITS	TOTAL NO. UNITS	ISBL FIELD COSTS (\$1,000 US)	OSBL FIELD COSTS (\$1,000 US)	INSTALLED COSTS (\$1,000 US)
1	Coal Clearing & Handling	MTPD (MF)	21,454	6	6	86,902	117,042	143,607
1.4	Coal Crushing & Drying	MTPD (MF)	17,879	12	12	100,844	135,550	166,316
2	Coal Liquefaction	MTPD (MF)	17,879	5	5	626,080	843,216	1,034,606
3	Gas Plant	Kg/h	125,471	1	1	46,123	62,119	76,219
5	Mixed Feed Hydrotreater	Kg/h	393,722	5	5	172,380	232,165	284,860
6	H2 Purification (PSA #2 & #3)	Kg/h	16,153	1	1	109,033	146,848	180,179
8	ROSE Unit	Kg/h	460,171	1	1	45,656	61,490	75,446
9-01	Methane Reforming	Kg/h	141,290	3	3	259,437	349,414	428,723
11	S Plant (Note 1)	Kg/h	4,470	1	1	13,053	17,580	21,570
38	NH3 Recovery (Note 2)	Kg/h	9,046	1	1	22,670	30,532	37,462
39	Phenol Recovery (Note 3)	Kg/h	1,357	1	1	8,531	11,490	14,097
	Total					1,490,509	2,007,445	2,463,086

NOTES:

1. S recovery based on 0.80 wt % organic sulphur in coal feed (MF).
2. N recovery based on 1.00 wt % organic nitrogen in coal feed (MF).
3. Phenol recovery based on 15 wt. % of the NH3 recovered.

**TABLE 1.2
YEARLY OPERATING COSTS.**

SCO PRODUCTION:		75,000 BPD		
OPERATING FACTOR:		88.40 %		YEARS OF OPERATION: 25.00
	UNIT RATE	QUANTITY	PRICE / UNIT	OPER. COST
			(\$)	(\$/yr)
FEEDS:				
Coal (ROM)	MT/D	19,476	10.00	62,839,700
Natural Gas	MMBTU/D	161,371	2.00	104,135,800
Total Feeds				166,975,500
BY-PRODUCT CREDITS:				
Fuel Gas	MMBTU/D	75,481	2.00	48,709,400
Propane	BPD	6,029	7.50	14,589,900
Sulphur	MT/D	107	88.18	3,052,200
Ammonia	MT/D	217	132.28	9,265,700
Electricity	kWh	183,985	0.05	2,968,200
Total By-Products				78,585,400
NET FEED COST (Feeds minus By-products)				88,390,100
UTILITIES:				
Raw Water Makeup	MGAL/D	23,189	0.10	748,200
Fuel	MMBTU/D	155,634	2.00	100,434,000
Total Utilities				101,182,200
LABOUR:				
Operation				11,525,500
Management & Supervision				701,000
Laboratory				1,506,000
Engineering				1,953,700
Environ., Health, Safety & Security				2,773,600
Administration				2,691,200
Maintenance (@ 1.01 % of Capital Invest.)				24,958,000
Total Labour (@ 1.87 % of Capital Invest.)				46,109,000
SUPPLIES & MATERIALS DISPOSAL:				
Catalysts & Chemicals				28,574,300
Ash Disposal Cost	MT/D	1,909	5.51	3,394,100
Refuse Disposal Cost	MT/D	3,576	2.20	2,543,500
Total Supplies & Materials Disposal				34,511,900
TOTAL DIRECT COSTS:				270,193,200
INDIRECT COSTS:				
Operating & Office Supplies (0.05 % of Capital Invest.)				1,231,500
Maintenance Materials (@ 0.75 % of Capital Invest.)				18,473,100
Taxes & Insurance (@ 0.25 % of Capital Invest.)				6,157,700
Total Indirect Costs				25,862,300
MANUFACTURING COSTS:				296,055,500
REVENUE FROM SALES OF SCO (@ 29.75 \$/BBL FOR BASE CASE)				719,853,500
NET PROFIT BEFORE TAXES				423,798,000
INTERNAL RATE OF RETURN BEFORE TAXES				16.75%

- Shortest possible project schedule to erect and start up.
- Mature technology allowing the overall stream factor of the complex to be the same as that of the First plant (spare process trains, overcapacity).

The format of the capital cost estimate is similar to that used in the Bechtel report. The installed plant costs for the complex were developed by taking the estimated Inside Battery Limit (ISBL) plant cost for each ISBL plant, adding the respective portion of the total Outside Battery Limit (OSBL) costs and then adding the proportional amount of home office costs, engineering fee and contingency.

The annual operating cost estimate includes the cost of raw materials less by-product credits; the costs of utilities, operating, maintenance and management labour; supplies and materials disposal plus indirect operating costs, as shown in Table 1.2. By-product credits are shown in the operating cost table to facilitate the financial analysis which was based on a determination of the synthetic crude oil price required to achieve a 15% return on equity to the project owners.

The financial analysis for the Nth plant scenario was based on the following key assumptions:

Years of Construction	5	
Years of Operation	25	
Operating Factor, %	88.4	
Depreciation, years		
Process Facilities	5	
Buildings, Services	25	
Working Capital, % of Revenue	10	
Bank Interest Rate, %	8	
Federal Income Tax, %	34	
Percent Equity	25	
Percent IRR on Equity	15	
General Inflation, %	3	
Raw Material Price Escalation	Same as Inflation	
State Income Tax	0	
Syncrude Premium	1.00 (multiplier)	

The results of the financial and sensitivity analysis, given in Table 1.3, indicate that coal-derived synthetic crude oil can be produced by the CFR advanced coal liquefaction process for a price that is only 25-70% above current crude oil price.

In order to further evaluate the future potential of the CFR advanced coal liquefaction process, it is recommended that the R&D program be continued so that assumptions made and questions raised during this study can be resolved. Key issues to be addressed in further R&D work include:

- Operation in larger pilot scale equipment for improved reliability of data.
- Operation with slurry oil recycle rather than on a once-through basis with coal-derived solvent.
- Operation with a heavy solvent recovery unit for the recovery and recycle as slurry oil of heavy VGO, residual oil and asphaltenes from the second stage reactor bottoms outlet stream.
- Operation with CO-rich synthesis gas rather than high purity carbon monoxide in the first stage of the coal liquefaction process.
- Operation with lower hydrogen rates in the second stage reactor to evaluate the effect of superficial gas velocity and flow regime on product yield structure.
- Reduction of first and second stage catalyst requirements.
- Increased coal loading in the first and second stage reactors.
- Mixed feed hydrotreating tests to confirm final synthetic crude oil quality as a function of hydrotreating severity.

At the conclusion of the next phase of the R&D program, a new economic feasibility study should be commissioned to improve the accuracy of, and confidence in, the financial merits of the technology.

TABLE 1.3
FINANCIAL RESULTS AND SENSITIVITIES

FINANCIAL CASES	CRUDE OIL EQUIVALENT PRICE (\$/BBL)
Base Case	29.75
Capital + 10 %	31.43
Capital - 10 %	28.06
Capital + 25 %	33.97
Capital - 25 %	25.52
Coal Price + 25 %	31.06
Coal Price - 25 %	28.43
Natural Gas Price + 25 %	31.46
Natural Gas Price - 25 %	28.04
Owner's Equity 50 % (Double the Base)	31.59
SCO Yield + 10 %	27.04
SCO Yield - 5 %	31.31

2.0 INTRODUCTION

This preliminary economic feasibility study of the CFR advanced coal liquefaction process was commissioned by Canadian Energy Developments Inc. as part of the US Department of Energy (DOE), Pittsburgh Energy Technology Center, contract with Canadian Energy and Alberta Research Council under the DOE Advanced Coal Liquefaction Program. The overall objective of the study was to develop preliminary technical and economic data for a conceptual coal liquefaction project using test run data provided by CED/ARC. The CFR advanced coal liquefaction project was configured similar to the Improved Baseline Design developed by Bechtel Corporation and AMOCO Oil Company using the HRI two stage coal liquefaction process (close-coupled, catalytic-catalytic).

The study was based on the production of 75,000 BPD of C_4^+ synthetic crude oil for subsequent processing in a conventional petroleum refinery from Black Thunder (Wyoming) sub-bituminous coal. The coal is slurried in recycle oil/bitumen, solubilized in the first stage liquefaction reactors in the presence of carbon monoxide and hydrogen, hydrogenated in the second stage liquefaction reactors in the presence of hydrogen and hydrotreated for heteroatom removal in secondary hydrotreating facilities. Carbon monoxide and hydrogen required in the liquefaction process are produced by steam reforming of natural gas followed by separation of the synthesis gas stream into high purity hydrogen and carbon monoxide-rich (57 mol % CO) synthesis gas streams.

Capital and operating cost data were developed for the two stage CFR advanced coal liquefaction process and close-coupled mixed feed hydrotreater in 1994 US dollars for a Wyoming location close to the coal mine supplying the feed coal. Cost data for all other process units, offsite facilities and utility systems were prorated from data provided in the Bechtel report for the Improved Baseline Design.

The financial and sensitivity analysis was based on determining the required synthetic crude oil price to meet a predetermined set of financial criteria, similar to the approach used in the Bechtel report.

3.0 TECHNICAL

The conceptual CFR advanced coal liquefaction facility will produce 75,000 BPD of synthetic crude oil from 15,970 tonnes/day (MAF basis) of Black Thunder sub-bituminous coal. The quality of the synthetic crude oil is expected to be similar to that currently being produced by Canadian oil sands upgrading plants, such that it can be readily processed to transportation fuels in a conventional petroleum refinery.

In addition to the synthetic crude oil product, the facility will also produce 6,030 BPD of propane, 107 tonnes/day of elemental sulphur, 217 tonnes/day of anhydrous ammonia and 184 MW of cogenerated electricity. The electricity is surplus to the estimated overall plant requirements of 180 MW.

3.1 PROCESS DESCRIPTION

Figure 3.1 presents an overall block flow diagram of the conceptual coal liquefaction facility. Stream numbers on the diagram correspond to stream numbers used in the Material Balance Summary provided in Section 3.2 of this report. The coal liquefaction plant consists of 12 main process areas, offsite and utility systems:

1. Coal Handling and Crushing
2. Coal Liquefaction
3. Mixed Feed Hydrotreater
4. ROSE Unit
5. Synthesis Gas Production
6. First Stage Recycle Gas Processing
7. Hydrogen Recovery
8. Gas Recovery
9. Sulphur Plant
10. Ammonia Recovery
11. Phenol Recovery
12. Offsite and Utility Systems

FIGURE 3.1

OVERALL BLOCK FLOW DIAGRAM
 CFR ADVANCED COAL LIQUEFACTION PROCESS
 DOE ADVANCED COAL LIQUEFACTION PROJECT

The main emphasis during the study was placed on the process units directly related to the CFR technology, namely the two stage coal liquefaction process, the use of carbon monoxide (CO)-rich synthesis gas in the first liquefaction stage, the production of high purity hydrogen plus CO-rich synthesis gas in the Steam Methane Reforming Unit and the use of a close-coupled, mixed feed hydrotreater for final upgrading of the synthetic crude oil product. All other process units are similar to those used by Bechtel in the Improved Baseline Study under the DOE Advanced Coal Liquefaction Program, and they will be described only briefly in this report.

3.1.1 Coal Handling and Crushing

Run-of-mine coal enters the coal liquefaction facility from an adjacent coal mine and passes through the coal cleaning and handling plant. Clean coal containing 10.7 wt % ash (MF) is further processed in standard grinding and drying equipment to a uniform size range of minus 18 mesh or 0.04 inch and to a moisture content of 8.2 wt %. A total of 19,476 tonnes/day of coal (15,970 tonnes/day MAF basis) is fed to the liquefaction plant.

3.1.2 Coal Liquefaction

The most important process plant in the entire facility is the two-stage coal liquefaction process and the associated carbon monoxide recovery and recycle system. The unique features of the CFR advanced coal liquefaction process include the use of CED's Counterflow Reactor (CFR) system in both stages of the liquefaction process, the use of CO-rich synthesis gas in the first coal liquefaction stage (for coal solubilization) and the use of hydrogen in the second coal liquefaction stage.

Key Design Parameters

The key design parameters for the two-stage coal liquefaction process and reactors were:

- Feed coal: Black Thunder sub-bituminous
- Coal slurry concentration: 41.9 wt % MAF basis
- Design Operating Conditions:

	First Stage	Second Stage
Temperature, °C	410	440
°F	770	824
Pressure, MPa	10.0	17.2
psig	1450	2495
Catalyst	Aluminate	Molybdate
Catalyst Addition,		
wt % (MAF Coal)	1.0	-
wppm (MAF Coal)	-	200 Mo
Coal WHSV, kg/hr/ℓ	1.75	1.00
CO Consumed,		
wt % (MAF Coal)	28.6	-
H ₂ Consumed,		
wt % (MAF Coal)	1.28	6.39

- Product Yield Structure.

	First Stage (wt % MAF coal plus solvent)	Second Stage	Net Total (wt % MAF coal)
H ₂ O	-	1.5	3.62
CO _x + H ₂	21.8	2.1	11.37
C ₁ - C ₃	0.0	3.0	7.13
Oil (C ₄ ⁺)	12.8	63.1	62.62
Asphaltenes	0.5	12.1	13.29
Preasphaltenes	-	0.9	2.11
Unreacted Coal	-	3.2	7.54
Total Net Distillate Oil Yield			62.2

- ARC/CED Test Run Basis: DOE-BU-015, YP-05/C1

- **Number of Reactor Trains: 5**
(Based on a maximum reactor diameter of 15 ft. i.d. and a maximum superficial gas velocity of 7.0 cm/sec (bubbly flow regime) in the reactors.

A total of 5 reactor trains are required to process the 41,620 tonnes/day of feed slurry needed to produce the 75,000 BPD of synthetic crude oil product. Each reactor train consists of a slurry mix system, first stage and second stage CF-reactors and associated pumps, heat exchangers, fired heaters and separators.

First Stage Liquefaction Area

The first stage liquefaction area includes coal slurry preparation, the first stage counterflow reactors (CF reactors) and first stage oil product recovery, as shown in Figure 3.2.

Prepared coal, slurry oil from the second stage liquefaction area, extract oil from the ROSE Unit, aluminate and molybdate catalysts are combined with a circulating coal slurry stream in high intensity mixers to ensure thorough wetting of the coal particles, uniform distribution of the catalysts and preparation of a uniform slurry mixture. Contents of the mixers are discharged directly into Slurry Holding Tanks.

A temperature of 120°C maximum is maintained in the slurry tanks to evaporate residual moisture contained in the incoming coal and to control the viscosity of the slurry feed to the high pressure slurry charge pumps.

The feed slurry is preheated to 350-400°C and charged to the first stage reactors which operate at 410°C and 10.0 MPa. Recycle plus makeup CO-rich synthesis gas and process water are combined and preheated to approximately 400°C and then introduced into the bottom of the reactors. The feed slurry and synthesis gas streams flow countercurrent to each other in the reactors. Coal solubilization takes place in the reactors in the presence of carbon monoxide and hydrogen; it is believed that the

FIGURE 3.2
SIMPLIFIED PROCESS FLOW DIAGRAM
FIRST STAGE CF REACTOR AREA
CFR ADVANCED COAL LIQUEFACTION PROCESS

formation of molecular hydrogen by the water gas shift reaction ($\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO} + \text{H}_2$) aids in the coal solubilization, particularly with low rank, sub-bituminous coals.

An overhead vapour stream, containing first stage reactor products and CO-rich gas, is withdrawn from each reactor, cooled and separated in a Cold High Pressure Separator. The gas stream is routed to the First Stage Recycle Gas Processing Area for further processing before being recycled to the first stage reactors. The recovered oil product is pumped directly to the Mixed Feed Hydrotreater Area.

The reactor bottoms stream, containing the dissolved coal, slurry oil, unreacted coal, ash and the molybdate catalyst is cooled to 250-300°C and charged to the second stage CF reactors.

Second Stage Liquefaction Area

The Second Stage Liquefaction Area consists of the CF reactors and associated heat exchangers and separators as shown in Figure 3.3.

The second stage CF reactors operate at 440°C and 17.2 MPa with preheated recycle plus makeup hydrogen being introduced into the bottom of the reactors to flow countercurrent to the downward flowing dissolved coal stream. Hydrogenation of the solubilized coal and slurry oil takes place in the reactors, with the distillate oil products being vaporized as they are formed. Temperature is controlled in the second stage reactors by adjusting the temperature of the incoming hydrogen stream or by introducing cold quench hydrogen into the reactors. The recycle rate of hydrogen was set to provide total makeup 2.5 times the consumption, in order to maintain the superficial gas velocity in the bubbly flow regime (below 7 cm/sec).

An overhead vapor stream, containing unreacted hydrogen, light hydrocarbons, heterogases (CO , CO_2 , H_2S , NH_3) and the main distillate oil product, is cooled to 375-400°C to condense the heavy fraction of the distillate oil product and separated in a

FIGURE 3.3
SIMPLIFIED PROCESS FLOW DIAGRAM
SECOND STAGE CF REACTOR AREA
CFR ADVANCED COAL LIQUEFACTION PROCESS

Hot High Pressure Separator. The overhead vapour stream from the separator, still containing a major portion of the distillate oil product, is routed directly to the Mixed Feed Hydrotreater Area. The recovered liquid product (heavy distillate), representing a major portion of the slurry oil required to slurry the incoming coal, is cooled to about 200°C and returned to the slurry mixing system.

The CF-reactor bottoms stream, containing vacuum gas oil (VGO), unconverted residual oil, unreacted coal and ash, is fed to a ROSE Unit for recovery of the VGO and residual oil.

3.1.3 Mixed Feed Hydrotreater

Recent research by Canadian Energy and Alberta Research Council has indicated that hydrotreating of the primary upgraded distillate oil from coal/heavy oil co-processing or coal liquefaction operations in a single mixed phase hydrotreating step can produce a synthetic crude oil product that can be easily processed to transportation fuels in a conventional refinery. This is similar to the approach being taken by Veba Oil in their Combi-Cracking Process and by CANMET in their Hydrocracking Process.

The major process equipment in the Hydrotreater Area is shown in Figure 3-4.

The overhead vapour product from the second stage liquefaction reactor high pressure separator, containing unreacted hydrogen, light hydrocarbon gases, heterogases and the distillate oil product, is combined with first stage distillate oil product and fed directly to the mixed phase hydrotreater operating at approximately 350°C and full second stage liquefaction pressure of 2,400 psig. Quench hydrogen is used to control temperature in the fixed bed hydrotreating reactors.

FIGURE 3.4

SIMPLIFIED PROCESS FLOW DIAGRAM
HYDROTREATER AREA
CFR ADVANCED COAL LIQUEFACTION PROCESS

The reactor effluent is cooled and separated in cold high pressure and low pressure separators to yield a high pressure hydrogen recycle stream, a low pressure C_5^- purge gas stream and a liquid distillate product stream. The purge gas stream is routed to the Gas Recovery Area and the liquid product is fed to a product fractionator for separation into naphtha, middle distillate and VGO products. These three product streams are subsequently recombined with C_4^+ liquid product to form the synthetic crude oil product.

The Hydrotreater Area consists of 5 hydrotreating reactor and high pressure separator trains, each closely coupled with one of the 5 coal liquefaction reactor trains, and a single low pressure separator and product fractionator. The product fractionator was provided even though the naphtha, mid distillate and VGO fractions are recombined as it may be necessary to use a portion of the VGO as coal slurry oil in order to increase the hydrogen content of the slurry oil.

