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CHEMICALS FROM COAL

Interim Report
for
FMC Corporation
COED Pyrolysis Process
Western Kentucky Syncrude

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ABSTRACT

This document contains the results of an investigation to determine the suitability of the FMC COED Pyrolysis Process Western Kentucky Syncrude as a petrochemical feedstock. A sample of the whole crude was distilled into four straight run fractions; IBP-350°F naphtha, 350-650°F mid-distillate, 650-850°F gas oil, and 850-FBP°F resid. Laboratory studies in metal reactors and computer and mathematical simulations were performed to provide overall material balance data for a conceptual plant. The naphtha was subjected to hydrotreating and reforming studies. The mid-distillate was hydrocracked to produce more naphtha which was further processed by hydrotreating and reforming. The gas oil was hydrocracked to produce more hydrocrackate naphtha which was mathematically hydrotreated and reformed. Steam coil cracking of the various naphtha and mid-distillate fractions was also performed to evaluate their potential as feedstocks for direct olefin production. None of the fractions surveyed was very attractive as an ethylene cracker feed. The reformate from each of the three distillates was then mathematically hydrodealkylated so that each fraction was converted to a product slate consisting of methane, LPG's, benzene, and fuel, along with the total hydrogen consumed. The value of the products obtained per 100 pounds of each distillate was $10.43, $7.29, and $7.12 for the naphtha, mid-distillate, and gas oil respectively. Based on these values, the gas oil was concluded to be economically unattractive as a petrochemical feedstock. The high aromatic yield obtained from the straight run and hydrocrackate naphthas, however, make these fractions very attractive as petrochemical feedstocks.

SUMMARY

The data presented herein was obtained from processing studies on a sample of FMC Corporation COED Western Kentucky Syncrude under contract with the United States Energy Research and Development Administration. The experimental work was done in the Hydrocarbons and Energy Research Laboratory of The Dow Chemical Company in Midland, Michigan. Included in this report is the data from laboratory inspections using hydroprocessing operations on three of the fractions distilled from the COED whole crude. A sample of the whole crude was distilled into four straight run fractions, whose boiling range and elemental composition are listed in Table 1.

TABLE 1

BOILING RANGE AND ELEMENTAL COMPOSITION OF COED STRAIGHT RUN FRACTIONS

	A-1 NAPHTHA IBP-350°F	A-2 MID-DISTILLATE 350-650°F	A-3 GAS OIL 650-850°F	A-4 RESID 850°F+
WT. % OF CRUDE	22.4	46.2	27.8	3.6
API GRAVITY, 60°F	44.5	20.7	12.0	
ELEMENTAL COMPOSITION				
C wt. %	86.6	88.3	89.0	89.3
H wt. %	13.0	11.2	10.7	10.7
O ppm	3420	3620	2460	NA
N ppm	560	1600	900	NA
S ppm	49	55	90	NA
BOILING RANGE, OF				
IBP	97	364	217	NA
10 wt. %	144	434	663	NA
20 wt. %	219	468	693	NA
30 wt. %	230	499	712	NA
40 wt. %	257	525	731	NA
50 wt. %	280	555	750	NA
60 wt. %	298	581	769	NA
70 wt. %	325	611	790	NA
80 wt. %	345	637	811	NA
90 wt. %	367	671	835	NA

The straight run mid-distillate was hydrocracked over Harshaw HT-400 E cobalt molybdenum catalyst. This catalyst was chosen for its neutral alumina support and its resistance to deactivation by nitrogen, oxygen, and sulfur in the feed. A higher ratio of normal/iso paraffins was also expected from this catalyst. Operating conditions of 1500-2500 psig and 850-1000°F with LHSV's of 0.3 and 0.7 were surveyed. The naphtha created from hydrocracking the mid-distillate was distilled off and the unconverted mid-distillate was hydrocracked a second time. Nominal requirements for 60% conversion to C_1-C_9 were 2500 psig, 940°F, and 0.7 LHSV.

The straight run gas oil was hydrocracked over the same catalyst. Only two acceptable runs were completed due to solids in the oil which plugged the check valves on the pump and the small amount of material available. Operating conditions of 2500 psig, 850°F, and a LHSV of 1.23 and 2500 psig, 932°F, and a LHSV of 1.45 were surveyed, with 57.2 and 77.9% conversion to 650°F minus respectively.

Both the straight run naphtha and the combined naphthas from two-pass hydrocracking the straight run mid-distillate were hydrotreated over Harshaw HT-100 E nickel molybdenum catalyst. This catalyst was chosen for its resistance to deactivation by heteroatoms in the feed and for its superior activity for denitrogenation. The straight run data is sketchy, due to a large extent to analytical and presulfiding technique difficulties. Sulfur, nitrogen, and oxygen were reduced to 2, 6, and 470 ppm respectively in two passes. The hydrocrackate naphtha was hydrotreated in one pass. Nitrogen in the feed to the hydrotreater was less than 1 ppm due to removal during hydrocracking. Sulfur was reduced from 40 to 1 ppm and oxygen remained at the 450 ppm level, achieved during hydrocracking.

The hydrotreated straight run and hydrocrackate naphthas were reformed over Cyanamid Aeroform® PHF-4 platinium chloride catalyst. This catalyst was chosen as a typical example of a readily available bifunctional reforming catalyst. At 250 psig and 950-960°F, the catalyst life was very short, as the straight run naphtha rapidly coked the catalyst. Naphthene conversion dropped from 98% to 83% in 100 hours. At 500 psig and 968°F, the hydrocrackate naphtha was reformed with a substantial increase in catalyst life. With a first day conversion of 93%, after 100 hours, the naphthene conversion was still at 89%.

Steam coil cracking experiments were conducted on the straight run and hydrocrackate mid-distillate and naphtha fractions to evaluate their potential as ethylene feedstocks. Due to the high aromatic content of these feedstocks, coke lay down in the reactor was a significant problem. None of the fractions surveyed was particularly attractive as feedstock for direct olefin production.

In addition to the hydroprocessing studies, each fraction was subjected to mathematical recycle hydrocracking to naphtha, hydrotreating, reforming, and hydroalkylation (HDA). As a result, each fraction was converted to methane, LPG's, benzene, and liquid fuel and the hydrogen required was also calculated. From this data, presented in Table 2, the relative value of each fraction was determined.

TABLE 2

PRODUCT PATTERNS AND VALUE FOR COED STRAIGHT RUN FRACTIONS

	STRAIGHT RUN NAPHTHA IBP-350°F	STRAIGHT RUN MID-DISTILLATE 350-650°F	STRAIGHT RUN GAS OIL 650-850°F
Processing Sequence	Hydrotreat	Recycle Hydrocrack	Recycle Hydrocrac Gas Oil
	Reform	Hydrotreat	Recycle Hydrocrac Mid-Distillate
	HDA	Reform	Hydrotreat
		HDA	Reform
			HDA
PRODUCT PATTERN, Wt. %			
HYDROGEN	-0.9	-6.3	-7.8
METHANE	20.4	20.0	22.9
LPG	20.2	53.3	52.7
BENZENE	53.5	31.4	30.8
LIQUID FUEL	6.8	1.4	1.3
VALUE/100 lb DISTILLATE (1980)	$10.43	$7.29	$7.12

Based on the yield data calculated for each fraction and the wt. % of each fraction from distillation, a mass balance for a conceptual plant operating on 100.00 lb/hr COED whole crude was calculated. With the flow rates and compositions of key streams known, the preliminary estimate for capital requirements and operating costs could be made. Only the naphtha and mid-distillate fractions were included in this balance, since the gas oil fraction was concluded to be economically unattractive as a petrochemical feedstock. The 46.2 lb/hr straight run mid-distillate was recycle hydrocracked mathematically, consuming 2.49 lb/hr hydrogen and producing 4.46 lb/hr methane, 16.48 lb/hr LPG's and 27.6 lb/hr naphtha. The straight run and hydrocrackate naphthas, 22.4 and 27.6 lb/hr respectively, were hydrotreated mathematically, consuming 0.19 lb/hr hydrogen and producing 3.67 lb/hr gas. The hydrotreated naphtha was then reformed, producing 1.04 lb/hr hydrogen, 5.14 lb/hr gas and 40.34 lb/hr reformate. An in house mathematical model for hydrodealkylation was used to convert the reformate to 8.56 lb/hr methane, 4.30 lb/hr ethane, 26.38 lb/hr benzene, and 2.15 lb/hr liquid fuel, while consuming 1.44 lb/hr hydrogen. With hydrogen needs met by converting part of the methane to hydrogen in an oil fired methane reformer, overall yields from the conceptual plant in pounds per 100 pounds of crude are presented in Table 3.

TABLE 3

OVERALL YIELD FROM CONCEPTUAL PLANT USING COED WHOLE CRUDE AS FEEDSTOCK

Yield, lb/100 lb crude

Methane	7.34
LPG's	28.96
34.94 wt. % ethane	
26.37 wt. % propane	
23.05 wt. % butanes	normal/iso = 3.7
15.64 wt. % pentanes	normal/iso = 1.3
Benzene	26.38
Fuel (HDA)	2.15
Fuel (Gas Oil)	31.40 (no allowance for plant fuel)

PART I - EXPERIMENTAL

Introduction

An increasing awareness of the energy crisis now facing the United States has prompted many to seriously consider the status of our fossil fuel resources and the factors shaping their future use patterns. The current situation with respect to gas and oil is worsening rapidly. Not only has there been a serious reduction of gas found to that which is used, the amount used is consistently greater than that produced. Similarly, oil production has been much less than the amount consumed. The deficit has been made up through increased imports which have compromised the independence of the country. In contrast, coal is the resource with the distinct advantage of long-term availability. It is also the resource with the highest sulfur and ash content, and the most difficult transportation requirements. Despite the problems associated with coal, it becomes clear that its availability warrants the development of schemes for prompt, optimum usage. It is not a question of development for chemical or energy needs but a necessity that both needs be met. In the "crisis" atmosphere related to energy, the dependence of petrochemical requirements on fossil fuels is commonly overlooked since these feedstocks currently comprise a relatively small percentage of total resource consumption. It is apparent, however, that hydrocarbon feedstock demands will continue to rise putting increased pressure on already short supplies. Although social, political, and economic factors may alter the timing of a considerable shift in the use pattern of remaining supplies of fossil fuels, some conclusions can still be reached. Domestic oil and gas supplies will not meet future chemicals demands for hydrocarbons, let alone handle the larger energy needs. Coal, the largest single hydrocarbon resource left, must therefore be developed for future chemicals production needs as a supplement to current coal-to-clean-energy development activities. It was with this in mind that The Dow Chemical Company proposed, and was subsequently granted, a contract by the United States Energy Research and Development Administration (ERDA), to evaluate coal derived liquid products as petrochemical feedstocks.

As stated in the ERDA Contract, the purpose of this research effort was to study the feasibility of using coal liquefaction products for the production of chemicals, with the following work objective:

> To estimate preliminary capital requirements and operating costs for a commercial plant which would use coal liquefaction products for the production of useful aliphatic and aromatic compounds.

In order to limit the scope of this investigation to a manageable size, certain boundary conditions were established prior to the beginning of experimental work. The large quantities of aromatic and saturated cyclic compounds found in coal derived liquids suggested that with appropriate choices in hydroprocessing operations, high yields of benzene should be obtained. Furthermore, if the aliphatic by-products from benzene production could be directed toward normal paraffins, useful olefins might also be produced to supplement the benzene value. It was decided that since this was a preliminary study, it would be limited to using "standard" hydroprocessing operations. No attempts were made to recover or further process the tar acids and bases present in these materials. This program was also limited to the use of only readily available commercial catalysts. It was not anticipated that the data generated from this research effort would be capable of being used to scale-up to commercialization in a single step. Rather, the plan was to produce laboratory data that could be reduced to a form where it would be useful in predicting the behavior of the material as it would exist in the commercial process and therefore form the basis for comparing various liquefaction products. As a final step in satisfying the objective of this contract, this data would provide the overall mass, elemental, and componential information needed to make a preliminary estimate of the capital investment and operating costs for a commercial plant.

Liquefaction Product

The sample of COED subjected to the hydroprocessing experiments was produced in the FMC Corporation pyrolysis process pilot plant. The average net yield of pyrolysis oil, as reported in Char Oil Energy Development Interim Report #5, August 1975, is 17.3% based on dry Western Kentucky Coal. The pyrolysis oil was hydrotreated at the FMC pilot plant, run H-55, prior to delivery. Nominal operating conditions of 2625 psig, 767°F, and 0.27 space velocity were used over a HDS-3/HDS-3A catalyst system and guard chamber during the hydrotreating run. A total of 90.3 wt. percent of the pyrolysis oil charged to the hydrotreater was recovered as syncrude, for an overall yield of 15.6 wt. percent based on dry coal. This syncrude was the liquid which was processed.

Processing Approach

In order to parallel existing processing technology for producing petrochemicals from crude oil, the following processing sequence was followed for all of the samples received:

1) Distillation into nominally three cuts --
   A-1 IBP -350°F (straight run naphtha)
   A-2 350°F-650°F (straight run mid-distillate)
   A-3 650°F-850°F (straight run gas oil - where practicable)

2) Hydrocracking of the mid-distillate and gas oil to produce more naphtha with some LPG's.

3) Hydrotreating of the straight run and hydrocrackate naphthas to remove the heteroatoms.

4) Reforming of the hydrotreated naphthas to produce maximum yields of aromatics.

These steps are shown schematically in Figure 1 and discussed sequentially below.

Distillations were carried out in a 72 liter Podbielniak® Fractioneer A batch distillation unit, instrumented to operate unattended. This still is capable of operating at pressures from 10mm Hg to atmospheric and temperatures up to 350°C.

The remaining three hydroprocessing steps were carried out in three similar reactors. The nominal 1 inch diameter tubular steel reactors were operated continuously in downflow with a fixed catalyst bed varying from 50 to 200 cm^3 in volume. Pressures up to 3000 psi, at 1300°F are attainable with these units. Either of two feed reservoir systems, one an unheated 1 gallon plastic bottle set upon scales and the other a heated 5 gallon tank equipped with a bubbler level indicator, provided a constant feed supply to a metering pump. The liquid product collected from the reactors was weighed periodically. Both hydrogen and vent gas flow rates were measured with calibrated integral orifice flowmeters. The vent gas flowmeter was equipped with a square root integrator to provide a time weighted average rate.

On-line analysis of the hydrocarbons in the vent gas was done on a gas chromatograph with a 20 ft Poropak Q® column using an internal standard method. In many cases, the use of the internal standard also allowed calculation of hydrogen in the vent gas by difference. A Beckman 3AM3 Gas Density Balance was used to provide a check on the vent gas density, needed to calculate mass flow rates from orifice pressure drop data. Mass balance closure for these experiments was typically better than ±2%.

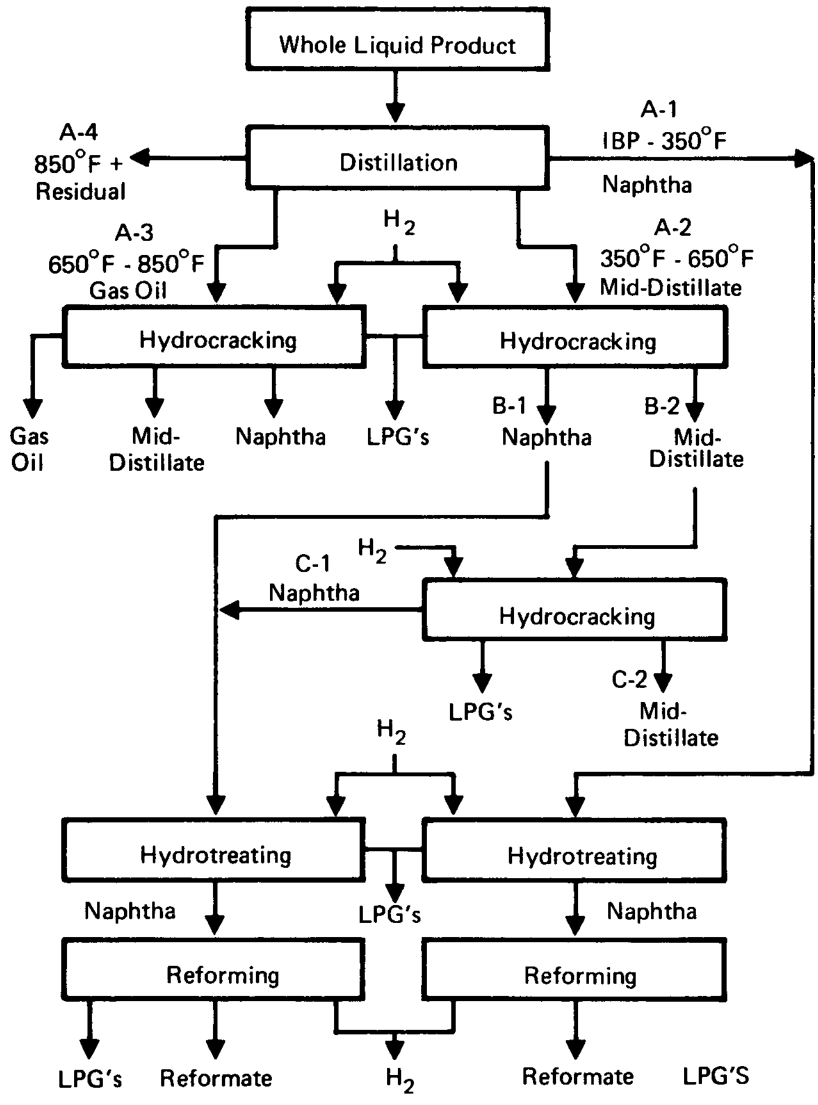
In addition to on-line vent gas analysis, the following analyses were performed on liquid samples as required:

1) Carbon-Hydrogen; Initially, a Perkin Elmer Model 240 CHN analyzer was used which required encapsulation of the volatile liquids in quartz vials. This was later replaced with a Model 1200 Chemical Data Systems Elemental Analyzer.

2) Sulfur; the Dohrmann Oxidative Microcoulemetric method was used.

Figure 1

PROCESSING SEQUENCE



3) Nitrogen; A Dohrmann Microcoulemetric Reactor first being used in the reductive mode was later replaced with an Antek Model 771 Pyroreactor with a chemiluminescent Nitrogen Detector.

4) Oxygen; a Karman Model A711 Neutron Generator was used for neutron activation analysis.

5) Water; an Aquatest I analyzer was used to measure dissolved water in a liquid sample with a coulemetric Karl-Fisher titration.

6) Naphtha Componential; analysis of the C_3-C_9 hydrocarbons was accomplished on a gas chromatograph with a 200 ft Squalane Capillary Column and a Flame Ionization Detector.

7) Simulated Distillations; the boiling range was measured on a gas chromatograph with an 8 ft Bonded Methyl Silicone Column and a Flame Ionization Detector (see ASTM D-2887-73). A simple internal standard variation was employed for non-distillates.

8) Mercury and Gallium; a General Electric TRIGA reactor provides slow neutrons for the neution activation analysis of these metals at the 10 to 50 ppb detection level.

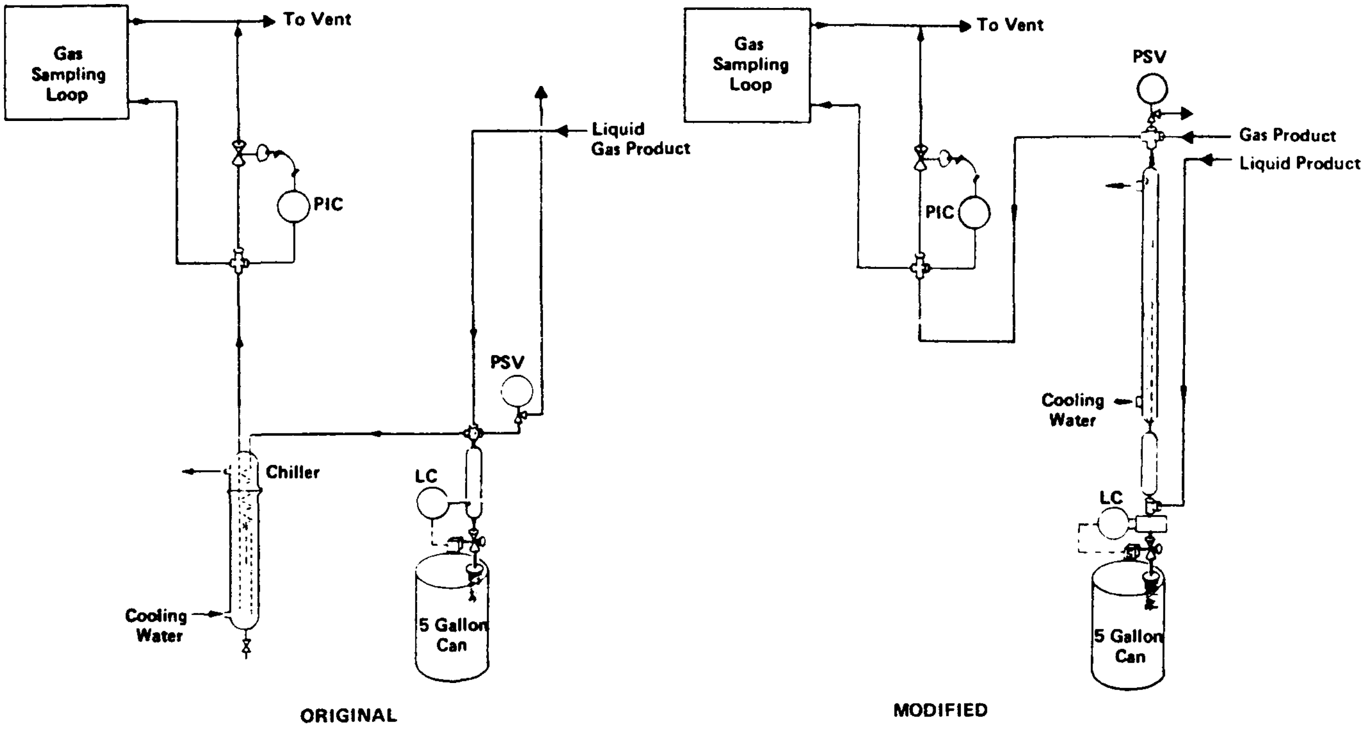
9) Common Metals; standard emission spectroscopy was used for this analysis.

