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BENCH-SCALE CO-PROCESSING
Contract No. DE-AC22-87PC79818

Technical Progress Report No. 23 (01/01/94-03/31/94)

by
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UOP's second co-processing contract, DE-AC22-87PC79818, began in April 1988. The major objective of this contract is to establish a database for the optimization of the co-processing concept by improving the effectiveness of the co-processing catalyst system. Two major mechanisms for improving the catalyst system are to be investigated: employment of more effective catalysts and utilization of improved catalytic environments. These two mechanisms are defined in the contract Statement of Work under Task 3.2 as Subtask 3.2.1 and 3.2.2, respectively.

This report covers the period of January 1, 1994 to March 31, 1994. During this period work on Task 2.0, Laboratory Support, and Task 4.0, Process Assessment was carried out. All the experimental data collected from the autoclave work over the last two quarters were compiled and analyzed. A design basis for the process assessment task was established and cost estimation of the UOP co-processing scheme was initiated.

CONVERSION OF LLOYDMINSTER
VACUUM RESID USING A STIRRED AUTOCLAVE

The objective of this autoclave study was to aid in the development of a high conversion co-processing process and provide directions for the experimental work under subtask 3.2.2, Improvement in Catalytic Environment.

Equipment

A new autoclave system was developed that consists of a 2-liter (l) stirred autoclave equipped with a continuous gas recycle system and a condenser for vaporized product recovery. A schematic flow diagram of this autoclave system is shown in Figure 1. Key features of the system are: effective hydrogen transfer, effective mixing, removal of the products. These enhanced features of the autoclave may help in minimizing secondary reactions, making low gas, increasing catalyst concentration and minimizing phase separation.

Feedstock

Lloydminster Vacuum resid was selected as the feedstock for this autoclave study. Analysis of the feedstock is shown in Table 1. The advantage of using a petroleum feedstock in contrast to a petroleum resid/coal feedstock are the following:

1. Thermal effects can be more readily differentiated from catalytic effects.
2. Retrogressive reactions can be more readily observed.
3. The slurry catalysts can be more easily recovered and characterized.
4. Petroleum asphaltene are larger and more difficult to convert than coal asphaltene.
5. Asphaltene and non-distillable conversion is decoupled from coal conversion.

Catalyst

The catalyst used for this study is UOP's Mo-based slurry catalyst.

Methodology

Weighted amounts of resid and catalyst are added to the autoclave. The autoclave is sealed and pressured with H_2/H_2S gas mixture through a displacement meter system to a predetermined pressure. The autoclave is systematically heated to the reaction temperature with mixing and gas recycle. The reaction temperature is maintained for a specified residence time and hydrogen is automatically added through a displacement meter system to maintain the desired reaction pressure. After maintaining the autoclave at the desired temperature for a pre-determined period of time, the heaters are turned off and the autoclave is cooled to room temperature. The autoclave is depressurized through a scrubber, a metering system, and dry gas sampler. Additional gas dissolved in the reaction mixture is removed with nitrogen. The liquid product (condensate) collected in the condenser (the knock-out pot) is removed. The material (resid/catalyst mixture) remaining in the autoclave is mixed with toluene and removed. Toluene is added to solubilize the product and disperse the solids. The toluene sample is removed with suction into a collection vessel. The autoclave is rinsed thoroughly with toluene to recover any residual oil and liquid. The centrate liquid is decanted, filtered, and flashed off to a rotary flash evaporator to remove toluene from the resid product. The solids (catalysts) are dried in a vacuum oven at $100^\circ C$. Weight recoveries are generally greater than 95%.

Experimental Program

The experimental program includes variations in pressure, temperature and catalyst concentration. The range of variables investigated are shown below:

Feedstock	Lloydminster Vacuum Resid
Pressure, psig	1000, 2000, and 3000
Temperature, °C	420 and 440
Residence Time, hrs.	2
Catalyst Concentration, wt-% Mo	0.05 and 0.5

The results from this series of runs are summarized in Appendix A. A complete set of plots of product distribution, mass balance, conversions, yields and product properties is given in Appendix B.

Black Oil Conversion Pathways

There are three reaction pathways for upgrading heavy oil to distillable product; thermal, catalytic, and a combination of thermal and catalytic (See Figure 2). The thermal reactions involve thermal rupture of a bond producing two free radicals (reacting fragments) which are highly reactive and which have short life. The free radicals seek stabilization by such means as are available to them, namely, the addition of an atom such as a hydrogen atom or a small group such as a methyl group. The reactive fragments can rearrange to form a stable molecule or can polymerize. Combined hydrogen contained in the feed is merely redistributed to produce a relatively hydrogen-rich fraction (distillable) and a hydrogen-poor fraction which eventually forms coke.

The catalytic reactions involve catalysts and molecular hydrogen to form stabilized intermediates which are hydrogenated and hydrocracked to lower molecular weight compounds. Molecular hydrogen is utilized to stabilize the residual oil, thereby precluding the abstraction of hydrogen and the resulting degradation reactions. The catalytic reaction proceeds with the addition of hydrogen to produce distillable product.

The combination of thermal and catalytic reactions generally occur when insufficient catalysts or catalysts with little or no hydrogenation function are used. The primary reactions are thermal which involve thermal rupture of bonds producing free radicals (reactive fragments). The reactive fragment instead of further reacting to produce light hydrocarbons, heavy polymers, and insoluble organic matter, can combine with the catalyst to form adsorbed intermediates. The adsorbed intermediates further crack forming light hydrocarbons and coke which is deposited on the catalyst. The catalyst in this system has two primary functions. It is utilized as a free radical stabilizer which inhibits the polymerization of the reactive fragments that result in coke formation. It is also utilized as a depositor for coke that is formed and provides the means for removing the coke from the reactor thereby lessening deposition of coke therein and the resulting plugging of the reactor.

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Differentiation of Thermal and Catalytic Reaction

Thermal and catalytic conversion of black oils produce similar yields and conversions and hence these are not good criteria for evaluating and differentiating thermal and catalytic processes. Thermal processes generally will produce somewhat higher coke and gas yields and the distillable product may be more unstable and contain higher olefin and sulfur content. However, these differences are generally not sufficiently great to clearly distinguish between the two mechanisms. These differences become less distinct when the reactions are a combination of thermal and catalytic.

The key to differentiating between the two reactions are to compare the quality of the non-distillable product. Typically, thermal conversion produces a degraded non-distillable product. It will have a lower API, higher heptane insoluble and generally similar sulfur content to that of the feedstock. Catalytic conversion produces an upgraded non-distillable product. It will have a higher API, lower heptane insoluble and a sulfur content lower than the feedstock.

Results and Discussion

Processing Without Added Catalyst

Lloydminster vacuum resid was processed without added catalyst (auto-catalytically) at 420°C, 3000 psig for 2 hours in Run No. 14. The 510°C+ non-distillable conversion was 77.6 wt-%, heptane insoluble conversion was 50.9 wt-% and desulfurization was 45.6 wt-%. The coke yield was 2.89 wt-%. The resid product (25.1 wt-%) had a 1.80 API and contained 4.2 wt-% S and 16.6 wt-% heptane insoluble. The quality of the resid product is poorer than the feed indicating retrograde reactions had occurred.

It is instructive to compare Run 11 with Run 14 where the reaction conditions were identical barring the presence of catalyst in Run 11. The API of the condensate was essentially the same, but the API of the toluene soluble "resid" remaining in the autoclave at the end of reaction differed significantly, 16 when 0.5 wt-% Mo catalyst was present and 1.8 in the absence of any catalyst. Distillation of the "condensate" showed that there was no marked difference in the relative yields of lighter and heavier oils between the two runs.

All the product analyses obtained are shown in Appendix A. The condensate collected was not split into various fractions (distillate and so on) for further analysis, and hence specific information on the quality of the distillate is not available.

Appreciable non-distillable conversion can be achieved processing without added catalyst, however, heptane insoluble conversion and desulfurization will be relatively low. Furthermore, the quality of the resid product will be poorer than the feed because of retrograde reactions.

For all the runs discussed in this report, conversion data and product properties are summarized in Table A-1; feedstock data are listed in Table A-2; autoclave condensate product properties are summarized in Table A-3; autoclave gas product data are listed in Table A-4; material balance data are in Table A-5; weight recovery and conversion calculations are shown in Table A-6, and autoclave bottoms simulated distillation data are shown in Table A-7. All the tabular data are graphically illustrated in Figures 1-1 to B-10.

The analysis of the depressurized gas in Run 25 indicates the presence of an unusually large excess of O_2 and N_2 at the expense of H_2 . O_2 is considered to have come from air and is normalized out (indicated in the row under "norm factor"), and in this case gave rise to seemingly high production of light gases. This is most likely an experimental artefact and not an indication of high gas make.

In this set of runs an attempt was made to compute H_2 consumption. The computed numbers showed a considerable scatter. What this points to is that it is not possible to obtain accurate estimates of H_2 consumption in the pilot plant set up here, as this amounts to trying to measure a very small quantity difference.

In the following discussion, when multiple runs were carried out at the same operating conditions, results are reported as the averages of the multiple runs.

Processing With 0.05 wt-% Molybdenum Catalyst

A pressure survey was run processing Lloydminster vacuum resid with 0.05 wt-% Mo catalyst, 420°C, 2 hours residence time and pressure of 1000, 2000 and 3000 psig (Run Nos. 6 through 10). Pressure had a pronounced effect in heptane insoluble conversion and to a lesser extent on desulfurization. As shown in Figure B-11, heptane insoluble conversion increased from 45.9 wt-% at 1000 psig to 72.4 wt-% at 3000 psig. Desulfurization (Figure B-12) increased from 45.8 wt-% at 1000 psig to 59.8 wt-% at 3000 psig. The 510°C+ non-distillable conversion, however, decreased with increasing pressure from 69.3 wt-% at 1000 psig to 60.7 wt-% at 3000 psig (Figure B-13). The coke yield also decreased with increasing pressure from 1.17 wt-% at 1000 psig to 0.31 wt-% at 3000 psig (Table A-1). Pressure also had an effect on the resid product quality. The quality of the resid product improved with increasing pressure (Figure B-14 and Table A-1). The resid product API increased from 3.90 at 1000 psig to 9.60 at 3000 psig and the sulfur and heptane insoluble content decreased from 2.9 wt-% and 16.5 wt-%, respectively, at 1000 psig to 2.0 wt-% and 7.4 wt-%, respectively, at 3000 psig. The quality of the resid product obtained at 1000 psig is poorer than the feed indicating retrograde reactions had occurred. The quality of the resid product obtained at 2000 psig is slightly better than the feed indicating some catalytic effects. The quality of the resid product obtained at 3000 psig was further improved indicating greater catalytic effects.

