**Development of High Energy Density
Fuels From Mild Gasification of Coal
Task 4: Proposed Upgrading
Schemes for Advanced Fuels**

Topical Report

October 1990

Work Performed Under Contract No.: DE-AC21-88MC25020

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

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1.0 INTRODUCTION AND BACKGROUND

ABB Lummus Crest Inc (Lummus), a wholly owned subsidiary of Asea Brown Boveri Inc (ABB), successfully responded to a DOE solicitation for the Development of High Energy Density Fuels (HEDF) from Mild Gasification of Coal which ultimately lead to DOE contract DE-AC21-88MC25020. The overall objective of the program is the determination of the minimal processing requirements to produce HEDF meeting a minimal energy density of 130,000 Btu/gal (conventional jet fuels have energy densities in the vicinity of 115,000 - 120,000 Btu/gal) and having acceptable advanced fuel specifications in accordance with the three defined categories of HEDF. The program encompasses assessing current technology capability; selecting acceptable processing and refining schemes; and generating samples of advanced test fuels. A task breakdown structure was developed containing eight key tasks.

This report summarizes the work that Amoco Oil Company (AOC), as key subcontractor, performed in the execution of Task 4, Proposed Upgrading Schemes for Advanced Fuel. In defining Task 4, it is necessary to understand the prior tasks wherein the inputs to Task 4 were generated. These earlier tasks, namely, Task 1 (Planning and Environmental Permitting); Task 2 (Transporting/Storage of Raw Fuel Sources and Products); and Task 3 (Screening of Processing and Upgrading Schemes), were aimed at the experimental acquisition of processing data based on the proposed approach to converting Mild Coal Gasification liquids to HEDF. This approach consists of a multi-step refining operation including hydrofining the HEDF-range distillates fractionated from the raw fuel sources and cracking, either via thermal cracking (e.g., delayed coking) or catalytic hydrocracking (e.g., LC-Fining), the atmospheric resid fraction of the raw fuel sources.

The initial program involved the evaluation of one MCG liquid and one shale oil, the former derived from the British COALITE process using a British coal similar in quality to that of a U.S. bituminous coal, and the latter derived from retorting of Colorado oil shale. Budgeting limitations midway in the program necessitated the deferral of the processing evaluation of the Colorado shale oil feedstock. Thus, this topical report presents the results of AOC's evaluation of the COALITE feedstock. Although the preliminary data generated in the Task 3 experiments showed that low yields of HEDF components would be projected from the Colorado shale oil feedstock over the range of operating conditions and catalyst types studied, the ultimate potential of the Colorado shale oil feedstock for HEDF manufacture would have to be determined in a more intense process screening effort which was outside the scope of the current program.

The intent of the Task 4 study was to represent all the candidate processing options, that were either studied in the experimental efforts of Task 3 or were available from the prior art in the open literature, in a linear program (LP) model. This type of optimization model is routinely utilized by the petroleum refining industry to assess the performance and economics of candidate crude oil feedstocks being considered for use in a particular refinery. The LP model would allow scaling of the bench-scale Task 3 results to commercial scale and would perform economic evaluations on any combination of the processes which might be used to make HEDF. Section 2.0 of this report summarizes the process and economic bases used. Sections 3.0 and 4.0 details the economics and processing sensitivities for HEDF production.

2.0 MODEL DEVELOPMENT

2.1 Processing Bases

Several processes for treating raw COALITE liquid, or some substituent boiling fractions thereof, were experimentally tested in the initial Task 3 campaigns. These processes were selected because of their potential ability to change some of the properties of the feed stream towards those required of the finished HEDF products. The desired properties for HEDF are discussed in prior project documents and are summarized in Table III. The selected processes performed generally as expected in the Task 3 studies. However, no one process was able to provide all the properties needed for the production of HEDF. For instance, hydrotreating reduced aromatics and heteroatom levels, but also reduced energy density. To meet all the specifications for HEDF, it was expected that several processing steps would need to be combined. This may have involved combining processes in ways that could not have been either predicted at the start of this program or studied experimentally in the limited time available.

A linear program (LP) model was built which incorporated the most promising test periods from the experimental program in Task 3. In addition, there were a number of other conventional hydrocarbon processes that might also move stream properties towards the specifications for HEDF. These were also included in the linear program model. Table I lists all the process alternatives incorporated in the model developed for this study. Sometimes, each process alternative included more than one process condition. For example, the hydrotreating alternatives included several reactor severities. When process data were not available from the Task 3 program, process performance and costs were estimated from correlations based on either literature studies with coal-based stocks or AOC's in-house experience with petroleum-based stocks. An example of a process option that was included in the LP model but could not be studied in Task 3 is the recycle of hydrocracker bottoms product to the extinction of that stream. Investigators are continuing to find other ways to produce high quality liquid products from coal-derived liquids (1).

The linear program model was able to combine any or all of these process alternatives and to blend various streams from these alternatives to make finished products, preferably HEDF. When the streams could not be used to make HEDF, they were allowed to be blended into some conventional co-products. Sales of these co-products could help subsidize the cost of HEDF production and make sure the plant did not produce any waste streams that might be an environmental disposal problem. Table II lists the co-products that were included in the LP model for this study. The LP model included technology to blend process streams to meet the product specifications for all the products listed in Table II. Proprietary AOC technology was used to describe properties, such as viscosity and flash point, that do not blend linearly. Typical ASTM specifications were used for the conventional fungible co-products and are not repeated here. Two different high energy density fuels were targeted - one in the jet fuel boiling range (Category I) and the other in the diesel fuel boiling range (Category III). Category II endothermic HEDF fuel was not considered in this study. The specifications used in the LP model for these high energy density fuels, which were developed in consultation with

TABLE I
PROCESS ALTERNATIVES INCLUDED

Alkylation
Aromatics Recovery
Catalytic Cracking
Coking
Diolefin Saturation
Distillate Extraction
Distillation
Dynaphen
Ebullated Bed Hydrotreating (LC-Fining)
Fixed Bed Naphtha Hydrotreating
Fixed Bed Distillate Hydrotreating
Fixed Bed Gas Oil Hydrotreating
Hydrocracking
Hydrogen Production (Steam Reforming)
Hydrogen Purification (PSA)
Isomerization
Naphtha Reforming for Aromatics
Naphtha Sweetening
Polygasoline Production
Sulfur Production
Utilities Generation

TABLE II
FEEDSTOCK COST/CO-PRODUCT PRICE BASES

<u>Stock</u>	<u>Price</u>	<u>Volume</u>	<u>Unit</u>
Natural gas	12.61		FOE Barrel
LPG/ Propane	7.60		Barrel
Mixed/ n-Butanes	11.76		Barrel
Isobutane	19.11		Barrel
Coalite/ HS Crude	18.00	10M, 40M	Barrel
Toluene	38.00		Barrel
Unleaded Regular	23.35		Barrel
Unleaded Premium	26.29		Barrel
Unleaded Mid-Grade	24.61		Barrel
Hydtrt Sweet Naphtha	25.40		Barrel
Reformer Feed	24.61		Barrel
Naphtha Jet Fuel(JP-4)	24.20		Barrel
Jet Fuel(JP-8)/Kerosene	21.84		Barrel
HED Jet Fuel	21.84	4M, 16M, max	Barrel
HED Diesel	21.84	4M, 16M, max	Barrel
Diesel Fuel	21.60		Barrel
Furnace Oil/ No. 2	21.00		Barrel
Coke	16.00		Ton
Sulfur	63.00		Ton
Fuel	2.00		MM Btu
Cooling Water	0.20		M gal
Power	0.05		KWH
Steam- High Pressure	5.00		M pound
Steam- Medium Pressure	4.40		M pound
Steam- Low Pressure	4.25		M pound

Note: M - thousand

TABLE III
HEDF SPECIFICATIONS USED

<u>Property</u>	<u>HED Jet Fuel</u>	<u>HED Diesel</u>
Specific Gravity	.850 min	
Sulfur, Wt %	.05 max	.05 max
Cetane Number		40 min
Heating Value, MBtu/gal	130 min	130 min
Freeze Point, °F	-50 max	-50 max
Hydrogen Content, Wt %	12.5 min	
Flash Point, °F	100 min	133 min
Aromatics Content, Wt %	25 max	25 max
	5 min	
Viscosity, cs at -4°F	12 max	
	8 min	
		12 max
		8 min
Distillation, % off		
at 400°F	10 min	
at 465°F	95 max	
at 540°F	96 min	
at 640°F		80 min
Paraffins Content, Wt %	50 max	

DOE, are shown in Table III. These are expected to result in compatibility with current jet fuel engine hardware components and mission requirements.

