Section 3

Bechtel Activities

3.1 Linear Programming Model - Task 3

A report on the design basis of the linear programming model for direct coal liquids is being developed.

Section 4

Amoco Activities

4.1 Indirect Wax Catalytic Cracking

A series of replicat microactivity tests (MAT) FCC cracking tests were completed. The objective of this work was to estimate the effect of high wax content on conversion with blends of petroleum heavy vacuum gas oil (HVGO) and FT wax. Earlier Amoco pilot plant runs studied blends of 20% and 40% wax in HVGO. The results are shown in Tables 4-1 and 4-2 and Figures 4-1, 4-2, 4-3.

In Figure 4-1, the conversion increases from 75% with pure HVGO to 93% with an 80% blend. In the earlier pilot plant runs the incremental conversion with this wax was 91% (72% with pure HVGO). Conversion of the blends is relatively insensitive to cat-to-oil ratio (see Figure 4-2). However, there is a lot of scatter in this data. The data was plugged into a regression model and Figure 4-3 shows predicted conversion as a function of cat-to-oil ratio. A slight increase is predicted as the cat-to-oil ratio increases.

4.2 Indirect Wax Hydrocracking

4.2.1 Run summary

A 54 day fixed bed hydrocracking run was completed with two feedstocks, pure light cracked cycle oil LCCO FL-2350 and a blend of 25 wt.% Fischer-Tropsch wax FL-2443 and 75 wt.% LCCO FL-2350. The unit was run at a pressure of 1250 psig with once-through hydrogen at an average flow rate of 9 MSCFB. 16 grams of catalyst were used. The top half of the bed was Akzo NiW catalyst while the bottom half was Akzo CoMo catalyst. The reactor bed temperature ranged from 730 to 760°F and the LHSV was 1.8.

The target conversion was based on the standard conversion for gasoline mode hydrocracking runs, 77 wt.% conversion to 380°F. Feed properties are shown in Table 4-3.

It should be noted that the end point of the wax/LCCO blend is greater than 1328°F. This is almost 600°F heavier than material used in feedstocks to conventional petroleum gasoline hydrocrackers.

The strategy for this run was to slowly bring the unit up to the target conversion with LCCO by raising the catalyst bed temperature. Once the target conversion was reached the feed was switched to the wax/LCCO blend and the temperature adjusted to achieve the target percent conversion. At the end of the run, unblended LCCO was again used to determine if there was any significant catalyst deactivation.

The entire run history is plotted on Figure 4-4. Both 380°F wt.% conversion and the corresponding average catalyst bed temperature are plotted versus days on oil.

Amoco Activities

For the first 28 days, the unit was fed with LCCO, FL-2350. The target conversion, 77wt.%, was achieved at around 740°F (see day 27). Weight balances were between 99 and 101%. The bed temperature was lowered 10°F and the wax/LCCO blend was started on day 30. Conversions were roughly the same the first day feeding the blend due in part to holdup time in the unit. The bed temperature was raised 10°F on day 31 and on day 32 a waxy haze was observed in the liquid product. The bed temperature was raised in an attempt to convert more wax but the haze persisted. The wax was separated from the liquid product by centrifuging and both fractions were analyzed. On day 34 the feed pump was off for 6 hours during a weekend. By the 36th day only a 70% conversion was achieved at 758°F so the temperature was dropped to 730°F and pure LCCO was again fed to the unit. Bed temperatures were slowly raised for the next 18 days in an attempt to reach the target conversion.

On the 48th day 76% conversion was reached at 763°F. The conversion was stable at these conditions. The catalyst had deactivated by 23°F from day 27 to day 48. The run was terminated on day 54.

4.2.3 Run analysis

Results with the wax/LCCO blends are summarized in Tables 4-4 and 4-5. The 380°F$^-$ is broken into 2 parts, LUC (Light Ultracrackate) and HUC (Heavy Ultracrackate). The distillation cut point is 210°F.

The yields were corrected to a constant basis in Table 4-5. From this data it appears that the higher boiling compounds were not being converted. The yield of the most valuable gasoline component, the Heavy Ultracrackate, dropped from 48.44% to 43.83% in only 4 days. This could be due to the unconverted wax plugging the catalyst pore structure. This plugging could potentially be reversible or the plugging material could convert to coke. It is apparent that the wax/LCCO blend had an end point that was much too high (>1300°F) to be converted by conventional hydrocracking.

With the exception of the HUC fraction, however, the product yields from the blends are comparable to that obtained from the LCCO feed alone.