The results indicate that catalytic effects are increased with increasing pressure whereas thermal effects are diminished. The results also indicate that heptane insoluble conversion, desulfurization and resid product quality are primarily catalytically induced whereas non-distillable conversion is primarily thermally induced.

To determine the response of the catalytic and thermal effects at higher temperature, Lloydminster vacuum resid was processed in Run No. 25 at 440°C, 3000 psig, and 2 hours residence time with 0.05 wt-% Mo catalyst. As shown in Table A-1, the conversion of 510°C+ non-distillable was 89.0 wt-%, heptane insoluble conversion was 85.1 wt-% and desulfurization was 75.1 wt-%. The coke yield was 0.62 wt-%. The resid product has an API of 3.0 and contained 1.6 wt-% S and 8.7 wt-% heptane insoluble.

All conversions responded positively when compared to the same processing condition at 420°C. The greatest impact was the 28% increase in 510°C+ non-distillable conversion. Desulfurization and heptane insoluble conversion also increased but to a lesser extent (16% and 13% respectively). The coke yield increased from 0.31 wt-% to 0.62 wt-%. The resid product API was lower (9.6 vs 3.0) and the heptane insoluble content slightly higher (Figure B-15). The resid product API (3.0) was also lower than the feed (6.6).

It is difficult to ascertain from the conversions which pathway, thermal or catalytic predominated at the higher temperature since all values increased with increased temperatures. Comparison of the coke yield and resid product API, however, indicate that thermal effects may have increased to a greater extent than the catalytic effects.

Processing With 0.5 wt-% Molybdenum Catalyst

Lloydminster vacuum resid was processed at pressures of 2000 and 3000 psig with 0.5 wt-% Mo catalyst, 420°C for 2 hours residence time in Run Nos. 13 (2000 psig) and 11, 12, and 22 (3000 psig). High conversion of heptane insoluble, non-distillable and desulfurization were achieved, however, the response to pressure increase was minimal (Table A-1). Heptane insoluble conversion increased from 85.1 wt-% at 2000 psig to 89.4 wt-% at 3000 psig (Figure B-11) and 510°C+ non-distillable conversion increased slightly from 71.7 wt-% at 2000 psig to 73.5 wt-% at 3000 psig (Figure B-13). Desulfurization was essentially the same -- 77.0 wt-% at 2000 psig and 76.4 wt-% at 3000 psig (Figure B-12). The coke yield decreased slightly from 0.91 wt-% at 2000 psig to 0.67 wt-% at 3000 psig. The quality of the resid product (Figure B-16) improved at the higher pressure, the API was 12.2 versus 16.4, sulfur content 1.22 versus 0.78 wt-% and the heptane insoluble 2.2 versus 0.70 wt-%. The quality of the resid product from both runs (2000 and 3000 psig) is significantly better than the feed indicating appreciable upgrading had occurred. At the above processing conditions the primary reaction pathways are believed to be catalytic.

A pressure survey was run processing Lloydminster vacuum resid with a 0.5 wt-% Mo catalyst, 440°C, 2 hours residence time and pressure of 1000 (Run 27), 2000 (Run 26) and 3000 (Runs 23 and 24) psig. Pressure had a pronounced effect on heptane insoluble conversion and

to a lesser extent on desulfurization (Table A-1). Heptane insoluble increased from 52.6 wt-% at 1000 psig to 93.0 wt-% at 3000 psig (Figure B-11). Desulfurization increased from 74.2 wt-% at 1000 psig to 86.7 wt-% at 3000 psig (Figure B-12). Also as illustrated in Figure B-13, appreciable non-distillable conversion was obtained at 1000 psig (89.6 wt-%). It was essentially the same at 2000 psig (90.1 wt-%) and increased slightly at 3000 psig (92.4 wt-%). The coke yield decreased with increasing pressure from 3.2 wt-% at 1000 psig to 0.7 wt-% at 3000 psig. There was significant difference in the quality of the resid product (Figure B-17). The resid product obtained at 1000 psig was appreciably degraded. It had a -10.70 API, 1.8 wt-% S and 28.0 % heptane insoluble. The quality of the resid product at 2000 psig was somewhat better. It had a negative API of -2.40 indicating some degradation reactions had occurred. Its sulfur content was 1.1 wt-% and its heptane insoluble content was 7.5 wt-%. The resid product obtained at 3000 psig was upgraded. It had a 8.35 API and contained 0.4 wt-%S and 1.1 wt-% heptane insoluble.

The results indicate that when processing with 0.5 wt-% Mo at 440°C temperature, catalytic effects increase with increasing pressure whereas thermal effects diminish. At 1000 psig pressure thermal effects predominate. At 2000 psig pressure, the reaction pathways are both thermal and catalytic and at 3000 psig pressure, catalytic effects predominate.

The effects of temperature when processing at 2000 psig with 0.5 wt-% Mo for 2 hours at 420°C (Run 13) and 440°C (Run 26) are listed in Table A-1 and summarized below. Non-distillable conversion increased with temperature but heptane insoluble conversion and desulfurization were essentially unchanged. The 510°C+ non-distillable conversion increased with temperature from 71.7 wt-% at 420°C to 90.1 wt-% at 440°C. Heptane insoluble conversion and desulfurization were 85.1 wt-% and 77.0 wt-% at 420°C and 84.1 wt-% and 78.7 wt-% at 440°C, respectively. The coke yield increased from 0.91 wt-% at 420°C to 1.27 wt-% at 440°C. There are significant differences in the quality of the resid product (Figure B-18). The resid product obtained at 420°C was upgraded. It had a 12.2 API and contained 1.2 wt-% S and 2.2 wt-% heptane insoluble. The quality of the resid product obtained at 440°C was poorer. It had a negative API of -2.4 indicating some degradation reactions had occurred. Its sulfur content was 1.1 wt-% and its heptane insoluble content was 7.5 wt-%.

The results indicate that when processing at 2000 psig with 0.5 wt-% Mo at 420°C, catalytic effects predominate whereas the catalytic effects are diminished at 440°C.

The effects of temperature when processing at 3000 psig with 0.5 wt-% Mo for 2 hours at 420°C (Runs 11, 12, and 22) and 440°C (Runs 23 and 24) are listed in Table A-1 and summarized below. The greatest impact was on non-distillable conversion which increased from 73.5 wt-% (average of Runs 11, 12, and 22) at 420°C to 92.4 wt-% (average of Runs 23 and 24) at 440°C. Desulfurization also increased but to a lesser extent from 76.4 wt-% at 420°C to 86.7 wt-% at 440°C. Heptane insoluble conversion increased slightly from 89.4 wt-% at 420°C to 93.0 wt-% at 440°C; however, at these temperatures the conversions were exceedingly high. The coke yield increased from 0.67 wt-% at 420°C to 0.72 wt-% at 440°C. As shown in Figure B-19, the resid products are highly upgraded. The resid product obtained at 420°C

(36.7 wt-%) had a 15.4 API and contained 0.9 wt-% S and 1.0 wt-% heptane insoluble. The resid product obtained at 440°C (7.4 wt-%) had a 8.4 API and contained 0.4 wt-% S and 1.1 wt-% heptane insoluble.

These results indicate that when processing at 3000 psig with 0.5 wt-% Mo at 420°C or 440°C, catalytic effects predominate over thermal effects. Catalytic effects are responsive to high pressure and high catalyst concentration. Thermal effects can be diminished or eliminated by processing at high pressures with high catalyst concentration.

The effects of catalyst concentration when processing at 420°C, 3000 psig for 2 hours with 0 (Run 14), 0.05 wt-% (Runs 9 and 25) and 0.5 wt-% (Runs 11, 12, and 22) Mo catalysts are shown in Figure B-20, Table A-1 and are summarized below. The greatest effect was on heptane insoluble conversion which increased from 50.9 wt-% with no catalyst to 72.4 wt-% with 0.05 wt-% Mo catalyst and increased further to 89.4 wt-% with 0.5 wt-% Mo catalyst. Catalyst concentration also effected desulfurization but to a lesser extent. It increased from 45.6 wt-% with no catalysts to 59.8 wt-% with 0.05 wt-% Mo catalysts and increased further to 76.4 wt-% with 0.5 wt-% Mo catalysts. Non-distillable conversion responded differently. The highest non-distillable conversion was obtained with no catalyst (77.7 wt-%). It decreased to 60.7 wt-% with 0.05 wt-% Mo catalyst, then increased to 73.5 wt-% with 0.5 wt-% Mo catalyst. The coke yield had a similar trend as non-distillable conversion. The highest coke was with no catalyst (2.9%). It decreased to 0.31 wt-% with 0.05 wt-% Mo catalyst then increased to 0.67 wt-% with 0.5 wt-% Mo catalyst. The quality of the resid product improved with increasing catalyst concentration (Figure B-21). The quality of the resid product obtained with no catalyst is poorer than the feed indicating some retrograde reactions had occurred. It had a 1.80 API and contained 4.2 wt-% S and 16.6 wt-% heptane insoluble. The resid product obtained with 0.05 wt-% Mo catalyst is upgraded. It had a 9.6 API and contained 2.0 wt-% S and 7.4 wt-% heptane insoluble. The resid product obtained with 0.5 wt-% Mo catalyst is further upgraded. It had a 15.4 API and contained 0.9 wt-% S and 1.0 wt-% heptane insoluble.

These results indicate that when processing at 3000 psig and 420°C, catalyst concentration has a pronounced effect on heptane insoluble conversion, desulfurization and quality of resid product. At these processing conditions, catalytic effect predominates over thermal effects even at low catalyst concentration (0.05 wt-% Mo) and predominant to a greater degree at the high catalyst concentration (0.5 wt-% Mo).