Because it was not always possible to measure each of the qualities needed for these specifications with each stock in the experimental program (usually because of limited sample size), the needed quality parameters were sometimes estimated from correlations with those properties that were measured. For example, Figure 1 shows how the hydrogen content and the heating value of the total liquid product (TLP) from hydrotreating 350-650F COALITE vary with hydrotreating reactor severity, while Figure 2 shows how stream flash point varies with simulated distillation (SD) initial boiling point. Other correlations were used that were developed from the extensive Task 3 experimental data set.

The linear program model contained almost 600 balance constraints (rows) and over 1200 process, blending, and economics options (columns). Each of the cases and sensitivities reported later considered each of these large numbers of process alternatives.

2.2 Economics Bases

Since it is not possible to produce HEDF without consuming some feedstocks and utilities or without producing some co-products, the economics require a pricing scenario for the feed, products, and utilities. Table II shows the price and volume bases used. For this study, it was assumed that the mild-gasification coal liquid exemplified by COALITE, was available for about the same price as current crude oil, namely \$18 per barrel. A crude oil price of \$30/B was studied later in a sensitivity case. The relative prices of the other feeds and products come from an average of AOC's in-house historical data.

Another component of the economics requires return on the capital that is employed to build the necessary processing units. The capital investment costs for these units were scaled to represent the size of the units required in each case using a power law factor. The investment costs were then escalated to be equivalent to mid-1988 construction completion. The calculated investment requirement for a process plant included a prorated portion for typical utilities and OSBL support facilities. It was assumed that 65% of the capital was financed at an annual cost of 12%, while the remaining 35% was financed internally at a required 15% annual DCF rate of return. Other economic parameters include a generic U.S. Gulf Coast location, three year plant construction period, no investment tax credit, a 20 year project life, a 90% on-stream operating factor, and no net plant salvage value at the end of the project life. Using the ten-year plant depreciation schedule from the Tax Recovery Act of 1986 and a 38% tax rate, a capital recovery factor of about 21% per year was found to represent these parameters. Another 4% per year was added to account for the cost of maintenance, local taxes, insurance, and overhead.

Figure 1

Effect of Reactor Severity

Coalite 350-650 F Feedstock

Rx Severity - 100,000 P/SV E(-35,000/RT)

Figure 2
Flash Point Prediction
Effect of Product SD IBP

SD - simulated distillation

3.0 ECONOMIC RESULTS

3.1 HEDF Diesel Fuel Production

The LP model was not able to produce HEDF in the diesel boiling range from COALITE liquid when using the specifications listed in Table III. There were indications that HEDF diesel could be produced if the viscosity specification was changed. However, the linear program computer modeling effort was halted due to budget limitations before additional studies could be done on this fuel target. However, HEDF jet fuel was produced in many case studies as discussed in section 3.2. A sensitivity case, as described in section 4.4, for waiving the HEDF jet fuel distillation specifications resulted in producing a heavier diesel-like HEDF fuel.

3.2 HEDF Jet Fuel Production

Several case studies were done on the LP model which produced various quantities of HEDF jet fuel from two alternative commercial feedrates, 40 MBCD (thousands of barrels per calendar day) and 10 MBCD. Interpolation and extrapolation of these cases can be used to project the economics at other feedrates. The case studies completed are discussed individually below. The first two cases are documented in detail to explain the implementation of the bases used in the model. Only the important economic parameters are given for the other cases, since all the economic and process conclusions can be drawn from these values.

3.2.1 40 MBCD Capacity - Maximum HEDF Jet Fuel

Figure 3 shows the liquid stream process units selected when the linear program model produced the maximum amount of HEDF jet fuel from 40 MBCD of COALITE liquids. The processing system first fractionated the COALITE liquids at 300F and at 650F to produce three streams for optimum processing. The 0.8 MBCD of raw 300F- naphtha was sweetened and had its diolefin content saturated to make it into an acceptable gasoline blending stock. This stock was sold as a co-product. The 20 MBCD of 300-650F raw COALITE distillate was hydrotreated using fixed bed hydrotreating technology. Most of the product from this step was redistilled, although 0.8 MBCD was directly blended to HEDF. The 400F minus naphtha from the redistillation was either blended to JP-4 jet fuel or sold as reformer charge stock. The 400-575F distillate from the redistillation was blended to HEDF jet fuel. The 575F+ from redistillation was routed to hydrocracking. The 19.2 MBCD of raw 650F+ COALITE was first hydrotreated using expanded-bed technology (LC-Fining). The naphtha from this step was blended to JP-4 jet fuel while the distillate was split between HEDF blending, redistillation, and further upgrading by hydrotreating in the fixed bed distillate hydrotreater, as shown in Figure 3. The 575F+ stream from the LC-Finer was hydrocracked along with the bottoms stream from the redistillation step. The naphtha produced in the hydrocracking step was blended to JP-4, while the distillate was split between direct blending to HEDF and redistillation. The recycle of the heavy stock to hydrocracking through redistillation resulted in extinction of this stream and in the sales of no products heavier than HEDF jet fuel. In total, almost 30 MBCD of HEDF jet fuel could be produced from 40 MBCD of COALITE, for a 75% yield.

FIGURE 3
MAXIMUM HED JET FUEL

Table IV gives the properties of the HEDF jet fuel produced in the maximum HEDF case column, and compares those properties with the specifications. The product slightly exceeded the desired minimum volumetric energy density. The limiting specifications were maximum aromatics content, minimum viscosity, and distillation endpoint.

Table V shows the process unit sizes that had to be constructed for this case, along with the corresponding investment costs. The capital total of 439 MM\$ includes 12.7 MM\$ for initial catalyst fills and 46 MM\$ for allocated costs of utilities and OSBL.

Table VI summarizes the economics for the maximum HEDF jet fuel case, as well as the volume of feed, product, and utilities required. The sum of raw material and utilities costs is about equal to the profit from sales of HEDF jet fuel and co-products. The added costs for fixed items and capital recovery leave a net cost (loss) of 315 M\$/CD. This is equivalent to a loss of \$10.53 per barrel of HEDF above its assumed \$21.84 selling price. Thus, the HEDF jet fuel must sell for about \$32.37/B in order to break-even with all the costs necessary for its production.

