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# UPGRADING OF COAL LIQUIDS

INTERIM REPORT

## HYDROTREATING AND FLUID CATALYTIC CRACKING OF H-COAL PROCESS DERIVED GAS OILS

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ABSTRACT

The objective of this work was to evaluate the applicability of commercial UOP hydrotreating and fluid catalytic cracking (FCC) processes to distillate liquids derived from the H-Coal process. All feedstocks for these studies were derived from the atmospheric still bottoms generated from the H-Coal syncrude operation.

The raw H-Coal atmospheric still bottoms were rerun in a laboratory column to remove heavy ends generated during storage. This operation also substantially reduced the contents of heptane insolubles, Conradson carbon, and steam jet gum.

The rerun H-Coal atmospheric still bottoms (H-Coal gas oil) was used to evaluate the relative hydrogenation activity of three UOP commercial catalysts. The UOP-DCB catalyst, which was found to have the highest hydrogenation activity, was employed in the H-Coal gas oil hydrotreating process variable studies. At base pressure, studies were conducted at five temperatures and three space velocities, while at 500 psig above base pressure studies were carried out at three temperatures and three space velocities. Two hydrotreating preparative runs were carried out to prepare two FCC feedstocks with two levels of hydrogen content.

Fluid catalytic cracking of H-Coal derived distillate liquids was carried out over a commercial zeolite catalyst. Three distinct feedstocks were studied. One was a rerun H-Coal atmospheric still bottoms (H-Coal gas oil). The second was a moderately hydrotreated gas oil. The third was the 195°C$^+$ fraction of a severely hydrotreated gas oil. The hydrogen contents of these three feeds were 9.14, 10.68, and 12.88 wt-%, respectively.

Two sets of processing conditions were employed to catalytically crack each of these feedstocks. Results show that feed hydrogen content is a dominant factor on conversion and yield structure. Hydrotreating substantially improved the cracking characteristics of the H-Coal gas oil. As more hydrogen was added, the feed showed higher conversion and increased gasoline yield with reduced carbon deposition. In the range of conditions investigated, high octane gasolines were obtained. Cycle oils containing 650°F$^-$ distillate as high as 93 vol-% were generated. The lighter portions of the cycle oil, boiling between 400-650°F, are valuable components of distillate fuels and heating oils.

Based on data obtained, it is concluded that with an appropriate degree of hydrotreatment the H-Coal process derived gas oil, or any other coal derived distillate of similar quality, can be readily processed into high quality gasolines by applying advanced commercial fluid catalytic cracking technology. The FCC cracker, in conjunction with a hydrotreater, shows potential in playing a major role in future commercial refining operations of coal derived liquids.

## 1. INTRODUCTION

The object of this program was to determine the applicability of commercial UOP conversion processes to coal distillate liquids generated by two DOE sponsored processes:H-Coal and Exxon Donor Solvent (EDS).

Four tasks were identified under this program. Each of these tasks covers coal liquids from both the H-Coal process and the EDS process. The first task involves two stage continuous hydrocracking of coal distillate liquids. The second task entails processing of distillates through continuous hydrotreating and fluid catalytic cracking units. The third task covers processing of coal derived naphthas through continuous hydrotreating-reforming bench scale units. The fourth task involves all data correlation.

This report covers work under Task 2 on hydrotreating and fluid catalytic cracking of H-Coal process derived distillate liquids. Investigation was carried out on three distinct gas oils. One was a rerun H-Coal atmospheric still bottoms (H-Coal gas oil). The other two were hydrotreated H-Coal gas oils.

Hydrotreating and fluid catalytic cracking of EDS process derived distillate liquids will be covered in a separate report.

For reporting purposes, the experimental conditions employed in this work were expressed in terms of base conditions:

| | |
|---|---|
| Temperature | T-T (base), °C |
| Pressure | P-P (base), psig |
| Space Velocity | LHSV/LHSV (base) |
| Catalyst/Oil Weight Ratio | $\frac{\text{Catalyst/Oil}}{\text{Catalyst/Oil (base)}}$ |

The base conditions for hydrotreating represent conditions employed commercially for hydrotreating a typical Arabian vacuum gas oil. Similarly the base conditions for fluid catalytic cracking referred to those conditions used commercially for a typical Arabian gas oil.

## 2. EQUIPMENT

Hydrotreating of H-Coal gas oils was carried out in bench scale continuous units (UOP Research Plants 532, 601, and 638H). A simplified flow diagram of a bench scale gas oil hydrotreating plant is shown in Figure 1. Hydrogen and gas oil feed were passed concurrently downflow over a fixed bed of commercial hydrotreating catalyst. The catalyst was a composite of Group VI and Group VIII metals on a high surface area refractory support.

Fluid catalytic cracking of H-Coal derived distillate liquids (gas oils) was conducted in UOP Research Plant 593, a once-through Quick Quench (all riser) unit. Figure 2 is a flow diagram of this small scale fluid catalytic cracker. An equilibrium zeolite catalyst withdrawn from a commercial FCC unit was used in this work.

## 3. CHARGE STOCKS

### 3.1. Gas Oil Hydrotreating

A two-drum shipment of H-Coal atmospheric still bottoms was received at Des Plaines on March 31, 1977. The total contents were found to be 90 gallons. These were assigned for work under Task 2. Inspections of these two samples (No. 37-1117 and No. 37-1118) are shown in Table 1. These charge stocks were rerun (Tables 2 and 3) in a laboratory vacuum flash unit to remove heavy ends generated during storage and to reduce heptane insolubles to $\leq$0.1 wt-%. Conradson carbon and steam jet gum were also sharply reduced. Inspections of the distillates (Gas Oils 3531-10 and 3531-11) are given in Table 1. H-Coal Gas Oil 3531-10 was used in the preliminary catalyst activity evaluation studies and H-Coal Gas Oil 3531-11 was employed in hydrotreating process variable studies, as well as in the preparation of two hydrotreated gas oils.

### 3.2. Fluid Catalytic Cracking

Fluid catalytic cracking studies were carried out on a rerun H-Coal atmospheric still bottoms and two hydrotreated gas oils.

The rerun H-Coal atmospheric still bottoms (H-Coal Gas Oil 3531-11) was the same charge stock employed in hydrotreating process variable studies. Inspections of this feed are shown in Table 1.

The hydrotreated gas oils were prepared from hydrotreating H-Coal Gas Oil 3531-11. The first hydrotreated gas oil (designated as Hydrotreated H-Coal Gas Oil 3531-25) was produced by moderate hydrotreatment, while the second hydrotreated gas oil (designated as Hydrotreated H-Coal Gas Oil 3531-27) was the 195°C$^+$ fraction of a severely hydrotreated H-Coal gas oil (designated as Hydrotreated H-Coal Liquid Product 3531-26). Inspections of these two FCC feedstocks are given in Tables 4 and 5. Figure 3 shows the steps involved in preparing these two hydrotreated gas oils as well as H-Coal Gas Oil 3531-11.

## 4. RESULTS AND DISCUSSION

### 4.1. Gas Oil Hydrotreating

The primary objective in the hydrotreating of H-Coal gas oils was to improve the cracking characteristics of the gas oils by saturating aromatic rings and reducing nitrogen content. Hydrogenation of FCC feeds serves to improve conversion, increase gasoline yield, and reduce coking tendencies.

### 4.1.1. Selection of a Highly Active Hydrogenation Catalyst

Rerun H-Coal Atmospheric Still Bottoms 3531-10 (H-Coal Gas Oil 3531-10, Table 1) was used in evaluating the relative hydrogenation activity of three commercial UOP catalysts. The object was the selection of a catalyst for preparing feeds for FCC studies. The catalyst was to be selected on the basis of its ability to saturate aromatic rings, rather than for highest nitrogen conversion activity.

One separate run was made for each of the three UOP catalysts: DCA, DCB, and DSA (for information on these catalysts, see Table 13, FE-2566-07). Hydrotreating studies were carried out in Plant 532 at 0.5 X base space velocity, base pressure, and base temperature. Data obtained are summarized in Tables 6, 7, and 8. While the UOP-DCA catalyst was as effective in reducing the nitrogen content as the UOP-DCB catalyst, the latter exhibited higher hydrogenation activity. The average hydrogen contents of the hydrotreated liquid products obtained from testing these three catalysts are:

| Catalyst | Average Product Hydrogen Content, Wt-% |
|---|---|
| UOP-DCB | 12.12 |
| UOP-DCA | 11.62 |
| UOP-DSA | 10.94 |

The UOP-DCB catalyst was the best for raising the hydrogen content of the H-Coal gas oil. This catalyst was therefore selected for a series of hydrotreating process variable studies and for preparing FCC feedstocks.

### 4.1.2. Hydrotreating Process Variable Studies

The primary objective of these studies was to investigate the effects of process variables and to arrive at two sets of optimum conditions for preparing two different feedstocks for FCC studies. Studies were carried out over a UOP-DCB catalyst in Plant 601. Inspections of the charge stock (H-Coal Gas Oil 3531-11) are given in Table 1.

In Run 758, studies were conducted at base pressure, five temperatures, and three space velocities. A log of this hydrotreating operation is given in Table 9. At base temperature the effect of space velocity on product hydrogen content was as follows:

| Period No. | LHSV / LHSV (base) | Product Hydrogen Content, Wt-% |
|---|---|---|
| 7 | 1.2 | 11.18 |
| 4 | 0.8 | 11.35 |
| 1 | 0.4 | 12.57 |

Figure 4 is a plot of temperature versus product hydrogen content.

The run was terminated after 522 hours on stream. Near the end of the run final catalyst activity check tests were made at conditions similar to those of Periods 1, 2, and 3. Data show a small decline in hydrogenation activity during 482 hours of hydrotreating studies:

| Period No. | Hours on Stream | Product Hydrogen Content, Wt-% |
|---|---|---|
| 1 | 30-40 | 12.57 |
| 44 | 512-522 | 11.85 |

Selected products at each set of conditions were analyzed and product distribution data were then obtained. Results have been summarized and listed in Tables 10 to 14. These tables cover studies carried out at base pressure, five temperatures, and three space velocities. Each table shows the hydrotreating conditions, properties of the liquid products, product distribution, and hydrogen consumption values. Product totals over 100% represent hydrogen added to the feed. Each of these tables covers data obtained at one temperature and three space velocities, except Table 14 which also contains, on the last column, data from a catalyst activity check test conducted at the startup conditions.

In Run 759, experiments were carried out at 500 psig above base pressure, three temperatures, and three space velocities. Table 15 is a log of this operation. These data were also graphically illustrated in Figure 5. At base temperature, product hydrogen content varied with space velocity in the following manner:

| Period No. | $\frac{\text{LHSV}}{\text{LHSV (base)}}$ | Product Hydrogen Content, Wt-% |
|---|---|---|
| 12 | 1.2 | 11.75 |
| 14 | 0.8 | 12.30 |
| 17 | 0.4 | 13.01 |

A comparison of these data with the corresponding data obtained at base pressure shows that hydrogen uptake increased as the pressure was increased from base to 500 psig above base. The run was on stream for 356 hours. Near the completion of the run, catalyst activity check tests (Periods 30 and 31) made at the initial conditions (Periods 1, 2, and 3) showed that no significant catalyst deactivation occurred:

| Period No. | Hours on Stream | Average Product Hydrogen Content, Wt-% |
|---|---|---|
| 1-3 | 15-45 | 11.78 |
| 30-31 | 336-356 | 11.72 |

These results reveal that the stability of the system was greatly improved at higher pressure.

Results from analyses on selected products, as well as product distribution data obtained, are listed in Tables 16, 17, and 18. These tables cover experiments carried out at 500 psig above base pressure, three temperatures, and three space velocities. Each table contains data at approximately the same temperature, except Table 18 which also includes data from a catalyst activity check test.

Figure 6 is a plot of hydrogen uptake versus product aromatic content. This figure contains data obtained at both base pressure and 500 psig above base pressure.

4.1.3. Preparation of Hydrotreated H-Coal Gas Oils

Two hydrotreating preparative runs were carried out for the purpose of preparing two feedstocks for FCC studies. Inspections of the charge stock (H-Coal Gas Oil 3531-11) are given in Table 1.

Plant 601, Run 760. This run of 300 hours duration was made at a single set of conditions: 500 psig above base pressure, 39°C below base temperature, and 1.2 X base space velocity. The object was to prepare 12 gallons of hydrotreated H-Coal gas oil containing 10-11 wt-% hydrogen. At the given operating conditions, the catalyst showed reasonable stability:

| Hours on Stream | Product Hydrogen Content, Wt-% |
|---|---|
| 35 | 10.80 |
| 65 | 10.82 |
| 135 | 10.79 |
| 195 | 10.72 |
| 265 | 10.79 |
| 295 | 10.35 |

The daily analyses are logged in Table 19.

Table 20 is a summary of an overall material balance made for the run for the purpose of obtaining product distribution and hydrogen consumption data. Since moderate conditions were employed, only a relatively small amount (0.2 wt-%) of gas ($C_1$-$C_4$) was produced. The yield of liquid product was very high (100.4 wt-%).

Similarly, a hydrogen balance was made to obtain distribution of hydrogen consumed. Results are summarized in Table 21. The table shows that 8.0% of the hydrogen consumed was involved in denitrogenation, desulfurization, and deoxygenation. The bulk (90.5%) of the total hydrogen consumed effected an increase in hydrogen content from 9.14 to 10.68 wt-% (Tables 1 and 4). Evidently this amount (1.6 wt-% of feed) of hydrogen was involved mainly in saturating the aromatic rings.

The hydrotreated H-Coal gas oils from the run were blended to give 12 gallons of FCC charge stock. Inspections of this feed (Hydrotreated H-Coal Gas Oil 3531-25) are given in Table 4.

Plant 638H, Run 17. The second hydrotreating preparative run was carried out in Plant 658H which has a catalyst loading about three times that of Plant 601. The object was to process 10 gallons of H-Coal Gas Oil 3531-11 and obtain a high (12-13 wt-%) hydrogen-containing feedstock for FCC runs.

The run was on stream for 531 hours. The daily analyses are logged in Table 22. Table 23 shows the product distribution and hydrogen consumption data obtained from an overall material balance made for the run. Distribution of hydrogen consumed is presented in Table 24.

The hydrotreated products were blended. Table 25 gives the inspections of this liquid product (Hydrotreated H-Coal Liquid Product 3531-26). This stock was then fractionated (Table 26) to obtain a 195°C$^+$ fraction for FCC studies. Inspections of this feedstock (Hydrotreated H-Coal Gas Oil 3531-27) are shown in Table 5.

Table 27 shows the inspections of the 195°C$^-$ fraction of the hydrotreated liquid product. This naphtha which is high in hydrogen (14.36 wt-% H) and low in aromatics can be further processed into a high octane gasoline by reforming. Since it was highly naphthenic, reforming could be successfully carried out at high space velocity and relatively low temperature with high gasoline yields. The only primary reaction required in the reforming operation would be naphthene dehydrogenation.

Figure 3 is a summary of the basic steps involved and yield data obtained in the preparation of the two hydrotreated FCC feedstocks. The figure also shows the preparation (and yield data) of the first FCC feedstock by rerunning raw H-Coal Atmospheric Still Bottoms 37-1118 to obtain a 94.9 wt-% asphaltene-free overhead. In the figure the yield data and hydrogen additions were expressed as weight percent of raw H-Coal Atmospheric Still Bottoms 3531-11. As shown in Figure 3, the yields of Hydrotreated H-Coal Gas Oil 3531-25 and Hydrotreated H-Coal Gas Oil 3531-27 are 95.3 and 45.1 wt-%, respectively.

### 4.2. Fluid Catalytic Cracking of H-Coal Process Derived Gas Oils

Fluid catalytic cracking of H-Coal derived liquids was carried out in Plant 593, using an equilibrium zeolite catalyst withdrawn from a commercial FCC unit.

Plant 593 (Figure 2) is a once-through Quick Quench fluid catalytic cracking unit. It comprises a riser reactor, a catalyst regenerator-hopper system, a catalyst stripper-separator system, and a fractionator. The preheated fresh feed enters the unit at the mixing "Y" where it is mixed with the hot regenerated catalyst which flows down from the regenerator-hopper system through the catalyst transfer line. The catalyst and the vaporized feed travel rapidly through the riser reactor. The cracked oil vapors and the spent catalyst enter the stripper-separator system where the adsorbed hydrocarbons are stripped from the catalyst surface, and the oil vapors are separated from the catalyst. The stripped spent catalyst is charged into a catalyst receiver and samples are taken for carbon content. The hydrocarbon vapors from the separator are sent to the fractionator for separation into gas, gasoline, and cycle oil. The spent catalyst is manually reloaded into the regenerator-hopper system, and is batch regenerated prior to the start of the next test.