The effects of catalyst concentration when processing at 440°C, 3000 psig for 2 hours with 0.05 wt-% (Run 25) and 0.5 wt-% (Run 23 and 24) Mo catalyst concentration are summarized below (Figure B-22, Table A-1). Heptane insoluble conversion increased from 85.1 wt-% with 0.05 wt-% Mo catalysts to 93.0 wt-% with 0.5 wt-% Mo catalysts. Desulfurization increased from 75.1 wt-% with 0.05 wt-% Mo catalysts to 86.7 wt-% with 0.5 wt-% Mo catalyst. Non-distillable conversion increased slightly from 89.0 wt-% with 0.05 wt-% Mo catalyst to 92.4 wt-% with 0.5 wt-% Mo catalysts. The coke yield was similar: 0.62 wt-% with 0.05 wt-% Mo catalyst and 0.72 wt-% with 0.5 wt-% Mo catalyst. The quality of the resid product improved with increasing catalyst concentration (Figure B-23). The resid obtained with

0.05 wt-% Mo catalysts had a 3.0 API which is lower than the feed indicating some degradation reactions had occurred. Its sulfur content was 1.6 wt-% and its heptane insoluble content was 8.7 wt-%. The resid product obtained with 0.5 wt-% Mo catalysts had an 8.4 API and contained 0.4 wt-% S and 1.1 wt-% heptane insoluble. This resid product is upgraded indicating that catalytic effects predominated over thermal effects.

The results indicate that when processing at 440°C and 3000 psig with 0.05 wt-% Mo catalyst concentration, the reaction pathways are both catalytic and thermal. Increasing the catalyst concentration to 0.5 wt-% Mo inhibits the thermal effects and the catalytic effects predominate.

DESIGN BASIS FOR THE ECONOMIC ASSESSMENT

The design basis for the co-processing economic assessment is selected as the long-term operability Run No. 37. The feedstock characteristics and co-processing product characteristics are reported in Tables 2 to 6. Work on the economic assessment will be reported in more detail in the next quarter as additional data are generated.

CONCLUSIONS

The following conclusions are made from the autoclave study with the Lloydminster vacuum resid:

- Petroleum resid can be thermally converted to distillable product in high yield, however, thermal reactions cause retrograde reactions that lead to coking and reactor fouling.
- Petroleum resid can be catalytically converted to distillable product in high yield under selected processing conditions that eliminate or suppress thermal reactions.
- Catalytic effects are increased with increasing pressure whereas thermal effects are diminished.
- Thermal effects are more responsive to temperature than catalytic effects.
- Heptane insoluble conversion and desulfurization are primarily catalytically induced.
- Non-distillable conversion is primarily thermally induced.
- Thermal effects can be diminished or eliminated by processing at high pressure and high catalyst concentration.

TABLE 1
Analysis of Lloydminster Vacuum Resid
UOP 58-1625

API Gravity	6.6
Specific Gravity	1.0246
Distillation, °C	
IBP	379
5	455
10	473
20	509
EP	512
% EP	22
% 510°C	81
C wt-%	83.6
H wt-%	10.3
S wt-%	4.8
N wt-%	0.6
MCRT wt-%	17.4
C ₇ Insoluble wt-%	13.6
Ni ppm	82
V ppm	183
Pour Point, °C	54

TABLE 2
Feedstock Characteristics for Economic Assessment

Feed Composition:	
Resid Type	Lloydminster
Resid wt-%	64
Coal Type	Illinois No. 6
Moisture-free Coal wt-%	36
Resid Properties:	
API Gravity	6.5
510- + °C, wt-%	19
Sulfur, wt-%	4.0
MCRT, wt-%	17
Carbon, wt-%	84
Hydrogen, wt-%	10
Oxygen, wt-%	0.5
Vanadium, ppm	160
Nickel, ppm	80
Coal Properties:	
Carbon, wt-%	71
Hydrogen, wt-%	5
Nitrogen, wt-%	1.4
Oxygen, wt-%	8.0
Sulfur, wt-%	3.2
Ash, wt-%	11.4

TABLE 3
Properties of Co-Processing Naphtha (C₇-177°C)

API Gravity	50.1
Distillation, °C, vol-%:	
IBP	91
10	106
30	123
50	135
70	146
90	162
EP	187
Sulfur, wt-%	0.13
Nitrogen, wt-%	0.12
Bromine Number	22
Composition, vol-%	
Paraffins	47.2
Olefin	2.6
Naphthenes	31.0
Aromatic	19.2

TABLE 4
Properties of Co-Processing Diesel

API Gravity	27.3
Distillation, °C, vol-%:	
IBP	213
10	216
30	218
50	238
70	264
90	297
EP	315
% over at EP	98
Sulfur, wt-%	0.5
Nitrogen, wt-%	0.45
Bromine Number	16
FIA, vol-%	
P + N	40.8
A	51.3
O	7.9
Pour Point, °C	-42
Cetane Number	27
Smoke Point, mm	8.6
Freeze Point, °C	-23

TABLE 5
Properties of Co-Processing Vacuum Gas Oil

API Gravity	5.4
Distillation, °C, vol-%:	
IBP	310
10	350
30	380
50	415
70	465
90	-
EP	-
% over at EP	85
Sulfur, wt-%	1.6
Nitrogen, wt-%	0.67
MCRT, wt-%	2.6
Composition, wt-%	
Carbon	86.4
Hydrogen	8.6
Metals, ppm	
Nickel	<1
Vanadium	<1

TABLE 6
Properties of Co-Processing Non-distillable

API Gravity	-19
Hydrogen, wt-%	6.2
Sulfur, wt-%	1.9
Nitrogen, wt-%	0.15
Metals, ppm	
Vanadium	54
Nickel	60
Heptane Insoluble, wt-%	96
Conradson Carbon, wt-%	54
Engler to Coke, wt-%	
Gas	19.7
Overhead	23.7
Coke	56.6

PLANT 559
9-28-92 TJW

FIGURE 1

Figure 2

Reaction Pathways For Conversion of Heavy Oil

APPENDIX A

Tables of Autoclave Run Data

TABLE A-1
Summary Run Data

RUN#	14	7	6	8	10	9	25	27	13	26	11
Notebook# 5758-	51	29	27	31	37	33	89	103	45	101	39
Resid Type	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10
Catalyst Type	M0	M0	M0	M0	M0	M0	M0	M0	M0	M0	M0
Catalyst, wt%	0	0.05	0.05	0.05	0.05	0.05	0.05	0.5	0.5	0.5	0.5
Temp., Deg C.	420	420	420	420	420	420	440	440	420	440	420
Pressure, atm.	3000	1000	2000	2000	2000	3000	3000	1000	2000	2000	3000
Res. Time, hrs.	2	2	2	2	2	2	2	2	2	2	2
Feed Additive	0	0	0	0	0	0	0	0	0	0	0
Weight Recovery, %	111.16	99.55		99.90	106.26	101.49	107.16	97.48	102.00	100.12	102.11
Ash Balance, %	0.00	154.86	169.10	156.28	168.73	144.49	128.75	122.44	150.09	146.03	100.25
Conversions, wt%											
Heptane Ins.	50.92	45.90	69.30	60.50	67.71	72.35	85.05	82.63	85.05	84.06	82.35
MCRT	-18.99	22.39	26.00	39.73	43.11	25.13	43.37	60.53	84.93	39.41	68.09
S10C+	77.61	69.31	68.26	67.07	67.16	60.69	89.01	89.55	71.68	90.08	70.22
S71C+	71.35	67.92	66.14	64.86	68.55	68.10	82.74	70.98	70.06	67.33	65.80
Desulfurization	45.61	45.81	57.45	52.32	56.42	59.78	75.08	74.24	76.97	78.74	74.30
Denitification	54.27	44.47	49.87	31.97	47.03	46.46	58.06	86.58	58.17	61.94	68.72
Coke Yield, Wt%	2.89	1.17	0.50	1.01	0.44	0.31	0.62	3.22	0.91	1.27	0.49
Product Yield, wt%											
H2O + COx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2S	1.86	2.30	2.89	2.62	2.72	3.01	3.82	4.16	4.48	4.37	3.71
NH3	0.29	0.34	0.33	0.24	0.29	0.32	0.39	0.41	0.43	0.43	0.49
C1-C4	4.95	2.54	2.13	2.19	2.64	1.96	13.28	4.25	3.93	4.32	2.08
C5-177C (incl. losses if	6.27	8.55	8.07	7.05	5.29	6.49	8.64	16.93	9.36	17.79	8.84
177-343C	30.41	24.32	23.61	22.06	23.66	21.25	32.46	34.58	26.04	35.45	24.30
343-510C	35.26	35.20	36.64	37.62	36.68	34.05	36.87	25.75	33.85	30.96	36.79
S10C+	20.45	25.11	26.41	27.03	28.68	32.79	9.68	8.37	23.74	8.16	24.98
H2 Consumption	-0.51	0.29	0.09	0.18	-0.04	-0.13	5.14	1.04	1.87	1.48	1.19
Total	98.97	98.65	100.17	98.99	99.92	99.73	110.29	95.49	103.75	102.96	102.38
Toluene Soluble Resid											
API	1.80	3.90	7.00	8.00	7.90	9.60	3.00	-10.70	12.20	-2.40	16.10
wt% carbon	84.49	86.36	83.28	86.70	82.90	94.00	89.07	89.63	87.84	89.80	87.67
wt% hydrogen	9.67	7.24	6.75	10.03	9.73	10.20	8.68	6.48	9.98	7.66	11.11
wt% sulfur	4.18	2.94	2.31	2.86	2.43	1.99	0.00	1.84	1.22	0.00	0.83
wt% nitrogen	0.78	0.59	0.55	0.67	0.54	0.48	0.66	0.90	0.43	0.66	0.24
wt% heptane ins.	16.61	16.47	9.26	9.42	9.48	7.43	8.70	28.03	2.20	7.45	0.88
wt% MCRT	32.26	22.70	18.25	17.55	18.50	15.64	24.05	40.70	10.82	25.89	7.35
auto.wk3 9/5/9											
Wt% Hydrocarbon Gas	5.53	2.54	2.13	2.19	2.72	1.96	14.92	4.25	4.07	4.32	2.08
Wt% Condensate Yield	74.57	57.32	56.17	49.41	56.02	49.40	77.19	77.09	58.93	82.55	59.27
Wt% Toluene Soluble R	25.11	35.86	39.15	44.35	43.87	46.21	15.46	8.53	33.87	8.08	36.54
Wt% Toluene Insolubles	3.23	1.54	0.74	1.32	0.85	0.50	0.95	4.54	2.13	2.36	1.24
	108.43	97.26	96.19	97.27	103.25	98.08	108.51	84.41	99.01	97.31	99.13
Gms HC gas	22.60	10.24	8.87	9.29	11.74	8.19	86.30	18.10	17.53	18.52	8.54
Gms Condensate	305.00	231.00	234.00	210.00	242.00	206.00	343.00	328.00	254.00	354.00	243.00
Gms Resid	102.70	144.50	163.10	188.50	189.50	192.70	68.70	36.30	148.00	34.70	149.80
Gms Tol insol	13.20	6.20	3.10	5.60	2.80	2.10	4.20	19.30	9.20	10.10	5.10
Gms Total Product	443.50	391.94	409.07	413.39	446.04	408.99	482.20	401.70	426.73	417.32	406.44
Feed sum	99.8	99.8	99.8	99.8	99.8	99.8	99.8	99.8	99.8	99.8	99.8
Condensate sum (CHS	98.41	93.92	96.63	96.35	106.94	98.8	1.8622	1.55866	98.75	1.4412	99.67
Resid product sum (CH	99.12703	97.13	92.89	100.1806	105.6	106.67	96.4145	96.8441	99.47	96.173	99.85
Toluene insoluble sum (C	100.38014	87.790574	82.021208	84.640638	82.771095	78.631587	70.848538	76.008159	80.136884	58.517295	61.462538