3.1.4 ROSE Unit

The bottoms product from the second stage CF reactors is processed in a Kerr-McGee critical solvent deashing (ROSE-SR) unit to recover the residual oil. The extract oil, containing VGO and recycle solvent is recycled to the coal liquefaction area as coal slurry oil and the ash concentrate is routed to a Fluid Bed Combustion (FBC) Unit for recovery of its thermal energy.

The yield of extract oil across the ROSE Unit was set to reject the total non-distillate oil contained in the second stage CF reactor bottoms product to prevent its accumulation. This yield is conservative in comparison to that used by Bechtel in the Baseline Study.

3.1.5 Synthesis Gas Production

Hydrogen and CO-rich synthesis gas required in the coal liquefaction process is produced by the steam reforming of natural gas, as shown in Figure 3.5.

FIGURE 3.5
SIMPLIFIED PROCESS FLOW DIAGRAM
SYNTHESIS GAS PRODUCTION AREA
CFR ADVANCED COAL LIQUEFACTION PROCESS

In the configuration for the production of hydrogen plus CO-rich synthesis gas, natural gas is preheated and desulphurized, then combined with steam produced in the reforming furnace plus carbon dioxide (CO₂) recovered from the synthesis gas and fed to the reforming furnace for conversion to synthesis gas. By controlling the quantity of CO₂ recycled to the reforming furnace, the molar ratio of hydrogen to carbon monoxide in the synthesis gas can be controlled.

The synthesis gas exiting the reformer is cooled and fed to a Carbonate CO₂ Recovery System. The recovered CO₂ is recycled to the reforming furnace and the CO₂-free synthesis gas is sent to a Pressure Swing Adsorption (PSA) unit.

The synthesis gas is separated into two streams in the PSA Unit, a hydrogen stream containing 99 mol % hydrogen and a CO-rich synthesis gas stream containing 56.8 mol % CO and 41.2 mol % hydrogen. The CO-rich synthesis gas is used in the first stage of the coal liquefaction process and the hydrogen is used in the second stage plus the hydrotreaters.

3.1.6 First Stage Recycle Gas Processing

The recycle gas from the first stage coal liquefaction process must be cleaned up before being recycled as it contains CO₂, hydrogen and light hydrocarbons (plus possibly a small quantity of hydrogen sulphide) formed in the first stage, as shown in Figure 3.6.

The recycle gas is first treated in a Carbonate CO₂ Removal System for removal of the formed CO₂. The recovered CO₂ is vented and the H₂-rich recycle gas is sent to a Membrane Separator for recovery of the excess hydrogen produced in the first stage. By proper control of operating conditions in the CO₂ removal system, any hydrogen sulphide will remain in the recycle gas rather than in the CO₂ vent stream.

A two stage Membrane Separator is used to recover hydrogen from the H₂-rich recycle gas. The recovered hydrogen is used in the second stage of the coal

liquefaction process and in the hydrotreaters and the CO-rich synthesis gas, containing 76.0 mol % CO, is combined with makeup synthesis gas and recycled to the first stage. The combined stream contains 67.2 mol % CO. A membrane separator was selected so that the pressure of the recycle gas would be maintained with the hydrogen being recovered as a lower pressure permeate.

A purge stream of membrane separator feed gas is removed to prevent the buildup of light hydrocarbons in the recycle gas stream.

3.1.7 Hydrogen Recovery

A hydrogen recovery system is included to recover hydrogen from recycle and purge gas streams for use in the second stage of coal liquefaction and the hydrotreaters, as shown in Figure 3.7.

As the coal liquefaction reactors and hydrotreaters are close coupled as discussed earlier, there is only one hydrogen recycle system with hydrogen recovered from the hydrotreaters being recycled to the second stage coal liquefaction system.

The hydrogen recovery system uses a two stage PSA Unit to maximize recovery of hydrogen from the first stage purge gas, the second stage and hydrotreater purge hydrogen stream and the C_5^- purge gas from the hydrotreaters. Makeup, recovered and recycle hydrogen streams are combined and recycled to the second stage of coal liquefaction process at a combined hydrogen purity of 90.3 mol %. The C_4^- product gas and C_4^+ liquid streams are sent to Gas Recovery.

3.1.8 Gas Recovery

A conventional gas recovery system consisting of an H_2S removal system and a propane recovery tower is used as shown in Figure 3.8.

FIGURE 3.7

SIMPLIFIED PROCESS FLOW DIAGRAM
HYDROGEN RECOVERY & COMPRESSION AREA
CFR ADVANCED COAL LIQUEFACTION PROCESS

FIGURE 3.8
SIMPLIFIED PROCESS FLOW DIAGRAM
GAS RECOVERY AREA
CFR ADVANCED COAL LIQUEFACTION PROCESS

The C_4^- product gas is fed to an amine H_2S absorber/regenerator system to remove H_2S from the gas stream. The H_2S stream is sent to the Sulphur Plant and the sweetened gas stream is chilled and separated into a fuel gas stream and a C_3/C_4 liquid stream. The liquid stream is combined with the C_4^+ liquid stream from the hydrogen recovery area and processed in a C_3/C_4 splitter to recover propane and a C_4^+ liquid stream. The C_4^+ liquid is combined with the liquid product stream from the hydrotreater to make up the C_4^+ synthetic crude oil product.

3.1.9 Sulphur, Ammonia and Phenol Recovery

A conventional Claus Sulphur Plant Recovery and Tail Gas Plant is used to convert the recovered hydrogen sulphide to elemental sulphur, which is sold as a by-product. The sulphur recovery unit was sized to recover all of the feed coal sulphur as elemental sulphur as an accurate sulphur balance was not available.

Conventional Chevron WWT and Phenosolvan Solvent Recovery Processes were used to recover H_2S , ammonia and phenols from the waste water prior to treating the waste water in a conventional biological treatment plant. The H_2S is routed to the Sulphur Plant, the ammonia is recovered as anhydrous ammonia for sale and the phenols are used as process fuel (for disposal).

3.1.10 Offsite and Utility Systems

The offsite and utility systems include two Fluid Bed Combustion (FBC) Units to combust the ash residue from the ROSE Unit and two steam turbine generator sets to generate electricity from the high pressure FBC steam, plus the standard systems common to all facilities.

The two FBC units are each designed to combust 2,800 tonnes/day (50%) of ash residue and to produce 880,000 kg/hr of high pressure steam for power generation. Limestone injection is used in the FBC Units to control sulphur dioxide emissions. The turbine generator sets include high pressure, intermediate pressure and low pressure

turbines, with high pressure steam being received from the FBC Units at 2,600 psig and the low pressure turbines operating under vacuum with surface condensers. A total of 364 MW of electricity is generated.

The balance of the offsite and utility systems, common to all facilities and similar to those used in the Bechtel study include:

- Relief and blowdown systems.
- Intermediate and product tankage.
- Electrical distribution.
- Raw, cooling and potable water systems.
- Fire protection systems.
- Sewage and effluent treatment.
- Instrument and plant air systems.
- Purge and flush oil systems.
- Solids waste disposal systems.
- Interconnecting piping.
- Site development.
- Buildings and telecommunications.

3.2 MATERIAL BALANCES

Overall material balances are presented in Table 3.1 for the coal liquefaction facility. The material balances are based on bench scale test data provided by Canadian Energy and Alberta Research Council and on data provided during previous studies by Canadian Energy and Chevron Research on the expected performance of coal liquids in mixed feed hydrotreaters.

Following are the key assumptions made during preparation of the material balances:

- Test run basis DOE-BU-015, YP-05/C1.

TABLE 2.1
MATERIAL BALANCE SUMMARY

STREAM NO DESCRIPTION	1	2	3	4	5	6	7	8	9	10	11
	COAL	TOTAL SLURRY OIL	COAL SLURRY TO STAGE 1	CO / H ₂ GAS TO STAGE 1	SOLUBILIZED COAL TO STAGE 2	STAGE 1 REACTOR OVERHEAD	STAGE 1 OIL PRODUCT TO HTU	STAGE 1 REC. GAS TO CO ₂ ABS.	PREHEATED H ₂ GAS TO STAGE 2	STAGE 2 OVERHEAD PRODUCT	STAGE 2 BOTTOMS TO ROSE
COMP. \ UNITS	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h
H ₂				14,662		10,645		10,645	106,466	63,905	
H ₂ S									420	420	
NH ₃											
CO				596,673		406,777		406,777	17,045	17,045	
CO ₂						341,519		341,519	64,532	117,406	
H ₂ O	66,541		66,541			543,152				23,980	
CH ₄				50,960		51,437		51,437	40,495	57,907	
C ₂									13,036	27,999	
C ₃									6,200	20,796	
C ₄									1,618	10,360	
C ₅									579	14,720	
COAL (MAF)	665,414		665,414		50,321						50,321
OIL		922,666	922,666		626,146	211,059	211,059			677,425	227,924
EXTRACT											
RESIDUE					365,773						102,401
ASH	79,525		79,525		79,525						79,525
IBP - 360 F											
300 - 650 F											
650 - 975 F											
Total	811,460	922,666	1,734,167	664,515	1,421,765	1,575,760	211,059	621,579	270,962	1,231,967	400,171
MOL. WT				20,740				23,205	4,623		
BPD											
Nm ³ /h				716,092				793,406	1,310,916		
B.G. (AP ₁)											

STREAM NO DESCRIPTION	12	13	14	15	16	17	18	19	20	21	22
	STAGE 2 O/VHD OIL TO SLURRY	STAGE 2 O/VHD TO HTU	NET OIL PLUS H ₂ TO HTU	QUENCH H ₂ TO HTU REACTOR	RECYCLE H ₂ TO STAGE 2	RECYCLE H ₂ PURGE	RECYCLE H ₂ MAKE UP	HTU C ₄ - GAS TO P&A #3	C ₅ + SYNTHETIC CRUDE	C ₄ + SYNTHETIC CRUDE	PROPANE
COMP. \ UNITS	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h
H ₂		63,905	63,905	12,564	37,635	14,714	66,631	1,630			
H ₂ S		420	420	139	420	163		710			
NH ₃											
CO		17,045	17,045	4,075	12,272	4,773	4,773				
CO ₂		117,406	117,406	28,071	64,532	32,674					
H ₂ O		23,980	23,980								
CH ₄		57,907	57,907	12,523	37,711	14,665	2,784	7,495			
C ₂		27,999	27,999	4,330	13,036	5,070		5,227			
C ₃		20,796	20,796	2,059	6,200	2,411		2,775			20,260
C ₄		10,360	10,360	537	1,618	629		680		13,342	
C ₅		14,720	14,720	192	579	225		245	13,672	14,142	
COAL (MAF)											
OIL	694,762	182,663	393,722								
EXTRACT											
RESIDUE											
ASH											
IBP - 360 F									39,957	39,957	
300 - 650 F									316,534	316,534	
650 - 975 F									24,489	24,489	
Total	694,762	537,225	748,283	64,490	194,205	75,524	76,187	16,967	394,650	406,463	20,260
MOL. WT				8,056	8,056	8,056	2,215	36,360			44,096
BPD											
Nm ³ /h				179,371	540,160	210,062	770,757	11,662			
B.G. (AP ₁)									0.836 (37.70)	0.823 (40.44)	

TABLE 3.1
MATERIAL BALANCE SUMMARY (CONTD)

STREAM NO	23	24	25	26	27	28	29	30	31	32	33
DESCRIPTION	FUEL GAS	WATER TO STAGE 1	SOUR H ₂ O FROM STAGE 1	SOUR H ₂ O FROM HTU	ROSE' EXTRACT TO SLURRY	ROSE' RESIDUE TO 'FBC'	SUPERHEAT STEAM EX 'FBC'	CO ₂ FROM STG 1 CO ₂ REMOVAL	CO/H ₂ GAS FROM CO ₂ REMOVAL	CO/H ₂ RECYCLE PURGE GAS	CO/H ₂ GAS TO H ₂ MEMBRANE
COMP. \ UNITS	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h
H ₂	3,938										
H ₂ S									19,845	1,965	17,881
NH ₃											
CO	45,003								406,777	40,878	367,899
CO ₂	32,674							341,519			
H ₂ O		508,873	643,152	23,980			3,869,931				
CH ₄	29,275								51,437	5,144	46,293
C ₂	19,071										
C ₃											
C ₄											
C ₅											
COAL (MAF)						50,321					
OIL											
EXTRACT					227,924						
RESIDUE						102,401					
ASH						79,525					
IBP - 360 F											
360 - 650 F											
650 - 975 F											
Total	130,158	508,873	643,152	23,980	227,924	232,247	3,869,931	341,519	480,059	48,006	432,053
MOL. WT	19.239						18.015	44.010	17.365	17.365	17.365
BPD											
Nm ³ /h	151,625						4,614,428	173,919	619,579	61,958	657,621
B.G. (API)											

STREAM NO	34	35	36	37	38	39	40	41	42	43	44
DESCRIPTION	H ₂ FROM MEMBRANE	CO/H ₂ RECYCLE TO STAGE 1	NAT. GAS TO STEAM REFORMER	H ₂ O TO STEAM REFORMER	CO ₂ REC. TO STEAM REFORMER	REFORMER EFFLUENT (WET)	DRY FEED GAS TO PBA #1	H ₂ FROM PBA #1	REFORMER CO/H ₂ GAS TO STAGE 1	H ₂ FROM PBA #2	PURGE FROM PBA #2
COMP. \ UNITS	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h
H ₂	15,360	2,501				50,757	50,767	38,578	12,182	12,091	4,006
H ₂ S											163
NH ₃											
CO	2,156	365,743				235,098	235,098	1,969	233,129	648	45,003
CO ₂					119,381	119,381					32,674
H ₂ O				389,201		237,995					
CH ₄		46,293	141,290			6,641	6,641	1,973	4,667	649	19,160
C ₂											5,070
C ₃											2,411
C ₄											629
C ₅											225
COAL (MAF)											
OIL											
EXTRACT											
RESIDUE											
ASH											
IBP - 360 F											
360 - 650 F											
650 - 975 F											
Total	17,516	414,637	141,290	389,201	119,381	649,872	292,468	42,518	249,978	13,968	100,543
MOL. WT	2.278	24.124	16.043	18.015		13.021	8.606	2.200	17.055	2.200	18.958
BPD											
Nm ³ /h	172,504	385,117	197,367	484,189		1,118,569	761,715	433,222	328,493	142,523	129,497
B.G. (API)											

(1,0104) (2,10104)

Note 1: Stream 49 refers to H2S from the HTU liquid product only. Total H2S and S balance is based on S content of Coal.

Note 2: The Sulphur and Ammonia Plants are conservatively sized for the total S and H2 in the Coal Feed. The Phenol production rate is estimated at 15 % of the H2S production rate.

The Sulphur and Arsenic Plants are conservatively sized for the total S and As in the Coal Feed. The Phenol production rate is estimated at 15 % of the NH₃ production rate.

- Commercial plant yields assumed to be the same as the bench scale yields which were based on once through operation with DOE Solvent V1074 (no slurry oil recycle), high purity carbon monoxide to the first stage and high purity hydrogen to the second stage.
- No process optimization.
- Pentane soluble oils and asphaltenes recovered in the ROSE Unit from the coal liquids will become distillable oil products in the recycle slurry oil operation and will not build up in the recycle stream. All non-distillable oils are rejected in the ROSE Unit.
- Operation of the first stage of the coal liquefaction process with a CO-rich synthesis gas containing 67 mol % CO gives similar results to those obtained with high purity CO. Limited autoclave data indicate that this is a valid assumption.
- Operation of the second stage of the coal liquefaction process with a total hydrogen makeup rate of 2.5 times consumption, to prevent excessive superficial gas velocities in the CF reactors.

3.3 UTILITY REQUIREMENTS

Overall utility requirements are summarized in Table 3.2 for the coal liquefaction facility. Annual and initial catalyst and chemical costs are provided in Table 3.3. Both tables are patterned after the Bechtel study report and the utility requirements, catalyst and chemical costs for all process units, offsite and utility systems other than the coal liquefaction plant, the mixed feed hydrotreater, the methane reformer and the hydrogen purification unit were prorated from the Bechtel report. Utility requirements, catalyst and chemical costs for those units unique to the CFR advanced coal liquefaction process were developed by Kilborn. First and second stage liquefaction

catalyst costs were based on current metal content costs plus estimated manufacturing costs.

TABLE 3.2
OVERALL UTILITY BALANCE - COAL LIQUEFACTION PLANT

OVERALL UTILITY BALANCE -- COAL LIQUEFACTION PLANT																
PLANT NO.	PLANT NAME	BASIS	RATE	Fuel Gas MMBtu/h	Power kW	Steam, Psig, lb/h				Cond (BFW) lb/h	Cooling Water gpm	Bour Water gpm	Waste Water gpm	Makeup Water gpm	Air scfm	N2 scfm
						600/2020 Sup/heat	600 @ 489 °F	150 @ 306 °F	50 @ 298 °F							
Processing Units																
1	Coal Cleanh & Handling	MTPD (MF)	21,454		6,751								638			
1.4	Coal Crushing & Drying	MTPD (MF)	17,879	560	13,959						277				6,863	86,500
2	Coal Liquefaction	MTPD (MF)	17,879	1,194	62,547	6,415	(171,806)	(103,822)	186,452	489,425	9,329	(3,035)				824
3	Gas Plant	Kg/h	125,471	(3,145)	899		245,173		27,028	(527,381)	17,517	(4)				
4	Mixed Feed Hydrotreater	Kg/h	393,722	382	2,448		70,660	(119,128)		54,163	376	(113)			(92)	
6	H2 Purification (PSA #2 & #3)	Kg/h	16,153		10,705				921	(27,608)	2,388	(37)			(31)	
8	ROSE Unit	Kg/h	460,171	1,458	4,878			28,420				(57)				
9-01	Methane Reforming	Kg/h	141,290	4,982	6,216		(986,607)			2,328,633	9,581	(767)				
11	S Plant	Kg/h	4,470	11	489		9,582	(29,811)	8,705	11,525	1,299	(14)				
ALL	Common Users					119,283		84,206	196,481	309,238				(853)	8,508	
	Sub Total (Process)			5,441	108,889	125,699	(832,997)	(113,447)	419,588	2,635,996	40,746	(4,027)	638	(977)	15,371	87,324
Offsites																
19	Relief & Blowdown				19											
20	Tankage				6,758			22,000	3,300	(25,300)	100					
30	Electrical Distribution															
31	Steam & Power Gener.			1,044		(125,699)			(485,143)	(1,353,196)			(537)	(5,006)		
31.1	Steam Turbine Gener.				(364,344)	3,869,931				(4,140,728)	202,107			(542)		
31.4	Fluid Bed Combustion				29,970	(3,869,931)				3,869,931			(154)	(154)		
32	Raw, Cooling & Potable Water Systems				10,927						(323,290)		(235)	16,103		
33	Fire Protection				44											
34	Sewage & Effluent Treat.				7,313				3,000	(3,000)				(235)		
35	Instrument & Plant Air				2,894										(15,371)	
36	Purge & Flush Oil Systems				258											
37	Solid Wastes Disposal				48											
38	NH3 Recovery				1,503		319,957	670,403		(890,361)	78,386	4,027		90		
39	Phenol Recovery				902			25,168	68,185	(93,342)	4,952		(1,052)			
Others	Bldgs, Light, Etc.				4,835											
	Nat. Gas Imported			(6,485)												
	Off Site BL & Evap.												1,850	(9,189)		
	Sub Total (Offsites)			(5,441)	(292,874)	(125,699)	319,957	817,561	(410,659)	(2,635,996)	(40,746)	4,027	(638)	(977)	(15,371)	
	GRAND TOTAL				(183,985)		(513,041)	804,113	8,927		0		(0)	0		87,324

TABLE 3.3
CATALYST AND CHEMICAL COSTS

PLANT NO.	PLANT NAME	BASE 1	BASE 2
		1,000 \$	1,000 \$
1	Coal Cleaning & Handling	462	343
2	Coal Liquefaction	22,400	7,168
3	Gas Plant	43	36
4	Mixed Feed Hydrotreater	696	2,265
6	H ₂ Purification (PSA #2 & #3)	56	279
8	ROSE Unit	100	425
9-01	Methane Reforming	560	1,680
11	S Plant (By-Products Recovery)	224	464
31	Steam & Power Gener.	178	48
31.4	Fluid Bed Combustion		
32	Raw, Cooling & Potable Water System	3,079	825
34	Sewage & Effluent Treat.	358	94
38	NH ₃ Recovery	391	133
39	Phenol Recovery	28	10
	TOTAL	28,574	13,769
Notes: BASE 1: Catalysts and chemicals cost per year as part of variable operating costs. BASE 2: Catalysts and chemicals cost as part of capital cost.			