All hydroprocessing experiments were conducted in much the same way. The reactor systems were instrumented to allow for 24 hr operation with only 8 hr per day being attended operation. This led to 24 hr minimum runs. Often, the lag between completion of a run and the corresponding analytical data increased the run time to 48 hours or more. Another important procedure to point out is that since the hydroprocessing steps must occur sequentially, both run data and the feed material for the next series of experiments were created simultaneously. As a result, the composite material produced from one hydroprocessing step, which was carried out at various operating conditions, is not likely to accurately represent material created in a production unit operating at optimum conditions. Differences between experimental and production derived materials will become greater as the processing sequence is followed from start to finish. Since 50 cc of catalyst seemed to be a real minimum catalyst loading, operating at nominal space velocities meant that some 2-1/2 to 5 or more liters of material was required for each run. This allowed for only three to five runs where the amount of some materials was limited.

There were some common problems encountered in all of the hydroprocessing experiments. Early results obtained for sulfur and nitrogen levels with the Dohrmann analyzer are suspect. In addition, early oxygen analyses were also suspect. Elemental balances calculated for oxygen on some of the runs resulted in impossible answers, indicating oxygen being produced during hydroprocessing. Another problem, common to all but the last few hydroprocessing runs, was the stripping of C_5-C_7 hydrocarbons from the liquid product by the vent gas. The mechanical configuration of the product handling system both before and after corrective measures were taken is illustrated in Figure 2 In the original design, the gas and liquid products were recombined after the pressure was reduced. The gas and liquid product was then conveyed via a 1/4 in. tube to the product recovery train. This two-phase flow appears to have been the cause of the large amount of C_5-C_7 in the vent gas. The product recovery train contained a flash vessel where liquid and gas were separated. The gas was then passed through a chiller to remove stripped hydrocarbons. The data would indicate that this chiller was inadequate to perform this operation. In order to alleviate this problem, the product recovery train was modified. An additional line between the reactor and product recovery train was installed so that the liquid and gas products could be transferred separately.

Figure 2

PRODUCT RECOVERY TRAIN



ORIGINAL

MODIFIED

In addition, only the liquid product was routed through the flash vessel. This was done so that any vapor formed by the flash accompanying liquid transfer would be separated. The gas separated in this manner was routed through a new chiller with larger surface area. The results of this modification are illustrated in Table 4. As a result of this problem, the liquids being processed beyond the first hydroprocessing step have artificially low fractions of C_5-C_7 components.

The raw data collected in the hydroprocessing experiments was reduced to a usable form with a series of computer programs. Programs were written for vent gas analysis, naphtha componentials, simulated distillations, elemental balances, and overall mass balances including C_1-C_9 componential yields. Chromatograph data from vent gas and naphtha componential analyses was converted to area percent of each component using a Varian Aerograph Chromatography Data System with a Model No. 220-20D, Class IV computer. The area percent data was in turn used to calculate mole and weight percent of each component using Fortran programs on an IBM 370 computer. In the case of hydrocracking, a sample of the composite material produced was distilled on a spinning band column to a 350°F$^-$ naphtha, which was analyzed componentially, and a 350°F$^+$ fraction. Material balance data from the distillation was used to check conversion of mid-distillates or gas oils to naphtha. No distillations were required for hydrotreating and reforming experiments, as these were all conducted using a naphtha feed. Results from the data reduction sequence are presented in the appendices of this report.

TABLE 4

VENT GAS FLOW RATE AND COMPOSITION

	ORIGINAL Run No. 6-13-3 Flow Rate - 11.86 Composition: G/100G. Feed			MODIFIED Run No. 6-18-2 Flow Rate - 6.18 Composition: G/100G. Feed		
	PARAFFIN	NAPHTHENE	AROMATIC	PARAFFIN	NAPHTHENE	AROMATIC
C_1	.000			.003		
C_2	.014			.004		
C_3	.027			.010		
C_4	.071			.012		
C_5	.334	.186		.078	.007	
C_6	.363	1.611	.991	.238	.870	.461
C_7	.559	1.112	.962	.327	.829	.634

PROCESSING RESULTS

Distillation

The COED whole liquid was distilled, yielding the following fractions:

Straight Run Naphtha - 22.4%
Straight Run Mid-distillate - 46.2%
Straight Run Vacuum Gas Oil - 27.8%
Residual - 3.6%

The physical properties of the COED liquid presented no unexpected problems in the distillation step. Results of analytical scans of the various straight run fractions are presented in Table 5. These fractions were subjected to the hydroprocessing sequence previously described.

Hydrocracking

The COED straight run mid-distillate fraction was single-pass hydrocracked. The first pass product was distilled to a 350°F$^-$ naphtha fraction and a 350°F$^+$ mid distillate. Only the mid-distillate fraction was hydrocracked a second time. The reactions were conducted using excess hydrogen, which was run through the reactor once and vented along with the LPG's produced. Both passes were conducted over a fixed bed of Harshaw HT-400 E 1/8" extrudate cobalt molybdate catalyst which had the following physical characteristics:

Composition - 3% cobalt oxide and 15% molybdenum dioxide on alumina.
Average Bulk Density - 50 lb/cu ft
Surface Area - 220 M^2/g
Crush Strength - 12 lb
Pore Volume - 0.5 cc/g

This catalyst was chosen because of its high activity for desulfurization and denitrogenation and because of its neutral alumina support. An alumina, or neutral support, was desired for two reasons. First, the unusually high levels of nitrogen and oxygen expected to be in some of the coal derived oil fractions would quickly deactivate Lewis acid sites, such as would be found in a silica supported catalyst. Secondly, Lewis acid site cracking creates C_4-C_9 paraffins with very low normal/iso ratios, typically around 0.6, as compared to 3 to 5 for neutral sites. A high yield of normal paraffins was desired because they are the better aliphatic feedstock for ethylene production in an ethylene cracker. A stainless steel wire mesh was placed into the bottom of the reactor to act as a filter, keeping catalyst dust and chips out of the small diameter tubing downstream. One-quarter inch Berl saddles were loaded on top of the screen to the point where the catalyst bed was to be located. The appropriate amount of undiluted catalyst, based on the desired liquid hourly space velocity (LHSV), was then loaded into the reactor. Finally, more Berl saddles were placed on top of the catalyst bed.

TABLE 5

ANALYTICAL RESULTS FOR COED FRACTIONS

WHOLE CRUDE-METALS ANALYSIS, PPM

Fe	Ni	Cr	Mn	Cu	Zn	Co	Mo	Ti	Sn	Pb	Mg	Hg	Ga
0.6	<0.5	<0.2	<0.2	0.1	<1.0	<0.1	<0.1	<0.1	<0.5	<0.5	<0.5	<0.02	<0.01

	A-1 NAPHTHA IBP-350°F	A-2 MID-DISTILLATE 350-650°F	A-4 GAS OIL 650-850°F
API GRAVITY, 60°F	44.5	20.7	12.0
ELEMENTAL COMPOSITION			
C wt. %	86.6	88.3	89.0
H wt. %	13.0	11.2	10.7
O ppm	3420	3620	2460
N ppm	560	1600	900
S ppm	49	55	90
BOILING RANGE FROM SIMULATED DISTILLATION, °F			
IBP	97	364	217
10 wt. %	144	434	663
20 wt. %	219	468	693
30 wt. %	230	499	712
40 wt. %	257	525	731
50 wt. %	280	555	750
60 wt. %	298	581	769
70 wt. %	325	611	790
80 wt. %	345	637	811
90 wt. %	367	671	835

Presulfiding of the catalyst was necessary to convert cobalt and molybdenum oxides to sulfides, thereby fully developing the catalyst activity. This was accomplished by passing a light naphtha (Stoddard Solvent) containing approximately 1% by weight carbon disulfide over the catalyst in a hydrogen atmosphere at moderate pressure and under carefully controlled temperature conditions. The cold reactor was brought up to 400 psig with hydrogen, the flow being fixed at 2 SCFH per 100 cc catalyst. The carbon disulfide in naphtha feed was started at 1 g. feed/g. catalyst/hour or 1 weight hourly space velocity (WHSV). After establishing flows, the reactor was heated to 200°C in steps of 25°C/half-hour and held at that temperature for four hours. The temperature was then increased to 325°C at 25°C/half-hour and held for 10 to 16 hours. The reactor pressure was then increased to that specified for run conditions and the presulfiding feed was replaced by the experimental feed. Finally, the reactor temperature was increased at 25°C/half-hour to the specified temperature for the run.

A range of processing conditions was surveyed by varying the reactor temperature, pressure, and the LHSV. Nominal reactor temperatures of 850 to 990°F were required for reasonable conversion rates. Pressures of 2500 and 1500 psig and LHSV's of 0.33 to 0.79 were surveyed. Since this was the first coal liquid to be hydrocracked, many combinations of these variables were examined in order to provide a basis for selecting optimum conditions for future experiments. The limited amount of time and feedstock available did not allow for variable studies followed by continuous operation at a single set of conditions to create naphtha and unconverted mid-distillate for further processing. The composite product from the process variable studies was used for further studies. Reactor and catalyst coking became a problem at the high end of the temperature range, thus limiting this variable. As would be expected, increasing pressure, decreasing LHSV, and increasing temperature all contributed to increased conversion. A notable aspect of these hydrocracking experiments is the reduction of nitrogen and oxygen levels. Virtually all of the nitrogen was converted and nominally 90% of the oxygen was removed in the hydrocracking step. The data indicates that, for hydrocracking of the COED mid-distillate, 200 ppm seems to be the practical limit for reducing the oxygen in this material. There is no obvious reason why this should be so. In fact, subsequent data on other oils leads to the conclusion that oxygen analysis below 400 to 500 ppm is highly suspect. In fact, oxygen levels <u>may</u> be much lower than the analysis indicates.

The straight run gas oil fraction was also subjected to hydrocracking to evaluate this feedstock for naphtha production. The gas oil runs were conducted subsequent to the mid-distillate runs over the same catalyst, catalyst load, and presulfiding. Because this material was very viscous at room temperature, it was fed from the 5 gallon heated feed tank with bubbler indicator. However, pumping difficulties were encountered due to solids present in the oil which plugged the check valves on the pumps.

Consequently, only two runs with acceptable data were obtained from the limited amount of this material.

Simplified results from the COED mid-distillate and gas oil hydrocracking experiments are presented in Table 6. Included are the operating conditions, C_1-C_9 yield expressed as weight %, a componential analysis of the C_1-C_9 fraction, the amount of hydrogen consumed, and the heteroatom concentrations in both feed and product liquids. Complete run data is included in the appendices.

Hydrotreating

The COED straight run naphtha fraction was hydrotreated twice to create a feedstock with heteroatoms reduced to levels low enough for successful reforming with a conventional bifunctional reforming catalyst. The single pass reactions were conducted with an excess of hydrogen, at a ratio of 2500 SCF/BBL of feed, which passed through once and was vented with the LPG's produced. Runs were carried out over a fixed bed of Harshaw HT-100 E 1/8" extrudate hydrotreating catalyst. This catalyst consisted of nickel and molybdenum on an alumina support and had the following physical characteristics:

Composition - 3.8% nickel oxide and 16.8% molybdenum trioxide on alumina	
Average Bulk Density -	38 lb/cu ft
Surface Area -	190 m^2/g
Crush Strength -	14 to 20 lb
Pore Volume -	0.54 cc/g

This nickel-molybdate catalyst was used because of its demonstrated high activity toward nitrogen, which was expected to be present in the coal naphthas in relatively large concentrations. It was expected that the use of this catalyst would result in a favorable trade off between nitrogen removal and aromatic saturation, the latter being considered detrimental to the goal of producing aromatic feedstocks. Catalyst was loaded in the reactor in the same manner as for the hydrocracking catalyst, described in the previous section. Presulfiding with 1% CS_2 in light naphtha to develop maximum catalyst activity was also performed according to the procedure outlined in the previous section for hydrocracking catalyst. Reactor conditions of 800°F, 925 psig, and LHSV of 3 were used for the first pass, while 750°F, 900 psig, and a LHSV of 3 were employed for the second pass.

Several problems were encountered during these hydrotreating runs. In addition to the analytical difficulties, which were not recognized until after some time had been spent attempting to correct processing conditions, the possibility of sulfur contamination of the product resulting from the method of

TABLE 6

HYDROCRACKING H-COAL MID-DISTILLATE AND GAS OIL FRACTIONS
SIMPLIFIED DATA

RUN NO.	TEMP. °F.	PRESS. PSIG	LHSV HR^{-1}	PPM O C_5+	PPM N C_5+	PPM S C_5+	C_1-C_9 YIELD WT. %	H_2 YIELD G/100G FEED	COMPONENTIAL ANALYSIS WT. %				
										C_2-C_4	C_5-C_9		
									METHANE	LPG'S	PARAF.	NAPH.	AROM.
STRAIGHT RUN MID-DISTILLATE				3600	1600	55							
4	837	2500	0.34	130	<2	11	19.9	-1.34	6.5	24.8	14.0	28.5	26.2
24	916	2500	0.35	180	<2	10	53.0	-2.97	10.5	25.3	15.0	27.0	22.3
6	918	2500	0.33	--	<2	41	60.7	-3.79	9.6	37.1	11.1	22.0	20.3
21	940	2500	0.35	190	<2	25	73.5	-3.79	9.4	35.6	12.5	21.2	21.1
26	975	2500	0.33	--	36	9	93.6	-6.22	13.6	40.9	6.0	16.3	23.1
7	919	2500	0.65	--	2	20	47.9	-2.66	9.9	33.7	12.7	21.2	22.5
23	934	2500	0.68	--	12	21	40.5	-2.44	9.3	42.9	11.3	16.1	21.4
8	937	2500	0.68	400	2	29	64.3	-3.00	9.6	34.3	10.7	19.1	26.4
25	992	2500	0.68	415	4	37	84.4	-5.02	15.5	37.5	4.6	9.6	32.8
9	850	1500	0.35	185	15	16	21.9	-0.76	7.0	23.4	13.3	24.1	32.3
14	930	1500	0.36	--	6	31	49.8	-1.71	12.1	31.3	11.9	16.5	28.2
12	933	1500	0.37	--	6	14	50.4	-1.76	12.0	34.0	11.8	16.1	26.0
15	936	1500	0.36	210	9	17	47.3	-1.90	13.2	37.1	10.1	15.8	23.9
11	849	1500	0.57	410	62	11	13.6	-0.61	8.2	22.2	12.0	24.5	33.0
13	931	1500	0.69	--	19	10	36.1	-1.20	13.1	34.6	11.2	15.1	26.0
16	936	1500	0.70	370	23	13	39.3	-1.06	11.5	29.7	13.2	18.5	27.1
HYDROCRACKED MID-DISTILLATE				380	26	18							
27	852	2500	0.33	140	<2	4	16.9	-1.66	5.0	33.3	11.0	25.3	30.5
35	916	2500	0.51	145	3	7	24.0	-1.91	10.0	35.7	11.5	19.0	25.3
30	928	2500	0.72	140	2	5	45.3	-2.85	8.1	35.6	12.6	18.8	28.1
34	938	2500	0.79	160	<1	4	47.0	-2.88	8.9	35.6	12.2	21.1	24.9
31	980	2500	0.72	255	3	2	81.7	-4.68	16.1	29.2	4.9	4.3	33.2
STRAIGHT RUN GAS OIL				2460	900	90							
820	851	2500	1.21	400	--	--	17.6	-1.19*	11.7	37.8	19.3	12.2	20.2
828	932	2500	1.45	650	61	31	34.3	-2.09	15.4	35.9	14.9	18.5	15.2

*Assuming complete conversion of S, N since actual data is not available.

presulfiding did not become apparent until long after these hydrotreating runs were completed. For these reasons most of the data generated for heteroatom conversions is suspect. Due to the expected high concentration of heteroatoms in the feed, a componential analysis was expected to be in error and was not obtained. Gas make data and hydrogen consumptions calculated from analytical carbon-hydrogen data were determined from these runs and are presented in Table 7.

Table 7

HYDROTREATING COED STRAIGHT RUN NAPHTHA SIMPLIFIED DATA

	OXYGEN, PPM	NITROGEN, PPM	SULFUR, PPM
STRAIGHT RUN NAPHTHA	3420	560	49
FIRST PASS	NA	84	17
SECOND PASS	280	6	<2

GAS MAKE - G/100G FEED

FIRST PASS - 6.90
SECOND PASS - 8.70

HYDROGEN CONSUMPTION-G/100G FEED

BOTH PASSES - 0.17

GAS COMPOSITION - G/100G FEED

	FIRST PASS	SECOND PASS
C_1	0.08	0.03
C_2	0.13	0.12
C_3	0.09	0.05
IC_4	0.07	0.10
NC_4	0.01	0.03
IC_5	0.40	0.25
NC_5	0.14	0.23
CYCLO C_5	0.22	0.25
IC_6	0.23	0.37
NC_6	0.46	0.63
METHYL CYCLO C_5	0.44	0.69
BENZENE	0.28	0.36
CYCLO C_6	1.67	1.91
IC_7	0.14	0.19
NC_7	0.28	0.38
METHYL CYCLO C_6	0.43	0.67
TOLUENE	1.83	2.47

The limited amount of material available did not allow repeating these inspections. None of the difficulties described above would lead to data which would indicate more success than was realized. On the contrary, these effects would indicate a less active catalyst and that hydrotreating this naphtha may be much easier than the data indicates. As a result, the need for two stage hydrotreating of the COED straight run naphtha was not absolutely established.

The naphtha produced from the two-pass hydrocracked mid-distillate was combined and hydrotreated in one pass. The Harshaw HT-100 E 1/8" extrudate hydrotreating catalyst was again used. The catalyst was loaded in the reactor in the same manner with the exception of the addition of 1.5 volumes of 6-10 mesh tabular alumina as a catalyst diluent. The catalyst was diluted in an attempt to eliminate suspected product contamination due to backmixing and channeling in the catalyst bed. Again, the catalyst was presulfided using 1% CS_2 in Stoddard Solvent. A nominal reactor temperature of 750°F, pressures of 800 and 1500 psig, and LHSV's of 1 and 2 were surveyed in the hydrotreating experiments on this hydrocrackate naphtha.

The analytical problems encountered with the straight run naphtha were reduced for this naphtha. The sulfur analyses were improved and the Dohrmann nitrogen analyzer was abandoned in favor of the Antek Pyroreactor. The possibility of sulfur contamination from presulfiding, although not recognized at the time, still existed. Due to the effectiveness of the hydrocracking processing step in reducing heteroatom levels, the naphtha was easily hydrotreated in a single step as the data presented in Table 8 below indicates.

TABLE 8

HYDROTREATING COED HYDROCRACKATE NAPHTHA
SIMPLIFIED DATA

RUN NUMBER	FEED	6-2-2	6-4-2	6-5-2
TEMPERATURE, °F		756	756	752
PRESSURE, psig		800	800	1500
LHSV, hr		1.9	1.0	1.0
YIELD, G/100G FEED				
HYDROGEN		-0.59	-0.46	-0.35
C_1-C_4 GAS		0.35	0.43	0.41
C_5-C_9 LIQUID	85.83	83.30	85.18	83.42
C_{10}+ LIQUID	14.17	16.94	14.85	16.52
AROMATIC SATURATION G/100G FEED		7.52	3.52	6.57
OXYGEN, ppm	500	460	460	440
NITROGEN, ppm	<1	<1	<1	<1
SULFUR, ppm	41	3.8	1.7	<1

This data shows that the hydrogen consumed went mainly to saturate aromatics to naphthenes. All aromatics were assumed to saturate at the same level of conversion. The data indicates that decreasing LHSV, while maintaining the same temperature and pressure, decreases hydrogen consumption and aromatic saturation. This is contrary to expectations and casts suspicion on the analysis of the hydrotreated product. The low hydrogen consumption reported for run 6-5-2 is also contrary to expectations and suspect.

Reforming

The COED hydrotreated naphthas were reformed over a conventional bifunctional platinum reforming catalyst to maximize aromatics. A hydrogen ratio of 4000 SCF/BBL of feed was used and the excess was vented with the LPG's produced. The single pass reactions were carried out over a fixed bed of Cyanamid Aeroform® PHF-4 1/16" extrudate reforming catalyst consisting of platinum and chloride on alumina with the following physical characteristics:

Composition - 0.3% platinum and 0.6% chloride on alumina
Crush Strength - 10 lb
Average Bulk Density - 35-40 lb/cu ft

The platinum catalyst was chosen over the newer bimetallics for several reasons. Bimetallics are much more susceptible to poisons, which were presumed to be in coal derived oils. Further, by operating at "severe" conditions, the expected hydrocracking activity of the platinum catalyst would purify the aromatics produced by selectively cracking away the paraffins. The result would be a reformate with a high enough aromatic content to be fed to a hydrodealkylator with the non-aromatics being converted to methane and ethane. Another alternative, which was not pursued, would have been to operate at less severe conditions while maintaining high naphthene conversions but reducing the likelihood of hydrocracking and isomerization. In this case the reformate would be extracted with raffinate going to a naphtha cracker and the extract to hydrodealkylation. Calculating the economic balance between these two alternatives requires more data than the scope of this investigation allows. The intent was to operate the reformer at constant conditions in order to better compare naphthas.