TABLE A-1 (Continued)
Summary Run Data

RUN#	12	22	23	24
Notebook# 5758-	41	81	93	97
Resid Type	R10	R10	R10	R10
Catalyst Type	M0	M0	M0	M0
Catalyst, wt%	0.5	0.49	0.49	0.49
Temp., Deg C.	420	420	440	440
Pressure, atm.	3000	3000	3000	3000
Res. Time, hrs.	2	2	2	2
Feed Additive	0	0	0	0
Weight Recovery, %	100.99	88.70	100.26	88.97
Ash Balance, %	143.97	159.08	152.25	144.85
Conversions, wt%				
Heptane Ins.	91.99	83.86	93.19	92.89
MCRT	73.01	42.33	37.35	30.43
S10C+	79.22	71.08	83.69	91.17
371C+	54.26	58.34	66.27	61.25
Desulfurization	79.73	75.16	88.21	85.10
Denitrification	68.62	59.01	73.34	64.96
Coke Yield, WT%	0.68	0.85	0.81	0.63
Product Yield, wt%				
H2O + COx	0.00	0.00	0.00	0.00
H2S	4.05	4.06	4.45	4.36
NH3	0.48	0.45	0.52	0.49
C1-C4	2.19	2.22	3.86	2.50
C5-177C (incl. losses if	9.23	6.60	16.26	11.48
177-343C	23.57	17.92	33.87	34.18
34C-510C	44.54	35.36	35.37	37.49
S10C+	17.24	21.08	5.20	7.03
H2 Consumption	1.30	1.35	-0.46	1.77
Total	102.60	89.04	99.07	99.30
Toluene Soluble Resid				
API	16.70	13.30	6.60	10.10
wt% carbon	86.45	85.91	86.58	86.70
wt% hydrogen	11.43	10.23	8.37	9.82
wt% sulfur	0.73	1.02	0.22	0.51
wt% nitrogen	0.26	0.36	0.00	0.31
wt% heptane ins.	0.42	1.57	1.11	1.00
wt% MCRT	7.00	10.27	16.37	13.29
auto.wk3 9/5/9				
WT%Hydrocarbon Gas	2.19	2.22	3.96	2.50
WT% Condensate Yield	57.08	43.32	83.52	81.10
WT% Toluene Soluble R	36.79	37.65	5.67	9.08
WT%Toluene Insolubles	1.72	2.20	1.67	1.63
	97.78	85.38	94.82	84.31
Gms HC gas	9.28	10.08	15.82	10.56
Gms Condensate	242.00	197.00	334.10	343.00
Gms Resid	156.00	171.20	22.70	38.40
Gms Tol insol	7.30	10.00	6.70	6.90
Gms Total Product	414.58	388.28	379.32	398.86
Feed sum	99.8	99.8	99.8	99.8
Condensate sum (CHS	98.92	101.6749	92.6561	98.2488
Resid product sum (CH	98.87173	97.5156	95.17	96.8326
Toluene insoluble sum (C	61.222983	58.407165	70.179988	62.807144

TABLE A-2
Feedstock Properties for each Run

RUN#	14	7	6	8	10	9	25	27	13	26	11
Notebook# 5756-	51	29	27	31	37	33	89	103	45	101	39
Temp., Deg C.	420	420	420	420	420	420	440	440	420	440	420
Pressure, atm.	3000	1000	2000	2000	2000	3000	3000	1000	2000	2000	3000
Res. Time, hrs.	2	2	2	2	2	2	2	2	2	2	2
Catalyst, wt%	0	0.050	0.050	0.050	0.050	0.050	0.05	0.5	0.5	0.5	0.5
Feedstock Data:											
Resid Type	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10	R10
wt% C	83.6	83.6	83.6	83.6	83.6	83.6	83.6	83.6	83.6	83.6	83.6
wt% H	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
wt% N	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
wt% S	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77
wt% O	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
wt% Ash	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
wt% HI	13.56	13.56	13.56	13.56	13.56	13.56	13.56	13.56	13.56	13.56	13.56
wt% MCRT	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39
wt ppm V	163	163	163	163	163	163	163	163	163	163	163
wt ppm Fe	34	34	34	34	34	34	34	34	34	34	34
wt ppm Ni	82	82	82	82	82	82	82	82	82	82	82
g D1160 Btms	155.2	155.2	155.2	155.2	155.2	155.2	155.2	155.2	155.2	155.2	155.2
Wt% D1160Btms	77.96995	77.96995	77.96995	77.96995	77.96995	77.96995	77.96995	77.96995	77.96995	77.96995	77.96995
g D1160 OH	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8
Wt%D1160OH	22.01005	22.01005	22.01005	22.01005	22.01005	22.01005	22.01005	22.01005	22.01005	22.01005	22.01005
wt% 177C-	0	0	0	0	0	0	0	0	0	0	0
wt% 343C-	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
wt% 371C-	4.875	4.875	4.875	4.875	4.875	4.875	4.875	4.875	4.875	4.875	4.875
wt% 510C-	81	81	81	81	81	81	81	81	81	81	81
Catalyst Type	none	Mo	Mo	Mo	Mo	Mo	Mo	Mo	Mo	Mo	Mo
wt% V	0	0	0	0	0	0	0	0	0	0	0
wt% Mo	0	100	100	100	100	100	100	100	100	100	100
wt% Fe	0	0	0	0	0	0	0	0	0	0	0
wt% S	0	0	0	0	0	0	0	0	0	0	0
wt% Ash	0	100	100	100	100	100	100	100	100	100	100
wt% moisture	0	0	0	0	0	0	0	0	0	0	0
Feed											
g Resid	409	403	416.6	425	432	417	444.3777	425.462	431	426.845	410
g Cat.	0	0.2015	0.2083	0.2125	0.216	0.2085	0.2223	2.138	2.155	2.155	2.05
g water w/ cat	0	0	0	0	0	0	0	0	0	0	0
g toluene w/ cat	0	0	0	0	0	0	0	0	0	0	0

TABLE A-2 (Continued)
Feedstock Properties for each Run

RUN#	12	22	23	24
Notebook# 5758-	41	81	83	87
Temp., Deg C.	420	420	440	440
Pressure, atm.	3000	3000	3000	3000
Res. Time, hrs.	2	2	2	2
Catalyst, wt%	0.5	0.49	0.49	0.49
Feedstock Data:				
Resid Type	R10	R10	R10	R10
wt% C	83.6	83.6	83.6	83.6
wt% H	10.3	10.3	10.3	10.3
wt% N	0.59	0.59	0.59	0.59
wt% S	4.77	4.77	4.77	4.77
wt% O	0.54	0.54	0.54	0.54
wt% Ash	0.041	0.041	0.041	0.041
wt% HI	13.56	13.56	13.56	13.56
wt% MCRT	17.39	17.39	17.39	17.39
wt ppm V	183	183	183	183
wt ppm Fe	34	34	34	34
wt ppm Ni	82	82	82	82
g D1180 Btms	155.2	155.2	155.2	155.2
Wt% D1180Btms	77.98995	77.98995	77.98995	77.98995
g D1180 OH	43.8	43.8	43.8	43.8
Wt%D1180OH	22.01005	22.01005	22.01005	22.01005
wt% 177C-	0	0	0	0
wt% 343C-	3.2	3.2	3.2	3.2
wt% 371C-	4.875	4.875	4.875	4.875
wt% 510C-	81	81	81	81
Catalyst Type	Mo	Mo	Mo	Mo
wt% V	0	0	0	0
wt% Mo	100	100	100	100
wt% Fe	0	0	0	0
wt% S	0	0	0	0
wt% Ash	100	100	100	100
wt% moisture	0	0	0	0
Feed				
g Resid	424	454.7607	400.0302	422.9175
g Cat.	2.12	2.2393	1.8698	2.125
g water w/ cat	0			
g toluene w/ cat	0			

