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QUARTERLY REPORT

This quarterly report is the sixth report for Contract DE-AC22-87PC79818. The objective of this contract is to extend and optimize UOP's single-stage slurry-catalyzed co-processing scheme, which was developed under previous Contract DE-AC22-84PC70002. Particular emphasis is given to defining and improving catalyst utilization and costs, evaluating alternative and disposable slurry-catalyst systems, and improving catalyst recycle and recovery techniques. The work during this quarter involved a series of bench-scale runs using a new Mo-based slurry catalyst. The results of bench-scale Runs 24 and 25 are discussed in the following report.

Run 24 Operations

Run 24 was the first bench-scale run to use UOP's new Mo-based slurry catalyst. A small batch of this catalyst, K6.2, was tested earlier in UOP's autoclave reactivity test and reported in Quarterly Report 3 for this contract [1]. Autoclave tests showed that the new Mo catalyst was 5 to 10 times more active than the V-based reference catalyst that was previously in use. A second larger batch of the Mo catalyst, K6.7, was prepared for bench-scale use. Run 24 was made with 0.13 wt-% of the K6.7 catalyst, measured on a metal per moisture and ash free feed (MAFF) basis. Reference feedstocks (2:1 Lloydminster Vacuum Resid:Illinois Coal No. 6) were used, and the run was started at

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standard operating conditions (425°C and 3,000 psig). The reactor temperature was gradually increased over the course of the run to determine the relationship between the conversions and temperature. Three test periods at each condition were worked up in detail. Periods 7, 8, and 11 were run at 427°C; periods 21, 22, and 24 at 432°C; and periods 33-35 at 438°C. Operating results from each of the test periods are summarized in Appendix A. Run 24 was shut down on August 6 (472 HOS) after the available feed was used up.

Run 25 Operations

Based on the results of Run 24, which failed to show the expected decline in the conversion of heptane insolubles above 435°C that had been observed in other runs, the decision was made to continue testing at even higher temperatures. A new batch of feed similar to that used for Run 24 was prepared. (The catalyst concentration, 0.11 wt-% Mo, actually turned out to be slightly lower than that used in Run 24.) The temperature was increased from 429°C to 460°C over the course of the run. The bench-scale unit has never been operated stably at temperatures this high before. During test period 32, the recycle pump packing blew out, and recycle flow was lost for about 40 minutes until the level of the high-pressure separator could be built back up. During this time, the reactor temperature reached an internal peak of about 485°C. At about the same time, a major upset in the vacuum column occurred because of plugging in the reboiler recirculation line. Run 25 was eventually shut down on Sept. 7 (504 HOS) because of these problems.

An examination of the reactor following the run showed considerable coke buildup on the walls in the top 12 inches of the reactor. However, whether this buildup was due to the operation at higher-than-normal severities or whether it was due to the temperature excursion that resulted from loss of the recycle stream is uncertain. Subsequent runs (see Quarterly Report No. 7) have shown good operation at 460-470°C [2], which tend to support the latter explanation. Run 25 results are summarized in Appendix B. A complete set of plots of the

Run 24 and 25 conversions, yields, and product properties vs. temperature is given in Appendix C.

Discussion of Results

Previous autoclave testing has demonstrated that equivalent conversions, yields, and product properties can be achieved with the new Mo-based catalyst using only about one-tenth of the metal concentration required for the former V-based reference catalyst [3]. This advantage was borne out in the bench-scale unit. As shown in Table 1, superior yields and product properties were achieved with 0.11 wt-% of Mo in Run 25 compared with 1.0 wt-% V in Run 21. These results are compared at maximum nondistillables conversion, which for the new Mo catalyst was at a significantly higher temperature.

Autoclave tests with both V and Mo catalysts have shown a decrease in MAF coal and heptane insoluble conversions at temperatures above 425°C. This is illustrated for the Mo catalyst in Figure 1. Similar results were also observed in the bench-scale unit in Run 5, in which a V-based reference catalyst was used [4]. The decline in conversions at high temperature has been attributed to retrograde reactions in which the asphaltenes that are formed by thermal break-up of the coal polymerize to form coke. In the presense of a catalyst and hydrogen, these reactive intermediates are preferentially converted to stable light products. However, at high temperatures, the rates of the retrogressive thermal reactions exceed those of the beneficial catalytic reactions, and pitch and coke are formed at the expense of more-valuable light products. Because coal conversion is measured by the disappearance of toluene insolubles and the formation of coke increases the measured toluene insolubles, the amount of "unconverted coal" actually increases at high temperatures as a result of coke formation.

Thus, it was surprising that the conversions in Runs 24 and 25 (Figure 2) showed an almost linear increase with temperature, with no signs of falling off, even at 460°C. The unconverted coal (toluene

insolubles less ash) showed a steady decrease without the characteristic upturn that is typically observed as a result of coking at higher temperatures (Figure 3). One major difference between Runs 24 and 25 and earlier temperature studies with V catalyst (Runs 5 and 9) is the inclusion of a liquid recycle stream from the bottom of the high-pressure separator to the reactor inlet. The space velocity was maintained constant between the runs, but the addition of the recycle stream (5:1 recycle:fresh feed) resulted in greater mixing and higher liquid velocities through the reactor. The improved high temperature conversions may be due to better contacting of the reactive coal fragments with hydrogen and catalyst (as a result of increased reactor back-mixing) or to decreased relative contact between the coke precursors and the hot reactor walls because of greater superficial liquid velocities in the reactor. Hydrodynamic differences resulting from the recycle may have also affected the flow regime, heat transfer characteristics, or gas void fraction in the reactor. Further reactor modeling studies are required to thoroughly understand these phenomena.

The extent of coking may also depend on the physical properties of the converted products. Petroleum resid and coal liquefaction products are complex mixtures of oils (heptane soluble and pentane soluble), resins (heptane soluble and pentane insoluble), and asphaltenes (heptane insoluble). Asphaltenes have little or no solubility in the oils. The resins help to keep the asphaltenes dispersed (peptized) in the continuous oils by acting as an intermediate phase. Figure 4 gives a theoretical illustration of this dispersion [5]. The asphaltenes of higher aromaticity are surrounded by resin components of lower aromaticity, which can coexist with oils of the lowest aromaticity. The solubility of the asphaltenes depends greatly on their H/C ratio, the number of aliphatic side chains that attach to the aromatic rings, and on the peptizing power of the resins, which is determined by the amount, aromaticity, and polarity of the resins. For the same aromaticity, resins with higher polarity (i.e., more heteroatoms) are better for peptizing the asphaltenes. At high severities, the aliphatic side chains are cracked from the asphaltenes and resins, and

heteroatoms are removed, making the resins less polar. Both of these effects lead to reduced asphaltene solubility. When the asphaltenes can no longer remain peptized, they precipitate out, undergo further thermal condensation, and ultimately become coke. Thus, asphaltene solubility may play as much of a role in coking as the reaction kinetics.