4.2.4 Comparison with previous wax hydrocracking tests

In tests conducted in 1985 and 1986, both UOP and Mobil were able to hydrocrack Fischer-Tropsch wax. An evaluation of their reports shows several important differences between this study and their earlier work.

Wax end point

Amoco Activities

In both the UOP and Mobil tests, the end point of the Fischer-Tropsch wax was much lower than the end point of the wax used in the End Use study. The end point of the wax used in the End Use study was over 1300°F while the UOP wax had an end point of 1000°F and the Mobil end point was estimated to be around 1100°F.

Conversion severity

The objective of the End Use hydrocracking test was to convert the wax to 380°F⁻ gasoline material while the objective of both the UOP and Mobil tests was to convert the wax to 650°F⁻ to 700°F⁻ mixture of gasoline and distillate products.

Run conditions

The Mobil test was made on a small bench-scale flow unit with pure wax (no blends). The pressure, 700 psig, was significantly lower than the pressure used in the End Use Study tests (1250 psig). Two different catalysts were studied. The first set of tests was conducted with a Mobil proprietary catalyst over a LHSV range from 0.5 to 2.0. The second set of tests was conducted using a Ketjen 742 catalyst at a LHSV of 0.5.

For the proprietary catalyst, the conversion (to 650°F-) was over 98% at temperatures over 650°F and LHSV of 0.5. At the same LHSV and a temperature of 625°F, the conversion decreased to 80%. At 625°F and a LHSV of 1.0, the conversion decreased further to 12.1%.

For the Ketjen catalyst the conversion ranged from 3.2 to 18.9% at temperatures ranging from 648 to 800°F. Only when the temperature was raised to 850°F did the conversion increase to 71%.

In summary, the Mobil hydrocracking tests were conducted at a relatively low pressure and resulted in adequate conversions only at low space velocities and/or high temperatures. These conditions would be conducive to catalyst deactivation due to coke laydown on the catalyst. It is possible that the neat wax could be hydrocracked at very high severity (LHSV - 0.5 and 850°F). However, when blended with LCCO (330 ppm nitrogen) the wax would be even more difficult to hydrocrack because of competitive adsorption effects.

A comparison of run conditions for the UOP tests could not be conducted because the reactor temperatures were not reported.

4.2.5 Wax hydrocracking conclusions

The conclusion from all these studies is that light Fischer-Tropsch wax with an end point of 1100°F or less can be hydrocracked to distillate range products. Heavier waxes with end

Amoco Activities

points in the 1300°F range should be catalytically cracked in a FCC unit rather than hydrocracked.

Potential solutions to the incomplete conversion of the wax is the use of a hydrocracking catalyst with a larger pore structure or the removal of the high boiling portion of the wax feed.

Amoco Activities

Table 4-1 - AU-58 Catalytic Cracking - Microactivity Results

	AU-58E MYU CONDITIONS									
Test #										
95-58	091	093	094	092	095	096	097	098	099	100
CATALYST	1397	1397	1397	1397	1397	1397	1397	1397	1397	1397
FEED, FCC	1411	1411	1411	1498	1498	1498	1498	1498	1498	1498
%WAX FHD 1670				0	0	20	40	60	60	80
FURNACE TEMP	971F	971F	971F	971F	971F	971F	971F	971F	971F	971F
AVG RUN TEMP	933	891	933	922	923	931	860	925	896	936
WT. CATALYST	3.003	3.001	3.001	4.002	4.003	4.007	4.001	4.001	4.004	4.001
WT FEED	1.0024	0.951	0.721	0.8767	0.9851	0.8667	1.1372	0.6937	1.3601	0.8825
	MYU YIELDS AND TEST RESULTS									
CAT-to-OIL	3.02	3.52	4.41	5.05	4.55	5.09	3.91	6.52	3.32	5.96
WHSV	23.86	20.47	16.34	14.27	15.84	14.13	18.4	11.05	21.7	12.08
CARBON ON CAT	1.834	1.521	1.516	0.958	1.063	1.11	1.096	0.963	1.615	1.023
COKE WT.%	6.03	5.81	7.26	4.93	4.94	5.78	4.39	6.4	5.5	6.22
CONVERSION %	72	63.6	73.3	78	77.7	82.3	73.8	93.5	85.5	93.2
RECOVERY %	99.3	89.7	94.5	95.8	94.6	96	95.2	93.7	94	80.5
RON	91.9	91.7	91.9	91.4	91.5	91.2	88.4	90.4	91.7	91
MON	80.8	80.6	81.2	81.5	81.4	81.5	79.4	81.4	81.1	81.9

Feed 1411 is a standard HVGO that is used to test the equipment. Feed 1498 is a range of blends of the HVGO used in the pilot plant tests and the wax.