In the current program, multiple tests were made for each set of conditions to obtain four or more independent sets of experimental data, and to provide sufficient liquid product for fractionation and analyses of the fractions.

FCC studies were carried out on three distinct feedstocks. One was the rerun H-Coal Atmospheric Still Bottoms 3531-11 (H-Coal Gas Oil 3531-11). Another was a moderately hydrotreated gas oil (Hydrotreated H-Coal Gas Oil 3531-25). The final charge stock was the 195°C$^+$ fraction of a severely hydrotreated gas oil (Hydrotreated H-Coal Gas Oil 3531-27). The hydrogen contents for these three feedstocks are 9.14, 10.68, and 12.88 wt-%, respectively (Tables 1, 2, and 3).

Generally two sets of processing conditions were employed for each of the feeds. Four or more tests were carried out for each feed at each set of conditions. All tests were conducted at 10 psig below base pressure.

### 4.2.1. H-Coal Gas Oil 3531-11

H-Coal Gas Oil 3531-11 was prepared by rerunning H-Coal Atmospheric Still Bottoms 37-1118. The object was to improve the cracking characteristics of the liquid by the removal of heavy ends generated during storage. Heptane insolubles, Conradson carbon, and steam jet gum were substantially reduced by the operation. Inspections of this feedstock are given in Table 1.

Fluid catalytic cracking of H-Coal Gas Oil 3531-11 was conducted at two sets of conditions. Results are summarized in Tables 28 and 29. Each of these tables shows the cracking conditions, product distribution, inspections of the gasoline products, and properties of the cycle oils. The table also includes the Research octane number (RON) of the leaded and unleaded gasolines. The first table (Table 28) contains data from four separate tests conducted at (or near) base temperature and base catalyst/oil ratio. Similarly, data on the second table (Table 29) were obtained at a higher temperature and a higher catalyst/oil ratio.

Conversion was low and carbon deposition was somewhat high at near-base conditions. At more severe conditions, conversion and gasoline yield were higher, but carbon deposition was also increased:

| Experiment No. | 256A/2 | 256B/7 |
|---|---|---|
| T-T (base), °C | 3 | 31 |
| $\frac{\text{Catalyst/Oil}}{\text{Catalyst/Oil (base)}}$ | 0.9 | 1.3 |
| Conversion, Vol-% | 30.6 | 42.2 |
| $C_5^+$ Gasoline, Vol-% | 15.5 | 20.0 |
| Carbon, Wt-% | 11.1 | 13.4 |

Low conversions and high carbon yields were expected. Even though the cracking quality of the feed was improved by the removal of heavy ends and the reductions of heptane insolubles, Conradson carbon, and steam jet gum, the feed was still low in hydrogen, high in nitrogen, and extremely high in aromatics (Table 1).

### 4.2.2. Hydrotreated H-Coal Gas Oil 3531-25

Hydrotreated H-Coal Gas Oil 3531-25 was prepared by moderate hydrotreatment which resulted in raising the hydrogen content from 9.14 to 10.68 wt-% and reducing the nitrogen content from 4100 to 856 wt-ppm (Table 4). Concentration of aromatics was lowered from 90.2 to 73.0 vol-% by ring saturation.

At near-base conditions, this hydrotreated feed exhibited much higher conversions and gasoline yields with lower carbon deposition as compared to untreated stock. Data also show that there was essentially no improvement in conversion or yield pattern when more severe conditions were employed:

| Experiment No. | 255/3 | 258/2 |
|---|---|---|
| T-T (base), °C | 1 | 26 |
| Catalyst Oil / Catalyst/Oil (base) | 1.1 | 1.4 |
| Conversion, Vol-% | 62.9 | 63.2 |
| $C_5$+ Gasoline, Vol-% | 45.7 | 41.2 |
| Carbon, Wt-% | 8.9 | 8.8 |

Data obtained at two sets of cracking conditions are summarized in Tables 30 and 31.

### 4.2.3. Hydrotreated H-Coal Gas Oil 3531-27

Hydrotreated H-Coal Gas Oil 3531-27 was the 195°C$^+$ fraction of a severely hydrotreated H-Coal liquid product. As shown in Table 26, this represents 48.4 wt-% of the total product. Table 5 shows that this feedstock contained 12.88 wt-% H, 1.6 wt-ppm N, and 12.3 vol-% aromatics. The low aromatic content reflects the high degree of aromatic ring saturation achieved by severe hydrotreatment.

Six separate tests were conducted at each set of conditions. Data obtained at near-base conditions are presented in Table 32, while data from more severe conditions are given in Table 33.

High conversion and high gasoline yield with reduced carbon deposition were observed at near-base conditions. At more severe conditions, conversion was slightly higher with carbon yield practically unchanged. However, the yield of $C_4^-$ products was increased at the expense of gasoline yield:

| Experiment No. | 257/1 | 259/3 |
|---|---|---|
| T-T (base), °C | 10 | 31 |
| Catalyst/Oil / Catalyst/Oil (base) | 1.1 | 1.5 |
| Conversion, Vol-% | 82.9 | 85.5 |
| $C_5^+$ Gasoline, Vol-% | 62.2 | 56.5 |
| $C_4^-$, Wt-% | 20.6 | 27.5 |
| Carbon, Wt-% | 6.3 | 6.9 |

### 4.2.4. Discussion

In view of the quality of the feed, the low conversions and high carbon yields observed in fluid catalytic cracking of untreated H-Coal Gas Oil 3531-11 did not come as a surprise. Analyses showed this feed contained 90.2 vol-% aromatics and 4100 wt-ppm nitrogen. Nitrogen-containing compounds are known to cause temporary catalyst poisoning. While catalytic cracking catalysts are much less sensitive to nitrogen than hydrocracking catalysts, nitrogen at levels above 1000 wt-ppm would reduce cracking activity markedly. An equally dominant factor on feed cracking characteristics is the content of aromatics. Although long alkyl side chains on aromatics are reactive, the aromatic rings are generally quite stable at cracking conditions, and usually go through the cracking operation with only a low degree of ring opening. High molecular weight aromatics are commonly known to be coke formers at cracking conditions. Coking tendencies of aromatics are the highest among the hydrocarbons (paraffins, naphthenes, and aromatics) in the feed. Since coke-forming tendencies of aromatics usually increase with the number of condensed rings, aromatics in untreated coal liquids are suspected to be heavy coke formers.

The moderately hydrotreated gas oil exhibited much higher conversion, increased gasoline yield, and reduced carbon deposition at similar severity levels. This feedstock has a hydrogen content of 10.68 wt-%. Hydrotreatment at a hydrogen consumption level of 1130 SCF/bbl (1.8 wt-% of feed) had reduced the gas oil aromatic content from 90.2 to 73.0 vol-%, and the nitrogen content to less than 1000 wt-ppm. While the content of aromatics remained high, apparently a large portion of the multi-ring aromatics had been partially saturated. These partially saturated aromatics were readily cracked to lower boiling aromatics.

Further improvements in conversion and gasoline yield with reduced coke deposition were demonstrated in processing the 195°$C^+$ fraction of the severely hydrotreated product. This feed had the highest hydrogen content (12.88%) and the lowest aromatic content (12.3 vol-%) among the three charge stocks studied. The nitrogen content of this feed was reduced to near-zero wt-ppm by the severe hydrotreatment.

These studies show that hydrotreatment improved the feed cracking characteristics by saturating the aromatic rings and reducing the nitrogen content. Feed hydrotreating therefore resulted in increased conversion and improved yield structure. The primary effects of hydrotreating on cracked product distribution are reduction of coke yields and increase in gasoline yields. As more hydrogen was added, the hydrotreated feed exhibited increased conversion and gasoline yield with lower coke-forming tendencies. The effect of feed hydrotreatment on cracking yield pattern are dramatic, as illustrated by the following data obtained with the three distinct feeds at comparable conditions:

| Feed Hydrogen Content, Wt-% | 9.14 | 10.68 | 12.88 |
|---|---|---|---|
| Conversion, Vol-% | 30.6 | 62.9 | 82.9 |
| $C_5$+ Gasoline, Vol-% | 15.5 | 45.7 | 62.2 |
| $C_4^{-}$,Wt-% | 4.3 | 11.8 | 20.6 |
| Carbon, Wt-% | 11.1 | 8.9 | 6.3 |

The effect of feed hydrogen content on fluid catalytic cracking yield and conversion data are further graphically illustrated in Figure 7.

For the purpose of investigating the effect of feed hydrogenation on catalytic cracking characteristics, one of the preparative hydrotreating runs was carried out at severe conditions. Attempt to add a high level of hydrogen to the feed resulted in a high degree of aromatic ring saturation. As shown in Table 23, the hydrogen consumption for this run was 5.6 wt-% of feed (3640 SCF/bbl). Table 24 shows that 86.9% of the hydrogen consumed was added directly into the liquid product. This amount of hydrogen effected an increase in hydrogen content from 9.14 to 13.75 wt-% and a reduction of aromatics from 90.2 to 7.4 vol-%. Because relatively severe conditions were employed, hydrocracking also became very significant. This led to the generation of 54.9 vol-% gasoline (195°C⁻). Therefore, a major portion of the hydrogen added to the feed was consumed inevitably in the hydrocracking of gas oil to gasoline.

While data from this work reveal the high potential improvement in the cracking characteristics of coal-derived FCC feed by hydrotreating, they also indicate that extremely high saturation of multi-ring aromatics is not necessary for cracking improvement. Actually, a consideration of the aromatic content of cracked gasoline will lead to the realization that an extremely highly saturated cracker feed may result in a gasoline lower in octane number than a gasoline obtained from a partially saturated feed. From the preceding data, it is evident that extremely high saturation of multi-ring aromatics, as compared to partial saturation, not only requires more severe hydrotreating conditions, but also results in a higher hydrogen consumption and the generation of excessive low octane gasoline by unselective hydrocracking.

Although all the cracked gasolines obtained from these FCC studies are high in octane number, data do indicate that at comparable conditions octane numbers of cracked gasoline decreased slowly as the feed hydrogen content increased:

| Feed Hydrogen Content, Wt-% | 9.14 | 10.68 | 12.88 |
|---|---|---|---|
| Conversion, Vol-% | 30.6 | 62.9 | 82.9 |
| $C_5^+$ Gasoline, Vol-% | 15.5 | 45.7 | 62.2 |
| RON, Clear | 99.4 | 95.5 | 93.4 |
| RON, 3 ml TEL/Gallon | 103.1 | 102.1 | 100.4 |

The FCC data also show the trend of improvement in the API gravity of the cycle oils, generated at equivalent conditions, as the hydrogen content of the cracker feed increased:

| Feed Hydrogen Content, Wt-% | 9.14 | 10.68 | 12.88 |
|---|---|---|---|
| Conversion, Vol-% | 30.6 | 62.9 | 82.9 |
| Cycle Oil | | | |
| °API | 5.0 | 5.5 | 12.9 |
| % Over at 650°F | 85.0 | 87.0 | 93.0 |
| °API of 650°F$^-$ | 7.7 | 7.8 | 15.5 |

Since the FCC feedstock with the highest hydrogen content was prepared by severe hydrotreatment which resulted in generating a large amount of liquid in the gasoline range ($C_5$-400°F), it is desirable to have data in terms of overall product distribution which comprises both hydrotreatment and FCC. The following yield data were derived from results shown in Tables 23, 26, 32 and 33, including gravity data in Tables 1, 5, 25, and 27:

| Cracking Conditions | Near Base | Above Base |
|---|---|---|
| Overall Product Distribution, Wt-% of Hydrotreater Feed | | |
| $C_3^-$ | 6.2 | 8.4 |
| $C_4$ | 8.0 | 9.0 |
| $C_5$-EP Gasoline | 78.3 | 76.1 |
| Cycle Oil | 9.0 | 7.7 |
| Carbon | 3.0 | 3.3 |
| $H_2O$ | 0.6 | 0.6 |
| $H_2S$ | 0.1 | 0.1 |
| $NH_3$ | 0.4 | 0.4 |
| Total | 105.6 | 105.6 |
| $C_5^+$ Gasoline Yield, Vol-% of Hydrotreated Feed | 100.1 | 97.0 |

"Above base" conditions referred to are 31°C above base temperature and 1.5 X base catalyst/oil ratio. Product totals over 100% represent hydrogen added to the feed during hydrotreating operation (Table 23). Because the gasoline products have a higher API gravity than the feed, gasoline volumetric yields are near or above 100% of the feed.

## TABLES AND FIGURES

Table 1

Inspections of H-Coal Atmospheric Still Bottoms

| | As Received | | After Flash Distillation | |
|---|---|---|---|---|
| HRI Sample No. | LO-585 | LO-586 | | |
| Sample No. | 37-1118 | 37-1117 | 3531-10 | 3531-11 |
| °API @ 60°F | 7.4 | 12.1 | 12.9 | 8.9 |
| Sp. Gr. @ 60°F | 1.0187 | 0.9854 | 0.9799 | 1.0078 |
| Distillation, ASTM D-1160 | | | | |
| IBP, °F | 412 | 410 | 418 | 415 |
| 5% | 463 | 467 | 467 | 462 |
| 10% | 485 | 474 | 480 | 490 |
| 20% | 509 | 495 | 499 | 518 |
| 30% | 530 | 519 | 517 | 538 |
| 40% | 558 | 545 | 536 | 553 |
| 50% | 580 | 566 | 557 | 571 |
| 60% | 603 | 591 | 578 | 590 |
| 70% | 631 | 621 | 603 | 615 |
| 80% | 661 | 666 | 639 | 645 |
| 90% | 715 | 710 | 690 | 689 |
| 95% | 768 | 772 | 727 | 715 |
| EP | 857 | 855 | 770 | 769 |
| % Over | 99.0 | 99.0 | 99.0 | 99.0 |
| % Bottoms | 1.0 | 1.0 | 1.0 | 1.0 |
| Hydrogen, Wt-% | - | - | 9.57 | 9.14 |
| Carbon, Wt-% | - | - | 89.28 | 88.98 |
| Sulfur, Wt-ppm | 951 | 690 | 500 | 800 |
| Nitrogen, Wt-ppm | 3534 | 2966 | 4180 | 4100 |
| Oxygen, Wt-ppm | 5006 | 5480 | 5200 | 5200 |
| Con. Carbon, Wt-% | 0.41 | 0.49 | 0.01 | <0.01 |
| Heptane Insoluble, Wt-% | 0.37 | 0.53 | 0.11 | 0.05 |
| FIA, Vol-% | | | | |
| A | 90.9 | 83.7 | 84.0 | 90.2 |
| O | 0.0 | 0.0 | 0.0 | 0.0 |
| P&N | 9.1 | 16.3 | 16.0 | 9.8 |
| Stm. Jet Gum, mg/100 ml | 620 | 933 | 4.7 | 37 |

Table 2

Vacuum Flash Distillation of Raw H-Coal Atmospheric Still Bottoms 37-1117 (LO-586)

| Cut Number | Boiling Range, °F | Volume, ml | Vol-% | Weight Grams | Wt-% |
|---|---|---|---|---|---|
| 1[(a)] | IBP-797 | 170,974 | 95.9 | 167,537 | 95.3 |
| Botts. | 797°+ | 7,372 | 4.1 | 8,205 | 4.7 |
| | | 178,346 | 100.0 | 175,742 | 100.0 |

(a)Designated as Rerun H-Coal Atmospheric Still Bottoms 3531-10 (H-Coal Gas Oil 3531-10)

Table 3

Vacuum Flash Distillation of Raw H-Coal Atmospheric Still Bottoms 37-1118 (LO-585)

| Cut Number | Boiling Range, °F | Volume, ml | Vol-% | Weight Grams | Wt-% |
|---|---|---|---|---|---|
| 1[(a)] | IBP-806° | 157,923 | 95.9 | 159,155 | 94.9 |
| Botts. | 806°+ | 6,729 | 4.1 | 8,576 | 5.1 |
| | | 164,652 | 100.0 | 167,731 | 100.0 |

(a)Designated as Rerun H-Coal Atmospheric Still Bottoms 3531-11 (H-Coal Gas Oil 3531-11)