Whatever the explanation, the improvement in pilot plant operability at high temperatures in Runs 24 and 25 represents an important process advance. The ability to operate at high nondistillable conversions, without significant carbon loss to retrograde reactions, significantly improves the economics of slurry co-processing. As shown in Figure 2, increasing the average reactor temperature by 30°C increases the conversion of nondistillables from about 55% to 85%. Based on a correlation of product values to hydrogen index for a marker crude price of \$17/barrel [6], this increase in nondistillable conversion corresponds to an increase of about \$4/barrel in the value of the C₅+ liquid product. Although the yield of C₅+ liquid product decreases from 86.2 wt-% of MAF feed to 83.7% as a result of the increased production of light ends, the total product value still increases by about 30% because of the improved product quality and increased by-product credits for sulfur. Table 2 compares the yields and product properties at 427°C, 446°C, and 459°C. Table 3 gives a simplified cost analysis for the three cases. Assuming that the higher temperature operation does not require more expensive metallurgy or fractionation (and that capital costs are, therefore, the same as the base case), operation with 0.12 wt-% of Mo catalyst would be profitable at a marker crude price of \$28/barrel.

References

1. D. A. Nafis, et al., "Quarterly Report No. 3," prepared for the United States Department of Energy under Contract No. DE-AC22-87PC79818, Feb. 15, 1989.
2. D. A. Nafis, et al., "Quarterly Report No. 7," prepared for the United States Department of Energy under Contract No. DE-AC22-87PC79818, Unissued.
3. D. A. Nafis, et al., "Quarterly Report 3."
4. J. G. Gatsis, et al., "Coal Liquefaction Co-Processing -- Topical Report No. 2," prepared for the United States Department of Energy under Contract No. DE-AC22-84PC70002, December 31, 1987, pp. 2-40.
5. D. E. Allan, et al., "Visbreaking Gains Renewed Interest", Chemical Engineering Progress, pp.85-89 (Jan. 1983).
6. D. A. Nafis, et al., "UOP Co-Processing Developments," Paper presented at the Pittsburgh Energy Technology Center Contractors' Review Meeting, Pittsburgh, PA, Oct. 2-4, 1989, p. 9.
7. D. A. Nafis, et al., "Coal Liquefaction Co-Processing Final Report," prepared for the United States Department of Energy under Contract No. DE-AC22-84PC70002, Sept. 19, 1988.

Table 1
Comparison of Bench-Scale Results for 0.11 wt-% Mo
and 1.0 wt-% V Catalysts

	<u>Run 21</u>	<u>Run 25</u>
Periods	17-19	31,41
Catalyst	K1.2	K6.7
wt-% metal	1.0 V	0.11 Mo
Temperature, °C	425.8	459.4
Space Velocity	Base	Base
Recycle:Fresh Feed	5.0	5.5
Conversions, wt-%		
MAF Coal	88.3	93.0
Heptane Insolubles	85.7	88.5
510+°C Nondistillables	56.4	85.7
371+°C Nondistillables	35.5	69.7
Yields, wt-% MAFF		
H ₂ O + CO _x	5.9	4.3
H ₂ S	1.5	3.5
NH ₃	0.2	0.8
C ₁₋₃ (Light Ends)	2.3	9.1
C _{4-177°C} (Naphtha)	5.7	14.5
177-343°C (Distillate)	17.7	36.0
343-510°C (VGO)	30.2	22.9
510+°C (Resid)	34.6	10.3
Unc. MAF Coal	3.9	2.3
H ₂ Consumption	(2.1)	(3.6)
Total	100.0	100.0
C ₅₊ Total Liquid Product		
wt-% of MAFF	88.2	83.7
API Gravity	16.8	19.9
Carbon, wt-%	84.6	84.4
Hydrogen, wt-%	11.4	11.0
Sulfur, wt-%	1.1	1.1
Nitrogen, wt-%	0.9	0.4
Hept. Insolubles, wt-%	2.5	3.1
MCRT, wt-%	8.3	6.2

Basis: R10 Lloydminster Resid, C1.4 Illinois Coal No. 6;
2:1 Resid:MAF Coal, 3000 psig.

Table 2
Effect of Severity on Yields and Product Properties

	Temperature, °C		
	427.4	446.0	459.4
Run	24	25	25
Periods	7,8,11	11,13	31,41
Recycle:Fresh Feed	5.7	5.8	5.5
Yields, wt% MAFF			
H ₂ O + CO _x	6.7	4.0	4.3
H ₂ S	1.6	3.3	3.5
NH ₃	0.2	0.4	0.8
C ₁ -C ₄ (Light Ends)	2.5	5.5	9.1
C ₅ -177°C (Naphtha)	5.4	12.0	14.5
177-343°C (Distillate)	17.6	24.0	36.0
343-510°C (VGO)	29.2	26.1	22.9
510+°C (Resid)	34.0	24.2	10.3
Unc. MAF Coal	5.6	3.6	2.3
H ₂ Consumption	(2.8)	(2.9)	(3.6)
Total	100.0	100.0	100.0
C ₅ + Total Liquid Product			
wt-% of MAFF	86.2	86.3	83.7
API Gravity	12.9	17.0	19.9
Carbon, wt-%	84.7	84.0	84.4
Hydrogen, wt-%	10.0	10.3	11.0
Sulfur, wt-%	2.1	1.4	1.1
Nitrogen, wt-%	0.9	0.8	0.4
Hept. Insolubles, wt-%	9.8	9.1	3.1
MCRT, wt-%	12.7	11.2	6.2
Hydrogen Index *	0.1142	0.1195	0.1285
C ₅ + Value, \$/bbl **	9.3	10.7	13.2

Basis: 0.12 wt-% K6.7 (Mo) Catalyst; 2:1 Resid:MAF Coal,
R10 Lloydminster Resid, C1.4 Illinois Coal No. 6;
3000 psig; base space velocity.