3.2.2 40 MBCD Capacity - 40% HEDF Jet Yield

Because the maximum HEDF jet fuel processing scheme had so many branches and recycles, another case was investigated that produced about half of this maximum production of HEDF jet fuel. Figure 4 shows that the same process units are required but the processing scheme is indeed simpler, as many of the branches and recycles have zero flow rates. Much of the raw 650F+ COALITE liquid and the heavy LC-Finer bottoms is diverted to plant fuel needs instead of finished product sales. These high boiling streams are obviously the most expensive to convert to HEDF or any other salable product, although they provide some of the desirable properties for HEDF. Table IV shows that the 40% HEDF yield jet fuel product is lower in specific gravity and volumetric heating value than the maximum HEDF product. The viscosity and distillation specifications are still limiting, but the aromatics content has been reduced to 12%.

Although Figures 3 and 4 do not show by-product gas streams (because gases are treated as fuel gas utilities), the high production of liquid plant fuel in the 40% yield HEDF case allows the plant to sell some by-product gases for fuel. Thus this case is a net exporter rather than importer of fuel gas as indicated in Table VI.

Table VII shows that the capital requirement has been reduced to 305 MM\$, or about 70% of that of the maximum HEDF yield case requirement. Since it produces only about 55% of the amount of HEDF, the capital and fixed costs per barrel of HEDF are higher. Since the feed is the same amount of COALITE liquid, the cost of raw material per barrel of HEDF has also increased as indicated in Table VI. On the other hand, relatively more of the COALITE is sold as co-product and as by-product fuel, so these cost elements are more favorable than in the maximum HEDF yield case. Overall, the losses are reduced to 274 M\$/CD, although the loss per barrel of HEDF is increased to \$17.11 per barrel.

TABLE IV
PRODUCT COMPARISON WITH SPECIFICATIONS
40, MBCD \$18/B Coalite

<u>Property</u>	<u>HED Jet Specif.</u>	<u>Max HEDF Product</u>	<u>40% HEDF Product</u>
Specific Gravity	.850 min	.868	.857
Sulfur, Wt %	.05 max	.032	.021
Heating Value, MBtu/gal	130 min	130.9	130.3
Freeze Point, °F	-50 max	-70	-70
Hydrogen Content, Wt %	12.5 min	13.2	13.9
Flash Point, °F	100 min	210	205
Aromatics Content, Wt %	25 max	25	12
	5 min		
Viscosity, cs at -4°F	12 max	8	8
	8 min		
Distillation, % off			
at 400°F	10 min	22	20
at 465°F	95 max	68	69
at 540°F	96 min	96	96
Paraffins Content, Wt %	50 max	49	40

TABLE V
INVESTMENT SUMMARY - MAXIMUM HEDF JET FUEL
40 MBCD \$18/B Coalite

<u>Process Unit</u>	<u>Size BSD</u>	<u>Investment MMS (1988)</u>
Naphtha Diolefin Hydrotreater	870	4.5
Hydrogen Manufacture	216*	113.3
Hydrocracker	34,300	33.2
Fixed Bed Hydrotreater	23,100	115.3
Power Distribution		8.6
Ebullated Bed Hydrotreater	21,300	122.5
Oil Distillation	44,000	29.9
Sulfur Plant	61**	10.4
Naphtha Sweetening	880	<u>0.8</u>
Total		438.7

Investment Includes Allocated Utilities and OSBL.

* Based on MMSCFSD instead of BSD.

** Based on LTSD instead of BSD.

TABLE VI
BASELINE CASES ECONOMIC BREAKDOWN SUMMARY
40 MBCD \$18/B Coalite

<u>Cost Component</u>	<u>Maximum HEDF Jet</u>		<u>40% Yield HEDF Jet</u>	
	<u>Costs,</u> <u>M\$/CD</u>	<u>HEDF Cost</u> <u>\$/Bbl</u>	<u>Costs,</u> <u>M\$/CD</u>	<u>HEDF Cost</u> <u>\$/Bbl</u>
Raw Materials Cost	794.2	26.56	762.2	47.64
HEDF Sales	-652.9	-21.84	-343.4	-21.83
Co-Product Sales	-388.0	-12.97	-265.0	-16.56
Utilities	250.8	8.39	-92.1	-5.76
Fixed Costs	54.0	1.81	39.4	2.46
Capital Recovery	256.6	8.58	178.6	11.16
Total Costs	314.7	10.53	273.7	17.11

<u>Purchases</u>	<u>Quantity</u>	<u>Unit</u>	<u>Quantity</u>	<u>Unit</u>
Coalite	40.0	MBCD	40.0	MBCD
Natural Gas	12.4	MFOEBCD	0	MFOEBCD
Catalyst & Chemical	72.2	M\$/CD	27.7	M\$/CD
Cooling Water	105.7	Mgal/CD	41.2	Mgal/CD
Process Water	3.7	Mgal/CD	1.7	Mgal/CD
Power	50.9	MW	21.3	MW

<u>Sales</u>				
HEDF Jet Fuel	29.9	MBCD	16.0	MBCD
Sweetened Naphtha	0.8	MBCD	0.8	MBCD
Reformer Feed	2.3	MBCD	1.0	MBCD
JP-4 Jet Fuel	12.2	MBCD	8.9	MBCD
Fuel Gas	0	MFOEBCD	9.3	MFOEBCD
Propane	1.7	MBCD	0.5	MBCD
Sulfur	58.	LTCD	31.	LTCD

FIGURE 4
40% HED JET FUEL

TABLE VII
ECONOMIC SUMMARY
\$18/B Feedstock Price Basis

<u>Coalite</u> <u>MBCD</u>	<u>HS Crude</u> <u>MBCD</u>	<u>HED Jet</u> <u>MBCD</u>	<u>Profit</u> <u>M\$/CD</u>	<u>Invest</u> <u>MMS</u>	<u>Equivalent S/B</u> <u>Feed Cost Basis</u> <u>\$18/B Breakeven</u>	
40	0	29.9	-315.	439	32.40	24.70
40	0	16	-274.	305	38.90	24.70
40	0	8	-244.	211	52.40	23.80
40	0	0	-229.	206	-	12.30*
10	0	7.5	-157.	217	42.90	28.90
10	0	4	-134.	147	55.30	29.20
10	0	0	-104.	55	-	7.60*
0	50	0	-97.	300	-	16.10*
0	40	0	-100.	265	-	15.50*
40	0	30.6	-264.	295	35.00	23.60**
40	0	20	-252.	318	28.40	22.50**
40	0	0	-229.	206	-	12.30*

* Based on feed rather than jet fuel.

** All HEDF specs waived, see Figure 12 and Table IX.

3.2.3 10 MBCD Capacity

Table VII summarizes the investment costs, net losses of cash flow (negative profit), and break-even HEDF costs when feeding 10 MBCD of COALITE instead of 40 MBCD. Similar processing routes were chosen as for the 40 MBCD cases, but the economics are less favorable because of decreased economies of scale.

3.2.4 No HEDF Production

Table VII and Figure 5 show the economics when no HEDF jet fuel is produced, and only co-products (chiefly JP-4 and normal diesel fuel) and by-products are sold. Obviously, the economic parameters per barrel of HEDF are undefined in these cases. Figure 5 shows that, in all cases studied, increased HEDF production for sale at \$21.84 per barrel results in lowered profits. The break-even cost calculations already discussed confirm that the cost of HEDF from COALITE is higher than this current jet fuel price.

