DOE/PC/91029--T13

Section 1

Introduction and Summary

Contract No. DE-AC22-93PC91029

This report is Bechtel's twelth quarterly technical progress report and covers the period of July 1, 1996 through September 30, 1996.

1.1 Introduction

Bechtel, with Southwest Research Institute, Amoco Oil R&D, and the M.W. Kellogg Co. as subcontractors, initiated a study on November 1, 1993, for the U.S. Department of Energy's (DOE's) Pittsburgh Energy Technology Center (PETC) to determine the most cost effective and suitable combination of existing petroleum refinery processes needed to make specification transportation fuels or blending stocks, from direct and indirect coal liquefaction product liquids. This 47-month study, with an approved budget of $4.4 million dollars, is being performed under DOE Contract Number DE-AC22-93PC91029.

A key objective is to determine the most desirable ways of integrating coal liquefaction liquids into existing petroleum refineries to produce transportation fuels meeting current and future, e.g. year 2000, Clean Air Act Amendment (CAAA) standards. An integral part of the above objectives is to test the fuels or blends produced and compare them with established ASTM fuels. The comparison will include engine tests to ascertain compliance of the fuels produced with CAAA and other applicable fuel quality and performance standards.

The final part of the project includes a detailed economic evaluation of the cost of processing the coal liquids to their optimum products. The cost analyses is for the incremental processing cost; in other words, the feed is priced at zero dollars. The study reflects costs for operations using state of the art refinery technology; no capital costs for building new refineries is considered. Some modifications to the existing refinery may be required. Economy of scale dictates the minimum amount of feedstock that should be processed.

To enhance management of the study, the work has been divided into two parts, the Basic Program and Option 1.

The objectives of the Basic Program are to:

- Characterize the coal liquids
- Develop an optimized refinery configuration for processing indirect and direct coal liquids
- Develop a LP refinery model with the Process Industry Modeling System (PIMS) software.

The work has been divided into six tasks.

Task 1 - Development of a detailed project management plan for the Basic Program
Task 2 - Characterization of four coal liquid feeds supplied by DOE
Task 3 - Optimization of refinery processing configurations by linear programming
Task 4 - Pilot plant analysis of critical refinery process units to determine yield, product quality and cost assumptions. Petroleum cuts, neat coal liquids, and coal liquids/petroleum blends will be processed through the following process units: reforming, naphtha and distillate hydrotreating, catalytic cracking and hydrocracking.

DISCLAIMER

- Task 5 -Development of the project management plan for Option 1
- Task 6 - Project management of the Basic Program and Option 1

The objectives of Option 1 are to:

- Confirm the validity of the optimization work of the Basic Program
- Produce large quantities of liquid transportation fuel blending stocks
- Conduct engine emission tests
- Determine the value and the processing costs of the coal liquids

This will be done by processing the coal liquids as determined by the optimization work, blending and characterizing the product liquids, and running engine emission tests of the blends. Option 1 has been divided into three tasks.

- Task 1 -Based on the pilot plant and linear programming optimization work of the Basic Program, production runs of pilot plants (hydrotreating, reforming, catalytic cracking, and hydrocracking) will be conducted to produce sufficient quantities for blending and engine testing.
- Task 2 -The pilot plant products will be blended, characterized, and engine tested
- Task 3 -An economic analysis will be conducted to determine the costs of processing the coal liquids through the existing refinery

Table 1-1 shows which organization has the primary responsibility for each task.

1.2 Summary

The major efforts conducted during the third quarter of 1996 were in the areas of:

- Option 1 hydrotreating production runs
- Option 1 FCC production run

Table 1-1 Project Task Primary Responsibility Chart

Task	Description	Bechtel	SwRI	Amoco	Kellogg
1	Project Management Plan (PMP) development	x			
2	Feed characterization		x		
3	Linear programming	x			
4	Pilot plant analysis -				
	Cat cracking of DL liquids				x
	Cat cracking of indirect wax			x	
	Hydrocracking of wax			x	
	Fractionation, reforming, hydrotreating, etc.		x		
5	Option 1 PMP development	x			
6	Project management	x			
Option 1 - Task 1	Pilot plant production -				
	Cat cracking of DL liquids and wax				x
	All other production work		x		
Option 1 - Task 2	Fuel blending, characterizing, engine testing		x		
Option 1 - Task 3	Economic analysis	x			