## Table 4

### Inspections of Hydrotreated H-Coal Gas Oil 3531-25

| | |
|---|---|
| Sample No. | 3531-25 |
| °API @ 60°F | 16.8 |
| Sp. Gr. @ 60°F | 0.9541 |
| Distillation, ASTM-D86 | |
| IBP°, F | 373 |
| 5% | 434 |
| 10% | 455 |
| 20% | 480 |
| 30% | 492 |
| 40% | 513 |
| 50% | 528 |
| 60% | 548 |
| 70% | 570 |
| 80% | 597 |
| 90% | 640 |
| 95% | 685 |
| % Over | 96.5 |
| % Bottoms | 3.5 |
| Hydrogen, Wt-% | 10.68 |
| Carbon, Wt-% | 88.77 |
| Sulfur, Wt-% | 6.7 |
| Nitrogen, Wt-ppm | 856.3 |
| Con. Carbon, Wt-% | <0.01 |
| Heptane Insolubles, Wt-% | <0.01 |
| Molecular Weight, Average | 201 |
| FIA, Vol-% | |
| A | 73.0 |
| O | 0.0 |
| P&N | 27.0 |

Table 5

Inspections of Hydrotreated H-Coal Gas Oil 3531-27

| | |
|---|---|
| Sample No. | 3531-27 |
| °API @ 60°F | 29.2 |
| Sp.Gr. @ 60°F | 0.8805 |
| Distillation, ASTM D-1160 | |
| IBP, °F | 395 |
| 5% | 425 |
| 10% | 431 |
| 20% | 442 |
| 30% | 454 |
| 40% | 466 |
| 50% | 480 |
| 60% | 495 |
| 70% | 511 |
| 80% | 531 |
| 90% | 566 |
| 95% | 595 |
| EP | 670 |
| % Over | 99.0 |
| % Bottoms | 1.0 |
| Hydrogen, Wt-% | 12.88 |
| Carbon, Wt-% | 87.76 |
| Sulfur, Wt-ppm | 0.18 |
| Nitrogen, Wt-ppm | 1.6 |
| FIA, Vol-% | |
| A | 12.3 |
| O | 0.0 |
| P&N | 87.7 |
| Cetane Number | 44.3 |
| Aniline Point, °F | 130.6 |
| Pour Point, °F | -70 |
| Viscosity, cSt, 210°F | 2.922 |

Table 6

$H_2$ Uptake Study on Rerun H-Coal Atmospheric Still Bottoms 3531-10

Plant 532 Run 1093

UOP -DCB Catalyst

LHSV/LHSV (base): 0.5; P-P (base) psig: 0; T-T (base) °C: 0

| Period No. | Hours on Stream | C Wt-% | H Wt-% | N Wt - ppm | S Wt - ppm | O Wt - ppm |
|---|---|---|---|---|---|---|
| Feed | | 89.28 | 9.57 | 4180 | 500 | 5200 |
| 1 | 28-38 | 86.74 | 12.73 | | | |
| 2 | 38-48 | 87.34 | 12.40 | 1.7 | 1.1 | |
| 3 | 48-58 | 87.63 | 12.10 | | | |
| 4 | 58-68 | 87.74 | 12.02 | 2.0 | 2.4 | |
| 5 | 68-78 | 87.93 | 12.16 | | | |
| 6 | 78-88 | 87.93 | 11.93 | 1.9 | 1.1 | |
| 7 | 88-98 | 87.60 | 12.15 | 1.1 | 0.77 | 109.2 |
| 8 | 98-108 | 87.61 | 11.85 | 2.2 | 0.65 | |

Table 7

$H_2$ Uptake Study on Rerun H-Coal Atmospheric Still Bottoms 3135-10

Plant 532 Run 1094

UOP - DCA Catalyst

LHSV/LHSV (base): 0.5; P-P (base) psig: 0; T-T (base) °C: 0

| Period No. | Hours on Stream | C Wt-% | H Wt-% | N Wt- ppm | S Wt- ppm | O Wt- ppm |
|---|---|---|---|---|---|---|
| Feed | | 89.28 | 9.57 | 4180 | 500 | 5200 |
| 1 | 28-38 | 87.51 | 11.64 | | | |
| 2 | 38-48 | 87.57 | 11.80 | 2.7 | 0.55 | |
| 3 | 48-58 | 87.79 | 11.90 | | | |
| 4 | 58-68 | 87.78 | 11.80 | 0.98 | 1.2 | |
| 5 | 68-78 | 88.54 | 11.50 | | | |
| 6 | 78-88 | 88.66 | 11.38 | 0.75 | 0.98 | |
| 7 | 88-98 | 88.41 | 11.39 | 0.66 | 0.55 | 180.6 |
| 8 | 98-108 | 88.30 | 11.57 | 0.77 | 0.55 | |

Table 8

$H_2$ Uptake Study on Rerun H-Coal Atmospheric Still Bottoms 3531-10

Plant 532 Run 1095

UOP-DSA Catalyst

LHSV/LHSV (base): 0.5; P-P (base) psig: 0; T-T (base) °C: 0

| Period No. | Hours on Stream | C Wt-% | H Wt-% | N Wt - ppm | S Wt - ppm | O Wt - ppm |
|---|---|---|---|---|---|---|
| Feed | | 89.28 | 9.57 | 4180 | 500 | 5200 |
| 1 | 28-38 | 88.37 | 11.17 | | | |
| 2 | 38-48 | 88.03 | 11.46 | 18.3 | 0.43 | |
| 3 | 48-58 | 88.11 | 11.70 | | | |
| 4 | 58-68 | 88.63 | 11.42 | 24.4 | 0.86 | |
| 5 | 68-78 | 88.42 | 11.37 | | | |
| 6 | 78-88 | 88.71 | 10.92 | 31.0 | 0.64 | |
| 7 | 88-98 | 88.71 | 10.94 | 21.7 | 2.5 | 107.2 |
| 8 | 98-108 | 88.71 | 10.94 | 26.9 | 1.1 | |

Table 9

Product Hydrogen Content

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11

Plant 601, Run 758

P-P (base), psig: 0

| Period No | Hours on Stream | LHSV / LHSV (base) | T-T (base), °C | Product Analysis, Wt-% H | C |
|---|---|---|---|---|---|
| Feed | | | | 9.14 | 88.98 |
| 1 | 30-40 | 0.41 | 1 | 12.57 | 87.60 |
| 2 | 40-50 | 0.40 | 1 | 12.53 | 87.83 |
| 3 | 50-60 | 0.44 | 1 | 12.46 | 88.00 |
| 4 | 70-78 | 0.82 | 2 | 11.35 | 89.09 |
| 5 | 78-86 | 0.89 | 1 | 11.36 | 88.94 |
| 6 | 86-94 | 0.80 | 1 | 11.23 | 88.81 |
| 7 | 100-106 | 1.23 | 2 | 11.18 | 89.81 |
| 8 | 106-112 | 1.22 | 1 | 11.37 | 88.36 |
| 9 | 112-118 | 1.20 | 1 | 11.07 | 88.62 |
| 10 | 130-136 | 1.23 | -14 | 10.87 | 88.88 |
| 11 | 136-142 | 1.15 | -14 | 11.00 | 89.03 |
| 12 | 142-148 | 1.17 | - 7 | 11.03 | 89.03 |
| 13 | 156-164 | 0.79 | -14 | 11.07 | 88.97 |
| 14 | 164-172 | 0.80 | -14 | 11.14 | 88.44 |
| 15 | 172-180 | 0.87 | -16 | 11.24 | 88.52 |
| 16 | 190-200 | 0.37 | -15 | 12.52 | 87.99 |
| 17 | 200-210 | 0.37 | -15 | 12.19 | 87.27 |
| 18 | 210-220 | 0.35 | -14 | 12.36 | 88.04 |
| 19 | 230-240 | 0.35 | 15 | 12.34 | 87.40 |
| 20 | 240-250 | 0.38 | 15 | 12.32 | 87.22 |
| 21 | 250-260 | 0.35 | 15 | 12.26 | 87.23 |
| 22 | 268-276 | 0.81 | 16 | 11.19 | 88.81 |
| 23 | 276-264 | 0.78 | 16 | 11.14 | 88.62 |
| 24 | 284-292 | 0.78 | 16 | 11.30 | 88.13 |
| 25 | 298-304 | 1.19 | 16 | 10.62 | 89.53 |
| 26 | 304-310 | 1.19 | 15 | 10.62 | 89.81 |
| 27 | 310-316 | 1.19 | 15 | 10.41 | 89.68 |
| 28 | 326-332 | 1.20 | -38 | 10.38 | 89.34 |
| 29 | 332-338 | 1.19 | -39 | 10.45 | 89.98 |
| 30 | 346-354 | 0.82 | -39 | 10.78 | 88.91 |
| 31 | 354-362 | 0.81 | -39 | 10.52 | 88.83 |
| 32 | 372-382 | 0.40 | -39 | 11.39 | 88.11 |
| 33 | 382-392 | 0.37 | -39 | 11.41 | 88.17 |
| 34 | 392-402 | 0.40 | -39 | 11.88 | 87.92 |
| [illegible] | 412-422 | 0.40 | 29 | 12.42 | 87.92 |
| 36 | 422-432 | 0.41 | 29 | 12.21 | 87.49 |
| 37 | 432-442 | 0.40 | 29 | 11.87 | 87.69 |
| 38 | 450-458 | 0.80 | 31 | 10.93 | 88.90 |
| 39 | 456-466 | 0.80 | 31 | 10.80 | 89.12 |
| 40 | 466-474 | 0.79 | 32 | 10.71 | 89.00 |
| 41 | 480-486 | 1.20 | 30 | 10.51 | 89.18 |
| 42 | 486-492 | 1.20 | 30 | 10.48 | 89.12 |
| 43 | 502-512 | 0.39 | 0 | 11.05 | 88.62 |
| 44 | 512-522 | 0.39 | 1 | 11.85 | 88.95 |

Table 10

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11
Plant 601, Run 758A

| Period No. | Feed | 2/3 | | 5/6 | | 7/9 | |
|---|---|---|---|---|---|---|---|
| Hours on Stream | | 40-80 | | 76-94 | | 100-112 | |
| Operating Conditions | | | | | | | |
| P-P (base), psig | | 0 | | 0 | | 0 | |
| T-T (base), °C | | 1 | | 1 | | 1 | |
| LHSV/LHSV (base) | | 0.44 | | 0.89 | | 1.23 | |
| Liquid Product Properties | | | | | | | |
| °API @ 60°F | 8.9 | 24.2 | | 19.0 | | 17.6 | |
| Sp. Gr. @ 60°F | 1.0078 | 0.9088 | | 0.9400 | | 0.9490 | |
| Elemental Analysis | | | | | | | |
| Hydrogen, Wt-% | 9.14 | 12.53 | | 11.36 | | 11.18 | |
| Carbon, Wt-% | 88.98 | 87.83 | | 88.94 | | 89.81 | |
| Sulfur, Wt-ppm | 800 | <0.1 | | 1.7 | | 4.0 | |
| Nitrogen, Wt-ppm | 4100 | 0.1 | | 39.7 | | 101.1 | |
| Oxygen, Wt-ppm | 5200 | 173.6 | | 1252.3 | | 883.8 | |
| FIA, Vol-% | | | | | | | |
| A | 90.2 | 30.3 | | 62.9 | | 70.6 | |
| O | 0.0 | 0.0 | | 0.0 | | 0.0 | |
| P&N | 9.8 | 69.7 | | 37.1 | | 29.4 | |
| Product Distribution, % of Feed | | Wt-% | Vol-% | Wt-% | Vol-% | Wt-% | Vol-% |
| $C_1$-$C_4$ Fraction | | 0.76 | | 0.41 | | 0.77 | |
| $C_5$-$C_6$ Fraction (in Plant Gas) | | 1.32 | 2.04 | 0.35 | 0.56 | 0.15 | 0.23 |
| $C_5$-FBP Fraction | | 100.67 | 111.63 | 100.78 | 108.05 | 100.37 | 106.60 |
| $H_2O$ | | 0.61 | | 0.48 | | 0.52 | |
| $NH_3$ | | 0.50 | | 0.50 | | 0.49 | |
| $H_2S$ | | 0.08 | | 0.09 | | 0.08 | |
| Total | | 103.94 | 113.67 | 102.61 | 108.61 | 102.38 | 106.83 |
| $H_2$ Consumption, Wt-% of Feed | | 3.94 | | 2.61 | | 2.38 | |

Table 11

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11
Plant 601, Run 758B

| Period No. | Feed | 10/12 | 14/15 | 17/18 |
|---|---|---|---|---|
| Hours on Stream | | 130-148 | 164-180 | 200-220 |
| Operating Conditions | | | | |
| P-P (base), psig | | 0 | 0 | 0 |
| T-T (base), °C | | -14 | -15 | -15 |
| LHSV/LHSV (base) | | 1.23 | 0.83 | 0.36 |
| Liquid Product Properties | | | | |
| °API @ 60°F | 8.9 | 16.7 | 19.0 | 22.0 |
| Sp. Gr. @ 60°F | 1.0078 | 0.9548 | 0.9403 | 0.9218 |
| Elemental Analysis | | | | |
| Hydrogen, Wt-% | 9.14 | 10.87 | 11.24 | 12.36 |
| Carbon, Wt-% | 88.98 | 88.88 | 88.52 | 88.04 |
| Sulfur, Wt-ppm | 800 | 2.5 | 1.2 | 0.4 |
| Nitrogen, Wt-ppm | 4100 | 277.0 | 103.3 | 5.0 |
| Oxygen, Wt-ppm | 5200 | 2294 | 2106 | 348 |
| FIA, Vol-% | | | | |
| A | 90.2 | 71.2 | 66.4 | 37.9 |
| O | 0.0 | 0.0 | 0.0 | 0.0 |
| P&N | 9.8 | 28.8 | 33.6 | 62.1 |

| Product Distribution, % of Feed | 10/12 Wt-% | 10/12 Vol-% | 14/15 Wt-% | 14/15 Vol-% | 17/18 Wt-% | 17/18 Vol-% |
|---|---|---|---|---|---|---|
| $C_1$-$C_4$ Fraction | 0.23 | | 0.32 | | 0.82 | |
| $C_5$-$C_6$ Fraction (in Plant Gas) | 0.20 | 0.31 | 0.03 | 0.05 | 0.33 | 0.51 |
| $C_5$-FBP Fraction | 100.71 | 106.30 | 101.11 | 108.38 | 101.44 | 110.90 |
| $H_2O$ | 0.35 | | 0.37 | | 0.59 | |
| $NH_3$ | 0.47 | | 0.49 | | 0.50 | |
| $H_2S$ | 0.09 | | 0.09 | | 0.08 | |
| Total | 102.05 | 106.61 | 102.41 | 108.43 | 103.76 | 111.41 |
| $H_2$ Consumption, Wt-% of Feed | 2.05 | | 2.41 | | 3.76 | |

Table 12

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11
Plant 601, Run 758C

| Period No. | Feed | 20/21 | | 23/24 | | 26/27 | |
|---|---|---|---|---|---|---|---|
| Hours on Stream | | 240-260 | | 276-292 | | 304-316 | |
| Operating Conditions | | | | | | | |
| P-P (base), psig | | 0 | | 0 | | 0 | |
| T-T (base), °C | | 15 | | 16 | | 15 | |
| LHSV/LHSV (base) | | 0.36 | | 0.78 | | 1.19 | |
| Liquid Product Properties | | | | | | | |
| °API @ 60°F | 8.9 | 23.5 | | 19.6 | | 17.4 | |
| Sp. Gr. @ 60°F | 1.0078 | 0.9129 | | 0.9365 | | 0.9503 | |
| Elemental Analysis | | | | | | | |
| Hydrogen, Wt-% | 9.14 | 12.32 | | 11.30 | | 10.62 | |
| Carbon, Wt-% | 88.98 | 87.22 | | 88.13 | | 89.81 | |
| Sulfur, Wt-ppm | 8.00 | 0.1 | | 0.5 | | 1.2 | |
| Nitrogen, Wt-ppm | 4100 | 1.4 | | 15.9 | | 568.0 | |
| Oxygen, Wt-ppm | 5200 | 148 | | 877 | | 1447 | |
| FIA, Vol-% | | | | | | | |
| A | 90.2 | 33.3 | | 61.3 | | 71.1 | |
| O | 0.0 | 0.0 | | 0.0 | | 0.0 | |
| P&N | 9.8 | 66.7 | | 38.7 | | 29.9 | |
| Product Distribution, % of Feed | | Wt-% | Vol-% | Wt-% | Vol-% | Wt-% | Vol-% |
| $C_1$-$C_4$ Fraction | | 0.91 | 1.90 | 0.45 | | 0.32 | |
| $C_5$-$C_6$ Fraction (in Plant Gas) | | 1.23 | 110.83 | 0.30 | 0.47 | 0.14 | 0.22 |
| $C_5$-FBP Fraction | | 100.40 | | 100.50 | 107.75 | 100.30 | 106.37 |
| $H_2O$ | | 0.61 | | 0.51 | | 0.46 | |
| $NH_3$ | | 0.50 | | 0.50 | | 0.42 | |
| $H_2S$ | | 0.08 | | 0.08 | | 0.08 | |
| Total | | 103.73 | 112.73 | 102.34 | 108.22 | 101.72 | 106.59 |
| $H_2$ Consumption, Wt-% of Feed | | 3.73 | | 2.34 | | 1.72 | |