4.0 FINANCIAL

4.1 CAPITAL COST ESTIMATE

The capital cost estimate for the conceptual CFR advanced coal liquefaction facility was developed on the basis of an Nth plant design, that is the commercial plant built N years after the first commercial coal liquefaction plant, for which the technology basis, plant design and operation are well known. The Nth plant has the following characteristics:

- Lowest reasonable plant contingency.
- No spare trains.
- Lowest reasonable engineering cost.
- Shortest possible project schedule to erect and start up.
- Mature technology allowing the overall stream factor of the complex to be the same as that of the First plant (spare process trains, over capacity).

The capital cost estimate is presented in Table 4.1. The capital costs for the process units unique to the CFR advanced technology were developed by Kilborn based on preliminary sizing of the liquefaction reactors, prorating costs for the remainder of the coal liquefaction unit equipment from previous Kilborn/CED studies, and soliciting preliminary cost information from technology licensors for the steam methane reforming unit (with CO₂ recycle), the PSA units and the membrane separation units. All other costs for process units similar to those used in the Bechtel study and the offsite and utility systems were prorated from the Bechtel study report.

The installed plant costs for the complex were developed by taking the estimated Inside Battery Limit (ISBL) plant cost for each ISBL plant, adding the respective portion of the total Outside Battery Limit (OSBL) costs and then adding the proportional amount of home office costs, engineering fee and contingency, as shown in Table 4.1.

Following are the bases for the capital cost estimates for the process units:

**Coal Cleaning, Handling,
Crushing & Drying**

Bechtel Baseline Study with adjustments for coarser coal grind and additional drying for sub-bituminous coal.

Coal Liquefaction

Kilborn developed, based on previous coal liquefaction and coprocessing studies.

Gas Plant

Bechtel Baseline Study.

Hydrotreater

Chevron, based on hydrotreating of coal liquids.

Hydrogen Purification

Bechtel Baseline Study with adjustment for CO recovery based on Monsanto membrane data.

ROSE Unit

Bechtel Baseline Study.

Methane Reforming

Bechtel Baseline Study with adjustment for CO₂ recycle based on Air Products data.

**Sulphur Plant, NH₃ Recovery,
Phenol Recovery**

Bechtel Baseline Study.

TABLE 4.1
CAPITAL COST INVESTMENT – COAL LIQUEFACTION PLANT

PLANT NO.	DESCRIPTION	BASIS	TOTAL RATE	NO. OF OPER UNITS	TOTAL NO. UNITS	ISBL FIELD COSTS (\$1,000 US)	OSBL FIELD COSTS (\$1,000 US)	INSTALLED COSTS (\$1,000 US)
1	Coal Cleaning & Handling	MTPD (MF)	21,454	6	6	88,902	117,042	143,607
1.4	Coal Crushing & Drying	MTPD (MF)	17,879	12	12	100,844	135,550	166,316
2	Coal Liquefaction	MTPD (MF)	17,879	5	5	626,080	843,216	1,034,606
3	Gas Plant	Kg/h	125,471	1	1	46,123	62,119	76,219
5	Mixed Feed Hydrotreater	Kg/h	393,722	5	5	172,380	232,165	284,860
6	H ₂ Purification (PSA #2 & #3)	Kg/h	16,153	1	1	109,033	146,848	180,179
8	ROSE Unit	Kg/h	460,171	1	1	45,656	61,490	75,446
9-01	Methane Reforming	Kg/h	141,290	3	3	259,437	349,414	428,723
11	S Plant (Note 1)	Kg/h	4,470	1	1	13,053	17,580	21,570
38	NH ₃ Recovery (Note 2)	Kg/h	9,046	1	1	22,670	30,532	37,462
39	Phenol Recovery (Note 3)	Kg/h	1,357	1	1	8,531	11,490	14,097
	Total					1,490,509	2,007,445	2,463,086

NOTES:

1. S recovery based on 0.60 wt % organic sulphur in coal feed (MF).
2. N recovery based on 1.00 wt % organic nitrogen in coal feed (MF).
3. Phenol recovery based on 15 wt. % of the NH₃ recovered.

4.2 OPERATING COST ESTIMATE

The annual operating cost estimate, presented in Table 4.2, includes the cost of raw materials less byproduct credits; the costs of utilities, operating, maintenance and management labour; supplies and materials disposal plus indirect operating costs (supplies, maintenance materials, taxes and insurance).

Raw Material and Utility Pricing

Feed Coal	\$10.00/tonne
Natural Gas	\$ 2.00/MMBTU
Raw Water	\$ 0.10/M Gal

Labour Costs

The overall staffing for the coal liquefaction complex was based on the Bechtel staffing philosophy that:

- The complex is operated by a major oil company with corporate engineering support.
- Process plants are divided into 5 areas with dedicated maintenance for each area.
- Contract maintenance will be used during plant turnarounds and for other non-routine maintenance.
- The complex is operated from one central control room, except for shipping and loading.

Total staffing and average annual salaries, using the Bechtel salary information are summarized below:

TABLE 4.2
YEARLY OPERATING COSTS.

SCO PRODUCTION: 75,000 BPD				
OPERATING FACTOR: 88.40 % YEARS OF OPERATION: 25.00				
	UNIT RATE	QUANTITY	PRICE / UNIT	OPER. COST
			(\$)	(\$/yr)
FEEDS:				
Coal (ROM)	MT/D	19,476	10.00	62,839,700
Natural Gas	MMBTU/D	161,371	2.00	104,135,800
Total Feeds				166,975,500
BY-PRODUCT CREDITS:				
Fuel Gas	MMBTU/D	75,481	2.00	48,709,400
Propane	BPD	6,029	7.50	14,589,900
Sulphur	MT/D	107	88.18	3,052,200
Ammonia	MT/D	217	132.28	9,265,700
Electricity	kWh	183,985	0.05	2,968,200
Total By-Products				78,585,400
NET FEED COST (Feeds minus By-products)				88,390,100
UTILITIES:				
Raw Water Makeup	MGAL/D	23,189	0.10	748,200
Fuel	MMBTU/D	155,634	2.00	100,434,000
Total Utilities				101,182,200
LABOUR:				
Operation				11,525,500
Management & Supervision				701,000
Laboratory				1,506,000
Engineering				1,953,700
Environ., Health, Safety & Security				2,773,600
Administration				2,691,200
Maintenance (@ 1.01 % of Capital Invest.)				24,958,000
Total Labour (@ 1.87 % of Capital Invest.)				46,109,000
SUPPLIES & MATERIALS DISPOSAL:				
Catalysts & Chemicals				28,574,300
Ash Disposal Cost	MT/D	1,909	5.51	3,394,100
Refuse Disposal Cost	MT/D	3,576	2.20	2,543,500
Total Supplies & Materials Disposal				34,511,900
TOTAL DIRECT COSTS:				270,193,200
INDIRECT COSTS:				
Operating & Office Supplies (0.05 % of Capital Invest.)				1,231,500
Maintenance Materials (@ 0.75 % of Capital Invest.)				18,473,100
Taxes & Insurance (@ 0.25 % of Capital Invest.)				6,157,700
Total Indirect Costs				25,862,300
MANUFACTURING COSTS:				296,055,500
REVENUE FROM SALES OF SCO (@ 29.75 \$/BBL FOR BASE CASE)				719,853,500
NET PROFIT BEFORE TAXES				423,798,000
INTERNAL RATE OF RETURN BEFORE TAXES				16.75%

Plant Management	9	\$77,900/yr
Laboratory	35	\$43,000/yr
Operations	320	\$36,000/yr
Engineering	40	\$48,800/yr
Environment, Health & Safety	56	\$49,500/yr
Administration	80	\$33,600/yr
Maintenance	420	\$59,400/yr

By-Product Credits

By-products from the coal liquefaction complex include elemental sulphur, anhydrous ammonia and propane. The prices used for the by-products is shown below:

Sulphur	\$ 88.18/tonne	(\$ 80/ton)
Ammonia	\$132.28/tonne	(\$120/ton)
Propane	\$ 7.50/bbl	

Fuel gas was shown as a by-product in the operating cost summary even though it is consumed as process fuel in the complex. The quantity of fuel shown under utility requirements has been adjusted accordingly.

4.3 PRODUCT REVENUE

The value of the synthetic crude oil was not estimated for the purposes of this study as the financial analysis was based on a determination of the synthetic crude oil price required to give a 15% return on equity.

For reference purposes the price of crude oil or synthetic crude oil derived from Canadian oil sands was assumed to be \$20.00/bbl.

4.4 FINANCIAL ANALYSIS

The key assumptions used in the financial model to determine the crude oil equivalent price is \$/bbl included:

Project Start Date	January 1995
Years of Construction	5
Years of Operation	25
Operating Factor, %	88.4
Depreciation, Years	
Process Facilities	5
Buildings, Services	25
Working Capital, % Revenue	10
Bank Interest Rate, %	8
Federal Income Tax, %	34
Percent Equity	25
Percent IRR on Equity	15
General Inflation, %	3
Raw Material Price Escalation	Same as Inflation
State Income Tax, %	0
Syncrude Premium	1.00 (multiplier)

The results of the financial and sensitivity analysis are shown in Table 4.3, with sensitivities to changes in project capital, raw material costs and owner's equity being evaluated.

TABLE 4.3
FINANCIAL RESULTS AND SENSITIVITIES

FINANCIAL CASES	CRUDE OIL EQUIVALENT PRICE (\$/BBL)
Base Case	29.75
Capital + 10 %	31.43
Capital - 10 %	28.06
Capital + 25 %	33.97
Capital - 25 %	25.52
Coal Price + 25 %	31.06
Coal Price - 25 %	28.43
Natural Gas Price + 25 %	31.46
Natural Gas Price - 25 %	28.04
Owner's Equity 50 % (Double the Base)	31.59
SCO Yield + 10 %	27.04
SCO Yield - 5 %	31.31

5.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this preliminary economic feasibility study, it appears that the CFR advanced coal liquefaction process offers considerable merit as the estimated synthetic crude oil price to give a 15% IRR on equity is only 25-70% above current crude oil price.

In order to further evaluate the future potential of the technology, it is recommended that the R&D program be continued so that assumptions made and questions raised during this study can be resolved. Key issues to be addressed in further R&D work include:

- Operation in larger scale pilot equipment so that larger samples of product can be obtained for analysis and further upgrading studies.
- Operation with slurry oil recycle (closed loop) rather than on a once-through basis with coal-derived solvent.
- Operation with a ROSE Unit or hot filter for the recovery and recycle of heavy VGO, residual oil and asphaltenes from the second stage CF reactor bottoms stream.
- Operation with a CO-rich synthesis gas rather than high purity carbon monoxide in the first stage coal liquefaction reactor.
- Operation with lower hydrogen rates in the second stage reactors to evaluate the effect of superficial gas velocity and flow regime on product yield structure.
- Reduction of first and second stage catalyst requirements.
- Increased coal loading in the first and second stage reactors.

- Mixed feed hydrotreating tests to confirm final synthetic crude oil quality as a function of hydrotreating severity.

At the conclusion of the next phase of the R&D program, a new economic feasibility study should be commissioned to improve the accuracy of, and confidence in the financial merits of the technology.

APPENDIX A

**Test Run Data provided by CED/ARC
for Run No. DOE-BU-015, YP-05/C1**

RUN No.: DOE-BU-015

M.B.No.: YP-05/C1

26-Apr-94

	Date	Time	Date	Time
START:			Dec. 16, 93	12:00
END:			Dec. 16, 93	20:00
DURATION (hours):				8.00

Feed:	Type	Wt% (maf)
Coal	BTH	41.88%
Solvent	V-1074	58.12%
Catalyst 1	Aluminate	2.00%
Catalyst 2	Molybdate	0.28%
Other	CS2	

OPERATING PARAMETERS:		
FEED TANK WI-110):	(G)	
Start of Mass Balance		13180.00
End of Mass Balance		6020.00
Rate	(G/HR)	895
FIRST STAGE:		
Operating Pressure:	(MPa)	10.34
Feed Temp.:	(C)	283
Reactor Temp.:	(C)	
TE-201I	(BTM)	409
TE-202I		411
TE-203I		411
TE-204I	(Top)	389
Liquid Level	(mm)	540
Separator Temperature:	(C)	46
CO-Feed Rate:	(L/MIN)	4.03
Water Feed Rate:	(ML/MIN)	1.62
Temperature:	(C)	188
Catalyst Feed:	(ML/MIN)	
Liquid Product (WI-220):	(G)	
Start of Mass Balance		
End of Mass Balance		1553.20
Nitrogen Rate:	(L/MIN)	3.93
SECOND STAGE:		
Operating Pressure:	(MPa)	17.24
Feed Temp.:	(C)	137
Reactor Temp.:	(C)	
TE-301I	(BTM)	440
TE-302I		440
TE-303I		440
TE-304I		439
TE-305I		438
TE-306I		437
TE-307I		434
TE-308I	(Top)	431
TE-309I	(VAP)	430
Liquid level	(mm)	900
Separator Temperature:	(C)	45
Hydrogen Feed Rate:	(L/MIN)	34.11
Temperature:	(C)	402
Liquid Product (WI-330):	(G)	
Start of Mass Balance		1200
End of Mass Balance		5310
Bottoms Product (WT-34 (G)		
Start of Mass Balance		-880
End of Mass Balance		870
Sulfiding Agent	(mL/HR)	10.49

MEASURED GAS COMPOSITIONS				
NAME	MW	Measured Volume %		
		Product Gas 11	Product Gas 21	Dissolved Gas 22
Hydrogen	2.02	4.28	98.45	47.23
CO2	44.01	13.03	0.09	11.53
CO	28.01	23.81	0.46	26.57
H2S	34.08			
Methane	16.04	0.05	0.72	1.26
Ethylene	28.05		0.04	0.05
Ethane	30.07		0.29	0.82
Propane	44.01		0.22	0.89
Propylene	42.08			
i-Butane	58.12		0.01	0.00
n-Butane	58.12		0.09	0.55
i-Butene	56.11			
n-Butene	56.11			
C2-Butene	56.11			
i-Pentane	72.15			
n-Pentane	72.15		0.13	1.45
Nitrogen	28.02			
TOTAL		41.17	100.49	90.3605
Gas Meter Readings				
DTM-260		DTM-360		DTM-350
Start of M.B. : (L)	2290.0	7356.0		8038.0
End of M.B. : (L)	7132.0	24481.8		8100.0
Total : (L)	4842.0	17125.8		62.0
Temperature: (C)	21.8	21.4		22.8
Meter Pressure : (mmHg)	704	704		704
Standard Volume: (L)	4154	14711		53
Nitrogen to R-200: (L)	1884			
Net Gas Out: (L)	2269	14711		53

Run Conditions		
Basis: MAF	First Stage	Second Stage
Pressure Mpa	10.3	17.2
Temperature deg C	411	440
Catalyst	Aluminate	Molybdate
Feed wt % maf coal	41.88%	
WHSV (kg / hr) / l	1.83	1.10
CO Rate kg / kg maf coal	0.89	
moles / 100g maf coal	3.17	
consumed moles / 100g maf coal	1.02	
Water Rate kg / kg maf coal	0.89	
moles / 100g maf coal	4.93	
Hydrogen kg / kg maf coal		0.54
moles / 100g maf coal		26.94
consumed wt % maf coal	1.28%	6.39%

PRODUCT YIELDS					
Description	Total Gross			Total Net	
	[grams]		wt. %	[grams]	wt. %
	measured		maf feed		maf coal
			normalized		
H2O	104.90	98.64	1.52%	98.64	3.62%
COx	329.56	309.91	4.76%	309.91	11.37%
H2S					
C1 to C3	206.77	194.44	2.99%	194.44	7.13%
C4 +	100.46	94.47	1.45%	94.47	3.47%
Oil	5250.68	4937.61	75.86%	1612.45	59.15%
Asphaltene	871.89	819.90	12.60%	362.18	13.29%
Preasphalt.	61.03	57.39	0.88%	57.39	2.11%
IOM	218.65	205.61	3.16%	205.61	7.54%
Total	7143.93	6717.98	103.21%	2935.09	107.67%

Simulated Distillation Profile THF-Extract						Crude Sim. Dist. (Comp. Sample)				
Fraction [deg C]	Feed [grams]	Product				Feed [grams]	Product			
		Total Gross		Total Net			Total Gross		Total Net	
		[grams]	----- normalized -----		[grams]		wt. % maf coal	[grams]	----- normalized -----	
			[grams]	[grams]					[grams]	[grams]
C4 - 182		188.91	177.65	177.65	6.52%		188.60	177.35	177.35	6.51%
182 - 343	151.32	2136.34	2008.97	1857.65	68.15%	68.09	1572.95	1479.17	1411.08	51.77%
343 - 524	3631.57	3534.11	3323.39	-308.18	-11.31%	3173.84	3491.69	3283.50	109.65	4.02%
524+		643.33	604.98	604.98	22.19%	540.95	1249.47	1174.97	634.02	23.26%
TOTAL	3782.89	6502.70	6114.98	2332.10	85.55%	3782.89	6502.70	6114.98	2332.10	85.55%
IBP - 524	3782.89	5859.37	5510.01	1727.12	63.36%	3241.93	5253.23	4940.01	1698.08	62.29%

