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QUARTERLY REPORT

This quarterly report is the fifth 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 has concentrated on Tasks 3.1.1 (Pilot Plant Modification), 3.1.2 (Plant Recertification), and 3.1.3 (Reactor Back-Mixing Study). The results of these tasks are discussed in this report.

PILOT PLANT MODIFICATIONS

A number of parallel tests were completed in both the bench-scale unit and a rocking autoclave under UOP's previous contract. The autoclave test was developed as a quick and inexpensive means of screening

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new feedstocks and catalysts to reduce the work load on the bench-scale unit. Operating conditions for the autoclave and bench-scale unit were set to make the autoclave results as useful as possible for predicting continuous-run performance. Reasonable correspondence between the tests was observed for the reference catalyst and feedstocks, but when a slurry iron catalyst was tried in Run 17, the performance of the bench-scale unit fell far short of the results predicted on the basis of the autoclave results. This run was also plagued with operating problems. The low-pressure (fractionation) side of the plant kept plugging and had to be bypassed. Conversions were observed to be little better than those obtained using no catalyst at all. The results were disappointing because catalyst costs for the reference vanadium-based slurry catalyst are high, and the use of an inexpensive throwaway iron catalyst would have made the process economics more attractive.

Differences in the performance of the autoclave and bench-scale units with the iron catalyst were difficult to reconcile. Either the autoclave results were not representative of true continuous performance, or the bench-scale unit was somehow mechanically limited and was not performing up to predictions. It was suggested that perhaps the bench-scale unit was not completely back-mixed. To minimize coking, any coke precursors that are formed must have intimate contact with the catalytic metal and hydrogen. Improved mixing also minimizes the contact of reactants with the hot reactor walls and helps to maintain a more uniform temperature profile. To test whether the bench-scale reactor was truly back-mixed, a liquid-recycle system was

added to the plant to return a portion of the liquid product from the bottom of the high-pressure separator to the inlet of the reactor. Gillespie and Carberry (1) have shown that the addition of a recycle stream to an unmixed reactor can be used to simulate a continuous stirred tank reactor (CSTR). As the ratio of recycle to fresh feed is increased, conversion approaches the conversion for an ideal CSTR. With a recycle ratio of 20, for example, the conversion in a plug-flow reactor becomes indistinguishable from that of the ideal CSTR. For a partly-mixed reactor, a lower recycle ratio of about 3:1 to 5:1 would be sufficient to achieve near-perfect mixing.

Prior to Run 20, the bench-scale unit was modified, as shown in Figure 1, to incorporate the liquid-recycle system. A recycle pump and high-pressure mass flow meter were added, and several other plant changes were made to accommodate the larger flows associated with liquid recycle. The volume of the high-pressure separator (HPS) was doubled, and a longer reactor preheat zone and new preheater were added to increase the heater duty.

PILOT PLANT RECERTIFICATION

Runs 20 and 21

The first run with the modified plant was a shakedown run to reference plant performance to that of the long-term operability study

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conducted in Run 19. In addition to the plant changes, new batches of the reference vanadium catalyst (K1.2) and feedstocks (Illinois Coal No. 6 batch C1.4 and Lloydminster Vacuum Resid batch R10) were used.

The bench-scale unit was started up with the system full of flush oil. Slurry feed was cut into the reactor at 0900 hrs on 1/24/89. During the start-up, a number of problems were encountered. At 60 hours on stream (HOS), loss of the fractionator bottoms pump as a result of electrical problems caused level fluctuations throughout the plant. The run eventually had to be shut down at 65 HOS because of plugging. After the run, the reactor system was disassembled and three inches of solids were found in the reactor preheater. Several additional attempts to restart the plant also led to plugging of the feed line. The problem was traced to the design of the new preheater, which differed in the dispersing section from the original design used during earlier runs. The preheater was remachined to conform with the old design, and the plant certification run was restarted on 2/17/89 as Run 21.

The first portion of Run 21 was conducted without recycle to compare the new reference feedstocks with those used previously in Run 19. The average results from four test periods (8, 10, 11, and 12) are summarized in Tables 1A and 1B, and are compared to the Run 19 averages. The coal, 510+°C nondistillable (ND), and 371+°C conversions were all equal to previous reference performance. However, the heptane insoluble (HI) conversion was about 4% higher than in Run 19. This trend was also observed in autoclave tests using the Run 19 and 21 feeds

(Table 2). Detailed analyses of the new reference feedstocks used in Run 21 (R10 and C1.4) and the prior reference feeds (R8 and C1.3) have been reported previously (2). The compositions of the feedstocks are so similar that any differences in Runs 19 and 21 are probably not feedstock related. More likely, the new reference catalyst (K1.2) is a little bit more active or better dispersed than the original reference catalyst (K1.0).

REACTOR BACK-MIXING STUDIES

Following test period 12 of Run 21 (181 HOS), the new liquid recycle system was brought on stream. Plant operation was lined out at a recycle ratio of 5:1 (recycle to fresh feed). Three test periods (17-19) were worked up at the 5:1 ratio. Then the recycle ratio was dropped to 2.5:1, and three more good test periods (21, 22 and 25) were obtained. The plant was shut down (as scheduled) on 3/3/89 to conserve feed.

Average results for the various recycle ratios are compared in Tables 3A and 3B, and detailed information on the individual test periods is given in the Appendix. Coal conversion is essentially constant at about 89 wt-% for all the recycle ratios tested. However, the presence of liquid recycle does appear to improve asphaltene conversion (as measured by the disappearance of HI's) and 510+°C ND conversion. At a 2.5:1 recycle to feed ratio, HI conversion increased

from 83.2 to 88.1 wt-% and the ND conversion increased from 57.7 to 63.3%. Further increases in the recycle ratio (to 5:1) did not, however, improve conversion any more. In fact, the average HI conversion dropped to 85.7%, and the ND conversion to 56.4%. Whether these differences are entirely due to increased back-mixing or to other effects that accompany the change in recycle rate is not clear.

Although every attempt was made to hold operating conditions constant for the three sets of tests, some differences did occur. As the recycle ratio was increased, the superficial velocity through the reactor also increased. Block temperatures on the preheater and reactor had to be hotter for the higher recycle cases to achieve the same average reactor temperatures. For example, the preheater block temperature was 314°C with no recycle, 450°C for 2.5:1 recycle, and 460°C for 5:1 recycle. The bottom and top block temperatures were 400 and 440°C with no recycle, 450 and 437°C at 2.5:1, and 452 and 450°C at 5:1. Internal reactor profiles are compared in Figure 2. The "best" (i.e., flattest) profile was achieved at the 2.5:1 recycle ratio. At 5:1, although the average reactor temperature was the same, the inlet temperature was low and the outlet temperature was high due to heat transfer limitations. Lower conversions at 5:1 were possibly due to insufficient temperature in the front end of the reactor and/or to retrograde reactions at the higher temperature at the back end of the reactor.

Improved back-mixing is probably at least partly responsible for the improved HI and ND conversions that were observed. Further data are needed before any quantitative conclusions can be reached. Regardless of whether or not there was any real improvement in conversion, there was a clear improvement in the operability of the bench-scale unit with added liquid recycle. The recycle stream had a "flywheel" effect that helped to keep the plant running stably, even after relatively major upsets in the feed rate or HPS level. The higher velocities through the reactor reduced the formation of coke on the hot reactor walls. The interior of the reactor was visibly cleaner after Run 21 than it had been after similar runs with no recycle. Thus, it may be possible to operate the plant at higher temperatures than were possible without the recycle. Because of these benefits and the possibility that improved back-mixing makes bench-scale results more representative of the conversions expected from a completely back-mixed commercial unit, liquid recycle was continued in subsequent runs. The recycle ratio was set at the maximum level for which a flat reactor temperature profile could be maintained.

Runs 22 and 23

Runs 22 and 23 were made in the bench-scale unit using 2 wt-% iron catalyst (Kerr-McGee porous iron oxide similar to that used at Wilsonville) with reference feedstocks and operating conditions. The same iron catalyst was used unsuccessfully in Runs 15 to 17 of the previous contract. The major difference between Runs 22 and 23 and the earlier

runs was the use of liquid recycle to improve reactor back-mixing.

Run 22 was plagued with operational problems. The first start-up attempt was made on 4/19/89. The reactor and HPS recycle system were started up using FCC clarified oil, liquid recycle was established, and temperatures were brought up to 400°C before cutting in the slurry feed. Then block temperatures were raised to give a 425°C average reactor temperature (ART). By 52 HOS, the line from the low-pressure separator (LPS) to the vacuum column had plugged, the vacuum column had to be bypassed, and the separator product had to be run directly into a collection pot. At 55 HOS, the lines to the collection pots were also plugged and the plant had to be shut down. After cleaning out all of the lines, a second attempt was made on 4/26/89 using the same procedure. This time the block temperatures were adjusted to give an ART of 435°C. The plant again had to be shut down after 48 hours of operation, this time because of plugging at the reactor inlet. For the third start-up attempt on 5/3/89, the LPS and vacuum column were bypassed, and the products went directly to a collection pot. An ART of 425°C was used, similar to the first try. At 24 HOS, the feed pump gearbox broke. A plug formed in the suction line to both HPS recycle pumps. Level problems in the HPS caused heavy hydrocarbon to carry over into the two recycle gas compressors, shutting them down, and the run was aborted once more. At that point, the whole reactor and separator section was disassembled and cleaned. The reactor itself was fairly clean. The HPS vessel, the hot knock out pot downstream of it, and various plugged lines were replaced.

Run 23 was a repeat of the unsuccessful Run 22. Feed was cut in on 5/16/89, and the block temperatures were lined out to give an ART of 425°C. The plant ran fairly well for 96 hours. The LPS and vacuum column were again bypassed to eliminate possible plugging there. Seven test periods were conducted. Yields and conversions for periods 2, 6, and 7 are summarized in Tables 4A and 4B. Compared with the average values for Run 17 (with 2% iron catalyst and no liquid recycle), the average conversions for Run 23 were 2 to 3% lower. Increasing the recycle ratio and degree of back-mixing apparently had no effect on either conversion or plant operability for the iron system.