Amoco Activities

Table 4-1 (continued) - AU-58 Catalytic Cracking - Microactivity Results

Test #										
95-58	091	093	094	092	095	096	097	098	099	100
SIM DIST RESULTS SHORT FORM(F)										
IBP - 200.0	13.63	9.25	16.5	19.33	18.56	23.56	21.58	31.06	30.07	34.5
200.0-430.0	33.77	31.75	35.1	37.29	37.19	38.94	33.67	42.01	35.35	42.61
430.0-650.0	28.23	26.1	28.9	31.07	32.05	28.5	31.25	21.68	27.37	18.96
650.0-700.0	5.46	5.8	5	3.97	4.03	3.41	4.44	1.69	2.76	1.22
700.0-750.0	5.32	6.6	4.75	2.83	3.06	2.42	3.45	1.32	1.93	0.99
750.0-800.0	5.27	7	4.18	2.06	2.04	1.48	2.42	0.86	1.15	0.68
800.0-850.0	3.83	5.6	2.65	1.32	1.24	0.79	1.42	0.51	0.6	0.39
850.0-900.0	2.43	3.9	1.56	0.91	0.84	0.89	0.82	0.87	0.78	0.64
900.0-950.0	1.18	2.25	0.74	0.59	0.99	0	0.42	0	0	0
950.0-1000.0	0.89	1.05	0.62	0.61	0	0	0.53	0	0	0
1000	0	0.7	0	0	0	0	0	0	0	0
LONG FORM(F)										
IPB- 0.0	0	0	1	1.43	1.25	1.67	2.43	2.1	3.1	2.25
0.0-20.0	1.24	0	0.3	0.34	0.72	0.8	0.5	0.69	1.01	0.86
20.0-40.0	0.29	0	0.45	0.35	0.35	0.8	0.57	0.52	0.31	0.86
40.0-60.0	0.48	1.67	1.39	2.01	1.52	2.53	2.36	3.86	3.28	3.83

Amoco Activities

Table 4-2 - AU-58 Catalytic Cracking Microactivity Results

TEST #						
95-58-	101	102	103	104	105	106
CATALYST	1397	1397	1397	1397	1397	1397
FEED, FCC	1498	1498	1498	1498	1498	1498
%WAX FHD 1670	80	60	40	20	0	40
FURNACE TEMP	971F	971F	971F	971F	971F	971F
AVG. RUN TEMP	897	850	825	911	877	891
WT. CATALYST	4.0000	4.0000	3.9958	4.0042	4.0019	4.0000
WT. FEED	0.7968	1.1882	1.1284	1.9742	1.1245	1.1408
MYU YIELDS AND TEST RESULTS						
CAT-to-OIL	5.72	3.72	3.96	4.22	3.93	3.86
WHSV	12.59	19.35	18.19	17.07	18.32	18.67
CARBON ON CAT	0.897	1.104	1.177	1.244	1.043	1.172
COKE WT.%	5.23	4.2	4.76	5.37	4.19	4.62
CONVERSION %	91.5	82.2	82.1	82.7	70.1	78.7
RECOVERY %	93	95.8	94.8	93.6	95.9	96.3
RON	88.2	87.8	88.3	90.9	90.7	88.5
MON	80	78.8	79.5	81	81	79.6
SIM DIST RESULTS SHORT FORM (F)						
IBP-200.0	34.07	29.58	28.58	11.59	8.54	26.58
200.0-430.0	42.23	36.32	36.52	16.83	15.21	36.02
430.0-650.0	19.84	25.81	25.96	67.42	70.29	25.97
650.0-700.0	1.24	3.1	3.34	1.59	1.9	3.93
700.0-750.0	1	2.22	2.43	1.1	1.46	3
750.0-800.0	0.64	1.42	1.51	0.67	1	2.09
800.0-850.0	0.37	0.7	0.76	0.82	0.65	1.14
850.0-900.0	0.62	0.85	0.9	0	0.43	0.66
900.0-950.0	0	0	0	0	0.53	0.61
950.0-1000.0	0	0	0	0	0	0
		0			0	
LONG FORM(F)						
IBP- 0.0	2.17	3	3.13	0	0	2.58
0.0-20.0	1.06	0.72	0.76	1.17	1.08	1.02
20.0-40.0	0.47	0.28	0.51	0.23	0.28	0.29
40.0-60.0	3.05	3.5	3.29	1.18	0.69	3.11