## Table 13

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11
Plant 601, Run 758D

| Period No. | Feed | 29 | 30/31 | 32/33 |
|---|---|---|---|---|
| Hours on Stream | | 332-338 | 346-362 | 372-392 |
| Operating Conditions | | | | |
| P-P (base), psig | | 0 | 0 | 0 |
| T-T (base), °C | | -39 | -39 | -39 |
| LHSV/LHSV (base) | | 1.19 | 0.81 | 0.39 |
| Liquid Product Properties | | | | |
| °API @ 60°F | 8.9 | | 16.3 | 19.2 |
| Sp. Gr. @ 60°F | 1.0078 | 0.9646 | 0.9574 | 0.9390 |
| Elemental Analysis | | | | |
| Hydrogen, Wt-% | 9.14 | 10.45 | 10.78 | 11.39 |
| Carbon, Wt-% | 88.98 | 89.98 | 88.91 | 88.11 |
| Sulfur, Wt-ppm | 800 | 8.5 | 4.2 | 2.5 |
| Nitrogen, Wt-ppm | 4100 | 882.0 | 548.0 | 83.2 |
| Oxygen, Wt-ppm | 5200 | 3000 | 1570 | 160 |
| FIA | | | | |
| A | 90.2 | 78.8 | 73.2 | |
| O | 0.0 | 0.0 | 0.0 | |
| P&N | 9.8 | 21.2 | 26.8 | |

| Product Distribution, % of Feed | 29 Wt-% | 29 Vol-% | 30/31 Wt-% | 30/31 Vol-% | 32/33 Wt-% | 32/33 Vol-% |
|---|---|---|---|---|---|---|
| $C_1$-$C_4$ Fraction | 0.15 | | 0.13 | | 0.15 | |
| $C_5$-$C_6$ Fraction (in Plant Gas) | 0.14 | 0.21 | 0.10 | 0.15 | 0.57 | 0.88 |
| $C_5$-FBP Fraction | 100.45 | 104.94 | 100.71 | 106.02 | 100.75 | 108.13 |
| $H_2O$ | 0.27 | | 0.44 | | 0.62 | |
| $NH_3$ | 0.39 | | 0.43 | | 0.50 | |
| $H_2S$ | 0.08 | | 0.08 | | 0.09 | |
| Total | 101.48 | 105.15 | 101.89 | 106.17 | 102.68 | 109.01 |
| $H_2$ Consumption, Wt-% of Feed | 1.48 | | 1.89 | | 2.68 | |

Table 14

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11
Plant 601, Run 758E

| Period No. | Feed | 35/36 | 35/36 | 41/42 | 43/44 |
|---|---|---|---|---|---|
| Hours on Stream | | 412-432 | 450-466 | 480-492 | 502-522 |
| Operating Conditions | | | | | |
| P-P (base), psig | | 0 | 0 | 0 | 0 |
| T-T (base), °C | | 29 | 31 | 30 | 1 |
| LHSV/LHSV (base) | | 0.40 | 0.80 | 1.21 | 0.39 |
| Liquid Product Properties | | | | | |
| °API @ 60°F | 8.9 | 24.4 | 20.6 | 17.8 | 18.6 |
| Sp. Gr. @ 60°F | 1.0078 | 0.9076 | 0.9304 | 0.9478 | 0.9427 |
| Elemental Analysis | | | | | |
| Hydrogen, Wt-% | 9.14 | 12.42 | 10.93 | 10.51 | 11.05 |
| Carbon, Wt-% | 88.98 | 87.92 | 88.90 | 89.19 | 88.62 |
| Sulfur, Wt-ppm | 800 | 0.22 | 0.82 | 1.2 | 0.53 |
| Nitrogen, Wt-ppm | 4100 | 1.6 | 2.4 | 60.1 | 18.1 |
| Oxygen, Wt-ppm | 5200 | 156 | 942 | - | - |
| FIA, Vol-% | | | | | |
| A | 90.2 | 39.3 | 65.0 | | |
| O | 0.0 | 0.0 | 0.0 | | |
| P&N | 9.8 | 60.7 | 35.0 | | |

| Product Distribution, % of Feed | Wt.-% | Vol-% | Wt-% | Vol-% | Wt-% | Vol-% | Wt-% | Vol-% |
|---|---|---|---|---|---|---|---|---|
| $C_1$-$C_4$ Fraction | 1.13 | | 1.12 | | 0.56 | | 0.66 | |
| $C_5$-$C_6$ Fraction | 0.87 | 1.37 | 0.71 | 1.10 | 0.20 | 0.32 | 1.03 | 1.59 |
| $C_5$-FBP Fraction | 100.75 | 111.86 | 99.29 | 107.55 | 99.86 | 105.18 | 99.45 | 106.32 |
| $H_2O$ | 0.61 | | 0.51 | | 0.51 | | 0.61 | |
| $NH_3$ | 0.49 | | 0.50 | | 0.49 | | 0.49 | |
| $H_2S$ | 0.09 | | 0.08 | | 0.08 | | 0.08 | |
| Total | 103.94 | 113.23 | 102.21 | 108.65 | 101.70 | 105.50 | 102.32 | 107.91 |
| $H_2$ Consumption, Wt-% of Feed | 3.94 | | 2.21 | | 1.70 | | 2.32 | |

Table 15

Product Hydrogen Content

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11

Plant 601, Run 759

P-P (base), psig: 500

| Period No. | Hours on Stream | LHSV / LHSV (base) | T-T (base), °C | Product Analysis, Wt-% H | C |
|---|---|---|---|---|---|
| Feed | | | | 9.14 | 88.98 |
| 1 | 15-25 | 0.40 | -38 | 11.54 | 88.49 |
| 2 | 25-35 | 0.42 | -39 | 11.99 | 88.56 |
| 3 | 35-45 | 0.40 | -39 | 11.83 | 87.67 |
| 4 | 53-61 | 0.81 | -39 | 11.04 | 88.55 |
| 5 | 61-69 | 0.80 | -38 | 11.10 | 88.38 |
| 6 | 69-77 | 0.83 | -41 | 11.54 | 89.09 |
| 7 | 83-89 | 1.22 | -37 | 10.97 | 89.29 |
| 8 | 89-95 | 1.22 | -41 | 10.73 | 88.91 |
| 9 | 95-101 | 1.20 | -39 | 10.82 | 89.01 |
| 10 | 111-117 | 1.20 | 4 | 12.19 | 87.66 |
| 11 | 117-123 | 1.20 | 2 | 11.94 | 87.39 |
| 12 | 123-129 | 1.20 | 1 | 11.75 | 87.77 |
| 13 | 137-145 | 0.81 | 2 | 12.30 | 87.71 |
| 14 | 145-153 | 0.81 | 1 | 12.30 | 87.53 |
| 15 | 153-161 | 0.81 | 1 | 12.06 | 87.36 |
| 16 | 170-180 | 0.40 | 1 | 12.82 | 87.73 |
| 17 | 180-190 | 0.41 | 0 | 13.01 | 86.49 |
| 18 | 190-200 | 0.39 | 2 | 13.18 | 86.90 |
| 19 | 210-220 | 0.40 | 30 | 13.29 | 86.61 |
| 20 | 220-230 | 0.39 | 31 | 12.83 | 87.30 |
| 21 | 230-240 | 0.42 | 31 | 13.01 | 87.09 |
| 22 | 248-256 | 0.81 | 30 | 12.13 | 87.42 |
| 23 | 256-264 | 0.79 | 30 | 12.12 | 87.41 |
| 24 | 264-272 | 0.81 | 30 | 12.12 | 87.59 |
| 25 | 278-284 | 1.19 | 33 | 11.73 | 86.93 |
| 26 | 284-291 | 1.26 | 36 | 11.23 | 88.22 |
| 27 | 291-296 | 1.25 | 34 | 11.40 | 87.70 |
| 28 | 306-316 | 0.43 | 30 | 12.66 | 87.63 |
| 29 | 316-326 | 0.43 | 32 | 12.78 | 86.99 |
| 30 | 336-346 | 0.41 | -39 | 11.65 | 88.53 |
| 31 | 346-356 | 0.37 | -39 | 11.78 | 88.55 |

Table 16

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11
Plant 601, Run 759A

| Period No. | Feed | 2/3 | 5/6 | 7/8 |
|---|---|---|---|---|
| Hours on Stream | | 25-45 | 61-77 | 83-95 |
| Operating Conditions | | | | |
| P-P (base), psig | | 500 | 500 | 500 |
| T-T (base), °C | | -39 | -40 | -39 |
| LHSV/LHSV (base) | | 0.42 | 0.83 | 1.22 |
| Liquid Product Properties | | | | |
| °API @ 60°F | 8.9 | 21.8 | 17.9 | 16.6 |
| Sp. Gr. @ 60°F | 1.0078 | 0.9230 | 0.9471 | 0.9554 |
| Elemental Analysis | | | | |
| Hydrogen, Wt-% | 9.14 | 11.99 | 11.54 | 10.97 |
| Carbon, Wt-% | 88.98 | 88.56 | 89.09 | 89.29 |
| Sulfur, Wt-ppm | 800 | 0.8 | 2.0 | 4.9 |
| Nitrogen, Wt-ppm | 4100 | 5.7 | 308.0 | 655.0 |
| Oxygen, Wt-ppm | 5200 | 567 | 2860 | 1828 |
| FIA, Vol-% | | | | |
| A | 90.2 | 40.1 | 66.6 | 74.6 |
| O | 0.0 | 0.0 | 0.0 | 0.0 |
| P&N | 9.8 | 59.9 | 33.4 | 25.4 |

| Product Distribution, % of Feed | Wt-% | Vol-% | Wt-% | Vol-% | Wt-% | Vol-% |
|---|---|---|---|---|---|---|
| $C_1$-$C_4$ Fraction | 1.24 | | 0.10 | | 0.12 | |
| $C_5$-$C_6$ Fraction (in Plant Gas) | 0.95 | 1.49 | 0.22 | 0.34 | 0.20 | 0.31 |
| $C_5$-FBP Fraction | 99.95 | 109.13 | 101.64 | 108.16 | 100.70 | 100.30 |
| $H_2O$ | 0.56 | | 0.28 | | 0.41 | |
| $NH_3$ | 0.49 | | 0.46 | | 0.42 | |
| $H_2S$ | 0.08 | | 0.08 | | 0.08 | |
| Total | 103.27 | 110.62 | 102.78 | 108.50 | 102.00 | 106.61 |
| $H_2$ Consumption, Wt-% of Feed | 3.27 | | 2.78 | | 2.00 | |

Table 17

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11
Plant 601, Run 759B

| Period No. | Feed | 11/12 | | 14/15 | | 17/18 | |
|---|---|---|---|---|---|---|---|
| Hours on Stream | | 117-129 | | 145-161 | | 180-200 | |
| Operating Conditions | | 500 | | 500 | | 500 | |
| P-P (base), psig | | 1 | | 1 | | 1 | |
| T-T (base), °C | | 1.20 | | 0.81 | | 0.40 | |
| LHSV/LHSV (base) | | | | | | | |
| Liquid Product Properties | | | | | | | |
| °API @ 60°F | 8.9 | 20.3 | | 21.9 | | 24.8 | |
| Sp. Gr. @ 60°F | 1.0078 | 0.9321 | | 0.9220 | | 0.9053 | |
| Elemental Analysis | | | | | | | |
| Hydrogen, Wt-% | 9.14 | 11.75 | | 12.30 | | 13.18 | |
| Carbon, Wt-% | 88.98 | 87.77 | | 87.53 | | 86.90 | |
| Sulfur, Wt-ppm | 800 | 0.4 | | 0.3 | | 0.1 | |
| Nitrogen, Wt-ppm | 4100 | 13.5 | | 11.7 | | 1.8 | |
| Oxygen, Wt-ppm | 5200 | 959 | | 492 | | 46 | |
| FIA, Vol-% | | | | | | | |
| A | 90.2 | 53.2 | | 43.0 | | 15.6 | |
| O | 0.0 | 0.0 | | 0.0 | | 0.0 | |
| P&N | 9.8 | 46.8 | | 57.0 | | 84.4 | |
| Product Distribution, % of Feed | | Wt-% | Vol-% | Wt-% | Vol-% | Wt-% | Vol-% |
| $C_1$-$C_4$ Fraction | | 0.33 | | 0.38 | | 0.47 | |
| $C_5$-$C_6$ Fraction (in Plant Gas) | | 0.39 | 0.61 | 0.46 | 0.71 | 0.91 | 1.40 |
| $C_5$- FBP Fraction | | 101.19 | 109.41 | 101.64 | 111.34 | 102.11 | 113.59 |
| $H_2O$ | | 0.52 | | 0.60 | | 0.63 | |
| $NH_3$ | | 0.50 | | 0.53 | | 0.50 | |
| $H_2S$ | | 0.09 | | 0.08 | | 0.08 | |
| Total | | 103.02 | 110.02 | 103.69 | 112.05 | 104.70 | 114.99 |
| $H_2$ Consumption, Wt-% of Feed | | 3.02 | | 3.69 | | 4.70 | |

Table 18

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11
Plant 601, Run 759C

| Period No. | Feed | 20/21 | 23/24 | 25/26 | 30/31 |
|---|---|---|---|---|---|
| Hours on Stream | | 220-240 | 256-272 | 278-291 | 336-356 |
| Operating Conditions | | | | | |
| P-P (base), psig | | 500 | 500 | 500 | 500 |
| T-T (base), °C | | 31 | 30 | 33 | -39 |
| LHSV/LHSV (base) | | 0.40 | 0.80 | 1.22 | 0.40 |
| Liquid Product Properties | | | | | |
| °API @ 60°F | 8.9 | 27.4 | 24.5 | 21.6 | 20.4 |
| Sp. Gr. @ 60°F | 1.0078 | 0.8900 | 0.9071 | 0.9242 | 0.9315 |
| Elemental Analysis | | | | | |
| Hydrogen, Wt-% | 9.14 | 12.83 | 12.12 | 12.63 | 11.65 |
| Carbon, Wt-% | 88.98 | 87.30 | 87.59 | 89.93 | 88.53 |
| Sulfur, Wt-ppm | 800 | 0.1 | 0.3 | 3.3 | 0.6 |
| Nitrogen, Wt-ppm | 4100 | 0.2 | 0.1 | 25.8 | 94.3 |
| Oxygen, Wt-ppm | 5200 | 23 | 178 | 322 | 1215 |
| FIA, Vol-% | | | | | |
| A | 90.2 | 13.1 | | 49.9 | 51.2 |
| O | 0.0 | 0.0 | | 0.0 | 0.0 |
| P&N | 9.8 | 86.9 | | 19.1 | 48.8 |

| Product Distribution, % of Feed | 20/21 Wt-% | 20/21 Vol-% | 23/24 Wt-% | 23/24 Vol-% | 25/26 Wt-% | 25/26 Vol-% | 30/31 Wt-% | 30/31 Vol-% |
|---|---|---|---|---|---|---|---|---|
| $C_1$-$C_4$ Fraction | 0.50 | | 0.96 | | 0.37 | | 0.21 | |
| $C_5$-$C_6$ Fraction (in Plant Gas) | 0.98 | 1.51 | 0.85 | 1.33 | 0.43 | 0.67 | 0.66 | 1.02 |
| $C_5$-FBP | 101.70 | 115.17 | 100.59 | 111.76 | 100.82 | 109.94 | 100.98 | 109.25 |
| $H_2O$ | 0.63 | | 0.61 | | 0.59 | | 0.48 | |
| $NH_3$ | 0.50 | | 0.51 | | 0.49 | | 0.49 | |
| $H_2S$ | 0.08 | | 0.08 | | 0.08 | | 0.08 | |
| Total | 104.39 | 116.68 | 103.60 | 113.19 | 102.78 | 110.61 | 102.90 | 110.27 |
| $H_2$ Consumption, Wt-% of Feed | 4.39 | | 3.60 | | 2.78 | | 2.90 | |

Table 19

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11

Plant 601, Run 760

(Preparative Run No. 1)