In an attempt to improve the conversions, the ART was increased to about 440°C after 96 HOS. Within 4 hours, the HPS liquid level control started to become erratic. Two more test periods were conducted, but the plant was not well lined out, and the resulting mass balances are high. These data for period 9 are summarized in Tables 5A and 5B. Conversions did improve relative to the 425°C case, but still fell far short of levels that have been achieved using other catalysts, such as vanadium or molybdenum, that have a strong hydrogenation function. At 123 HOS, the plugging became so severe into and out of the collection pots that a steady level could not be maintained. Maintaining a steady HPS liquid recycle also became difficult, and the run was aborted on 5/20/89.

The absence of a strong hydrogenation function for the iron catalyst system has consistently resulted in excessive coking during bench-scale trials. This problem has not occurred in the autoclave because the analytical workup of the products is done manually. However, because of the relatively small line sizes in the bench-scale unit, the unit is especially susceptible to plugging problems. In numerous attempts (Runs 15, 16, 17, 22 and 23), the low-pressure side of the plant has never successfully been operated. The main problem has been in the bottoms outlet line from the LPS, where after the light ends are flashed off, the solids (unconverted coal and catalyst) tend to come out of solution and plug the inlet line to the vacuum column. This phenomenon has not been observed with vanadium or molybdenum catalysts and may have to do with the properties of the liquid product. The more highly hydrogenated and paraffinic product produced by the V and Mo catalysts appears to have a greater affinity for keeping the solids in solution. In the case of the iron catalyst, many of the paraffins may be cracked out, leaving a more refractory aromatic material. The liquid-product properties for Runs 23 and 21 are compared in Tables 6A and 6B. The product from the iron run has a much lower API gravity, a lower hydrogen content, higher sulfur content, and much greater levels of heptane insolubles and micro-carbon (MCRT).

Going to higher pressures, larger line sizes, or incorporating a bottoms recycle loop on the LPS to increase the liquid velocity in the LPS outlet line may all improve the operability of the LPS system with the iron catalyst. However, the iron catalyst simply does not make as

highly hydrogenated a product as other available slurry catalyst systems. Even if all of the operability problems can be solved, a question still exists as to whether or not the iron system is really any less expensive than competing vanadium or molybdenum catalysts. At current raw material prices (3), Fe_2O_3 goes for \$0.205/lb (\$0.293/lb Fe), V_2O_5 for \$6.65/lb (\$11.88/lb V), and MoO_3 for \$3.60/lb (\$5.42/lb Mo). Preliminary work with a new molybdenum catalyst (to be reported in greater detail in the next quarterly report), has shown that with as little as 0.13 wt-% molybdenum, bench-scale unit yields and conversions can be achieved that are superior to those for the 2.0 wt-% iron catalyst while still maintaining excellent plant operability. The 15-times lower catalyst concentration for the molybdenum relative to the iron nearly offsets the 18.5-times greater catalyst cost. When the yield and product quality advantages of the molybdenum system are taken into account, the economics for the molybdenum catalyst become superior to those for iron, even on a throwaway catalyst basis. With ongoing optimization of the molybdeum system and the development of a catalyst recovery process to further reduce catalyst costs, the advantage of the molybdenum system over iron in slurry catalyst applications can only be expected to intensify. For this reason and because of the poor plant operability when using the iron catalyst, the decision was made to discontinue all further work with iron catalysts and concentrate on development of a molybdenum-based slurry catalyst system.

CONCLUSIONS

The continuous bench-scale unit was successfully rereferenced after the addition of a HPS liquid-recycle system. This recycle system was added to simulate improved reactor back-mixing. At a 2.5:1 ratio of recycle to fresh feed, asphaltene and nondistillable conversions increased by about 5 wt-% over reference performance with no recycle. Coal conversion was unchanged. The recycle system also improved the operability of the bench-scale unit by giving it more inertia against feed upsets. Higher superficial velocities in the reactor helped to decrease coking at the reactor walls.

Testing of a slurry iron catalyst in Runs 22 and 23 resulted in coking and plugging of the low-pressure side of the plant. The addition of the recycle system did not improve conversions over Runs 15 to 17 with the same iron catalyst but no recycle. The development of a Mo slurry catalyst system that is less expensive than the iron, even on a throwaway basis, has caused further work with iron catalysts to be discontinued.

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REFERENCES

1. B. Gillespie and J. Carberry, "Influence of Mixing on Isothermal Reactor Yield and Adiabatic Reactor Conversion", I & EC Fundamentals 5 (May 1966):164-171.
2. D. A. Nafis, et al, "Bench-Scale Co-Processing: Quarterly Report No. 2," prepared for the United States Department of Energy under Contract No. DE-AC22-87PC79818, Feb. 15, 1989.
3. Chemical Marketing Reporter, Vol. 236, No. 4, July 24, 1989.

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Table 1A- Plant Recertification

Run Test Period	19 Ave. LTOS	21 Ave. 8,10-12	Run Test Period	19 Ave. LTOS	21 Ave. 8,10-12
Ave Rx Int T, DegC	425.5	425.8	Products:		
Rx Outlet P, psig	3058	3022	Grams Gas COx	2.7	0.4
WHSV/Base WHSV	1.0	1.2	Grams Gas C1	45.7	17.3
Rec. H2 Pty., mol%	86.1	86.1	Grams Gas C2	36.6	14.1
HPS Rec/Feed Ratio	0.0	0.0	Grams Gas C3	38.3	13.4
Feed Code	F08	F09	Grams Gas C4	22.9	8.1
Grams MAF feed	5285.8	2485.5	Grams Gas C5+	26.9	7.5
Resid Code	R08	R10	Grams Gas NH3	NA	8.3
Grams Resid	3475.6	1657.0	Grams Gas H2S	35.4	30.8
Coal Code	C1.2	C1.4	Grams Net H2O	282.8	124.8
Grams MAF Coal	1810.1	828.5	Grams S w/Net H2O	NA	NA
Catalyst Code	K1.0	K1.2	Grams OH Product	2308.7	1182.5
wt% cat. met./MAFF	1.00	0.99	Grams TSB Product	2439.6	1027.5
Feed Distribution:			Grams Unconv.coal	194.3	87.4
wt% C5-177C	0.0	0.0	Grams H2 Consump.	124	55.5
wt% 177-343C	0.6	0.5	Total (MAF) wt bal	100.8	99.7
wt% 343-510C	13.0	11.4	Total C balance	101.5	99.1
wt% 510+C	52.2	54.8	Total H balance	106.6	101.0
wt% MAF Coal	34.2	33.3	Total S balance	66.9	79.5
wt% H2 Consump.	2.4	2.2	Total N balance*	100.0	100.0
wt% total feed	102.4	102.2	Total ash balance	101.0	87.2
Feed Analysis:			Total Cat. balance	90.4	NA
API gravity	-6.8	-7.2	Normalized Conversions:		
wt% carbon	76.65	75.72	Coal	89.3	89.5
wt% hydrogen	7.90	8.03	C7 Insoluble	79.3	83.2
wt% sulfur	4.38	3.99	Nondist. (510C+)	56.2	57.5
wt% nitrogen	0.80	0.94	Dist. (371C+)	34.9	34.1
wt% hept. insol.	8.49	8.34	Product Distribution:		
wt% MCRT	10.55	10.70	wt% H2O+COx	5.3	5.2
wt% dist. (371C-)	0.96	0.66	wt% H2S	0.6	1.3
			wt% NH3	0.4	0.3
			wt% C1-C4	2.7	2.2
			wt% C5-177C	5.9	5.5
			wt% 177-343C	18.2	17.5
			wt% 343-510C	31.5	32.9
			wt% 510+C	34.2	33.9
			wt% Unc MAF Coal	3.7	3.5
			wt% total prod	102.4	102.2

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

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Table 1B- Plant Recertification

Run Test Period	19 Ave. LTOS	21 Ave. 8,10-12	Run Test Period	19 Ave. LTOS	21 Ave. 8,10-12
Toluene Soluble Bottoms Product Properties:			Overhead Product Properties:		
TSB API	3.3	4.4	OH API	24.4	23.9
TSB wt% C	85.98	86.48	OH wt% C	NA	84.99
TSB wt% H	10.18	9.95	OH wt% H	NA	11.60
TSB wt% S	2.27	2.21	OH wt% S	1.44	1.29
TSB wt% N	NA	1.33	OH wt% N	0.33	0.31
TSB wt% HI	11.65	9.14	OH GLC, wt%		
TSB wt% MCRT	NA	19.95	IBP, Deg C.	38.0	0.3
TSB wt% ash	0.01	0.00	5%	120.0	101.0
TSB ppm Cat.	38	32	10%	163.3	168.8
TSB D1160, vol%			20%	219.8	244.8
IBP, Deg C	398.3	410.5	30%	261.0	288.3
5%	457.3	477.3	40%	298.0	322.8
10%	473.3	496.5	50%	332.0	352.3
20%	493.0	NA	60%	361.0	380.0
30%	512.8	NA	70%	388.3	406.3
40%	NA	NA	80%	415.0	431.3
50%	NA	NA	90%	442.8	457.5
60%	NA	NA	95%	460.5	474.5
EP	542.8	537.8	EP	488.5	514.0
% @EP	NA	28.1	% @EP	100.0	100.0
wt% D1160 OH	42.42	28.30	Total Liquid Properties*		
TSB OH API	10.9	12.9	API	13.6	14.9
TSB OH GLC, wt%			wt% C	NA	85.6
IBP, Deg C	340.3	327.0	wt% H	NA	10.8
5%	412.0	402.8	wt% S	1.9	1.7
10%	434.5	427.8	wt% N	NA	0.8
20%	459.0	456.0	wt% HI	6.0	4.0
30%	474.8	473.8	wt% MCRT	NA	9.0
40%	488.8	487.0	wt% dist. (371C-)	31.9	30.8
50%	500.3	498.5	Unconverted Coal Solids Properties**		
60%	511.8	509.8	UCC wt% C	NA	82.1
70%	523.5	520.8	UCC wt% H	NA	5.6
80%	536.5	532.3	UCC wt% S	NA	10.7
90%	554.5	548.0	UCC wt% N	NA	1.6
95%	568.5	562.5	% Desulf.***		
EP	577.5	572.8		64.6	77.4
% @EP	100.0	97.0	% Denitrif.***		
wt% D1160 Btms	57.6	71.7		NA	32.9
TSB Btms API	-4.0	-3.5			

*Weighted average of overhead and toluene soluble bottoms products.