The catalyst was loaded into the reactor in the same manner as the hydrotreating catalyst, with the screen in the bottom of the reactor and Berl saddles to position the bed in the thermocouple zone. The catalyst was diluted with an equal volume of 6-8 mesh tabular alumina to prevent backmixing and channeling in the catalyst bed, as well as to permit better monitoring of the endotherm. The catalyst was calcined as follows:

Hydrogen flow was established at ∿ 1.25 SCFH with the reactor pressure at 50 psig. The temperature was increased at 25°C/half hour to 530°C and held at these conditions for 2 hours. The temperature was then reduced to 455°C and again held for 2 hours. Pressure was then increased to that specified for the run and the hydrocarbon feed introduced. Finally, the hydrogen flow rate was established at that specified for the run and the reactor temperature was increased at 25°C/half hour to the temperature specified for the run.

The straight run hydrotreated naphtha was reformed at 955°F and 250 psig with a LHSV of 2. Prior to reforming, the naphtha was dried to less than 10 ppm water with Linde® 4A molecular sieve. The initial activity was very encouraging, but catalyst activity declined very rapidly as the naphthene conversion data in Table 9 indicates.

TABLE 9

REFORMING COED HYDROTREATED STRAIGHT RUN NAPHTHA SIMPLIFIED DATA

RUN NUMBER	FEED	108	109	112	113	114	115
TEMP., °F		955	955	954	954	955	950
PRESS., psig		250	250	250	250	250	250
LHSV, HR^{-1}		2.0	2.0	2.0	2.1	2.0	1.9
CHEM. OXYGEN, ppm	NA						
WATER, ppm	<10						
NITROGEN, ppm	6						
SULFUR, ppm	2						
<u>YIELD, G/100G FEED</u>							
HYDROGEN		2.33	1.69	2.21	1.59	1.37	1.18
C_1-C_5 GAS		12.8	12.9	11.2	12.1	12.5	12.2
C_6-C_9							
PARAFFIN	10.9	4.0	7.7	6.1	7.8	8.1	8.6
NAPHTHENE	50.1	0.9	5.6	2.2	8.3	11.1	14.1
AROMATIC	28.7	73.9	63.5	68.1	58.9	55.6	53.6
C_{10}+	10.3	6.0	8.7	10.2	11.3	11.3	10.3
%NAPHTHENE CONVERSION	--	98.2	88.8	95.6	83.4	77.8	71.9
%AROMATIC C_6-C_9	32.0	93.8	87.2	89.1	78.5	74.3	70.2

The apparent activity increase for run 112 resulted from the liquid feed being shut off for the weekend. Upon startup, the following Monday, the catalyst was probably "cleaned" by the hydrogen flow, which was established before hydrocarbon feed was introduced. Following run 115, the catalyst was unloaded and analyzed to contain 13.6% coke. This coking was probably due to the large aromatic content of the hydrocarbon material.

The hydrocrackate hydrotreated naphtha was reformed at 968°F and 500 psig with a LHSV of 2 over a fresh load of calcined reforming catalyst. The catalyst was diluted with 2 volumes of 6-10 mesh tabular alumina. The data presented in Table 10 would seem to indicate that doubling the pressure significantly decreased the deactivation rate. The limited amount of this material allowed for only a 100 hour run at these conditions, making it difficult to determine if the catalyst was "breaking in" or if the decreased deactivation rate would continue. The deactivation might be attributed to high oxygen levels; 280 ppm in the straight run naphtha and 185 ppm in the hydrocrackate naphtha. The oxygen data is, however, suspect below 400 to 500 ppm and actual levels may be much lower than the analysis indicate.

TABLE 10

REFORMING COED HYDROTREATED HYDROCRACKATE NAPHTHA
SIMPLIFIED DATA

RUN NUMBER	FEED	822	823	824	825
TEMP., °F		968	968	968	968
PRESS., psig		500	500	500	500
LHSV, HR^{-1}		1.9	2.0	2.0	2.1
CHEM. OXYGEN, ppm	185				
WATER, ppm	92				
NITROGEN, ppm	<1				
SULFUR, ppm	3				
YIELD, G/100G FEED					
HYDROGEN		1.96	1.97	1.90	1.99
C_1-C_5 GAS		12.1	10.5	10.7	10.3
C_6-C_9					
PARAFFIN	13.7	6.4	7.2	8.5	8.4
NAPHTHENE	35.7	2.2	3.1	3.0	3.9
AROMATIC	33.4	70.7	70.0	68.7	71.1
C_{10}^+	17.2	6.6	7.4	7.3	4.3
%NAPHTHENE CONVERSION		93.4	91.3	91.6	89.1
%AROMATIC C_6-C_9	40.5	89.2	87.2	85.7	85.3

Steam Coil Cracking

The COED straight run naphtha, straight run mid-distillate, hydrocrackate naphtha and hydrocrackate mid-distillate were each subjected to steam coil cracking experiments to evaluate these materials for direct olefin production. The liquid hydrocarbons and water were pumped to a vaporizer preheater. The vaporized feed entered a tubular steel reactor. The reaction products were condensed and the gas was separated and analyzed with a gas chromatograph. The liquid feed and product were analyzed using another gas chromatograph. Using a proprietary in-house correlative technique, the analyses collected were used as inputs to a computer program which adjusted each feed to the same cracking severity, mathematically recycled LPG's, and hydrodealkylated toluene and C_8 aromatics to yield the simplified data in Table 11 below.

TABLE 11

STEAM COIL CRACKING VARIOUS COED FRACTIONS
SIMPLIFIED DATA

YIELD, G/100G FEED

PRODUCT	STRAIGHT RUN NAPHTHA	STRAIGHT RUN MID-DISTILLATE	HYDROCRACKATE NAPHTHA	HYDROCRACKATE MID-DISTILLATE
HYDROGEN	0.60	0.89	0.52	1.16
METHANE	15.85	11.77	16.46	12.01
ETHYLENE	19.10	13.88	19.61	16.11
PROPYLENE	7.86	6.50	7.63	6.58
BUTADIENE	2.17	1.30	1.34	1.45
BENZENE	25.34	9.87	31.58	11.63
FUEL	29.08	55.80	22.86	51.06

The olefin yield of these feedstocks is relatively low and none is very attractive as an ethylene cracker feed. All of the oils coked badly in the reactor, much worse than petroleum oils, which presumably was the result of the high aromatic content of these materials.

PART II - CONCEPTUAL PROCESS

Introduction

A conceptual process is to be used as the basis for comparison of the various coal liquefaction products surveyed under this contract. The data included in the conceptual process will be used to calculate preliminary capital and operating costs, which will in turn serve as the data for economic evaluations of the proposed process. The laboratory data presented in Part I of this report was reduced to kinetic equations which describe the conversions and selectivities observed. Where necessary, engineering judgement has been used to "smooth" inconsistencies in the laboratory data. The kinetic expressions derived from the laboratory data were utilized to determine mass, componential, and elemental balances for a conceptual process. Each of the three fractions from the distillation step was analyzed individually as a feedstock to the conceptual plant. The product patterns presented in the tables following are therefore based on 100.00 mass units of each fraction. From this data, the relative value of each fraction can be readily assessed based on the respective yields of aliphatic and aromatic products along with the hydrogen consumed.

Also included in this section of the report is a schematic diagram of the conceptual process. Mass-per-unit-time, elemental, and componential data for selected streams is also presented. The basis for this data is a flow rate of 100.00 lb/hr of whole crude to the distillation column. Componential data for the selected streams presented is given in weight percent of each component in the stream.

REDUCTION OF LABORATORY DATA

Hydrocracking Mid-Distillate

The data obtained from the laboratory inspections on the two-pass hydrocracked COED mid-distillate was reduced to obtain average first order rate constants for each pass. Rate constants were calculated from conversion and process variable data for each run according to the following equation:

$$\ln(1-C) = -k e^{\frac{-E}{RT}} P_{H_2}^{1.25} \text{LHSV}^{-0.5}$$

where - $C = C_1\text{-}C_9$ yield, wt. fraction
k = rate constant
E = 38000 cal/g mole
R = 1.987 cal/g mole °K
T = reactor temperature, °K
P_{H_2} = pressure, psia
LHSV = liquid space velocity, vol/vol-hr

The average rate constants determined by this method were used as a basis for estimating the rate constants for consecutive passes so that recycle hydrocracking calculations might be made. In order to complete the recycle hydrocracking calculations, selectivity data for each pass was also needed. This data was obtained from laboratory inspections for first and second pass and was estimated for consecutive passes. Several assumptions were used in making recycle hydrocracking calculations. First, it was assumed that the reaction rate for virgin material is unaffected by the presence of recycle material. Second, after having been recycled four times, there is no further change in reaction rate for that material. Finally, it was assumed that selectivities would remain constant after the third pass. Laboratory data obtained for COED hydrocracking run 8 and 34 was used to obtain selectivities for the first and second pass. A plot of experimental versus the calculated conversions computed from the first and second pass average rate constants is presented in Figure 3. The straight line 45° plot confirms the assumed first order kinetics for mid-distillate hydrocracking conversions. Table 12, includes the reactor conditions, rate constants, and selectivities used to make recycle hydrocracking calculations.

Hydrocracking Gas Oil

The single pass data obtained for hydrocracking COED straight run gas oil was also converted to recycle hydrocracking data. Since only two runs were completed on this feedstock, first order rate constants could not be derived as they were for mid-distillate hydrocracking. In order to estimate conversions and selectivities for recycle hydrocracking the gas oil, several assumptions were made. The conversion reaction for virgin material was assumed to be noncompetitive with the conversion reaction for recycle material. The first recycle was assumed to have a reaction rate 0.72 times that of the virgin material. The reaction rate was assumed to be 0.61 times that of the virgin material for all other passes. The selectivities observed for the single pass hydrocracked gas oil from hydrocracking run 828 were assumed to be valid for all recycle passes. Reaction rates for the laboratory data were calculated according to the following equation using the conversion data from run 828:

$$1-C = e^{-K}$$

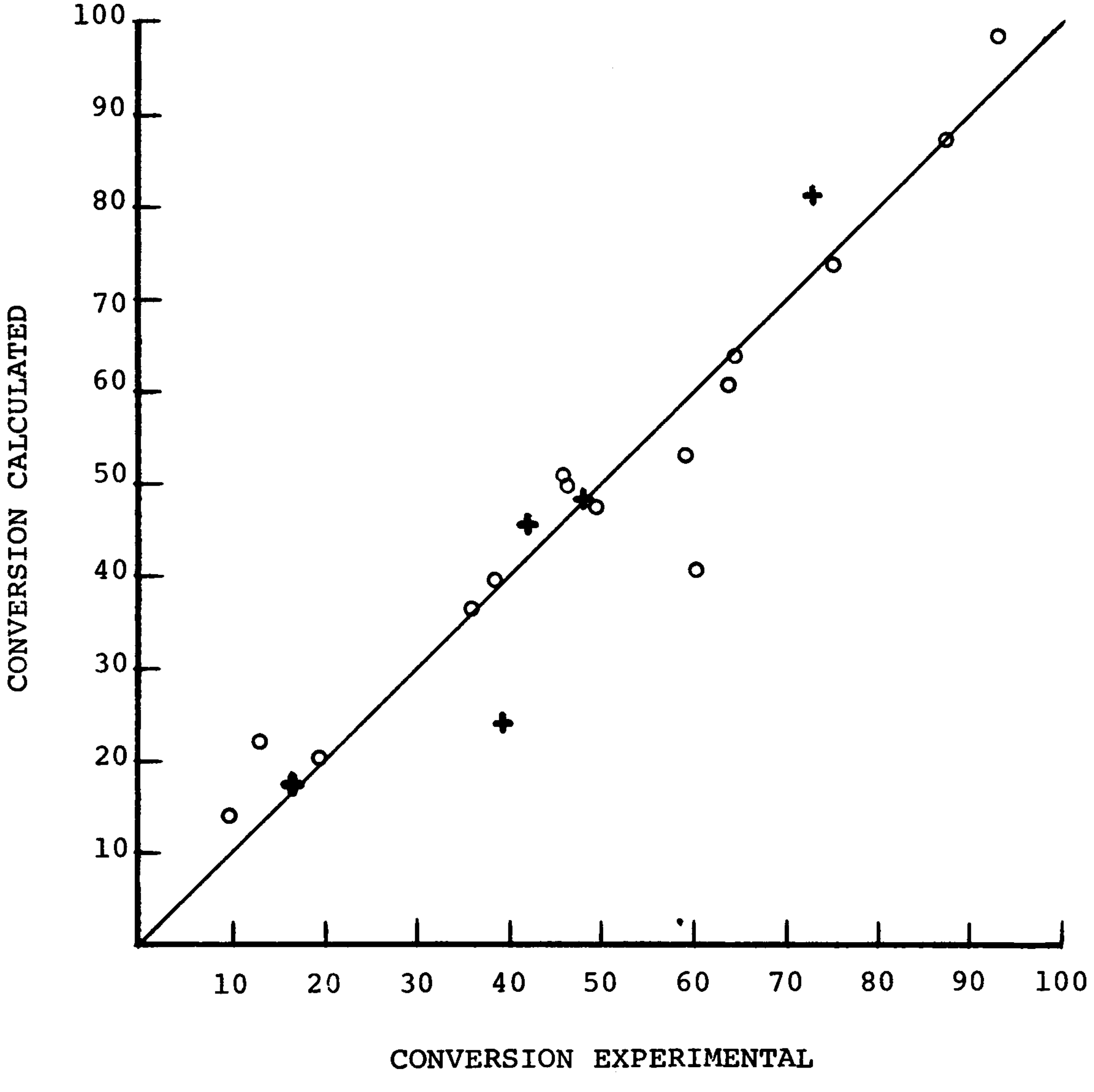
where C = conversion to naphtha or mid-distillate, wt. fraction
K = reaction rate

Table 13 includes the reactor conditions, reaction rates for first pass naphtha and mid-distillate conversions, and selectivities used to make recycle hydrocracking calculations.

Figure 3

PLOT OF EXPERIMENTAL VERSUS

CALCULATED CONVERSIONS



○ FIRST PASS

✚ SECOND PASS

TABLE 12

MID-DISTILLATE RECYCLE HYDROCRACKING DATA

Reactor Conditions

940°F
2500 psig
LHSV 0.7 volumes/volume - hr
Recycle = 0.982/1 virgin

Rate Constants

1st Pass	2.23×10^6 hr^{-1}	
2nd Pass	1.50×10^6 hr^{-1}	
3rd Pass	1.25×10^6 hr^{-1}	- assumed -
4th+ Pass	1.15×10^6 hr^{-1}	- assumed -

1ST PASS SELECTIVITIES
lb/100 lb Feed

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
Hydrogen	-5.3				
Methane	9.5				
Ethane	10.3				
Propane	13.6				
C_4	9.1	1.9			
C_5	2.9	1.7	1.5		
C_6	0.9	1.0	3.6	4.4	5.2
C_7	1.1	1.9	3.3	3.7	8.5
C_8	1.0	0.5	2.1	1.4	4.9
C_9	0.5	0.5	0.1	0.4	5.2

TABLE 12 Cont'd

2ND PASS SELECTIVITIES
lb/100 lb Feed

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
Hydrogen	-5.6				
Methane	8.9				
Ethane	9.4				
Propane	12.1				
C_4	9.3	2.0			
C_5	2.7	1.6	2.7		
C_6	1.2	0.7	6.0	2.4	4.7
C_7	1.0	2.4	3.8	2.3	8.1
C_8	0.8	0.7	2.3	0.9	4.8
C_9	0.6	0.5	0.3	0.4	7.3

3RD PASS + SELECTIVITIES (ASSUMED)
lb/100 lb Feed

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
Hydrogen	-5.8				
Methane	8.6				
Ethane	9.0				
Propane	11.7				
C_4	9.5	2.0			
C_5	2.8	1.7	2.8		
C_6	1.3	0.7	6.1	2.4	4.7
C_7	1.0	2.5	3.9	2.3	8.1
C_8	0.9	0.7	2.3	0.9	4.9
C_9	0.6	0.5	0.3	0.4	7.4

TABLE 13

GAS OIL RECYCLE HYDROCRACKING DATA

Reactor Conditions

930°F
2500 psig
LHSV 1.2 vol feed/vol reactor - hr

Reaction Rates

$K_1 = 0.4204$ C_1-C_9 Naphtha from 1st pass
$K_2 = 0.5715$ C_{10}-650 Mid-distillate from 1st pass

SELECTIVITY TO C_1-C_9

lb/100 lb Feed

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
Hydrogen	-2.1				
Methane	15.4				
Ethane	12.8				
Propane	14.1				
C_4	7.2	1.8			
C_5	2.0	1.2	0.4		
C_6	2.5	1.4	2.7	4.7	1.9
C_7	2.2	1.8	1.7	5.6	4.4
C_8	1.5	0.8	1.2	0.9	4.5
C_9	0.9	0.7	0.3	1.0	4.4

Hydrotreating Naphthas

The selectivity data for the liquid product from hydrotreating the straight run naphtha was not obtained. Analytical carbon-hydrogen data provided the hydrogen consumption data. The product pattern used for the conceptual process calculations is the result of combining gas make data from both passes with the liquid recovery rates and a componential analysis of the composite two-pass hydrotreated product.

Laboratory data from single pass hydrotreating the COED hydrocrackate naphtha was reduced to provide selectivity data. Because of the relatively low heteroatom levels in this material, all of the hydrogen consumed was assumed to go to saturating aromatics to naphthenes. Conversion levels of aromatics to naphthenes was assumed to be the same for all carbon numbers. Therefore, the appropriate level of aromatic saturation was calculated to yield the hydrogen consumption calculated from analytical carbon-hydrogen data. The selectivity data for hydrotreating COED hydrocrackate naphtha is presented in Table 14 below.

TABLE 14

HYDROTREATING COED HYDROCRACKATE NAPHTHA
SELECTIVITY DATA

Reactor Conditions
759°F
800 psig
LHSV 1 vol/vol - hr

Selectivity, lb/100 lb Feed

H_2	-0.5
C_1	0.02
C_2	0.03
C_3	0.12

The C_4-C_9 paraffins and C_5 naphthenes were assumed to be unchanged during the hydrotreating step.

Reforming Naphthas

The laboratory data for reforming the hydrotreated straight run naphtha was reduced to give conversion and selectivity data for the conceptual process. Conversions of both paraffins and C_5 and C_6 naphthenes were calculated and are presented in the following tables. Paraffin production as weight percent on the feed is also reported for C_1-C_6. The paraffin product normal/iso ratio for C_6-C_9 hydrocarbons is also presented. Hydrogen production was then calculated from analytical carbon-hydrogen data collected from analyses of the feed and product streams. The same data reduction from laboratory results to conversion and selectivity data for the conceptual process was completed for the reforming of the hydrotreated hydrocrackate naphtha. Tables 15 and 16 contain the reforming data for the conceptual process.

TABLE 15

STRAIGHT RUN NAPHTHA REFORMING DATA
CONVERSIONS, WT. % OF COMPONENT IN FEED

	PARAFFIN	NAPHTHENE	
		CYCLO PENT	CYCLO HEXANE
C_6	-0-	58	98.6
C_7	40	83	98.8
C_8	83	95	99.0
C_9	96 (assumed)	98	99.1
C_{10}^+	60 (assumed)		

Selectivity lb/100 lb Feed

	NORM PARAF	ISO PARAF	CYCLO PENT
C_1	1.8		
C_2	2.6		
C_3	3.1		
C_4	1.7	1.0	
C_5	1.1	1.2	0.2
C_6	0.6	0.3	

Paraffin Normal/Iso Ratio (Total Product)

C_7	0.5
C_8	0.5
C_9	0.5

TABLE 16

HYDROCRACKATE NAPHTHA REFORMING DATA
CONVERSIONS, WT. % OF COMPONENT IN FEED

	PARAFFIN	NAPHTHENE CYCLO PENT	 CYCLO HEXANE
C_6	-0-	57	98.4
C_7	62	89	98.8
C_8	84	97	99.5
C_9	95 (assumed)	99	99.5
C_{10}^+	57		

Selectivity lb/100 lb Feed

	NORM PARAF	ISO PARAF	CYCLO PENT
C_1	0.8		
C_2	1.6		
C_3	2.6		
C_4	1.5	1.0	
C_5	0.5	1.4	0.1
C_6	0.4	1.4	

Paraffin Normal/Iso Ratio (Total Product)

C_6	0.7
C_7	0.3
C_8	0.3
C_9	0.3 (assumed)

Hydrodealkylating Reformates

The reformates, whether straight run or hydrocrackate were mathematically hydrodealkylated. Selectivity data for converting paraffins, naphthenes, and aromatics to methane, ethane, benzene, and liquid fuel as well as the hydrogen required was calculated from an internally developed model. The selectivity data is reported as weight percent of each product for each hydrocarbon classification by carbon number. This data is presented in Table 17.