P-P (base), psig: 500

| Period No. | Hours on Stream | LHSV / LHSV(base) | T-T (base), °C | Product Analysis, Wt-% H | C |
|---|---|---|---|---|---|
| Feed | | | | 9.14 | 88.98 |
| 1 | 30-40 | 1.20 | -39 | 10.80 | 88.51 |
| 2 | 40-50 | 1.20 | -39 | 10.91 | 89.02 |
| 3 | 50-60 | 1.20 | -39 | 11.00 | 89.20 |
| 4 | 60-70 | 1.20 | -39 | 10.82 | 88.58 |
| 5 | 70-80 | 1.20 | -39 | 11.01 | 88.68 |
| 6 | 80-90 | 1.21 | -38 | 10.30 | 88.70 |
| 7 | 90-100 | 1.21 | -39 | 10.72 | 89.03 |
| 8 | 100-110 | 1.20 | -39 | 11.71 | 88.50 |
| 9 | 110-120 | 1.20 | -39 | 10.60 | 89.04 |
| 10 | 120-130 | 1.18 | -39 | 11.46 | 88.37 |
| 11 | 130-140 | 1.22 | -39 | 10.79 | 88.87 |
| 12 | 140-150 | 1.24 | -39 | 10.69 | 89.40 |
| 13 | 150-160 | 1.21 | -40 | 10.76 | 89.05 |
| 14 | 160-170 | 1.18 | -38 | 10.84 | 89.28 |
| 15 | 170-180 | 1.18 | -41 | 10.73 | 88.53 |
| 16 | 180-190 | 1.21 | -38 | 10.33 | 89.15 |
| 17 | 190-200 | 1.22 | -38 | 10.72 | 88.98 |
| 18 | 200-210 | 1.24 | -40 | 10.33 | 88.37 |
| 19 | 210-220 | 1.20 | -39 | 10.68 | 89.16 |
| 20 | 220-230 | 1.20 | -40 | 10.60 | 89.28 |
| 21 | 230-240 | 1.18 | -39 | 10.79 | 89.45 |
| 22 | 240-250 | 1.19 | -39 | 10.29 | 89.65 |
| 23 | 250-260 | 1.19 | -41 | 10.94 | 88.34 |
| 24 | 260-270 | 1.19 | -41 | 10.79 | 89.53 |
| 25 | 270-280 | 1.23 | -40 | 10.63 | 89.70 |
| 26 | 280-290 | 1.19 | -38 | 10.66 | 89.57 |
| 27 | 290-300 | 1.21 | -38 | 10.35 | 89.32 |

Table 20

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11
Product Distribution and Hydrogen Consumption
Plant 601, Run 760

| | |
|---|---|
| Product Distribution, Wt-% of Feed | |
| $C_1$-$C_4$ | 0.2 |
| $C_5$ and $C_6$ (in Plant Gas) | 0.1 |
| Liquid Product[(a)] | 100.4 |
| $H_2O$ | 0.6 |
| $H_2S$ | 0.1 |
| $NH_3$ | 0.4 |
| Total | 101.8 |
| Hydrogen Consumption, Wt-% of Feed | 1.8 |
| Hydrogen Consumption, SCF/bbl | 1130 |

(a) Designated as Hydrotreated H-Coal Gas Oil 3531-25.

Table 21

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11
Distribution of Hydrogen Consumption
Plant 601, Run 760

| | |
|---|---|
| Hydrogen Consumption, Wt-% | |
| $C_1$-$C_4$ | 0.9 |
| $C_5$ and $C_6$ (in Plant Gas) | 0.6 |
| Liquid Product[(a)] | 90.5 |
| $H_2O$ | 3.7 |
| $H_2S$ | 0.3 |
| $NH_3$ | 4.0 |
| Total | 100.0 |
| Total Hydrogen Consumption | 1130 |

(a)Designated as Hydrotreated H-Coal Gas Oil 3531-25.

Table 22

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11
Plant 638H, Run 17

(Preparative Run No. 2)

P-P (base), psig: 500

| Period No. | Hours on Stream | $\frac{LHSV}{LHSV(base)}$ | T-T(base), °C | Product Analysis, Wt-% H[a] | C |
|---|---|---|---|---|---|
| Feed | | | | 9.14 | 88.98 |
| 1 | 12-24 | 0.41 | 1 | 12.30 | 88.21 |
| 2 | 24-36 | 0.40 | 1 | - | - |
| 3 | 44-56 | 0.40 | 22 | 11.93 | 87.20 |
| 4 | 56-68 | 0.40 | 21 | 11.74 | 87.67 |
| 5 | 68-80 | 0.39 | 21 | 12.08 | 87.90 |
| 6 | 80-92 | 0.40 | 21 | 12.00 | 87.72 |
| 7 | 92-104 | 0.39 | 22 | 12.01 | 87.71 |
| 8 | 104-116 | 0.39 | 22 | 11.89 | 88.81 |
| 9 | 116-128 | 0.40 | 21 | 11.94 | 87.56 |
| 10 | 128-135 | 0.38 | 22 | 12.13 | 87.98 |
| 11 | 147-159 | 0.30 | 21 | | |
| 12 | 159-171 | 0.30 | 23 | 12.03 | 87.36 |
| 13 | 171-183 | 0.30 | 21 | 12.33 | 87.82 |
| 14 | 183-195 | 0.30 | 23 | 12.47 | 87.11 |
| 15 | 195-207 | 0.30 | 23 | 12.74 | 87.88 |
| 16 | 207-219 | 0.30 | 24 | 12.82 | 86.97 |
| 17 | 219-231 | 0.29 | 21 | 12.60 | 87.78 |
| 18 | 231-243 | 0.30 | 23 | | |
| 19 | 243-255 | 0.30 | 23 | 12.81 | 87.56 |
| 20 | 255-267 | 0.30 | 23 | 12.56 | 87.31 |
| 21 | 267-279 | 0.29 | 22 | 12.71 | 87.68 |
| 22 | 279-291 | 0.30 | 21 | 12.89 | 86.40 |
| 23 | 291-303 | 0.30 | 22 | 13.06 | 86.86 |
| 24 | 303-315 | 0.30 | 23 | 13.36 | 86.50 |
| 25 | 315-327 | 0.30 | 21 | 13.35 | 86.37 |
| 26 | 327-339 | 0.30 | 21 | 13.67 | 86.78 |

(a)Products which contain less than 12% H are to be reprocessed.

Table 22, Cont'd.

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11
Plant 638H, Run 17

(Preparative Run No. 2)

P-P (base), psig: 500

| Period No. | Hours on Stream | LHSV / LHSV(base) | T-T (base), °C | Product Analysis, Wt-% H | Product Analysis, Wt-% C |
|---|---|---|---|---|---|
| Feed | | | | 9.14 | 88.98 |
| 27 | 339-351 | 0.29 | 21 | 13.71 | 86.42 |
| 28 | 351-363 | 0.29 | 21 | 13.64 | 86.17 |
| 29 | 363-375 | 0.29 | 20 | 13.85 | 85.91 |
| 30 | 375-387 | 0.30 | 21 | 13.91 | 89.59 |
| 31 | 387-399 | 0.30 | 21 | 14.33 | 85.99 |
| 32 | 399-411 | 0.29 | 22 | 14.36 | 86.09 |
| 33 | 411-423 | 0.30 | 21 | 14.16 | 85.04 |
| 34 | 423-435 | 0.30 | 21 | 14.35 | 85.22 |
| 35 | 435-447 | 0.30 | 22 | - | - |
| 36 | 447-459 | 0.30 | 21 | 14.58 | 85.62 |
| 37 | 459-471 | 0.29[1] | 22 | - | - |
| 38 | 471-483 | 0.30 | 22 | 14.29 | 84.96 |
| 39 | 483-495 | 0.30 | 22 | 14.66 | 85.41 |
| 40 | 495-507 | 0.29 | 20 | 14.80 | 85.23 |
| 41 | 507-519 | 0.30 | 25 | - | - |
| 42 | 519-531 | 0.30 | 27 | - | - |

Table 23

Hydrotreated Rerun H-Coal Atmospheric Still Bottoms 3531-11
Product Distribution and Hydrogen Consumption
Plant 638H, Run 17

| | |
|---|---|
| Product Distribution, Wt-% of Feed | |
| $C_1$-$C_4$ | 4.4 |
| $C_5$ and $C_6$ (in Plant Gas) | 2.0 |
| Liquid Product[a] | 98.1 |
| $H_2O$ | 0.6 |
| $H_2S$ | 0.1 |
| $NH_3$ | 0.4 |
| Total | 105.6 |
| Hydrogen Consumption, Wt-% of Feed | 5.6 |
| Hydrogen Consumption, SCF/bbl | 3640 |

(a)Designated as Hydrotreated H-Coal Liquid Product 3531-26.

Table 24

Hydrotreating Rerun H-Coal Atmospheric Still Bottoms 3531-11
Distribution of Hydrogen Consumption
Plant 638H, Run 17

| | |
|---|---|
| Hydrogen Consumption, Wt-% | |
| $C_1$-$C_4$ | 7.5 |
| $C_5$ and $C_6$ (in Plant Gas) | 2.8 |
| Liquid Product[(a)] | 86.9 |
| $H_2O$ | 1.1 |
| $H_2S$ | 0.1 |
| $NH_3$ | 1.6 |
| Total | 100.0 |
| Total Hydrogen Consumption, SCF/bbl | 3640 |

(a) Designated as Hydrotreated H-Coal Liquid Product 3531-26.

Table 25

Inspections of Hydrotreated H-Coal Liquid Product 3531-26

| | |
|---|---|
| Sample No. | 3531-26 |
| °API @ 60°F | 40.9 |
| Sp. Gr. @ 60°F | 0.8208 |
| | |
| Distillation, ASTM D-86 | |
| IBP, °F | 165 |
| 5% | 190 |
| 10% | 207 |
| 20% | 238 |
| 30% | 270 |
| 40% | 322 |
| 50% | 370 |
| 60% | 409 |
| 70% | 444 |
| 80% | 478 |
| 90% | 516 |
| 95% | 557 |
| EP | 592 |
| % Over | 98.5 |
| % Bottoms | 1.5 |
| | |
| Hydrogen, Wt-% | 13.75 |
| Carbon, Wt-% | 86.33 |
| Sulfur, Wt-ppm | 9.7 |
| Nitrogen, Wt-ppm | 0.73 |
| Oxygen, Wt-ppm | 325.3 |
| Con. Carbon, Wt-% | 0.01 |
| Heptane Insolubles, Wt-% | <0.01 |
| | |
| FIA, Vol-% | |
| A | 7.4 |
| O | 0.0 |
| P & N | 92.6 |

Table 26

Vacuum Fractionation of Hydrotreated H-Coal Liquid Product 3531-26

| Cut Number | Boiling Range, °C | Volume, ml | Vol-% | Wt., Grams | Wt-% |
|---|---|---|---|---|---|
| 1[a] | IBP-195°C | 20,962 | 54.9 | 16,155 | 51.6 |
| Botts.[b] | 195°C+ | 17,214 | 45.1 | 15,145 | 48.4 |
| | | 38,176 | 100.0 | 31,300 | 100.0 |

(a)Designated as Hydrotreated Liquid Product 3531-28.

(b)Designated as Hydrotreated H-Coal Gas Oil 3531-27.

Table 27

Inspections of Hydrotreated H-Coal Liquid Product 3531-28

| | |
|---|---|
| Sample No. | 3531-28 |
| °API @ 60°F | 52.3 |
| Sp. Gr. @ 60°F | 0.7699 |
| Distillation, ASTM D-86 | |
| IBP, °F | 155 |
| 5% | 175 |
| 10% | 186 |
| 20% | 201 |
| 30% | 213 |
| 40% | 227 |
| 50% | 243 |
| 60% | 263 |
| 70% | 286 |
| 80% | 314 |
| 90% | 339 |
| 95% | 355 |
| EP | 385 |
| % Over | 99.0 |
| % Bottoms | 1.0 |
| Hydrogen, Wt-% | 14.36 |
| Carbon, Wt-% | 85.61 |
| Sulfur, Wt-ppm | 0.20 |
| Nitrogen, Wt-ppm | 0.26 |
| Oxygen, Wt-ppm | 193.5 |
| FIA, Vol-% | |
| A | 3.9 |
| O | 0.0 |
| P&N | 96.1 |
| RON, Clear | 65.0 |
| RON, 3 ml TEL/Gallon | 83.6 |

Table 28

Fluid Catalytic Cracking of H-Coal Gas Oil 3531-11
Plant 593, Run 256A

| Test No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Operating Conditions | | | | |
| P-P (base), psig | -10 | -10 | -10 | -10 |
| T-T (base), °C | 2 | 3 | 9 | 1 |
| $\left[\frac{\text{Cat./Oil}}{\text{Cat./Oil (base)}}\right]$ | 1.19 | 0.88 | 1.12 | 0.92 |
| Conversion, Vol-% | 36.4 | 30.6 | 33.7 | 32.8 |
| Product Distribution, Wt-% | | | | |
| $C_3$- | 5.6 | 2.9 | 4.9 | 2.5 |
| $C_4$ | 7.3 | 1.4 | 2.1 | 1.4 |
| $C_5$ | 2.1 | 1.0 | 1.3 | 1.0 |
| $C_6$-EP Gasoline | 13.5 | 11.8 | 11.7 | 13.4 |
| Cycle Oil | 65.6 | 71.4 | 68.4 | 69.1 |
| Carbon | 13.1 | 11.1 | 14.5 | 11.7 |
| Wt. Recovery | 107.2 | 99.6 | 102.9 | 99.1 |
| Products, Vol-% | | | | |
| $C_5$-EP Gasoline | 19.2 | 15.5 | 15.7 | 17.4 |
| Cycle Oil | 63.6 | 69.4 | 66.3 | 67.2 |
| Inspections of $C_5$-EP Gasoline | | | | |
| °API @ 60°F | 38.9 | 39.2 | 36.8 | - |
| Sp. Gr. @ 60°F | 0.8304 | 0.8289 | 0.8408 | - |
| Distillation, ASTM D-86 | | | | |
| IBP, °F | 113 | 120 | 120 | - |
| 5% | 135 | 133 | 136 | - |
| 10% | 158 | 146 | 154 | - |
| 50% | 242 | 257 | 271 | - |
| 90% | 385 | 374 | 387 | - |
| 95% | 406 | 398 | 404 | - |
| EP | 431 | 420 | 416 | - |
| RON, Clear | ← 99.4 → | | | |
| RON, 3 ml TEL/Gallon | ← 103.1 → | | | |
| FIA, Vol-% | | | | |
| A | 60.1 | 54.1 | 57.4 | 57.8 |
| O | 17.9 | 25.8 | 21.1 | 19.4 |
| P&N | 22.0 | 20.1 | 21.5 | 22.8 |

Table 28, Cont'd.

| Test No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Properties of Cycle Oil | | | | |
| °API @ 60°F | 4.5 | 5.0 | 5.1 | 4.6 |
| Sp. Gr. @ 60°F | 1.0404 | 1.0366 | 1.0359 | 1.0397 |
| Distillation, UOP - No. 1 | | | | |
| IBP, °F | 452 | 450 | 455 | 454 |
| 5% | 474 | 470 | 470 | 473 |
| 10% | 485 | 480 | 482 | 481 |
| 15% | 495 | 490 | 489 | 492 |
| % Over at 650°F | 86.0 | 85.0 | 84.0 | 85.0 |
| °API of 650°F⁻ @ 60°F | 6.9 | 7.7 | 7.8 | 7.6 |
| Sp. Gr. of 650°F⁻ @ 60°F | 1.0224 | 1.0165 | 1.0158 | 1.0173 |
| °API of 650°F⁺ @ 60°F | -6.7 | -6.9 | -9.1 | -5.7 |
| Sp. Gr. of 650°F⁺ @ 60°F | 1.1338 | 1.1356 | 1.1560 | 1.1249 |
| $C_3$-, Mole % | | | | |
| $H_2$ | 32.5 | 64.0 | 65.7 | 60.0 |
| $C_1$ | 6.9 | 10.0 | 10.2 | 10.3 |
| $C_2$ (Total) | 10.3 | 10.2 | 9.7 | 11.0 |
| $C_3$ Olefins | 36.0 | 12.3 | 10.9 | 14.4 |
| $C_3$ | 14.3 | 3.5 | 3.5 | 4.3 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| $C_4$, Vol-% | | | | |
| $C_4$ Olefins | 42.4 | 61.2 | 58.8 | 60.2 |
| i-$C_4$ | 38.4 | 24.7 | 26.9 | 25.7 |
| n-$C_4$ | 19.2 | 14.1 | 14.3 | 14.1 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| $C_5$, Vol-% | | | | |
| $C_5$ Olefins | 43.9 | 68.4 | 72.4 | 59.3 |
| i-$C_5$ | 53.3 | 27.7 | 24.6 | 36.5 |
| n-$C_5$ | 2.8 | 3.9 | 3.0 | 4.2 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