Table 4-3 - Wax hydrocracking feed properties

Feed material	LCCO	Blend (25% wax/75% LCCO)
API gravity	23.4	
Nitrogen, ppm	334	
Sulfur, wt%	0.94	
Simulated distillation, °F		
IBP	169	211
5 wt%	361	397
10 wt%	409	441
20 wt%	452	484
30 wt%	482	512
40 wt%	506	545
50 wt%	530	578
60 wt%	559	621
70 wt%	586	670
80 wt%	617	853
90 wt%	651	1271
95 wt%	679	>1328
99 wt%	729	
FBP	748	
380- naphtha fraction, %	6.3	4.2
Ca (wt% aromatic carbon)	47.1	
Carbon, wt%	88.79	
Hydrogen, Wt%	10.55	

Amoco Activities

Table 4-4 - Wax hydrocracking tests

Sample No.	Days on Stream	Wt.% 380°F CONV.	KAT °F	Total Product wt.(gm)	Wax %	C_6^+ wt.%	Naphtha	C_1-C_3	LUC	HUC	380^+F
21	29	66.6	736			65.67	30.96	4.51	13.36	33.50	30.64
23	31	69.8	742	423.5	3.74	60.74	27.27	5.19	15.14	29.97	27.76
24	34	69.9	754	392.44	6.66	60.58	27.56	5.85	14.85	30.20	27.66
25	35	57.9	747	473.5	6.64	62.49	24.82	4.35	12.49	27.11	38.62

Table 4-5 - Corrected Yields (700°F; 77wt.% conversion)

Sample No.	C_1-C_3	C_4	C_5	LUC	HUC	C_5I/N
21	4.80	15.22	12.67	18.88	48.44	4.74
23	5.12	16.25	14.80	20.35	43.48	6.52
24	5.38	15.32	14.11	19.79	45.40	7.34
25	4.89	16.17	15.07	20.05	43.83	7.60