To provide an alternative way to evaluate these economics, the linear program model was run feeding petroleum crude oil and no COALITE, at rates of 40 and 50 MBCD, respectively. The LP model chose typical refinery process units and produced no HEDF. Table VII and Figure 5 show the economics of these cases. The small refineries produced in these crude oil cases lost money, confirming the industry-wide lack of current and scheduled refinery construction plans. Since even crude oil processing loses money with the economic bases assumed here, the small economies of scale and pricing assumptions used in this study also bias the above HEDF cases. Another way to state this is that the above HEDF costs include the losses that any small grass-roots processing plant would incur, and are not related to the true inherent or incremental HEDF costs.

To look at the economics without these small plant inefficiency costs, we will price the feedstock at its break-even cost, and determine true product costs from that base point. The break-even costs per barrel of feedstock for these crude oil cases, and also the no HEDF cases, are shown in Table VII and as the lower points in Figure 6. The difference between the crude oil and COALITE lines implies that COALITE liquid is worth only about \$3/B less than crude oil for making conventional products. This might be expected from the lower hydrogen and higher aromatics content of COALITE and its more severe refining processing requirements compared with crude oil.

If COALITE were priced at this break-even cost (\$7.60/B at 10 MBCD and \$12.30/B at 40 MBCD), we get a different picture of the incremental cost of producing HEDF. The costs for the 40% HEDF yield case are shown in Table VII under the break-even feedstock cost column and as the center points in Figure 6. These HEDF costs are in the mid- to high- twenty dollar per barrel range, and are not that far from the current jet fuel price (\$21.84/B). Table VII shows that the trends in the \$/B costs for the maximum HEDF yield cases are very similar to the 40% HEDF yield cases. Thus, if processing units were available that could process COALITE to conventional products, the incremental costs for making high energy density analogs would not be very much higher.

Figure 5

Feedstock Rate Effect on Profit

\$18/B Feedstock Cost

Figure 6

Effect of Feedstock Rate

40% HEDF Yield - \$18/B Feedstock Cost

4.0 SENSITIVITY STUDIES

4.1 Effect of Energy Density

Since Table IV shows that the HEDF jet fuels produced in the cases discussed above slightly exceeded the 130,000 Btu/gallon specification, a question might be asked of how high an energy density could be produced with the technologies currently known as a result of this project. To answer that question, the energy density specification was incrementally increased and the volume and cost of the resultant HEDF was calculated. Figure 7 shows that the volume of HEDF that can be produced at 132,500 Btu/gallon is about half of the baseline volume. The fully loaded cost for this higher heating value product is about \$6/B higher with \$18/B feedstock costs, while the cost using the break-even feedstock cost is only about \$3/B higher. It was not possible to produce a HEDF with a heating value of 133,000 Btu/gallon using the current database generated from the Task 3 screening program. Figure 8 shows how these higher energy density costs compare to the current jet fuel cost as a function of feedstock price. Further \$30/B feedstock cost cases are discussed in section 4.3.

4.2 Improvement Areas

Figure 9 shows the componential break down of HEDF dollar per barrel transfer costs for the \$18/B feedstock cost, 40 MBCD cases into component areas. Figure 9 shows that net raw material cost (feedstock minus by- and co-products) is the major cost component. Capital costs account for about a quarter of the total HEDF costs. Hydrogen costs, taken as the sum of hydrogen plant capital, fixed, and operating costs, amount to just over \$8/B, so improvements in the costs of hydrogen generation might lead to reductions in the cost of HEDF manufacture. Not much improvement could be expected from reduction of the fixed expense components since these represent a small fraction of the total HEDF costs. The net variable operating costs for catalyst, chemicals, and utilities are the next smallest component over fixed expenses.

4.3 Effect of Crude Oil and By-Product Prices

To provide a sensitivity to feedstock and product prices, the crude oil and COALITE price was increased to \$30/B from \$18/B. The by-product, co-product, and utility prices in Table II were also increased by the same proportion. Since hydrogen is made from either natural gas or a fuel gas which is a by-product of these feedstocks, the hydrogen cost will roughly escalate with these prices also. Capital related costs remained constant in these sensitivity studies.

Table VIII and Figure 10 show the economic trends for the cases with these higher feed and product prices. These data can be compared with Table VII and Figure 5 that use the \$18/B price basis. The LP model predicts a small profit for the crude oil only case. Table VIII shows that the profit for the 40 MBCD COALITE feedstock cases shows an optimum in the intermediate range of jet fuel production, although the overall profit for the plant is still in the negative range. This optimum is confirmed by a break-even cost in that range that falls below the \$36.40/B base jet fuel price that is consistent with the \$30/B

Figure 7

Effect of Heating Value Specification

\$18/B Feedstock Cost

Figure 8
HEDF Cost vs Heating Value

Figure 9

HEDF Cost Breakdown

\$18/B Feedstock Cost

TABLE VIII
SENSITIVITY CASES ECONOMIC SUMMARY
\$30/B*Feedstock Price Basis

<u>Coalite</u> <u>MBCD</u>	<u>HS Crude</u> <u>MBCD</u>	<u>HED Jet</u> <u>MBCD</u>	<u>Profit</u> <u>MS/CD</u>	<u>Invest</u> <u>MMS</u>	<u>Equivalent \$/B</u> <u>Feed Cost Basis</u> <u>\$30/B Breakeven</u>	
40	0	30.0	-216.	443	43.60	37.10
40	0	16.0	-173.	420	47.20	35.00
40	0	13.1	-195.	387	51.20	36.30
40	0	0	-196.	398	-	25.10*
10	0	7.5	-130.	217	53.80	39.00
10	0	4.0	-122.	150	66.80	39.00
10	0	0	-111.	120	-	11.10*
0	40	0	7.	310	-	30.20*
40	0	22.3	-326.	499	51.10	42.30**
40	0	0	-196.	398	-	25.10*

* Based on feed rather than jet fuel.

** Based on 132,500 Btu/gallon specification.

Figure 10

Feedstock Rate Effect on Profit

\$30/B Feedstock Cost

feedstock cost. Since it is known that the hydroprocessing routes selected by the LP are capital intensive, raising product prices helps to encourage the more severe processing needed to produce HEDF by providing more net sales margin to cover capital recovery costs. However, as more HEDF production is required with a fixed COALITE feedrate, costs eventually rise because ultimately stocks are selected for which the incremental processing costs are higher than the jet fuel selling price.

The \$/B analysis of these cases is shown in Table VIII and Figure 11 for comparison with Table VII and Figure 6. Because the crude oil only case shows a slight profit, the breakeven \$/B for this case is above, rather than below, the \$30/B starting basis. COALITE is worth about \$5/B less than crude oil at this price level. This is about 17% below the crude oil price, as in the \$18/B cases.

4.4 HEDF Specifications

It was recognized that the HEDF specifications listed in Table III were somewhat arbitrary. Experience with petroleum based fuels and current fuel delivery systems was used to set their levels. If a HEDF was needed for some specialized application, a hardware solution could be found for most cases of non-compliance with the specifications listed. For example, if the new HEDF was produced that was more viscous than current specifications, a higher power fuel pump might be specified in the target engine instead. A case was run to see what HEDF would be produced if all specifications in Table III were waived except energy density.

Figure 12 shows that over 95% yield of HEDF could be obtained from the COALITE starting material. The processing options selected include the same sweetening and diolefin hydrotreating for the COALITE naphtha as in the baseline cases. The whole 300F+ COALITE stream is treated in an expanded-bed LC-Finer. The light LC-Finer naphtha is blended to gasoline, while the heavy LC-Finer naphtha is sold as reformer feed. The LC-Finer distillate is blended directly to HEDF. The LC-Finer bottoms stream is hydrocracked, and the hydrocracked products are blended in the same manner as the corresponding LC-Finer streams.