**Calculated as (gTIBx)/(gTIBC + gTIBH + gTIBS - gCatS + gTIBN)*100%

***Calculated as (Feed S or N - Liquid Prod. S or N)/(Feed S or N)*100%

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Table 2 - Comparison of Autoclave Results for Run 19 and Run 21 Feeds

Feed from:	Run 19	Run 21
Autoclave Test:	5392-****	6431-009
Coal Type	MF C1.2	MF C1.4
Resid Type	R8	R10
Catalyst Type	K1.0	K1.2
Resid/Coal, wt/wt	1.92	2.00
Catalyst, wt% MAFF	1.01	1.00
Temp., Deg C.	420	420
Pressure, atm.	200	200
Res. Time, hrs.	2	2
Weight Recovery, %	96.44	94.48
MAF Wt. Rec., %	96.18	94.67
Ash Balance, %	99.76	89.50
Conversions, wt% *		
MAF Coal	90.52	93.01
Heptane Ins.	80.40	83.72
510C+	70.16	68.92
371C+	49.03	47.55
Prod. Dist., wt%		
NH3	0.2	0.2
H2O	0.0	2.9
H2S	2.8	3.2
CO2	0.2	0.3
C1-C4	2.7	4.9
C5-371C**	45.7	38.6
371-510C	24.6	24.7
510C+	22.5	25.1
MAF Coal*	3.3	2.5
H2 Consumption***	-2.18	-2.21
Total	100.0	100.0
Total Liquid Product Properties		
API	15.4	15.9
wt% carbon	85.04	85.33
wt% hydrogen	10.98	10.51
wt% sulfur	2.00	1.55
wt% nitrogen	0.67	1.01
wt% heptane ins.	5.945	5.483
wt% MCRT	NA	10.9

* Adjusted for Ash Balance, if Ash Balance < 100%.

** Adjusted for 100% MAF Recovery.

*** Adjusted for catalyst reduction.

**** Average of tests 5392-031, 5392-041, 5392-059 & 5392-101.

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Table 3A- Comparison of Recycle Ratios

Run Test Periods Recycle Ratio	21 Ave. 8,10-12	21 Ave. 22,23,25	21 Ave. 17-19	Run Test Periods Recycle Ratio	21 Ave. 8,10-12	21 Ave. 22,23,25	21 Ave. 17-19
Ave Rx Int T, DegC	425.8	425.4	425.8	Products:			
Rx Outlet P, psig	3022	3006	3005	Grams Gas COx	0.4	0.0	0.0
WHSV/Base WHSV	1.2	1.07	1.1	Grams Gas C1	17.3	17.5	17.2
Rec. H2 Pty., mol%	86.1	85.87	87.1	Grams Gas C2	14.1	13.3	13.9
Feed Code	F09	F09	F09	Grams Gas C3	13.4	14.3	14.5
Grams MAF feed	2485.5	2270.2	2348.4	Grams Gas C4	8.1	8.1	7.7
Resid Code	R10	R10	R10	Grams Gas C5+	7.5	6.4	6.5
Grams Resid	1657.0	1513.5	1565.6	Grams Gas NH3	8.3	12.5	4.3
Coal Code	C1.4	C1.4	C1.4	Grams Gas H2S	30.8	31.9	36.1
Grams MAF Coal	828.5	756.7	782.8	Grams Net H2O	124.8	146.3	137.7
Catalyst Code	K1.2	K1.2	K1.2	Grams S w/Net H2O	NA	NA	NA
wt% cat. met./MAFF	0.99	0.99	0.99	Grams OH Product	1182.5	1299.5	1011.3
Feed Distribution:				Grams TSB Product	1027.5	743.1	1043.2
wt% C5-177C	0.0	0.0	0.0	Grams Unconv.coal	87.4	84.3	91.0
wt% 177-343C	0.5	0.5	0.5	Grams H2 Consump.	55.5	69.3	48.2
wt% 343-510C	11.4	11.4	11.4	Total (MAF) wt bal	99.7	101.6	99.4
wt% 510+C	54.8	54.8	54.8	Total C balance	99.1	101.4	99.0
wt% MAF Coal	33.3	33.3	33.3	Total H balance	101.0	101.7	106.2
wt% H2 Consump.	2.2	3.0	2.1	Total S balance	79.5	71.2	74.2
wt% total feed	102.2	103.0	102.1	Total N balance*	100.0	100.0	100.0
Feed Analysis:				Total ash balance	87.2	74.1	86.8
API gravity	-7.2	-7.2	-7.2	Total Cat. balance	NA	NA	NA
wt% carbon	75.72	75.72	75.72	Normalized Conversions:			
wt% hydrogen	8.03	8.03	8.03	Coal	89.5	89.0	88.3
wt% sulfur	3.99	3.99	3.99	C7 Insoluble	83.2	88.1	85.7
wt% nitrogen	0.94	0.94	0.94	Nondist. (510C+)	57.5	63.3	56.4
wt% hept. insol.	8.34	8.34	8.34	Dist. (371C+)	34.1	38.4	35.5
wt% MCRT	10.70	10.70	10.70	Product Distribution:			
wt% dist. (371C-)	0.66	0.66	0.66	wt% H2O+COx	5.2	6.3	5.9
				wt% H2S	1.3	1.4	1.5
				wt% NH3	0.3	0.5	0.2
				wt% C1-C4	2.2	2.3	2.3
				wt% C5-177C	5.5	6.3	5.7
				wt% 177-343C	17.5	19.8	17.7
				wt% 343-510C	32.9	34.1	30.2
				wt% 510+C	33.9	28.6	34.6
				wt% Unc MAF Coal	3.5	3.7	3.9
				wt% total prod	102.2	103.0	102.1

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



Table 3B- Comparison of Recycle Ratios

Run	21 Ave.	21 Ave.	21 Ave.	Run	21 Ave.	21 Ave.	21 Ave.
Test Periods	8,10-12	22,23,25	17-19	Test Periods	8,10-12	22,23,25	17-19
Recycle Ratio	0.0	2.5	5.0	Recycle Ratio	0.0	2.5	5.0
Toluene Soluble Bottoms Product Properties:				Overhead Product Properties:			
TSB API	4.4	7.7	7.4	OH API	23.9	22.2	26.4
TSB wt% C	86.48	87.8	88.3	OH wt% C	84.99	85.7	84.8
TSB wt% H	9.95	10.6	11.0	OH wt% H	11.60	11.9	11.8
TSB wt% S	2.21	1.5	1.6	OH wt% S	1.29	0.8	0.7
TSB wt% N	1.33	1.2	1.6	OH wt% N	0.31	0.2	0.2
TSB wt% HI	9.14	4.4	4.9	OH GLC, wt%			
TSB wt% MCRT	19.95	16.77	16.4	IBP, Deg C.	0.3	1.7	-3.3
TSB wt% ash	0.00	0.0	0.0	5%	101.0	100.7	89.3
TSB ppm Cat.	32	NA	11.6	10%	168.8	174.0	157.3
TSB D1160, vol%				20%	244.8	247.3	233.3
IBP, Deg C	410.5	290.3	210.3	30%	288.3	290.0	273.0
5%	477.3	470.7	467.0	40%	322.8	325.3	306.0
10%	496.5	493.0	481.3	50%	352.3	356.3	335.3
20%	NA	518.7	504.0	60%	380.0	385.7	362.7
30%	NA	NA	527.3	70%	406.3	414.0	388.7
40%	NA	NA	NA	80%	431.3	440.7	414.0
50%	NA	NA	NA	90%	457.5	473.0	440.0
60%	NA	NA	NA	95%	474.5	500.0	455.0
EP	537.8	544.0	539.7	EP	514.0	561.7	480.7
% @EP	28.1	32.7	36.3	% @EP	100.0	98.7	100.0
wt% D1160 OH	28.30	32.8	36.3	Total Liquid Properties*			
TSB OH API	12.9	14.8	14.5	API	14.9	16.8	16.8
TSB OH GLC, wt%				wt% C	85.6	86.4	86.6
IBP, Deg C	327.0	236.7	252.7	wt% H	10.8	11.4	11.4
5%	402.8	389.7	403.3	wt% S	1.7	1.0	1.2
10%	427.8	424.3	431.7	wt% N	0.8	0.5	0.9
20%	456.0	456.0	459.0	wt% HI	4.0	1.6	2.5
30%	473.8	475.3	475.0	wt% MCRT	9.0	6.1	8.3
40%	487.0	488.7	487.0	wt% dist. (371C-)	30.8	35.1	31.6
50%	498.5	501.0	497.7	Unconverted Coal Solids Properties**			
60%	509.8	512.7	508.0	UCC wt% C	82.1	81.0	82.2
70%	520.8	524.0	519.3	UCC wt% H	5.6	5.6	5.7
80%	532.3	536.0	531.0	UCC wt% S	10.7	11.2	10.2
90%	548.0	553.0	545.3	UCC wt% N	1.6	2.2	1.8
95%	562.5	NA	559.7	% Desulf.***			
EP	572.8	571.3	572.0		77.4	86.4	85.2
% @EP	97.0	95.3	97.3	% Denitrif.***			
wt% D1160 Btms	71.7	67.2	63.7		32.9	53.0	22.3
TSB Btms API	-3.5	5.8	5.7				

*Weighted average of overhead and toluene soluble bottoms products.