Figure 4-1 - Wax MAT conversion vs. percent wax

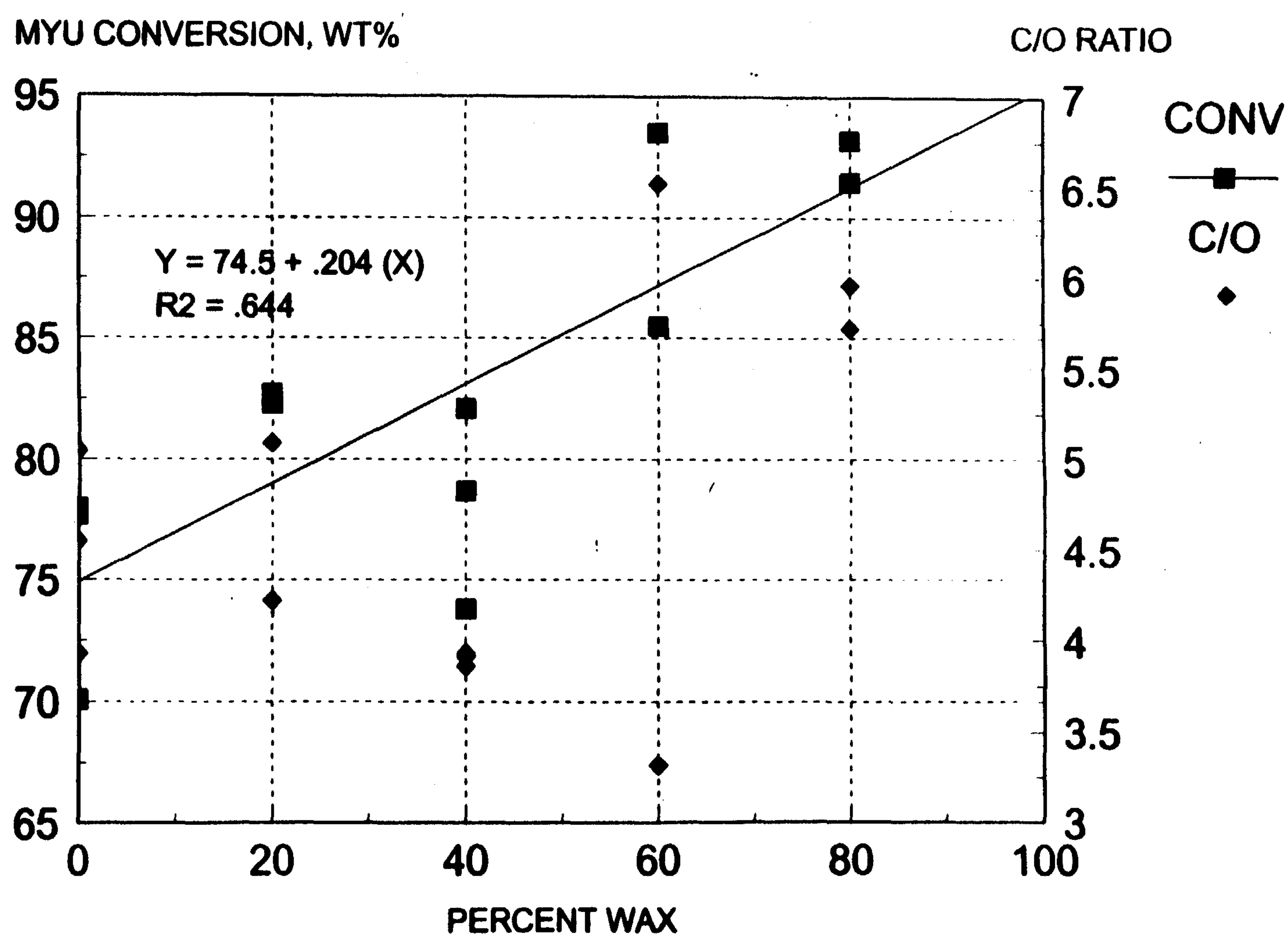


Figure 4-2 - Wax MAT conversion vs. catalyst:oil ratio