The properties of the HEDF produced are shown in Table IX. This HEDF exceeds the energy density specification and is much heavier than conventional jet fuel as the high viscosity and the 50% off at 540F shows. The viscosity is probably equivalent to around 5 cs at 68F, and would be slightly lower than diesel fuel. The high aromatics and low hydrogen contents suggest a fuel that would require major jet engine modifications. However, some intermediate processing between this case and those previously discussed may be worth pursuing to improve yields and energy density.

4.5 Effect of HEDF Fuel Yield

Figure 13 shows how the HEDF jet fuel cost from the 40 MBCD plant size varies as a function of HEDF yield for both feedstock costs. The HEDF cost falls as the yield increases. However, at best, the HEDF cost remains some \$8-10/B above the conventional jet fuel cost when the feedstock is priced at \$18/B. Figure 14 shows the same trends for the 10 MBCD size plant, with some of the 40MBCD points shown for reference as dashed lines. The smaller scale of the 10 MBCD plant always leads to higher HEDF costs.

TABLE IX
PRODUCT COMPARISON WITH SPECIFICATIONS
40 MBCD \$18/B Coalite

<u>Property</u>	<u>HED Jet Specif.</u>	<u>Max HEDF Product</u>	<u>All Specs Waived*</u>
Specific Gravity	.850 min	.868	.949
Sulfur, Wt %	.05 max	.032	.033
Heating Value, MBtu/gal	130 min	130.9	134.5
Freeze Point, °F	-50 max	-70	-45
Hydrogen Content, Wt %	12.5 min	13.2	10.7
Flash Point, °F	100 min	210	200
Aromatics Content, Wt %	25 max	25	79
	5 min		
Viscosity, cs at -4°F	12 max	8	24
	8 min		
Distillation, % off			
at 400°F	10 min	22	11
at 465°F	95 max	68	29
at 540°F	96 min	96	50
Paraffins Content, Wt %	50 max	49	21

* See Figure 12 for processing.

Figure 11

Effect of Feedstock Rate

40% HEDF Yield - \$30/B Feedstock Cost

FIGURE 12
MAXIMUM HED JET FUEL - NO SPECS

Figure 13

Effect of HEDF Yield

Figure 14

Effect of HEDF Yield

FIGURE 15

HEDF Cost SummaryHEDF Jet Fuel from Coalite

5.0 CONCLUSIONS/RECOMMENDATIONS

The major conclusions of the LP study when applied to refining COALITE liquids utilizing the current database obtained during the Task 3 screening efforts are as follows:

- o The COALITE (MCG) liquid feedstock cost is a major component of the HEDF transfer price. For a 40,000 bpcd refinery operated under the constraints of an \$18/bbl petroleum crude-based economy, the allowable COALITE cost with conventional products is estimated at \$12.30 per barrel. This represents only a \$3 per barrel disadvantage relative to high sulfur petroleum crude. When the refinery is allowed to produce HEDF products, the allowable COALITE cost decreases only to about \$10-11 per barrel.
- o Refining of COALITE to HEDF products is capital intensive and capital recovery costs can amount up to 25% of the HEDF transfer price.
- o Hydrogen-related costs, operating as well as capital costs, can represent up to 15-25% of the HEDF transfer costs suggesting the importance for development of catalysts to improve hydrogen utilization.
- o The economy of scale also has a great affect on HEDF transfer prices and refining capacities on the order of a hundred thousand barrels per day or greater should significantly reduce the per barrel cost of upgrading COALITE.
- o Determining the use value of a high density jet fuel could have a great impact on the processing alternatives and the allowable production costs of MCG liquids via Mild Coal Gasification. In this study, the baseline case assumed the HEDF product would have a value equivalent to that of conventional JP-8 fuel, namely, \$21.84/bbl. Raising product prices helps to encourage the more severe processing needed to produce HEDF by providing more net sales margin to cover capital recovery costs.
- o Current Task 3 screening efforts are aimed at producing HEDF products with higher energy densities with the target being 135,000 Btu/gal. If this target is achieved and the proper premium is placed on this type of fuel, when used either for military or commercial applications, an LP model study could indicate that the MCG to HEDF route might be economically viable in the near future.

6.0 REFERENCES

1. Yu, D., Xue, Z., Ma, X., Zhou, M., Jin, J., Shi, S., "Extraction of Diesel Oil from Middle Distillate in Coal Liquefaction by Hydrotreating and Hydrocracking," International Chemical Engineering, Vol. 30, No. 2, April 1990, p. 334-342.

7.0 ACKNOWLEDGEMENTS

We would like to acknowledge the technical guidance of Charles Byrer, DOE Contracting Officer's Technical Representative and Jim Burchfield of the Extraction Projects Management Division, both at the Morgantown Energy Technology Center. Amoco Oil Company would like to acknowledge the efforts of Dr. Joe Masin, Lead Process Engineer on the Task 4 LP modeling study and Dr. Dave Soderberg, AOC Subcontractor Project Manager. ABB Lummus Crest would like to acknowledge the efforts of Marvin Greene, Lummus' Project Manager/Principal Investigator.

8.0 APPENDIX

8.1 Sample LP Model Printout

... (NONE)

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE

COALITE MILD GASIFICATION SOURCE

1. 1. 1

NEW FACILITY INVESTMENT SUMMARY

PROCESS	SIZE/SD	\$/U/CD	INVESTMENT M\$				EXPENSES \$/CD	CAP REC \$/CD
			PLANT	OFFSITE	CATALYST	ROYALTY	TOTAL	
DIO NAP DIOLEFIN HYDR	870	-4.048	4,073	450	22		4,545	2,659
H2M H2 MAUFAC CAP'Y	215,926	-0.400	95,644	14,777	2,867		113,288	66,266
HCK DIST HYCK CAP'Y	45,481	-0.572	26,159	3,293	3,775		33,227	19,436
HVM FB HRT CAPACITY	30,365	-2.953	102,006	11,426	1,865		115,297	67,441
KWH POWER DIST CAP'Y	84,142	-0.079	8,645				8,645	5,057
LCF EB HRT CAPACITY	33,758	-2.819	106,220	12,140	4,147		122,507	71,658
ODS OIL DISTILL CAP'Y	43,956	-0.525	26,915	2,961			29,876	17,475
SUL SULFUR PLT CAP'Y	61	-158.353	9,436	948	46		10,430	6,101
TRT NAPHTHA SWEETENING	879	-0.791	694	146			840	491
SUB-TOTAL UNITS			379,791	46,140	12,722		438,653	256,582

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE

COALITE MILD GASIFICATION SOURCE

2. 1. 1

MATERIAL AND ECONOMIC BALANCE

PRODUCTS (WEIGHT BASIS)	\$/TONS	C/LB	QUANTITY		\$/CD	MTONS/YR	LIMITS		INCR PROFIT**	
			BBL/CD*	TONS/CD			MINIMUM	MAXIMUM	\$/TONS	C/LB
SUL SULFUR-ST	63.000	3.150		58	3,674	21				
LSA EXPANSION AND LOSS				-58		-21				
TOTAL PRODUCTION (WEIGHT)					3,674					