## Table 29

**Fluid Catalytic Cracking of H-Coal Gas Oil 3531-11**
**Plant 593, Run 256B**

| Test No. | 5 | 6 | 7 | 8 |
|---|---|---|---|---|
| **Operating Conditions** | | | | |
| P-P (base), psig | -10 | -10 | -10 | -10 |
| T-T (base), °C | 40 | 36 | 31 | 36 |
| $\left[\frac{\text{Cat./Oil}}{\text{Cat./Oil (base)}}\right]$ | 1.47 | 1.43 | 1.30 | 1.48 |
| Conversion, Vol-% | 41.5 | 43.1 | 42.2 | 42.1 |
| **Product Distribution, Wt-%** | | | | |
| $C_3$- | 6.1 | 6.5 | 5.3 | 9.6 |
| $C_4$ | 2.2 | 7.0 | 2.4 | 3.6 |
| $C_5$ | 1.2 | 1.7 | 1.5 | 2.1 |
| $C_6$-EP Gasoline | 14.7 | 14.5 | 15.2 | 14.8 |
| Cycle Oil | 61.7 | 59.3 | 60.5 | 60.6 |
| Carbon | 13.4 | 15.5 | 13.4 | 14.2 |
| Wt. Recovery | 99.3 | 104.5 | 98.3 | 104.9 |
| **Products, Vol-%** | | | | |
| $C_5$-EP Gasoline | 19.0 | 19.9 | 20.0 | 20.5 |
| Cycle Oil | 58.5 | 56.9 | 57.8 | 57.9 |
| **Inspections of $C_5$-EP Gasoline** | | | | |
| °API @ 60°F | 37.2 | 39.2 | 38.4 | 38.7 |
| Sp. Gr. @ 60°F | | | 0.8328 | |
| Distillation, ASTM D-86 | | | | |
| IBP, °F | | | 104 | |
| 5% | | | 132 | |
| 10% | | | 151 | |
| 50% | | | 269 | |
| 90% | | | 378 | |
| 95% | | | 399 | |
| EP | | | 444 | |
| RON, Clear | ← | 101.2 | | → |
| RON, 3 ml TEL/Gallon | ← | 104.5 | | → |
| FIA, Vol-% | | | | |
| A | 72.6 | 67.4 | 63.1 | |
| O | 11.6 | 12.1 | 13.8 | |
| P & N | 15.8 | 20.5 | 23.1 | |

Table 29, Cont'd.

| Test No. | 5 | 6 | 7 | 8 |
|---|---|---|---|---|
| Properties of Cycle Oil | | | | |
| °API @ 60°F | 1.7 | 3.1 | 2.7 | 2.6 |
| Sp. Gr. @ 60°F | 1.0623 | 1.0513 | 1.0544 | 1.0552 |
| Distillation, UOP - No. 1 | | | | |
| IBP, °F | 445 | 449 | 446 | 454 |
| 5% | 470 | 469 | 464 | 469 |
| 10% | 484 | 476 | 477 | 480 |
| 15% | 493 | 489 | 485 | 488 |
| % Over at 650°F | 81.0 | 81.0 | 82.0 | 81.0 |
| °API of 650°F− @ 650°F | 5.1 | 6.0 | 5.3 | 5.2 |
| Sp. Gr. of 650°F− @ 60°F | 1.0359 | 1.0291 | 1.0344 | 1.0351 |
| °API of 650°F+ @ 60°F | -10.6 | -8.0 | -6.4 | -10.9 |
| Sp. Gr. of 650°F+ @60°F | 1.1704 | 1.1456 | 1.1312 | 1.1733 |
| $C_3$-, Mole % | | | | |
| $H_2$ | 49.4 | 35.8 | 47.8 | 47.6 |
| $C_1$ | 19.3 | 13.2 | 18.2 | 18.7 |
| $C_2$ (total) | 14.1 | 13.9 | 14.5 | 14.6 |
| $C_3$ Olefins | 12.4 | 27.1 | 14.0 | 13.2 |
| $C_3$ | 4.8 | 10.0 | 5.5 | 5.9 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| $C_4$, Vol-% | | | | |
| $C_4$ Olefins | 54.9 | 56.1 | 56.3 | 51.7 |
| i-$C_4$ | 30.4 | 26.9 | 27.8 | 35.1 |
| n-$C_4$ | 14.7 | 17.0 | 15.9 | 15.2 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| $C_5$, Vol-% | | | | |
| $C_5$ Olefins | 49.7 | 56.3 | 51.9 | 57.5 |
| i-$C_5$ | 44.7 | 35.1 | 42.4 | 37.6 |
| n-$C_5$ | 5.6 | 4.6 | 5.7 | 4.9 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

Table 30

Fluid Catalytic Cracking of Hydrotreated H-Coal Gas Oil 3531-25
Plant 593, Run 255

| Test No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Operating Conditions | | | | | |
| P-P (base), psig | -10 | -10 | -10 | -10 | -10 |
| T-T (base), °C | 3 | 3 | 1 | 3 | 5 |
| [Cat./Oil / Cat./Oil (base)] | 1.03 | 1.14 | 1.14 | 1.12 | 1.56 |
| Conversion, Vol-% | 66.0 | 64.2 | 62.9 | 62.6 | 64.4 |
| Product Distribution, Wt-% | | | | | |
| $C_3$- | 8.0 | 6.5 | 6.4 | 6.4 | 6.7 |
| $C_4$ | 6.8 | 5.5 | 5.4 | 5.8 | 4.2 |
| $C_5$ | 4.1 | 3.7 | 4.1 | 3.7 | 3.2 |
| $C_6$-EP Gasoline | 37.7 | 34.8 | 34.5 | 34.8 | 32.2 |
| Cycle Oil | 36.9 | 38.6 | 40.1 | 40.4 | 38.6 |
| Carbon | 8.5 | 9.6 | 8.9 | 9.2 | 10.7 |
| Wt. Recovery | 102.0 | 98.7 | 99.4 | 100.3 | 95.6 |
| Products, Vol-% | | | | | |
| $C_5$-EP Gasoline | 49.1 | 45.4 | 45.7 | 45.7 | 42.0 |
| Cycle Oil | 34.0 | 35.8 | 37.1 | 37.4 | 35.6 |
| Inspections of $C_5$-EP Gasoline | | | | | |
| °API @ 60°F | 43.1 | 43.7 | 44.1 | 45.2 | 44.0 |
| Sp. Gr. @ 60°F | 0.8104 | 0.8076 | 0.8058 | 0.8008 | 0.8063 |
| Distillation, ASTM D-86 | | | | | |
| IBP, °F | 120 | 121 | 121 | 122 | 130 |
| 5% | 144 | 145 | 148 | 146 | 150 |
| 10% | 157 | 157 | 160 | 159 | 161 |
| 50% | 245 | 244 | 239 | 236 | 230 |
| 90% | 376 | 375 | 361 | 361 | 344 |
| 95% | 398 | 404 | 384 | 382 | 370 |
| EP | 417 | 429 | 422 | 417 | 410 |
| RON, Clear | 96.0 | 95.9 | ←95.5→ | | 96.9 |
| RON, 3 ml TEL/Gallon | 102.4 | 102.3 | ←102.1→ | | 103.2 |
| FIA, Vol-% | | | | | |
| A | 49.9 | 49.5 | 45.2 | 45.4 | 50.7 |
| O | 5.4 | 6.0 | 6.2 | 5.1 | 4.2 |
| P&N | 44.7 | 44.5 | 48.6 | 49.5 | 45.1 |

## Table 30, Cont'd.

| Test No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Properties of Cycle Oil | | | | | |
| °API @ 60°F | 5.1 | 5.7 | 5.5 | 5.9 | 5.1 |
| Sp. Gr. @ 60°F | 1.0359 | 1.0313 | 1.0328 | 1.0298 | 1.0359 |
| Distillation, UOP - No. 1 | | | | | |
| IBP, °F | 438 | 436 | 432 | 430 | 431 |
| 5% | 463 | 462 | 449 | 450 | 450 |
| 10% | 470 | 468 | 462 | 459 | 460 |
| 15% | 476 | 479 | 470 | 466 | 466 |
| % Over at 650°F | 86.0 | 86.0 | 87.0 | 89.0 | 85.0 |
| °API of 650 $°F^-$ @ 60°F | 8.0 | 8.2 | 7.8 | 7.9 | 7.9 |
| Sp.Gr. of $650°F^-$ @ 60°F | 1.0143 | 1.0129 | 1.0158 | 1.0151 | |
| °API of $650°F^+$ @ 60°F | -8.8 | -6.4 | -5.7 | -6.7 | -7.1 |
| Sp. Gr. of 650 $°F^+$ @ 60°F | 1.1532 | 1.1313 | 1.1377 | 1.1334 | 1.1377 |
| $C_3$-, Mole % | | | | | |
| $H_2$ | 25.2 | 30.5 | 32.0 | 29.6 | 32.4 |
| $C_1$ | 13.7 | 13.6 | 11.2 | 11.1 | 13.8 |
| $C_2$ (total) | 16.4 | 15.4 | 15.1 | 15.4 | 16.2 |
| $C_3$ Olefins | 27.6 | 25.0 | 25.5 | 27.3 | 21.8 |
| $C_3$ | 17.1 | 15.6 | 16.2 | 16.6 | 15.8 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| $C_4$, Vol-% | | | | | |
| $C_4$ Olefins | 29.5 | 30.9 | 27.1 | 29.1 | 26.2 |
| $\underline{i}$-$C_4$ | 48.4 | 47.0 | 50.1 | 49.6 | 52.4 |
| $\underline{n}$-$C_4$ | 22.1 | 22.2 | 22.8 | 21.3 | 21.4 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| $C_5$, Vol-% | | | | | |
| $C_5$ Olefins | 12.2 | 13.3 | 15.2 | 15.3 | 15.9 |
| $\underline{i}$-$C_5$ | 80.5 | 78.3 | 77.3 | 77.4 | 75.4 |
| $\underline{n}$-$C_5$ | 7.3 | 8.4 | 7.5 | 7.3 | 8.7 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Table 31

Fluid Catalytic Cracking of Hydrotreated H-Coal Gas Oil 3531-25
Plant 593, Run 258

| Test No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Operating Conditions | | | | | |
| P-P (base), psig | -10 | -10 | -10 | -10 | -10 |
| T-T (base), °C | 28 | 26 | 26 | 33 | 2 |
| $\left[\frac{\text{Cat./Oil}}{\text{Cat./Oil(base)}}\right]$ | 1.34 | 1.44 | 1.48 | 1.62 | 1.04 |
| Conversion, Vol-% | 64.6 | 63.2 | 63.6 | 63.7 | 62.4 |
| Product Distribution, Wt-% | | | | | |
| $C_3$- | 11.6 | 8.3 | 12.4 | 10.6 | 7.7 |
| $C_4$ | 8.4 | 6.1 | 8.0 | 7.0 | 5.9 |
| $C_5$ | 4.4 | 4.3 | 4.5 | 4.7 | 5.4 |
| $C_6$-EP Gasoline | 34.1 | 30.5 | 30.7 | 31.1 | 33.6 |
| Cycle Oil | 38.6 | 40.3 | 39.7 | 39.7 | 40.6 |
| Carbon | 8.1 | 8.8 | 10.1 | 9.3 | 7.5 |
| Wt. Recovery | 105.2 | 98.3 | 105.4 | 102.4 | 100.7 |
| Products, Vol-% | | | | | |
| $C_5$-EP Gasoline | 45.6 | 41.2 | 41.8 | 42.4 | 46.5 |
| Cycle Oil | 35.4 | 36.8 | 36.4 | 36.3 | 37.6 |
| Inspections of $C_5$-EP Gasoline | | | | | |
| °API @ 60°F | 44.1 | 45.1 | 44.3 | 44.2 | 45.3 |
| Sp. Gr. @ 60°F | 0.8058 | 0.8012 | 0.8049 | 0.8054 | 0.8003 |
| Distillation, ASTM D-86 | | | | | |
| IBP, °F | 110 | 110 | 107 | 101 | 106 |
| 5% | 128 | 132 | 134 | 132 | 130 |
| 10% | 139 | 145 | 149 | 148 | 143 |
| 50% | 227 | 224 | 229 | 228 | 229 |
| 90% | 352 | 336 | 335 | 335 | 360 |
| 95% | 379 | 364 | 362 | 365 | 389 |
| EP | 415 | 404 | 400 | 414 | 410 |
| RON, Clear | ←97.8→ | | ←98.8→ | | 96.2 |
| RON, 3 ml TEL/Gallon | ←103.9→ | | ←104.4→ | | 102.1 |
| FIA, Vol-% | | | | | |
| A | 52.4 | 54.3 | 55.9 | 57.3 | 44.2 |
| O | 5.5 | 4.6 | 4.6 | 5.0 | 5.1 |
| P&N | 42.1 | 41.1 | 39.5 | 37.7 | 50.7 |

Table 31, Cont'd.

| Test No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Properties of Cycle Oil | | | | | |
| °API @ 60°F | 4.4 | 4.1 | 4.7 | 3.8 | 5.8 |
| Sp. Gr. @ 60°F | 1.0412 | 1.0435 | 1.0389 | 1.0458 | 1.0306 |
| Distillation, UOP - No. 1 | | | | | |
| IBP, °F | 435 | 427 | 432 | 428 | 442 |
| 5% | 454 | 448 | 442 | 452 | 459 |
| 10% | 462 | 457 | 452 | 460 | 465 |
| 15% | 468 | 467 | 459 | 473 | 471 |
| % Over at 650°F | 85.0 | 85.0 | 87.0 | 86.0 | 89.0 |
| °API of 650°F− @ 60°F | 7.4 | 7.2 | 7.1 | 6.5 | 8.0 |
| Sp. Gr. of 650°F− @ 60°F | 1.0187 | 1.0202 | 1.0209 | 1.0254 | 1.0143 |
| °API of 650°F+ @ 60°F | -9.9 | -10.9 | -7.3 | -8.9 | -8.3 |
| Sp. Gr. of 650°F+ @ 60°F | 1.1637 | 1.1733 | 1.1390 | 1.1542 | 1.1485 |
| $C_3^-$, Mole % | | | | | |
| $H_2$ | 46.7 | 41.9 | 38.3 | 30.9 | 38.6 |
| $C_1$ | 11.5 | 13.6 | 14.3 | 17.2 | 10.2 |
| $C_2$ (total) | 11.7 | 13.6 | 15.2 | 17.2 | 14.1 |
| $C_3$ Olefins | 18.2 | 18.1 | 19.0 | 20.7 | 23.7 |
| $C_3$ | 11.9 | 12.8 | 13.2 | 14.0 | 13.4 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| $C_4$, Vol-% | | | | | |
| $C_4$ Olefins | 28.7 | 28.7 | 26.3 | 25.2 | 31.1 |
| i-$C_4$ | 51.2 | 49.3 | 52.1 | 68.0 | 63.1 |
| n-$C_4$ | 20.1 | 22.0 | 21.6 | 6.8 | 5.8 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| $C_5$, Vol-% | | | | | |
| $C_5$ Olefins | 22.9 | 21.6 | 23.5 | 25.2 | 31.1 |
| i-$C_5$ | 70.1 | 71.1 | 69.4 | 68.0 | 63.1 |
| n-$C_5$ | 7.0 | 7.3 | 7.1 | 6.8 | 5.6 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Table 32