TABLE 17

REFORMATE HYDRODEALKYLATION SELECTIVITY DATA

	C_6	C_7	C_8	C_9
PARAFFIN				
HYDROGEN	-0.074	-0.077	-0.080	-0.081
METHANE	0.434	0.426	0.421	0.417
ETHANE	0.640	0.651	0.659	0.664
NAPHTHENE				
HYDROGEN	-0.088	-0.089	-0.090	-0.090
METHANE	0.440	0.431	0.425	0.421
ETHANE	0.648	0.658	0.665	0.669
AROMATIC				
HYDROGEN	-0-	-0.024	-0.041	-0.057
METHANE	-0-	0.146	0.261	0.347
ETHANE	-0-	0.004	0.047	0.069
BENZENE	1.00	0.843	0.689	0.581
LIQ. FUEL	-0-	0.031	0.044	0.060

CONCEPTUAL PROCESS YIELDS FOR INDIVIDUAL DISTILLATE FRACTIONS

Straight Run Naphtha

The COED straight run naphtha was subjected to the mathematical calculations for hydrotreating, reforming, and hydrodealkylation. Componential data for the product from each hydroprocessing step is presented in the tables following. The basis for the componential data is 100.00 lb of naphtha from distillation. Therefore, the values reported for each component are the actual mass values in pounds of the component based on the feed. Table 18 is the result of the conceptual hydrotreating step, Table 19 the result of conceptual reforming, Table 20 the result of conceptual hydrodealkylation, and Table 21 is the total conceptual product pattern from the straight run naphtha. The values for the products were derived from those published by Spitz and Ross[1]. Hydrogen was estimated at $2.10/MCF from a methane reformer operating on $3.25/MM BTU gas.

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[1] Spitz, P. H. and Ross, G. N., "What is Feedstock Worth?" Hydrocarbon Processing, April, 1976.

TABLE 18

CONCEPTUAL HYDROTREATING
COED STRAIGHT RUN NAPHTHA

Basis 100.00 lb from Distillation

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
Hydrogen	-.23				
Methane	.11				
Ethane	.24				
Propane	.14				
C_4	.16	.04			
C_5	.63	.35	.45		
C_6	1.13	1.39	2.07	9.27	1.26
C_7	1.11	1.84	2.42	17.10	5.28
C_8	2.74	1.29	4.74	6.18	7.29
C_9	.86	1.23	2.02	7.67	12.41
$C_{10}+$	8.81				

TABLE 19

CONCEPTUAL REFORMING
COED STRAIGHT RUN NAPHTHA

Basis 98.11 lb C_5+ From Hydrotreating

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
Hydrogen	2.41				
Methane	1.77				
Ethane	2.55				
Propane	3.04				
C_4	1.67	.98			
C_5	1.08	1.18	.20		
C_6	1.62	1.80	.87	.13	10.55
C_7	.59	1.18	.41	.21	22.42
C_8	.23	.46	.24	.06	17.01
C_9	.02	.06	.04	.07	21.23
$C_{10}+$	4.03				

TABLE 20

CONCEPTUAL HYDRODEALKYLATION COED STRAIGHT RUN NAPHTHA

	Basis 83.23 lb C_6+ From Reforming
Hydrogen	-3.08
Methane	18.52
Ethane	7.53
Benzene	53.50
Liq. Fuel	6.75

TABLE 21

CONCEPTUAL PROCESS PRODUCTS COED STRAIGHT RUN NAPHTHA

	Basis 100 lb From Distillation
Hydrogen	-0.90
Methane	20.40
Ethane	10.32
Propane	3.18
Butanes	2.85
Pentanes	3.89
Benzene	53.50
Liq. Fuel	6.75
Value/100 lb Distillate (1980)	$10.43

Straight Run Mid-Distillate

The COED straight run mid-distillate was subjected to mathematical recycle hydrocracking, hydrotreating, reforming, and hydrodealkylation. Componential data for each step is reported based on 100.00 lb of mid-distillate from distillation. Table 22 lists the componential product pattern for recycle hydrocracking, Table 23 the product from hydrotreating, Table 24 the product from reforming, Table 25 the product from hydrodealkylation, and Table 26 the total conceptual product pattern from the straight run mid-distillate with the product value.

TABLE 22

CONCEPTUAL RECYCLE HYDROCRACKING COED MID-DISTILLATE

Basis 100.00 lb From Distillation

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
Hydroden	-5.39				
Methane	9.66				
Ethane	10.36				
Propane	13.56				
C_4	9.70	2.05			
C_5	2.99	1.76	2.09		
C_6	1.07	.91	4.82	3.61	5.25
C_7	1.12	2.22	3.68	3.29	8.76
C_8	.98	.64	2.29	1.25	5.11
C_9	.56	.49	.12	.19	6.37
C_{10}^+	.49				

TABLE 23

CONCEPTUAL HYDROTREATING COED MID-DISTILLATE HYDROCRACKATE NAPHTHA

Basis 60.06 lb C_5+ From Recycle Hydrocracking

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
Hydrogen	-.30				
Methane	.01				
Ethane	.02				
Propane	.07				
C_4	--	--			
C_5	2.99	1.76	2.09		
C_6	1.07	.91	4.82	4.75	4.19
C_7	1.12	2.22	3.68	5.17	6.99
C_8	.98	.64	2.29	2.33	4.08
C_9	.56	.49	.12	1.54	5.08
C_{10}^+	.49				

TABLE 24

CONCEPTUAL REFORMING COED MID-DISTILLATE HYDROCRACKATE NAPHTHA

Basis 53.52 lb C_6+ From Hydrotreating

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
Hydrogen	+1.09				
Methane	.43				
Ethane	.86				
Propane	1.39				
C_4	.80	.54			
C_5	.27	.75	.05		
C_6	1.56	2.22	2.07	.08	10.35
C_7	.29	.98	.40	.06	14.02
C_8	.06	.20	.07	.01	7.92
C_9	.01	.04		.01	6.48
C_{10}+	.21				

TABLE 25

CONCEPTUAL HYDRODEALKYLATION COED MID-DISTILLATE HYDROCRACKATE NAPHTHA

Basis 47.04 lb C_6+ From Reforming

Hydrogen	-1.67
Methane	9.86
Ethane	6.08
Benzene	31.39
Liq. Fuel	1.38

TABLE 26

CONCEPTUAL PROCESS PRODUCTS
COED STRAIGHT RUN MID-DISTILLATE

	Basis 100 lb From Distillation
Hydrogen	-6.3
Methane	19.96
Ethane	17.32
Propane	15.02
Butanes	13.09
Pentanes	7.86
Benzene	31.39
Liq. Fuel	1.38
Value/100 lb Distillate (1980)	$7.29

Straight Run Gas Oil

The COED straight run gas oil was first subjected to mathematical recycle hydrocracking to naphtha and C_{10}-650°F mid-distillate. The componential data from these calculations is presented in Table 27. The C_{10}-650°F mid-distillate from the gas oil hydrocracking was then recycle hydrocracked mathematically to produce naphtha, for which the componential data is presented in Table 28. The naphtha produced from the gas oil was combined and mathematically hydrotreated. The conceptual product pattern from hydrotreating is presented in Table 29. Following hydrotreating, the naphtha was mathematically reformed and hydrodealkylated. Tables 30 and 31 respectively, contain the componential product patterns for these processing steps. Table 32 lists the total conceptual product pattern from the straight run gas oil with the product value.

CONCEPTUAL PLANT BALANCE

With the pattern and value known for the products of each distillate fraction, the remaining step is to calculate the mass balance for a conceptual plant using the whole crude as the primary feedstock. From this data, the preliminary capital requirements and operating costs for a commercial plant can be estimated. The basis for the mass balance data is a flow of 100.00 lb/hr of the whole crude to the distillation step. With the fuel value of the crude feedstock ranging from $6.25 to $6.75 per 100 pounds, it would appear, from the conceptual process product values presented for each fraction

TABLE 27

CONCEPTUAL RECYCLE HYDROCRACKING COED GAS OIL

Basis 100.00 lb From Distillation

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
Hydrogen	-4.33				
Methane	7.06				
Ethane	5.87				
Propane	5.90				
C_4	3.30	.81			
C_5	.90	.56	.18		
C_6	1.13	.65	1.23	2.15	.86
C_7	1.02	.82	.76	2.57	2.02
C_8	.67	.35	.56	.40	2.05
C_9	.42	.34	.13	.46	2.00
C_{10}^+	58.92				

TABLE 28

CONCEPTUAL RECYCLE HYDROCRACKING COED MID-DISTILLATE FROM GAS OIL

Basis 58.92 lb C_{10}-650°F From
Gas Oil HC

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
Hydrogen	-3.18				
Methane	5.69				
Ethane	6.10				
Propane	7.99				
C_4	5.72	1.21			
C_5	1.76	1.04	1.23		
C_6	.63	.54	2.84	2.13	3.09
C_7	.66	1.31	2.17	1.94	5.16
C_8	.58	.38	1.35	.74	3.01
C_9	.33	.29	.07	.11	3.75
C_{10}^+	.29				

TABLE 29

CONCEPTUAL HYDROTREATING HYDROCRACKATE COED NAPHTHA FROM GAS OIL & MID-DISTILLATE

Basis 22.23 lb C_5+ From Recycle Hydrocrack Gas Oil
Plus 35.39 lb C_5+ From Recycle Hydrocrack Mid-Distillate From Gas Oil

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
Hydrogen	-.29				
Methane	.01				
Ethane	.02				
Propane	.07				
C_4	--	--			
C_5	2.66	1.60	1.41		
C_6	1.76	1.19	4.07	5.25	3.05
C_7	1.68	2.13	2.93	6.26	5.54
C_8	1.25	.73	1.91	2.36	3.91
C_9	.75	.63	.20	1.95	4.44
C_{10}+	.29				

TABLE 30

CONCEPTUAL REFORMING COED GAS OIL HYDROCRACKATE NAPHTHA

Basis 52.28 lb C_6+ From Hydrotreating

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
Hydrogen	1.33				
Methane	.37				
Ethane	.75				
Propane	1.21				
C_4	.70	.47			
C_5	.23	.65	.05		
C_6	1.56	2.23	1.75	.08	10.01
C_7	.34	1.11	.32	.08	13.79
C_8	.08	.26	.06	.01	7.88
C_9	.02	.05	.00	.01	6.48
C_{10}+	.12				

TABLE 31

CONCEPTUAL HYDRODEALKYLATION COED GAS OIL HYDROCRACKATE NAPHTHA

	Basis 46.54 lb C_6+ From Reforming
Hydrogen	-1.32
Methane	9.73
Ethane	6.02
Benzene	30.83
Liq. Fuel	1.28

TABLE 32

CONCEPTUAL PROCESS PRODUCTS COED STRAIGHT RUN GAS OIL

	Basis 100 lb From Distillation
Hydrogen	-7.79
Methane	22.86
Ethane	18.76
Propane	15.17
Butanes	12.21
Pentanes	6.60
Benzene	30.83
Liq. Fuel	1.28
Value/100 lb Distillate (1980)	$7.12

in Tables 21, 26, and 32, that mid-distillate processing could be only marginally attractive. With the added processing charges for gas oil hydroprocessing, it is unlikely to be economically attractive as a petrochemical feedstock. For this reason, the gas oil hydroprocessing sequence was not included in the overall conceptual plant mass balance. A schematic diagram of the conceptual plant with selected streams identified by number is included in Figure 4. Tables 33 through 38 include mass flow rates, elemental, and, where known, the componential analysis of the various streams identified in the schematic diagram. The componential data for each stream identified is presented as weight percent of each component by carbon number. Note that part of the process derived methane is converted to hydrogen in an oil fired methane reformer. Enough hydrogen is produced to supply hydroprocessing needs.

Figure 4

CONCEPTUAL PLANT

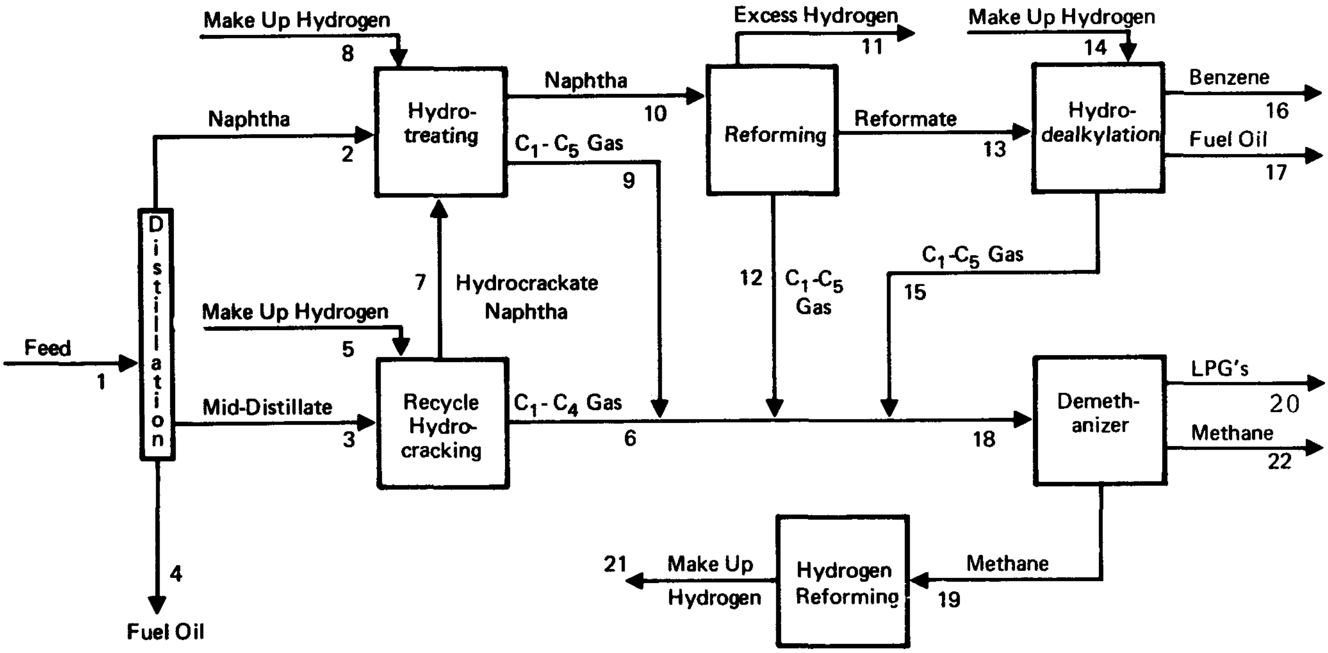


TABLE 33

DISTILLATION

Whole Crude

Stream Identification No. 1
Flow Rate 100 lb/hr

API Gravity, 60°F - 23.1

	WT. %
Carbon	88.1
Hydrogen	11.5
Oxygen	0.344
Nitrogen	0.125
Sulfur	0.013

Straight Run Naphtha

Stream Identification No. 2
Flow Rate 22.4 lb/hr

API Gravity, 60°F - 44.5

	WT. %
Carbon	86.6
Hydrogen	13.0
Oxygen	0.342
Nitrogen	0.056
Sulfur	0.005

Mid-Distillate

Stream Identification No. 3
Flow Rate 46.2 lb/hr

API Gravity, 60°F - 20.7

	WT. %
Carbon	88.0
Hydrogen	11.4
Oxygen	0.362
Nitrogen	0.160
Sulfur	0.006

Gas Oil 900°F E.P.

Stream Identification No. 4
Flow Rate 31.4 lb/hr

API Gravity, 60°F - 12.0

	WT. %
Carbon	89.0
Hydrogen	10.7
Oxygen	0.246
Nitrogen	0.090
Sulfur	0.009

TABLE 34

CONCEPTUAL PLANT HYDROPROCESSING LIQUID STREAMS

Hydrocrackate Naphtha

Stream Identification No. 7
Flow Rate 27.6 lb/hr

	WT. %
Carbon	87.54
Hydrogen	12.40
Nitrogen	.0001
Oxygen	.048
Sulfur	.004

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
C_5	4.98	2.93	3.48		
C_6	1.78	1.51	8.03	6.01	8.74
C_7	1.86	3.70	6.13	5.48	14.59
C_8	1.63	1.07	3.81	2.08	8.51
C_9	.93	.82	.20	.32	10.61
C_{10}^+	.82				

Hydrotreated Naphtha

Stream Identification No. 10
Flow Rate 46.52 lb/hr

	Wt. %
Carbon	87.07
Hydrogen	12.93

	NORM PARAF	ISO PARAF	CYCLO PENT	CYLCO HEXANE	AROMATIC
C_6	1.60	1.57	5.76	9.17	4.75
C_7	1.64	3.08	4.80	13.36	9.45
C_8	2.29	1.25	4.55	5.28	7.55
C_9	.97	1.08	1.09	5.22	11.01
C_{10}^+	4.74				

TABLE 34 (Cont'd)

Reformate C_6^+

Stream Identification No. 13
Flow Rate 40.34 lb/hr

	WT. %
Carbon	90.03
Hydrogen	9.97

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
C_6	2.67	3.53	2.84	.16	17.63
C_7	.66	1.76	.68	.18	28.38
C_8	.20	.48	.21	.05	18.45
C_9	.02	.08	.02	.05	19.15
C_{10}^+	2.48				

TABLE 35

CONCEPTUAL PLANT HYDROPROCESSING GAS STREAMS

Hydrocracking Gas Make

Stream Identification No. 6
Flow Rate 20.94 lb/hr

	WT. %
Carbon	80.00
Hydrogen	20.00

	NORM PARAF	ISO PARAF
Methane	21.30	
Ethane	22.87	
Propane	29.89	
C_4	21.40	4.52

TABLE 35 (Cont'd)

Hydrotreating Gas Make

Stream Identification No. 9
Flow Rate 3.67 lb/hr

	WT. %
Carbon	83.72
Hydrogen	16.28

	NORM PARAF	ISO PARAF	CYCLO PENT
Methane	.82		
Ethane	1.63		
Propane	1.63		
C_4	.82	.27	
C_5	41.42	24.25	29.16

Reformer Gas Make

Stream Identification No. 12
Flow Rate 5.14 lb/hr

	WT. %
Carbon	81.06
Hydrogen	18.94

	NORM PARAF	ISO PARAF	CYCLO PENT
Methane	11.60		
Ethane	18.86		
Propane	25.66		
C_4	14.42	9.07	
C_5	7.16	11.88	1.36

TABLE 36

CONCEPTUAL PLANT HYDRODEALKYLATOR STREAMS

Hydrodealkylator Gas Make

Stream Identification No. 15
Flow Rate 12.86 lb/hr

Methane - 66.56
Ethane - 33.44

	WT. %
Carbon	76.47
Hydrogen	23.53

Benzene Product

Stream Identification No. 16
Flow Rate 26.38 lb/hr

Benzene - 100.0

	WT. %
Carbon	92.2
Hydrogen	7.8

Hydrodealkylator Bottoms

Stream Identification No. 17
Flow Rate 2.15 lb.hr

C_{10}^{+} - 100.0

	WT. %
Carbon	93.63
Hydrogen	6.37

TABLE 37

CONCEPTUAL PLANT DEMETHANIZER STREAMS

Feed to Demethanizer

Stream Identification No. 18
Flow Rate 42.61 lb/hr

	WT. %
Carbon	79.38
Hydrogen	20.62

	NORM PARAF	ISO PARAF	CYCLO PENT
Methane	32.03		
Ethane	23.75		
Propane	17.92		
C_4	12.33	3.34	
C_5	4.43	3.52	2.68

Methane To Hydrogen Production (Reformer)

Stream Identification No. 19
Flow Rate 6.31 lb/hr

Methane - 100.0

	WT. %
Carbon	74.8
Hydrogen	25.2

LPG's

Stream Identification No. 20
Flow Rate 28.96 lb.hr

	WT. %
Carbon	81.54
Hydrogen	18.46

	NORM PARAF	ISO PARAF	CYCLO PENT
Ethane	34.94		
Propane	26.37		
C_4	18.14	4.91	
C_5	6.52	5.18	3.94

Methane to Export

Stream Identification No. 22
Flow Rate 7.34 lb/hr

Methane - 100.0

	WT. %
Carbon	74.8
Hydrogen	25.2

TABLE 38

HYDROGEN

FLOW RATE

to Hydrocracking	-2.49 lb/hr	Stream I.D.	5
to Hydrotreating	-0.19 lb/hr	Stream I.D.	8
from Reforming	+1.04 lb/hr	Stream I.D.	11
to Hydrodealkylation	-1.44 lb/hr	Stream I.D.	14
from Methane Reforming	3.08 lb.hr	Stream I.D.	21

APPENDICES TO PART I

PROCESS EQUIPMENT DESCRIPTION
HYDROPROCESSING EQUIPMENT

The equipment used for the hydroprocessing experiments is shown in Figures I, II, III, and IV. Figures I and II are engineering sketches of the original reactor and product recovery train. Figures III and IV are sketches of the same equipment after modifications were made to reduce stripping of light hydrocarbons from the liquid by the gaseous product. All descriptions of the experimental equipment reported in this text refer to these figures.

Gaseous Feed - Hydrogen is supplied to the laboratory as a utility at two different pressures, nominally 1200 and 3200 psig. The hydrogen is routed to each reactor via a header system and through a flow transmitter. The Foxboro integral orifice differential pressure cell flow transmitters used for hydrogen flow control were equipped with orifices ranging from 0.003 to 0.007 inches in diameter. Pressure differentials of 0 to 20 or 0 to 40 inches of water were used. In order to obtain maximum accuracy for a given hydrogen flow rate, orifice size and differential pressure drop were chosen so that control settings of greater than 30% of maximum flow were utilized. Also, flow transmitters were zeroed before the start of each experiment using a Foxboro current calibrator. From the flow transmitter, the hydrogen is routed to the top of the reactor and the pressure at that point is recorded.