GAS ANALYSIS

First Stage Product Gas (DTM-250)										Second Stage Product Gas (DTM-350)										Dissolved Gas (DTM-350)									
Number of Samples: 1										Number of Samples: 6										Number of Samples: 2									
Name	vol. %	vol. %	vol. %	vol. %	vol. %	vol. %	vol. %	vol. %	vol. %	Name	vol. %	vol. %	vol. %	vol. %	vol. %	vol. %	vol. %	vol. %	vol. %	Name	vol. %	vol. %	vol. %	vol. %	vol. %	vol. %	vol. %	vol. %	vol. %
Hydrogen	4.275	88.938	88.317	88.773	88.317	88.317	88.317	88.317	88.317	Hydrogen	4.275	88.938	88.317	88.773	88.317	88.317	88.317	88.317	88.317	Hydrogen	4.275	88.938	88.317	88.773	88.317	88.317	88.317	88.317	88.317
CO ₂	13.029	0.096	0.089	0.089	0.084	0.084	0.084	0.084	0.084	CO ₂	13.029	0.096	0.089	0.089	0.084	0.084	0.084	0.084	0.084	CO ₂	13.029	0.096	0.089	0.089	0.084	0.084	0.084	0.084	0.084
CO	23.812	0.480	0.456	0.422	0.416	0.416	0.416	0.416	0.416	CO	23.812	0.480	0.456	0.422	0.416	0.416	0.416	0.416	0.416	CO	23.812	0.480	0.456	0.422	0.416	0.416	0.416	0.416	0.416
H ₂ S										H ₂ S										H ₂ S									
Methane	0.050	0.737	0.736	0.728	0.713	0.713	0.713	0.713	0.713	Methane	0.050	0.737	0.736	0.728	0.713	0.713	0.713	0.713	0.713	Methane	0.050	0.737	0.736	0.728	0.713	0.713	0.713	0.713	0.713
Ethylene		0.032	0.031	0.029	0.031	0.031	0.031	0.031	0.031	Ethylene		0.032	0.031	0.029	0.031	0.031	0.031	0.031	0.031	Ethylene		0.032	0.031	0.029	0.031	0.031	0.031	0.031	0.031
Ethane		0.291	0.280	0.286	0.281	0.281	0.281	0.281	0.281	Ethane		0.291	0.280	0.286	0.281	0.281	0.281	0.281	0.281	Ethane		0.291	0.280	0.286	0.281	0.281	0.281	0.281	0.281
Propane		0.220	0.225	0.224	0.220	0.219	0.220	0.220	0.220	Propane		0.220	0.225	0.224	0.220	0.219	0.220	0.220	0.220	Propane		0.220	0.225	0.224	0.220	0.219	0.220	0.220	0.220
Propylene		0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	Propylene		0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	Propylene		0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
i-Butane		0.084	0.085	0.085	0.083	0.084	0.084	0.084	0.084	i-Butane		0.084	0.085	0.085	0.083	0.084	0.084	0.084	0.084	i-Butane		0.084	0.085	0.085	0.083	0.084	0.084	0.084	0.084
n-Butane										n-Butane										n-Butane									
n-Butene										n-Butene										n-Butene									
C2-Butene										C2-Butene										C2-Butene									
i-Pentane										i-Pentane										i-Pentane									
n-Pentane										n-Pentane										n-Pentane									
Nitrogen										Nitrogen										Nitrogen									
TOTAL	41.168									TOTAL	41.168									TOTAL	41.168								
Av.vol. %										Av.vol. %										Av.vol. %									

GAS CALCULATIONS

Name	Mol.Weight	First Stage Product Gas (DTM-260)				Second Stage Product Gas (DTM-360)				Dissolved Gas (DTM-350)			
		Average Mol Weight:		16.59 (g/mole)		Average Mol Weight:		2.60 (g/mole)		Average Mol Weight:		17.37 (g/mole)	
		Volume		Weight (norm.)		Volume		Weight (norm.)		Volume		Weight (norm.)	
		meas. %	norm. %	(G)	%	meas. %	norm. %	(G)	%	meas. %	norm. %	(G)	%
Hydrogen	2.02	4.28	10.38	21.24	0.69	98.45	97.97	1299.07	76.02	47.23	52.27	2.50	6.08
CO ₂	44.01	13.03	31.65	1410.58	45.88	0.09	0.09	25.78	1.51	11.53	12.76	13.28	32.33
CO	28.01	23.81	57.84	1640.73	53.37	0.46	0.46	84.54	4.95	26.57	29.40	19.48	47.41
H ₂ S	34.08												
Methane	16.04	0.05	0.12	1.95	0.06	0.72	0.72	75.71	4.43	1.26	1.40	0.53	1.29
Ethylene	28.05					0.04	0.04	6.81	0.40	0.05	0.05	0.04	0.09
Ethane	30.07					0.29	0.29	56.38	3.30	0.82	0.91	0.65	1.58
Propane	44.01					0.22	0.22	63.68	3.73	0.89	0.98	1.03	2.50
Propylene	42.08												
i-Butane	58.12					0.01	0.01	2.02	0.12	0.00	0.00	0.01	0.01
n-Butane	58.12					0.09	0.09	35.69	2.09	0.55	0.61	0.84	2.04
i-Butene	56.11												
n-Butene	56.11												
C2-Butene	56.11												
i-Pentane	72.15												
n-Pentane	72.15					0.13	0.12	59.15	3.46	1.45	1.61	2.75	6.68
Nitrogen	28.02												
TOTAL		41.17	100.00	3074.48	100.00	100.49	100.00	1708.83	100.00	90.36	100.00	41.09	100.00

A-4

First Stage Shift Reaction

		CO	+	H ₂ O	=	CO ₂	+	H ₂
Stoichiometric	[moles]	27.81		27.81		27.81		27.81
Produced	[moles]					4.24		-17.30
Total	[moles]	27.81		27.81		32.05		10.52
Stoichiometric	[grams]	779.05		501.20		1224.07		56.18
Produced	[grams]					186.49		-34.94
Total	[grams]	779.05		501.20		1410.58		21.24

Hydrocarbon Gases

		First	Second	Dissolved	Total
C1 to C3	[grams]	1.95	202.57	2.24	206.77
C4 +	[grams]		96.87	3.59	100.46
Total	[grams]	1.95	299.44	5.83	307.22

Hydrogen

		First Up-Take	In	Second Out	Up-Take	Total Up-Take
Hydrogen	[grams]	34.94	1475.80	1301.57	174.23	209.17

M.B.No.: YP-05/C1

[illegible]

	Feed	V-220	Products V-340 (BTMS)	V-330
----- In grams of analysis sample -----				
Total Sample	50.30	14.70	52.27	62.69
Water	2.50	5.99		1.60
Oils+Asphaltenes	26.58	8.71	41.98	57.92
Oils	23.36	8.37	31.14	50.70
Asphaltenes	3.22	0.34	10.84	7.22
Pre-Asphaltenes			1.02	0.41
Insolubles	21.22		9.27	2.78
IOM	19.15		4.55	1.01
Ash	2.07		4.72	1.75
TOTAL	50.3	14.7	52.27	62.69
----- In wt% of analysis sample -----				
Water	4.97%	40.77%		2.55%
Oils+Asphaltenes	52.83%	59.23%	80.31%	92.39%
Oils (on fraction)	87.90%	86.12%	74.19%	87.53%
(on total)	46.44%	58.93%	59.58%	80.87%
Asphalt. (on fract.)	12.10%	3.88%	25.81%	12.47%
(on total)	6.39%	2.30%	20.73%	11.52%
Pre-Asphaltenes			1.85%	0.65%
Insolubles	42.20%		17.74%	4.41%
IOM (on fraction)	90.23%		49.09%	38.60%
(on total)	38.07%		8.71%	1.61%
Ash (on fraction)	9.78%		50.91%	63.40%
(on total)	4.12%		9.03%	2.79%
TOTAL	100.00%	100.00%	100.00%	100.00%
----- In grams of feed / product -----				
Total Feed / Product	7160	1553	1750	4110
Water	355.9	633.2		104.9
Oils+Asphaltenes	3782.9	920.0	1405.5	3797.1
Oils (on fraction)	3325.2	884.3	1042.7	3323.7
(on total)	3325.2	884.3	1042.7	3323.7
Asphalt. (on fract.)	457.7	35.7	362.8	473.4
(on total)	457.7	35.7	362.8	473.4
Pre-Asphaltenes			34.1	26.9
Insolubles	3021.2		310.4	181.1
IOM (on fraction)	2725.9		152.4	68.3
(on total)	2725.9		152.4	68.3
Ash (on fraction)	295.3		158.0	114.8
(on total)	295.3		158.0	114.8
TOTAL (as is)	7160.0	1553.2	1750.0	4110.0
TOTAL (MAF)	6508.8	920.0	1592.0	3890.3

Distillation Profile THF-Extract						D-1160		
Fractions deg C	Feed	Products				Feed	Product	
		V-220	V-340 (BTMS)	V-330	Total		Comp. Sample	
							as is	corr.
IBP - 182		45.54	23.03	19.88	88.48		88.14	88.14
182 - 343	151.32	503.13	92.14	1541.08	2138.34	68.09	1572.95	1572.95
343 - 524	3631.57	371.30	899.76	2263.05	3534.11	3173.84	3491.69	3491.69
524+			577.05	68.28	643.33	540.95	1627.19	1249.47
TOTAL	3782.89	919.97	1591.98	3890.29	6402.24	3782.89	6779.97	6402.24

Feed		Products (nomalized)				Feed		Products (nomalized)			
		V-220	V-340 (BTMS)	V-330	Total			V-220	V-340 (BTMS)	V-330	Total
----- In wt% of total feed (as is) -----						----- In wt% of total feed (MAF) -----					
4.69%	4.69%		1.38%	6.07%					1.52%	1.52%	
52.99%	12.12%	18.51%	50.02%	80.65%	58.12%	13.29%	20.31%	54.86%	88.46%		
48.58%	11.65%	13.74%	43.78%	69.17%	51.09%	12.78%	15.06%	48.02%	75.86%		
6.41%	0.47%	4.78%	6.24%	11.49%	7.03%	0.52%	5.24%	6.84%	12.60%		
		0.45%	0.35%	0.80%			0.49%	0.39%	0.88%		
42.32%		4.40%	2.61%	7.02%							
38.18%		2.01%	0.87%	2.88%	41.88%			0.96%	3.16%		
4.14%		2.40%	1.74%	4.14%							
100.00%	18.81%	23.37%	54.37%	94.54%		100.00%	13.29%	23.00%	57.72%	94.01%	

PROCESS YIELD STRUCTURE

RUN No.: DOE-BU-015 M.B. No.: YP-05/C1

FEED
wt% (coal+solvent)
as ls maf

PRODUCT
wt% (coal+solvent)
as ls maf

			COx+H2	19.9%	21.8%
			C1 - C4	0.0%	0.0%
53.0%	58.1%	Solvent			
47.0%	41.9%	Coal			
100.0%	100.0%				
			Oil	12.1%	13.3%
			Water	4.7%	
10.9%	12.0%	CO (shift)			
7.0%	7.7%	Water (shift)			
			COx	1.9%	2.1%
			C1 - C4	4.0%	4.4%
			Oil	50.4%	55.2%
			Water	1.4%	1.5%
2.4%	2.7%	Hydrogen (consumed)			
			Oil	19.0%	20.8%
			Coal (maf)	2.9%	3.2%
			Ash	4.1%	
120.4%	122.3%			120.4%	122.3%

Remarks:

ELEMENTAL BALANCE												
RUN No.: DOE-BU-015 M.B.No.: YP-05/C1												
COMPONENT (1)	Mass Balance (2)	CARBON		HYDROGEN		NITROGEN		SULPHUR		OXYGEN		ELEMENT BALANCE
		in (1)	in (2)	in (1)	in (2)	in (1)	in (2)	in (1)	in (2)	in (1)	in (2)	
FEED												
Coal	41.88%	75.70%	31.70%	5.60%	2.35%	1.03%	0.43%	0.43%	0.18%	17.24%	2%	
Solvent	58.12%	87.80%	51.03%	8.50%	4.94%	0.85%	0.49%	0.05%	0.03%	2.80%	3%	
CO	11.97%	42.90%	5.13%							57.10%	3%	
Water	7.70%			11.00%	0.85%					87.20%	1%	
Hydrogen	2.68%			100.00%	2.68%							
TOTAL FEED	122.35%		87.87%		10.81%		0.93%		0.21%		22.40%	122.21%
PRODUCT												
CO2	22.07%	27.30%	6.02%							72.70%	16.04%	
CO	1.50%	42.90%	0.64%							57.10%	0.86%	
H2S				5.90%				94.10%				
Water	1.52%			11.00%	0.17%					87.20%	1.32%	
Hydrogen	0.33%			100.00%	0.33%							
CH4	1.13%	75.00%	0.85%	25.00%	0.28%							
C2H6	0.92%	80.00%	0.74%	20.00%	0.18%							
C3H8	0.93%	81.80%	0.76%	18.20%	0.17%							
C4+	1.45%	83.00%	1.20%	17.00%	0.25%							
IBP - 182	1.27%	83.90%	1.07%	13.30%	0.17%	0.23%	0.00%	0.78%	0.01%	1.79%	0.02%	
182 - 343	22.73%	84.80%	19.27%	9.90%	2.25%	0.61%	0.14%	0.23%	0.05%	4.46%	1.01%	
343 - 524	50.45%	86.90%	43.84%	9.70%	4.89%	0.76%	0.38%	0.11%	0.06%	2.53%	1.28%	
524+	18.05%	84.40%	15.24%	7.30%	1.32%	1.05%	0.19%	0.13%	0.02%	7.12%	1.29%	
TOTAL PRODUCT	122.35%		89.64%		10.01%		0.71%		0.14%		21.82%	122.32%
COMPONENT BALANCE	100.00%		102.01%		92.58%		77.21%		67.49%		97.42%	100.09%

APPENDIX B
Material Balance Backup Data

**PROCESS YIELD STRUCTURE
CONSISTENCY CHECK**
(Basis: wt %)

WT % FEED (Coal + Solvent)				WT % PRODUCT (Coal + Solvent)		
AS IS	MAF			AS IS	MAF	
53.21%	58.10%	Solvent	Stg. 1	COx+H2	19.99%	21.83%
46.79%	41.90%	Coal		C1-C4	0.03%	0.03%
100.00%				Oil	12.17%	13.29%
				Water	3.84%	0.00%
10.96%	11.97%	CO Gas				
7.05%	7.70%	Water				
				COx	1.90%	2.07%
				C1-C5	4.03%	4.40%
				Oil	50.60%	55.25%
				Water	1.38%	1.51%
2.45%	2.68%	H2 (consumed)	Stg. 2			
				Oil Residue	19.05%	20.80%
				Coal (maf)	2.90%	3.17%
				Ash	4.59%	
120.47%	122.35%				120.47%	122.35%

Remarks:

PROCESS YIELD STRUCTURE
CONSISTENCY CHECK
 (Basis: Kg/h)

Kg/h FEED (Coal + Solvent)				Kg/h PRODUCT (Coal + Solvent)	
AS IS	MAF			AS IS	MAF
				COx+H2	346,682
				C1-C4	477
922,686	922,686	Solvent	Stg. 1	Oil	211,059
811,480	665,414	Coal		Water	66,541
1,734,167	1,588,100				
190,096	190,096	CO Gas			
122,262	122,262	Water			
				COx	32,874
				C1-C5	69,876
			Stg. 2	Oil	877,425
				Water	23,980
42,561	42,561	H2 (consumed)		Oil Residue	330,325
				Coal (maf)	50,321
				Ash	79,525
2,089,085	1,943,019			2,089,085	1,943,019

Remarks:

OVERALL MATERIAL BALANCE FOR STAGE 1 AND 2:

(MAFBAL12)

	First Stage	Second Stage	First Stage	Second Stage
	(MAF)	(MAF)	(AS IS)	(AS IS)
Material In:				
MAF Coal Rate Kg/h (MAF)	665,413.94			
MT/D (MAF)	15,969.93			
ROM Coal Rate Kg/h (as is)	611,480.42		611,480.42	
Slurry Oil Kg/h (MAF)	922,666.16		922,666.16	
Feed Slurry Kg/h (MAF)	1,588,100.10	1,342,240.59		
Feed Slurry Kg/h (as is)	1,734,166.58		1,734,166.58	1,421,765.41
CO Rate	596,872.55	17,044.77	596,872.55	17,044.77
CO ₂ Rate		84,532.30		84,532.30
H ₂ Rate	14,662.27	106,466.23	14,662.27	106,466.23
H ₂ S Rate		419.57		419.57
CH ₄ Rate	50,960.43	40,494.66	50,960.43	40,494.66
C ₂ Rate		13,037.95		13,037.95
C ₃ Rate		6,200.33		6,200.33
C ₄ Rate		1,017.57		1,017.57
C ₅ Rate		576.64		576.64
H ₂ O Rate	596,872.55		596,872.55	
Total (MAF) Kg/h (MAF)	2,651,487.91	1,612,632.62		
Total (as is) Kg/h (as is)	2,997,554.36		2,997,654.36	1,692,157.64
Material Consumed:				
CO Kg/h	190,095.56		190,095.56	
H ₂ O	122,262.09		122,262.09	
H ₂	6,517.30	42,561.08	6,517.30	42,561.08
Material Produced:				
H ₂ O Kg/h		23,980.31	66,541.39	23,980.31
CO ₂	341,519.11	32,673.67	341,519.11	32,673.67
H ₂ S				
H ₂	13,660.44		13,660.44	
CH ₄	476.43	17,412.41	476.69	17,412.41
C ₂		14,961.30		14,961.30
C ₃		14,596.09		14,596.09
C ₄		8,762.90		8,762.90
C ₅		14,141.70		14,141.70
Oil Product	211,056.50	677,425.31	211,056.50	677,425.31
Material Out:				
H ₂ Kg/h	19,645.41	63,905.16	19,645.41	63,905.16
CO	406,776.97	17,044.77	406,776.97	17,044.77
CO ₂	341,519.11	117,405.97	341,519.11	117,405.97
H ₂ S		419.57		419.57
H ₂ O	476,610.46	23,980.31	543,151.86	23,980.31
CH ₄	51,436.86	57,907.29	51,437.12	57,907.29
C ₂		27,999.25		27,999.25
C ₃		20,798.43		20,798.43
C ₄		10,380.47		10,380.47
C ₅		14,720.34		14,720.34
Oil	211,056.50	677,425.31	211,056.50	677,425.31
Total Dry Gas	821,576.35	330,561.23	821,576.61	330,561.23
Total Products	1,609,247.32	1,231,966.65	1,575,786.97	1,231,966.65
Total Bottoms	1,342,240.59	380,645.97	1,421,765.41	400,170.60
Oil Residue		330,324.62		330,324.62
Coal (MAF)	2,902	50,321.16		50,321.16
Ash (as is) (Calc)				79,524.62
Material In - Material Out				79,526.08
Actual Coal Ash Kg/h (as is)				
Ash % Error				-0.00%

COAL LIQUEFACTION CONDITIONS:

	First Stage	Second Stage	First Stage	Second Stage
	(MAF)	(MAF)	(AS IS)	(AS IS)
Conditions				
Pressure Mpa				
Temperature °C				
Catalyst				
Coal Feed Wt% coal	41.9000		47.0000	
CO Rate Kg/Kg coal	0.9000			
CO Used	0.2857		0.2343	
H ₂ O Rate	0.9000			
H ₂ O Used	0.1638		0.1507	
H ₂ Rate		0.1600		
H ₂ Used Wt% coal	1.2800	6.3962	1.0496	5.2449
Products:				
Oil Product Wt% Slurry	13.2900	55.2500	12.1706	50.5964
Oil Residue		20.8000		19.0460
Coal Residue Wt% Slurry (MAF)		3.1600		2.9017
Ash Wt% Slurry				4.6856
Water		1.5100	3.6371	1.3626
C ₁ - C ₅	0.0300	4.4000	0.0275	4.0294
CO _x + H ₂	21.6300		19.9913	
CO _x		2.0700		1.6956

COAL PROPERTIES

Composition	WT %
Organic Matter	82.00
Ash	9.60
Moisture	6.20
Total (as is)	100.00

COAL SULFUR & NITROGEN

Component	WT %
S (MF)	0.60
N (MF)	1.00

ROSE PROCESS YIELDS:

(ROSE)

COMPONENT	OIL FEED Kg/h	EXTRACT OIL Kg/h	RESIDUE Kg/h	EXTRACT TO COAL SLURRY Kg/h	FBC FEED Kg/h	SLURRY OIL EX STAGE 2 Kg/h	HYD FEED EX STAGE 1 Kg/h	HYD FEED EX STAGE 2 Kg/h	TOTAL OIL TO HTU Kg/h				
H2													
H2S													
NH3													
CO													
CO2													
H2O													
CH4													
C2													
C3													
C4													
C5													
OIL	330,324.82	227,924.13	102,400.69	227,924.13	102,400.69	694,762.03	211,056.50	182,663.27	393,721.78				
COAL (MAF)	50,321.15		50,321.15		50,321.15								
ASH	79,524.82		79,524.82		79,524.82								
Total	460,170.80	227,924.13	232,246.67	227,924.13	232,246.67	694,762.03	211,056.50	182,663.27	393,721.78				
MOL WT													
BPD													
API													
S.G.													