Fluid Catalytic Cracking of Hydrotreated H-Coal Gas Oil 3531-27
Plant 593, Run 257

| Test No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Operating Conditions | | | | |
| P-P (base), psig | -10 | -10 | -10 | -10 |
| T-T (base), °C | 10 | 5 | 9 | 1 |
| [Cat./Oil / Cat./Oil (base)] | 1.07 | 1.02 | 1.45 | 1.02 |
| Conversion, Vol-% | 82.9 | 82.9 | 83.3 | 83.0 |
| Product Distribution, Wt-% | | | | |
| $C_3$- | 9.6 | 7.7 | 11.4 | 7.3 |
| $C_4$ | 11.0 | 10.6 | 12.0 | 9.2 |
| $C_5$ | 9.0 | 9.0 | 8.8 | 7.5 |
| $C_6$-EP Gasoline | 45.5 | 46.6 | 44.3 | 44.2 |
| Cycle Oil | 19.1 | 18.9 | 18.4 | 18.8 |
| Carbon | 6.3 | 4.5 | 8.1 | 7.4 |
| Wt. Recovery | 100.5 | 97.3 | 103.1 | 94.4 |
| Products, Vol-% | | | | |
| $C_5$-EP Gasoline | 62.2 | 63.8 | 61.1 | 59.1 |
| Cycle Oil | 17.1 | 17.1 | 16.7 | 17.0 |
| Inspections of $C_5$-EP Gasoline | | | | |
| °API @ 60°F | 52.3 | 53.2 | 53.1 | 52.1 |
| Sp. Gr. @ 60°F | 0.7699 | 0.7661 | 0.7665 | 0.7707 |
| Distillation, ASTM D-86 | | | | |
| IBP, °F | 104 | 104 | 108 | 114 |
| 5% | 122 | 122 | 124 | 134 |
| 10% | 134 | 133 | 135 | 143 |
| 50% | 215 | 211 | 212 | 217 |
| 90% | 350 | 343 | 340 | 346 |
| 95% | 375 | 372 | 367 | 372 |
| EP | 400 | 402 | 417 | 419 |
| RON, Clear | 93.4 | 92.1 | 92.5 | 92.0 |
| RON, 3 ml TEL/Gallon | 100.4 | 100.2 | 99.7 | 99.7 |
| FIA, Vol-% | | | | |
| A | 33.9 | 30.3 | 31.8 | 34.0 |
| O | 5.1 | 5.8 | 5.6 | 6.1 |
| P&N | 61.0 | 63.9 | 62.6 | 59.9 |

Table 32, Cont'd.

| Test No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Properties of Cycle Oil | | | | |
| °API @ 60°F | 12.9 | 13.3 | 14.0 | 14.0 |
| Sp. Gr. @ 60°F | 0.9799 | 0.9772 | 0.9725 | 0.9725 |
| Distillation, UOP - No. 1 | | | | |
| IBP, °F | 208 | 433 | 430 | 420 |
| 5% | 440 | 447 | 441 | 441 |
| 10% | 452 | 453 | 447 | 450 |
| 15% | 462 | 460 | 454 | 458 |
| % Over at 650°F | 92.0 | 93.0 | 94.0 | 93.0 |
| °API of 650°F$^-$ @ 60°F | 14.9 | 15.5 | 16.0 | 16.2 |
| Sp. Gr. of 650°F$^-$ @ 60°F | 0.9665 | 0.9626 | 0.9593 | 0.9580 |
| °API of 650°F$^+$ @ 60°F | -6.4 | -7.6 | -8.1 | -6.6 |
| Sp. Gr. of 650 °F$^+$ @ 60°F | 1.1309 | 1.1423 | 1.1457 | 1.1329 |
| $C_3$-, Mole % | | | | |
| $H_2$ | 28.4 | 25.7 | 39.7 | 40.9 |
| $C_1$ | 11.8 | 9.6 | 9.8 | 8.9 |
| $C_2$ (total) | 14.9 | 14.2 | 11.0 | 10.0 |
| $C_3$ Olefins | 26.3 | 30.0 | 23.1 | 23.4 |
| $C_3$ | 18.6 | 20.5 | 16.4 | 16.8 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| $C_4$, Vol-% | | | | |
| $C_4$ Olefins | 21.7 | 21.9 | 20.7 | 21.1 |
| $\underline{i}$-$C_4$ | 59.3 | 58.4 | 60.9 | 61.7 |
| $\underline{n}$-$C_4$ | 19.0 | 19.7 | 18.4 | 17.2 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| $C_5$, Vol-% | | | | |
| $C_5$ Olefins | 12.9 | 12.2 | 15.7 | 14.9 |
| $\underline{i}$-$C_5$ | 79.2 | 80.4 | 76.6 | 76.9 |
| $\underline{n}$-$C_5$ | 7.9 | 7.4 | 7.7 | 8.2 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

Table 33

Fluid Catalytic Cracking of Hydrotreated H-Coal Gas Oil 3531-27
Plant 593, Run 259

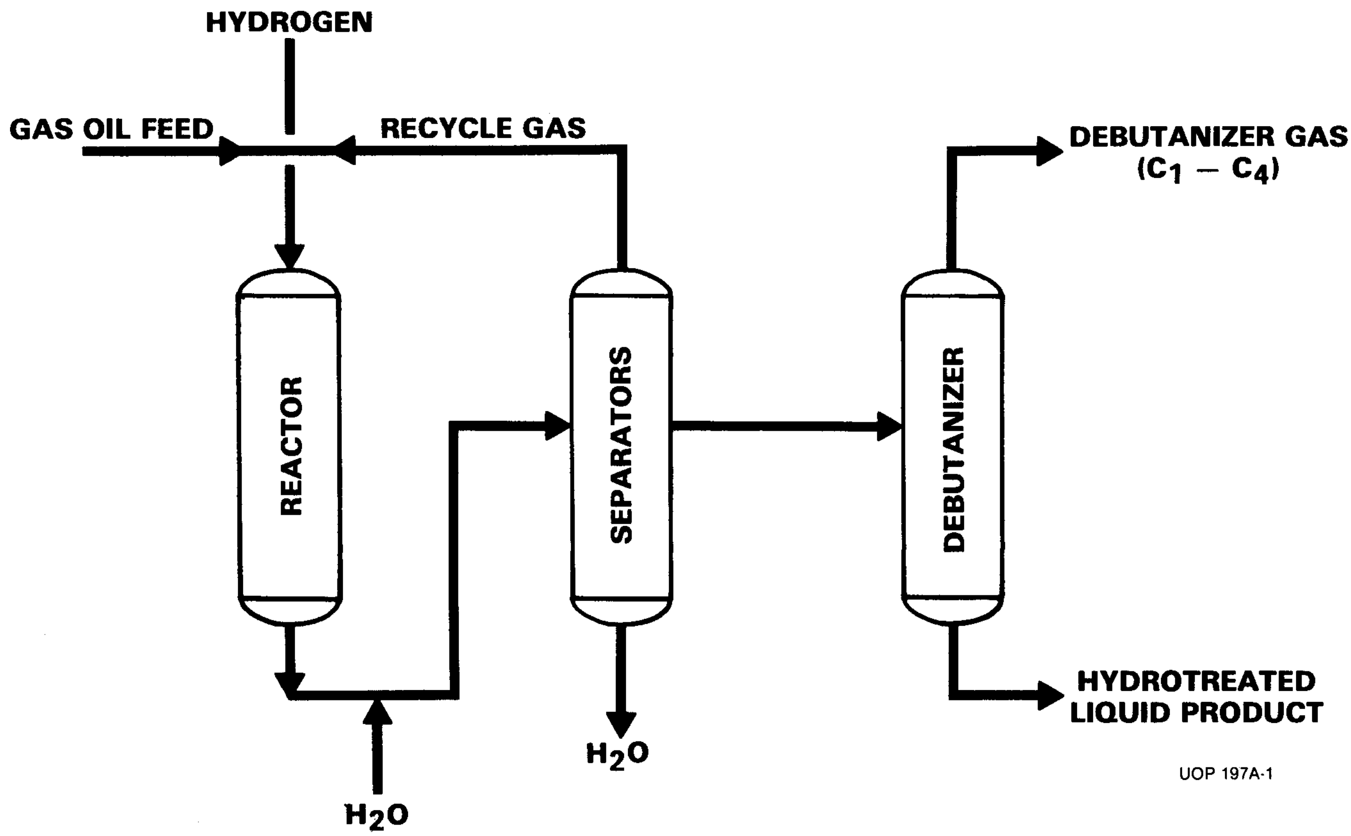
| Test No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Operating Conditions | | | | |
| P-P (base), psig | -10 | -10 | -10 | -10 |
| T-T (base), °C | 35 | 25 | 31 | 31 |
| $\left[\frac{\text{Cat./Oil}}{\text{Cat./Oil (base)}}\right]$ | 1.61 | 1.53 | 1.54 | 1.35 |
| Conversion, Vol-% | 85.5 | 85.6 | 85.5 | 83.4 |
| Product Distribution, Wt-% | | | | |
| $C_3$- | 13.1 | 9.0 | 14.4 | 9.9 |
| $C_4$ | 12.3 | 5.2 | 13.1 | 7.8 |
| $C_5$ | 9.0 | 8.7 | 9.2 | 8.4 |
| $C_6$-EP Gasoline | 41.0 | 40.3 | 40.7 | 41.5 |
| Cycle Oil | 16.3 | 16.2 | 16.3 | 18.5 |
| Carbon | 6.0 | 7.6 | 6.9 | 5.8 |
| Wt. Recovery | 97.7 | 87.0 | 100.6 | 92.0 |
| Products, Vol-% | | | | |
| $C_5$-EP Gasoline | 56.8 | 55.7 | 56.5 | 56.7 |
| Cycle Oil | 14.5 | 14.4 | 14.5 | 16.6 |
| Inspections of $C_5$-EP Gasoline | | | | |
| °API @ 60°F | 52.3 | 52.1 | 52.0 | 51.2 |
| Sp. Gr. @ 60°F | 0.7699 | 0.7707 | 0.7711 | 0.7745 |
| Distillation, ASTM D-86 | | | | |
| IBP, °F | 102 | 104 | 100 | 108 |
| 5% | 116 | 120 | 118 | 125 |
| 10% | 126 | 130 | 127 | 135 |
| 50% | 210 | 215 | 210 | 217 |
| 90% | 337 | 343 | 342 | 351 |
| 95% | 364 | 378 | 371 | 387 |
| EP | 415 | 429 | 428 | 417 |
| RON, Clear | 96.3 | 96.1 | 96.2 | 95.1 |
| RON, 3 ml TEL/Gallon | 102.4 | 102.3 | 102.3 | 101.8 |
| FIA, Vol-% | | | | |
| A | 38.8 | 39.8 | 37.1 | 39.9 |
| O | 7.7 | 7.0 | 8.4 | 8.5 |
| P&N | 53.5 | 53.2 | 54.5 | 51.6 |

## Table 33, Cont'd.

| Test. No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Properties of Cycle Oil | | | | |
| °API @ 60°F | ← 11.0 → | | ← 11.9 → | |
| Sp. Gr. @ 60°F | ← 0.9930 → | | ← 0.9868 → | |
| Distillation, UOP - No. 1 | | | | |
| IBP, °F | ← 411 → | | ← 440 → | |
| 5% | ← 441 → | | ← 448 → | |
| 10% | ← 449 → | | ← 458 → | |
| 15% | ← 457 → | | ← 463 → | |
| % Over at 650°F | ← 91.0 → | | ← 91.0 → | |
| °API of 650°F$^-$ @ 60°F | ← 13.6 → | | ← 14.5 → | |
| Sp. Gr. of 650°F @ 60°F | ← 0.9752 → | | ← 0.9692 → | |
| °API of 650°F$^+$ @ 60°F | ← -8.1 → | | ← -7.0 → | |
| Sp. Gr. of 650°F @ 60°F | ← 1.1467 → | | ← 1.1365 → | |
| $C_3$-, Mole % | | | | |
| $H_2$ | 26.8 | 35.8 | 31.4 | 31.2 |
| $C_1$ | 14.1 | 17.4 | 13.6 | 14.8 |
| $C_2$ (total) | 15.7 | 15.3 | 14.8 | 15.9 |
| $C_3$ Olefins | 28.4 | 19.1 | 25.3 | 24.9 |
| $C_3$ | 15.0 | 12.4 | 14.9 | 13.2 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| $C_4$, Vol-% | | | | |
| $C_4$ Olefins | 27.9 | 24.9 | 26.9 | 23.7 |
| *i*-$C_4$ | 53.9 | 55.8 | 55.6 | 60.2 |
| *n*-$C_4$ | 18.2 | 19.3 | 17.5 | 16.1 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| $C_5$, Vol-% | | | | |
| $C_5$ Olefins | 15.9 | 17.1 | 16.8 | 20.3 |
| *i*-$C_5$ | 75.6 | 74.9 | 74.8 | 72.0 |
| *n*-$C_5$ | 8.5 | 8.0 | 8.4 | 7.7 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