**Calculated as (gTIBx)/(gTIBC + gTIBH + gTIBS - gCatS + gTIBN)*100%

***Calculated as (Feed S or N - Liquid Prod. S or N)/(Feed S or N)*100%

Table 4A- Comparison of Iron Catalyst Runs

Run Test Period	17 Ave. 4,5,12,13	23 Ave. 2,6,7	Run Test Period	17 Ave. 4,5,12,13	23 Ave. 2,6,7
Ave Rx Int T, DegC	425.7	426.2	Products:		
Rx Outlet P, psig	3000	3012	Grams Gas COx	0.7	4.2
WHSV/Base WHSV	0.5	1.07	Grams Gas C1	5.9	18.8
Rec. H2 Pty., mol%	90.1	87.01	Grams Gas C2	4.6	13.7
HPS Rec/Feed Ratio	0.0	5.4	Grams Gas C3	4.2	12.4
Feed Code	F06	F10	Grams Gas C4	1.5	4.3
Grams MAF feed	1017.0	2260.5	Grams Gas C5+	1.6	10.4
Resid Code	R08	R10	Grams Gas NH3	NA	4.8
Grams Resid	678.0	1529.5	Grams Gas H2S	6.6	8.3
Coal Code	C1.2	C1.4	Grams Net H2O	29.5	170.8
Grams MAF Coal	339.0	731.1	Grams S w/Net H2O	NA	NA
Catalyst Code	K3.0	K3.1	Grams OH Product	14.9	0.0
wt% cat. met./MAFF	2.95	2.49	Grams TSB Product	808.7	1922.2
Feed Distribution:			Grams Unconv.coal	94.7	251.3
wt% C5-177C	0.0	0.0	Grams H2 Consump.	20	36.6
wt% 177-343C	0.6	0.5	Total (MAF) wt bal	93.9	105.6
wt% 343-510C	13.2	11.6	Total C balance	NA	102.2
wt% 510+C	52.9	55.6	Total H balance	NA	100.0
wt% MAF Coal	33.3	32.3	Total S balance	99.3	128.6
wt% H2 Consump.	2.0	1.6	Total N balance*	NA	108.7
wt% total feed	102.0	101.6	Total ash balance	98.6	112.3
Feed Analysis:			Total Cat. balance	87.3	105.0
API gravity	-6.8	-7.8	Normalized Conversions:		
wt% carbon	76.91	76.29	Coal	70.3	67.4
wt% hydrogen	7.96	8.13	C7 Insoluble	52.2	50.0
wt% sulfur	4.40	4.03	Nondist. (510C+)	47.5	41.6
wt% nitrogen	0.80	0.94	Dist. (371C+)	25.3	25.6
wt% hept. insol.	8.63	8.53	Product Distribution:		
wt% MCRT	10.73	10.94	wt% H2O+COx	3.2	7.5
wt% dist. (371C-)	0.97	0.67	wt% H2S	0.7	0.4
			wt% NH3	NA	0.2
			wt% C1-C4	1.7	2.1
			wt% C5-177C	1.7	1.5
			wt% 177-343C	16.4	12.2
			wt% 343-510C	33.0	26.5
			wt% 510+C	35.4	40.8
			wt% Unc MAF Coal	9.9	10.6
			wt% total prod	102.0	101.6

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

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Table 4B- Comparison of Iron Catalyst Runs

Run Test Period	17 Ave. 4,5,12,13	23 Ave. 2,6,7	Run Test Period	17 Ave. 4,5,12,13	23 Ave. 2,6,7
Toluene Soluble Bottoms Product Properties:			Overhead Product Properties:		
TSB API	10.2	5.9	OH API	0.00	0.0
TSB wt% C	84.81	84.74	OH wt% C	0.00	0.0
TSB wt% H	9.95	9.63	OH wt% H	0.00	0.0
TSB wt% S	2.71	3.5	OH wt% S	0.00	0.0
TSB wt% N	NA	0.8	OH wt% N	0.00	0.0
TSB wt% HI	12.35	12.7	OH GLC, wt%		
TSB wt% MCRT	NA	16.05	IBP, Deg C.	0.0	0.0
TSB wt% ash	0.00	0.0	5%	0.0	0.0
TSB ppm Cat.	0	0.0	10%	0.0	0.0
TSB D1160, vol%			20%	0.0	0.0
IBP, Deg C	121.5	159.0	30%	0.0	0.0
5%	232.8	282.3	40%	0.0	0.0
10%	281.8	335.0	50%	0.0	0.0
20%	344.8	398.0	60%	0.0	0.0
30%	394.5	440.0	70%	0.0	0.0
40%	435.0	480.0	80%	0.0	0.0
50%	NA	514.0	90%	0.0	0.0
60%	NA	NA	95%	0.0	0.0
EP	521.5	535.0	EP	0.0	0.0
% @EP	NA	55.0	% @EP	0.0	0.0
wt% D1160 OH	64.76	53.5			
TSB OH API	15.2	15.1	Total Liquid Properties*		
TSB OH GLC, wt%			API	10.0	5.9
IBP, Deg C	185.5		wt% C	83.3	84.7
5%	231.3	188.2	wt% H	9.8	9.6
10%	257.3	247.2	wt% S	2.7	3.5
20%	305.8	284.7	wt% N	NA	0.8
30%	343.8	323.7	wt% HI	12.1	12.7
40%	375.3	356.2	wt% MCRT	NA	16.1
50%	403.3	385.0	wt% dist. (371C-)	25.8	21.4
60%	431.3	411.3	Unconverted Coal Solids Properties**		
70%	455.5	435.5	UCC wt% C	NA	84.9
80%	479.0	459.3	UCC wt% H	NA	6.2
90%	510.0	486.2	UCC wt% S	NA	6.5
95%	531.3	512.2	UCC wt% N	NA	2.3
EP	596.3	543.7			
% @EP	100.0	99.0	% Desulf.***	54.4	31.3
wt% D1160 Btms	35.2	46.5	% Denitrif.***	NA	33.4
TSB Btms API	-7.3	-4.5			

*Weighted average of overhead and toluene soluble bottoms products.
 **Calculated as (gTIBx)/(gTIBC + gTIBH + gTIBS - gCatS + gTIBN)*100%
 ***Calculated as (Feed S or N - Liquid Prod. S or N)/(Feed S or N)*100%

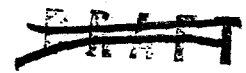


Table 5A- Severity Comparison for Iron Catalyst

Run Test Period	23 Ave. 2,6,7	23 Ave. 9	Run Test Period	23 Ave. 2,6,7	23 Ave. 9
Ave Rx Int T, DegC	426.2	441.0	Products:		
Rx Outlet P, psig	3012	3019	Grams Gas COx	4.2	4.6
WHSV/Base WHSV	1.07	0.78	Grams Gas C1	18.8	24.9
Rec. H2 Pty., mol%	87.01	82.78	Grams Gas C2	13.7	20.9
HPS Rec/Feed Ratio	5.4	7.2	Grams Gas C3	12.4	17.3
Feed Code	F10	F10	Grams Gas C4	4.3	5.3
Grams MAF feed	2260.5	1649.9	Grams Gas C5+	10.4	3.2
Resid Code	R10	R10	Grams Gas NH3	4.8	3.6
Grams Resid	1529.5	1116.3	Grams Gas H2S	8.3	16.0
Coal Code	C1.4	C1.4	Grams Net H2O	170.8	120.1
Grams MAF Coal	731.1	533.6	Grams S w/Net H2O	NA	NA
Catalyst Code	K3.1	K3.1	Grams OH Product	0.0	0.0
wt% cat. met./MAFF	2.49	2.49	Grams TSB Product	1922.2	1606.4
Feed Distribution:			Grams Unconv. coal	251.3	164.3
wt% C5-177C	0.0	0.0	Grams H2 Consump.	36.6	50.3
wt% 177-343C	0.5	0.5	Total (MAF) wt bal	105.6	116.9
wt% 343-510C	11.6	11.6	Total C balance	102.2	117.3
wt% 510+C	55.6	55.6	Total H balance	100.0	100.0
wt% MAF Coal	32.3	32.3	Total S balance	128.6	146.2
wt% H2 Consump.	1.6	3.0	Total N balance*	108.7	114.0
wt% total feed	101.6	103.0	Total ash balance	112.3	142.9
Feed Analysis:			Total Cat. balance	105.0	126.8
API gravity	-7.8	-7.8	Normalized Conversions:		
wt% carbon	76.29	76.29	Coal	67.4	73.6
wt% hydrogen	8.13	8.13	C7 Insoluble	50.0	57.5
wt% sulfur	4.03	4.03	Nondist. (510C+)	41.6	53.7
wt% nitrogen	0.94	0.94	Dist. (371C+)	25.6	34.4
wt% hept. insol.	8.53	8.53	Product Distribution:		
wt% MCRT	10.94	10.94	wt% H2O+COx	7.5	6.5
wt% dist. (371C-)	0.67	0.67	wt% H2S	0.4	0.8
			wt% NH3	0.2	0.2
			wt% C1-C4	2.1	3.5
			wt% C5-177C	1.5	2.9
			wt% 177-343C	12.2	18.8
			wt% 343-510C	26.5	29.5
			wt% 510+C	40.8	32.2
			wt% Unc MAF Coal	10.6	8.5
			wt% total prod	101.6	103.0

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

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Table 5B- Severity Comparison for Iron Catalyst