ROSE PROCESS - YIELDS AND PRODUCT PROPERTIES:

COMPONENT	WT %	VOL %	API	WT % S	PPM N2
RESIDUE	31.00	26.17	-7.40	8.70	6,600.00
OIL	69.00	71.83	10.70	3.60	2,200.00
Total	100.00	100.00			

C1 - C5 PRODUCT GAS FROM STAGE 2:

COMPONENT	MW	VOL %	NORM VOL %	NORM WT %	NORM VOL %	NORM WT %
C1	16.04	0.72	48.00	24.92		
C2	30.07	0.33	22.00	21.41	42.31	26.52
C3	44.01	0.22	14.67	20.69	28.21	27.62
C4	58.12	0.10	6.67	12.54	12.82	16.70
C5	72.15	0.13	8.67	20.24	16.67	26.96
TOTAL		1.50	100.00	100.00	100.00	100.00

CALCULATED COAL LIQUEFICATION PLANT CAPACITY:

C4+ SCO	Kg/h	406,482.59
% Of Coal (MAF)		61.38
API		40.44
S.G		0.8229
Lb/Bbl		268.16
BPD		75,000

COAL LIQUEFICATION PLANT CAPACITY REQUIREMENTS:

C4+ SCO	BPD	75,000
Coal Rate	Kg (MAF) / Bbl	212.93
	Kg (MAF) / Day	15,969,935
	MT (MAF) / Day	15,970
	MT (as is) / Day	19,476
Feed Slurry	MT (MAF) / Day	38,114.4
Slurry Oil	Kg/h (MAF)	922,686
Coal	Kg/h (MAF)	665,413.94
Feed Slurry	Kg/h (MAF)	1,588,100 1,588,100.10

STAGE 1 CO / H₂ FEED AND PRODUCT GAS:

(STAGE1)

COMPONENT	(ESTIMATED)				6				31				30
	CO/H ₂ GAS TO STAGE 1				CO/H ₂ GAS FROM STAGE 1				RECYCLE GAS FROM CO ₂ RECOVERY				CO ₂ GAS
	Kg/h	Mol/h	WT %	MOL %	Kg/h	Mol/h	WT %	MOL %	Kg/h	Mol/h	WT %	MOL %	Kg/h
H ₂	14,662.27	7,283.59	2.21	22.68	19,845.41	9,844.93	2.42	27.81	19,845.41	9,844.93	4.13	35.61	
H ₂ S													
NH ₃													
CO	598,872.55	21,380.38	90.12	67.15	408,778.97	14,593.78	49.78	41.22	408,778.97	14,593.78	85.15	52.79	
CO ₂					341,519.11	7,760.07	41.57	21.92					341,519.11
H ₂ O													
CH ₄	50,960.43	3,176.57	7.67	9.08	51,436.88	3,206.27	6.26	9.06	51,436.88	3,206.27	10.71	11.00	
C ₂													
C ₃													
C ₄													
C ₅													
C ₄ - 350 F													
350 - 650 F													
650 - 975 F													
Total	664,515.22	32,040.53	100.00	100.00	821,578.35	35,405.03	100.00	100.00	480,059.25	27,844.98	100.00	100.00	341,519.11
MOL. WT		20.74				23.21				17.37			44.01
Temp., °C		410.00											
Press., kPa (abs.)		10,000.00											
Density, Kg/m ³		38.52											

HYDROGEN RECOVERY FROM STAGE 1 MEMBRANE UNIT:

(STAGE1)

COMPONENT	32				33				34			
	CO/H2 RECYCLE PURGE				CO/H2 GAS TO H2 MEMBRANE				H2 GAS FROM H2 MEMBRANE			
	Kg/h	Mol/h	WT %	MOL %	Kg/h	Mol/h	WT %	MOL %	Kg/h	Mol/h	WT %	MOL %
H2	1,984.64	984.49	4.13	35.61	17,660.67	8,660.44	4.13	35.61	15,360.95	7,619.98	87.69	99.00
H2S												
NH3												
CO	40,877.70	1,459.38	65.15	62.79	367,699.27	13,134.36	65.15	62.79	2,155.95	78.97	12.31	1.00
CO2												
H2O												
CH4	5,143.69	320.63	10.71	11.60	48,293.18	2,665.64	10.71	11.60				
C2												
C3												
C4												
C5												
C4 - 380 F												
380 - 650 F												
650 - 975 F												
Total	48005.92	2784.50	100.00	100.00	432053.32	24880.48	100.00	100.00	17516.30	7666.95	100.00	100.00
MOL. WT		17.37				17.37				2.26		
Temp., °C												
Press., kPa (abs.)												
Density, Kg/m ³												

CO/H2 RECYCLE % PURGE:

10.000 %

H2 RECOVERY

99.00

MOL %

STAGE 1 CO BALANCE:

H2 PURITY

99.00

•

CH4

•

CO

1.00

•

Total

100.00

•

	Kg/h	MOL/h
CO RATE TO STAGE 1	598,872.63	21,380.36
CO FROM PSA #1 RECYCLE	365,743.32	13,057.41
REQ'D CO MAKE-UP	233,129.23	8,322.95

MAKE UP H2 BALANCE:

REQ'D H2 MAKE-UP	53,917.06	20,747.23
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MAKE UP H2/CO RATIO:

0.231 3.214

REFORMER H2/CO RATIO:

0.216 3.000

DIFFERENCE:

0.015 0.214

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STAGE 1 CO₂/H₂ GAS BALANCE:

COMPONENT	35				42				46 (CALCULATED)				STAGE 7
	CO/H2 RECYCLE TO STAGE 1				CO/H2 GAS FROM PSA #1				CO/H2 FEED GAS TO STAGE 1				(CALC - EST.)
	Kg/h	Mol/h	WT %	MOL %	Kg/h	Mol/h	WT %	MOL %	Kg/h	Mol/h	WT %	MOL %	MOL % DIFF.
H2	2,500.62	1,240.46	0.00	7.22	12,181.75	6,043.13	4.87	41.23	14,682.27	7,283.59	2.21	22.68	
H2S													
NH3													
CO	365,743.32	13,057.41	88.23	75.99	233,129.23	8,322.95	93.26	56.78	595,872.55	21,380.36	90.12	67.15	
CO2													
H2O													
CH4	45,293.18	2,685.64	11.17	16.79	4,667.26	290.93	1.87	1.06	50,960.44	3,176.57	7.67	9.98	
C2													
C3													
C4													
C5													
C4 - 360 F													
360 - 650 F													
650 - 975 F													
Total	414537.02	17183.51	100.00	100.00	249976.24	14657.02	100.00	100.00	664515.26	31640.53	100.00	100.00	
MOL. WT		24.12				17.06				20.87			
Temp., °C													
Press., kPa (abs.)													
Density, Kg/m³													

REFORMER BALANCE:

CO PRODUCED
CH₄ REQUIRED

26.47 Kg/mole CH₄ (CORATE)
 141,290.07 Kg/h
 6,807.18 Moles/h (CH₄ RATE)

HTU - MATERIAL BALANCE BASIS

(HTUBASIS)

OIL FEED	SP.GR	API	WT % COAL (MAF)	WT %	VOL %	Kg/h	WT % S	WT % N	S	N		
									Kg/h	Kg/h		
IBP - 360 F	0.7940	46.71	6.51	10.45	12.81	41,141.71	0.110	0.230	45.256	94.626		
360 - 650 F	0.9090	14.53	51.77	83.10	81.54	327,174.58	0.230	0.610	752.502	1995.765		
650 - 975 F	1.0320	5.61	4.02	6.45	5.95	25,405.48	0.760	0.760	198.163	193.062		
Total	0.9508	17.31	62.30	100.00	100.00	393,721.78	0.253	0.580	995.920	2263.473		

OIL PRODUCT	SP.GR	API	WT % YIELD	WT %	VOL %	% S CONV	% N CONV	WT % S	WT % N	S	N	
										Kg/h	Kg/h	
IBP - 360 F *	0.7487	57.49	97.12	10.49	11.85	95.00	90.00	0.006	0.024	2.263	0.463	
360 - 650 F	0.8590	33.42	96.75	83.08	81.94	85.00	80.00	0.036	0.126	112.875	399.153	
650 - 975 F	0.8700	30.03	96.39	6.43	6.21	70.00	65.00	0.243	0.278	59.449	67.579	
Total	0.8402	35.73	96.76	100.00	100.00					174.587	476.194	

LIQUID VOLUME (% OF FEED): 108.73
 % Feed Conversion To Light Ends Kg/h 4.65

BASIS: Oil Conversion to Light Products.

Comp.	WT %	Comp. Kg/h	H2 Kg/h
C1	24.85	4,745.29	1,192.51
C2	21.52	4,109.35	826.45
C3	20.65	5,601.82	1,035.29
C4	23.66	4,579.10	794.05
C5			
Total	100.00	19,095.51	3,648.30

Basis for Pure H2 to HTU:	Consumption	Quench	Solution Losses *
Pure H2 Rate SCFB	1,500.00	2,000.00	207.69
Oil Feed Rate BPD	62,569.24	62,569.24	62,569.24
Pure H2 Rate SCFH	3,910,577.72	5,214,103.62	541,470.70
" " Lb Mole/h	10,304.55	13,739.40	1,426.80
" " Lb/h	20,773.98	27,998.64	2,878.43
" " Kg/h	9,423.01	12,564.02	1,304.74
" " Kg/h/Bbl	3.61	4.82	0.50

* Based on 34.34 % H2 Recovery from P8A Unit #3.

BASIS: S and N2 Conversion.

	Total Kg/h	H2 Kg/h
S Converted	821.333	
H2S Produced	572.975	51.642
N Conversion	1807.278	
NH3 Produced	2197.425	390.147
H2 Used		441.789

BASIS: H2 Addition TO OIL

Oil Fraction	FEED Kg/h	C Loss Kg/h	H2 Added Kg/h	S Loss Kg/h	N Loss Kg/h	Product Kg/h	Product Wt %	Yield Wt %
IBP - 360 F *	41,141.71	1,593.25	536.36	42.993	65.163	39,956.07	10.49	97.12
360 - 650 F	327,174.58	12,070.11	4,265.35	639.626	1596.612	316,533.69	83.08	96.75
650 - 975 F	25,405.48	983.65	331.21	138.714	125.503	24,488.63	6.43	96.39
Total	393,721.78	15,247.21	5,132.93	821.333	1807.278	380,978.69	100.00	96.76

HTU - OVERALL MATERIAL BALANCE

COMPONENT	14			15			(Total)		(SW Draw)	(HTUBAL2)				
	HTU FEED			H2 QUENCH TO HTU			HTU PRODUCT		CHPS WATER	CHPS OIL	15 + 16 + 17			
	Kg/h	WT %	VOL %	Kg/h	WT %	VOL %	Kg/h	WT %	Kg/h	Kg/h	Kg/h	WT %	VOL %	
H2	63,905.15	8.54		12,564.02	19.48	77.88	67,048.16	8.25		1,932.96	65,113.19	19.48	77.88	
H2S	419.57	0.06		139.33	0.22	0.05	1,431.87	0.18		709.81	722.07	0.22	0.05	
NH3							2,197.43	0.27	2,197.43					
CO	17,044.77	2.28		4,076.25	6.32	1.82	21,120.01	2.60			21,120.01	6.32	1.82	
CO2	117,405.07	15.69		28,070.68	43.63	7.97	145,475.65	17.90			145,475.65	43.63	7.97	
H2O	23,980.31	3.20					23,980.31	2.95	23,980.31					
CH4	67,907.29	7.74		12,522.77	19.42	0.75	75,175.29	9.25		10,275.68	64,899.40	19.42	0.75	
C2	27,999.25	3.74		4,329.52	6.71	1.80	36,438.12	4.48		14,000.34	22,437.78	6.71	1.80	
C3	20,798.43	2.78		2,056.95	3.19	0.58	28,519.19	3.51		17,648.67	10,670.52	3.19	0.58	
C4	10,380.47	1.39		537.15	0.83	0.12	15,496.72	1.91		12,712.94	2,783.77	0.83	0.12	
C5	14,720.34	1.97		192.15	0.30	0.03	14,912.49	1.83		13,916.68	995.81	0.30	0.03	
IBP - 360 F	41,141.71	5.50	12.61				39,956.67	4.92		39,956.67				
360 - 650 F	327,174.58	43.72	81.54				316,533.59	38.94		316,533.59				
650 - 975 F	25,405.46	3.40	5.95				24,488.63	3.01		24,488.63				
Total	748,283.32	100.00	100.00	64,489.80	100.00	100.00	612,773.12	100.00	28,177.74	452,376.17	334,219.21	100.00	100.00	
MOL WT				8.06										
BPD														
API														
S.G.														

HTU - OVERALL MATERIAL BALANCE

	15				18	53	20							
	H2 QUENCH FROM CHPS			CLPS LIQ	CLPS VAP	C4 - TO GRU	C5+ SCO							
COMPONENT	Kg/h	WT %	VOL %	Kg/h	Kg/h	Kg/h	Kg/h							
H2	12,564.02	19.48	77.88	103.28	1,829.68	103.28								
H2S	139.33	0.22	0.06		709.81									
NH3														
CO	4,076.25	6.32	1.82											
CO2	28,070.68	43.63	7.97											
H2O														
CH4	12,522.77	19.42	0.75	2,781.18	7,494.70	2,781.18								
C2	4,329.52	6.71	1.80	8,773.26	5,227.09	8,773.26								
C3	2,056.95	3.19	0.58	15,073.95	2,774.72	15,073.95								
C4	537.15	0.83	0.12	12,027.27	685.68	12,027.27								
C5	192.15	0.30	0.03	13,671.68	245.12		13,671.68							
IBP - 360 F				39,956.67			39,956.67							
360 - 650 F				316,533.59			316,533.59							
650 - 975 F				24,488.63			24,488.63							
Total	64,489.80	100.00	100.00	433,409.97	18,968.80	38,758.93	394,650.44							
MOL WT	8.06					38.39								
BPD							71,308							
API							37.70							
S.G.							0.8363							

0.00

HTU - OVERALL MATERIAL BALANCE (CONT'D)

COMPONENT	16 + 17				17	18	18				8		
	CHPS H2 RECYCLE TO HTU				PURGE GAS	REG. GAS	STAGE 2 H2 MAKEUP				H2 FEED TO STAGE 2		
	Kg/h	Mol/h	WT %	MOL %	Kg/h	Kg/h	Kg/h	Mol/h	WT %	MOL %	Kg/h	WT %	MOL %
H2	52,549.17	26,068.64	19.48	77.88	14,713.77	37,835.40	68,630.83	34,046.45	90.06	99.00	106,468.23	39.37	90.30
H2S	582.74	17.10	0.22	0.05	163.17	419.57					419.57	0.16	0.02
NH3													
CO	17,044.77	606.52	0.32	1.82	4,772.53	12,272.23	4,772.53	170.38	6.20	0.50	17,044.77	6.30	1.04
CO2	117,405.97	2,667.72	43.53	7.97	32,873.67	84,532.30					84,532.30	31.26	3.28
H2O													
CH4	52,376.64	3,264.65	19.42	9.75	14,665.46	37,711.18	2,783.70	173.52	3.65	0.50	40,494.68	14.98	4.32
C2	18,108.26	602.22	6.71	1.80	5,070.31	13,037.95					13,037.95	4.82	0.74
C3	8,611.57	195.29	3.19	0.58	2,411.24	6,200.33					6,200.33	2.29	0.24
C4	2,248.63	38.65	0.89	0.12	629.06	1,617.57					1,617.57	0.60	0.05
C5	803.66	11.14	0.30	0.03	225.03	578.64					578.64	0.21	0.01
C4 - 360 F													
360 - 650 F													
650 - 975 F													
Total	299,729.41	33,474.13	100.00	100.00	75,524.23	164,205.17	76,167.06	34,390.35	100.00	100.00	270,392.23	100.00	100.00
MOL. WT		8.06				8.06		8.06		2.22			4.62
Temp., °C													440.00
Press., kPa (abs.)													17,000.00
Density, Kg/m ³													13.25

Pure H2 Balance:

	Kg/h
H2 Produced in Stage 1	5,163.14
H2 Consumed in Stage 2	42,501.08
H2 Consumed in the HTU	9,423.01
H2 Solution Loss in the CHPS	1,032.06
Total Consumption	53,917.06
Recycle H2 Make up	14,713.77
Total	68,630.83

Pure H2 Recovery Balance:

	Kg/h	Mol/h	% H2 Recovery
H2 Recycle Purge	14,713.77	7,299.22	
H2 from Membrane	15,360.35	7,619.08	66.000
H2 from PSA #1	38,575.55	19,136.59	78.000
H2 from PSA #2	12,000.72	6,205.62	78.000
H2 from PSA #3	2,004.23	994.26	34.335
Total H2 Recovered	68,630.64	34,046.46	
Total Stage 2 Make up	68,630.83	34,046.45	
Net H2 Production	0.02	0.01	

Stage 2 H2 Recycle Mol % Purge: 20.00 ; 90.90 Mol % H2 TO STAGE 2

% PURGE	CHPS H2	H2 RECYCLE	H2 PURGE	REG. H2	MAKE UP H2*	H2 TO STG 2	SELECTION BASIS FOR H2 TO STG 2	
%	Mol/h	Mol/h	Mol/h	MOL %	MOL %	MOL %	(MOL % > = 92 %)	(RHPURGE)
	26068.64	26,068.64		77.88	26,747.23	99.00	87.31	
2.00		25,547.27	521.37		27,268.60		87.52	2.00
4.00		25,025.90	1,042.76		27,789.97		87.73	4.00
6.00		24,504.53	1,564.12		28,311.34		87.93	6.00
8.00		23,983.15	2,085.49		28,832.72		88.14	8.00
10.00		23,461.78	2,606.86		29,354.09		88.35	10.00
12.00		22,940.41	3,128.24		29,875.46		88.57	12.00
14.00		22,419.03	3,649.61		30,396.84		88.78	14.00
16.00		21,897.66	4,170.98		30,918.21		88.99	16.00
18.00		21,376.29	4,692.36		31,439.58		89.21	18.00
20.00		20,854.92	5,213.73		31,960.95		89.42	20.00
22.00		20,333.54	5,735.10		32,482.33		89.64	22.00
24.00		19,812.17	6,256.47		33,003.70		89.86	24.00
26.00		19,290.80	6,777.85		33,525.07		90.08	26.00
28.00		18,769.42	7,299.22		34,046.45		90.30	28.00
30.00		18,248.05	7,820.59		34,567.82		90.52	30.00
32.00		17,726.68	8,341.97		35,089.19		90.74	32.00
34.00		17,205.31	8,863.34		35,610.57		90.96	34.00
36.00		16,683.93	9,384.71		36,131.94		91.19	36.00
38.00		16,162.56	9,906.08		36,653.31		91.41	38.00

* Total of Purge and Chemical Consumption.