* ESTIMATED FROM WEIGHT AND SPECIFIC GRAVITY

** POSITIVE INCR PROFIT IMPLIES INCENTIVE FOR INCREASED ACTIVITY

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE

COALITE MILD GASIFICATION SOURCE

3. 1. 1

MATERIAL AND ECONOMIC BALANCE

PRODUCTS (VOLUME BASIS)	\$/BBL	C/GAL	QUANTITY		\$/CD	MBBL/YR	LIMITS		INCR PROFIT**	
			BBL/CD	TONS/CD*			MINIMUM	MAXIMUM	\$/BBL	C/GAL
SWM HYD SWEET NAPHTHA	25.400	60.477	792	119	20,117	289				
RFF REFORMER FEED	24.610	58.596	2,280	338	56,113	832				
JDA NAPH JET FUEL	24.200	57.620	12,189	1,640	294,978	4,449				
HEJ HIGH-DEM. JET FUEL	21.840	52.001	29,896	4,539	652,928	10,912	29,896	29,896	-13.020	-31.000

LPG	LPG/PROPANE	7.600	18.096	1,723	153	13,092	629
LOS	EXPANSION AND LOSS			-995			-363

TOTAL PRODUCTION (VOLUME)	45,885	1,037,227
---------------------------	--------	-----------

FEEDS (VOLUME BASIS)

NGS	NATURAL GAS-FOE B	-12.610	-30.024	5,885	783	-74,207	2,148			
CTE	COALITE LIQUID	-18.000	-42.858	40,000	7,001	-720,000	14,600	40,000	40,000	1.864 4.437

TOTAL FEEDSTOCKS (VOLUME)	45,885	-794,207
---------------------------	--------	----------

PRODUCTION MARGIN	243,019
-------------------	---------

* ESTIMATED FROM VOLUME AND SPECIFIC GRAVITY

** POSITIVE INCR PROFIT IMPLIES INCENTIVE FOR INCREASED ACTIVITY

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE

COALITE MILD GASIFICATION SOURCE

4. 1. 1

UTILITY PURCHASES AND SALES

	PURCHASES	COST	TOTAL	SALES	PRICE	TOTAL	INCR VAL
CCM CAT/CHEM DOLLARS	28,191	-2.560	-72,169				-2.560
FUL FUEL MM BTU	40,876	-2.000	-81,753		1.999		-2.000
H2O COOL H2O M GALS	105,885	-0.200	-21,137				-0.200
KWH POWER KWH							-0.053
PWR POWER KWH	1,221,591	-0.050	-61,080				-0.050
STM HP STEAM M LBS		-5.000					-4.850
STM MP STEAM M LBS		-4.400					-2.650
STL LP STEAM M LBS		-4.250					-1.000
H2P PROC H2O M GALS	3,666	-4.000	-14,662				-4.000
TEL TEL G-GL/BBL		-0.280					0.
PPP POOLING RECURSION		-100.000					-33.928

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FINAL TOTAL	-250,800
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HIGH ENERGY DENSITY FUELS FROM SYNCRUDE

COALITE MILD GASIFICATION SOURCE

5. 1. 1

OVERALL ECONOMIC SUMMARY

	\$/CD	N\$/YR
FROM WEIGHT BASIS SUMMARY		
SALES	3,674	
PURCHASES		
NET	3,674	
FROM VOLUME BASIS SUMMARY		
SALES	1037,227	
PURCHASES	-794,207	
NET	243,019	
GROSS OPERATING REVENUE	246,694	90,043
UTIL & MISC OPER COSTS	-250,800	-91,542
NET OPERATING REVENUE	-4,106	-1,499
NEW EQUIPMENT EXPENSES		
MAINTENANCE	-24,036	
INS,TAX,OHD	-24,036	
FIXED OPER COST	-5,943	
TOTAL UNITS	-54,014	-19,715
NET OPER PROFIT	-58,120	-21,214
CAPITAL RECOVERY		
UNITS	-256,582	-93,652
TOTAL	-256,582	-93,652
NET REVENUE	-314,702	-114,866

ENERGY DENSITY FUELS FROM SYNCRUDE COALITE MILD GASIFICATION SOURCE

6. 1. 1

SPECIFICATION BLENDS

LPG/PROPANE (LPG)

COMPOSITION REPORT

COMPONENT TO BLEND	VOLUME BBL/CD	VOLUME PCT COMPOSITION
-----------------------	------------------	---------------------------

C3S PROPANE	1,723	100.0
	-----	-----
TOTAL	1,723	100.0

QUALITY REPORT

PROPERTY	MINIMUM	QUALITY	MAXIMUM	INCR VAL
-----	-----	-----	-----	-----

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE COALITE MILD GASIFICATION SOURCE

6. 2. 1

SPECIFICATION BLENDS

HYD SWEET NAPHTHA (SWN)

COMPOSITION REPORT

COMPONENT TO BLEND	VOLUME BBL/CD	VOLUME PCT COMPOSITION
-----	-----	-----
SWH HYDRT SWEETEN MAP	792	100.0
	-----	-----
TOTAL	792	100.0

QUALITY REPORT

PROPERTY	MINIMUM	QUALITY	MAXIMUM	INCR VAL
-----	-----	-----	-----	-----

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE COALITE MILD GASIFICATION SOURCE

6. 3. 1

SPECIFICATION BLENDS

REFORMER FEED (RFF)

COMPOSITION REPORT

COMPONENT	VOLUME	VOLUME PCT
-----------	--------	------------

	TO BLEND	BBL/CD	COMPOSITION
L01	300-400 CUT LCF	818	35.9
L08	350-400 CUT FB HI	1,462	64.1
	TOTAL	2,280	100.0

QUALITY REPORT

PROPERTY	MINIMUM	QUALITY	MAXIMUM	INCR VAL
----------	---------	---------	---------	----------

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE COALITE MILD GASIFICATION SOURCE

6. 4. 1

SPECIFICATION BLENDS

NAPH JET FUEL (JP4)

COMPOSITION REPORT

COMPONENT TO BLEND	VOLUME BBL/CD	VOLUME PCT COMPOSITION
L03 275-400 CUT FB	823	5.1
L08 350-400 CUT FB HI	1,976	16.2
N01 LCF C5-300	1,165	9.6
N02 FB C5-275	7,055	57.9
N03 HCM C5-300	1,370	11.2
TOTAL	12,189	100.0

QUALITY REPORT

PROPERTY	MINIMUM	QUALITY	MAXIMUM	INCR VAL
----------	---------	---------	---------	----------

SPG	SPECIFIC GRAVITY	0.751	0.769	0.802	
SUL	SULFUR WT%		0.003	0.400	
ARO	AROMATICS		22.7	25.0	
RVP	REID VAPOR PRESS	2.000	2.000	3.000	-0.1367
290	PERCENT OFF 290F	20.0	73.9		

370 PERCENT OFF 370F 50.0 87.9
 470 PERCENT OFF 470F 90.0 100.0

API API GRAVITY 52.6 (RECALCULATED FROM SPG)

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE COALITE MILD GASIFICATION SOURCE

6. 5. 1

SPECIFICATION BLENDS

HIGH-DEN. JET FUEL (HEJ)

COMPOSITION REPORT

COMPONENT TO BLEND	VOLUME BBL/CD	VOLUME PCT COMPOSITION
005 LCF 300-575	2,706	9.1
009 FB 275-575	6,713	22.5
101 400-500 CUT LCF	0	0.0
102 400-550 CUT HCK	1,542	5.2
103 400-500 CUT FB	1,079	3.6
104 400-500 CUT FB	4,560	15.3
105 400-500 CUT LCF	1,227	4.1
108 400-500 CUT FB HI	7,735	25.9
104 275-400 CUT FB	2,717	9.1
105 500-575 CUT LCF	1,321	4.4
109 500-575 CUT FB	296	1.0
TOTAL	29,896	100.0