$$\text{*Hydrogen Index} = [(\text{wt-\% H}) - 2/32 * (\text{wt-\% S}) - 3/14 * (\text{wt-\% N})] / (\text{wt-\% C})$$

$$\text{**Product Value} = f(\text{Hydrogen Index, \$17/bbl Crude}) [6]$$

Table 3
Product Values and Feed Costs vs. Reactor Severity

	Temperature, °C		
	<u>427.4</u>	<u>446.0</u>	<u>459.4</u>
Run	24	25	25
Periods	7,8,11	11,13	31,41
Product Values, \$/MT MAFF			
Sulfur	1.66	3.42	3.62
Ammonia	0.18	0.36	0.72
Fuel Gas (C ₁ -C ₄)	2.87	6.31	10.44
Naphtha (C ₅ -177°C)	15.25	33.88	40.94
Distillate (177-343°C)	38.02	51.84	77.77
VGO (343-510°C)	54.99	49.15	43.13
Resid (510+°C)	<u>29.90</u>	<u>21.28</u>	<u>9.06</u>
Total	142.87	166.25	185.68
Feed Costs, \$/MT MAFF			
Coal	13.81	13.79	13.79
Resid	58.58	58.63	58.63
Hydrogen	<u>20.12</u>	<u>20.84</u>	<u>25.87</u>
Total	92.51	93.26	98.29
Product - Feed Margin, \$/MT MAFF	50.36	-72.99	87.39
Operating Costs, \$/MT MAFF			
Utilities	5.13	5.24	6.02
Capital-Related Costs *	26.73	26.73	26.73
Labor-Related Costs	0.77	0.77	0.77
Catalyst (Throwaway Basis)	<u>16.59</u>	<u>16.59</u>	<u>16.59</u>
Total	49.22	49.33	50.11
Operating Profit, \$/MT MAFF	1.14	23.66	37.28

Cost Basis:

Illinois Coal No. 6	- \$35/MT AR	Power	\$0.049/kWh
Marker Crude Price	- \$28/BBL	Fuel	\$2.607/MM BTU
Product Prices = % of marker crude:		150# Steam	\$5.27/M#
Naphtha	1.15 x MC = \$32.2/BBL	600# Steam	\$7.91/M#
Distillate	1.05 x MC = \$29.4/BBL	BFW-Cond	\$0.18/M#
VGO	1.00 x MC = \$28.0/BBL	CW	\$0.05/M Gal
Resid	0.50 x MC = \$14.0/BBL		
Fuel Gas	- \$2.60/MM BTU	Direct Labor	\$13/hr
Hydrogen	- \$718.6/MT	Fringe	25% of DL
Sulfur	- \$110/MT	Supervision	35% of DL
Ammonia	- \$90/MT	G&A Overhead	100%
MoO ₃	- \$3.60/lb		

*Estimated Erected Cost for Co-Processing Unit for 2,474 MT/D of coal and 25,677 BPD of Resid is \$165.4 million [7].
Capital Charges @ 28.5%, Maintenance @ 3%, Ins. & Taxes @ 2% of EEC/yr.

Figure 1

Conversions vs. Temperature

K6.2 Catalyst, R8 Resld, C1.3 Coal

Figure 2

Conversions vs. Temp.

Runs 24 and 25

•	<u>MAF Coal</u>	+	<u>Heptane Insolubles</u>
*	<u>510+C Non-distill.</u>	□	<u>371+C Non-distill.</u>

K6.7 Catalyst (0.11-0.13% Mo)
 C1.4 Coal, R10 Resid, 2:1 Resid:Coal
 3000 psig, base WHSV

Figure 3

Unconverted MAF Coal vs Temperature

Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

Figure 4
Theoretical Depiction of Asphaltene Dispersion in Oil [5]

Appendix A

Run No. 24 - 2:1 Lloydminster Resid:Illinois Coal No. 6
0.13 wt% Mo Catalyst

Run	24	24	24	24	24	24	24	24	24	19 Ave.	21 Ave.
Test Period	7	8	11	21B	22	24	33	34	35	LTOS	17-19
Initial HOS	84	96	132	280	292	316	424	436	448		
Ave Rx Int T, DegC	427	426.7	428.5	432	431.8	433	437.8	438.9	437.6	425.5	425.8
Rx Outlet P, psig	3029	3025	3022	3026	3030	3036	3000	3006	3011	3058	3005
WHSV, x base	0.91	1.09	0.97	1.01	0.98	1.06	0.97	1.33	0.88	1.00	1.11
HPS Rec/Feed Ratio	6.1	5.2	5.8	5.6	6.0	5.3	5.7	4.2	6.4	NA	5.0
Feed Code	F11	F11	F11	F11	F11	F11	F11	F11	F11	F08	F09
Grams MAF feed	1911.39	2297.71	2049.15	2135.86	2068.71	2234.61	2049.15	2809.66	1848.38	5285.8	2348.4
Resid Code	R10	R10	R10	R10	R10	R10	R10	R10	R10	R08	R10
Grams Resid	1262.42	1517.58	1353.41	1410.68	1366.33	1475.90	1353.41	1855.71	1220.81	3475.6	1565.6
Coal Code	C1.4	C1.4	C1.4	C1.4	C1.4	C1.4	C1.4	C1.4	C1.4	C1.2	C1.4
Grams MAF Coal	648.97	780.13	695.74	725.18	702.38	758.71	695.74	953.95	627.57	1810.1	782.8
Catalyst Code	K6.7	K6.7	K6.7	K6.7	K6.7	K6.7	K6.7	K6.7	K6.7	K1.0	K1.2
wt% cat. met./MAFF	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	1.00	0.99
Feed Distribution:											
wt% C5-177C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0
wt% 177-343C	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.6	0.5
wt% 343-510C	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	13.0	11.4
wt% 510+C	54.27	54.27	54.27	54.27	54.27	54.27	54.27	54.27	54.27	52.2	54.8
wt% MAF Coal	33.95	33.95	33.95	33.95	33.95	33.95	33.95	33.95	33.95	34.2	33.3
wt% H2 Consump.	2.53	3.05	2.88	2.86	2.55	2.30	2.98	3.31	5.13	2.4	2.1
wt% total feed	102.53	103.05	102.88	102.86	102.55	102.30	102.98	103.31	105.13	102.4	102.1
Feed Analysis:											
API gravity	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6.8	-7.2
wt% carbon	78.36	78.36	78.36	78.36	78.36	78.36	78.36	78.36	78.36	76.65	75.72
wt% hydrogen	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	7.90	8.03
wt% sulfur	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.38	3.99
wt% nitrogen	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.80	0.94
wt% hept. insol.	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	2.49	8.34
wt% MCRT	11.07	11.07	11.07	11.07	11.07	11.07	11.07	11.07	11.07	10.55	10.70
wt% dist. (371C-)	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.96	0.66