STEAM REFORMER:

(REFORMER)

COMPONENT	37 STEAM REFORMER FEED				39 STEAM REFORMER PRODUCT				38 CO2 GAS	40 DRY REFORMER PRODUCT TO PSA #1			
	Kg/h	Mol/h	WT %	MOL %	Kg/h	Mol/h	WT %	MOL %	Kg/h	Kg/h	Mol/h	WT %	MOL %
H2					50,757.30	25,179.73	7.81	50.45		50,757.30	25,179.73	17.35	74.09
H2S													
NH3													
CO					235,098.09	8,393.24	36.18	18.82		235,098.09	8,393.24	50.38	24.70
CO2	119,381.49	2,712.61	18.37	8.19	119,381.49	2,712.61	18.37	5.43	119,381.49				
H2O	389,200.62	21,604.01	59.89	65.22	237,994.67	13,210.77	36.62	26.47					
CH4	141,290.07	8,807.18	21.74	26.59	6,640.63	413.94	1.02	0.83		6,640.63	413.94	2.27	1.22
C2													
C3													
C4													
C5													
C4 - 360 F													
360 - 650 F													
650 - 975 F													
Total	649,872.19	33,123.81	100.00	100.00	649,872.19	49,910.29	100.00	100.00		202,496.02	33,968.91	100.00	100.00
MOL. WT		19.62				13.02					8.61		
BPD													
API													
S.G.													

FEED COMPOSITION:
(Moles / Mole CH4 Feed)

	Mol/Mol	Mol/h	Mol %	WT %	(CH4 FEED)
CH4	1.00	8,807.18	26.59	21.74	
H2O	2.453	21,604.01	65.22	59.89	
CO2	0.308	2,712.61	8.19	18.37	
Total:	3.76	33,123.81	100.00	100.00	
Mol. WL			19.62		

STOICHIOMETRY:

CH4 + H2O <----> CO + 3H2
CO + H2O <----> CO2 + H2

PRODUCT COMPOSITION:
(Moles / Mole CH4 Feed)

COMP.	Mol/Mol	Mol %	WT %	Mol/h	Kg/h
H2	2.859	50.45	7.81	25,179.73	50,757.30
H2O	1.500	26.47	36.62	13,210.77	237,994.67
CH4	0.047	0.83	1.02	413.94	6,640.63
CO	0.953	18.82	36.18	8,393.24	235,098.09
CO2 (Fixed)	0.308	5.43	18.37	2,712.61	119,381.49
Total	5.667	100.000	100.000	49,910.291	649,872.189
Mol. WL		13.0208			13.0208

FUEL GAS / FEED GAS RATIO: 0.6036 (Based on ambient Combustion Air)

PSA UNIT #1 BALANCE:

COMPONENT	40 DRY REFORMER PRODUCT TO PSA #1				41 H2 GAS FROM PSA #1				42 CO/H2 GAS FROM PSA #1				(PSA1)
	Kg/h	Mol/h	WT %	MOL %	Kg/h	Mol/h	WT %	MOL %	Kg/h	Mol/h	WT %	MOL %	
H2	50,757.30	25,179.73	17.35	74.09	35,575.55	19,136.59	90.73	99.00	12,181.75	6,043.13	4.87	41.23	
H2S													
NH3													
CO	235,098.09	8,393.24	80.38	24.70	1,968.87	70.29	4.63	0.36	233,129.23	8,322.95	93.26	56.78	
CO2													
H2O													
CH4	6,640.63	413.94	2.27	1.22	1,973.37	123.01	4.64	0.64	4,667.26	290.93	1.87	1.98	
C2													
C3													
C4													
C5													
C4 - 300 F													
300 - 650 F													
650 - 975 F													
Total	292496.02	33986.91	100.00	100.00	42517.79	19329.89	100.00	100.00	249978.24	14657.02	100.00	100.00	
MOL WT		8.61				2.20				17.06			
BPD													
API													
S.G.													

PSA UNIT SPECIFICATIONS:

H2 RECOVERY	76.00	MOL %
H2 PURITY	99.00	.
CH4	0.64	.
CO	0.36	.
Total	100.00	.

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PSA UNIT #2 BALANCE: (H2 RECYCLE PURGE GAS & CO/H2 RECYCLE PURGE)

	32 + 17				43				44				PSA2
COMPONENT	PURGE GAS TO PSA #2				H2 GAS FROM PSA #2				PSA #2 PURGE GAS TO PSA #3				
	Kg/h	Mol/h	WT %	MOL %	Kg/h	Mol/h	WT %	MOL %	Kg/h	Mol/h	WT %	MOL %	
H2	18,698.31	8,283.71	13.52	68.25	12,690.72	6,295.62	90.73	99.00	4,007.59	1,988.00	3.66	34.41	
H2S	163.17	4.79	0.13	0.04					163.17	4.79	0.15	0.08	
NH3													
CO	45,650.23	1,629.78	36.95	13.43	647.72	23.12	4.63	0.36	45,002.61	1,606.64	41.08	27.81	
CO2	32,873.67	748.98	26.81	6.18					32,873.67	748.98	30.01	12.93	
H2O													
CH4	19,809.14	1,234.78	16.04	10.17	649.21	40.47	4.64	0.64	19,159.94	1,194.32	17.49	20.67	
C2	5,070.31	168.62	4.10	1.39					5,070.31	168.62	4.63	2.92	
C3	2,411.24	64.68	1.95	0.45					2,411.24	64.68	2.20	0.95	
C4	629.06	10.82	0.51	0.09					629.06	10.82	0.57	0.19	
C5	225.03	3.12	0.18	0.03					225.03	3.12	0.21	0.05	
C4 - 360 F													
360 - 650 F													
650 - 975 F													
Total	123530.16	12197.26	100.00	100.00	13987.65	6359.21	100.00	100.00	109542.61	5778.04	100.00	100.00	
MOL WT		10.18				2.20				18.98			
BPD													
API													
B.G.													

PSA UNIT SPECIFICATIONS:

H2 RECOVERY	78.00	MOL %
H2 PURITY	99.00	"
CH4	0.64	"
CO	0.36	"
Total	100.00	"

PSA UNIT #3 BALANCE:

(PSA #2 PURGE GAS & HTU C4- GAS)

(PSA3)

COMPONENT	44 + 19				45				46			
	PSA #2 PURGE & C4- GAS TO PSA #3				H2 GAS FROM PSA #3				PURGE GAS TO H2S ABSORBER			
	Kg/h	Mol/h	WT %	MOL %	Kg/h	Mol/h	WT %	MOL %	Kg/h	Mol/h	WT %	MOL %
H2	5,837.28	2,895.76	4.54	39.00	2,004.23	994.26	92.56	99.00	3,833.05	1,901.50	3.03	29.61
H2S	872.98	25.62	0.68	0.35					872.98	25.62	0.69	0.40
NH3												
CO	45,002.51	1,606.64	35.02	21.64					45,002.51	1,606.64	35.62	25.02
CO2	32,873.67	748.96	26.58	10.66					32,873.67	748.96	26.02	11.63
H2O												
CH4	26,654.64	1,661.49	20.74	22.37	161.12	10.04	7.44	1.00	26,493.52	1,651.45	20.97	25.72
C2	10,297.40	342.45	8.01	4.61					10,297.40	342.45	8.15	5.33
C3	5,185.96	117.61	4.04	1.58					5,185.96	117.61	4.10	1.83
C4	1,314.73	22.62	1.02	0.30					1,314.73	22.62	1.04	0.35
C5	470.15	6.52	0.37	0.09					470.15	6.52	0.37	0.10
C4 - 360 F												
360 - 650 F												
650 - 975 F												
Total	128509.31	7425.67	100.00	100.00	2165.35	1004.30	100.00	100.00	128343.96	6421.36	100.00	100.00
MOL WT		17.31				2.18				19.68		
BPD												
API												
S.G.												

PSA UNIT SPECIFICATIONS:

H2 RECOVERY	54.34	MOL %
H2 PURITY	99.00	"
CH4	1.00	"
CO		"
Total	100.00	"

TOTAL FEED TO GAS RECOVERY UNIT:

(GRUFEED)

COMPONENT	48				53				48 + 53			
	LEAN GAS FROM H2S ABSORBER				C4 - LIQ FROM THE HTU				TOTAL FEED TO GAS RECOVERY UNIT			
	Kg/h	Mol/h	WT %	MOL %	Kg/h	Mol/h	WT %	MOL %	Kg/h	Mol/h	WT %	MOL %
H2	3,833.05	1,901.50	3.05	29.73	103.28	51.23	0.27	4.61	3,936.33	1,952.74	2.40	26.17
H2S												
NH3												
CO	45,002.51	1,606.64	35.87	25.12					45,002.51	1,606.64	27.40	21.53
CO2	32,873.67	748.96	26.20	11.68					32,873.67	748.96	20.02	10.01
H2O												
CH4	26,493.52	1,651.45	21.12	25.62	2,781.18	173.36	7.16	16.28	29,274.70	1,824.81	17.83	24.46
C2	10,297.40	342.45	8.21	5.35	8,773.26	291.77	22.64	27.39	19,070.66	634.22	11.61	6.50
C3	5,185.96	117.61	4.13	1.84	15,073.95	341.84	38.69	32.09	20,259.91	459.45	12.34	6.18
C4	1,314.73	22.62	1.05	0.35	12,027.27	206.93	31.03	19.43	13,342.00	229.55	8.12	3.06
C5	470.15	6.52	0.37	0.10					470.15	6.52	0.29	0.09
C4 - 360 F												
360 - 650 F												
650 - 975 F												
Total	125,470.99	6,395.74	100.00	100.00	38,758.93	1,065.13	100.00	100.00	164,229.92	7,460.88	100.00	100.00
MOL WT												
BPD												
API												
S.G.												

PRODUCTS FROM GAS RECOVERY UNIT:

COMPONENT	FUEL GAS		PROPANE PRODUCT		C4 PRODUCT TO SCO		MOL %
	Kg/h	WT %	Kg/h	WT %	Mol/h	WT %	
H2	3,936.33	1,952.74					
NH3							
CO	45,002.51	34.58					
CO2	32,873.87	25.28					
H2O							
CH4	29,274.70	22.49					
C2	19,070.88	14.65					
C3	634.22						
C4			20,259.91	459.45	13,342.00	229.65	97.24
C5					470.16	0.62	2.76
C4 - 360 F							
360 - 650 F							
650 - 975 F							
Total	130,167.87	9,765.37	20,259.91	459.45	13,812.16	230.06	100.00
MOL WT							
BPD							
API							
S.G.							

SYNTHETIC CRUDE OIL (SCO) PRODUCT:

TOTAL		TOTAL	
C4 + SCO	Kg/h	C8 + SCO	Kg/h
COMPONENT			
H2			
NH3			
CO			
CO2			
H2O			
CH4			
C2			
C3			
C4			
C5			
C4 - 360 F	13,671.66		
360 - 650 F	30,856.07		
650 - 975 F	316,533.59		
Total	394,650.44		
MOL WT			
BPD	75,000		
API	37.70		
S.G.	0.836		

H2 RECOVERY FROM P&A AND MEMBRANE UNITS:

COMPONENT	TOTAL H2 GAS RECOVERY				(H2REC)							
	Kg/h	Mol/h	WT %	MOL %								
H2	68,630.84	34,046.46	90.08	99.00								
H2S												
NH3												
CO	4,772.54	170.38	6.28	0.50								
CO2												
H2O												
CH4	2,783.70	173.52	3.65	0.50								
C2												
C3												
C4												
C5												
C4 - 300 F												
300 - 650 F												
650 - 976 F												
Total	78187.08	34390.36	100.00	100.00								
MOL WT		2.22										
BPD												
API												
B.G.												

FBC MATERIAL BALANCE

TOTAL INPUT:		
ASH	Kg/h	79,525
UNCONVERTED COAL	Kg/h	50,321
OIL	Kg/h	102,401
ASH CONCENTRATE	Kg/h	232,247
LIMESTONE	Kg/h	34,370
AIR	Kg/h	2,811,417
N.G.	MMbtu/h	1,458
TOTAL	Kg/h	3,078,033
TOTAL OUTPUT:		
FLUE GAS	Kg/h	2,953,094
ASH	Kg/h	125,129.96
TOTAL		3,078,224
MATERIAL IN - MATERIAL OUT		

FBC - UTILITIES CONSUMPTION:

UTILITY	UNITS	FLUIDIZED BED COMBUST.	STEAM & POWER GENER.	STEAM TURBINE GENER.
FUEL GAS	MMbtu/h	1,458		
POWER	KW	29,970		(304,344)
STEAM	600/2620 psig	(3,669,931)	(125,009)	3,669,931
	600 psig			
	150 psig			
	50 psig		(485,143)	
COND/BFW	lb/h	3,669,931	(1,353,190)	(4,140,726)
COOLING WATER	us gpm			282,264
WASTEWATER	us gpm	(154)	(537)	
MAKEUP WATER	us gpm	(154)	(5,006)	(542)

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APPENDIX C
Financial Analysis Data

COAL LIQUEFACTION PLANT CASH FLOW CALCULATIONS.

Page 1

Case Description: Base Case

75,000 BPD C4+ SCO

25.00 % Equity Financing

Input for Project Taxation Structure:

Revenue Sensitivity Factor	1.00
Operating Cost Sensitivity Factor	1.00
Capital Cost Sensitivity Factor	1.00
Feedstock Sensitivity Factor	1.00
Inflation Sensitivity Factor	1.03
Price Escalation Sensitivity Factor (Product)	1.00
Operation Escalation Sensitivity Factor	1.00
Equity Ratio (%)	25.00
Bank Interest Rate (%)	8.00
State Income Tax (%)	
Investment Tax Credit (%)	

Revenue and Costs:

Revenue / Costs Description	Major (1,000 \$)	Minor (1,000 \$)	Total (1,000 \$)
Revenue from Products	719,854	78,585	798,439
Feedstock Costs	166,976		166,976
Other Operating Costs			217,470

SCO Price at 15.00 % ROE:

After Tax DCF ROE, %:	15.00
SCO PRICE, \$/BBL	29.75

Project Schedule and Sensitivity Factors:

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Project Facilities Schedule		0.10	0.20	0.35	0.35					
Building & Services Schedule			0.30	0.40	0.30					
Indirect Schedule	0.10	0.20	0.30	0.25	0.15					
Contingencies Schedule		0.10	0.20	0.35	0.35					
Working Capital Schedule						1.00				
Production Schedule						1.00	1.00	1.00	1.00	1.00
Feed Schedule						1.00	1.00	1.00	1.00	1.00
Inflation Sensitivity Factor	1.030	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00
Price Escalat. Sensit. (Product)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Operation Escal. Sensit. Factor	1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Capital Cost:

Basis	(1,000 \$)
Process Facilities Capital Cost *	1,504,278
Building & Services Capital Cost	516,936
Indirects Capital Cost	387,295
Contingencies	68,346
Total	2,476,856

* Including initial catalyst and chemical costs.

Working Capital:

Basis	(1,000 \$)
Working Capital (@ 10 % of Rev.)	79,844

Case Description: Base Case

Construction Period, years			5
Operating Period, years			25
Equity Financing, %			25

Cash Flow Summary:

Basis	(1,000 \$)
Revenue	23,140,200
Working Capital Recovery	92,600
Sub - Total (Revenue plus Working Capital Recovery)	23,232,800
Operating Costs	11,141,900
Net Federal Income Tax	2,347,700
State Income Tax	
Interest Paid From Revenue	2,438,000
Debt Repayments	2,469,100
Capital Cost From Revenue	
Equity Capital Cost	693,900
Equity Working Capital/Inflation Cost	23,100
Sub - Total (Total Costs, Interests and Taxes)	19,113,700
Net Cash Flow	4,119,100

Capital Cost, Payback and SCO Price:

Total Capital Cost, 1,000 \$	3,186,100
Before Tax DCF % ROE	17.7
After Tax DCF % ROE	15.0
Payback Period, years	6.8
SCO PRICE, \$/BBL	29.75

COAL LIQUEFACTION PLANT CASH FLOW CALCULATIONS

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Case Description: Base Case

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CASH FLOW:																
+ Revenue						925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610
+ Working Capital Recovery																
- Operating Costs						445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678
- Net Federal Income Tax														9,721	113,601	119,958
- State Income Tax																
- Interest Paid From Revenue						265,236	271,600	253,493	235,385	217,280	199,173	181,066	162,960	144,853	126,747	108,640
- Debt Repayments							164,606	164,606	164,606	164,606	164,606	164,606	164,606	164,606	164,606	164,606
- Capital Cost From Revenue																
- Equity Capital Cost	9,973	62,254	100,028	240,301	221,304											
- Working Capital/Inflation						23,140										
= CASH FLOW - Current	(9,973)	(62,254)	(100,028)	(240,301)	(221,304)	101,555	43,726	61,833	79,940	98,046	116,153	134,259	152,366	170,473	188,579	206,686
- Accumulated	(9,973)	(72,227)	(232,255)	(472,556)	(693,860)	(502,304)	(458,578)	(396,745)	(318,806)	(218,759)	(102,607)	31,653	184,019	344,770	419,548	606,277
Cash Flow - Current Before Tax	(9,973)	(62,254)	(100,028)	(240,301)	(221,304)	101,555	43,726	61,833	79,940	98,046	116,153	134,259	152,366	170,473	188,579	206,686

CAPITAL EXPENDITURE:

Process Facilities		150,426	300,856	526,497	526,497											
Buildings + Service			155,061	206,774	155,061											
Indirects	38,730	77,459	116,189	96,624	58,094											
Contingency		6,635	13,669	23,921	23,921											
Working Capital						79,644										
Total Capital Costs	38,730	234,721	565,794	854,017	763,594	79,644										
Inflation	1,162	14,295	54,319	107,187	121,621	12,717										
Interest during constn	549	6,775	33,442	94,345	182,977											
Capitalized Costs																
= TOTAL CAPITAL - Current	40,440	255,791	673,555	1,055,548	1,068,192	92,561										
- Accumulated	40,440	296,231	969,787	2,025,335	3,093,527	3,186,068	3,186,068	3,186,068	3,186,068	3,186,068	3,186,068	3,186,068	3,186,068	3,186,068	3,186,068	3,186,068

OPERATING COST:

Feedstock						166,976	166,976	166,976	166,976	166,976	166,976	166,976	166,976	166,976	166,976	166,976
Other Costs						217,470	217,470	217,470	217,470	217,470	217,470	217,470	217,470	217,470	217,470	217,470
Inflation						61,232	61,232	61,232	61,232	61,232	61,232	61,232	61,232	61,232	61,232	61,232
Total Operating Costs						445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678

Case Description: Base Case

YEAR	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	TOTAL
+ Revenue	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	23,140,230
+ Working Capital Recovery														92,561	92,561
-- Operating Costs	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	11,141,945
-- Net Federal Income Tax	126,114	132,270	138,426	144,583	150,739	156,895	156,895	156,895	156,895	156,895	156,895	156,895	156,895	156,895	2,347,670
-- State Income Tax															
-- Interest Paid From Revenue	90,533	72,427	54,320	36,213	18,107										2,438,033
-- Debt Repayments	164,606	164,606	164,606	164,606	164,606										2,469,088
-- Capital Cost From Revenue															
-- Equity Capital Cost															693,860
-- Working Capital/Inflation															23,140
= CASH FLOW -- Current	98,679	110,629	122,580	134,530	146,480	323,037	323,037	323,037	323,037	323,037	323,037	323,037	323,037	415,507	4,119,064
-- Accumulated	604,956	715,585	838,164	972,694	1,119,174	1,442,211	1,765,247	2,088,284	2,411,320	2,734,357	3,057,393	3,380,430	3,703,467	4,119,064	
Cash Flow -- Current Before Tax	224,793	242,899	261,006	279,113	297,219	479,932	479,932	479,932	479,932	479,932	479,932	479,932	479,932	572,493	6,466,734
CAPITAL EXPENDITURE:															
Process Facilities															1,504,278
Buildings + Service															516,930
Indirects															387,295
Contingency															68,346
Working Capital															79,844
Total Capital Costs															2,556,700
Inflation															311,300
Interest during constn															318,088
Capitalized Costs															
= TOTAL CAPITAL -- Current															3,186,088
-- Accumulated	3,186,088	3,186,088	3,186,088	3,186,088	3,186,088	3,186,088	3,186,088	3,186,088	3,186,088	3,186,088	3,186,088	3,186,088	3,186,088	3,186,088	
OPERATING COST:															
Feedstock	166,976	166,976	166,976	166,976	166,976	166,976	166,976	166,976	166,976	166,976	166,976	166,976	166,976	166,976	4,174,388
Other Costs	217,470	217,470	217,470	217,470	217,470	217,470	217,470	217,470	217,470	217,470	217,470	217,470	217,470	217,470	5,436,752
Inflation	61,232	61,232	61,232	61,232	61,232	61,232	61,232	61,232	61,232	61,232	61,232	61,232	61,232	61,232	1,530,805
Total Operating Costs	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	11,141,945

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COAL LIQUEFACTION PLANT TAX CALCULATIONS.