Liquid Feed - Each reactor has provision for liquid feed from either a one-gallon jug on scales, or a five-gallon feed tank equipped with a bubbler level indicator. A multiple head Milton Roy metering pump delivers the liquid feed to the reactor at operating pressure at a controlled rate, nominally 25 to 400 ml/hr.

The Reactor - Three similar reactors were used for the hydroprocessing studies. All of the reactors consisted of a heavy wall nickel-free stainless steel tube suspended in a furnace. The furnace is divided into three heating zones on two of the reactors and eight zones on the third. The temperature of each zone is controlled through the use of thermocouples located on the outside wall of each reactor. During normal operations a thermowell is placed in the center of the reactor. The thermowell consists of a closed end piece of 430 stainless 1/4 inch tubing with a 0.035 inch wall. It is silver soldered into special

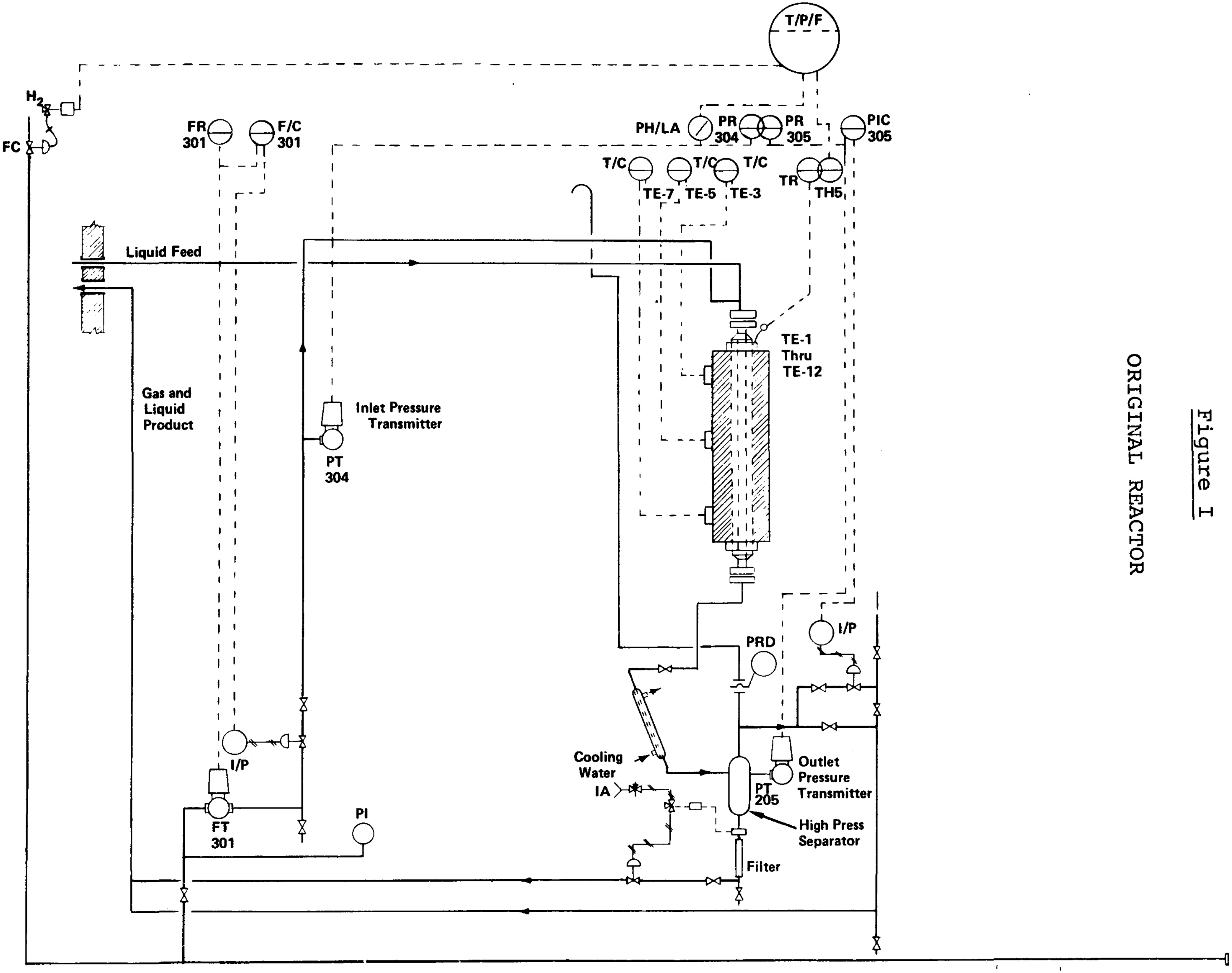
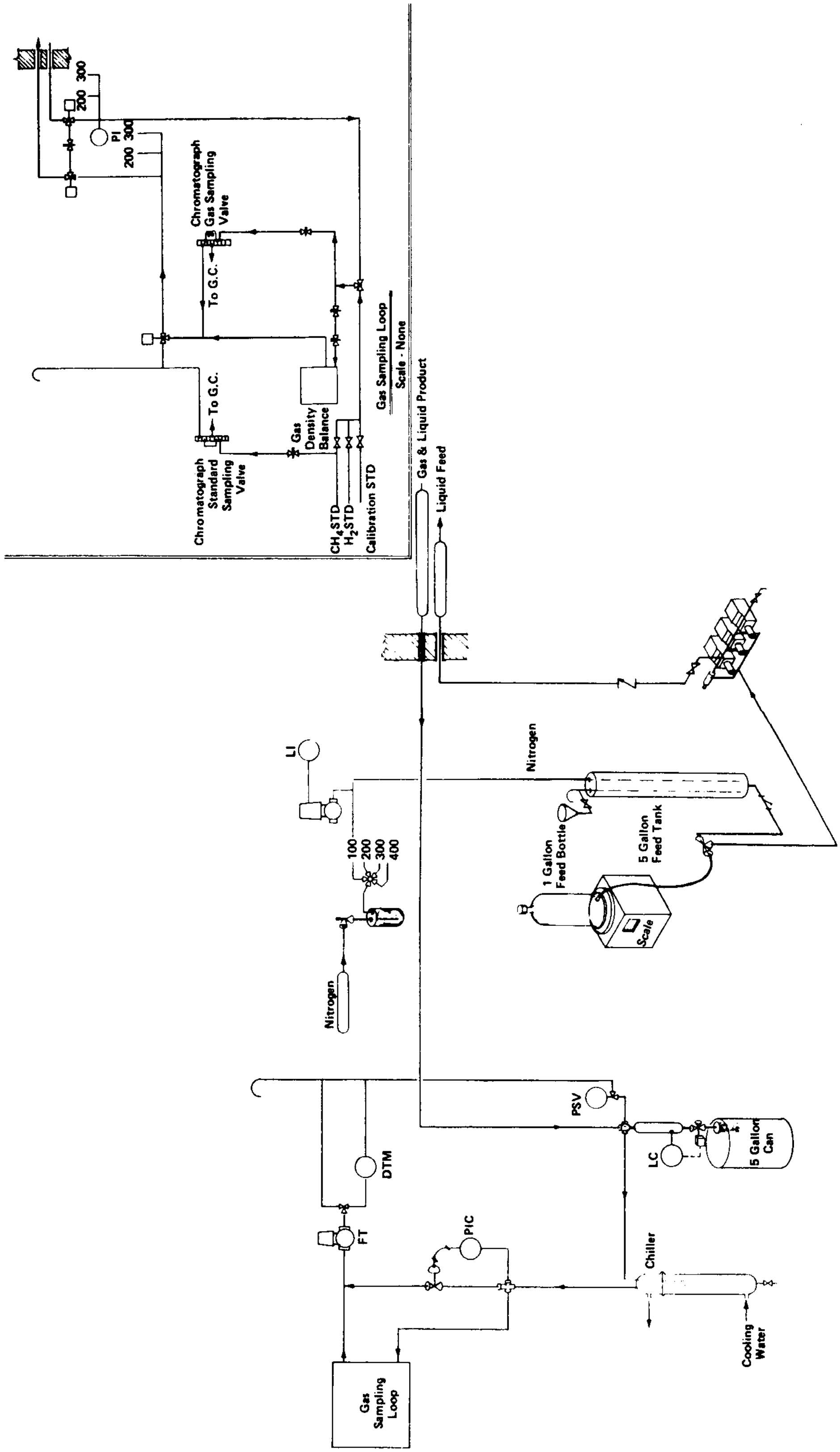


Figure I

ORIGINAL REACTOR

Figure II

ORIGINAL FEED AND PRODUCT RECOVERY EQUIPMENT



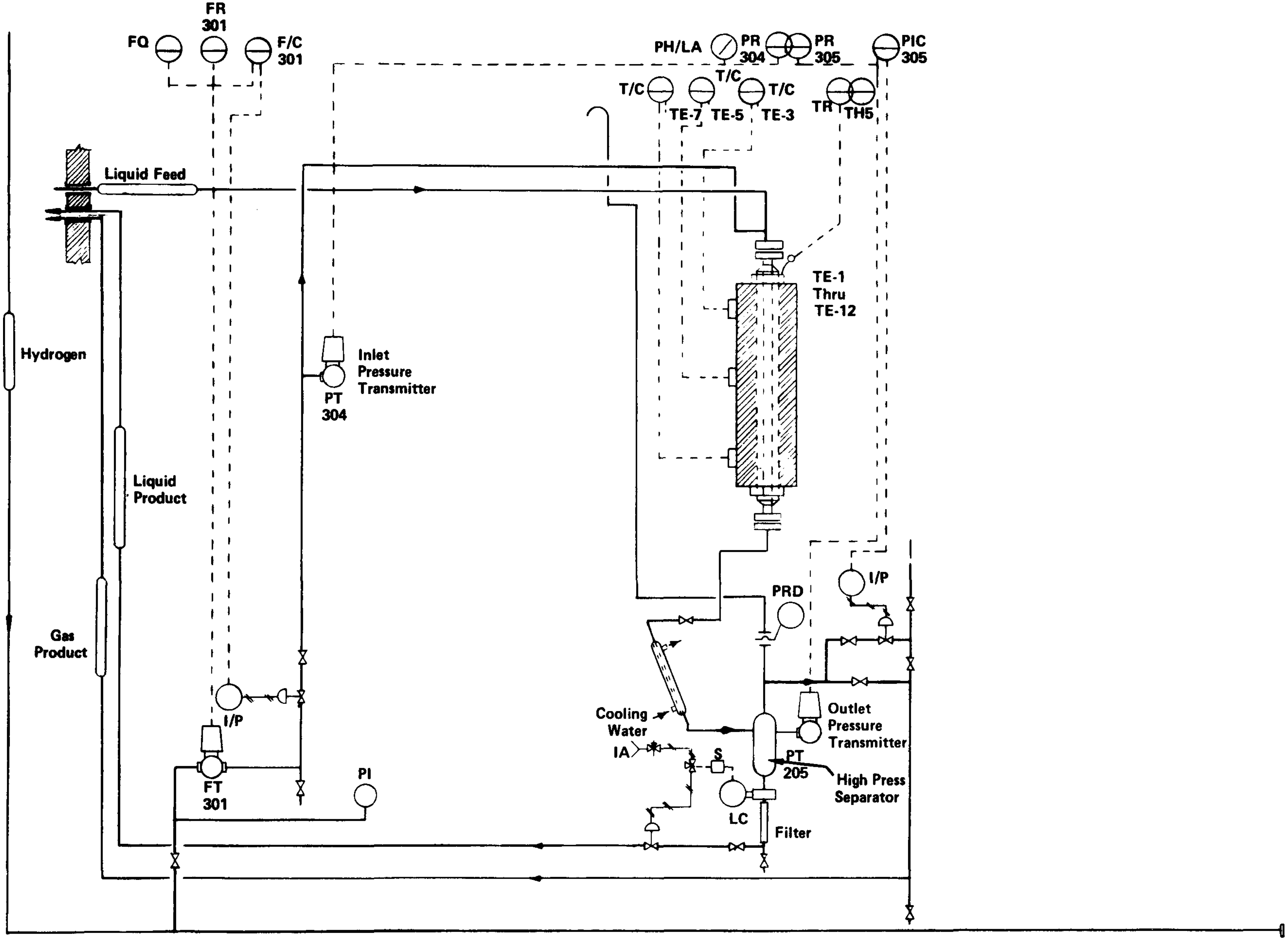
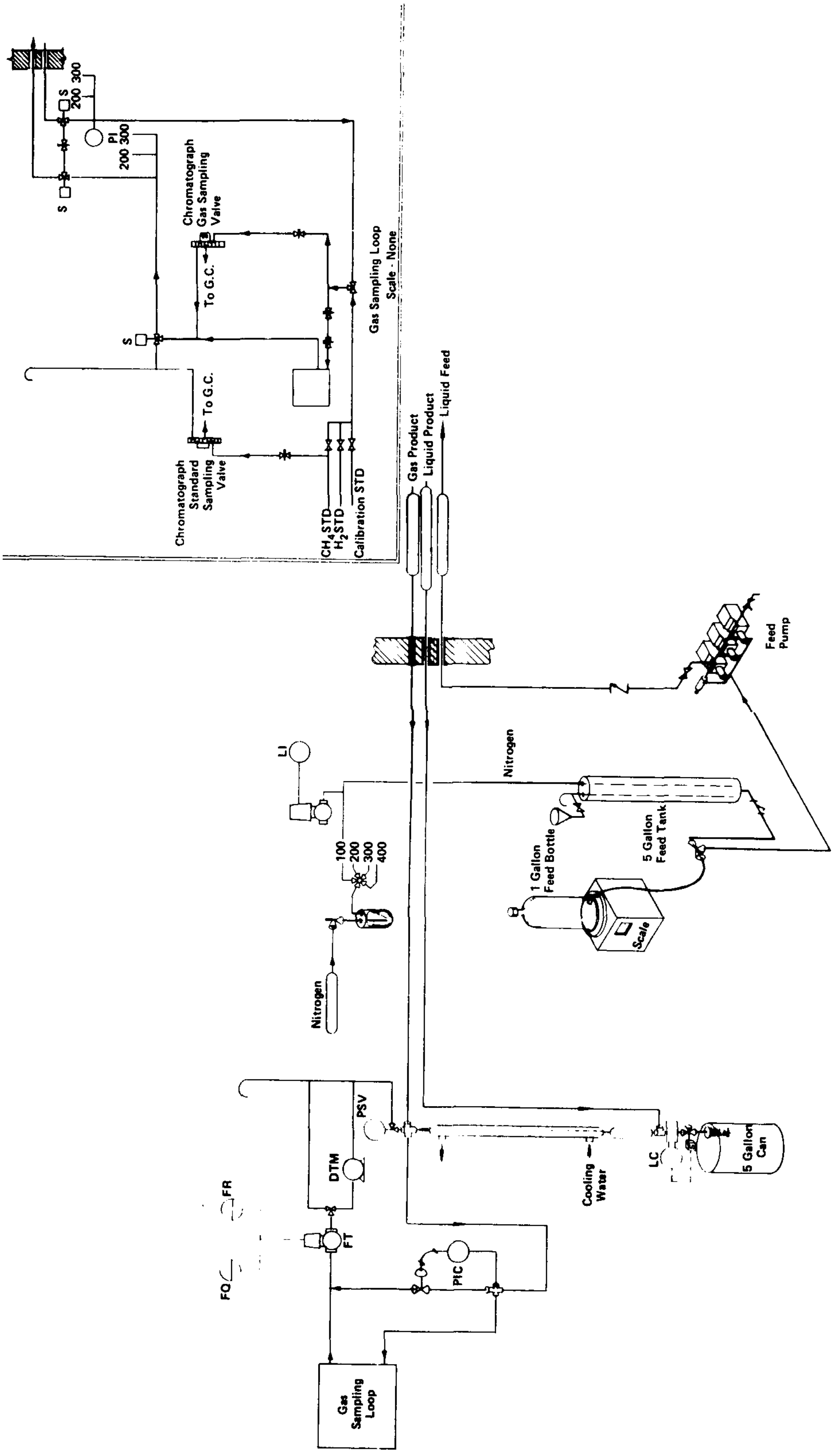


Figure III

MODIFIED REACTOR

Figure IV

MODIFIED FEED AND PRODUCT RECEOVERY EQUIPMENT



Conax® fittings and drilled with some dozen very small holes. Four 0.062 inch Megapak® type thermocouples are led through the Conax® fitting and sealed leak tight against the reactor pressure. The four internal thermocouples are positioned to measure temperature variations across the catalyst bed. One reactor has a one inch schedule 40 Type 446 stainless steel pipe inside a machined pressure shell of Type 316 stainless steel. The maximum operating pressure at temperatures below 1350°F is 1000 psig for this reactor. Because of the low pressure rating, this reactor was used for reforming runs. The other two reactors have a one inch schedule 80 Type 430 stainless steel pipe inside a machined pressure shell of "MO-RE" 1®. The maximum operating pressure at temperatures below 1250°F is 3000 psig for these reactors. Hydrocracking and hydrotreating experiments were conducted in these reactors.

High Pressure Separator - The reactor effluent is cooled in a tubular heat exchanger and the gas products are separated from the liquid in the high pressure separator. A pressure transmitter on the separator provides a signal for the recording of reactor outlet pressure, and through a controller and control valve, the back pressure control on the reactor. The gases are let down through the reactor pressure control valve, while the liquid level in the high pressure separator is controlled by a sonic level switch, which periodically energizes a solenoid valve which in turn opens the liquid level control valve. The liquid and gaseous products are recombined in the transfer line to the low pressure receiver in the original design. This was modified later when separate lines for each were provided.

Low Pressure Separator - In the original design the recombined gas and liquid products entered the low pressure separator at about 3 psig. Here the final liquid-gas separation took place. In the modified design only the liquid product entered the separator where the gas produced from the flash associated with the pressure drop from the high pressure to low pressure separators was disengaged from the liquid. Both gas streams were then recombined. The liquid level is controlled by a sonic level switch which operates a solenoid valve, dropping the liquid into an appropriate receiver. The gaseous products are further cooled in a tubular heat exchanger. A Taylor Fulscope® controller and control valve provide the 3 psig back pressure control. The back pressure control provides a continuous flow gas sample through paired solenoid valves located in the control room near the gas sampling loop and hence back to a flow transmitter. When energized, the paired solenoid valves provide a gas sample for analysis while maintaining the total gas flow through the flow transmitter. The flow rate is displayed at the control panel and is integrated, the square root integral is displayed as well. If desired, the total vent gas flow can be routed through a test meter for verification of the vent rate integral. The Foxboro integral orifice differential pressure cell flow transmitter used to measure the gaseous product flow rate was equipped with orifices ranging from 0.015 to 0.050 inches in diameter and operated at differential pressures from 0 to 20 inches of water. This flow transmitter was also calibrated before the start of each run with a Foxboro current calibrator.

DISTILLATION EQUIPMENT

The 20 gallon Podbielniak distillation column used to separate the various oils is designed to run unattended. It is capable of handling either light or heavy oils. The distillation kettle, column, and receivers are steam traced and the overhead condenser is cooled by a tempered water cooling system. A cold trap is also provided for very low boiling materials.

Distillations may be conducted at atmospheric pressure or under vacuum. The vacuum is provided by two vacuum pumps and is controlled by setting the vacuum rate metering valve and setting the set point using a mercury switch.

The boil-up rate is controlled by a pressure drop controller which controls the kettle heaters. The kettle is equipped with a hot oil temperature limit switch to prevent boiling the kettle dry.

The vapors going overhead are condensed in a reflux condenser at the top of the column. Condensed vapors are removed from the column just below the condenser. The overheads are split between reflux back to the column and overheads product by the overheads splitter which is controlled by two timers, one of which opens the valve in the overheads product line, and the other closes the valve. The overheads valve is maintained in the closed or total reflux position by the condenser temperature recorder controller when the cut point is reached.