Run No. 24 - 2:1 Lloydminster Resid:Illinois Coal No. 6

0.13 wt% Mo Catalyst

Run	24	24	24	24	24	24	24	24	24	19 Ave.	21 Ave.
Test Period	7	8	11	21B	22	24	33	34	35	LTOS	17-19

Products:

Grams Gas COx	3.50	3.49	2.86	4.41	4.93	4.59	3.79	4.04	3.79	2.7	0.0
Grams Gas C1	17.16	17.84	14.83	22.21	22.20	23.04	24.87	28.32	26.42	45.7	17.2
Grams Gas C2	13.33	14.67	12.50	18.22	18.55	18.87	21.17	24.38	22.76	36.6	13.9
Grams Gas C3	12.53	14.46	13.04	17.94	18.35	18.91	21.43	24.68	22.03	38.3	14.5
Grams Gas C4	7.92	9.07	8.11	14.69	13.17	12.06	13.35	16.74	11.73	22.9	7.7
Grams Gas C5+	9.24	11.78	11.01	9.73	10.77	16.43	17.14	17.97	13.02	26.9	6.5
Grams Gas NH3	3.30	4.51	3.69	6.25	5.97	6.32	9.49	6.06	4.80	NA	4.3
Grams Gas H2S	25.22	28.59	32.14	41.11	41.04	43.50	35.66	52.86	43.45	35.4	36.1
Grams Net H2O	154.6	113.0	132.0	93.9	68.7	76.8	92.0	92.0	63.0	282.8	137.7
Grams S w/Net H2O	12.4	NA	NA	15.1	12.3	11.2	NA	NA	NA	NA	NA
Grams OH Product	657.00	872.00	785.00	614.00	764.00	927.00	765.00	1194.00	852.00	2308.7	1011.3
Grams TSB Product	946.55	1079.77	983.07	1156.98	1047.92	1038.57	816.48	1334.49	828.74	2439.6	1043.2
Grams Unconv.coal	110.35	127.97	110.50	112.69	93.48	88.84	68.59	149.31	73.88	194.3	91.0
Grams H2 Consump.	48.31	70.07	59.07	61.08	52.74	51.32	61.05	92.94	94.91	124	48.2

Total (MAF) wt bal	100.68	97.02	100.03	6.83	100.00	100.01	89.52	101.46	101.15	100.8	99.4
Total C balance	96.97	97.31	98.02	96.59	100.16	99.88	89.91	104.83	105.03	101.5	99.0
Total H balance	93.60	88.22	92.32	90.05	95.55	96.52	86.23	92.08	83.70	106.6	106.2
Total S balance	94.18	82.84	87.09	102.70	105.53	100.40	78.99	94.56	96.38	66.9	74.2
Total N balance*	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.0	100.0
Total ash balance	110.28	109.54	101.03	99.60	89.91	94.77	89.01	121.69	108.48	101.0	86.8
Total Cat. balance	84.21	108.75	96.47	82.07	79.69	80.26	78.73	105.77	97.97	90.4	62.7

Normalized Conversions:

Coal	83.11	83.09	84.12	83.95	86.69	88.29	88.99	84.57	88.36	89.3	88.3
C7 Insoluble	66.05	66.44	69.29	59.57	70.21	72.25	71.56	59.68	55.97	79.3	85.7
Nondist. (510C+)	55.90	53.56	55.71	46.39	58.06	61.07	62.10	57.43	61.99	56.2	56.4
Dist. (371C+)	36.22	34.52	33.94	33.33	38.66	41.63	41.38	38.88	40.42	34.9	35.5

Product Distribution:

wt% H2O+COx	8.22	5.23	6.58	4.75	3.56	3.64	5.22	3.37	3.57	5.3	5.9
wt% H2S	1.99	1.28	1.57	2.76	2.62	2.48	1.94	1.85	2.32	0.6	1.5
wt% NH3	0.17	0.20	0.18	0.30	0.29	0.28	0.52	0.21	0.26	0.4	0.2
wt% C1-C4	2.65	2.51	2.37	3.53	3.49	3.26	4.41	3.30	4.44	2.7	2.3
wt% C5-177C	4.86	5.70	5.62	8.77	2.31	5.03	5.73	4.82	7.07	5.9	5.7
wt% 177-343C	17.24	18.81	16.68	13.07	24.06	24.40	21.70	23.60	22.87	18.2	17.7
wt% 343-510C	28.53	28.34	30.82	22.42	29.25	28.88	30.03	28.59	31.07	31.5	30.2
wt% 510+C	33.17	35.23	33.68	41.85	32.49	30.37	29.70	32.32	29.58	34.2	34.6
wt% Unc MAF Coal	5.73	5.74	5.39	5.45	4.52	3.98	3.74	5.24	3.95	3.7	3.9
wt% total prod	102.57	103.05	102.88	102.91	102.59	102.33	102.98	103.31	105.13	102.4	102.1

*100% Nitrogen Balance assumed to calculate NH3 by disappearance of N from liquid streams.