Case Description: Base Case															
YEAR	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	TOTAL
FEDERAL INCOME TAX:															
+ Revenue	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	925,610	23,140,239
- Operating Costs	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	445,678	11,141,945
- Interest	90,533	72,427	54,320	36,213	18,107										2,438,033
- Loss Carry Forwards															5,019,807
- Class 3	18,475	18,475	18,475	18,475	18,475	18,475	18,475	18,475	18,475	18,475	18,475	18,475	18,475	18,475	461,880
- Class 29															2,193,470
= Taxable Income	370,923	389,030	407,137	425,243	443,350	461,457	461,457	461,457	461,457	461,457	461,457	461,457	461,457	461,457	1,885,103
Income Tax @ 34%* (1 - State Tax)	126,114	132,270	138,426	144,583	150,739	156,895	156,895	156,895	156,895	156,895	156,895	156,895	156,895	156,895	2,347,670
- Investment Tax Credit															
= Net Federal Income Tax	126,114	132,270	138,426	144,583	150,739	156,895	156,895	156,895	156,895	156,895	156,895	156,895	156,895	156,895	2,347,670
STATE INCOME TAX:															
Federal Taxable Income	370,923	389,030	407,137	425,243	443,350	461,457	461,457	461,457	461,457	461,457	461,457	461,457	461,457	461,457	1,885,103
Income Tax															
CAPITAL COST ALLOWANCE:															
Class 3															581,909
Class 29															2,193,470
No Allowance															92,561
Total															2,867,939
Class 3	378,742	360,266	341,791	323,316	304,841	286,366	267,890	249,415	230,940	212,465	193,990	175,514	157,039	138,564	
Class 29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

COAL LIQUEFACTION PLANT CASH FLOW CALCULATIONS

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Case Description: Base Case

LOSS POOL

INVESTMENT TAX POOL

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
INTEREST BORROWED:																
+ Capital Expenditure	39,891	249,016	640,113	961,203	883,214											
+ Working Capital						92,561										
+ Interest	549	3,424	8,602	13,217	12,172	1,273										
- Capital From Revenue						23,140										
- Capital From Equity	9,973	62,254	160,028	240,301	221,304											
= Capital Borrowed - Government																
- Private	29,919	186,762	480,065	720,903	663,911	69,421										
Interest Borrowed	549	3,424	8,602	13,217	12,172	1,273										
INTEREST COSTS:																
+ Interest From Year Start		3,351	24,640	81,128	170,606	263,963	271,600	253,493	235,366	217,280	199,173	181,066	162,960	144,853	126,747	108,640
+ Interest During Year	549	3,424	8,602	13,217	12,172	1,273										
- Interest From Revenue						265,236	271,600	253,493	235,366	217,280	199,173	181,066	162,960	144,853	126,747	108,640
= Total Interest Borrowed	549	6,775	33,442	94,345	182,977											
+ Debt at Year Start		30,467	224,004	737,631	1,552,779	2,399,667	2,469,066	2,304,482	2,139,676	1,975,270	1,810,664	1,646,059	1,481,453	1,316,847	1,152,241	987,635
+ Capital Borrowed	29,919	186,762	480,065	720,903	663,911	69,421										
+ Total Interest Borrowed	549	6,775	33,442	94,345	182,977											
- Debt Repayment - Government																
- Private							164,606	164,606	164,606	164,606	164,606	164,606	164,606	164,606	164,606	164,606
- Debt at Year End	30,467	224,004	737,631	1,552,779	2,399,667	2,469,066	2,304,482	2,139,676	1,975,270	1,810,664	1,646,059	1,481,453	1,316,847	1,152,241	987,635	823,029

Case Description: Base Case

LOSS POOL

INVESTMENT TAX POOL

YEAR	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	TOTAL
INTEREST BORROWED:															
+ Capital Expenditure															2,775,438
+ Working Capital															92,561
+ Interest															39,435
- Capital From Revenue															23,140
- Capital From Equity															693,860
= Capital Borrowed - Government															
- Private															2,151,000
Interest Borrowed															39,435
INTEREST COSTS:															
+ Interest From Year Start	90,533	72,427	54,320	36,213	18,107										2,716,087
+ Interest During Year															39,435
- Interest From Revenue	90,533	72,427	54,320	36,213	18,107										2,438,033
= Total Interest Borrowed															318,088
+ Debt at Year Start	823,029	658,423	493,818	329,212	164,606										24,697,152
+ Capital Borrowed															2,151,000
+ Total Interest Borrowed															318,088
- Debt Repayment - Government															
- Private	164,606	164,606	164,606	164,606	164,606										2,469,088
- Debt at Year End	658,423	493,818	329,212	164,606											24,697,152

COAL LIQUEFACTION PLANT CASH FLOW CALCULATIONS.

Page 1

Case Description: 10.00% Extra Capital Cost

75,000 BPD C4+ SCO

25.00 % Equity Financing

Input for Project Taxation Structure:

Revenue Sensitivity Factor	1.00
Operating Cost Sensitivity Factor	1.00
Capital Cost Sensitivity Factor	1.00
Feedstock Sensitivity Factor	1.00
Inflation Sensitivity Factor	1.03
Price Escalation Sensitivity Factor (Product)	1.00
Operation Escalation Sensitivity Factor	1.00
Equity Ratio (%)	25.00
Bank Interest Rate (%)	8.00
State Income Tax (%)	
Investment Tax Credit (%)	

Revenue and Costs:

Revenue / Costs Description	Major (1,000 \$)	Minor (1,000 \$)	Total (1,000 \$)
Revenue from Products	760699	78,585	839,284
Feedstock Costs	166,976		166,976
Other Operating Costs			217,470

SCO Price at 15.00 % ROE:

After Tax DCF ROE, %:	15.00
SCO PRICE, \$/BBL	31.43

Project Schedule and Sensitivity Factors:

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Project Facilities Schedule		0.10	0.20	0.35	0.35					
Building & Services Schedule			0.30	0.40	0.30					
Indirect Schedule	0.10	0.20	0.30	0.25	0.15					
Contingencies Schedule		0.10	0.20	0.35	0.35					
Working Capital Schedule						1.00				
Production Schedule						1.00	1.00	1.00	1.00	1.00
Feed Schedule						1.00	1.00	1.00	1.00	1.00
Inflation Sensitivity Factor	1.030	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00
Price Escalat. Sensit. (Product)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Operation Escal. Sensit. Factor	1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Capital Cost:

Basis	(1,000 \$)
Process Facilities Capital Cost *	1,654,706
Building & Services Capital Cost	568,630
Indirects Capital Cost	426,025
Contingencies	75,181
Total	2,724,541

* Including initial catalyst and chemical costs.

Working Capital:

Basis	(1,000 \$)
Working Capital (@ 10 % of Rev.)	83,928

Case Description: 10.00 Extra Capital Cost

Construction Period, years			5
Operating Period, years			25
Equity Financing, %			25

Cash Flow Summary:

Basis	(1,000 \$)
Revenue	24,324,000
Working Capital Recovery	97,300
Sub-Total (Revenue plus Working Capital Recovery)	24,421,300
Operating Costs	11,141,800
Net Federal Income Tax	2,578,000
State Income Tax	
Interest Paid From Revenue	2,678,800
Debt Repayments	2,712,600
Capital Cost From Revenue	
Equity Capital Cost	763,200
Equity Working Capital/Inflation Cost	24,300
Sub-Total (Total Costs, Interests and Taxes)	19,898,800
Net Cash Flow	4,522,500

Capital Cost, Payback and SCO Price:

Total Capital Cost, 1,000 \$	3,500,200
Before Tax DCF % ROE	17.7
After Tax DCF % ROE	15.0
Payback Period, years	6.8
SCO PRICE, \$/BBL	31.43

COAL LIQUEFACTION PLANT CASH FLOW CALCULATIONS.

Page 1

Case Description: - 10.00% Extra Capital Cost

75,000 BPD C4+ SCO

25.00 % Equity Financing

Input for Project Taxation Structure:

Revenue Sensitivity Factor	1.00
Operating Cost Sensitivity Factor	1.00
Capital Cost Sensitivity Factor	1.00
Feedstock Sensitivity Factor	1.00
Inflation Sensitivity Factor	1.03
Price Escalation Sensitivity Factor (Product)	1.00
Operation Escalation Sensitivity Factor	1.00
Equity Ratio (%)	25.00
Bank Interest Rate (%)	8.00
State Income Tax (%)	
Investment Tax Credit (%)	

Revenue and Costs:

Revenue / Costs Description	Major (1,000 \$)	Minor (1,000 \$)	Total (1,000 \$)
Revenue from Products	678,967	78,585	757,552
Feedstock Costs	166,976		166,976
Other Operating Costs			217,470

SCO Price at 15.00 % ROE:

After Tax DCF ROE, %:	15.00
SCO PRICE, \$/BBL	28.06

Project Schedule and Sensitivity Factors:

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Project Facilities Schedule		0.10	0.20	0.35	0.35					
Building & Services Schedule			0.30	0.40	0.30					
Indirect Schedule	0.10	0.20	0.30	0.25	0.15					
Contingencies Schedule		0.10	0.20	0.35	0.35					
Working Capital Schedule						1.00				
Production Schedule						1.00	1.00	1.00	1.00	1.00
Feed Schedule						1.00	1.00	1.00	1.00	1.00
Inflation Sensitivity Factor	1.030	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00
Price Escalat. Sensit. (Product)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Operation Escal. Sensit. Factor	1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Capital Cost:

Basis	(1,000 \$)
Process Facilities Capital Cost *	1,353,850
Building & Services Capital Cost	465,243
Indirects Capital Cost	348,566
Contingencies	61,512
Total	2,229,170

* Including initial catalyst and chemical costs.

Working Capital:

Basis	(1,000 \$)
Working Capital (@ 10 % of Rev.)	75,755

Case Description: - 10.00 Extra Capital Cost			
Construction Period, years			5
Operating Period, years			25
Equity Financing, %			25
Cash Flow Summary:			
Basis			(1,000 \$)
Revenue			21,955,300
Working Capital Recovery			87,800
Sub - Total (Revenue plus Working Capital Recovery)			22,043,100
Operating Costs			11,141,900
Net Federal Income Tax			2,116,900
State Income Tax			
Interest Paid From Revenue			2,197,300
Debt Repayments			2,225,600
Capital Cost From Revenue			
Equity Capital Cost			624,500
Equity Working Capital/Inflation Cost			22,000
Sub - Total (Total Costs, Interests and Taxes)			18,928,200
Net Cash Flow			3,714,900
Capital Cost, Payback and SCO Price:			
Total Capital Cost, 1,000 \$			2,872,000
Before Tax DCF % ROE			17.7
After Tax DCF % ROE			15.0
Payback Period, years			6.8
SCO PRICE, \$/BBL			28.08

COAL LIQUEFACTION PLANT CASH FLOW CALCULATIONS.

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Case Description: 25.00% Extra Capital Cost

75,000 BPD C4+ SCO

25.00 % Equity Financing

Input for Project Taxation Structure:

Revenue Sensitivity Factor	1.00
Operating Cost Sensitivity Factor	1.00
Capital Cost Sensitivity Factor	1.00
Feedstock Sensitivity Factor	1.00
Inflation Sensitivity Factor	1.03
Price Escalation Sensitivity Factor (Product)	1.00
Operation Escalation Sensitivity Factor	1.00
Equity Ratio (%)	25.00
Bank Interest Rate (%)	8.00
State Income Tax (%)	
Investment Tax Credit (%)	

Revenue and Costs:

Revenue / Costs Description	Major (1,000 \$)	Minor (1,000 \$)	Total (1,000 \$)
Revenue from Products	821,997	78,585	900,583
Feedstock Costs	166,976		166,976
Other Operating Costs			217,470

SCO Price at 15.00 % ROE:

After Tax DCF ROE, %:	15.00
SCO PRICE, \$/BBL	33.97

Project Schedule and Sensitivity Factors:

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Project Facilities Schedule		0.10	0.20	0.35	0.35					
Building & Services Schedule			0.30	0.40	0.30					
Indirect Schedule	0.10	0.20	0.30	0.25	0.15					
Contingencies Schedule		0.10	0.20	0.35	0.35					
Working Capital Schedule						1.00				
Production Schedule						1.00	1.00	1.00	1.00	1.00
Feed Schedule						1.00	1.00	1.00	1.00	1.00
Inflation Sensitivity Factor	1.030	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00
Price Escalat. Sensit. (Product)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Operation Escal. Sensit. Factor	1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Capital Cost:

Basis	(1,000 \$)
Process Facilities Capital Cost *	1,880,347
Building & Services Capital Cost	646,170
Indirects Capital Cost	484,119
Contingencies	85,433
Total	3,096,070

* Including initial catalyst and chemical costs.

Working Capital:

Basis	(1,000 \$)
Working Capital (@ 10 % of Rev.)	90,058

Case Description: 25.00 Extra Capital Cost				
Construction Period, years	5			
Operating Period, years	25			
Equity Financing, %	25			
Cash Flow Summary:				
Basis	(1,000 \$)			
Revenue	26,100,800			
Working Capital Recovery	104,400			
Sub - Total (Revenue plus Working Capital Recovery)	26,205,000			
Operating Costs	11,141,900			
Net Federal Income Tax	2,923,800			
State Income Tax				
Interest Paid From Revenue	3,039,900			
Debt Repayments	3,077,900			
Capital Cost From Revenue				
Equity Capital Cost	867,900			
Equity Working Capital/Inflation Cost	26,100			
Sub - Total (Total Costs, Interests and Taxes)	21,076,900			
Net Cash Flow	5,128,100			
Capital Cost, Payback and SCO Price:				
Total Capital Cost, 1,000 \$	3,971,900			
Before Tax DCF % ROE	17.7			
After Tax DCF % ROE	15.0			
Payback Period, years	6.8			
SCO PRICE, \$/BBL	33.97			

COAL LIQUEFACTION PLANT CASH FLOW CALCULATIONS.

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Case Description: **~25.00% Extra Capital Cost**

75,000 BPD C4+ SCO

25.00 % Equity Financing

Input for Project Taxation Structure:

Revenue Sensitivity Factor	1.00
Operating Cost Sensitivity Factor	1.00
Capital Cost Sensitivity Factor	1.00
Feedstock Sensitivity Factor	1.00
Inflation Sensitivity Factor	1.03
Price Escalation Sensitivity Factor (Product)	1.00
Operation Escalation Sensitivity Factor	1.00
Equity Ratio (%)	25.00
Bank Interest Rate (%)	8.00
State Income Tax (%)	
Investment Tax Credit (%)	

Revenue and Costs:

Revenue / Costs Description	Major (1,000 \$)	Minor (1,000 \$)	Total (1,000 \$)
Revenue from Products	617,669	78,585	696,255
Feedstock Costs	166,976		166,976
Other Operating Costs			217,470

SCO Price at 15.00 % ROE:

After Tax DCF ROE, %:	15.00
SCO PRICE, \$/BBL	25.52

Project Schedule and Sensitivity Factors:

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Project Facilities Schedule		0.10	0.20	0.35	0.35					
Building & Services Schedule			0.30	0.40	0.30					
Indirect Schedule	0.10	0.20	0.30	0.25	0.15					
Contingencies Schedule		0.10	0.20	0.35	0.35					
Working Capital Schedule						1.00				
Production Schedule						1.00	1.00	1.00	1.00	1.00
Feed Schedule						1.00	1.00	1.00	1.00	1.00
Inflation Sensitivity Factor	1.030	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00
Price Escalat. Sensit. (Product)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Operation Escal. Sensit. Factor	1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Capital Cost:

Basis	(1,000 \$)
Process Facilities Capital Cost *	1,128,208
Building & Services Capital Cost	387,702
Indirects Capital Cost	290,472
Contingencies	51,260
Total	1,857,642

* Including initial catalyst and chemical costs.

Working Capital:

Basis	(1,000 \$)
Working Capital (@ 10 % of Rev.)	69,625

Case Description: -25.00 Extra Capital Cost

Construction Period, years			5
Operating Period, years			25
Equity Financing, %			25

Cash Flow Summary:

Basis	(1,000 \$)
Revenue	20,178,700
Working Capital Recovery	80,700
Sub - Total (Revenue plus Working Capital Recovery)	20,259,400
Operating Costs	11,141,900
Net Federal Income Tax	1,771,100
State Income Tax	
Interest Paid From Revenue	1,836,100
Debt Repayments	1,860,300
Capital Cost From Revenue	
Equity Capital Cost	520,400
Equity Working Capital/Inflation Cost	20,200
Sub - Total (Total Costs, Interests and Taxes)	17,150,000
Net Cash Flow	3,109,400

Capital Cost, Payback and SCO Price:

Total Capital Cost, 1,000 \$	2,400,900
Before Tax DCF % ROE	17.7
After Tax DCF % ROE	15.0
Payback Period, years	6.8
SCO PRICE, \$/BBL	25.52

COAL LIQUEFACTION PLANT CASH FLOW CALCULATIONS.

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Case Description: Coal Price + 25 %

75,000 BPD C4+ SCO

25.00 % Equity Financing

Input for Project Taxation Structure:

Revenue Sensitivity Factor	1.00
Operating Cost Sensitivity Factor	1.00
Capital Cost Sensitivity Factor	1.00
Feedstock Sensitivity Factor	1.00
Inflation Sensitivity Factor	1.03
Price Escalation Sensitivity Factor (Product)	1.00
Operation Escalation Sensitivity Factor	1.00
Equity Ratio (%)	25.00
Bank Interest Rate (%)	8.00
State Income Tax (%)	
Investment Tax Credit (%)	

Revenue and Costs:

Revenue / Costs Description	Major (1,000 \$)	Minor (1,000 \$)	Total (1,000 \$)
Revenue from Products	751688	78,585	830,273
Feedstock Costs	182,686		182,686
Other Operating Costs			233,180

SCO Price at 15.00 % ROE:

After Tax DCF ROE, %:	15.00
SCO PRICE, \$/BBL	31.08

Project Schedule and Sensitivity Factors:

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Project Facilities Schedule		0.10	0.20	0.35	0.35					
Building & Services Schedule			0.30	0.40	0.30					
Indirect Schedule	0.10	0.20	0.30	0.25	0.15					
Contingencies Schedule		0.10	0.20	0.35	0.35					
Working Capital Schedule						1.00				
Production Schedule						1.00	1.00	1.00	1.00	1.00
Feed Schedule						1.00	1.00	1.00	1.00	1.00
Inflation Sensitivity Factor	1.030	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00
Price Escalat. Sensit. (Product)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Operation Escal. Sensit. Factor	1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Capital Cost:

Basis	(1,000 \$)
Process Facilities Capital Cost *	1,504,278
Building & Services Capital Cost	516,936
Indirects Capital Cost	387,295
Contingencies	68,346
Total	2,476,856

* Including initial catalyst and chemical costs.