- x = key participant

Section 2

SwRI Activities

2.0 Hydrotreating of DL2 Distillates for Option 1 Test Fuel Blending

Two hydrotreating runs for Option 1 were completed. The runs were made in support of the objective to produce working quantities of transportation fuel blending stocks using coal liquids for the engine performance and emission testing. Information developed in Task 4 provided inputs to the Process Industry Modeling System (PIMS) linear program which in turn provided the feed compositions and processing objectives. More details are provided in the "Option 1, Direct Liquid 2, Fuel Production Work Plan" (Option 1 Plan) available in draft form, June 1996.

2.1 Petroleum Light Distillate Hydrotreating for Option 1

In SwRI run 58, a petroleum light distillate was hydrotreated, primarily to remove sulfur. The run was made in response to the objectives listed in table 5 of the Option 1 Work Plan using the feed FL-2342, Amoco designation CRU Feed LMD (straight run), obtained from Amoco. The hydrotreating in the large reactor system, guard-bed plus main reactor, produced 24 gallons in a short run. Table 2-1 provides the processing conditions obtained from the operator logs, and Table 2-2 shows the feed and product properties. The processing reduced the sulfur from about 1500 PPM to less than 10 PPM.

2.2 Petroleum Heavy Distillate Hydrotreating for Option 1

In SwRI run 59, a blend of petroleum heavy distillates was hydrotreated, also to remove sulfur. The run was made in response to the objectives listed in table 6 of the Option 1 Work Plan. The feed blend contained 36.5 vol.% FL-2338, DDU Feed Light Coker Gas Oil, and 63.5 vol.% FL-2341, #11 Pipe Still LVGO, both obtained from Amoco. The two components were blended by weight in a stainless steel tank to provide 78 gallons of feed prior to starting the hydrotreater.

The hydrotreating in the large reactor system produced 58 gallons. The start-up and off-specification material accounted for the remainder. Table 2-3 gives the processing conditions obtained from the operator logs, and Table 2-4 shows the feed and product properties. The processing reduced the sulfur from about 10,400 PPM to less than 10 PPM.

SwRI Activities

Table 2-1 Processing Conditions for Petroleum Light Distillate Hydrotreating

Average Temperature, °F	563
Reactor Pressure, Psig	500
Feed LHSV (Gal Feed/Gal Cat/Hr)	1.46
Hydrogen Contacting Rate, SCFB	1604

Table 2-2 Feed and Product Properties for Petroleum Light Distillate Hydrotreating

Property	Method	Feed, FL-2342	Product, FL-2605
Density, g/mL, 15 °C	D 4052		0.8059
Specific Gravity, 60 F		0.8100	0.8063
API Gravity		43.2	44.0
Sulfur	ICP	1490	9.3
Hydrogen, M%	D 4808	13.9	14.0
Hydrocarbon Types, Vol%:			
Saturates	D 1319	NM	84.7
Olefins		NM	0.1
Aromatics		NM	14.3
Cetane Index	D 976	NM	44.5
Cetane Index	D 4737	NM	46.0
Smoke Point, mm	D 1322	NM	24.7
Pour Point, °F(°C)	D 97	NM	-49(-45)
Distillation, °F at Vol.%			
IBP/5	D 86	NM	309/347
10/20		NM	356/370
30/40		NM	382/393
50/60		NM	403/417
70/80		NM	431/450
90/95		NM	470/487
EP		NM	511
NM - Not measured.			