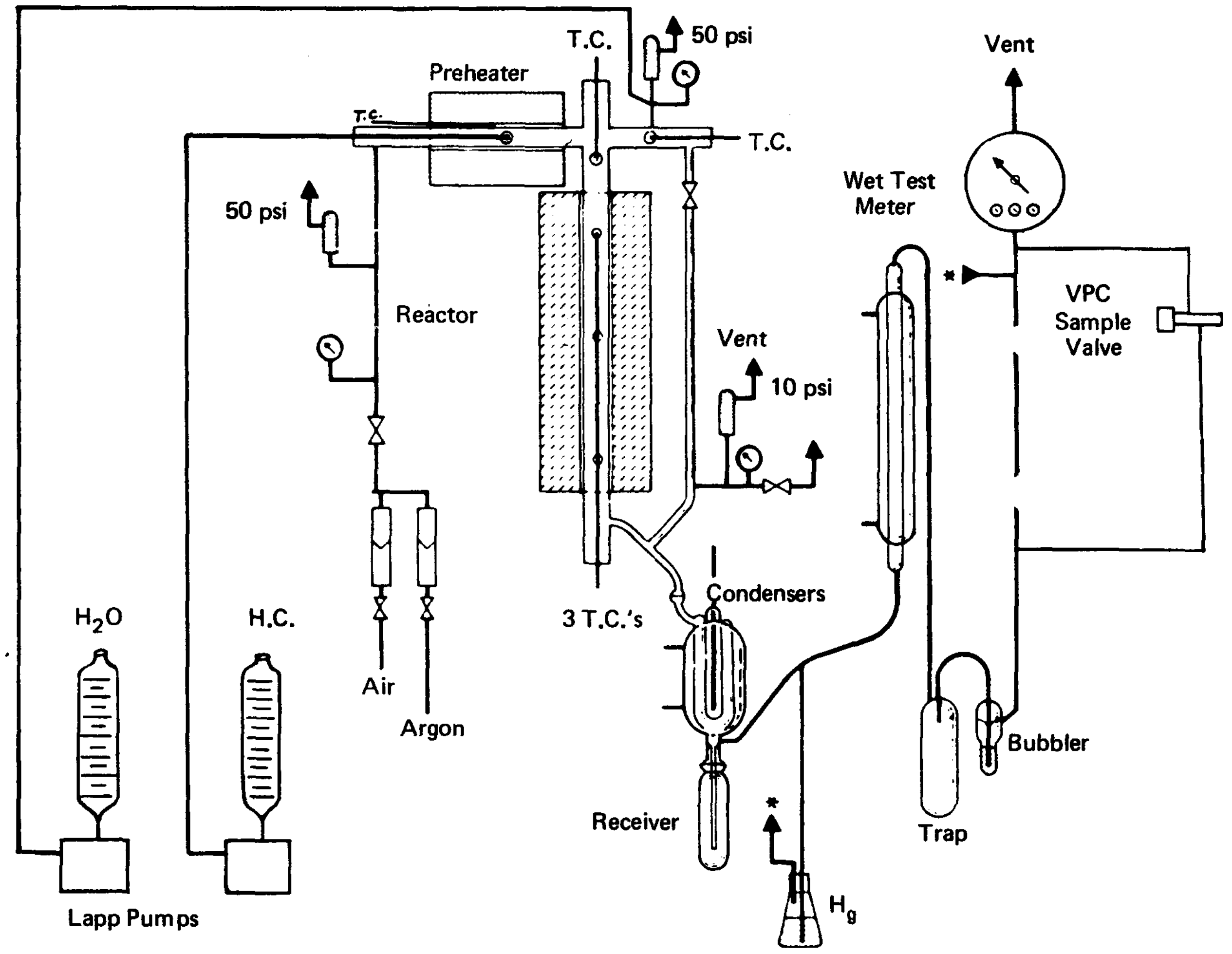
The cold trap provided for condensing very light materials can only be used for atmospheric distillations.

STEAM COIL CRACKING EQUIPMENT

The equipment used for the steam coil cracking experiments is shown in Figure V. Lapp metering pumps of 2000 ml/hr capacity are used to pump hydrocarbon and water from

Figure V

STEAM COIL CRACKING EQUIPMENT



graduated funnels into the reactor. After the water and liquid hydrocarbon are vaporized and preheated to about 500°C, the vapors enter the reactor where they are rapidly heated to cracking temperature. The hot effluent stream is cooled to below room temperature in a glass condenser using refrigerated glycol-water as coolant. The liquid products are collected in the receiver and the gases pass through a vapor phase chromatograph (V.P.C.) sampling valve and then through a wet test meter. The reactor and preheater are constructed of one inch Incoloy pipe and are electrically heated. The feed samples and both the liquid and gas phases of the cooled effluent stream were analyzed by V.P.C. methods. Gas samples were injected via two 7-Port Microtek sampling valves into the chromatographs for hydrogen and hydrocarbon analyses. An Aerograph Isothermal V.P.C. equipped with an activated charcoal column was used for hydrogen analysis with Argon as carrier gas. Using a standard set of operating conditions, the hydrogen concentration can be read from a standard curve of mole percent hydrogen versus peak area. The curve was prepared from analyses of known mixtures. An F&M temperature programmed Model 300 Chromatograph with a 10 ft flourosilicone on a activated alumina column was used for the analysis of the hydrocarbons in the gas phase. The liquid phase samples were first separated in a spinning band distillation column into an IBP-210°C cut, a 210-280°C, and a 280°C plus.

The IBP-210°C was analyzed using a squalane capillary column, 0.01 inch I.D. by 200 ft long. The 210-280°C was analyzed on a carbowax capillary column, 0.01 inch I.D. by 300 ft long. The 280°C plus material was not analyzed. Using the measured liquid sample weight and gas volume, the analyses of the two effluent streams were combined in the appropriate ratio to give the composition of the hot effluent stream from the reactor.

DATA REDUCTION TECHNIQUES

The data reduction techniques, methodology and assumptions described below were used to convert the hydroprocessing data to a useful form. With aid of the computer programs developed, fast accurate data reduction was possible.

Reactor Vent Gas Analysis - The objective of the vent gas analysis is to obtain material balance and hydrogen uptake information. To achieve this, the componential makeup of the vent gas and the mass flowrate must be determined. Vent gas hydrocarbons are quantitatively identified via gas chromatography. The sample injection is followed by a constant volume injection of methane. By injecting a sample gas of known composition, a methane response factor (RF_{CH_4}) may be defined as:

$$RF_{CH_4} = \frac{\text{Area \% of Pure } CH_4 \text{ Injection}}{\text{Area \% of Calibration Gas } CH_4} \times \text{mole \% } CH_4 \text{ in calibration gas}$$

Non-methane response factors are then related to the methane response factor in a computer program which uses area percent of each identified component in the gas as input data. Mole percent of each component and the corresponding weight percents are calculated. The unanalyzed portion of the gas is assumed to have a molecular weight of 2.016. The specific gravity is back calculated from these results and can be checked against the specific gravity measured on-line by a Beckman 3AM3 Gas Density balance. Weight percent carbon and hydrogen are also calculated. This program does not take into account the H_2O, H_2S, and NH_4 present in the vent gas.

SIMULATED DISTILLATION - The purpose of this analysis is to obtain a true boiling point distribution of a hydrocarbon. The assumption behind this test is that any hydrocarbon in the sample boiling at "x"°F will elute from the particular G.C. column used with the same retention time. A calibration mixture containing normal C_5 to C_{44} paraffins with known boiling points are used to obtain a boiling point versus time correlation. The sample chromatogram is divided by the Varian® computer into constant area percents, the end of each segment correlating with a boiling point. The result is a set of data points relating weight percent off versus boiling point.

SPINNING BAND DISTILLATION - The purpose of this procedure is to separate a sample of the composite material produced from hydrocracking experiments into a 350°F minus naphtha and a 350°F plus bottoms. In this manner, the simulated distillation results can be checked against the weight percent off at 350°F. More important, however, is that the naphtha distilled can be further analyzed to obtain componential data. This number is also used to identify the weight percent of C_{10}+ material in a sample. The approximately 40 theoretical plates in this column allow for very accurate distillation cuts.

NAPHTHA COMPONENTIALS - The purpose of this analysis is to quantitatively identify the C_4 to C_{12} hydrocarbons in a 375°F endpoint naphtha. The chromatogram of the sample is compared to a chromatogram with previously identified peaks. Peaks are assigned identification numbers. These identification numbers and their corresponding area percents are then fed into a program which calculates individual compound weight percent, mole percent, and liquid volume percent as well as the sample's average molecular weight, liquid specific gravity, API gravity, atomic H/C ratio and weight percent hydrogen. The compounds are then classified by carbon number and structural type. Weight percents and volume percents in each category are reported.

DATA REDUCTION PROGRAM - The purpose of this program is to combine the elemental and componential data from the vent gas, naphtha componential, and in the case of hydrocracking a weight percent off at 350°F (all C_{10}+ material) in the appropriate ratio to give the composition of the total effluent leaving the reactor. Mass flow rate data obtained from the experiments conducted was also input data to the computer program. Hydrogen consumed or produced, as well as a C_1-C_9 compounds classified by carbon number and structural type and the weight percent C_{10}+ material for the total hydroprocessing product.

ELEMENTAL BALANCE PROGRAM - The purpose of this program is to provide a carbon, hydrogen, oxygen, nitrogen, and sulfur elemental balance check on the data obtained from hydroprocessing experiments. Analytical results for weight percent C, H, O, N, S in the feedstock and liquid product are combined with the vent gas analysis for weight percent carbon and hydrogen in the appropriate ratio, based on mass flow rate data from the experiments, to give the product/feed balance for the elements present. The difference between the weight percent hydrogen calculated for the feed and for the products yields the hydrogen consumption or production since elements are also calculated in mass flow units.

ANALYTICAL EQUIPMENT AND TECHNIQUES

The laboratory is equipped with a number of gas chromatograph (G.C.) instruments for performing various analyses of the samples from the coal liquefaction processes and from our laboratory processing experiments. Process vent gas and liquid streams are both analyzed by this procedure. A varian Aerograph Chromatography Data System with a model No. 220-20D, Class IV computer completes this analytical capability.

NAPHTHA COMPONENTIAL

Analyses of C_3-C_9 hydrocarbon components, up to a 350°F endpoint, in the liquid product are performed using a Hewlett Packard 5710A G.C. equipped as follows:

Detector: Flame Ionization Detector (F.I.D.)

Column: 200 ft, 0.01 in. I.D. Squalane Capillary Column

Temperature Program:
Time 1 : 0
Temp 1 : 0°C
Rate : 2°C/min
Temp 2 : 100°C
Time 2 : Hold

A 0.5 micro liter sample is used.

VENT GAS COMPONENTIAL

Analysis of vent gas, generated by laboratory processing experiments, for hydrocarbon components is performed by using a Hewlett Packard 5700A G.C. with a methane internal standard method. The G.C. is equipped as follows:

Detector: Thermal Conductivity Detector (T.C.)

Column: 20 ft Porapak Q 80/100 mesh

Temperature Program:
Time 1 : 4 min
Temp 1 : 70°C
Rate : 16°C/min
Temp 2 : 230°C
Time 2 : 16 min

SIMULATED DISTILLATION

An analysis to obtain a true boiling point distribution for a liquid hydrocarbon sample which boils below 1000°F is performed using a Hewlett Packard 5710A G.C. A Varian Aerograph Simulated Distillation package included with the Varian Chromatography Data System implements programs that acquire and accept information through a teletype and store the data in the computer. The computer calibrates the chromatograph, calculates the boiling point temperature, and lists these versus the percent samples eluted. A 0.2 micro liter sample is used. For hydrocarbon containing fractions that boil above 1000°F, an internal standard variation may be used. The method instituted on the Varian apparatus is D 2887-73, adopted by the American Society for Testing and Materials (ASTM). The G.C. is equipped as follows:

Detector: F.I.D.

Column: 2 mm I.D. x 8 ft Bonded Methyl Silicone
on 100-110 Anakrom AW

Effluent Splitter: 1:10

Temperature Program:
Temp 1 : -20°C
Time 1 : 0
Rate : 16°C/min
Temp 2 : 350°C
Temp 2 : 4 min

CARBON AND HYDROGEN

Liquid samples are analyzed for the relative amounts of carbon and hydrogen present using a Model 1200 Chemical Data System Elemental Analyzer Peak Identifier. A 0.2 micro liter sample is passed over a copper oxide catalyst at 800°C where the carbon and hydrogen are converted to CO_2 and H_2O respectively. The amounts of carbon dioxide and water are determined with a vapor phase chromatograph equipped with a Porapak column and a T.C. detector.

NITROGEN

Determination of the amount of nitrogen present in a liquid sample is made using an Antek Model 771 Pyroreactor. Nitrogen in the sample is converted to NO_x at 1000°C. The level of nitrogen oxides produced is measured with a model 720 Chemiluminescent Nitrogen Detector and compared with a known standard.

SULFUR

The apparatus used for performing sulfur analyses on liquid samples is a Dohrmann Microcoulemetric Reactor. Sulfur present in the samples is converted to SO_2. Sulfur dioxide levels are determined by titrating with iodine and comparing results with known standards.

WATER

The concentration of water present in liquid samples is measured using a Photovolt Aquatest I analyzer. The Aquatest I is a coulometer, designed specifically for Karl Fischer titrations of water. Titration indicates the addition of a reagent. Electrical current adds the reagent in the case of the Aquatest I. Faraday's Law applies (1 equivalent = 96,500 coulombs), and the instrument reads out directly in micrograms of water.

TOTAL OXYGEN

Total oxygen content of liquid hydrocarbon samples is determined using neutron activation analysis. A Karman Model A711 Neutron Generator (14.3 x 10^6 electron volts) produces the necessary activation energy. Samples are conveyed to and from source and detector via a pneumatic transfer system. A scinilation detector equipped with a sodium iodide crystal detects the induced radioactive isotope (Nitrogen 16) at energies of 6.1 and 7.3 x 10^6 electron volts. The isotope has a 7.1 sec half-life, and decays back to oxygen, making the analysis a non-destructive method.

MERCURY AND GALLIUM

Analyses of various liquid samples for Mercury and Gallium at a 100 ppb detection level are carried out using a General Electronics TRIGA Reactor. Samples are irradiated in the nuclear reactor for approximately two hours causing them to become radioactive. Radiation count rates characteristic for the elements being detected are measured with an ORTEC (Ge)(Li) detector and compared to known standards.

COMMON METALS

Analyses of the liquid fractions for common metals are performed at detection levels from 0.1 to 3 ppm, depending on the particular element measured, by Atomic Emission. The samples are digested using sulfuric and nitric acids. The residue is taken up in a 20% $NaNo_3$ buffer. An aliquot of the buffer solution is dried on the ends of graphite electrodes and excited in a 9 amp A.C. arc discharge. The energy emitted from the discharge is dispersed by a grating spectrograph and collected on a photographic plate. The intensity of the spectral lines produced from the atoms in the discharge are converted to concentrations.

API GRAVITY

The API Gravity reported for the various fractions was determined using a hydrometer and was corrected to 60°F.

HYDROPROCESSING AND STEAM COIL CRACKING RUN DATA

Tables of the run data obtained from the hydroprocessing and steam coil cracking experiments are presented. The reactor conditions listed are the averages for the data set. Conversions were calculated from simulated distillation results for the hydrocracking runs. The componential data, including hydrogen consumption or production, was calculated from analyses performed on the gas and liquid products and combined in the computer programs. The elemental material balance data was derived from analytical results for elemental analyses and the flow rates from the run data and was calculated from a computer program. The steam coil cracking data presented is a combination of reactor conditions and analytical and computer data reduction.

HYDROPROCESSING DATA

DATE 9-13-74 DATA BOOK NO. 103-1-10
RUN, SAMPLE NO. COED 4
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	837
LHSV - VOL/VOL-HR	.36	CATALYST VOLUME CC	200
MATERIAL BALANCE %	96.24	FORCE BALANCED ON	OIL FEED
HYDROGEN RATIO SCF/BBL	8200	OIL PRODUCT RATE G/HR	57.75
OIL FEED RATE G/HR	63.18	TAIL GAS RATE G/HR	14.38
HYDROGEN FEED RATE G/HR	8.95	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 32.2 500°F + 87.9

YIELD: G/100G OIL FEED

HYDROGEN	-1.23[A]	-1.34[B]	WATER	---
METHANE	1.35			
ETHANE	1.60			
PROPANE	1.77			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	1.51	.25				1.76
C_5	.64	.37	.14			1.15
C_6	.16	.06	.34	1.18	.31	2.05
C_7	.19	.27	.50	1.59	1.46	4.01
C_8	.44	.18	.67	1.15	1.55	3.99
C_9	.21	.31	.04	.14	1.91	2.61
TOTAL	3.15	1.44	1.69	4.06	5.23	15.57

UNIDENTIFIED C_4 - C_9 .03 C_{10}+ 80.90

HYDROGEN YIELD SCF/BBL -706[A] -770[B]

ELEMENTAL MATERIAL BALANCE

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.0
HYDROGEN		13.6				
TOTAL	88.3	24.8	.16	.36	.005	113.6
PRODUCTS						
LIQUID	80.6	10.8	.000	.013	.001	91.41
HC GAS	7.57	1.66				9.23
HYDROGEN		12.4				12.4
NH_3		.035	.16			.195
H_2O		.044		.347		.391
H_2S		.000			.004	.004
TOTAL	88.2	24.94	.16	.36	.005	113.6

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 9-18-74 DATA BOOK NO. 103-1-20
RUN, SAMPLE NO. COED 6
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	918
LHSV - VOL/VOL-HR	.33	CATALYST VOLUME CC	200
MATERIAL BALANCE %	99.28	FORCE BALANCED ON	---
HYDROGEN RATIO SCF/BBL	8300	OIL PRODUCT RATE G/HR	39.14
OIL FEED RATE G/HR	61.57	TAIL GAS RATE G/HR	30.79
HYDROGEN FEED RATE G/HR	8.87	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 79.0 500°F + 96.0

YIELD: G/100G OIL FEED

HYDROGEN	-2,92[A]	-3.79[B]	WATER	---
METHANE	5.79			
ETHANE	6.35			
PROPANE	8.20			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	6.53	1.42				7.95
C_5	1.52	.80	.88			3.20
C_6	.16		.98	2.76	.91	4.81
C_7	.58	.72	2.06	3.12	3.98	10.46
C_8	1.04	.54	2.02	1.62	2.72	7.94
C_9	.53	.72	.27	.52	4.91	6.95
TOTAL	10.36	4.20	6.21	8.02	12.52	41.31

UNIDENTIFIED $C_4 - C_9$ --- $C_{10}+$ 40.44

HYDROGEN YIELD SCF/BBL -1680[A] -2180[B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.0
HYDROGEN		14.5				14.5
TOTAL	88.3	25.7	.16	.36	.005	114.5
PRODUCTS						
LIQUID	56.2	7.87	.000	NA	.003	64.1
HC GAS	32.0	7.08				39.1
HYDROGEN		11.3				11.3
NH_3		.035	.16			.195
H_2O		NA		NA		NA
H_2S		.000			.002	.002
TOTAL	88.2	26.3	.16		.005	114.7

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 9-19-74 DATA BOOK NO. 103-1-23
RUN, SAMPLE NO. COED 7
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	919
LHSV - VOL/VOL-HR	.64	CATALYST VOLUME CC	200
MATERIAL BALANCE %	101.37	FORCE BALANCED ON	OIL FEED
HYDROGEN RATIO SCF/BBL	4270	OIL PRODUCT RATE G/HR	89.60
OIL FEED RATE G/HR	120.14	TAIL GAS RATE G/HR	39.40
HYDROGEN FEED RATE G/HR	8.86	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 60.7 500°F + 80.6

YIELD: G/100G OIL FEED

HYDROGEN	-1.82[A]	-2.66[B]	WATER	---
METHANE	4.74			
ETHANE	4.75			
PROPANE	5.90			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	4.65	.87				5.52
C_5	1.50	.87	.66			3.03
C_6	.64	.41	1.59	2.14	2.17	6.95
C_7	.51	.80	1.38	2.00	4.04	8.73
C_8	.52	.33	1.20	.89	2.36	5.30
C_9	.24	.24	.08	.22	2.18	2.96
TOTAL	8.06	3.52	4.91	5.25	10.75	32.49

UNIDENTIFIED $C_4 - C_9$ .01 $C_{10}+$ 53.88

HYDROGEN YIELD SCF/BBL -1045[A] -1530[B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.0
HYDROGEN		7.38				7.38
TOTAL	88.3	18.58	.16	.36	.005	107.38
PRODUCTS						
LIQUID	65.8	8.74	.000	NA	.002	74.6
HC GAS	22.2	5.08				27.28
HYDROGEN		5.56				5.56
NH_3		.035	.16			.195
H_2O		NA		NA		NA
H_2S		.000			.003	.003
TOTAL	88.0	19.42	.16	NA	.005	107.44

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 9-20-74 DATA BOOK NO. 103-1-27
RUN, SAMPLE NO. COED 8
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	937
LHSV - VOL/VOL-HR	.65	CATALYST VOLUME CC	200
MATERIAL BALANCE %	103.61	FORCE BALANCED ON	OIL FEED
HYDROGEN RATIO SCF/BBL	4080	OIL PRODUCT RATE G/HR	85.13
OIL FEED RATE G/HR	125.35	TAIL GAS RATE G/HR	49.06
HYDROGEN FEED RATE G/HR	8.84	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 72.6 500°F + 86.7

YIELD: G/100G OIL FEED

HYDROGEN	-2.98 [A]	-3.00 [B]	WATER	---
METHANE	5.96			
ETHANE	6.34			
PROPANE	8.23			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	5.53	1.15				6.68
C_5	1.68	.97	.61			3.26
C_6		.51	2.43	2.46	3.89	9.29
C_7	.69	1.14	1.86	2.13	6.30	12.12
C_8	.62	.39	1.30	.81	3.38	6.50
C_9	.32	.28	.04	.19	2.77	3.60
TOTAL	8.84	4.44	6.24	5.59	16.34	41.45

UNIDENTIFIED C_4 - C_9 --- C_{10}+ 40.93

HYDROGEN YIELD SCF/BBL -1710 [A] -1720 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.0
HYDROGEN		7.05				7.05
TOTAL	88.3	18.25	.16	.36	.005	107.05
PRODUCTS						
LIQUID	60.2	7.63	.000	.04	.002	67.91
HC GAS	28.4	6.53				34.93
HYDROGEN		4.18				4.18
NH_3		.035	.16			.195
H_2O		.040		.32		.36
H_2S		.000			.003	.003
TOTAL	88.6	18.42	.16	.36	.005	107.58

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 9-24-74 DATA BOOK NO. 103-1-30
RUN, SAMPLE NO. COED 9
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	1500	TEMPERATURE °F	850
LHSV - VOL/VOL-HR	.36	CATALYST VOLUME CC	200
MATERIAL BALANCE %	98.36	FORCE BALANCED ON	OIL FEED
HYDROGEN RATIO SCF/BBL	6750	OIL PRODUCT RATE G/HR	59.68
OIL FEED RATE G/HR	65.58	TAIL GAS RATE G/HR	13.54
HYDROGEN FEED RATE G/HR	7.64	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 29.0 500°F + 46.7