Working Capital:

Basis	(1,000 \$)
Working Capital (@ 10 % of Rev.)	83,027

Case Description: Coal Price + 25 %

Construction Period, years			5
Operating Period, years			25
Equity Financing, %			25

Cash Flow Summary:

Basis	(1,000 \$)
Revenue	24,062,900
Working Capital Recovery	96,300
Sub-Total (Revenue plus Working Capital Recovery)	24,159,200
Operating Costs	12,052,600
Net Federal Income Tax	2,350,900
State Income Tax	
Interest Paid From Revenue	2,440,500
Debt Repayments	2,471,900
Capital Cost From Revenue	
Equity Capital Cost	693,900
Equity Working Capital/Inflation Cost	24,100
Sub-Total (Total Costs, Interests and Taxes)	20,033,900
Net Cash Flow	4,125,300

Capital Cost, Payback and SCO Price:

Total Capital Cost, 1,000 \$	3,189,800
Before Tax DCF % ROE	17.7
After Tax DCF % ROE	15.0
Payback Period, years	6.8
SCO PRICE, \$/BBL	31.06

COAL LIQUEFACTION PLANT CASH FLOW CALCULATIONS.

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Case Description: Coal Price – 25 %

75,000 BPD C4+ SCO

25.00 % Equity Financing

Input for Project Taxation Structure:

Revenue Sensitivity Factor	1.00
Operating Cost Sensitivity Factor	1.00
Capital Cost Sensitivity Factor	1.00
Feedstock Sensitivity Factor	1.00
Inflation Sensitivity Factor	1.03
Price Escalation Sensitivity Factor (Product)	1.00
Operation Escalation Sensitivity Factor	1.00
Equity Ratio (%)	25.00
Bank Interest Rate (%)	8.00
State Income Tax (%)	
Investment Tax Credit (%)	

Revenue and Costs:

Revenue / Costs Description	Major (1,000 \$)	Minor (1,000 \$)	Total (1,000 \$)
Revenue from Products	687,979	78,585	766,564
Feedstock Costs	151,268		151,268
Other Operating Costs			201,760

SCO Price at 15.00 % ROE:

After Tax DCF ROE, %:	15.00
SCO PRICE, \$/BBL	28.43

Project Schedule and Sensitivity Factors:

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Project Facilities Schedule		0.10	0.20	0.35	0.35					
Building & Services Schedule			0.30	0.40	0.30					
Indirect Schedule	0.10	0.20	0.30	0.25	0.15					
Contingencies Schedule		0.10	0.20	0.35	0.35					
Working Capital Schedule						1.00				
Production Schedule						1.00	1.00	1.00	1.00	1.00
Feed Schedule						1.00	1.00	1.00	1.00	1.00
Inflation Sensitivity Factor	1.030	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00
Price Escalat. Sensit. (Product)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Operation Escal. Sensit. Factor	1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Capital Cost:

Basis	(1,000 \$)
Process Facilities Capital Cost *	1,504,278
Building & Services Capital Cost	516,936
Indirects Capital Cost	387,295
Contingencies	68,346
Total	2,476,856

* Including initial catalyst and chemical costs.

Working Capital:

Basis	(1,000 \$)
Working Capital (@ 10. % of Rev.)	76,656

Case Description: Coal Price - 25 %

Construction Period, years			5
Operating Period, years			25
Equity Financing, %			25

Cash Flow Summary:

Basis	(1,000 \$)
Revenue	22,216,400
Working Capital Recovery	88,900
Sub - Total (Revenue plus Working Capital Recovery)	22,305,300
Operating Costs	10,231,300
Net Federal Income Tax	2,344,000
State Income Tax	
Interest Paid From Revenue	2,435,500
Debt Repayments	2,466,300
Capital Cost From Revenue	
Equity Capital Cost	693,900
Equity Working Capital/Inflation Cost	22,200
Sub - Total (Total Costs, Interests and Taxes)	18,193,200
Net Cash Flow	4,112,100

Capital Cost, Payback and SCO Price:

Total Capital Cost, 1,000 \$	3,182,400
Before Tax DCF % ROE	17.7
After Tax DCF % ROE	15.0
Payback Period, years	6.8
SCO PRICE, \$/BBL	28.43

COAL LIQUEFACTION PLANT CASH FLOW CALCULATIONS.

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Case Description: Natural Gas Price + 25 %

75,000 BPD C4+ SCO

25.00 % Equity Financing

Input for Project Taxation Structure:

Revenue Sensitivity Factor	1.00
Operating Cost Sensitivity Factor	1.00
Capital Cost Sensitivity Factor	1.00
Feedstock Sensitivity Factor	1.00
Inflation Sensitivity Factor	1.03
Price Escalation Sensitivity Factor (Product)	1.00
Operation Escalation Sensitivity Factor	1.00
Equity Ratio (%)	25.00
Bank Interest Rate (%)	8.00
State Income Tax (%)	
Investment Tax Credit (%)	

Revenue and Costs:

Revenue / Costs Description	Major (1,000 \$)	Minor (1,000 \$)	Total (1,000 \$)
Revenue from Products	761208	90,763	851,971
Feedstock Costs	193,009		193,009
Other Operating Costs			244,258

SCO Price at 15.00 % ROE:

After Tax DCF ROE, %:	15.00
SCO PRICE, \$/BBL	31.48

Project Schedule and Sensitivity Factors:

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Project Facilities Schedule		0.10	0.20	0.35	0.35					
Building & Services Schedule			0.30	0.40	0.30					
Indirect Schedule	0.10	0.20	0.30	0.25	0.15					
Contingencies Schedule		0.10	0.20	0.35	0.35					
Working Capital Schedule						1.00				
Production Schedule						1.00	1.00	1.00	1.00	1.00
Feed Schedule						1.00	1.00	1.00	1.00	1.00
Inflation Sensitivity Factor	1.030	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00
Price Escalat. Sensit. (Product)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Operation Escal. Sensit. Factor	1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Capital Cost:

Basis	(1,000 \$)
Process Facilities Capital Cost *	1,504,278
Building & Services Capital Cost	516,936
Indirects Capital Cost	387,295
Contingencies	68,346
Total	2,476,856

* Including initial catalyst and chemical costs.

Working Capital:

Basis	(1,000 \$)
Working Capital (@ 10 % of Rev.)	85,197

Case Description: Natural Gas Price + 25 %

Construction Period, years			5
Operating Period, years			25
Equity Financing, %			25

Cash Flow Summary:

Basis	(1,000 \$)
Revenue	24,691,700
Working Capital Recovery	98,800
Sub - Total (Revenue plus Working Capital Recovery)	24,790,500
Operating Costs	12,672,800
Net Federal Income Tax	2,353,200
State Income Tax	
Interest Paid From Revenue	2,442,200
Debt Repayments	2,473,700
Capital Cost From Revenue	
Equity Capital Cost	693,900
Equity Working Capital/Inflation Cost	24,700
Sub - Total (Total Costs, Interests and Taxes)	20,660,500
Net Cash Flow	4,130,000

Capital Cost, Payback and SCO Price:

Total Capital Cost, 1,000 \$	3,192,300
Before Tax DCF % ROE	17.7
After Tax DCF % ROE	15.0
Payback Period, years	6.8
SCO PRICE, \$/BBL	31.46

COAL LIQUEFACTION PLANT CASH FLOW CALCULATIONS.

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Case Description: Natural Gas Price – 25 %

75,000 BPD C4+ SCO

25.00 % Equity Financing

Input for Project Taxation Structure:

Revenue Sensitivity Factor	1.00
Operating Cost Sensitivity Factor	1.00
Capital Cost Sensitivity Factor	1.00
Feedstock Sensitivity Factor	1.00
Inflation Sensitivity Factor	1.03
Price Escalation Sensitivity Factor (Product)	1.00
Operation Escalation Sensitivity Factor	1.00
Equity Ratio (%)	25.00
Bank Interest Rate (%)	8.00
State Income Tax (%)	
Investment Tax Credit (%)	

Revenue and Costs:

Revenue / Costs Description	Major (1,000 \$)	Minor (1,000 \$)	Total (1,000 \$)
Revenue from Products	678,458	66,408	744,866
Feedstock Costs	140,942		140,942
Other Operating Costs			190,682

SCO Price at 15.00 % ROE:

After Tax DCF ROE, %:	15.00
SCO PRICE, \$/BBL	28.04

Project Schedule and Sensitivity Factors:

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Project Facilities Schedule		0.10	0.20	0.35	0.35					
Building & Services Schedule			0.30	0.40	0.30					
Indirect Schedule	0.10	0.20	0.30	0.25	0.15					
Contingencies Schedule		0.10	0.20	0.35	0.35					
Working Capital Schedule						1.00				
Production Schedule						1.00	1.00	1.00	1.00	1.00
Feed Schedule						1.00	1.00	1.00	1.00	1.00
Inflation Sensitivity Factor	1.030	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00
Price Escalat. Sensit. (Product)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Operation Escal. Sensit. Factor	1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Capital Cost:

Basis	(1,000 \$)
Process Facilities Capital Cost *	1,504,278
Building & Services Capital Cost	516,936
Indirects Capital Cost	387,295
Contingencies	68,346
Total	2,476,856

* Including initial catalyst and chemical costs.

Working Capital:

Basis	(1,000 \$)
Working Capital (@ 10 % of Rev.)	74,487

Case Description: Natural Gas Price -- 25 %			
Construction Period, years	5		
Operating Period, years	25		
Equity Financing, %	25		
Cash Flow Summary:			
Basis	(1,000 \$)		
Revenue	21,587,600		
Working Capital Recovery	86,400		
Sub - Total (Revenue plus Working Capital Recovery)	21,674,000		
Operating Costs	9,611,100		
Net Federal Income Tax	2,341,700		
State Income Tax			
Interest Paid From Revenue	2,433,800		
Debt Repayments	2,464,400		
Capital Cost From Revenue			
Equity Capital Cost	693,900		
Equity Working Capital/Inflation Cost	21,600		
Sub - Total (Total Costs, Interests and Taxes)	17,566,500		
Net Cash Flow	4,107,500		
Capital Cost, Payback and SCO Price:			
Total Capital Cost, 1,000 \$	3,179,900		
Before Tax DCF % ROE	17.7		
After Tax DCF % ROE	15.0		
Payback Period, years	6.8		
SCO PRICE, \$/BBL	28.04		

COAL LIQUEFACTION PLANT CASH FLOW CALCULATIONS.

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Case Description: Base Case with 50.00 % Equity Financing

75,000 BPD C4+ SCO

50.00 % Equity Financing

Input for Project Taxation Structure:

Revenue Sensitivity Factor	1.00
Operating Cost Sensitivity Factor	1.00
Capital Cost Sensitivity Factor	1.00
Feedstock Sensitivity Factor	1.00
Inflation Sensitivity Factor	1.03
Price Escalation Sensitivity Factor (Product)	1.00
Operation Escalation Sensitivity Factor	1.00
Equity Ratio (%)	50.00
Bank Interest Rate (%)	8.00
State Income Tax (%)	
Investment Tax Credit (%)	

Revenue and Costs:

Revenue / Costs Description	Major (1,000 \$)	Minor (1,000 \$)	Total (1,000 \$)
Revenue from Products	764,411	78,585	842,997
Feedstock Costs	166,976		166,976
Other Operating Costs			217,470

SCO Price at 15.00 % ROE:

After Tax DCF ROE, %:	15.00
SCO PRICE, \$/BBL	31.59

Project Schedule and Sensitivity Factors:

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Project Facilities Schedule		0.10	0.20	0.35	0.35					
Building & Services Schedule			0.30	0.40	0.30					
Indirect Schedule	0.10	0.20	0.30	0.25	0.15					
Contingencies Schedule		0.10	0.20	0.35	0.35					
Working Capital Schedule						1.00				
Production Schedule						1.00	1.00	1.00	1.00	1.00
Feed Schedule						1.00	1.00	1.00	1.00	1.00
Inflation Sensitivity Factor	1.030	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00
Price Escalat. Sensit. (Product)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Operation Escal. Sensit. Factor	1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Capital Cost:

Basis	(1,000 \$)
Process Facilities Capital Cost *	1,504,278
Building & Services Capital Cost	516,936
Indirects Capital Cost	387,295
Contingencies	68,346
Total	2,476,856

* Including initial catalyst and chemical costs.

Working Capital:

Basis	(1,000 \$)
Working Capital (@ 10 % of Rev.)	84,300

Case Description: Base Case with 50.00 % Equity Financing

Construction Period, years			5
Operating Period, years			25
Equity Financing, %			50

Cash Flow Summary:

Basis	(1,000 \$)
Revenue	24,431,600
Working Capital Recovery	97,700
Sub - Total (Revenue plus Working Capital Recovery)	24,529,300
Operating Costs	11,141,900
Net Federal Income Tax	3,062,300
State Income Tax	
Interest Paid From Revenue	1,627,700
Debt Repayments	1,648,600
Capital Cost From Revenue	
Equity Capital Cost	1,387,700
Equity Working Capital/Inflation Cost	48,900
Sub - Total (Total Costs, Interests and Taxes)	18,917,100
Net Cash Flow	5,612,200

Capital Cost, Payback and SCO Price:

Total Capital Cost, 1,000 \$	3,085,200
Before Tax DCF % ROE	17.8
After Tax DCF % ROE	15.0
Payback Period, years	5.2
SCO PRICE, \$/BBL	31.59

Case Description: 10.00 % Extra Yield of C4+ SCO
82500 C4+ SCO
25.00 % Equity Financing

Input for Project Taxation Structure:	1.00
Revenue Sensitivity Factor	1.00
Operating Cost Sensitivity Factor	1.00
Capital Cost Sensitivity Factor	1.00
Feedstock Sensitivity Factor	1.00
Inflation Sensitivity Factor	1.03
Price Escalation Sensitivity Factor (Product)	1.00
Operation Escalation Sensitivity Factor	1.00
Equity Ratio (%)	25.00
Bank Interest Rate (%)	8.00
State Income Tax (%)	
Investment Tax Credit (%)	

Revenue and Costs:	Major	Minor	Total
Revenue / Costs Description	(1,000 \$)	(1,000 \$)	(1,000 \$)
Revenue from Products	719833	78,585	798,418
Feedstock Costs	166,976		166,976
Other Operating Costs			217,470

SCO Price at 15.00 % ROE:	15.00
After Tax DCF ROE %:	27.04
SCO PRICE, \$/BBL	

Project Schedule and Sensitivity Factors:

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Project Facilities Schedule	0.10	0.20	0.35	0.35						
Building & Services Schedule		0.30	0.40	0.30						
Indirect Schedule	0.10	0.20	0.30	0.25	0.15					
Contingencies Schedule		0.10	0.20	0.35	0.35					
Working Capital Schedule					1.00					
Production Schedule					1.00	1.00	1.00	1.00	1.00	1.00
Feed Schedule						1.00	1.00	1.00	1.00	1.00
Inflation Sensitivity Factor	1.030	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00
Price Escalat. Sensit. (Product)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Operation Escal. Sensit. Factor	1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Capital Cost:

Basis	(1,000 \$)
Process Facilities Capital Cost *	1,504,278
Building & Services Capital Cost	516,936
Indirects Capital Cost	387,295
Contingencies	68,346
Total	2,476,856

* Including initial catalyst and chemical costs.

Working Capital:

Basis	(1,000 \$)
Working Capital (@ 10 % of Rev.)	79,842

Case Description: 10.00 % Extra Yield of C4+ SCO

Construction Period, years			5
Operating Period, years			25
Equity Financing, %			25

Cash Flow Summary:

Basis	(1,000 \$)
Revenue	23,139,600
Working Capital Recovery	92,600
Sub-Total (Revenue plus Working Capital Recovery)	23,232,200
Operating Costs	11,141,900
Net Federal Income Tax	2,347,500
State Income Tax	
Interest Paid From Revenue	2,438,000
Debt Repayments	2,469,100
Capital Cost From Revenue	
Equity Capital Cost	693,900
Equity Working Capital/Inflation Cost	23,100
Sub-Total (Total Costs, Interests and Taxes)	19,113,500
Net Cash Flow	4,118,700

Capital Cost, Payback and SCO Price:

Total Capital Cost, 1,000 \$	3,186,100
Before Tax DCF % ROE	17.7
After Tax DCF % ROE	15.0
Payback Period, years	6.8
SCO PRICE, \$/BBL	27.04

COAL LIQUEFACTION PLANT CASH FLOW CALCULATIONS.

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Case Description: - 5.00 % Extra Yield of C4+ SCO

71250 C4+ SCO

25.00 % Equity Financing

Input for Project Taxation Structure:

Revenue Sensitivity Factor	1.00
Operating Cost Sensitivity Factor	1.00
Capital Cost Sensitivity Factor	1.00
Feedstock Sensitivity Factor	1.00
Inflation Sensitivity Factor	1.03
Price Escalation Sensitivity Factor (Product)	1.00
Operation Escalation Sensitivity Factor	1.00
Equity Ratio (%)	25.00
Bank Interest Rate (%)	8.00
State Income Tax (%)	
Investment Tax Credit (%)	

Revenue and Costs:

Revenue / Costs Description	Major (1,000 \$)	Minor (1,000 \$)	Total (1,000 \$)
Revenue from Products	719833	78,585	798,418
Feedstock Costs	166,976		166,976
Other Operating Costs			217,470

SCO Price at 15.00 % ROE:

After Tax DCF ROE, %:	15.00
SCO PRICE, \$/BBL	31.31

Project Schedule and Sensitivity Factors:

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Project Facilities Schedule		0.10	0.20	0.35	0.35					
Building & Services Schedule			0.30	0.40	0.30					
Indirect Schedule	0.10	0.20	0.30	0.25	0.15					
Contingencies Schedule		0.10	0.20	0.35	0.35					
Working Capital Schedule						1.00				
Production Schedule						1.00	1.00	1.00	1.00	1.00
Feed Schedule						1.00	1.00	1.00	1.00	1.00
Inflation Sensitivity Factor	1.030	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00
Price Escalat. Sensit. (Product)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Operation Escal. Sensit. Factor	1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Capital Cost:

Basis	(1,000 \$)
Process Facilities Capital Cost *	1,504,278
Building & Services Capital Cost	516,936
Indirects Capital Cost	387,295
Contingencies	68,346
Total	2,476,856

* Including initial catalyst and chemical costs.

Working Capital:

Basis	(1,000 \$)
Working Capital (@ 10 % of Rev.)	79,842

Case Description: - 5.00 % Extra Yield of C4+ SCO			
Construction Period, years	5		
Operating Period, years	25		
Equity Financing, %	25		
Cash Flow Summary:			
Basis	(1,000 \$)		
Revenue	23,139,600		
Working Capital Recovery	92,600		
Sub - Total (Revenue plus Working Capital Recovery)	23,232,200		
Operating Costs	11,141,900		
Net Federal Income Tax	2,347,500		
State Income Tax			
Interest Paid From Revenue	2,438,000		
Debt Repayments	2,469,100		
Capital Cost From Revenue			
Equity Capital Cost	693,900		
Equity Working Capital/Inflation Cost	23,100		
Sub - Total (Total Costs, Interests and Taxes)	19,113,500		
Net Cash Flow	4,118,700		
Capital Cost, Payback and SCO Price:			
Total Capital Cost, 1,000 \$	3,186,100		
Before Tax DCF % ROE	17.7		
After Tax DCF % ROE	15.0		
Payback Period, years	6.8		
SCO PRICE, \$/BBL	31.31		