Table 2-3 Processing Conditions for Petroleum Heavy Distillate Hydrotreating

Average Temperature, °F	647
Reactor Pressure, Psig	700
Feed LHSV (Gal Feed/Gal Cat/Hr)	1.41
Hydrogen Contacting Rate, SCFB	1970

Table 2-4 Feed and Product Properties for Petroleum Heavy Distillate Hydrotreating

Property	Method	Feed, Blend	Product, FL-2614
Density, g/mL, 15°C	D 4052	0.8599	0.8398
Specific Gravity, 60 °F		0.8604	0.8393
API Gravity		33.0	37.0
Sulfur	ICP	10,400	6.3
Hydrogen, M%	D 4808	12.75	13.4
Hydrocarbon Types, Vol%:			
Saturates	D 1319	NM	56.5
Olefins		NM	1.0
Aromatics		NM	42.5
Cetane Index	D 976	NM	51.2
Cetane Index	D 4737	NM	51.7
Pour Point, °F(°C)	D 97	NM	+1.4(-17)
Distillation, °F at Vol.%			
IBP/5	D 86	NM	328/417
10/20		NM	437/468
30/40		NM	486/504
50/60		NM	517/531
70/80		NM	544/560
90/95		NM	580/597
EP		NM	618
NM - Not measured.			

Section 3

Bechtel Activities

There was no project activity for this reporting period.

Section 4

Amoco Activities

There was no project activity for this reporting period.

Section 5

M.W. Kellogg Activities

5.0 Option 1 FCC Production Run

During this quarter, the FCC1 pilot plant was run for a total of 145 good hours, processing about 80 gallons of feed and completing the Option 1 production portion of the FCC program. Feedstock is 43.1 wt% DL2 heavy distillate (F-9819) and 56.9 wt% Amoco vacuum gas oil (F-9888). Four batches of feed were prepared ranging from 25.0-25.3°API.

Run conditions with the 80-foot riser were:

Catalyst/oil ratio, lb/lb	10.0
Riser temperature, °F	985
Catalyst preheat temperature, °F	1250

Coke yields averaged 4.44 ± 0.14 wt%. Figure 5- 1 shows the coke yields over the 145 hours of good operation.

Two two-hour periods were worked up for official yields, one early in the production run (Run H-2038-4, August) and the other in the second half (Run H-2038-4A, September). Conversions (wt% basis GCSD) and coke yields for the two periods were 75.6 & 4.4 and 76.0 & 4.3, respectively.

Table 5-1 lists the operating conditions for the two runs. Operating targets were successfully obtained. Figure 5- 2 plots some key temperatures: catalyst temperature, riser average temperature, and oil inlet temperature, over the 145 good hours of operation. Averages for these variables were:

Catalyst Temperature	1251 ± 3°F
Riser Average Temperature	984 ± 1°F
Oil Inlet Temperature	232 ± 4°F

Table 5-2 shows the yields with blended feed in runs H-2038-4 and 4A and compares them with weighted averages of runs on the two individual components of the blend. Agreement is quite close, as had been observed in previous work on both DL2 and DL1. (Gas yields for H-2038-1 and 2 have been adjusted due to a correction in the response factor for ethylene. Only the ethylene yield is significantly different than had been previously reported.)

Table 5-3 presents the yields including a componential breakdown of the C_5 products. These were calculated from the PIANO results from samples of the products gases and the undebutanized product liquids taken directly from the FCC pilot plant during the official periods of runs H-2038-4 and 4A. Isopentane is, by far, the most predominant C_5 component.

5.1 Batch Distillation of FCC Products

The objective of the FCC product distillation program was to create blendstocks that will be used to produce gasoline, jet and diesel fuels for the engine performance and emission testing. These FCC product cuts will be combined with other blendstocks based on recipes from the linear programming analysis.

M.W. Kellogg Activities

The remaining product liquids from the 145 good hours of FCC pilot plant operation were combined and charged to the batch still. The batch still consists of a 55-gallon reboiler, a 6-inch diameter by 15-foot stainless steel column packed with 1/2-inch intalox saddles, an overhead condenser with reflux splitter, and a train of product coolers to collect the distillate.

To debutanize, the still was run on total reflux with maximum cooling on all condensers. It was assumed that the C_4's would escape to the flare since there is no gas collection vessel on the still similar to those on the small debutanization still in our laboratory.

After the unit temperature profile stabilized, indicating that liquid was now refluxing, the reflux timer was set at 5:1 and the light naphtha cut was taken up to a vapor temperature of 120°F. A heavy naphtha cut was then made up to a vapor temperature of 430°F.