Run No. 24 - 2:1 Lloydminster Resid:Illinois Coal No. 6
0.13 wt% Mo Catalyst

Run	24	24	24	24	24	24	24	24	24	19 Ave.	21 Ave.
Test Period	7	8	11	21B	22	24	33	34	35	LTOS	17-19

Toluene Soluble Bottoms Product Properties:

TSB API	3.3	3.4	3.4	2.3	3.9	2.9	0.3	0.7	0.3	3.3	7.4
TSB wt% C	85.62	85.33	85.34	86.45	85.56	86.16	86.29	85.75	86.47	85.98	88.3
TSB wt% H	9.15	9.14	9.11	9.40	9.54	9.38	9.15	9.27	9.14	10.18	11.0
TSB wt% S	2.39	2.73	2.62	2.04	2.26	2.14	2.24	2.45	2.04	2.27	1.6
TSB wt% N	1.23	1.23	1.30	1.03	1.00	1.12	0.98	1.11	1.16	NA	1.6
TSB wt% HI	17.96	17.88	16.24	21.27	16.32	17.07	19.02	25.76	33.71	11.65	4.9
TSB wt% MCRT	21.13	23.34	22.76	22.28	20.29	21.66	24.09	23.20	24.50	NA	16.4
TSB wt% ash	0	0	0	0	0	0	0	0	0	0.01	0.0
TSB ppm Mo	0	0	0	0	0	0	0	0	0	38	11.6
TSB D1160, vol%											
IBP, Deg C	NA	NA	NA	372	NA	182	369	NA	130	398.3	210.3
5%	NA	NA	NA	428	NA	392	430	NA	415	457.3	467.0
10%	NA	NA	NA	454	NA	432	461	NA	445	473.3	481.3
20%	NA	NA	NA	487	NA	470	483	NA	481	493.0	504.0
30%	NA	NA	NA	NA	NA	502	509	NA	511	512.8	527.3
40%	NA	NA	NA	NA	NA	537	NA	NA	525	NA	NA
50%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
60%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EP	NA	NA	NA	503	NA	551	532	NA	525	542.8	539.7
% @EP	NA	NA	NA	28	NA	45	39	NA	40	NA	36.3
wt% D1160 OH	41.32	39.3	39.97	28	43.8	45	38.7	37.08	39.6	42.42	36.3
TSB OH API	NA	NA	NA	11.5	NA	11.7	10.3	NA	11.8	10.9	14.5
TSB OH GLC, wt%											
IBP, Deg C	NA	NA	NA	273	NA	237	286	NA	108	340.3	252.7
5%	NA	NA	NA	348	NA	324	361	NA	340	412.0	403.3
10%	NA	NA	NA	374	NA	366	385	NA	374	434.5	431.7
20%	NA	NA	NA	403	NA	408	415	NA	408	459.0	459.0
30%	NA	NA	NA	423	NA	434	434	NA	429	474.8	475.0
40%	NA	NA	NA	438	NA	454	449	NA	446	488.8	487.0
50%	NA	NA	NA	451	NA	470	463	NA	462	500.3	497.7
60%	NA	NA	NA	465	NA	483	473	NA	475	511.8	508.0
70%	NA	NA	NA	477	NA	499	484	NA	488	523.5	519.3
80%	NA	NA	NA	491	NA	515	499	NA	503	536.5	531.0
90%	NA	NA	NA	510	NA	535	520	NA	523	554.5	545.3
95%	NA	NA	NA	526	NA	549	535	NA	537	568.5	559.7
EP	NA	NA	NA	562	NA	574	567	NA	565	577.5	572.0
% @EP	NA	NA	NA	99.5	NA	99	99.5	NA	100	100.0	97.3
wt% D1160 Btms	58.68	60.7	60.03	72	56.2	55	61.3	62.92	60.4	57.6	63.7
TSB Btms API	-2.2	-4.9	-5.4	-2.8	-1.7	-5.8	-6.4	-5.6	-6.7	-4.0	5.7

Run No. 24 - 2:1 Lloydminster Resid:Illinois Coal No. 6

0.13 wt% Mo Catalyst

Run	24	24	24	24	24	24	24	24	24	19 Ave.	21 Ave.
Test Period	7	8	11	21B	22	24	33	34	35	LTOS	17-19
Overhead Product Properties:											
OH API	24.9	24.9	26.2	29.6	20.9	24.3	25.1	24.5	25.9	24.4	26.4
OH wt% C	84.47	83.72	83.22	81.66	83.95	83.06	85.17	85.85	84.48	NA	84.8
OH wt% H	11.1	11.18	11.36	11.63	11.21	10.93	11.56	11.4	11.52	NA	11.8
OH wt% S	1.42	1.61	1.55	1.39	1.43	1.32	1.18	1.17	1.2	1.44	0.7
OH wt% N	0.4	0.412	0.331	0.367	0.474	0.423	0.435	0.43	0.416	0.33	0.2
OH GLC, wt%											
IBP, Deg C.	3	19	20	-16	141	16	0	4	0	38.0	-3.3
5%	114	112	104	49	188	106	87	111	75	120.0	89.3
10%	164	166	165	79	211	175	166	183	147	163.3	157.3
20%	218	222	226	105	242	223	225	228	219	219.8	233.3
30%	252	256	263	193	268	253	257	258	252	261.0	273.0
40%	282	287	298	252	293	280	285	285	283	298.0	306.0
50%	312	317	330	285	315	304	311	309	310	332.0	335.3
60%	341	345	359	314	337	328	337	333	337	361.0	362.7
70%	369	373	387	344	361	354	363	358	364	388.3	388.7
80%	397	401	416	375	386	381	388	383	392	415.0	414.0
90%	429	431	449	410	415	411	418	414	425	442.8	440.0
95%	449	452	476	429	431	429	434	432	445	460.5	455.0
EP	505	507	519	464	467	476	469	460	474	488.5	480.7
% OEP	99.5	100	100	100	100	100	100	100	100	100.0	100.0
Total Liquid Properties*											
API	12.1	13.0	13.5	11.8	11.1	13.0	12.3	11.9	13.3	13.6	16.8
wt% C	85.1	84.6	84.4	85.5	84.9	84.7	85.7	85.8	85.5	NA	86.6
wt% H	9.9	10.1	10.1	10.2	10.2	10.1	10.3	10.3	10.3	NA	11.4
wt% S	2.0	2.2	2.1	1.8	1.9	1.8	1.7	1.8	1.6	1.9	1.2
wt% N	0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.8	0.8	NA	0.9
wt% HI	10.6	9.9	9.0	13.9	9.4	9.0	9.8	13.6	16.6	6.0	2.5
wt% MCRT	12.5	12.9	12.7	14.6	11.7	11.4	12.4	12.2	12.1	NA	8.3
wt% dist. (371C-)	30.9	32.3	30.2	29.1	35.6	38.6	36.8	37.5	38.6	31.9	31.6
Unconverted Coal Solids Properties**:											
UCC wt% C	84.8	84.9	85.2	85.9	84.5	83.4	82.7	82.9	83.5	NA	82.2
UCC wt% H	5.9	6.2	6.5	6.1	6.2	5.9	5.7	5.8	5.7	NA	5.7
UCC wt% S	7.1	6.9	6.2	5.9	7.1	8.6	9.4	9.2	8.8	NA	10.2
UCC wt% N	2.2	2.1	2.1	2.1	2.1	2.0	2.2	2.2	2.1	NA	1.8
% Desulf.***	60.99	55.85	56.87	64.91	61.00	64.03	68.91	61.22	65.77	64.6	76.7
% Denitrif.***	26.46	27.71	25.86	34.58	32.84	31.36	45.48	29.83	29.80	NA	22.3

*Weighted average of overhead and toluene soluble bottoms products.