Run Test Period	23 Ave. 2,6,7	23 Ave. 9	Run Test Period	23 Ave. 2,6,7	23 Ave. 9
Toluene Soluble Bottoms Product Properties:			Overhead Product Properties:		
TSB API	5.9	7.6	OH API	0.0	0.0
TSB wt% C	84.74	86.32	OH wt% C	0.0	0.0
TSB wt% H	9.63	9.63	OH wt% H	0.0	0.0
TSB wt% S	3.5	3.0	OH wt% S	0.0	0.0
TSB wt% N	0.8	0.7	OH wt% N	0.0	0.0
TSB wt% HI	12.7	10.9	OH GLC, wt%		
TSB wt% MCRT	16.05	15.16	IBP, Deg C.	0.0	0.0
TSB wt% ash	0.0	0.0	5%	0.0	0.0
TSB ppm Cat.	0.0	0.0	10%	0.0	0.0
TSB D1160, vol%			20%	0.0	0.0
IBP, Deg C	159.0	115.5	30%	0.0	0.0
5%	282.3	191.5	40%	0.0	0.0
10%	335.0	282.5	50%	0.0	0.0
20%	398.0	342.0	60%	0.0	0.0
30%	440.0	382.5	70%	0.0	0.0
40%	480.0	419.0	80%	0.0	0.0
50%	514.0	449.0	90%	0.0	0.0
60%	NA	496.5	95%	0.0	0.0
EP	535.0	532.5	EP	0.0	0.0
% @EP	55.0	66.5	% @EP	0.0	0.0
wt% D1160 OH	53.5	65.3	Total Liquid Properties*		
TSB OH API	15.1	15.1	API	5.9	7.6
TSB OH GLC, wt%			wt% C	84.7	86.3
IBP, Deg C	NA	110.0	wt% H	9.6	9.6
5%	188.2	162.5	wt% S	3.5	3.0
10%	247.2	237.0	wt% N	0.8	0.7
20%	284.7	278.5	wt% HI	12.7	10.9
30%	323.7	312.5	wt% MCRT	16.1	15.2
40%	356.2	344.0	wt% dist. (371C-)	21.4	32.0
50%	385.0	374.0	Unconverted Coal Solids Properties**		
60%	411.3	402.5	UCC wt% C	84.9	84.5
70%	435.5	430.0	UCC wt% H	6.2	5.9
80%	459.3	458.5	UCC wt% S	6.5	11.3
90%	486.2	491.5	UCC wt% N	2.3	2.8
95%	512.2	516.5	% Desulf.***		
EP	543.7	569.0		31.3	33.9
% @EP	99.0	100.0	% Denitrif.***		
wt% D1160 Btms	46.5	34.7		33.4	30.8
TSB Btms API	-4.5	-9.2			

*Weighted average of overhead and toluene soluble bottoms products.
 **Calculated as (gTIBx)/(gTIBC + gTIBH + gTIBS - gCatS + gTIBN)*100%
 ***Calculated as (Feed S or N - Liquid Prod. S or N)/(Feed S or N)*100%

Table 6A- Comparison of V and Fe Catalysts

Run Test Period	21 Ave. 22,23,25	23 Ave. 2,6,7	Run Test Period	21 Ave. 22,23,25	23 Ave. 2,6,7
Ave Rx Int T, DegC	425.4	426.2	Products:		
Rx Outlet P, psig	3006	3012	Grams Gas COx	0.0	4.2
WHSV/Base WHSV	1.07	1.07	Grams Gas C1	17.5	18.8
Rec. H2 Pty., mol%	85.87	87.01	Grams Gas C2	13.3	13.7
HPS Rec/Feed Ratio	2.5	5.4	Grams Gas C3	14.3	12.4
Feed Code	F09	F10	Grams Gas C4	8.1	4.3
Grams MAF feed	2270.2	2260.5	Grams Gas C5+	6.4	10.4
Resid Code	R10	R10	Grams Gas NH3	12.5	4.8
Grams Resid	1513.5	1529.5	Grams Gas H2S	31.9	8.3
Coal Code	C1.4	C1.4	Grams Net H2O	146.3	170.8
Grams MAF Coal	756.7	731.1	Grams S w/Net H2O	NA	NA
Catalyst Code	K1.2	K3.1	Grams OH Product	1299.5	0.0
wt% cat. met./MAFF	0.99	2.49	Grams TSB Product	743.1	1922.2
Feed Distribution:			Grams Unconv.coal	84.3	251.3
wt% C5-177C	0.0	0.0	Grams H2 Consump.	69.3	36.6
wt% 177-343C	0.5	0.5	Total (MAF) wt bal	101.6	105.6
wt% 343-510C	11.4	11.6	Total C balance	101.4	102.2
wt% 510+C	54.8	55.6	Total H balance	101.7	100.0
wt% MAF Coal	33.3	32.3	Total S balance	71.2	128.6
wt% H2 Consump.	3.0	1.6	Total N balance*	100.0	108.7
wt% total feed	103.0	101.6	Total ash balance	74.1	112.3
Feed Analysis:			Total Cat. balance	NA	105.0
API gravity	-7.2	-7.8	Normalized Conversions:		
wt% carbon	75.72	76.29	Coal	89.0	67.4
wt% hydrogen	8.03	8.13	C7 Insoluble	88.1	50.0
wt% sulfur	3.99	4.03	Nondist. (510C+)	63.3	41.6
wt% nitrogen	0.94	0.94	Dist. (371C+)	38.4	25.6
wt% hept. insol.	8.34	8.53	Product Distribution:		
wt% MCRT	10.70	10.94	wt% H2O+COx	6.3	7.5
wt% dist. (371C-)	0.66	0.67	wt% H2S	1.4	0.4
			wt% NH3	0.5	0.2
			wt% C1-C4	2.3	2.1
			wt% C5-177C	6.3	1.5
			wt% 177-343C	19.8	12.2
			wt% 343-510C	34.1	26.5
			wt% 510+C	28.6	40.8
			wt% Unc MAF Coal	3.7	10.6
			wt% total prod	103.0	101.6

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

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Table 6B- Comparison of V and Fe Catalysts

Run Test Period	21 Ave. 22,23,25	23 Ave. 2,6,7	Run Test Period	21 Ave. 22,23,25	23 Ave. 2,6,7
Toluene Soluble Bottoms Product Properties:			Overhead Product Properties:		
TSB API	7.7	5.9	OH API	22.2	0.0
TSB wt% C	87.8	84.74	OH wt% C	85.7	0.0
TSB wt% H	10.6	9.63	OH wt% H	11.9	0.0
TSB wt% S	1.5	3.5	OH wt% S	0.8	0.0
TSB wt% N	1.2	0.8	OH wt% N	0.2	0.0
TSB wt% HI	4.4	12.7	OH GLC, wt%		
TSB wt% MCRT	16.77	16.05	IBP, Deg C.	1.7	0.0
TSB wt% ash	0.0	0.0	5%	100.7	0.0
TSB ppm Cat.	NA	0.0	10%	174.0	0.0
TSB D1160, vol%			20%	247.3	0.0
IBP, Deg C	290.3	159.0	30%	290.0	0.0
5%	470.7	282.3	40%	325.3	0.0
10%	493.0	335.0	50%	356.3	0.0
20%	518.7	398.0	60%	385.7	0.0
30%	NA	440.0	70%	414.0	0.0
40%	NA	480.0	80%	440.7	0.0
50%	NA	514.0	90%	473.0	0.0
60%	NA	NA	95%	500.0	0.0
EP	544.0	535.0	EP	561.7	0.0
% @EP	32.7	55.0	% @EP	98.7	0.0
wt% D1160 OH	32.8	53.5	Total Liquid Properties*		
TSB OH API	14.8	15.1	API	16.8	5.9
TSB OH GLC, wt%			wt% C	86.4	84.7
IBP, Deg C	236.7	NA	wt% H	11.4	9.6
5%	389.7	188.2	wt% S	1.0	3.5
10%	424.3	247.2	wt% N	0.5	0.8
20%	456.0	284.7	wt% HI	1.6	12.7
30%	475.3	323.7	wt% MCRT	6.1	16.1
40%	488.7	356.2	wt% dist. (371C-)	35.1	21.4
50%	501.0	385.0	Unconverted Coal Solids Properties**		
60%	512.7	411.3	UCC wt% C	81.0	84.9
70%	524.0	435.5	UCC wt% H	5.6	6.2
80%	536.0	459.3	UCC wt% S	11.2	6.5
90%	553.0	486.2	UCC wt% N.	2.2	2.3
95%	NA	512.2	% Desulf.***		
EP	571.3	543.7	% Denitrif.***		
% @EP	95.3	99.0		86.4	31.3
wt% D1160 Btms	67.2	46.5		53.0	33.4
TSB Btms API	5.8	-4.5			

*Weighted average of overhead and toluene soluble bottoms products.