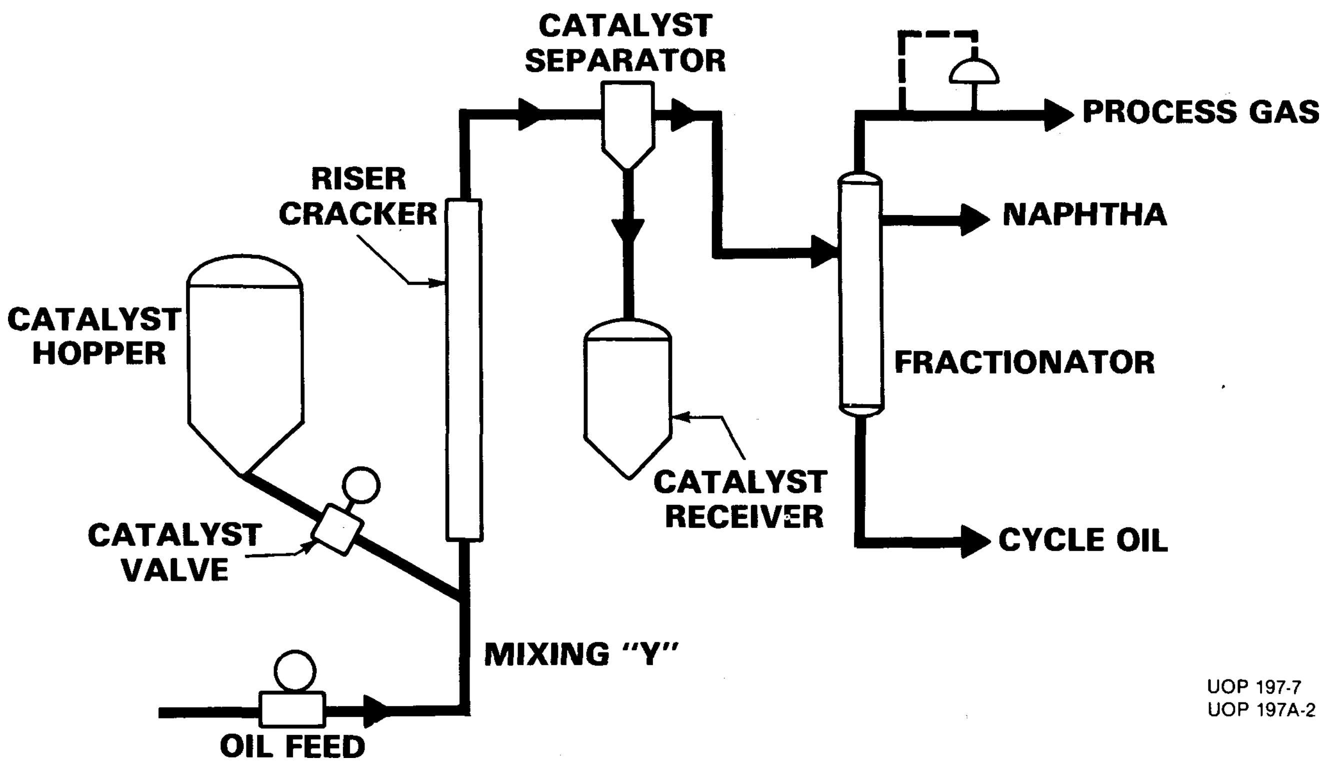
**FIGURE 1**

# GAS OIL HYDROTREATING PLANT



## FIGURE 2

# SMALL SCALE FLUID CATALYTIC CRACKER



## FIGURE 3

# PREPARATION OF H-COAL DERIVED FCC FEEDSTOCKS

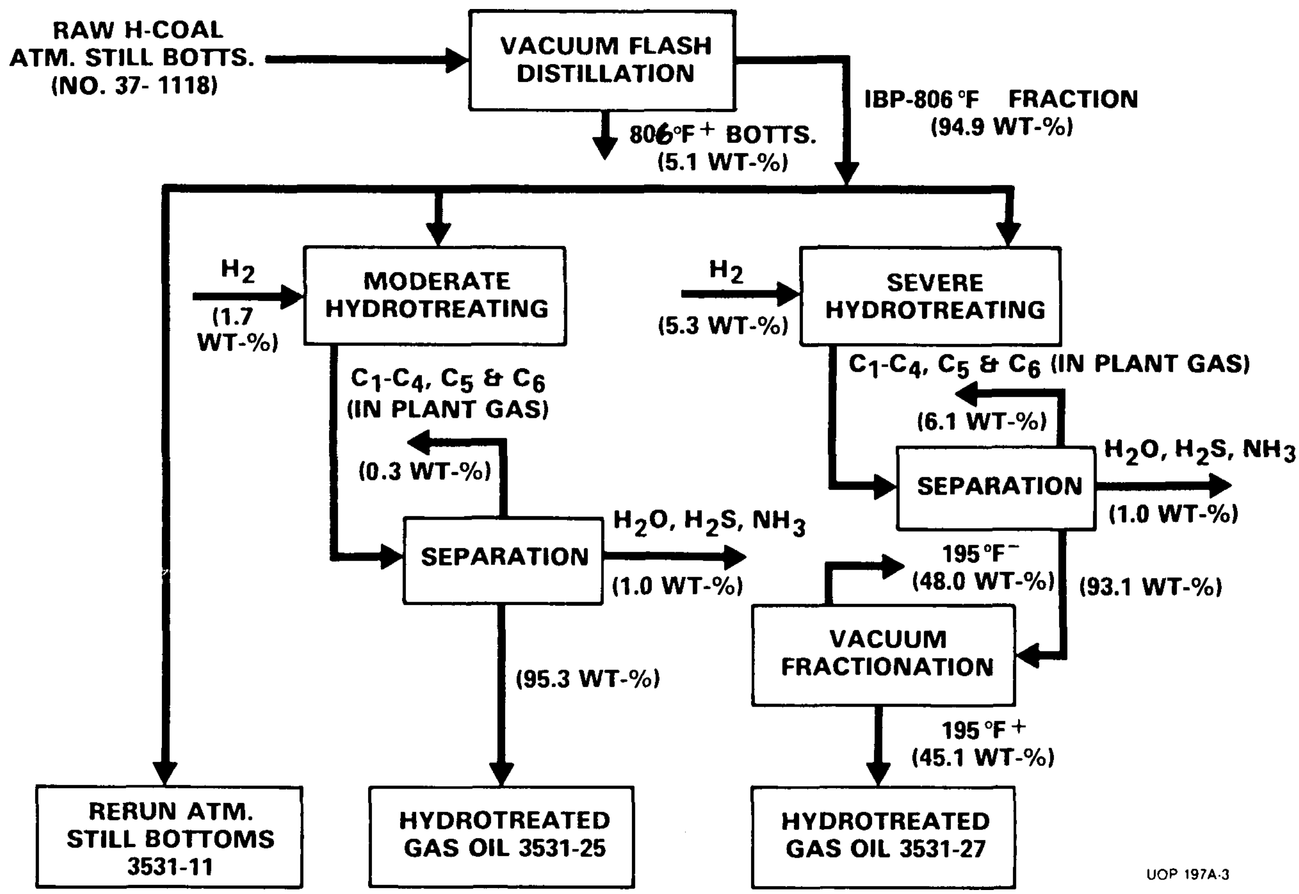


FIGURE 4

# TEMPERATURE vs. PRODUCT HYDROGEN CONTENT HYDROTREATING RERUN H-COAL ATMOSPHERIC STILL BOTTOMS 3531-11

**PLANT 601, RUN 758**

**P-P (BASE), PSIG: 0**

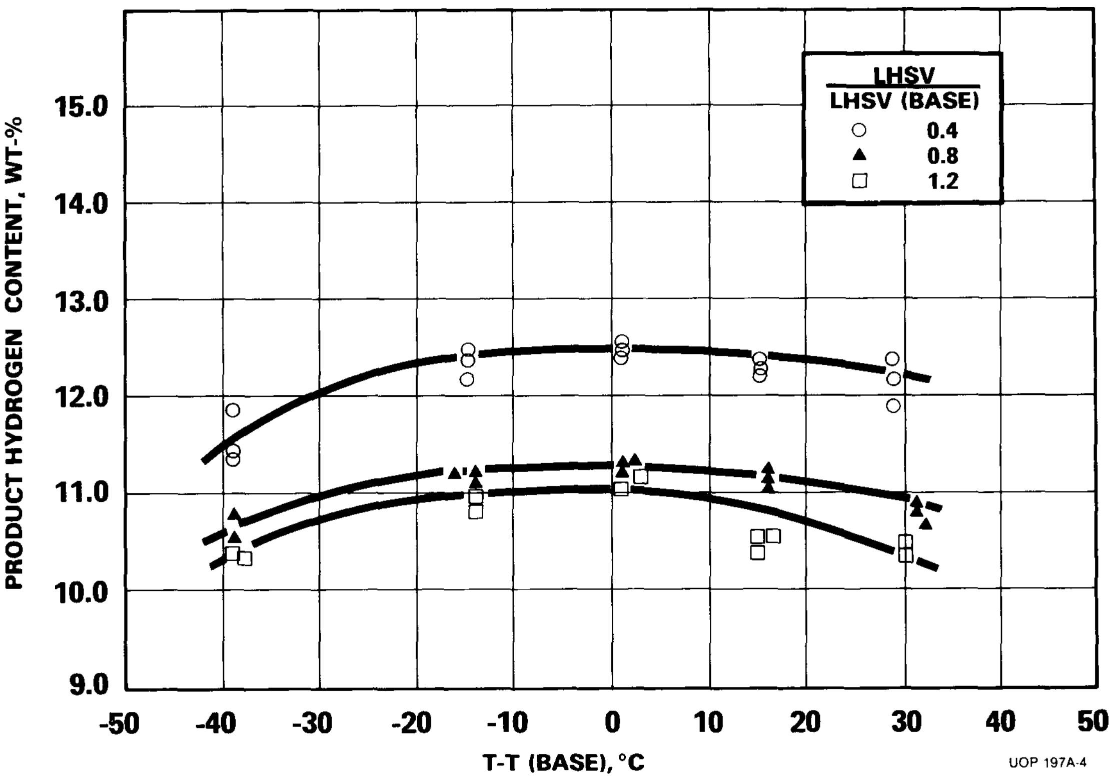
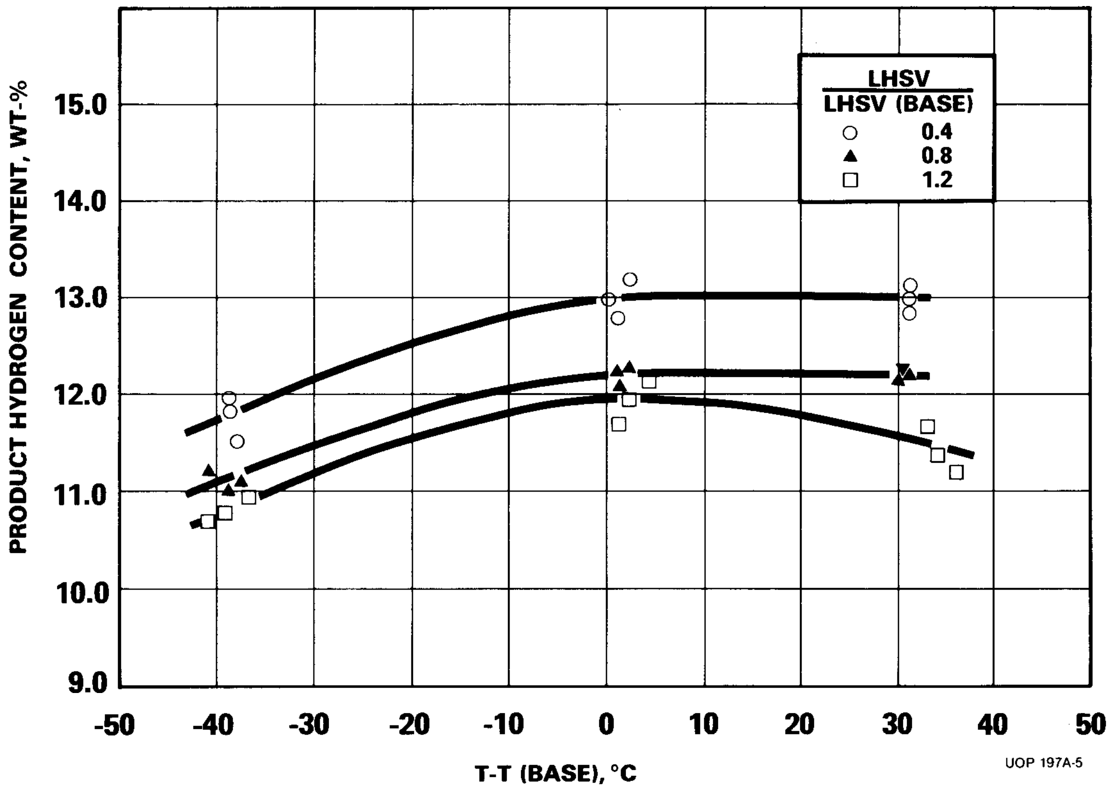


**FIGURE 5**

# TEMPERATURE vs. PRODUCT HYDROGEN CONTENT HYDROTREATING RERUN H-COAL ATMOSPHERIC STILL BOTTOMS 3531-11

**PLANT 601, RUN 759**

**P-P (BASE), PSIG: 500**



## FIGURE 6

# HYDROGEN UPTAKE vs. PRODUCT AROMATIC CONTENT HYDROTREATING RERUN H-COAL ATMOSPHERIC STILL BOTTOMS 3531-11

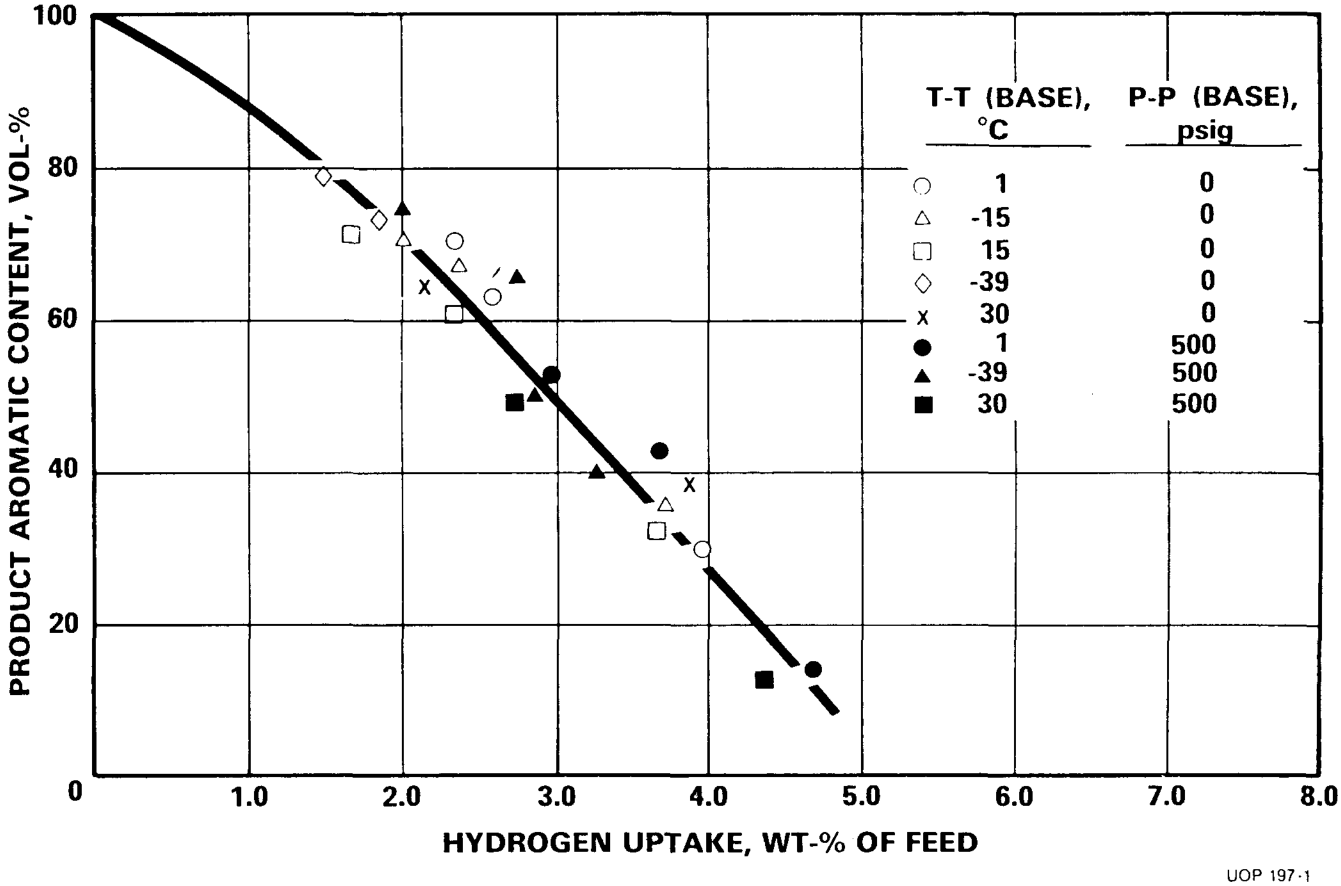
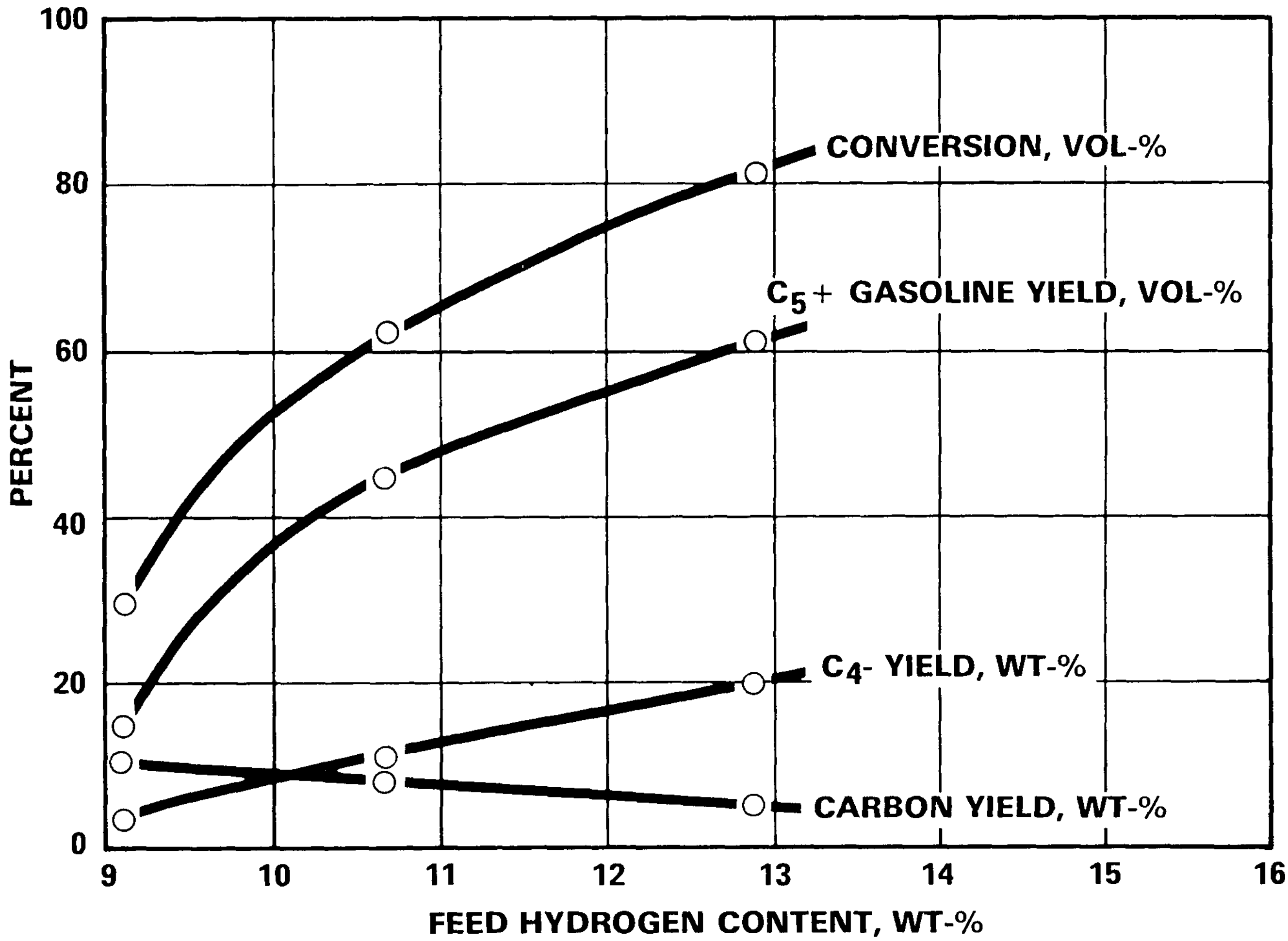


FIGURE 7

# EFFECT OF FEEDSTOCK HYDROGEN CONTENT ON RESPONSE TO FLUID CATALYTIC CRACKING

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