After cooling the reboiler contents, distillation was resumed at 20 mm Hg vacuum with reflux set at 2:1. The light gas oil cut ended at a vapor temperature of 415°F, equivalent to 650°F at atmospheric pressure. the 650°F+ heavy gas oil was recovered upon dumping the reboiler.

The batch still results, % yields by weight were:

IBP-120°F	5.18
120-430°F	58.24
430-650°F	23.27
650°F+	8.31
Total Recovered	95.00
Expected Loss on Debut	2.86 (Based on 2 samples debutanized in the Lab)
Material Balance	97.86

For comparison, the expected yields, basis GCSD were:

IBP-C_4	2.15
C_5 -120°F	5.92
120-430°F	57.48
430-650°F	27.65
650°F+	6.80

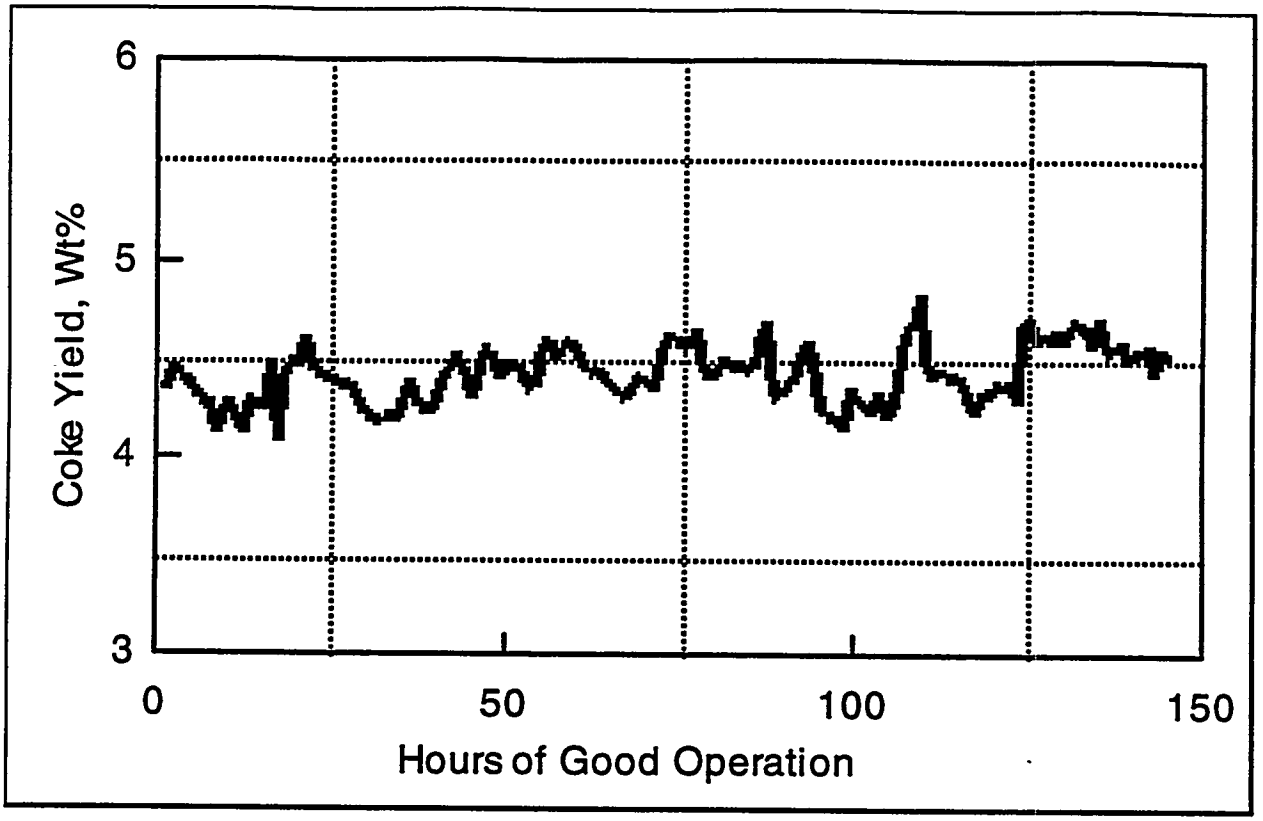
Overall the yields look good. PIANO analysis of the light and heavy naphthas showed that only about 77% of the expected amount of C_5's was recovered. About 87% of this was recovered in the C_5 -120°F cut. Losses of isopentane during sample handling may account for much of the missing material.