**Calculated as $(g \text{ TIB X}) / (g \text{ TIB C} + g \text{ TIB H} + g \text{ TIB S} - g \text{ Cat S} + g \text{ TIB N}) * 100\%$

***Calculated as $\%(\text{Feed S or N} - \text{Liquid Prod. S or N}) / (\text{Feed S or N}) * 100\%$

Appendix B

Run No. 25 - 2:1 Lloydminster Resid:Illinois Coal No. 6
0.11 wt% Mo Catalyst

Run	25	25	25	25	25	25	25	25	25	25	19 Ave.	21 Ave.
Test Period	6	7	11	13	17	21	23	27	31	41	LTOS	17-19
Initial HOS	72	84	132	156	204	252	276	324	372	492		
Ave Rx Int T, DegC	429	428.7	445	447	450.2	451	458	456.5	460.2	458.5	425.5	425.8
Rx Outlet P, psig	3008	3007	3010	3013	3014	3000	3000	3000	3000	3000	3058	3005
WHSV, x base	0.93	0.96	0.83	1.11	1.16	1.05	0.86	1.12	1.00	1.10	1.00	1.11
HPS Rec/Feed Ratio	6.0	6.0	6.5	5.1	5.1	5.5	6.7	5.1	6.0	5.0	NA	5.0
Feed Code	F12	F12	F12	F12	F12	F12	F12	F12	F12	F12	F08	F09
Grams MAF feed	1971.20	2026.62	1758.12	2336.20	2447.99	2216.76	1817.36	2363.91	2103.06	2328.55	5285.8	2348.4
Resid Code	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R08	R10
Grams Resid	1313.92	1350.86	1171.90	1557.22	1631.74	1477.61	1211.38	1575.69	1401.82	1552.13	3475.6	1565.6
Coal Code	C1.4	C1.4	C1.4	C1.4	C1.4	C1.4	C1.4	C1.4	C1.4	C1.4	C1.2	C1.4
Grams MAF Coal	657.27	675.75	586.22	778.98	816.25	739.15	605.98	788.22	701.24	776.43	1810.1	782.8
Catalyst Code	K6.7	K6.7	K6.7	K6.7	K6.7	K6.7	K6.7	K6.7	K6.7	K6.7	K1.0	K1.2
wt% cat. met./MAFF	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.00	0.99
Feed Distribution:												
wt% C5-177C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0
wt% 177-343C	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.6	0.5
wt% 343-510C	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	13.0	11.4
wt% 510+C	54.77	54.77	54.77	54.77	54.77	54.77	54.77	54.77	54.77	54.77	52.2	54.8
wt% MAF Coal	33.34	33.34	33.34	33.34	33.34	33.34	33.34	33.34	33.34	33.34	34.2	33.3
wt% H2 Consump.	2.59	2.61	3.25	2.51	3.37	2.70	3.46	2.82	3.38	3.73	2.4	2.1
wt% total feed	102.59	102.61	103.25	102.51	103.37	102.70	103.46	102.82	103.38	103.73	102.4	102.1
Feed Analysis:												
API gravity	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6.8	-7.2
wt% carbon	78.38	78.38	78.38	78.38	78.38	78.38	78.38	78.38	78.38	78.38	76.65	75.72
wt% hydrogen	8.32	8.32	8.32	8.32	8.32	8.32	8.32	8.32	8.32	8.32	7.90	8.03
wt% sulfur	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.38	3.99
wt% nitrogen	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.80	0.94
wt% hept. insol.	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.49	8.34
wt% MCRT	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	10.55	10.70
wt% dist. (371C-)	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.96	0.66