YIELD: G/100G OIL FEED

HYDROGEN - .10[A] -.76[B] WATER ---
METHANE 1.55
ETHANE 1.65
PROPANE 1.91

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	1.42	.26				1.68
C_5	.59	.36	.22			1.17
C_6	.28	.20	.67	1.05	.91	3.11
C_7	.24	.39	.62	1.06	2.25	4.56
C_8	.32	.19	.64	.62	2.11	3.88
C_9	.12	.15	.05	.15	1.49	1.96
TOTAL	2.97	1.55	2.20	2.88	6.76	16.36

UNIDENTIFIED C_4 - C_9 --- C_{10}^+ 78.59

HYDROGEN YIELD SCF/BBL -60[A] -440[B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.0
HYDROGEN		11.7				11.7
TOTAL	88.3	22.9	.16	.36	.005	111.7
PRODUCTS						
LIQUID	80.8	10.2	.001	.019	.001	91.00
HC GAS	7.33	1.68				9.01
HYDROGEN		11.6				11.6
NH_3		.035	.16			.195
H_2O		.04		.34		.38
H_2S		.000			.004	.004
TOTAL	88.13	23.48	.16	.36	.005	112.19

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 10-1-74 DATA BOOK NO. 103-1-33
RUN, SAMPLE NO. COED 11
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	1500	TEMPERATURE °F	849
LHSV - VOL/VOL-HR	.74	CATALYST VOLUME CC	200
MATERIAL BALANCE %	78.33	FORCE BALANCED ON	OIL FEED
HYDROGEN RATIO SCF/BBL	4470	OIL PRODUCT RATE G/HR	99.75
OIL FEED RATE G/HR	105.41	TAIL GAS RATE G/HR	13.80
HYDROGEN FEED RATE G/HR	8.14	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 24.9 500°F + 77.8

YIELD: G/100G OIL FEED

HYDROGEN	- .28 [A]	-.61 [B]	WATER	---
METHANE	1.35			
ETHANE	1.30			
PROPANE	1.28			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	.89	.16				1.05
C_5	.32	.18	.10			.60
C_6	.16	.13	.26	.68	.27	1.50
C_7	.14	.20	.29	.78	1.10	2.51
C_8	.23	.14	.42	.65	1.66	3.10
C_9	.10	.11	.05	.16	1.41	1.83
TOTAL	1.84	.92	1.12	2.27	4.44	10.59

UNIDENTIFIED C_4 - C_9 0.0 C_{10}+ 85.77

HYDROGEN YIELD SCF/BBL -161 [A] -350 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.0
HYDROGEN		7.72				7.72
TOTAL	88.3	18.92	.16	.36	.005	107.72
PRODUCTS						
LIQUID	84.0	10.7	.006	.041	.001	94.7
HC GAS	4.53	1.11				5.64
HYDROGEN		7.44				7.44
NH_3		.03	.154			.159
H_2O		.04		.32		.36
H_2S		.000			.004	.004
TOTAL	88.5	19.32	.16	.36	.005	108.30

[A] From Hydrogen Mass Balance

[B] From Elemental Balance

HYDROPROCESSING DATA

DATE 10-3-74 DATA BOOK NO. 103-1-35
RUN, SAMPLE NO. COED 12
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	1500	TEMPERATURE °F	933
LHSV - VOL/VOL-HR	.37	CATALYST VOLUME CC	200
MATERIAL BALANCE %	101.0	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	6460	OIL PRODUCT RATE G/HR	48.65
OIL FEED RATE G/HR	68.33	TAIL GAS RATE G/HR	27.31
HYDROGEN FEED RATE G/HR	7.63	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 60.8 500°F + 76.2

YIELD: G/100G OIL FEED

HYDROGEN	-1.86[A]	-1.76[B]	WATER	---
METHANE	6.05			
ETHANE	5.61			
PROPANE	6.61			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	4.02	.92				4.94
C_5	1.38	.81	.81			3.00
C_6	.64	.40	1.94	1.11	2.62	6.71
C_7	.55	.82	1.43	1.01	5.48	9.29
C_8	.43	.35	.82	.48	3.34	5.42
C_9	.25	.28	.07	.20	2.49	3.29
TOTAL	7.27	3.58	5.07	2.80	13.93	32.65

UNIDENTIFIED $C_4 - C_9$ .01 $C_{10}+$ 51.49

HYDROGEN YIELD SCF/BBL -1070[A] -1010[B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.0
HYDROGEN		11.2				11.2
TOTAL	88.3	22.4	.16	.36	.005	111.2
PRODUCTS						
LIQUID	63.8	7.40	.000	NA	.001	71.2
HC GAS	25.1	5.52				30.62
HYDROGEN		9.38				9.38
NH_3		.035	.16			.195
H_2O		NA				NA
H_2S		.000			.004	.005
TOTAL	88.9	22.34	.16	NA	.005	111.40

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 10-4-74 DATA BOOK NO. 103-1-36
RUN, SAMPLE NO. COED 13
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	1500	TEMPERATURE °F	931
LHSV - VOL/VOL-HR	.69	CATALYST VOLUME CC	200
MATERIAL BALANCE %	99.37	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	3460	OIL PRODUCT RATE G/HR	101.62
OIL FEED RATE G/HR	128.55	TAIL GAS RATE G/HR	34.62
HYDROGEN FEED RATE G/HR	7.69	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 46.6 500°F + 63.2

YIELD: G/100G OIL FEED

HYDROGEN - .77 [A] -1.20 [B] WATER ---
METHANE 4.73
ETHANE 4.24
PROPANE 4.77

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	2.87	.66				3.53
C_5	1.03	.62	.51			2.16
C_6	.51	.33	1.26	.84	1.22	4.16
C_7	.40	.55	.87	.79	3.36	5.97
C_8	.36	.24	.63	.40	2.99	4.62
C_9	.01	.26	.05	.23	2.17	2.72
TOTAL	5.18	2.66	3.32	2.26	9.74	23.16

UNIDENTIFIED $C_4 - C_9$ .01 $C_{10}+$ 63.87

HYDROGEN YIELD SCF/BBL -440 [A] -690 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.0
HYDROGEN		5.98				5.98
TOTAL	88.3	17.18	.16	.36	.005	105.98

PRODUCTS

LIQUID	70.83	8.22	.002	NA	.001	79.05
HC GAS	17.57	4.15				21.72
HYDROGEN		5.21				5.21
NH_3		.034	.16			.194
H_2O		NA		NA		NA
H_2S		.000			.004	.004
TOTAL	88.40	17.61	.16	NA	.005	106.18

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 10-9-74 DATA BOOK NO. 103-1-38
RUN, SAMPLE NO. COED 14
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	1500	TEMPERATURE °F	930
LHSV - VOL/VOL-HR	.36	CATALYST VOLUME CC	200
MATERIAL BALANCE %	92.11	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	7440	OIL PRODUCT RATE G/HR	48.44
OIL FEED RATE G/HR	66.75	TAIL GAS RATE G/HR	26.89
HYDROGEN FEED RATE G/HR	8.58	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 62.3 500°F + 86.3

YIELD: G/100G OIL FEED

HYDROGEN	-1.21 [A]	-1.71 [B]	WATER	---
METHANE	6.01			
ETHANE	5.36			
PROPANE	5.88			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	3.48	.80				4.28
C_5	1.22	.73	.75			2.70
C_6	.61	.39	1.81	1.02	1.83	5.66
C_7	.54	.91	1.37	1.06	5.23	9.11
C_8	.50	.35	.96	.54	4.22	6.57
C_9	.33	.40	.05	.24	3.13	4.15
TOTAL	6.68	3.58	4.94	2.86	14.41	32.47

UNIDENTIFIED C_4 - C_9 0.00 $C_{10}+$ 51.55

HYDROGEN YIELD SCF/BBL -695 [A] -980 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.0
HYDROGEN		12.85				12.85
TOTAL	88.3	24.05	.16	.36	.005	112.85
PRODUCTS						
LIQUID	65.09	7.48	.000	NA	.002	72.57
HC GAS	23.26	5.39				28.65
HYDROGEN		11.64				11.64
NH_3		.035	.16			.195
H_2O		NA				NA
H_2S		.000			.003	.003
TOTAL	88.35	24.54	.16	NA	.005	113.06

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 10-10-74 DATA BOOK NO. 103-1-39
RUN, SAMPLE NO. COED 15
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	1500	TEMPERATURE °F	936
LHSV - VOL/VOL-HR	.36	CATALYST VOLUME CC	200
MATERIAL BALANCE %	104.41	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	7440	OIL PRODUCT RATE G/HR	45.93
OIL FEED RATE G/HR	66.75	TAIL GAS RATE G/HR	29.39
HYDROGEN FEED RATE G/HR	8.57	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 57.6 500°F + 75.4

YIELD: G/100G OIL FEED

HYDROGEN	-1.47[A]	-1.90[B]	WATER	---
METHANE	6.23			
ETHANE	5.80			
PROPANE	6.79			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	3.98	.95				4.93
C_5	1.32	.84	.70			2.86
C_6	.48	.27	1.56	.86	1.73	4.90
C_7	.50	.72	1.31	.93	4.99	8.45
C_8	.35	.27	.67	.41	3.04	4.74
C_9	.25	.18	.04	.15	3.28	3.90
TOTAL	6.88	3.23	4.28	2.35	13.04	29.78

UNIDENTIFIED $C_4 - C_9$ --- $C_{10}+$ 53.36

HYDROGEN YIELD SCF/BBL -845[A] -1090[B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.0
HYDROGEN		12.84				12.84
TOTAL	88.3	24.04	.16	.36	.005	112.84
PRODUCTS						
LIQUID	61.86	6.95	.001	.023	.001	68.83
HC GAS	26.59	6.07				32.66
HYDROGEN		11.37				11.37
NH_3		.035	.16			.195
H_2O		.04		.34		.38
H_2S		.000			.004	.004
TOTAL	88.45	24.47	.16	.36	.005	113.44

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 10-11-74 DATA BOOK NO. 103-1-40
RUN, SAMPLE NO. COED 16
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	1500	TEMPERATURE °F	936
LHSV - VOL/VOL-HR	.70	CATALYST VOLUME CC	200
MATERIAL BALANCE %	102.16	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	3830	OIL PRODUCT RATE G/HR	102.62
OIL FEED RATE G/HR	129.2	TAIL GAS RATE G/HR	35.13
HYDROGEN FEED RATE G/HR	8.55	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 49.8 500°F + 72.1

YIELD: G/100G OIL FEED

HYDROGEN - .91 [A] -1.06 [B] WATER ---
METHANE 4.54
ETHANE 4.07
PROPANE 4.46

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	2.65	.63				3.28
C_5	.99	.59	.56			2.14
C_6	.58	.37	1.47	.95	1.17	4.54
C_7	.54	.71	1.25	1.01	3.88	7.39
C_8	.48	.36	.84	.62	3.77	6.07
C_9	.28	.32	.07	.19	2.09	2.95
TOTAL	5.52	2.98	4.19	2.77	10.91	26.37

UNIDENTIFIED C_4 - C_9 --- C_{10}+ 61.58

HYDROGEN YIELD SCF/BBL -520 [A] -610 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.0
HYDROGEN		6.62				6.62
TOTAL	88.3	17.82	.16	.36	.005	106.62
PRODUCTS						
LIQUID	71.27	8.15	.002	.038	.001	79.47
HC GAS	17.35	4.03				21.38
HYDROGEN		5.71				5.71
NH_3		.035	.16			.195
H_2O		.04		.32		.36
H_2S		.000			.004	.004
TOTAL	88.62	17.97	.16	.36	.005	107.12

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 10-18-74 DATA BOOK NO. 103-1-45
RUN, SAMPLE NO. COED 21
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	940
LHSV - VOL/VOL-HR	.35	CATALYST VOLUME CC	200
MATERIAL BALANCE %	121.77	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	6960	OIL PRODUCT RATE G/HR	37.37
OIL FEED RATE G/HR	65.86	TAIL GAS RATE G/HR	36.40
HYDROGEN FEED RATE G/HR	7.91	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 83.6 500°F + 96.4

YIELD: G/100G OIL FEED

HYDROGEN	-3.27 [A]	-3.79 [B]	WATER	---
METHANE	6.88			
ETHANE	7.68			
PROPANE	10.07			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	6.79	1.46				8.25
C_5	2.20	1.27	1.43			4.90
C_6	1.34	.81	4.52	.82	4.16	11.65
C_7	.77	1.37	2.51	2.86	6.32	13.83
C_8	.67	.27	1.49	1.02	3.45	6.90
C_9	.28	.36	.07	.31	4.65	5.67
TOTAL	12.05	5.54	10.02	5.01	18.58	51.20

UNIDENTIFIED C_4 - C_9 --- C_{10}+ 28.60

HYDROGEN YIELD SCF/BBL -1880 [A] -2180 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.0
HYDROGEN		12.01				12.01
TOTAL	88.3	23.21	.16	.36	.005	112.01
PRODUCTS						
LIQUID	50.28	6.46	.000	.024	.002	56.76
HC GAS	38.08	8.45				46.53
HYDROGEN		8.74				8.74
NH_3		.035	.16			.195
H_2O		.042		.336		.378
H_2S		.000			.003	.003
TOTAL	88.36	23.73	.16	.36	.005	112.61

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 10-23-74 DATA BOOK NO. 103-1-47
RUN, SAMPLE NO. COED 23
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	934
LHSV - VOL/VOL-HR	.68	CATALYST VOLUME CC	200
MATERIAL BALANCE %	98.80	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	3620	OIL PRODUCT RATE G/HR	97.61
OIL FEED RATE G/HR	126.63	TAIL GAS RATE G/HR	36.94
HYDROGEN FEED RATE G/HR	7.92	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 50.2 500°F + 67.2

YIELD: G/100G OIL FEED

HYDROGEN	-3.19 [A]	-2.44 [B]	WATER	---
METHANE	3.76			
ETHANE	4.98			
PROPANE	6.85			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	4.20	.94				5.14
C_5	1.21	.76	.47			2.44
C_6	.47	.32	1.07	1.27	1.23	4.36
C_7	.37	.49	.88	1.23	2.98	5.95
C_8	.38	.24	.72	.73	2.34	4.41
C_9	.18	.21	.05	.16	2.23	2.83
TOTAL	6.81	2.96	3.19	3.39	8.78	25.13

UNIDENTIFIED C_4 - C_9 --- $C_{10}+$ 61.87

HYDROGEN YIELD SCF/BBL -1830 [A] -1400 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.0
HYDROGEN		6.25				6.25
TOTAL	88.3	17.45	.16	.36	.005	106.25
PRODUCTS						
LIQUID	68.44	8.65	.001	NA	.002	77.08
HC GAS	21.12	4.99				26.11
HYDROGEN		3.06				3.06
NH_3		.035	.16			.195
H_2O		NA				NA
H_2S		.000			.003	.003
TOTAL	89.56	16.70	.16	NA	.005	106.45

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 10-23-74 DATA BOOK NO. 103-1-48
RUN, SAMPLE NO. COED 24
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	916
LHSV - VOL/VOL-HR	.35	CATALYST VOLUME CC	200
MATERIAL BALANCE %	79.86	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	8000	OIL PRODUCT RATE G/HR	47.86
OIL FEED RATE G/HR	64.13	TAIL GAS RATE G/HR	25.13
HYDROGEN FEED RATE G/HR	8.86	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 62.2 500°F + 78.9

YIELD: G/100G OIL FEED

HYDROGEN	-1.44 [A]	-2.97 [B]	WATER	---
METHANE	5.56			
ETHANE	4.86			
PROPANE	5.00			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	3.12	.64				3.76
C_5	1.13	.63	.68			2.44
C_6	.66	.40	1.90	2.09	1.88	6.93
C_7	.55	1.01	1.65	2.16	4.41	9.78
C_8	.58	.35	1.34	.94	2.84	6.05
C_9	.25	.13	.10	.30	2.79	3.57
TOTAL	6.29	3.16	5.67	5.49	11.92	32.53

UNIDENTIFIED $C_4 - C_9$ .02 $C_{10}+$ 53.08

HYDROGEN YIELD SCF/BBL -830 [A] -1705 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.0
HYDROGEN		13.8				13.8
TOTAL	88.3	25.0	.16	.36	.005	113.8
PRODUCTS						
LIQUID	65.74	8.89	.000	.015	.001	74.65
HC GAS	21.63	5.20				26.83
HYDROGEN		12.36				12.36
NH_3		.035	.16			.195
H_2O		.043		.345		.388
H_2S		.000			.004	.004
TOTAL	87.37	26.54	.16	.36	.005	114.43

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 10-25-74 DATA BOOK NO. 103-3-2
RUN, SAMPLE NO. COED 25 REV
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	992
LHSV - VOL/VOL-HR	.68	CATALYST VOLUME CC	200
MATERIAL BALANCE %	115.13	FORCE BALANCED ON	TAIL GAS
HYDROGEN RATIO SCF/BBL	4050	OIL PRODUCT RATE G/HR	61.33
OIL FEED RATE G/HR	126.83	TAIL GAS RATE G/HR	74.36
HYDROGEN FEED RATE G/HR	8.86	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 85.1 500°F + 95.7

YIELD: G/100G OIL FEED

HYDROGEN	- 5.02 [A]	-4.17 [B]	WATER	---
METHANE	13.06			
ETHANE	13.13			
PROPANE	12.52			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	4.31	1.71				6.03
C_5	1.07	.68	1.70			3.45
C_6	.41	.17	2.70	.74	7.52	11.54
C_7	.34	.56	1.05	1.06	11.43	14.44
C_8	.17	.05	.53	.27	4.90	5.93
C_9	.28	.12	.00	.04	3.83	4.28
TOTAL	6.59	3.29	5.99	2.11	27.69	45.67

UNIDENTIFIED $C_4 - C_9$ .04 $C_{10}+$ 20.59

HYDROGEN YIELD SCF/BBL -2905 [A] -2410 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.00
HYDROGEN		6.99				6.99
TOTAL	88.3	18.19	.16	.36	.005	106.99
PRODUCTS						
LIQUID	43.73	4.62	.000	.014	.001	48.37
HC GAS	46.00	10.67				53.77
HYDROGEN		1.96				1.96
NH_3		.034	.16			.194
H_2O		.043		.346		.389
H_2S		.000			.004	.004
TOTAL	89.73	17.34	.16	.36	.005	107.58

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 10-29-74 DATA BOOK NO. 103-3-3
RUN, SAMPLE NO. COED 26 REV
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	975
LHSV - VOL/VOL-HR	.33	CATALYST VOLUME CC	200
MATERIAL BALANCE %	110.77	FORCE BALANCED ON	TAIL GAS
HYDROGEN RATIO SCF/BBL	8270	OIL PRODUCT RATE G/HR	16.63
OIL FEED RATE G/HR	62.00	TAIL GAS RATE G/HR	54.22
HYDROGEN FEED RATE G/HR	8.85	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 93.2 500°F + 98.1

YIELD: G/100G OIL FEED

HYDROGEN	-6.22 [A]	-6.62 [B]	WATER	---
METHANE	12.72			
ETHANE	14.27			
PROPANE	15.53			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	6.36	2.17				8.53
C_5	1.78	1.06	3.10			5.93
C_6	.73	.27	5.27	2.66	8.68	17.61
C_7	.47	.95	.75	2.68	9.44	14.29
C_8	.18	.06	.43	.24	2.18	3.09
C_9	.10	.09	.08	.03	1.33	1.62
TOTAL	9.60	4.59	9.63	5.61	21.64	51.07

UNIDENTIFIED $C_4 - C_9$ .05 $C_{10}+$ 12.56

HYDROGEN YIELD SCF/BBL -3600 [A] -3830 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	88.3	11.2	.16	.36	.005	100.0
HYDROGEN		14.27				14.27
TOTAL	88.3	25.47	.16	.36	.005	114.27

PRODUCTS						
LIQUID	23.97	2.85	.002	NA	.000	26.82
HC GAS	64.46	14.94				79.40
HYDROGEN		8.05				8.05
NH_3		.034	.16			.194
H_2O		NA				NA
H_2S		.000			.005	.005
TOTAL	88.43	25.87	.16	NA	.005	114.47

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 10-31-74 DATA BOOK NO. 103-3-5
RUN, SAMPLE NO. COED 27
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED 2nd PASS MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	852
LHSV - VOL/VOL-HR	.33	CATALYST VOLUME CC	200
MATERIAL BALANCE %	97.87	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	8390	OIL PRODUCT RATE G/HR	56.36
OIL FEED RATE G/HR	60.50	TAIL GAS RATE G/HR	12.98
HYDROGEN FEED RATE G/HR	8.84	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 29.6 500°F + 45.1

YIELD: G/100G OIL FEED

HYDROGEN - .93 [A] -1.66 [B] WATER ---
METHANE .84
ETHANE 1.00
PROPANE 1.46

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	1.60	.23				1.83
C_5	.44	.27	.27			.98
C_6	.17	.09	.79	.77	.84	2.66
C_7	.17	.22	.77	.72	1.72	3.60
C_8	.20	.13	.47	.36	.98	2.14
C_9	.09	.12	.06	.13	1.74	2.14
TOTAL	2.67	1.06	2.36	1.98	5.28	13.35