TABLE A-3
Product Properties

RUN#	14	7	6	8	10	9	25	27	13	26	11
Notebook# 5758-	51	29	27	31	37	33	89	103	45	101	39
Total Condensate Prod.											
gm condensate	305	231	234	210	242	206	343	328	254	354	243
API	29.9	30.7	31.3	30.9	31.1	30.7	31.9	33.8	32.2	33	30.4
wt% C	83.33	81.37	83.2	84.87	81.6	84.61	85.3	85.4	84.2		85.5
wt% H	12.44	9.75	11.2	11.07	13.1	11.9	11.7	11.7	13.19		12.4
wt% S	2.46	2.65	2.05	2.21	2.04	2.08	1.85	1.35	1.2	1.23	1.6
wt% N	0.4	0.11	0.16	0.87	0.1	1.04					0.2
wt% O	0	0	0	0	0	0			0		0
wt% N (chem)	0.18	0.15	0.18	0.2	0.2	0.21	0.2122	0.2079	0.16	0.2112	0.17
wt ppm Mo								3			
wt ppm V								0			
wt ppm Ni								0			
wt ppm Fe								4.6			
wt% HI											
wt% MCRT	0.16	0.072	0.096	0.034	0.035	0.115	0.0805	0.0855	0.058	0.067	0.042
Brs g Br/100g	17.4	18.5	20.9	16.4	19.9	11.2	6.6	11.4	7.8	8.2	7.3
Aromatics, LV%	51.1	42.4	46.4	43.5	46.2	43.7	41.3	36.6	42.1	35.6	42.6
Olefins, LV%	0.3	7.3	5.1	5.4	4.7	3.2	0	0	0	0	0
Paraffins & Naphthenes	48.6	50.2	48.5	51.1	49.1	53.1	56.7	63.4	57.9	64.4	57.4
OH GLC, wt%											
IBP, Deg C	20	25	32	10	19	34	0	1	21	0	80
5%	98	104	100	98	97	100	82	72	101	85	118
10%	132	147	144	142	130	144	131	116	143	125	134
20%	187	206	205	224	180	207	181	167	204	180	201
30%	234	252	250	250	230	252	237	212	249	226	250
40%	274	291	287	289	272	282	277	249	286	264	290
50%	312	325	325	325	312	328	316	284	321	301	324
60%	347	358	357	360	348	363	351	320	354	336	357
70%	381	390	389	393	382	396	385	356	385	371	389
80%	416	423	423	427	418	431	421	383	419	407	421
90%	457	459	461	465	457	469	463	440	459	451	460
95%	487	487	489	495	486	499	486	475	480	486	488
99%	537	533	534	556	532	555	555	561	549	553	539
wt% 177C-	18.2	14.9	15.4	14.3	19.4	15.2	17.7	22.0	15.6	19.5	16.4
wt% 343C-	58.9	55.5	55.6	55.1	58.6	54.3	57.7	66.4	56.7	62.0	55.8
wt% 371C-	67.1	64.1	64.4	63.3	66.8	62.4	65.9	74.2	65.5	70.0	64.4
wt% 510C-	96.8	97.0	96.9	96.0	97.1	95.8	95.9	96.6	96.4	96.4	96.7

TABLE A-3 (Continued)
Product Properties

RUN#	12	22	23	24
Notebook# 5758-	41	91	93	97
Total Condensate Prod.				
gm condensate	242	197	334.1	343
API	30.5	31.3	32	31.7
wt% C	84.46	87.21	81.11	86.03
wt% H	13.05	12.75	10.7	11.18
wt% S	1.24	1.54	0.68	0.85
wt% N	0.2		0.37	0.29
wt% O	0			
wt%N (chem)	0.17	0.1749	0.1861	0.1888
wt ppm Mo				
wt ppm V				
wt ppm Ni				
wt ppm Fe				
wt% HI				
wt% MCRT	0.026	0.0865	0.11	0.122
Brd g Br/100g	11.4	9	8.3	8
Aromatics, LV%	42.3	42.7	38.7	37.9
Olefins, LV%	0	0	0	0
Paraffins & Naphthenes	57.7	57.3	61.3	62.1
OH GLC, wt%				
IBP, Deg C	17	-1	-3	89
5%	100	97	88	117
10%	145	144	131	155
20%	210	207	191	208
30%	255	252	236	250
40%	295	292	277	288
50%	329	328	315	324
60%	364	362	350	357
70%	396	394	383	389
80%	429	428	418	424
90%	466	466	459	464
95%	496	496	489	496
99%	548	545	534	547
wt% 177C-	14.9	15.2	17.7	14.2
wt% 343C-	54.0	54.4	58.0	55.8
wt% 371C-	62.2	62.8	66.4	64.4
wt% 510C-	96.1	96.1	98.9	96.1

Table A-4
Product Gas Properties

RUN#	14	7	6	8	10	9	25	27	13	26	11
Notebook# 5758-	51	29	27	31	37	33	99	103	45	101	39
Depressurized Gas	X	X	X	X	X						
Rate, CF	9.857	3.74	6.952	6.61	7.45	11.005	9.571	3.75	7.33	7.03	10.835
Sample, L	0.3	0.1	0.25	0.1	1.1	0.2	1.04	1.16	0.22	1.392	0.23
mole% O2	1.1	2.9	0.7	1.4	1.5	0.5	19.2	0.9	0.8	5.5	0.6
mole% N2	5.2	19.1	12.3	16.7	6.7	6.7	77.1	17.1	3.7	27.4	4.2
mole% H2	88.9	71.3	82.9	78.3	88	80.3	1.1	86.9	90.5	80.8	92.8
mole% CO	0	0	0	0	0	0			0		0
mole% CO2	0	0	0	0	0	0			0		0
mole% CH4	3.2	4.5	2.8	2.4	2.6	1.8	1.3	10.5	2.9	3.9	1.7
mole% C2	1	1.4	0.8	0.8	0.8	0.5	0.6	3	0.9	1.3	0.5
mole% C2=	0	0	0	0	0	0			0		0
mole% C3	0.5	0.7	0.4	0.4	0.4	0.3	0.4	1.4	0.5	0.9	0.3
mole% C3=	0	0	0	0	0	0			0		0
mole% IC4	0	0	0	0	0	0	0.1		0.3	0.2	0.1
mole% nC4	0.1	0.1	0.1	0	0	0.1	0.1	0.2	0.3		0
mole% C4=	0	0	0	0	0	0			0		0
mole% IC5	0	0	0	0	0	0			0		0
mole% nC5	0	0	0	0	0	0	0.1		0		0
mole% C6+	0	0	0	0	0	0			0		0
norm factor	1.0527845	1.1523153	1.0329575	1.0681615	1.0733875	1.0233215	8.0087135	1.0427768	1.0378439	1.3345611	1.0281189
gmol	10.850439	4.19657	7.6604991	7.3470434	8.2296481	12.254363	10.58314	4.1677101	8.1188053	7.8131634	12.133584
Stripped Gas											
Rate, CF	3.085	3.023	3.15	3.835	3.2	2.87	3.4	3.913	3.259	3.639	3.63
Sample, L	0.1	0.1	0.1	0.1	0.6	0.08	0.4	0.415	0.5	0.405	0.1
mole% O2	1.6	1.2	1.4	1	1.9	3.7	3.8	0.3	3	2.4	4
mole% N2	78.8	71	79.6	79.2	85.9	74.3	91.6	86	81.6	87.4	88
mole% H2	14.1	24.7	17.6	17.5	9.8	21.3	3.7	10.4	11	8.5	7.5
mole% CO	0	0	0	0	0	0			0		0
mole% CO2	0	0	0	0	0	0			0		0
mole% CH4	0.7	1.6	0.8	1.1	0.4	0.4	0.3	1.8	0.6	0.6	0.2
mole% C2	0.6	0.8	0.3	0.3	0.3	0.1	0.3	0.8	0.4	0.3	0
mole% C2=	0	0	0	0.2	0	0			1.9		0
mole% C3	1.1	0.6	0.4	0.3	0.3	0.2	0.3	0.7	0.4	0.6	0.2
mole% C3=	0	0	0	0.1	0	0			0.9		0
mole% IC4	1.6	0	0	0.1	0.8	0			0		0
mole% nC4	0.7	0.1	0.1	0.2	0.5	0			0.1	0.2	0.1
mole% C4=	0	0	0	0	0	0			0		0
mole% IC5	0.3	0	0	0	0	0			0		0
mole% nC5	0	0	0	0	0	0			0.1		0
mole% C6+	0.5	0	0	0	0.1	0					0
norm factor	1.0786649	1.0578608	1.0681615	1.0477568	1.094813	1.202857	1.2084882	1.0138636	1.1583996	1.1228284	1.2229723
gmol	3.3961593	3.3927994	3.4705089	4.264266	3.5389173	3.1989182	3.7807406	4.3179841	3.6254289	4.0320962	4.0658686
Ambient T, DegF	78	70	78	72	76	71	74	74	75	72	70
Ambient P, mm Hg	748.2	745.5	748.8	743	743.5	742.2	741	739.6	746.3	738.3	744.2
H2O Vapor P, mm Hg	24.87	19.06	24.87	20.39	23.29	19.72	21.80	21.80	22.53	20.39	19.06
SU Gas, vol% H2	90	90	90	90	90	90	90	90	90	90	90
SU Gas, vol% H2S	10	10	10	10	10	10	10	10	10	10	10
SU Gas, Cycles	60	22	43	43	43	65	67.8	16	43	47	74
SU Gas, SCF/cycle	0.1410757	0.1389756	0.1410757	0.1395006	0.1405507	0.1382381	0.1400256	0.1400256	0.1402882	0.1395006	0.1389756
MU Gas, Cycles	0	6	2	2	4.875	6.5	6.75	12.4	21.5	10	11
MU Gas, SCF/cycle	0.193569	0.1906874	0.193569	0.1914078	0.1929486	0.1910476	0.1921262	0.1921262	0.1924884	0.1914078	0.1906874
g Water out	0	0	0	0	0	0	0	0	0	0	0
g Water removed	0	0	0	0	0	0	0	0	0	0	0
In drying step											
g Feed H2O	0	0	0	0	0	0	0	0	0	0	0
g SU + MU H2	19.410888	9.9266029	14.897564	14.731235	18.254833	23.918683	25.075454	11.206038	24.378378	19.912503	26.828298
g H2 Cons.	-2.1033189	1.1884214	0.3575755	0.7889368	-0.1827474	-0.5612733	22.856588	4.428705	8.0738891	8.355853	4.8883769