The C_5 -120°F cut was about 6.6 wt% C_4's, 90.4 wt% C_5's, and 3.0 wt% C_6's. This is comparable to analyses made on previous C_5 -120°F cuts made in the lab TBP still on FCC product after debutanization in the lab debut still.

All four liquid products from the batch still were shipped to Southwest Research Institute.

M.W. Kellogg Activities

Figure 5-1 Option 1 FCC Production Run Coke Yields



M.W. Kellogg Activities

Figure 5-2 Option 1 FCC Production Run Operations

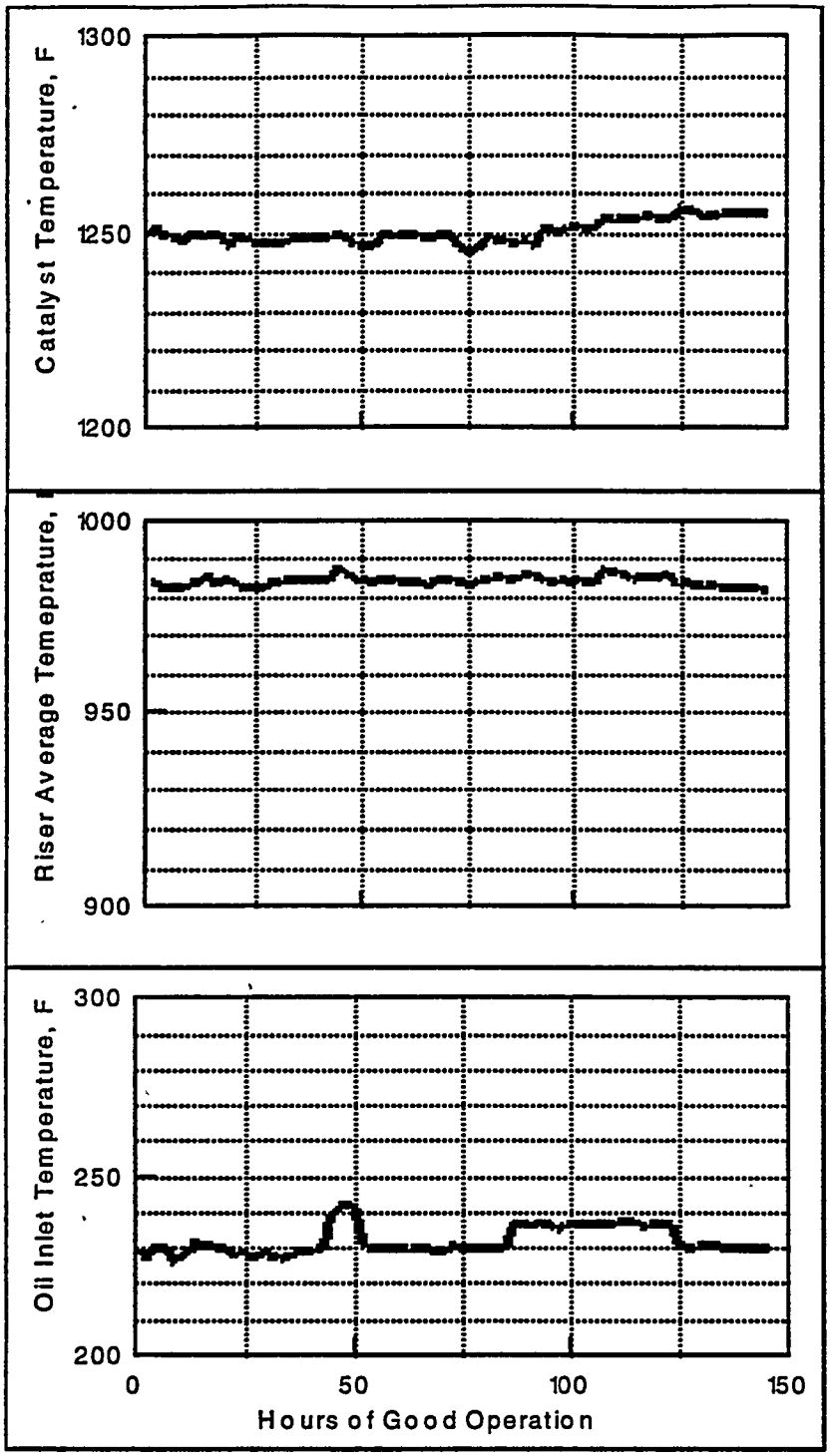


Table 5-1
Option 1 FCC Production Run
Operating Conditions

FEEDSTOCK:	F-9819/9888	F-9819/9888
CATALYST:	F-9804	F-9804
RUN NUMBER: H-2038-	4	4A
DATE:	8/13/96	9/5/96
OIL FEED RATE , GRAM/HR	1920	1935
CATALYST RATE , LB/HR	44.0	45.0
CATALYST/OIL RATIO	10.4	10.6
MATERIAL BALANCE:		
CLOSURE, WT%	101.87	101.15
GASOLINE, WT%	50.08	51.00
CONVERSION, WT%	75.63	76.05
COKE YIELD, WT%	4.42	4.27
SELECTIVITY, W/W	0.66	0.67
C/(1-C), W/W	3.10	3.18
RISER OUTLET PRESSURE , PSIG	35.0	35.0
TEMPERATURES, DEG F:		
OIL PREHEAT	229	237
CATALYST INLET	1250	1252
RISER PROFILE, FT		
0.58 (MIXING ZONE)	994	979
5.47	984	982
9.22	984	985
17.10	984	985
19.18	982	976
22.87	989	991
26.12	981	N.G.
33.99	983	987
36.08	984	979
41.33	982	N.G.
45.08	984	986
50.92	982	988
55.64	986	987
60.45	967	975
64.78	984	986
69.53	989	986
75.45	983	987
RISER AVERAGE (EX MIX ZONE)	983	984