Run No. 25 - 2:1 Lloydminster Resid:Illinois Coal No. 6
0.11 wt% Mo Catalyst

Run	25	25	25	25	25	25	25	25	25	25	19 Ave.	21 Ave.
Test Period	6	7	11	13	17	21	23	27	31	41	LTOS	17-19
Products:												
Grams Gas COx	3.82	3.84	4.22	3.56	4.83	4.81	2.88	6.30	3.97	4.74	2.7	0.0
Grams Gas C1	20.00	20.91	32.63	33.15	39.65	41.22	42.65	53.93	52.47	52.57	45.7	17.2
Grams Gas C2	16.47	16.59	26.85	29.74	34.88	35.94	40.20	52.60	47.51	49.35	36.6	13.9
Grams Gas C3	15.78	15.89	27.59	31.25	35.72	39.09	48.71	61.68	56.48	57.70	38.3	14.5
Grams Gas C4	10.49	10.56	15.97	18.52	19.20	21.86	35.63	40.37	47.40	48.56	22.9	7.7
Grams Gas C5+	16.00	14.45	23.50	32.03	29.17	22.98	34.81	34.87	44.98	65.76	26.9	6.5
Grams Gas NH3	2.07	4.85	6.53	9.82	7.96	7.77	7.77	12.40	16.69	19.19	NA	4.3
Grams Gas H2S	40.93	41.49	44.49	50.67	55.91	51.76	45.03	58.72	56.98	75.54	35.4	36.1
Grams Net H2O	33.3	118.1	80.0	67.1	10.8	65.9	13.7	119.4	104.3	80.7	282.8	137.7
Grams S w/Net H2O	7.7	7.9	15.0	18.9	19.2	16.1	17.3	17.6	14.7	9.3	NA	NA
Grams OH Product	730.00	713.00	957.00	1113.00	1358.00	1195.00	1077.00	1382.00	1118.00	1417.00	2308.7	1011.3
Grams TSB Product	1014.35	1032.81	522.00	798.20	818.00	560.54	408.49	498.20	689.84	475.17	2439.6	1043.2
Grams Unconv.coal	141.88	117.02	61.62	81.93	75.87	57.99	60.67	68.83	55.13	51.49	194.3	91.0
Grams H2 Consump.	51.14	52.80	57.16	58.66	82.62	59.80	62.82	66.71	71.13	86.76	124	48.2
Total (MAF) wt bal	101.51	101.83	100.12	95.53	99.15	93.17	97.59	99.02	106.18	99.66	100.8	99.4
Total C balance	102.76	99.27	96.20	94.29	103.58	94.38	100.25	97.37	102.37	97.72	101.5	99.0
Total H balance	92.71	93.93	92.50	94.65	91.21	90.77	90.86	98.14	105.52	97.05	106.6	106.2
Total S balance	109.64	103.77	109.72	100.85	104.81	98.38	107.58	102.33	100.29	111.33	66.9	74.2
Total N balance*	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.0	100.0
Total ash balance	130.11	109.06	101.58	109.92	92.85	77.73	106.98	96.87	87.58	82.03	101.0	86.8
Total Cat. balance	122.63	88.90	88.53	91.97	83.73	71.99	112.23	98.15	85.64	108.03	90.4	62.7
Normalized Conversions:												
Coal	78.73	82.99	89.50	88.99	90.63	91.58	89.74	91.18	92.59	93.35	89.3	88.3
C7 Insoluble	39.80	57.91	73.88	72.87	77.52	79.93	59.68	77.25	88.25	88.70	79.3	85.7
Nondist. (510C+)	42.00	50.73	70.36	66.63	72.93	77.52	77.22	78.61	84.56	86.82	56.2	56.4
Dist. (371C+)	28.71	33.02	52.38	49.43	50.62	56.07	60.21	59.89	66.86	72.57	34.9	35.5
Product Distribution:												
wt% H2O+COx	1.85	5.91	4.78	3.17	0.64	3.42	0.93	5.37	4.85	3.68	5.3	5.9
wt% H2S	2.46	2.42	3.43	3.17	3.14	3.33	3.58	3.31	3.25	3.68	0.6	1.5
wt% NH3	0.10	0.24	0.37	0.44	0.33	0.38	0.44	0.53	0.75	0.83	0.4	0.2
wt% C1-C4	3.14	3.10	5.85	5.05	5.33	6.69	9.43	8.91	9.13	8.97	2.7	2.3
wt% C5-177C	4.41	4.06	11.32	12.70	3.22	3.02	9.43	3.56	13.23	15.72	5.9	5.7
wt% 177-343C	16.10	16.67	25.01	22.95	34.47	34.97	33.43	34.51	34.50	37.75	18.2	17.7
wt% 343-510C	23.45	26.83	26.41	25.69	32.43	31.13	26.21	27.84	24.31	21.51	31.5	30.2
wt% 510+C	44.02	37.75	22.62	25.73	20.73	17.00	16.65	15.91	11.14	9.39	34.2	34.6
wt% Unc MAF Coal	7.09	5.67	3.50	3.67	3.13	2.81	3.42	2.94	2.47	2.22	3.7	3.9
wt% total prod	102.62	102.63	103.30	102.56	103.42	102.75	103.52	102.87	103.42	103.75	102.4	102.1

*100% Nitrogen Balance assumed to calculate NH3 by disappearance of N from liquid streams.

Run No. 25 - 2:1 Lloydminster Resid:Illinois Coal No. 6
0.11 wt% Mo Catalyst

Run	25	25	25	25	25	25	25	25	25	25	19 Ave.	21 Ave.
Test Period	6	7	11	13	17	21	23	27	31	41	LTOS	17-19
Toluene Soluble Bottoms Product Properties:												
TSB API	2.3	2.1	-2.5	-1.2	0	-0.8	-4.3	-5	0.7	0.4	3.3	7.4
TSB wt% C	85.92	85.71	86.62	86.84	86.48	87.38	87.84	86.57	86.91	86.88	85.98	88.3
TSB wt% H	9.15	9.16	8.54	8.90	8.75	8.75	8.20	7.81	8.48	8.48	10.18	11.0
TSB wt% S	2.64	2.51	1.96	1.94	2.01	1.85	1.82	1.99	1.52	1.91	2.27	1.6
TSB wt% N	1.18	1.06	1.32	1.16	1.14	1.39	1.33	1.22	0.51	0.52	NA	1.6
TSB wt% HI	36.34	24.31	25.52	21.89	19	21	59.34	31.48	8.12	12.56	11.65	4.9
TSB wt% MCRT	27.69	23.76	30.50	27.93	25.23	26.3	31.98	32.90	19.24	20.01	NA	16.4
TSB wt% ash	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0.01	0.0
TSB ppm Mo	0	0	0	0	0	0	0	0	0	0	38	11.6
TSB D1160, vol%												
IBP, Deg C	116	140	119	130	150	138	208	305	254	284	398.3	210.3
5%	480	444	475	458	361	350	454	451	352	350	457.3	467.0
10%	510	463	486	473	432	403	474	465	374	375	473.3	481.3
20%	539	495	502	492	470	473	495	497	400	399	493.0	504.0
30%	NA	521	520	514	494	499	515	523	423	424	512.8	527.3
40%	NA	NA	NA	533	519	521	NA	NA	447	455	NA	NA
50%	NA	NA	NA	NA	NA	NA	NA	NA	472	492	NA	NA
60%	NA	NA	NA	NA	NA	NA	NA	NA	506	525	NA	NA
EP	550	539	535	533	532	530	530	540	533	547	542.8	539.7
% @EP	25	38	37	40	46	45	38	36	67	65	NA	36.3
wt% D1160 OH	22.98	36.12	35.60	38.31	46	45	35.76	35.08	66.85	64.57	42.42	36.3
TSB OH API	11.6	11.5	7.2	8.2	9.7	9.4	5.1	4	8	8.1	10.9	14.5
TSB OH GLC, wt%												
IBP, Deg C	111	110	111	111	119	110	195	250	200	177	340.3	252.7
5%	117	317	404	384	244	228	353	382	306	249	412.0	403.3
10%	396	405	433	420	302	286	409	411	332	275	434.5	431.7
20%	442	444	458	445	384	375	440	439	360	302	459.0	459.0
30%	468	463	472	460	423	419	456	457	378	320	474.8	475.0
40%	484	475	481	472	444	444	468	471	395	337	488.8	487.0
50%	499	486	492	481	460	462	477	481	411	355	500.3	497.7
60%	511	499	503	492	473	475	487	494	426	373	511.8	508.0
70%	524	512	514	505	485	488	500	507	442	392	523.5	519.3
80%	535	527	528	520	502	505	514	522	461	414	536.5	531.0
90%	552	544	543	538	527	527	532	538	484	440	554.5	545.3
95%	570	561	560	553	544	543	545	550	506	463	568.5	559.7
EP	570	574	573	566	573	567	573	574	546	507	577.5	572.0
% @EP	95	97	97	97	98	98	99	99	100	100	100.0	97.3
wt% D1160 Btms	77.02	63.88	64.40	61.69	54	55	64.24	64.92	33.15	35.43	57.6	63.7
TSB Btms API	2.3	-1.5	-8.8	-8.3	-8.9	-10.2	-11.4	-21.2	-12.8	-12.6	-4.0	5.7