Table A-4 (Continued)
Product Gas Properties

RUN#	12	22	23	24
Notebook# 5758-	41	81	83	87
Depressurized Gas				
Rate, CF	10.905	10.268	10.179	10.04
Sample, L	0.4	1.3	1.16	1.04
mole% O2	0.6	7.9	0.7	8.1
mole% N2	4.2	44.5	3.3	37.1
mole% H2	82.6	45.8	91.7	52.4
mole% CO	0			
mole% CO2	0			
mole% CH4	1.7	1.2	2.8	1.8
mole% C2	0.5	0.4	0.9	0.5
mole% C2=	0			
mole% C3	0.3	0.2	0.5	0.3
mole% C3=	0			
mole% IC4	0			
mole% nC4	0.1		0.1	
mole% C4=	0			
mole% IC5	0			
mole% nC5	0			
mole% C6+	0			
norm factor	1.0281189	1.5627002	1.0329575	1.5852835
gmol	11.81387	11.543599	11.358813	11.171858
Stripped Gas				
Rate, CF	3.36	3.185	3.574	3.85
Sample, L	0.5	0.896	0.928	0.405
mole% O2	4.9	1.4	1.8	3
mole% N2	80.4	85.1	87.8	86.1
mole% H2	13.5	11.5	8.2	0.5
mole% CO	0			
mole% CO2	0			
mole% CH4	0.4	0.4	0.3	0
mole% C2	0.3	0.5	0.4	
mole% C2=	0			
mole% C3	0.4	0.8	0.9	0.2
mole% C3=	0			
mole% IC4	0		0.1	0.1
mole% nC4	0.1	0.3	0.4	0.1
mole% C4=	0		0	
mole% IC5	0		0	
mole% nC5	0		0	
mole% C6+	0		0.1	
norm factor	1.287568	1.0881615	1.0893768	1.1583896
gmol	3.6544327	3.5829425	4.0079119	4.2841853
Ambient T, DegF	80	74	72	77
Ambient P, mm Hg	740.9	752.7	743.2	752
H2O Vapor P, mm Hg	26.54	21.80	20.39	24.07
SU Gas, vol% H2	80	80	80	80
SU Gas, vol% H2S	10	10	10	10
SU Gas, cycles	74	80	48	88
SU Gas, SCF/cycle	0.1418007	0.1400256	0.1385006	0.1408132
MU Gas, Cycles	11	9	10	10
MU Gas, SCF/cycle	0.1842894	0.1821282	0.1814078	0.1832088
g Water out	0			
g Water removed	0			
in drying step				
g Feed H2O	0			
g SU + MU H2	29.474734	23.872282	20.552308	26.235205
g H2 Cons.	5.5197089	8.1264424	-1.8560491	7.4763583

TABLE A-5
Material Balance Data

RUN#	14	7	6	8	10	9	25	27	13	26	11
Notebook# 5758-	51	29	27	31	37	33	99	103	45	101	39
g Feed	409	403	416.6	425	432	417	444.3777	425.462	431	428.845	410
g Feed Ash	0.16789	0.36673	0.379106	0.38575	0.39312	0.37947	0.4044949	2.3124394	2.33171	2.3308265	2.2181
g Feed HI	55.4604	54.6468	56.48096	57.63	58.5792	56.5452	60.257816	57.892647	58.4436	58.151382	55.596
g Feed MCRT	71.1251	70.0817	72.44674	73.9075	75.1248	72.5163	77.277282	73.987842	74.9509	74.578146	71.299
g Feed 177C+	409	403	416.6	425	432	417	444.3777	425.462	431	428.845	410
g Feed 343C+	406.11932	400.16158	413.8858	422.00863	428.95733	414.06298	441.24785	422.48538	427.96437	425.82455	407.11228
g Feed 371C+	404.61147	398.67585	412.12982	420.43979	427.36488	412.52583	439.60957	420.89684	426.37541	424.24354	405.60074
g Feed 510C+	336.0629	331.15259	342.32797	349.2304	354.98243	342.85665	365.15342	349.61004	354.18071	352.38991	336.90462
g Feed C	341.824	336.908	348.2776	355.3	361.152	348.812	371.48976	365.88623	360.316	358.51442	342.76
g Feed H	40.023681	42.887421	43.267375	44.541937	44.313253	42.389727	68.627481	48.251291	52.488889	50.528888	47.118377
g Feed S	19.5093	19.2231	19.87182	20.2725	20.8064	19.8909	21.198816	20.294537	20.5587	20.455907	19.557
g Feed N	2.4131	2.3777	2.45794	2.5075	2.5488	2.4803	2.8218284	2.5102258	2.5429	2.5301855	2.419
g Feed V	0.066657	0.065689	0.0679056	0.089275	0.070416	0.067971	0.0724336	0.0893503	0.070253	0.0899017	0.06683
g Feed Mo	0	0.2015	0.2083	0.2125	0.218	0.2085	0.2223	2.138	2.155	2.155	2.05
g Feed Fe	0.013906	0.013702	0.0141644	0.01445	0.014688	0.014178	0.0151088	0.0144857	0.014854	0.0145807	0.01394
g Feed Ni	0.033538	0.033046	0.0341812	0.03485	0.035424	0.034184	0.036439	0.0348879	0.033342	0.0351853	0.03362
g Gas H2 in product/N2	21.514207	8.7381815	14.538988	13.964298	16.437581	24.478956	2.2188657	6.7783329	16.304489	13.55865	24.039921
g Gas C1	6.2746042	4.4115893	3.9106412	3.8094189	3.8327098	3.4650278	17.892477	8.5834806	4.3236412	6.9585167	3.5611357
g Gas C2	4.0958843	2.8991594	2.2379585	2.2809242	2.4746759	2.0010442	15.702245	4.9736537	2.7854818	4.4844874	1.8755792
g Gas C3	4.2949112	2.4419273	2.0493095	1.9750141	2.0705505	1.9977783	15.548443	4.0337415	2.5981812	5.3352806	2.0885166
g Gas C4	5.5608915	0.4896541	0.6753565	0.7790254	2.8282086	0.7288337	9.8521825	0.505178	2.2029749	1.7383107	1.0140383
g Gas C5	0.7929251	0	0	0	0	0	0	0	0	0	0
g Gas C6	1.5783404	0	0	0	0.3338559	0	7.3035395	0	0.3618875	0	0
g Gas C2+, C3+, C4+	0	0	0	0.4404469	0	0	0	0	5.2627976	0	0
g Gas CO, CO2	0	0	0	0	0	0	0	0	0	0	0
g Gas H2O (net)	0	0	0	0	0	0	0	0	0	0	0
g Gas H2S	7.6005134	9.2732332	12.054706	11.138127	11.789544	12.533688	16.992436	17.71023	19.302006	18.725106	15.185368
g Gas NH3	1.1931765	1.3735568	1.3789553	1.0025638	1.2540954	1.3408128	1.738209	1.744752	1.8344183	1.8573543	2.0018204
g Gas C	18.04075	8.0123531	8.9427034	7.3110554	9.3051846	8.4223488	52.853207	14.101559	14.203704	14.578647	6.7037534
g Gas H	5.2201003	3.0248204	2.8913397	2.8232524	3.3565971	2.7527748	14.784862	8.358083	4.8032844	5.3817734	3.0934447
g Gas S, by S Bal	7.1492189	8.722618	11.338935	10.47678	11.070706	11.789486	15.983479	16.858652	18.155916	17.613268	14.293115
g Gas N, by N Bal	0.9813178	1.12967	1.13411	0.82455	1.03142	1.10274	1.4303975	1.4349563	1.5087	1.5275651	1.84638
g Prod Ash	0	0.56792	0.84108	0.816	0.86332	0.54831	0.5208	2.83131	3.49888	3.4037	2.2236
g Prod HI	30.25847	29.43123	17.58198	22.7407	20.10128	15.8893	9.8561	28.84358	8.91232	9.28145	4.34444
g Prod MCRT, incl. TIC	93.75822	54.14674	84.29993	44.50015	45.4119	85.10508	46.89635	28.47131	34.4576	45.240155	23.2308
g Prod 177C+	281.17705	249.42834	285.30128	285.05009	270.8625	243.21072	351.10333	292.28863	288.90062	319.83091	286.78948
g Prod 343C+	156.801	151.42838	186.94568	171.27891	188.4826	154.80285	206.87	145.18189	156.85842	167.79344	167.15524
g Prod 371C+	128.83359	127.30849	141.33318	147.58897	142.80807	133.55073	175.53898	119.08276	130.21628	138.78966	141.83037
g Prod 510C+	83.660791	101.18735	110.03676	114.8964	123.88787	136.7248	43.023207	35.802422	102.32276	35.008281	102.43217
g Prod C (exc gas)	352.75493	317.46814	332.58786	345.9349	386.8019	356.7114	83.85831	46.2329	346.0428	36.82066	341.10816
g Prod H (exc gas)	48.45389	33.19262	37.34993	42.88555	50.24703	44.23303	6.18518	3.25208	48.28592	3.08121	46.84414
g Prod S (exc gas)	12.380081	10.500482	8.5328847	9.7957201	8.5358942	8.1014138	5.2133375	3.8358853	2.4027843	2.8426384	5.2638852
g Prod N (exc gas)	1.4317822	1.24803	1.32383	1.68295	1.51738	1.35756	1.1914309	1.0752895	1.0342	1.0028204	0.77262
g Prod V	0.0480643	0.06014	0.06896	0.1339675	0.08384	0.0609	0.0685818	0.0580089	0.05888	0.0627241	0.02958
g Prod Mo	0.0588401	0.2356	0.23901	0.257992	0.24276	0.2205	0.29802	1.8925231	2.0424	1.9084205	1.2648
g Prod Ni	0.0263577	0.03534	0.03751	0.0336	0	0.03318	0.0521331	0.0428052	4.232	0.0699329	0
g Prod Fe	0.0601185	0.0248	0.031	0.1580515	0	0.01889	0.1006067	0.0567467	0	0.0830963	0