Table 5-2
Option 1 FCC Production Run
Product Yield Spectrum

	NORMALIZED, BASIS FRESH FEED, WT%					
FEEDSTOCK:	F-9819	F-9888	F-9819/ F-9888			
CATALYST:	F-9804	F-9804	F-9804	F-9804	Average	Weighted Avg
RUN NUMBER: H-2038-	1	2	4	4A	4 & 4A	1&2
H2S	0.00	0.00	0.00	0.00	0.00	0.00
H2	0.13	0.17	0.16	0.15	0.16	0.15
CH4	1.13	0.75	1.07	1.02	1.05	0.97
C2H4	0.87	0.71	0.69	0.53	0.61	0.80
C2H6	0.80	0.51	0.61	0.48	0.55	0.68
C3H6	5.65	4.28	5.34	5.32	5.33	5.06
C3H8	1.41	1.74	1.47	1.50	1.49	1.55
C4H6	0.09	0.04	0.07	0.04	0.06	0.07
1-C4H8	2.02	1.12	1.39	1.34	1.37	1.63
I-C4H8	1.92	0.73	1.00	1.05	1.03	1.41
T-2-C4H8	1.71	1.06	1.67	1.65	1.66	1.43
C-2-C4H8	0.94	0.59	1.29	1.29	1.29	0.79
IC4H10	4.24	5.03	5.13	5.16	5.15	4.58
NC4H10	1.26	1.60	1.24	1.25	1.25	1.41
C5+ IN GAS	4.22	3.94	5.40	5.94	5.67	4.10
IBP-430 F	45.67	51.03	44.68	45.06	44.87	47.98
430-650 F	17.21	19.33	19.61	19.18	19.40	18.13
650+ F	5.69	3.70	4.76	4.76	4.76	4.83
COKE	5.04	3.66	4.42	4.27	4.35	4.45
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
SUMMARY						
TOTAL C2 & LIGHTER	2.93	2.14	2.53	2.18	2.36	2.59
TOTAL C3'S	7.06	6.02	6.81	6.82	6.82	6.61
TOTAL C4'S	12.18	10.17	11.79	11.78	11.79	11.31
TOTAL GASOLINE	49.89	54.97	50.08	51.00	50.54	52.08
TOTAL CYCLE OIL	22.90	23.04	24.37	23.95	24.16	22.96
COKE	5.04	3.66	4.42	4.27	4.35	4.45
CONVERSION	77.10	76.96	75.63	76.05	75.84	77.04