QUALITY REPORT

PROPERTY	MINIMUM	QUALITY	MAXIMUM	INCR VAL
PG SPECIFIC GRAVITY	0.850	0.868		
SUL SULFUR WTS		0.032	0.050	
ARO AROMATICS	5.0	25.0	25.0	0.1241
PAR PARAFFINS		49.5	50.0	
HYD HYDROGEN WTS	12.5	13.2		
PI FLASH POINT INDEX				
00 PERCENT OFF 400F	10.0	22.3		
65 PERCENT OFF 485F		67.7	95.0	
40 PERCENT OFF 540 F	98.0	98.0		-0.4797
JI POUR/ FREEZE INDEX				
22 VISC J FACTOR 122F				-0.4301
TV HT VALUE,MMBTU/BBL	5.5	5.5		

API API GRAVITY 31.6 (RECALCULATED FROM SPG)

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE COALITE MILD GASIFICATION SOURCE

6. 6. 1

BLEND GROUP SUMMARY, BBL/CD

GASOLINE BLENDS

	GUR	GUP	GLR	SWN	RFF	TOTALS	
	---	---	---	---	---	---	
300-400 CUT LCF					818	818	L01
350-400 CUT FB HI					1,462	1,462	L08
HYDRT SWEETEN NAP	0	0	0	792		792	SWH
	-----	-----	-----	-----	-----		
TOTALS	0	0	0	792	2,280		

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE COALITE MILD GASIFICATION SOURCE

6. 7. 1

BLEND GROUP SUMMARY, BBL/CD

DISTILLATE BLENDS

	KER	PDS	FO2	JP4	JP8	HED	HEJ	TOTALS	
	---	---	---	---	---	---	---	---	
LCF 300-575		0	0	0	0	0	2,706	2,706	D05
FB 275-575		0	0	0	0	0	6,713	6,713	D09
400-500 CUT LCF		0	0	0	0	0	0	0	H01
400-550 CUT HCK		0	0	0	0	0	1,542	1,542	H02
400-500 CUT FB		0	0	0	0	0	1,079	1,079	H03
400-500 CUT FB		0	0	0	0	0	4,560	4,560	H04
400-500 CUT LCF		0	0	0	0	0	1,227	1,227	H05
400-500 CUT FB HI		0	0	0	0	0	7,735	7,735	H08
275-400 CUT FB		0	0	623	0	0	0	623	L03
275-400 CUT FB		0	0	0	0	0	2,717	2,717	L04
350-400 CUT FB HI		0	0	1,976	0	0	0	1,976	L09
LCF C5-300				1,165				1,165	N01
FB C5-275				7,055				7,055	N02
HCK C5-300				1,370				1,370	N03
500-575 CUT LCF		0	0	0	0	0	1,321	1,321	T05
500-575 CUT FB		0	0	0	0	0	296	296	T09
	-----	-----	-----	-----	-----	-----	-----		
TOTALS	0	0	0	12,189	0	0	29,896		

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE COALITE MILD GASIFICATION SOURCE

6. 8. 1

BLEND GROUP SUMMARY, BBL/CD

RESID FUELS - SALES AND PLANT FUEL

PRF	TOTALS
---	-----

COALITE LIQUID		0				CTE
ETHANE		0				C2S
ETHYLENE		0				C2W
PROPANE		0		0	0	-716 C3S
PROPYLENE		0				C3W
BUTYLENES		0				C4U
C5- FRACT OF ILL						C5M
C6+ FRACT OF LCM						C6P

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE

COALITE MILD GASIFICATION SOURCE

8. 1. 2- 2

UNIT OPERATIONS RECAP - VOLUME BASIS - BBL/CD

[illegible]

400-500 CUT FB				H03
400-500 CUT FB				H04
400-500 CUT LCF				H05
400-500 CUT HT CKR				H06
400-500 CUT FB LO				H07
400-500 CUT FB HI				H08
400-500 CUT FB				H09
HYCKD JPA			0	H43
160-... HYCKD GASO				0 H8M
HYCKD JP8				0 H83
ISOBUTANE	0	-297	0	0 IC4

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE

COALITE MILD GASIFICATION SOURCE

8. 1. 3-2

UNIT OPERATIONS RECAP - VOLUME BASIS - BBL/CD

[illegible]

PURCHASED I BUTANE	0	PI4
BUTYLENE POLYGAS		PLB
PROPYLENE POLYGAS		PLP
PHENOL	0 0	PNL
PURCHASED N BUTANE	0	PN4
RAFFINATE-CS+		RAF
AROMATICS REF FEED		RFA
SWEETEN NAPHTHA		SWE
HYDRT SWEETEN NAP		SWH
TERT BUTANOL		TBA
TOLUENE		TOL
500-600 CUT LCF		0 T01
550-750 CUT HCK		9,252 T02
500-575 CUT FB		2,192 T03

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE

COALITE WILD GASIFICATION SOURCE

8. 1. 4- 2

UNIT OPERATIONS RECAP - VOLUME BASIS - BBL/CD

	VDYN	VEXT	VFCH	VFRC	VFL4	VH2N	VHCG	VHC4	VHCK	
	----	----	----	----	----	----	----	----	----	
500-600 CUT FB										2,426 T04
500-575 CUT LCF										0 T05
500-575 CUT HT CKR										0 T06
500-650 CUT FB LO										0 T07
500-650 CUT FB HI										6,016 T08
500-575 CUT FB										-296 T09
REFORMER POLYMER										UFP
WHOLE REFORMATE										WAR
XYLENE										XYL
XYLENOLS				0						XYO
300- COALITE										30W
300+ COALITE										30P
650+ COALITE										65P
UNLEADED REG GASO										GUR
UNLEADED PREM GASO										GUP
UNLEADED MID-GRADE										GLR
HYD SWEET NAPHTHA										SWN
REFORMER FEED										RFF
NAPH JET FUEL										JP4
JET FUEL										JP0
HIGH-DEN. JET FUEL										HEJ
HIGH-DEN. DIESEL										HED
KERO/JET FUEL										KER
PREMIER DSL FUEL										PDS
FURNACE OIL										FO2
PLANT RESID FUEL										PRF

TOTALS

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE

COALITE WILD GASIFICATION SOURCE

8. 1. 1- 3

UNIT OPERATIONS RECAP - VOLUME BASIS - BBL/CD

	VHYM	VISM	VLCF	VNDS	VNHA	VODS	VPCU	VPFL	VPSA
	FB HYDRTRT	ISOMERIZ'N	EB HYDRTRT	NAPH DIST	NAPH HYDRT	OIL DISTIL	C3U CONC'N	PLANT FUEL	H2 PURIFIC
LS 1984 TEXAS CITY									LTC
HS 1984 TEXAS CITY									TCH
LPG/PROPANE									LPG
PS C3 & LTR (LIQ) #1								0	1FG
PS C3 & LTR (LIQ) #2								0	2FG
VIRGIN PENTANES #1		0			0				1LL
VIRGIN PENTANES #2		0			0				2LL
3# RVP NAPHTHA #1					0				1IS
3# RVP NAPHTHA #2					0				2IS
REFORMER FEED #1					0				1IIS
REFORMER FEED #2					0				2HS
REFORMER PFB #1					0				1HS
REFORMER PFB #2					0				2HS
JET A #1									1SK
JET A #2									2SK
FO 650 EP #1									1SR
FO 650 EP #2									2SR
ATMOS RESID 650+ #1									1RC
ATMOS RESID 650+ #2									2RC
LVGO #1									1LV
LVGO #2									2LV
HVGO #1									1HV
HVGO #2									2HV
VAC RESID #1									1VA
VAC RESID #2									2VA
ANYLENE ALKY-CG1									AA1
ANYLENE ALKY-CGH									AA2
C3U ALKYLATE									AL3
C4U ALKYLATE									AL4
BENZENE									BNZ
DDU NAPHTHA									CFG
LCN HH SEV C5-230									CGH
LCN LO SEV C5-230									CG1
HCN HH SEV 230-430					0				CNH
HCN LO SEV 230-430					0				CN1
FUEL COKE									COK
LCO LO SEV 430-700									CO1
LCO HI SEV 430-700									CO2
CRESYLIC ACIDS									CSA
300-650 COALITE	20,000					-20,000			CTD
COALITE LIQUID						40,000			CTE
ETHANE								0	C2S
ETHYLENE								0	C2U
PROPANE	-166		-841		0		0	0	C3S
PROPYLENE							0	0	C3U
BUTYLENES								0	C4U
C5- FRACT OF 1LL					0				C5H
C6+ FRACT OF LCN									C6P