TABLE A-5 (Continued)
Material Balance Data

RUN#	12	22	23	24
Notebook# 5758-	41	81	83	87
g Feed	424	454.7807	400.0302	422.9175
g Feed Ash	2.29384	2.4257519	2.1338124	2.2983862
g Feed HI	57.4944	61.885551	54.244095	57.347813
g Feed MCRT	73.7336	79.062886	69.565252	73.545353
g Feed 177C+	424	454.7807	400.0302	422.9175
g Feed 343C+	421.01368	451.55772	397.2127	419.8388
g Feed 371C+	418.45052	449.88116	385.73782	418.37964
g Feed 510C+	348.40868	373.88532	328.71225	347.51917
g Feed C	354.464	380.17895	334.42525	353.58803
g Feed H	49.191709	52.965785	39.347081	51.038882
g Feed S	20.2248	21.892085	19.081441	20.173185
g Feed N	2.5016	2.6830881	2.3801782	2.4852133
g Feed V	0.089112	0.074126	0.0852049	0.0889356
g Feed Mo	2.12	2.2383	1.9898	2.125
g Feed Fe	0.014416	0.0154619	0.013801	0.0143782
g Feed Ni	0.034768	0.0372904	0.0328025	0.0346782
g Gas H2 in product/N2	23.955025	17.54585	22.406357	18.758845
g Gas C1	3.6138783	3.7184182	5.4786793	4.5451575
g Gas C2	2.250625	2.7467728	3.8888909	2.8627355
g Gas C3	2.4363888	2.8443792	4.3185893	2.7801548
g Gas C4	0.9794017	0.8891883	1.9505862	0.578877
g Gas C5	0	0	0	0
g Gas C6	0	0	0.3782291	0
g Gas C2+,C3+,C4+	0	0	0	0
g Gas CO,CO2	0	0	0	0
g Gas H2O (net)	0	0	0	0
g Gas H2S	17.170334	18.467548	17.800823	18.458914
g Gas NH3	2.0340901	2.0540526	2.1000752	2.0767374
g Gas C	7.297964	7.9308981	12.502994	8.2718006
g Gas H	3.363257	3.8095389	4.7510907	3.7582019
g Gas S, by S Bal	16.150814	17.371004	16.743867	17.363823
g Gas N, by N Bal	1.67292	1.8893379	1.7271889	1.7078949
g Prod Ash	3.30252	3.859	3.24883	3.32925
g Prod HI	4.65268	8.82884	3.70314	3.95283
g Prod MCRT, incl. TI C	20.0955	40.45374	43.89639	49.81084
g Prod 177C+	321.95015	272.26895	297.77567	332.86226
g Prod 343C+	222.00285	190.75389	182.27838	188.31885
g Prod 371C+	193.76804	186.23908	133.83425	157.2182
g Prod 510C+	73.108902	95.84439	20.788648	29.745465
g Prod C (exc gas)	342.1387	322.74262	293.87157	331.0391
g Prod H (exc gas)	49.51108	42.87026	37.88659	42.33839
g Prod S (exc gas)	4.0738858	4.3210815	2.337874	2.8063417
g Prod N (exc gas)	0.82868	0.9937502	0.6329893	0.7872184
g Prod V	0.054276	0.0867	0.05293	0.07176
g Prod Mo	2.0371368	2.89	1.4472	1.9458
g Prod Ni	0.04015	0.113	0.03618	0.05382
g Prod Fe	0.048726	0.0858	0.02211	0.05037

TABLE A-6
Yield and Conversion Data

RUN#	14	7	6	8	10	9	25	27	13	26	11
Notebooks 5758-	51	29	27	31	37	33	89	103	45	101	39
Weight Recovery, %	111.15629	89.554682	101.28032	89.895789	106.25658	101.49286	107.16108	97.482191	102.00365	100.1242	102.10654
Ash Balance, %	0	154.86052	189.1031	159.27802	168.73219	144.49364	128.75318	122.43823	150.09071	146.02975	100.24796
C Balance, %	108.44389	86.606122	97.488487	89.421884	113.22296	104.16559	31.443497	16.962832	89.980712	14.280404	101.47418
H Balance, %	134.10558	84.823015	83.006033	102.17089	120.96523	110.84243	30.487752	17.840275	101.18611	16.749485	105.96324
S Balance, %	100	100	100	100	100	100	100	100	100	100	100
N Balance, %	100	100	100	100	100	100	100	100	100	100	100
V Balance, %	72.09609	81.552619	86.607188	183.38506	90.861213	89.897034	84.882348	83.646208	83.811367	89.731821	44.261559
Mo Balance, %	NA	116.82308	114.74316	121.408	112.38889	105.7554	128.66367	88.518386	84.774842	88.8042	61.697561
Ni Balance, %	78.590584	106.94184	109.80293	86.413189	0	87.034567	143.08963	122.12033	11974.421	198.88911	0
Fe Balance, %	432.32777	180.99548	218.85855	1100.7024	0	131.82385	865.8787	382.28429	0	638.48861	0
Conversions, wt%											
Heptane Ins.	50.917132	45.901803	89.304871	80.499006	67.705805	72.348001	85.04616	52.625261	85.050106	84.058957	82.347062
MCRT	-18.59119	22.382088	25.995971	39.726587	43.110706	25.127816	43.366778	80.52503	54.929491	39.412211	68.090598
510C+	77.605493	89.30721	68.262674	67.085795	67.155237	80.885512	89.005125	89.563511	71.675899	80.077515	70.223931
371C+	71.354469	67.92433	86.140158	84.880384	68.551617	88.102267	62.738153	70.981486	70.059612	67.325912	65.802403
Desulfurization	45.605638	45.814228	57.445559	52.323728	56.422176	59.780102	75.084458	74.241643	76.971596	78.74062	74.303842
Denitrification	54.269972	44.488076	49.86562	31.874973	47.025176	46.457968	58.055851	86.583813	58.1703	61.84124	68.719808
% V removal	82.451588	100	100	-2.0389751	100	100	86.672163	89.842971	100	89.851077	100
% Ni removal	87.764595	100	100	100	100	100	87.548053	89.58381	100	89.308262	100
Charge Dist., wt%											
H2	-0.5142589	0.2948936	0.0658319	0.1804557	-0.0423026	-0.1345978	5.1435048	1.0409167	1.6732921	1.4820863	1.1922871
177C-	0	0	0	0	0	0	0	0	0	0	0
177-343C	0.7043216	0.7043216	0.7043216	0.7043216	0.7043216	0.7043216	0.7043216	0.7043216	0.7043216	0.7043216	0.7043216
343-510C	17.123819	17.123819	17.123819	17.123819	17.123819	17.123819	17.123819	17.123819	17.123819	17.123819	17.123819
510C+	82.171859	82.171859	82.171859	82.171859	82.171859	82.171859	82.171859	82.171859	82.171859	82.171859	82.171859
Total	99.485741	100.29489	100.06583	100.18046	99.957697	99.865402	105.1435	101.04092	101.87329	101.48209	101.19229
Product Yield, wt%											
COx	0	0	0	0	0	0	0	0	0	0	0
H2O	0	0	0	0	0	0	0	0	0	0	0
H2S	1.8583162	2.3010504	2.8935923	2.6207357	2.7244315	3.0056829	3.8238723	4.1625878	4.4784241	4.3664041	3.7061872
NH3	0.2917302	0.3408329	0.3310022	0.2358974	0.2902999	0.3215378	0.3913808	0.4100841	0.4256186	0.4331062	0.4882489
C1-C4	4.9453035	2.5415161	2.1299245	2.1870187	2.6403113	1.9646719	13.278174	4.2532738	3.9844725	4.3177781	2.0827487
C5-177C	14.13834	8.5510312	8.6555488	7.0502152	10.844887	7.5278821	15.278841	16.830154	8.2620103	16.058203	9.7306152
177-343C	30.409794	24.317112	23.609122	22.063807	23.857385	21.248891	32.457374	34.575835	26.042737	35.452778	24.296156
343-510C	35.258828	35.189512	36.641533	37.616237	36.881533	34.047207	36.871086	25.750635	33.845863	30.863211	36.79465
510C+	20.454961	25.108524	26.413047	27.034447	28.677749	32.787721	9.6816755	8.3678439	23.740779	8.1636185	24.983457
losses	-7.8715319	1.8353155	-0.5879383	1.3720861	-8.9589082	-1.0380014	-8.8378787	6.5904028	0.0833876	1.725989	-0.8897758
Total	99.485741	100.29489	100.06583	100.18046	99.957697	99.865402	105.1435	101.04092	101.87329	101.48209	101.19229
Non Dist Conv	77.605493	89.30721	68.262674	67.085795	67.155237	80.885512	89.005125	89.563511	71.675899	80.077515	70.223931

TABLE A-6 (Continued)
Yield and Conversion Data

RUN#	12	22	23	24
Notebook# 5758-	41	81	83	87
Weight Recovery, %	100.99297	88.898577	100.26389	96.967234
Ash Balance, %	143.87342	158.0847	152.25472	144.85101
C Balance, %	98.581708	86.978107	91.612271	95.970085
H Balance, %	107.48628	87.752712	108.36848	90.320183
S Balance, %	100	100	100	100
N Balance, %	100	100	100	100
V Balance, %	78.533385	133.15167	81.174853	104.08723
Mo Balance, %	86.081358	120.12883	73.489388	81.567059
Ni Balance, %	115.47975	303.02724	110.29655	155.19373
Fe Balance, %	337.89945	619.58895	162.56128	350.29777
Conversions, wt%				
Heptane Ins.	91.98716	83.858482	93.19116	92.891867
MCRT	73.013789	42.32873	37.351793	30.434112
S10C+	79.223219	71.083615	83.892983	91.172922
S71C+	54.258514	58.340083	86.270099	61.246579
Desulfurization	79.733302	75.156455	88.213338	85.085617
Denitrification	68.819878	59.014236	73.344359	64.955783
% V removal	97.517074	100	100	100
% Ni removal	100	100	100	100
Charge Dist., wt%				
H2	1.3018181	1.3471794	-0.4639773	1.7678056
177C-	0	0	0	0
177-343C	0.7043216	0.7043216	0.7043216	0.7043216
343-510C	17.123819	17.123819	17.123819	17.123819
S10C+	82.171859	82.171859	82.171859	82.171859
Total	101.30182	101.34718	99.538023	101.76781
Product Yield, wt%				
COx	0	0	0	0
H2O	0	0	0	0
H2S	4.0496072	4.0609377	4.4498698	4.3648973
NH3	0.4797382	0.4516777	0.5249792	0.4910502
C1-C4	2.1887481	2.2162725	3.8616499	2.4981054
C5-177C	8.5174185	6.8010848	14.84902	11.47688
177-343C	23.572477	17.924889	33.671765	34.178159
343-510C	44.535837	35.363941	35.370262	37.484838
S10C+	17.242194	21.075785	5.1982698	7.0333965
losses	0.7158001	13.852632	1.4122078	4.2306792
Total	101.30182	101.34718	99.538023	101.76781
Non Dist Conv	79.223219	71.083615	83.892983	91.172922