Table 5-3
Option 1 FCC Production Run
Product Yield Spectrum
(Using GCSD PIANO Input)

	NORMALIZED, BASIS FRESH FEED, WT%		
FEEDSTOCK:	F-9819/ F-9888		
CATALYST:	F-9804	F-9804	Average
RUN NUMBER: H-2038-	4	4A	4 & 4A
H2S	0.00	0.00	0.00
H2	0.16	0.15	0.16
CH4	1.07	1.02	1.05
C2H4	0.69	0.53	0.61
C2H6	0.61	0.48	0.55
C3H6	5.34	5.32	5.33
C3H8	1.47	1.50	1.49
C4H6	0.07	0.04	0.06
1-C4H8	1.39	1.34	1.37
I-C4H8	1.00	1.05	1.03
T-2-C4H8	1.67	1.65	1.66
C-2-C4H8	1.29	1.29	1.29
IC4H10	5.13	5.16	5.15
NC4H10	1.24	1.25	1.25
3-Methylbutene-1	0.09	0.11	0.10
i-Pentane	5.09	5.88	5.49
Pentene-1	0.21	0.23	0.22
2-Methylbutene-1	0.49	0.54	0.52
n-Pentane	0.58	0.64	0.61
Isoprene	0.04	0.03	0.04
t-Pentene-2	0.53	0.58	0.56
c-Pentene-2	0.30	0.33	0.32
2-Methylbutene-2	0.89	0.97	0.93
1t,3-Pentadiene	0.03	0.02	0.03
1c,3-Pentadiene	0.07	0.06	0.07
Cyclopentene	0.23	0.24	0.24
Cyclopentane	0.00	0.03	0.02
C6-430 F	41.53	41.34	41.44
430-650 F	19.61	19.18	19.40
650+ F	4.76	4.76	4.76
COKE	4.42	4.27	4.35
TOTAL	100.00	100.00	100.00
SUMMARY			
TOTAL C2 & LIGHTER	2.53	2.18	2.36
TOTAL C3'S	6.81	6.82	6.82
TOTAL C4'S	11.79	11.78	11.79
TOTAL GASOLINE	50.08	51.00	50.54
TOTAL CYCLE OIL	24.37	23.95	24.16
COKE	4.42	4.27	4.35
CONVERSION	75.63	76.05	75.84

Section 6

Project Management

6.1 Reports and Schedules

The milestone schedule and status for the Basic Program and Option 1 is shown in Figure 6-1.