INIT OPERATIONS RECAP - VOLUME BASIS - BBL/CD

[illegible]

ISOBUTANE	0	0	297	IC4
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HIGH ENERGY DENSITY FUELS FROM SYNCRUDE COALITE MILD GASIFICATION SOURCE 8. 1. 3-3

UNIT OPERATIONS RECAP - VOLUME BASIS - BBL/CD

[illegible]

TOLUENE			TOL
500-600 CUT LCF	-0		T01
550-750 CUT HCK	-9,252		T02
500-575 CUT FB	-2,192		T03

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE COALITE MILD GASIFICATION SOURCE 0. 1. 4- 3

UNIT OPERATIONS RECAP - VOLUME BASIS - BBL/CD

	VHYN	VISM	VLCF	VNDS	VNHA	VODS	VPCU	VPFL	VPSA	
	----	----	----	----	----	----	----	----	----	
300-600 CUT FB						-2,426				T04
500-575 CUT LCF						-1,321				T05
500-575 CUT HT CKR						0				T06
500-650 CUT FB LG						0				T07
500-650 CUT FB HI						-6,016				T08
500-575 CUT FB						0				T09
REFORMER POLYMER										UFP
WHOLE REFORMATE										WAR
XYLENE										XYL
XYLENOLS										XYO
300+ COALITE						-800				30M
300+ COALITE				0		0				30P
650+ COALITE			19,200			-19,200				65P
UNLEADED REG GASO										GUR
UNLEADED PREM GASO										GUP
UNLEADED MID-GRADE										GLR
HYD SWEET NAPHTHA										SWM
REFORMER FEED										RFF
NAPH JET FUEL										JP4
JET FUEL										JP8
HIGH-DEN. JET FUEL										HEJ
HIGH-DEN. DIESEL										HED
KERO/JET FUEL										KER
PREMIER DSL FUEL										PDS
FURNACE OIL								0		FO2
PLANT RESID FUEL										PRF

TOTALS

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE COALITE MILD GASIFICATION SOURCE 0. 1. 1- 4

UNIT OPERATIONS RECAP - VOLUME BASIS - BBL/CD

VRFA	VRTT
REFORMER A	SWEETENING
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LS 1984 TEXAS CITY	LTC
HS 1984 TEXAS CITY	TCH
LPG/PROPANE	LPG
PS C3 & LTR (LIQ) #1	1FG
PS C3 & LTR (LIQ) #2	2FG

CS/C6 ISOMERATE			ISM
HTRT CKR GAS OIL			KGH
HTRT CKR GAS OIL			KGL
CD CKR 575+ GASOIL			KGO
CD CKR 300-575			KKD
CD CKR C5-300 NAPH			KKN
COKER NAPH HSEV HT			KNH
COKER NAPH LSEV HT			KNL
LS CKR 360-650			LKE
LS CKR 650-1000			LKF
LS HVY CKR NAPHTHA			LKG
LS LT CRK NAPHTHA			LKK
EXPANSION AND LOSS	0	-8	LOS
LT HYDCKD CRKD FD			LUC
C5-180 HYCKD GASO			LUG
HYDRCKD KEROSENE			LUK
LT HYDCKD VIRG FD			LUN
300-400 CUT LCF			LO1
275-400 CUT FB			LO3
275-400 CUT FB			LO4
300-400 CUT HT CKR			LO6
350-400 CUT FB LO			LO7
350-400 CUT FB HI			LO8
275-400 CUT FB			LO9
M,P-CRESOL			MCR
METHANOL			MEQ
MTBE			MT6
NORMAL BUTANE	0		NCA
NATURAL GAS-FOE B			NGS
NEUTRAL OIL			NTP
LCF C5-300			NO1
FB C5-275			NO2
HCK C5-300			NO3
O-CRESOL			OCR
POLY GRADE C3U			PGP
PURCHASED I BUTANE			PI4
BUTYLENE POLYGAS			PLB
PROPYLENE POLYGAS			PLP
PHENOL			PNL
PURCHASED N BUTANE			PN4
RAFFINATE-C5+			RAF
AROMATICS REF FEED	0		RFA
SWEETEN NAPHTHA		-792	SWE
HYDRT SWEETEN NAP			SWH
TERT BUTANOL			TBA
TOLUENE			TOL
500-600 CUT LCF			TO1
550-750 CUT HCK			TO2
500-575 CUT FB			TO3

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE

COALITE MILD GASIFICATION SOURCE

8. 1. 4- 4

UNIT OPERATIONS RECAP - VOLUME BASIS - BBL/CD

VRFA

VTRT

500-600 CUT FB			T04
500-575 CUT LCF			T05
500-575 CUT HT CKR			T06
500-650 CUT FB LO			T07
500-650 CUT FB HI			T08
500-575 CUT FB			T09
REFORMER POLYMER	0		UFP
WHOLE REFORMATE	0		WAR
XYLENE			XYL
XYLENOLS			XYO
300+ COALITE		800	30M
300+ COALITE			30P
650+ COALITE			65P
UNLEADED REG GASO			GUR
UNLEADED PREM GASO			GUP
UNLEADED MID-GRADE			GLR
HYD SWEET NAPHTHA			SWN
REFORMER FEED			RFF
NAPH JET FUEL			JP4
JET FUEL			JP8
HIGH-DEN. JET FUEL			HEJ
HIGH-DEN. DIESEL			HED
KERO/JET FUEL			KER
PREMIER DSL FUEL			PDS
FURNACE OIL			FO2
PLANT RESID FUEL			PRF

TOTALS

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE	COALITE WILD GASIFICATION SOURCE	9. 1. 1
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OPERATIONS SUMMARY - WEIGHT BASIS - TONS/CO

	<u>PURCHASES</u>	<u>UNITS</u>	<u>REC BLN</u>	<u>SPEC BLN</u>	<u>SALES</u>	<u>TRANSFER</u>	<u>INVENTORY</u>	<u>TOTALS</u>	<u>INCR VAL, \$</u>
EXPANSION AND LOSS		58			-58			-0 LSA	
SULFUR-ST		-58			58			0 SUL	-63.000

TOTALS

HIGH ENERGY DENSITY FUELS FROM SYNCRUDE	COALITE WILD GASIFICATION SOURCE	10. 1. 1
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OPERATIONS SUMMARY - VOLUME BASIS - BBL/CO

	<u>PURCHASES</u>	<u>UNITS</u>	<u>REC BLN</u>	<u>SPEC BLN</u>	<u>SALES</u>	<u>TRANSFER</u>	<u>INVENTORY</u>	<u>TOTALS</u>	<u>INCR VAL, \$</u>
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END

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