Run No. 25 - 2:1 Lloydminster Resid:Illinois Coal No. 6
0.11 wt% Mo Catalyst

Run	25	25	25	25	25	25	25	25	25	25	19 Ave.	21 Ave.
Test Period	6	7	11	13	17	21	23	27	31	41	LTOS	17-19
Overhead Product Properties:												
OH API	23.2	23.7	26.9	30.7	20.6	19.6	24.6	19.9	32.8	25.5	24.4	26.4
OH wt% C	82.23	83.91	81.31	83.44	86.6	87.38	85.14	87.06	82.86	83.63	NA	84.8
OH wt% H	10.99	11.11	11.03	11.64	11.2	10.82	10.66	11.34	12.73	11.75	NA	11.8
OH wt% S	1.45	1.41	1.02	0.99	1.06	0.98	0.91	0.97	0.54	1.03	1.44	0.7
OH wt% N	0.471	0.459	0.469	0.455	0.551	0.625	0.485	0.51	0.345	0.366	0.33	0.2
OH GLC, wt%												
IBP, Deg.C.	20	23	-16	-38	146	152	0	139	37	36	38.0	-3.3
5%	113	115	37	34	194	199	72	193	94	98	120.0	89.3
10%	185	186	87	64	215	219	157	214	125	128	163.3	157.3
20%	237	236	196	159	245	248	221	244	169	173	219.8	233.3
30%	273	269	239	224	270	272	251	269	200	208	261.0	273.0
40%	305	299	271	259	294	296	278	294	226	236	298.0	306.0
50%	334	326	302	291	316	318	301	316	248	266	332.0	335.3
60%	363	353	331	320	340	342	326	339	272	296	361.0	362.7
70%	389	379	361	349	363	365	351	363	297	329	388.3	388.7
80%	417	406	390	378	387	391	377	388	324	372	415.0	414.0
90%	445	432	423	409	415	421	408	419	368	447	442.8	440.0
95%	465	448	443	428	432	439	427	439	448	488	460.5	455.0
EP	494	489	475	465	466	496	464	472	506	560	488.5	480.7
% @EP	100	100	100	100	100	100	99.5	99.5	100	100	100.0	100.0
Total Liquid Properties*												
API	11.0	10.9	16.5	17.4	12.9	13.1	16.7	13.3	20.6	19.2	13.6	16.8
wt% C	84.4	85.0	83.2	84.9	86.6	87.4	85.9	86.9	84.4	84.4	NA	86.6
wt% H	9.9	10.0	10.2	10.5	10.3	10.2	10.0	10.4	11.1	10.9	NA	11.4
wt% S	2.1	2.1	1.4	1.4	1.4	1.3	1.2	1.2	0.9	1.3	1.9	1.2
wt% N	0.9	0.8	0.8	0.8	0.8	0.9	0.7	0.7	0.4	0.4	NA	0.9
wt% HI	21.1	14.4	9.0	9.1	7.1	6.7	16.3	8.3	3.1	3.2	6.0	2.5
wt% MCRT	16.1	14.1	10.8	11.7	9.5	8.4	8.8	8.7	7.3	5.0	NA	8.3
wt% dist. (371C-)	26.9	28.1	47.9	45.7	48.8	52.0	56.9	54.1	62.4	69.3	31.9	31.6
Unconverted Coal Solids Properties**:												
UCC wt% C	86.4	86.4	84.4	83.7	84.0	82.9	83.4	83.7	82.9	83.6	NA	82.2
UCC wt% H	6.0	5.9	5.4	5.6	5.7	5.6	5.3	5.2	5.6	4.8	NA	5.7
UCC wt% S	5.5	5.7	8.3	8.9	8.3	9.9	9.0	9.9	10.7	11.0	NA	10.2
UCC wt% N	2.1	2.1	1.9	1.8	2.1	1.6	2.3	1.3	0.8	0.7	NA	1.8
% Desulf.***	56.19	59.01	73.71	73.75	70.87	76.97	78.05	77.20	81.85	76.48	64.6	76.7
% Denitrif.***	23.51	31.27	36.80	39.98	32.84	32.66	42.72	45.75	65.61	67.91	NA	22.3

*Weighted average of overhead and toluene soluble bottoms products.

**Calculated as $(g \text{ TIB } x) / (g \text{ TIB } C + g \text{ TIB } H + g \text{ TIB } S - g \text{ Cat } S + g \text{ TIB } N) * 100\%$

***Calculated as $(\text{Feed } S \text{ or } N - \text{Liquid Prod. } S \text{ or } N) / (\text{Feed } S \text{ or } N) * 100\%$

MAF Coal Conversion vs. Temperature

Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

Nondistillable Conversion vs. Temperature

Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

Hept. Insol. Conversion vs. Temperature

Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

371°C+ ND Conversion vs. Temperature

Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

Wt-% H₂ Consumption vs. Temperature

Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

Light Ends Yields vs. Temperature

+ Run 24 - 0.13% Mo

x Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

C5-177°C Naphtha Yield vs. Temperature

+ Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

177-343°C Dist. Yield vs. Temperature

Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

343-510°C VGO Yield vs. Temperature

Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

510°C+ ND Yield vs Temperature

Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

C5-510°C Liquid Yield vs. Temperature

Run 24 - 0.13 % Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

C5+ Total Liquid Yield vs. Temperature

Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

C5+ Liquid Product °API vs. Temperature

Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

C5+ Product Wt-% S vs. Temperature

+ Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

C5+ Product Wt-% N vs. Temperature

Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

C5+ Product Wt-% HI vs. Temperature

Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

C5+ Product Wt% MCRT vs. Temperature

Run 24 - 0.13% Mo

Run 25 - 0.11% Mo

K6.7 Catalyst, C1.4 Coal, R10 Resid
3000 psig, base WHSV, 2:1 Resid:Coal

- END -

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