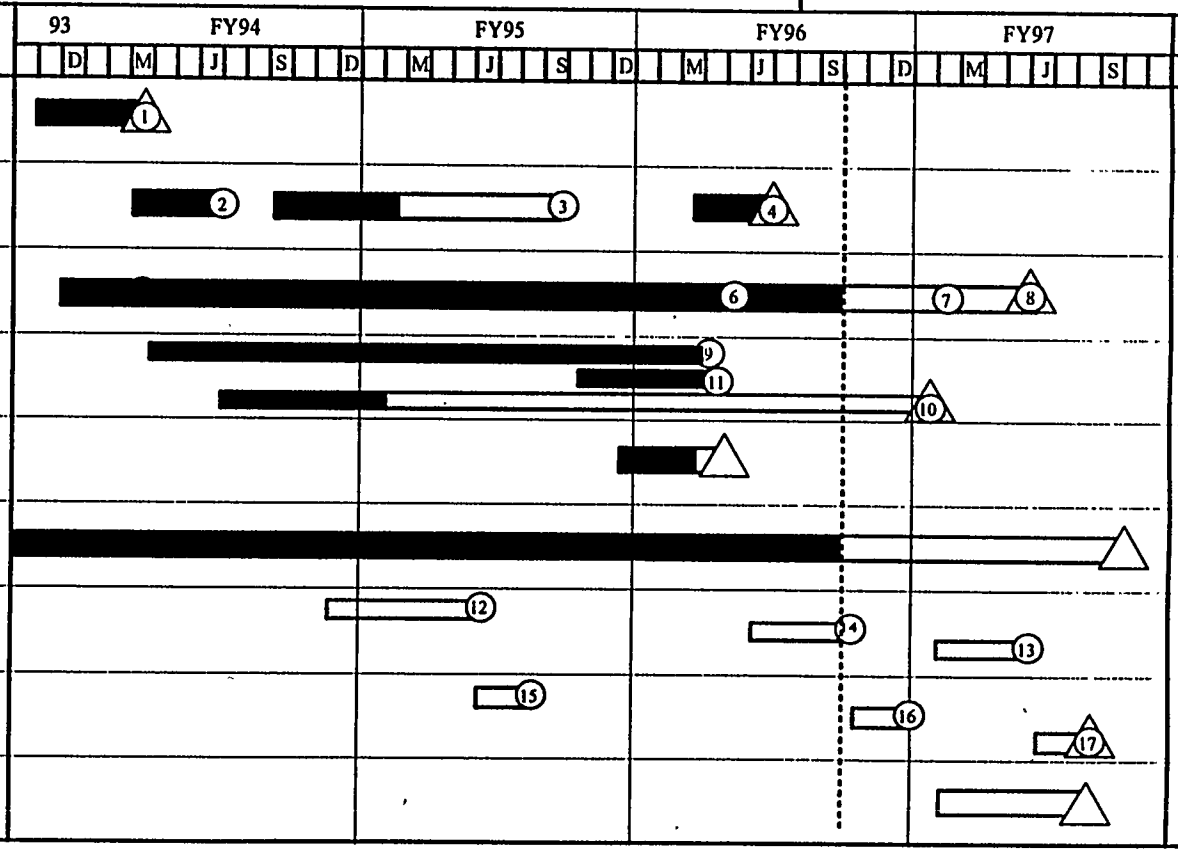
DOE F1332.3
(11-84)

FORM APPROVED
OMB NO 1901-1400

Figure 6-1
Milestone Schedule for Basic Program & Option 1

☐ PLAN ■ STATUS REPORT

1. TITLE	Refining and End Use Study of Coal Liquids	2. REPORTING PERIOD 7/1/96 to 9/30/96	3. IDENTIFICATION NUMBER DE-AC22-93PC91029
4. PARTICIPANT NAME AND ADDRESS	Bechtel Corporation 50 Beale Street San Francisco, CA 94105		5. START DATE 11/1/93 6. ESTIMATED COMPLETION DATE 9/30/97



7. ELEMENT CODE	8. REPORTING ELEMENT	10. PERCENT COMPLETE a. Plan	b. Actual
Task 1	Project Work Plan	100	100
Task 2	Feed Characterization	100	70
Task 3	Linear Programming (LP) Analysis	95	82
Task 4	Pilot Plant Analysis	97	67
Task 5	Option 1 Work Plan	100	60
Task 6	Administration Task	72	71
Option 1 Task 1	Pilot Plant Analysis (Produce Fuels)	55	0
Option 1 Task 2	Characterization, Blending, and Testing	0	0
Option 1 Task 3	Economic Study	0	0

1 Submit Final Work Plan
2 Characterize DL1 liquid
3 Characterize IL liquid
4 Characterize DL2 liquid
5 Develop LP model
6 Input DL pilot plant data
7 Input IL pilot plant data
8 Conduct evaluation runs
9 Conduct DL1 pilot plant tests
10 Conduct IL pilot plant tests
11 Conduct DL2 pilot plant tests
12 Production runs for DL1 (deleted from program)
13 Production runs for IL
14 Production runs for DL2
15 ASTM tests for DL1 (deleted from program)
16 ASTM tests for IL
17 ASTM tests for DL2

11. SIGNATURE OF PARTICIPANT'S PROJECT MANAGER AND DATE

Cliff Lowe 10/24/96