**Calculated as $(gTIBx)/(gTIBC + gTIBH + gTIBS - gCatS + gTIBN) * 100\%$

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

**Figure 1 - Co-Processing Pilot Plant
with Liquid Recycle**

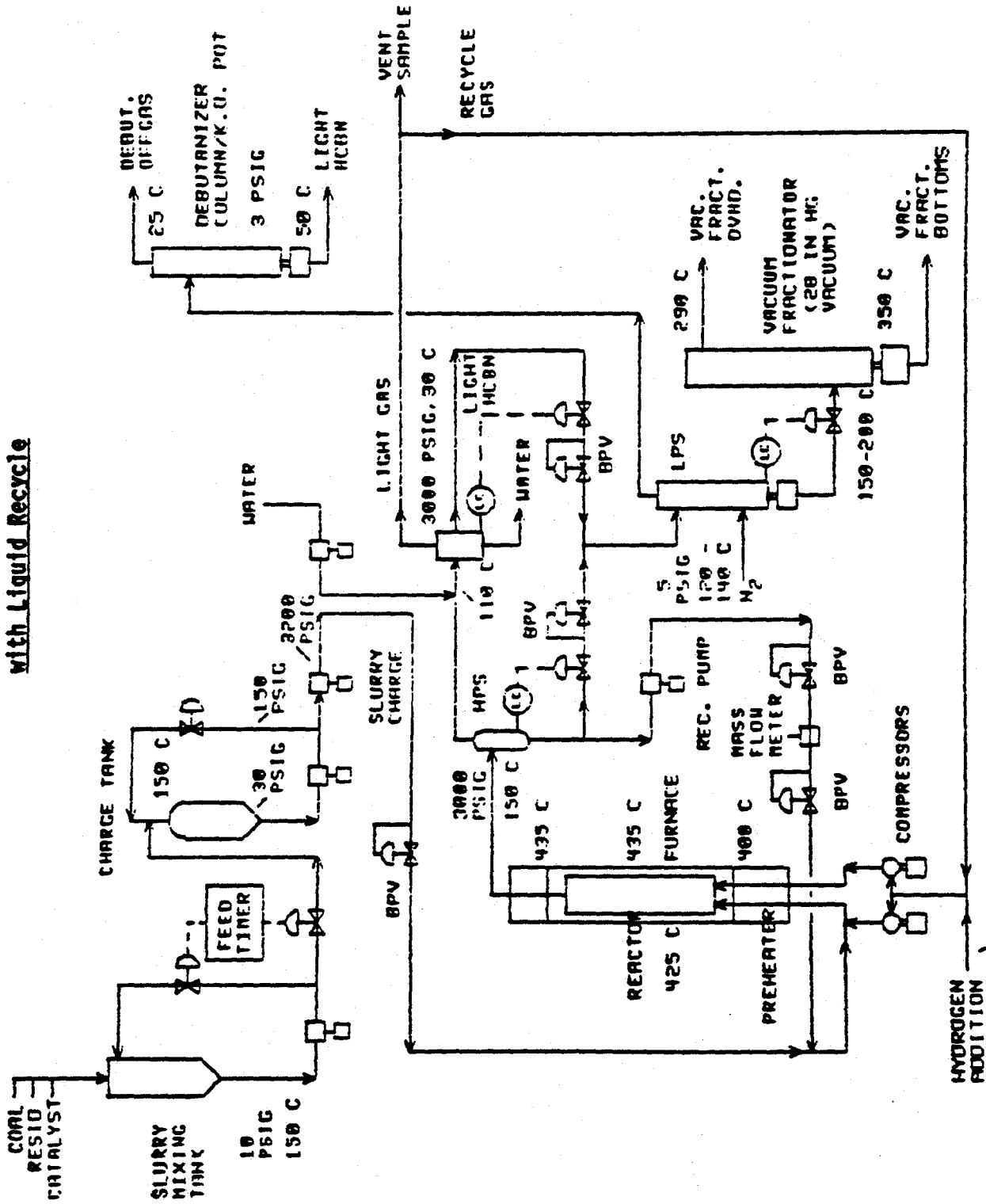
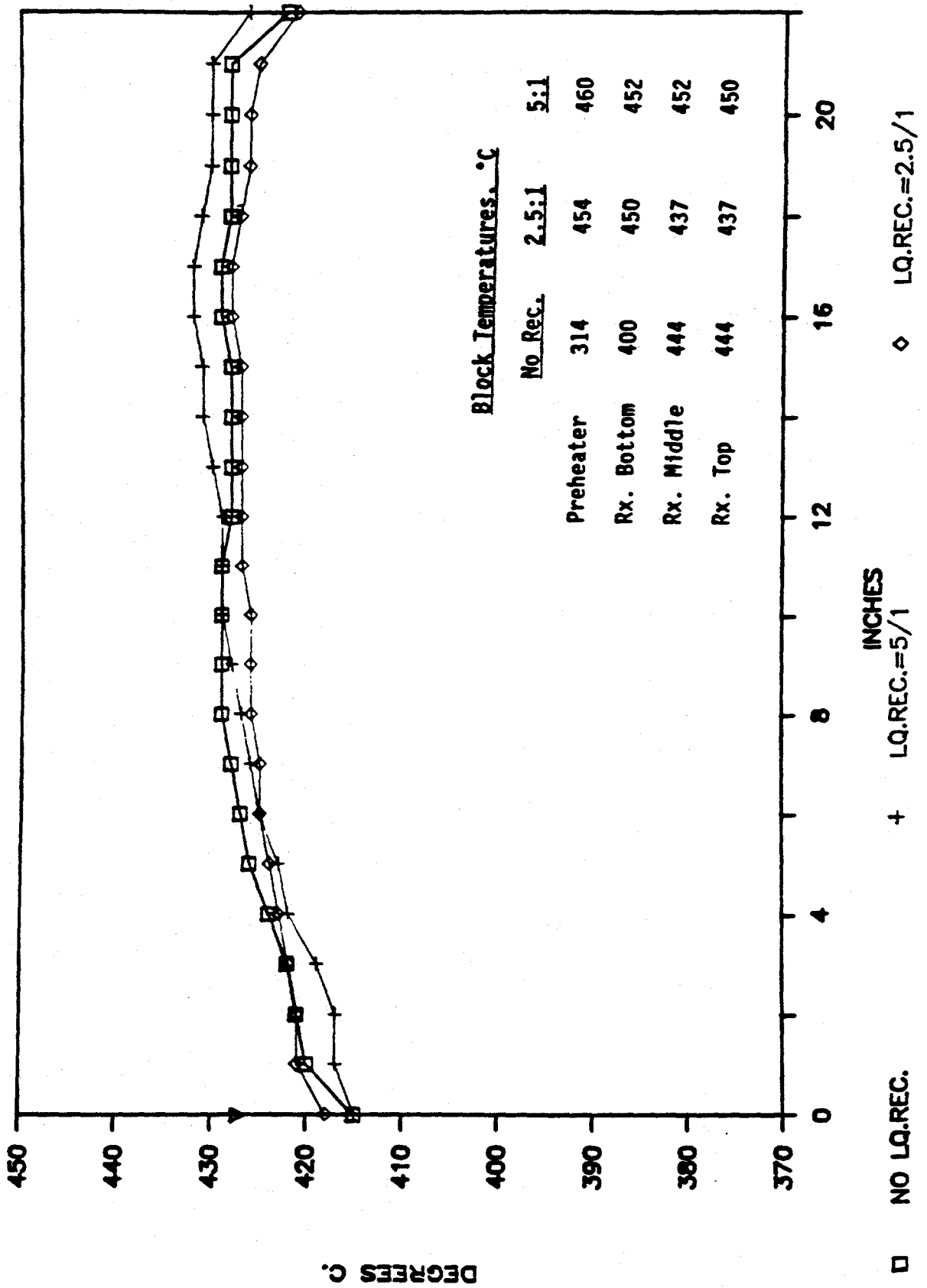


Figure 2 - Reactor Internal Temperature Profiles
for Different Recycle Ratios



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APPENDIX
Detailed Test Results

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Run No. 21 - 2:1 Lloydminster Resid:Illinois Coal No. 6

1 wt% U Catalyst

Run	19 Ave.	21	21	21	21	21	21	21	21	21	21
Test Period	LTD5	8	10	11	12	17	18	19	22	23	25
Per. Length, hrs	30	12	12	12	12	12	12	12	12	12	12
Initial HDS		109	133	145	157	229	241	253	289	301	325
Ave Rx Int T, DegC	425.5	424.5	424	428	426.6	425	425.5	427	426.4	424.1	425.7
Rx Outlet P, psig	3058	3015	3020	3051	3000	3008	3000	3006	3000	3007	3010
WHSV/Base WHSV	1.0	1.12	1.43	1.12	1.04	1.16	1.13	1.05	1.11	1.12	1.00
Rec. H2 Pty., mol%	86.1	86.65	86.33	85.00	86.53	87.65	87.00	86.76	86.11	85.64	85.87
HPS Rec/feed Ratio	0.0	0.0	0.0	0.0	0.0	4.7	5.0	5.3	2.6	2.1	2.7

Feed Code	F08	F09	F09	F09	F09	F09	F09	F09	F09	F09	F09
Grams MAF feed	5285.8	2369.62	3020.38	2356.67	2195.13	2447.14	2382.52	2215.44	2336.37	2369.60	2104.67
Resid Code	R08	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10
Grams Resid	3475.6	1579.74	2013.59	1571.12	1463.42	1631.43	1588.35	1476.96	1557.58	1579.73	1403.11
Coal Code	C1.2	C1.4	C1.4	C1.4	C1.4	C1.4	C1.4	C1.4	C1.4	C1.4	C1.4
Grams MAF Coal	1810.1	789.87	1006.79	785.56	731.71	815.71	794.17	738.48	778.79	789.87	701.56
Catalyst Code	K1.0	K1.2	K1.2	K1.2	K1.2	K1.2	K1.2	K1.2	K1.2	K1.2	K1.2
wt% cat. net./MAFF	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99

Feed Distribution:

wt% C5-177C	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
wt% 177-343C	0.6	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
wt% 343-510C	13.0	11.42	11.42	11.42	11.42	11.42	11.42	11.42	11.42	11.42	11.42
wt% 510+C	52.2	54.78	54.78	54.78	54.78	54.78	54.78	54.78	54.78	54.78	54.78
wt% MAF Coal	34.2	33.33	33.33	33.33	33.33	33.33	33.33	33.33	33.33	33.33	33.33
wt% H2 Consump.	2.5	2.38	2.01	2.34	2.26	1.77	2.14	2.27	2.90	3.73	2.45
wt% total feed	102.4	102.38	102.01	102.34	102.28	101.77	102.14	102.27	102.90	103.73	102.45

Feed Analysis:

RPI gravity	-6.8	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2
wt% carbon	76.65	75.72	75.72	75.72	75.72	75.72	75.72	75.72	75.72	75.72	75.72
wt% hydrogen	7.90	8.03	8.03	8.03	8.03	8.03	8.03	8.03	8.03	8.03	8.03
wt% sulfur	4.38	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99
wt% nitrogen	0.80	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
wt% hept. insol.	8.49	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34
wt% MCR1	10.55	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70
wt% dist. (371C-)	0.96	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66

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Run No. 21 - 2:1 Lloydminster Resid:Illinois Coal No. 6
1 wt% U Catalyst

Run	19 Ave.	21	21	21	21	21	21	21	21	21	21
Test Period	LT05	8	10	11	12	17	18	19	22	23	25

Products:

Grans Gas COx	2.7	0.45	0.46	0.43	0.46	0.00	0.00	0.00	0.00	0.00	0.00
Grans Gas C1	45.7	16.36	16.59	18.33	17.99	15.67	17.93	17.92	19.52	16.51	16.36
Grans Gas C2	36.6	12.91	12.70	15.77	14.96	13.36	14.52	13.97	14.88	12.17	12.84
Grans Gas C3	38.3	12.44	12.10	15.29	13.73	13.77	14.93	14.76	16.11	12.97	13.83
Grans Gas C4	22.9	7.73	7.52	9.08	8.02	8.02	7.78	7.43	10.04	7.69	6.68
Grans Gas C5+	26.9	6.21	6.27	9.44	7.92	6.61	7.70	5.07	7.43	5.16	6.67
Grans Gas NH3	NA	5.28	8.89	12.74	6.47	3.92	2.45	6.47	11.08	16.12	10.41
Grans Gas H2S	35.4	29.86	27.47	34.74	31.31	34.90	42.78	30.51	37.34	26.89	31.49
Grans Net H2O	282.8	179.0	69.0	151.0	100.0	127.0	154.0	132.0	164.0	159.0	116.0
Grans S w/Net H2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Grans OH Product	2308.7	1027.00	1152.00	1325.00	1226.00	1002.00	1057.00	975.00	1509.00	1338.36	1051.00
Grans TSB Product	2439.6	1063.83	1433.89	862.19	750.29	1107.15	1109.92	912.59	612.50	798.87	818.01
Grans Unconv.coal	194.3	82.59	115.14	79.37	72.37	104.44	90.98	77.68	66.57	100.51	85.75
Grans H2 Consump.	124	56.32	60.70	55.06	49.98	43.27	51.01	50.38	67.83	88.45	51.51

Total (MAF) wt bal	100.8	100.73	92.89	105.04	100.20	97.85	103.55	96.80	102.67	101.47	100.60
Total C balance	101.5	98.23	94.42	103.15	100.45	98.15	102.20	96.57	101.42	102.12	100.62
Total H balance	106.6	100.49	93.72	106.23	103.49	106.22	109.31	103.17	105.11	94.09	105.95
Total S balance	66.9	79.00	77.42	79.79	81.65	73.99	79.08	69.56	69.72	71.99	71.74
Total N balance*	100.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total ash balance	101.0	89.09	83.01	85.60	90.91	95.17	84.46	80.77	57.33	83.28	81.64

Normalized Conversions:

Coal	89.3	89.62	87.69	90.38	90.13	86.91	88.94	89.13	91.67	87.46	87.85
C7 Insoluble	79.3	85.22	81.64	81.91	83.97	85.05	84.95	87.01	90.50	86.89	86.77
Nondist. (510C+)	56.2	57.97	49.24	59.82	62.96	53.60	56.43	59.03	67.82	60.50	61.70
Dist. (371C+)	34.9	34.63	28.25	35.15	38.32	33.26	35.60	37.57	40.88	36.99	37.41

Product Distribution:

wt% H2O+COx	5.3	7.52	2.48	6.12	4.57	5.30	6.24	6.15	6.84	6.61	5.48
wt% H2S	0.6	1.25	0.98	1.40	1.42	1.46	1.73	1.42	1.56	1.12	1.49
wt% NH3	0.4	0.22	0.32	0.51	0.29	0.16	0.10	0.30	0.46	0.67	0.49
wt% C1-C4	2.7	2.07	1.74	2.36	2.49	2.12	2.24	2.52	2.52	2.05	2.35
wt% C5-177C	5.9	4.74	6.15	5.27	5.93	4.41	6.26	6.57	5.95	7.49	5.42
wt% 177-343C	18.2	17.07	14.73	17.42	20.67	17.55	17.07	18.62	21.28	18.32	19.86
wt% 343-510C	31.5	32.47	30.90	33.85	34.26	29.87	30.10	30.58	35.95	32.67	33.61
wt% 510+C	34.2	33.58	40.62	32.20	29.35	36.53	34.71	32.48	25.58	30.62	29.70
wt% Unc MAF Coal	3.7	3.46	4.10	3.21	3.29	4.36	3.69	3.62	2.78	4.18	4.05
wt% total prod	102.4	102.38	102.01	102.34	102.28	101.77	102.14	102.27	102.90	103.73	102.45

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

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Run No. 21 - 2:1 Lloydminster Resid:Illinois Coal No. 6
1 wt% U Catalyst

Run	19 Ave.	21	21	21	21	21	21	21	21	21	21
Test Period	LT05	8	10	11	12	17	18	19	22	23	25

Toluene Soluble Bottoms Product Properties:

TSB API	3.3	4.4	4.5	4.4	4.4	7.6	7.3	7.3	6.9	7.5	8.7
TSB wt% C	85.98	85.64	85.21	86.61	88.47	88.25	87.88	88.67	88.48	87.19	87.7
TSB wt% H	10.18	10.11	9.63	9.64	10.41	11	11.01	11.1	10.91	10.17	10.8
TSB wt% S	2.27	2.4	2.6	2.01	1.81	1.68	1.61	1.38	1.42	1.7	1.27
TSB wt% N	NA	1.4	1.23	1.04	1.64	1.6	1.67	1.54	1.62	0.73	1.12
TSB wt% NI	11.65	6.29	7.19	12.8	10.27	4.27	5.98	4.42	4.89	4.14	4.03
TSB wt% MCRT	NA	19.4	16.55	22.2	21.65	16.6	16.95	15.75	17.72	17.44	15.15
TSB wt% ash	0.01	0	0	0	0	0	0	0	0	0	0
TSB ppm Cat.	38	27	42	30	29	12	13	9.9	6.4	NA	10.2
TSB D1160, vol%											
IBP, Deg C	398.3	400	398	433	411	131	113	387	377	117	377
5X	457.3	464	464	497	484	472	458	471	477	470	465
10X	473.3	488	481	518	499	488	478	478	498	499	482
20X	493.0	514	505	NA	522	507	499	506	525	528	503
30X	512.8	536	530	NA	NA	528	526	528	NA	544	523
40X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	544
50X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
60X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EP	542.8	546	538	538	529	537	538	544	539	544	549
X CEP	NA	34.5	33	19	26	35	36	38	27	30	41
wt% D1160 OH	42.42	34.5	33.1	19.5	26.1	35.0	35.7	38.2	27.1	30	41.4
TSB OH API	10.9	13	13	12.6	13.1	14.3	14.5	14.6	14.3	14.8	15.4
TSB OH GLC, wt%											
IBP, Deg C	340.3	309	321	343	335	330	114	314	297	110	303
5X	412.0	385	397	413	416	417	392	401	387	380	402
10X	434.5	410	423	436	442	442	425	428	417	426	430
20X	459.0	438	452	463	471	466	454	457	448	463	457
30X	474.8	458	470	481	486	479	472	474	468	484	474
40X	488.8	472	483	496	497	490	484	487	482	499	485
50X	500.3	483	495	509	507	500	495	498	495	512	496
60X	511.8	494	508	521	516	510	506	508	507	524	507
70X	523.5	505	521	531	526	521	518	519	519	534	519
80X	536.5	519	535	540	535	532	530	531	531	546	531
90X	554.5	534	556	554	548	547	545	544	545	567	547
95X	568.5	545	574	568	563	561	560	558	559	NA	562
EP	577.5	571	574	572	574	571	570	575	568	573	573
X CEP	100.0	100	95	96	97	97	97	98	97	92	97
wt% D1160 Btms	57.6	65.50	66.90	80.50	73.91	65.00	64.29	61.82	72.91	70.00	58.60
TSB Btms API	-4.0	-4	-5.1	-8	3.3	4.3	8	4.8	6.7	5.2	5.4

Run No. 21 - 2:1 Lloydminster Resid:Illinois Coal No. 6
1 wtX V Catalyst

Run	19 Ave.	21	21	21	21	21	21	21	21	21	21
Test Period	LTOS	8	10	11	12	17	18	19	22	23	25

Overhead Product Properties:

OH API	24.4	23.5	25.2	23.6	23.4	25.7	26.4	27	18.4	23.3	24.9
OH wtX C	NA	85.65	84.65	84.86	84.79	84.85	84.27	85.27	85.47	86.13	85.51
OH wtX H	NA	11.45	11.65	11.73	11.55	11.73	11.8	11.9	11.91	11.51	12.27
OH wtX S	1.44	1.31	1.29	1.21	1.35	0.76	0.74	0.69	0.85	0.77	0.7
OH wtX N	0.33	0.345	0.337	0.253	0.304	0.191	0.191	0.189	0.215	0.195	0.174
OH GLC, wtX											
TBP, Deg C.	38.0	0	0	1	0	-6	0	-4	4	0	1
5X	120.0	102	86	115	101	97	89	82	112	92	98
10X	163.3	174	134	190	177	179	149	144	194	153	175
20X	219.8	245	231	258	245	242	230	228	257	241	244
30X	261.0	285	278	302	288	279	272	268	299	288	283
40X	298.0	317	314	338	322	310	306	302	335	325	316
50X	332.0	345	344	368	352	339	336	331	367	358	344
60X	361.0	372	372	397	379	365	364	359	397	389	371
70X	388.3	397	399	423	406	390	390	386	427	418	397
80X	415.0	422	425	446	432	414	416	412	455	445	422
90X	442.8	449	452	470	459	439	441	440	492	477	450
95X	460.5	467	469	486	476	454	455	456	527	502	471
EP	488.5	514	502	536	504	477	482	483	559	573	553
X @EP	100.0	100	100	100	100	100	100	100	98	99	99

Total Liquid Properties*

API	13.6	13.8	13.7	16.0	16.2	16.2	16.6	17.5	15.1	17.4	17.8
wtX C	NA	85.6	85.0	85.5	86.2	86.6	86.1	86.9	86.3	86.5	86.5
wtX H	NA	10.8	10.5	10.9	11.1	11.3	11.4	11.5	11.6	11.0	11.6
wtX S	1.9	1.9	2.0	1.5	1.5	1.2	1.2	1.0	1.0	1.1	0.9
wtX N	NA	0.9	0.8	0.6	0.8	0.9	0.9	0.8	0.6	0.4	0.6
wtX HI	6.0	3.2	4.0	5.0	3.9	2.2	3.1	2.1	1.4	1.5	1.8
wtX MCRT	NA	9.9	9.2	8.8	8.2	8.7	8.7	7.6	5.1	6.5	6.6
wtX dist. (371C-)	31.9	29.9	27.2	30.7	35.5	29.7	31.4	33.7	36.8	34.3	34.2

Unconverted Coal Solids Properties**:

UCC wtX C	NA	86.2	81.6	80.9	79.9	84.3	81.9	80.4	81.8	79.4	81.8
UCC wtX H	NA	5.4	5.3	5.8	5.7	5.6	5.9	5.7	5.8	5.3	5.5
UCC wtX S	NA	6.7	11.4	11.8	12.8	8.2	10.4	12.2	10.1	13.0	10.6
UCC wtX N	NA	1.7	1.7	1.5	1.6	1.9	1.8	1.7	2.3	2.2	2.1

X Desulf.***	64.6	61.96	60.08	67.26	68.26	75.23	75.06	79.83	78.70	76.69	80.50
X Denitrif.***	NA	23.88	30.30	48.86	28.55	21.53	15.60	29.80	44.86	65.15	48.91

*Weighted average of overhead and toluene soluble bottoms products.