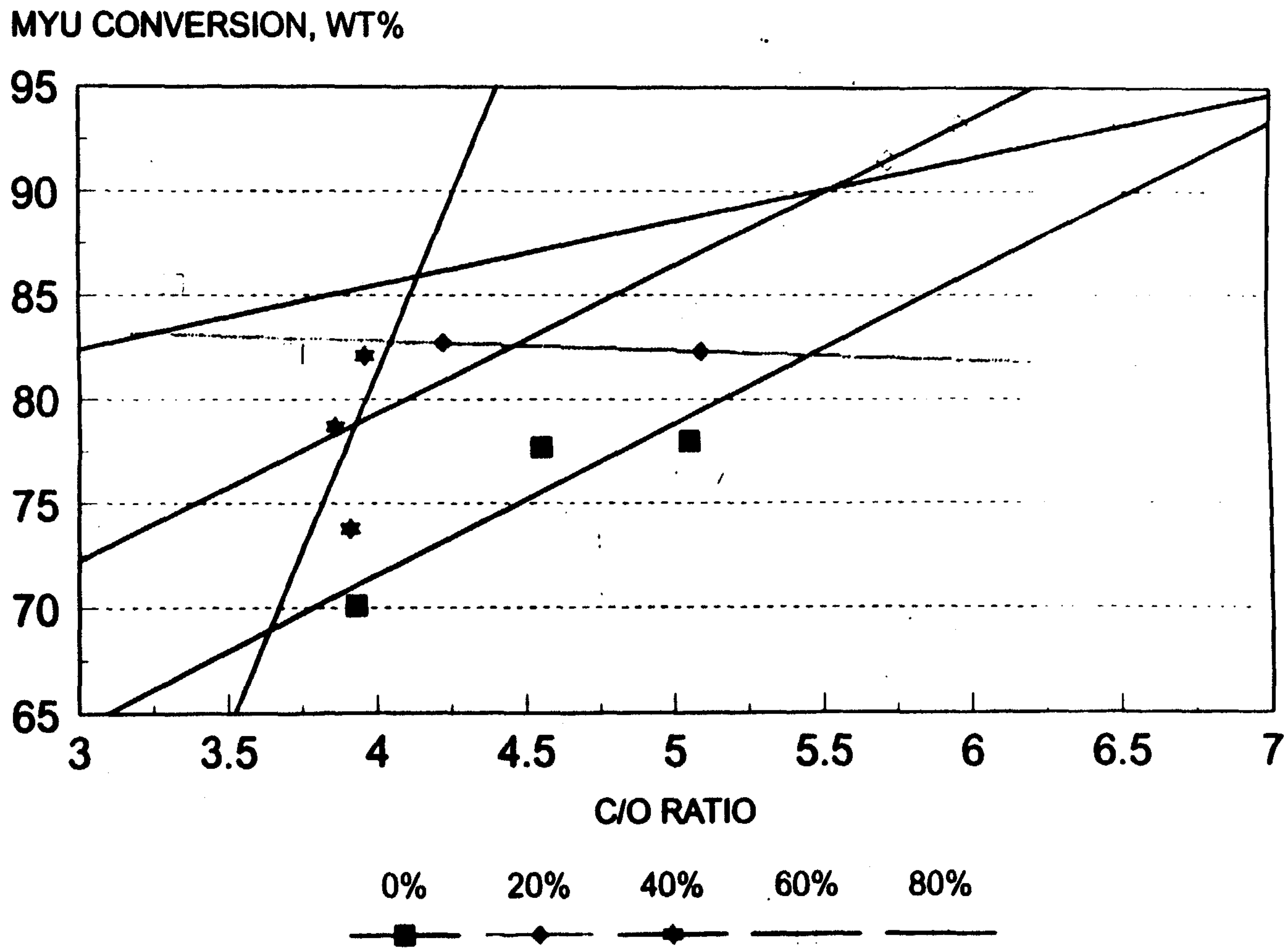


Figure 4-3 - Wax MAT regressed conversion vs. catalyst:oil ratio

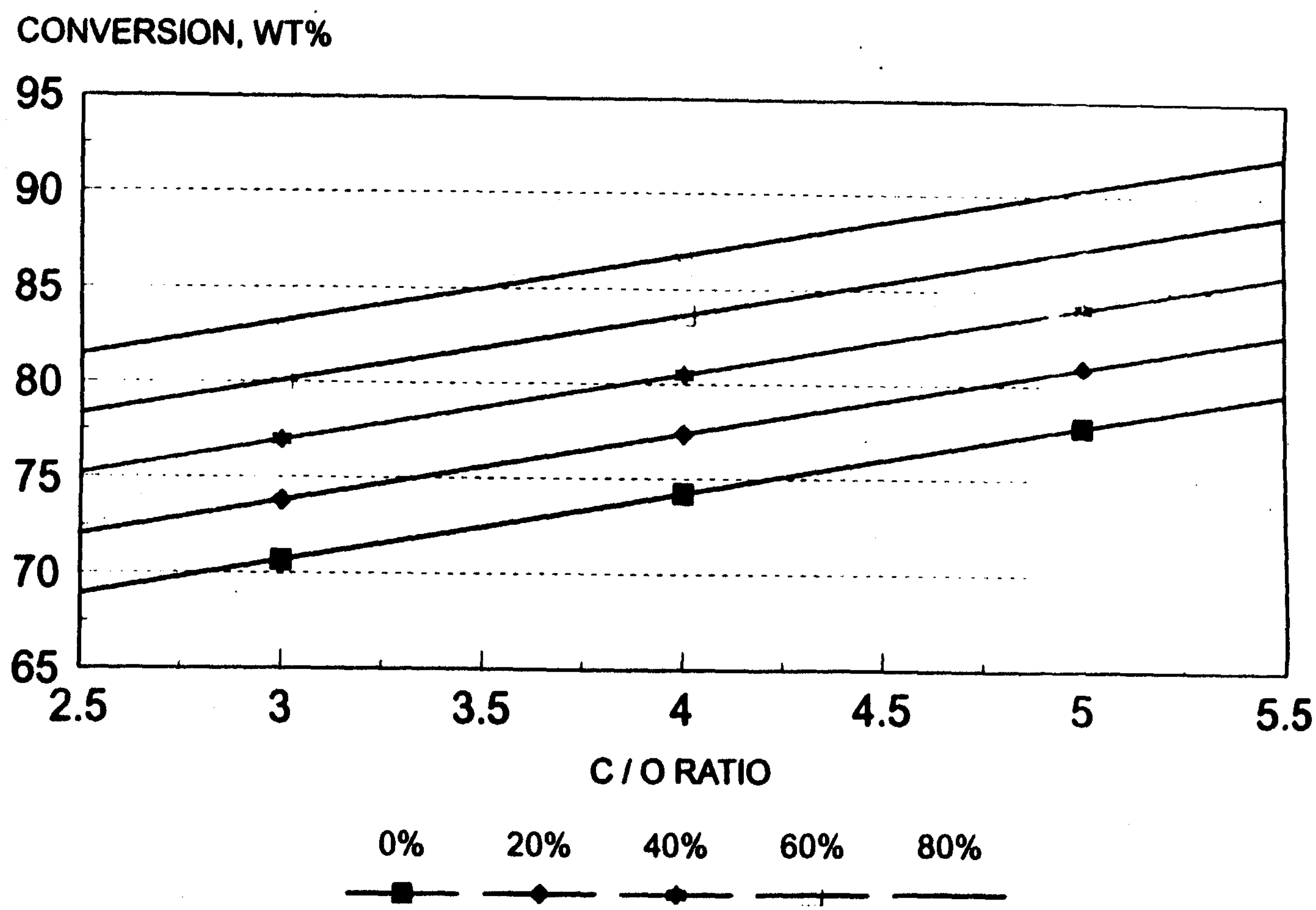
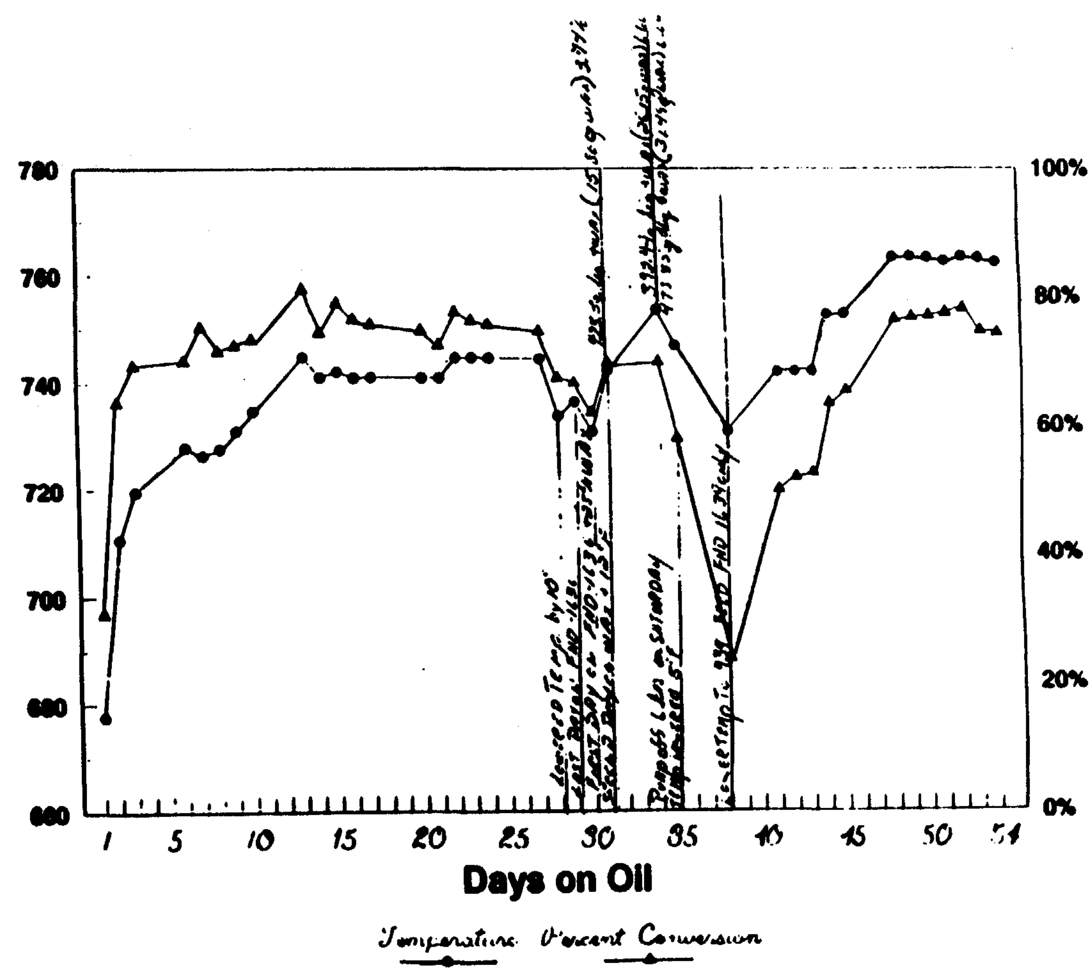


Figure 4-4 - Wax hydrocracking test run summary



Section 5

M.W. Kellogg Activities

There was no project activity for this reporting period.