TABLE A-7
Resid Product Properties

RUN#	14	7	6	8	10	9	25	27	13	26	11
Notebook# 5758-	51	29	27	31	37	33	99	103	45	101	39
Total Resid Product											
g TRP	102.7	144.5	163.1	188.5	189.5	192.7	68.7	36.3	146	34.7	149.8
API	1.8	3.9	7	8	7.9	9.6	3	-10.7	12.2	-2.4	16.1
wt% C	84.49	86.36	83.28	86.7	82.9	84	89.07	89.83	87.84	89.8	87.67
wt% H	9.67	7.24	6.75	10.03	9.73	10.2	8.66	8.46	9.98	7.66	11.11
wt% S	4.18	2.94	2.31	2.86	2.43	1.99	1.59	1.84	1.22	1.06	0.83
wt% N	0.7786	0.59	0.55	0.67	0.54	0.48	0.6909	0.9044	0.43	0.6576	0.24
wt% O		0	0	0	0	0					
wt% Ash		0	0	0	0	0					
wt% TI	1.86	1.63	1.06	0.76	1.06	0.41	0.54	0.378	0.052	0.027	0.026
wt% HI	16.61	16.47	9.26	9.42	9.48	7.43	8.7	28.03	2.2	7.45	0.96
wt% MCRT	32.26	22.7	18.25	17.55	18.5	15.64	24.045	40.7	10.82	25.885	7.35
wt ppm V	49	0	0	375	0	0	14	3		3	
wt ppm Mo	3	0	0	112	0	0	0	67		15	
wt ppm Fe	25	0	0	719	0	0	3.3	33		529	
wt ppm Ni	7.3	0	0	0	0	0	13	4		7	
wt ppm P							5.7				
TLP D1160, vol%											
wt% Botts	69.2	63.4	58.7	54.9	60.1	64.4	0	0	62.7	0	57.5
g D1160 Botts	71.0684	91.613	95.7397	103.4865	113.8895	124.0988	0	0	91.542	0	86.135
Botts API	-11.1	-7.3	-3.5	3.4	2.6	0.2			8.5		11.7
wt% OH	30.8	36.6	41.3	45.1	39.9	35.6	100	100	37.3	100	42.5
g D1160 OH	31.6316	32.887	37.3603	41.0135	35.6105	31.6012	68.7	36.3	64.458	34.7	63.665
OH API	8.1	14	16.3	16.3	16.4	17.2	--		18.2		18.9
OH GLC, wt%		0	0	0	0	0					
IBP, Deg C	268	243	229	246	236	219	190	284	240	273	260
5%	343	322	326	318	317	307	254	368	304	363	326
10%	370	351	358	348	347	340	343	403	333	400	358
20%	400	383	391	381	379	378	401	455	365	448	385
30%	413	403	411	402	401	401	438	489	387	488	416
40%	429	416	428	414	412	417	467	545	402	528	435
50%	443	429	443	431	427	432	491	599	415	577	452
60%	456	442	459	444	441	445	516	699	429	661	467
70%	470	456	473	459	455	459	543		443		482
80%	486	472	488	476	470	474	574		459		497
90%	508	491	511	499	490	495	615		480		517
95%	526	510	528	517	505	513	645		497		533
99%	561	550	560	544	536	543	691		533		567
wt% 177C-	0	0	0	0	0	0	0	0	0	0	0
wt% 343C-	1	8.2413793	6.3125	9.3333333	9.6666667	11.908091	10	3.8095238	14.448276	4.1111111	6.3125
wt% 371C-	10.333333	16.25	13.936394	16.969697	17.5	18.157895	14.827586	8.4285714	21.875	6.0610611	13.513514
wt% 510C-	90.66	95	89.66	96.5	96.1	94.25	57.6	32.391304	87.2	35.5	86.9
Tol. Ins. Prod.											
g TIP	13.2	6.2	3.1	5.6	2.8	2.1	4.2	19.3	9.2	10.1	5.1
wt% C	89.6	76.02	66.78	76.4	67.3	60.8	65.91	70.97	42.7	54.06	39.5
wt% H	4.4	3.36	4.28	9.5	3.81	3.03	4.81	4.7	2.31	4.19	1.36
wt% S	5.75	7.62	10.78	6.74	11.3	14.8	9.2		15.12	16.3	20.6
wt% N	0.63	0.79	0.18	0	0.36	0	0.2273	0.3371	0.1126	0.2652	
wt% Ash		9.16	20.68	11	23.89	26.11	12.4	14.67	36.04	33.7	43.6
wt% V	0.326	0.97	2.16	1.13	2.28	2.9	1.81	0.3	0.64	0.82	0.58
wt% Mo	0.451	3.8	7.71	4.23	8.67	10.5	6.81	9.79	22.2	18.9	24.8
wt% Fe	0.436	0.4	1	0.42	0	0.89	2.39	0.28		0.74	
wt% Ni	0.194	0.57	1.21	0.6	0	1.58	1.22	0.22	46	0.69	
wt% P							0.35				

TABLE A-7 (Continued)
Resid Product Properties

RUN#	12	22	23	24
Notebook# 5758-	41	91	93	97
Total Resid Product				
g TRP	156	171.2	22.7	38.4
API	16.7	13.3	6.6	10.1
wt% C	86.45	85.91	86.58	86.7
wt% H	11.43	10.23	8.37	9.82
wt% S	0.73	1.02	0.22	0.51
wt% N	0.26	0.3556	0.3066	0.3126
wt% O	0			
wt% Ash	0			
wt% Ti	0.061	0.011		0.022
wt% HI	0.42	1.57	1.11	0.995
wt% MCRT	7	10.27	16.37	13.285
wt ppm V	11		1.9	8.1
wt ppm Mo	2.8		5.8	3.3
wt ppm Fe	3.5		4	2.8
wt ppm Ni	0		3.9	2.4
wt ppm P			29	10
TLP D1160, vol%				
wt% Botts	25.6	36.5	0	0
g D1160 Btms	36.936	65.912	0	0
Btms API	4.2	2.6		
wt% OH	74.4	61.5	100	100
g D1160 OH	116.064	105.288	22.7	38.4
OH API	18.8	17.7		
OH GLC, wt%				
IBP, Deg C	264	271.5	310	292
5%	331	333	368	346
10%	364	365	369	379
20%	401	400.5	417	414
30%	424	425	450	444
40%	445	445	476	470
50%	463	463	500	483
60%	479	479.5	522	516
70%	495	495.5	545	541
80%	511	512	573	570
90%	531	534	612	611
95%	547	551	643	645
99%	578	581	692	705
wt% 177C-	0	0	0	0
wt% 343C-	4.6363636	4.125	3.2758621	4.7777778
wt% 371C-	11.891892	11.690141	5.483871	8.7878788
wt% 510C-	79.6	78.787879	64.545455	57.391304
Tol. Ins. Prod.				
g TIP	7.3	10	6.7	6.9
wt% C	39.5	38.61	48.2	38.6
wt% H	1.36	2.39	3.7	3.19
wt% S	20.2	17	18.11	20.73
wt% N	0.16	0.4041	0.1676	0.284
wt% Ash	45.24	38.59	48.49	48.25
wt% V	0.72	0.987	0.79	1.04
wt% Mo	27.9	26.9	21.6	26.2
wt% Fe	0.66	0.958	0.33	0.73
wt% Ni	0.55	1.13	0.54	0.78
wt% P		0.679	0.62	0.69

APPENDIX B

Figures for Autoclave Run Data

FIGURE B-1
Distribution of Products

FIGURE B-2
Conversion of Heptane Insolubles

FIGURE B-3
Conversion of Non-Distillable

FIGURE B-4
Feed Desulfurization Results

FIGURE B-5
Gas Yield Data

FIGURE B-6
Coke Yield Data

FIGURE B-7
Carbon on Catalysts

FIGURE B-8
API of Resid Products

FIGURE B-9
Heptane Insolubles in Resid Product

FIGURE B-10
Sulfur Content of Resid Product

FIGURE B-11
Effect of Pressure on C₇ Insoluble Conversion

FIGURE B-12
Effect of Pressure on Feed Desulfurization

FIGURE B-13
Effect of Pressure on Non-Distillable Conversion

FIGURE B-14
Effect of Pressure on Resid Product Properties
(0.05 wt-% Mo, 420°C, 2 hr)

FIGURE B-15
Effect of Temperature on Resid Product Properties
(0.05 wt-% Mo, 3000 psig, 2 hr)

FIGURE B-16
Effect of Pressure on Resid Product Properties
(0.5 wt-% Mo, 420°C, 2 hr)

FIGURE B-17
Effect of Pressure on Resid Product Properties
(0.5 wt-% Mo, 440°C, 2 hr)

FIGURE B-18
Effect of Temperature on Resid Product Properties
(0.5 wt-% Mo, 2000 psig, 2 hr)

FIGURE B-19
Effect of Temperature on Resid Product Properties
(0.5 wt-% Mo, 3000 psig, 2 hr)

FIGURE B-20
Effect of Catalyst Concentration on Conversion
(420°C, 3000 psig, 2 hr)

FIGURE B-21
Effect of Catalyst Concentration on Resid Properties
(420°C, 3000 psig, 2 hr)

FIGURE B-22
Effect of Catalyst Concentration on Conversion
(440°C, 3000 psig, 2 hr)

FIGURE B-23
Effect of Catalyst Concentration on Resid Properties
(440°C, 3000 psig, 2 hr)

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