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

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

~~SECRET~~

Run No. 23 - 2:1 Lloydminster Resid:Illinois Coal No. 6
2 wt% Fe Catalyst

Run	23	23	23	23	23
Test Period	2	6	7	9C	9D
Per. Length, hrs	12	12	12	12	12
Initial HDS	24	72	84	108	108
Ave Rx Int I, DegC	424	427	427.5	441	441
Rx Outlet P, psig	3025	3000	3012	3019	3019
WHSV/Base WHSV	1.16	1.15	0.91	0.78	0.78
Rec. H2 Pty., mol%	88.42	84.63	87.99	83.55	82.00
HPS Rec/feed Ratio	5.2	4.8	6.1	7.2	7.2

Feed Code	F10	F10	F10	F10	F10
Grams MAF feed	2446.44	2418.56	1916.63	1649.86	1649.86
Resid Code	R10	R10	R10	R10	R10
Grams Resid	1655.26	1636.40	1296.79	1116.30	1116.30
Coal Code	C1.4	C1.4	C1.4	C1.4	C1.4
Grams MAF Coal	791.18	782.16	619.84	533.56	533.56
Catalyst Code	K3.1	K3.1	K3.1	K3.1	K3.1
wt% cat. wt./MAFF	2.49	2.49	2.49	2.49	2.49

Feed Distribution:

wt% C5-177C	0.00	0.00	0.00	0.00	0.00
wt% 177-343C	0.48	0.48	0.48	0.48	0.48
wt% 343-510C	11.59	11.59	11.59	11.59	11.59
wt% 510+C	55.60	55.60	55.60	55.60	55.60
wt% MAF Coal	32.34	32.34	32.34	32.34	32.34
wt% H2 Consump.	1.70	1.58	1.57	3.03	3.06
wt% total feed	101.70	101.58	101.57	103.03	103.06

Feed Analysis:

API gravity	-7.8	-7.8	-7.8	-7.8	-7.8
wt% carbon	76.29	76.29	76.29	76.29	76.29
wt% hydrogen	8.13	8.13	8.13	8.13	8.13
wt% sulfur	4.03	4.03	4.03	4.03	4.03
wt% nitrogen	0.94	0.94	0.94	0.94	0.94
wt% hept. insol.	8.53	8.53	8.53	8.53	8.53
wt% MCRT	10.94	10.94	10.94	10.94	10.94
wt% dist. (371C-)	0.67	0.67	0.67	0.67	0.67

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Run No. 23 - 2:1 Lloydminster Resid:Illinois Coal No. 6
2 wt% Fe Catalyst

Run	23	23	23	23	23
Test Period	2	6	7	9C	9D

Products:

Grams Gas COx	2.86	3.72	6.01	4.60	4.52
Grams Gas C1	14.02	17.39	25.10	25.17	24.70
Grams Gas C2	10.07	13.58	17.41	20.87	20.87
Grams Gas C3	9.57	12.39	15.34	17.32	17.30
Grams Gas C4	3.92	4.00	5.06	5.33	5.33
Grams Gas C5+	25.57	2.38	3.40	3.26	3.24
Grams Gas NH3	0.00	14.51	0.00	0.00	7.22
Grams Gas H2S	7.89	8.77	8.18	16.05	16.05
Grams Net H2O	139.3	199.4	173.8	116.0	124.3
Grams S w/Net H2O	NA	NA	NA	NA	NA
Grams OH Product	0.00	0.00	0.00	0.00	0.00
Grams TSB Product	2174.58	1958.75	1633.21	1635.22	1577.52
Grams Unconv.coal	263.24	270.41	220.12	141.15	187.49
Grams H2 Consump.	41.54	38.25	30.05	50.04	50.49

Total (NAF) wt bal	106.55	101.97	108.27	116.77	116.95
Total C balance	104.94	97.70	103.85	117.64	116.93
Total H balance*	100.00	100.00	100.00	100.00	100.00
Total S balance	125.05	125.23	135.58	137.31	155.01
Total N balance*	107.12	100.00	119.03	128.06	100.00
Total ash balance	110.63	109.14	116.99	138.50	147.33
Total Cat. balance	105.43	114.44	95.20	123.07	130.57

Normalized Conversions:

Coal	68.77	66.10	67.20	77.34	69.95
C7 Insoluble	53.21	48.09	48.83	59.10	55.97
Nondist. (510C+)	38.28	42.05	44.44	54.84	52.55
Dist. (371C+)	22.45	25.56	28.72	35.46	33.25

Product Distribution:

wt% H2O+COx	5.45	8.24	8.67	6.26	6.68
wt% H2S	0.30	0.36	0.39	0.83	0.83
wt% NH3	0.00	0.59	0.00	0.00	0.37
wt% C1-C4	1.44	1.92	3.03	3.57	3.53
wt% C5-177C	0.98	1.63	1.75	3.76	2.14
wt% 177-343C	12.29	11.23	12.94	19.22	18.41
wt% 343-510C	26.95	26.66	25.94	29.69	29.36
wt% 510+C	44.18	40.00	38.25	32.39	32.01
wt% Unc NAF Coal	10.10	10.96	10.61	7.33	9.72
wt% total prod	101.70	101.58	101.57	103.03	103.06

*100% Hydrogen and Nitrogen Balances assumed to calculate H2O and NH3 based only on liquid stream analyses.

~~SECRET~~

Run No. 23 - 2:1 Lloydminster Resid:Illinois Coal No. 6
2 wt% Fe Catalyst

Run	23	23	23	23	23
Test Period	2	6	7	9C	9D

Toluene Soluble Bottoms Product Properties:

TSB API	5.7	6.4	5.7	8.1	7
TSB wt% C	84.24	84.89	85.08	86.20	86.44
TSB wt% H	9.68	10.03	9.19	9.60	9.66
TSB wt% S	3.40	3.60	3.53	2.72	3.18
TSB wt% N	0.92	0.43	1.01	1.05	0.38
TSB wt% HI	11.18	13.33	13.51	11.37	10.47
TSB wt% MCRT	16.37	15.79	16.00	14.92	15.40
TSB wt% ash	0	0	0	0	0
TSB ppm Fe	0	0	0	0	0
TSB D1160, vol%					
IBP, Deg C	241	120	116	116	115
5X	302	288	257	125	258
10X	342	341	322	271	294
20X	406	391	397	340	344
30X	452	425	443	384	381
40X	491	466	483	419	419
50X	526	502	514	441	457
60X	NA	NA	NA	490	503
EP	535	530	540	524	541
% BEP	53	56	56	66	67
wt% D1160 OH	50.8	55	54.8	65	65.6
TSB OH API	14.8	14.6	15.8	15.7	14.4
TSB OH GLC, wt%					
IBP, Deg C	211	112	112	111	109
5X	252	225	217	115	210
10X	275	261	253	229	245
20X	314	306	297	272	285
30X	346	346	331	307	318
40X	374	378	362	338	350
50X	400	407	389	368	380
60X	424	433	415	396	409
70X	446	456	439	424	436
80X	471	480	464	452	465
90X	499	509	494	485	498
95X	523	531	517	509	524
EP	564	569	558	563	575
% BEP	99	99	99	100	100
wt% D1160 Btms	49.2	45	45.2	35	34.4
TSB Btms API	-4.4	-4.5	-4.5	-9.3	-9.1

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Run No. 23 - 2:1 Lloydminster Resid:Illinois Coal No. 6
2 wt% Fe Catalyst

Run	23	23	23	23	23
Test Period	2	6	7	9C	9D

Overhead Product Properties:

OH API	0	0	0	0	0
OH wt% C	0	0	0	0	0
OH wt% H	0	0	0	0	0
OH wt% S	0	0	0	0	0
OH wt% N	0	0	0	0	0
OH GLC, wt%					
IBP, Deg C.	0	0	0	0	0
5X	0	0	0	0	0
10X	0	0	0	0	0
20X	0	0	0	0	0
30X	0	0	0	0	0
40X	0	0	0	0	0
50X	0	0	0	0	0
60X	0	0	0	0	0
70X	0	0	0	0	0
80X	0	0	0	0	0
90X	0	0	0	0	0
95X	0	0	0	0	0
EP	0	0	0	0	0
X BEP	0	0	0	0	0

Total Liquid Properties*

API	5.7	6.4	5.7	8.1	7.0
wt% C	84.2	84.9	85.1	86.2	86.4
wt% H	9.7	10.0	9.2	9.6	9.7
wt% S	3.4	3.6	3.5	2.7	3.2
wt% N	0.9	0.4	1.0	1.1	0.4
wt% NI	11.2	13.3	13.5	11.4	10.5
wt% MCRT	16.4	15.8	16.0	14.9	15.4
wt% dist. (371C-)	19.8	20.8	23.6	33.1	30.8

Unconverted Coal Solids Properties**:

UCC wt% C	85.5	87.2	82.1	84.9	84.0
UCC wt% H	6.4	6.5	5.9	5.9	6.0
UCC wt% S	5.6	4.8	9.2	10.7	11.8
UCC wt% N	2.5	1.5	2.9	3.0	2.6

X Desulf.***	30.33	32.78	30.65	37.85	29.90
X Denitrif.***	19.33	65.65	15.10	-2.65	64.16

*Weighted average of overhead and toluene soluble bottoms products.

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

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