Section 6

Project Management

6.1 Plans

6.2 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)

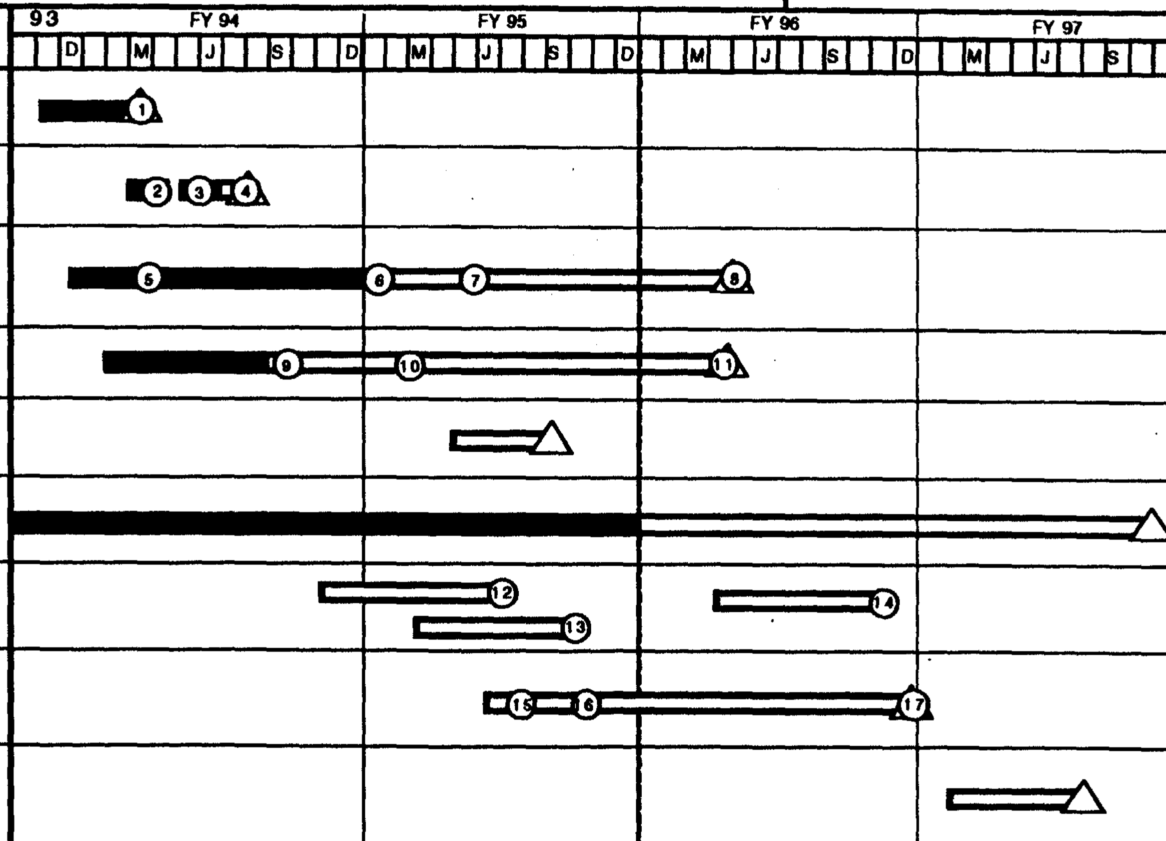
Figure 6-1
Milestone Schedule for Basic Program & Option 1

☐ PLAN ■ STATUS REPORT

FORM APPROVED
OMB NO 1901.1400

1. TITLE Refining and End Use Study of Coal Liquids	2. REPORTING PERIOD 9/25/95 to 12/31/95	3. IDENTIFICATION NUMBER DE-RP22-93PC91029
4. PARTICIPANT NAME AND ADDRESS Bechtel Corporation, 50 Beale Street, San Francisco, CA 94105		5. START DATE 11/1/93
		6. 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	67
Task 3	Linear Programming (LP) Analysis	87	76
Task 4	Pilot Plant Analysis	89	37
Task 5	Option 1 Work Plan	100	0
Task 6	Administration Task	57	57
Option I Task 1	Pilot Plant Analysis (Produce Fuels)	39	0
Option 1 Task 2	Characterization, Blending, and Testing	0	0
Option 1 Task 3	Economic Study	0	0



1 Submit final Project Work Plan
2 Characterize DL1 liquid
3 Characterize IL liquid
4 Characterize DL2 liquid
5 Develop LP model
6 Conduct final DL1 LP runs
7 Conduct final IL LP runs
8 Conduct final DL2 runs
9 Conduct DL1 pilot plant tests
10 Conduct IL pilot plant tests
11 Conduct DL2 pilot plant tests
12 Production runs for DL1
13 Production runs for IL
14 Production runs for DL2
15 ASTM tests for DL1
16 ASTM tests for IL
17 ASTM tests for DL2

11. SIGNATURE OF PARTICIPANT'S PROJECT MANAGER AND DATE
Cliff Lowe for Sam Tam