UNIDENTIFIED $C_4 - C_9$ --- $C_{10}+$ 84.60

HYDROGEN YIELD SCF/BBL -535 [A] -950 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	89.2	10.80	.003	.038	.002	100.0
HYDROGEN		14.61				14.61
TOTAL	89.2	25.41	.003	.038	.002	114.61
PRODUCTS						
LIQUID	82.11	11.04	.000	.013	.000	93.16
HC GAS	6.36	1.42				7.78
HYDROGEN		13.68				13.68
NH_3		.000	.003			.003
H_2O		.003		.025		.028
H_2S		.000			.002	.002
TOTAL	88.47	26.14	.003	.038	.002	114.65

A *From Hydrogen Mass Balance* B *From Elemental Balance*

HYDROPROCESSING DATA

DATE 11-5-74 DATA BOOK NO. 103-3-9
RUN, SAMPLE NO. COED 30
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED 2nd PASS MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	928
LHSV - VOL/VOL-HR	.72	CATALYST VOLUME CC	200
MATERIAL BALANCE %	98.77	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	3810	OIL PRODUCT RATE G/HR	102.04
OIL FEED RATE G/HR	133.29	TAIL GAS RATE G/HR	40.10
HYDROGEN FEED RATE G/HR	8.85	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 57.8 500°F + 73.7

YIELD: G/100G OIL FEED

HYDROGEN	-3.32[A]	-2.85[B]	WATER	---
METHANE	3.88			
ETHANE	4.20			
PROPANE	5.70			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	3.79	.95				4.74
C_5	1.20	.73	1.55			3.48
C_6	.68	.42	2.52	.77	2.77	7.16
C_7	.45	1.02	1.44	.80	4.49	8.20
C_8	.38	.31	.91	.34	2.69	4.63
C_9	.30	.25	.11	.20	4.10	4.96
TOTAL	6.80	3.68	6.53	2.11	14.05	33.17

UNIDENTIFIED C_4 - C_9 .02 C_{10}+ 56.51

HYDROGEN YIELD SCF/BBL -1910[A] -1640[B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	89.2	10.8	.003	.038	.002	100.0
HYDROGEN		6.64				6.64
TOTAL	89.2	17.44	.003	.038	.002	106.64
PRODUCTS						
LIQUID	67.87	8.66	.000	.011	.001	76.54
HC GAS	21.78	4.99				26.77
HYDROGEN		3.32				3.32
NH_3		.001	.003			.004
H_2O		.003		.027		.030
H_2S		.000			.001	.001
TOTAL	89.65	16.97	.003	.038	.002	106.67

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 11-7-74 DATA BOOK NO. 103-3-10
RUN, SAMPLE NO. COED 31
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED 2nd PASS MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	980
LHSV - VOL/VOL-HR	.72	CATALYST VOLUME CC	200
MATERIAL BALANCE %	101.27	FORCE BALANCED ON	TAIL GAS
HYDROGEN RATIO SCF/BBL	3850	OIL PRODUCT RATE G/HR	65.38
OIL FEED RATE G/HR	132.00	TAIL GAS RATE G/HR	75.47
HYDROGEN FEED RATE G/HR	8.85	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 90.7 500°F + 95.4

YIELD: G/100G OIL FEED

HYDROGEN	-4.41[A]	-4.68[B]	WATER	---
METHANE	12.81			
ETHANE	13.79			
PROPANE	13.00			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	4.40	2.19				6.59
C_5	1.02	.99	.15			2.16
C_6	.31	.17	1.56	.29	6.27	8.60
C_7	.22	.46	.75	.33	10.29	12.05
C_8	.12	.12	.29	.12	6.27	6.92
C_9	.39	.09	.02	.04	4.26	4.80
TOTAL	6.46	4.02	2.77	.78	27.09	41.12

UNIDENTIFIED C_4 - C_9 .02 C_{10}+ 23.62

HYDROGEN YIELD SCF/BBL -2530[A] -2690[B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	89.2	10.8	.003	.038	.002	100.0
HYDROGEN		6.70				6.70
TOTAL	89.2	17.50	.003	.038	.002	106.70
PRODUCTS						
LIQUID	44.97	4.55	.000	.012	.000	49.53
HC GAS	43.96	10.93				54.89
HYDROGEN		2.29				2.29
NH_3		.000	.003			.003
H_2O		.003		.026		.029
H_2S		.000			.002	.002
TOTAL	88.93	17.77	.003	.038	.002	106.75

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 12-13-74 DATA BOOK NO. 103-3-17
RUN, SAMPLE NO. COED 34
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED 2nd PASS MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	938
LHSV - VOL/VOL-HR	.79	CATALYST VOLUME CC	200
MATERIAL BALANCE %	98.90	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	3570	OIL PRODUCT RATE G/HR	108.63
OIL FEED RATE G/HR	145.07	TAIL GAS RATE G/HR	45.45
HYDROGEN FEED RATE G/HR	9.01	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 62.5 500°F + 77.9

YIELD: G/100G OIL FEED

HYDROGEN	-2.16 [A]	-2.88 [B]	WATER	---
METHANE	4.19			
ETHANE	4.41			
PROPANE	5.68			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	4.76	.84				5.60
C_5	1.35	.82	.79			2.96
C_6	.50	.24	2.75	1.35	2.12	6.96
C_7	.49	1.21	1.95	1.21	3.87	8.73
C_8	.42	.36	1.11	.49	2.34	4.72
C_9	.28	.18	.13	.20	3.49	4.28
TOTAL	7.80	3.65	6.73	3.25	11.82	33.25

UNIDENTIFIED $C_4 - C_9$ .02 $C_{10}+$ 54.62

HYDROGEN YIELD SCF/BBL -1240 [A] -1650 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	89.2	10.8	.003	.038	.002	100.0
HYDROGEN		6.21				6.21
TOTAL	89.2	17.01	.003	.038	.002	106.21
PRODUCTS						
LIQUID	66.35	8.52	.000	.013	.000	74.88
HC GAS	22.12	5.16				27.28
HYDROGEN		4.05				4.05
NH_3		.000	.003			.003
H_2O		.003		.025		.028
H_2S		.000			.002	.002
TOTAL	88.47	17.73	.003	.038	.002	106.24

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 12-17-74 DATA BOOK NO. 103-3-18
RUN, SAMPLE NO. COED 35
PROCESS: HYDROCRACKING MID-DISTILLATE
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED 2nd PASS MID-DISTILLATE

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	916
LHSV - VOL/VOL-HR	.51	CATALYST VOLUME CC	200
MATERIAL BALANCE %	102.24	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	5560	OIL PRODUCT RATE G/HR	81.45
OIL FEED RATE G/HR	93.88	TAIL GAS RATE G/HR	21.52
HYDROGEN FEED RATE G/HR	9.09	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

400°F + 39.5 500°F + 55.4

YIELD: G/100G OIL FEED

HYDROGEN	-1.09[A]	-1.91[B]	WATER	---
METHANE	2.41			
ETHANE	2.38			
PROPANE	2.67			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	2.43	.36				2.79
C_5	.67	.38	.40			1.45
C_6	.23	.13	.88	1.02	.94	3.20
C_7	.21	.53	.46	.71	1.87	3.78
C_8	.20	.15	.50	.33	1.02	2.20
C_9	.10	.17	.06	.23	2.34	2.90
TOTAL	3.84	1.72	2.30	2.29	6.17	16.32

UNIDENTIFIED $C_4 - C_9$ --- $C_{10}+$ 77.28

HYDROGEN YIELD SCF/BBL -630[A] -1100[B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	89.2	10.8	.003	.038	.002	100.0
HYDROGEN		9.68				9.68
TOTAL	89.2	20.48	.003	.038	.002	109.68
PRODUCTS						
LIQUID	76.76	9.98	.000	.013	.001	86.75
HC GAS	11.65	2.73				14.38
HYDROGEN		8.59				8.59
NH_3		.000	.003			.003
H_2O		.003		.025		.028
H_2S		.000			.001	.001
TOTAL	88.41	21.30	.003	.038	.002	109.75

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 8-20-75 DATA BOOK NO. 103-2-24
RUN, SAMPLE NO. COED 820 REV.
PROCESS: HYDROCRACKING GAS OIL
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN GAS OIL

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	851
LHSV - VOL/VOL-HR	1.21	CATALYST VOLUME CC	150
MATERIAL BALANCE %	98.89	FORCE BALANCED ON	OIL FEED
HYDROGEN RATIO SCF/BBL	4860	OIL PRODUCT RATE G/HR	157.50
OIL FEED RATE G/HR	178.89	TAIL GAS RATE G/HR	35.54
HYDROGEN FEED RATE G/HR	14.15	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

650°F + 56.7 750°F + 65.4

YIELD: G/100G OIL FEED

HYDROGEN	-0.23 [A]	-1.19 [B]	WATER	---
METHANE	1.90			
ETHANE	1.63			
PROPANE	2.07			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	2.05	.37				2.42
C_5	.73	.49	.13			1.34
C_6	.42	.32	.43	.86	.24	2.26
C_7	.08	.50	.19	.99	1.06	2.82
C_8	.20	.17	.24	.21	.65	1.47
C_9	.12	.10	.02	.13	1.32	1.69
TOTAL	3.60	1.94	1.01	2.19	3.26	12.00

UNIDENTIFIED $C_4 - C_9$ 0.0 $C_{10}+$ 82.62

HYDROGEN YIELD SCF/BBL -141 [A] -730 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	89.0	10.7	.090	.246	.009	100.00
HYDROGEN		7.91				7.91
TOTAL	89.0	18.61	.090	.246	.009	107.91
PRODUCTS						
LIQUID	78.39	9.66	---	.035	---	88.05
HC GAS	9.98	2.20				12.18
HYDROGEN		7.68				7.68
NH_3						
H_2O		.026		.211		.237
H_2S						
TOTAL	88.37	19.57		.246		108.19

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 8-28-75 DATA BOOK NO. 103-2-26
RUN, SAMPLE NO. COED 828
PROCESS: HYDROCRACKING GAS OIL
CATALYST: HARSHAW HT-400-1/8-E
FEED: COED ST. RUN GAS OIL

REACTOR CONDITIONS

PRESSURE - PSIG	2500	TEMPERATURE °F	932
LHSV - VOL/VOL-HR	1.45	CATALYST VOLUME CC	150
MATERIAL BALANCE %	118.36	FORCE BALANCED ON	OIL FEED
HYDROGEN RATIO SCF/BBL	3820	OIL PRODUCT RATE G/HR	168.86
OIL FEED RATE G/HR	214.6	TAIL GAS RATE G/HR	59.06
HYDROGEN FEED RATE G/HR	13.33	WATER PRODUCT G/HR	---

CONVERSIONS WEIGHT PERCENT

650°F + 77.9 750°F + 87.0

YIELD: G/100G OIL FEED

HYDROGEN	-2.71[A]	-2.09[B]	WATER	---
METHANE	5.30			
ETHANE	4.41			
PROPANE	4.83			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	2.48	.61				3.09
C_5	.68	.42	.14			1.25
C_6	.85	.49	.92	1.62	.65	4.54
C_7	.76	.62	.57	1.93	1.52	5.41
C_8	.50	.26	.42	.30	1.54	3.01
C_9	.31	.25	.10	.34	1.50	2.49
TOTAL	5.57	2.65	2.16	4.20	5.21	19.78

UNIDENTIFIED $C_4 - C_9$ --- $C_{10}+$ 68.14

HYDROGEN YIELD SCF/BBL -1665[A] -1285[B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	89.0	10.7	.090	.246	.009	100.0
HYDROGEN		6.21				6.21
TOTAL	89.0	16.91	.090	.246	.009	106.21
PRODUCTS						
LIQUID	70.47	8.16	.005	.051	.002	78.69
HC GAS	19.44	4.58				24.02
HYDROGEN		3.50				3.50
NH_3		.018	.085			.103
H_2O		.024		.195		.219
H_2S		.000			.007	.007
TOTAL	89.91	16.28	.090	.246	.009	106.54

A From Hydrogen Mass Balance B From Elemental Balance

COED
ST. RUN NAPHTHA
HYDROTREATED FEED
TO
REFORMING

Carbon	87.1
Hydrogen	12.9

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
C_6	0.7	0.4	1.2	6.8	0.8
C_7	0.9	1.7	2.8	15.2	5.0
C_8	3.2	1.5	5.5	7.2	8.5
C_9	1.0	1.4	2.4	9.0	14.5
C_{10}^+	10.3				

HYDROPROCESSING DATA

DATE 1-8-76 DATA BOOK NO. 103-4-62
RUN, SAMPLE NO. 10876
PROCESS: REFORMING
CATALYST: CYANAMID AERO PHF-4
FEED: COED HYDROTREATED ST. RUN NAPHTHA

REACTOR CONDITIONS

PRESSURE - PSIG	250	TEMPERATURE °F	955
LHSV - VOL/VOL-HR	2.0	CATALYST VOLUME CC	50
MATERIAL BALANCE %	99.29	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	4000	OIL PRODUCT RATE G/HR	61.27
OIL FEED RATE G/HR	79.56	TAIL GAS RATE G/HR	24.29
HYDROGEN FEED RATE G/HR	6.40	WATER PRODUCT G/HR	---

YIELD: G/100G OIL FEED

HYDROGEN	+3.03[A]	2.32[B]	WATER	---
METHANE	1.79			
ETHANE	2.64			
PROPANE	3.10			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	1.66	1.05				2.71
C_5	1.08	1.24	.15			2.47
C_6	1.28	.69	.40	.0	7.05	9.43
C_7	.45	1.03	.25	.0	21.85	23.58
C_8	.00	.61	.05	.0	24.16	24.81
C_9	.00	.09	.02	.0	20.30	20.42
TOTAL	4.47	4.71	.87	.0	73.36	83.41

UNIDENTIFIED C_4 - C_9 0.0 C_{10}^{+} 6.01

HYDROGEN YIELD SCF/BBL 1510[A] 1150[B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	87.1	12.9				100.0
HYDROGEN		8.04				8.04
TOTAL	87.1	20.94				108.04
PRODUCTS						
LIQUID	69.6	7.40				77.01
HC GAS	16.8	3.18				19.94
HYDROGEN		11.08				11.08
NH_3						
H_2O						
H_2S						
TOTAL	86.4	21.65				108.03

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 1-9-76 DATA BOOK NO. 103-4-62
RUN, SAMPLE NO. 10976
PROCESS: REFORMING
CATALYST: CYANAMID AERO PHF-4
FEED: COED HYDROTREATED ST. RUN NAPHTHA

REACTOR CONDITIONS

PRESSURE - PSIG	250	TEMPERATURE °F	955
LHSV - VOL/VOL-HR	2.01	CATALYST VOLUME CC	50
MATERIAL BALANCE %	96.11	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	3990	OIL PRODUCT RATE G/HR	61.76
OIL FEED RATE G/HR	80.00	TAIL GAS RATE G/HR	24.67
HYDROGEN FEED RATE G/HR	6.43	WATER PRODUCT G/HR	---

YIELD: G/100G OIL FEED

HYDROGEN	2.73[A]	1.68[B]	WATER	---
METHANE	1.83			
ETHANE	2.54			
PROPANE	3.00			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	1.76	1.10				2.85
C_5	.97	1.22	.24			2.44
C_6	1.15	1.30	.98	.37	5.78	9.57
C_7	.75	1.52	1.15	.90	18.74	23.06
C_8	.44	.96	.55	.74	20.35	23.04
C_9	.58	1.15	.22	.34	17.79	20.08
TOTAL	5.64	7.25	3.14	2.35	62.66	81.04

UNIDENTIFIED C_4 - C_9 0.0 C_{10}+ 8.61

HYDROGEN YIELD SCF/BBL 1360[A] 835[B]

OIL	87.1	12.9	100.0
HYDROGEN		8.04	8.04
TOTAL	87.1	20.94	108.04

PRODUCTS

LIQUID	69.2	8.01	77.20
HC GAS	16.7	3.21	19.88
HYDROGEN		10.77	10.77
NH_3			
H_2O			
H_2S			
TOTAL	85.9	21.99	107.84

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 1-12-76 DATA BOOK NO. 103-4-63
RUN, SAMPLE NO. 011276
PROCESS: REFORMING
CATALYST: CYANAMID AERO PHF-4
FEED: COED HYDROTREATED ST. RUN NAPHTHA

REACTOR CONDITIONS

PRESSURE - PSIG	250	TEMPERATURE °F	954
LHSV - VOL/VOL-HR	2.01	CATALYST VOLUME CC	50
MATERIAL BALANCE %	92.98	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	3940	OIL PRODUCT RATE G/HR	62.76
OIL FEED RATE G/HR	80.00	TAIL GAS RATE G/HR	23.58
HYDROGEN FEED RATE G/HR	6.35	WATER PRODUCT G/HR	---

YIELD: G/100G OIL FEED

HYDROGEN	3.49 ^{A}	2.21 ^{B}	WATER	---
METHANE	1.79			
ETHANE	2.37			
PROPANE	2.63			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	1.30	.94				2.24
C_5	.71	1.11	.10			1.91
C_6	.88	1.19	.49	.08	6.88	9.53
C_7	.54	1.15	.49	.28	20.74	23.20
C_8	.25	.82	.27	.22	21.56	23.13
C_9	1.18	.09	.14	.08	17.88	19.38
TOTAL	4.87	5.30	1.49	.66	67.07	79.39

UNIDENTIFIED C_4 - C_9 0.0 $C_{10}+$ 10.13

HYDROGEN YIELD SCF/BBL 1730 ^{A} 1100 ^{B}

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	87.1	12.9				100.0
HYDROGEN		7.94				7.94
TOTAL	87.1	20.85				107.94
PRODUCTS						
LIQUID	70.58	7.88				78.46
HC GAS	15.08	2.82				17.90
HYDROGEN		11.42				11.42
NH_3						
H_2O						
H_2S						
TOTAL	85.66	22.12				107.78

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 1-13-76 DATA BOOK NO. 103-4-63
RUN, SAMPLE NO. 011376
PROCESS: REFORMING
CATALYST: CYANAMID AERO PHF-4
FEED: COED HYDROTREATED ST. RUN NAPHTHA

REACTOR CONDITIONS

PRESSURE - PSIG	250	TEMPERATURE °F	954
LHSV - VOL/VOL-HR	2.12	CATALYST VOLUME CC	50
MATERIAL BALANCE %	100.18	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	3750	OIL PRODUCT RATE G/HR	64.93
OIL FEED RATE G/HR	84.30	TAIL GAS RATE G/HR	25.73
HYDROGEN FEED RATE G/HR	6.36	WATER PRODUCT G/HR	---

YIELD: G/100G OIL FEED

HYDROGEN	3.19[A]	1.59[B]	WATER	---
METHANE	1.79			
ETHANE	2.41			
PROPANE	2.73			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	1.62	.95				2.57
C_5	1.10	1.11	.20			2.40
C_6	1.17	1.15	1.41	.23	5.43	9.39
C_7	.89	1.61	1.80	1.16	16.98	22.45
C_8	.67	1.12	1.16	1.16	17.96	22.06
C_9	.09	1.16	.32	.77	17.55	19.90
TOTAL	5.55	7.11	4.89	3.31	57.92	78.78

UNIDENTIFIED $C_4 - C_9$ 0.0 $C_{10}+$ 11.04

HYDROGEN YIELD SCF/BBL 1585[A] 790[B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	87.1	12.9				100.0
HYDROGEN		7.54				7.54
TOTAL	87.1	20.44				107.54
PRODUCTS						
LIQUID	68.85	8.17				77.02
HC GAS	16.59	3.14				19.73
HYDROGEN		10.74				10.74
NH_3						
H_2O						
H_2S						
TOTAL	85.44	22.05				107.49

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 1-14-76 DATA BOOK NO. 103-4-64
RUN, SAMPLE NO. 011476
PROCESS: REFORMING
CATALYST: CYANAMID AERO PHF-4
FEED: COED HYDROTREATED ST. RUN NAPHTHA

REACTOR CONDITIONS

PRESSURE - PSIG	250	TEMPERATURE °F	955
LHSV - VOL/VOL-HR	2.04	CATALYST VOLUME CC	50
MATERIAL BALANCE %	102.22	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	3910	OIL PRODUCT RATE G/HR	62.16
OIL FEED RATE G/HR	81.20	TAIL GAS RATE G/HR	25.44
HYDROGEN FEED RATE G/HR	6.40	WATER PRODUCT G/HR	---

YIELD: G/100G OIL FEED

HYDROGEN	2.75 [A]	1.36 [B]	WATER	---
METHANE	1.97			
ETHANE	2.55			
PROPANE	2.79			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	1.67	.98				2.65
C_5	1.10	1.06	.22			2.37
C_6	1.30	1.15	1.62	.83	4.85	9.76
C_7	1.04	2.02	1.29	2.41	15.65	22.40
C_8	.82	.94	1.26	1.29	16.93	21.24
C_9	.17	.75	.18	1.84	17.22	20.15
TOTAL	6.10	6.89	4.57	6.37	54.64	78.57

UNIDENTIFIED $C_4 - C_9$ 0.0 $C_{10}+$ 11.10

HYDROGEN YIELD SCF/BBL 1370 [A] 680 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	87.1	12.9				100.0
HYDROGEN		7.88				7.88
TOTAL	87.1	20.79				107.88
PRODUCTS						
LIQUID	68.32	8.23				76.55
HC GAS	17.11	3.31				20.43
HYDROGEN		10.63				10.63
NH_3						
H_2O						
H_2S						
TOTAL	85.43	22.18				107.61

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 1-15-76 DATA BOOK NO. 103-4-64
RUN, SAMPLE NO. 011576
PROCESS: REFORMING
CATALYST: CYANAMID AERO PHF-4
FEED: COED HYDROTREATED ST. RUN NAPHTHA

REACTOR CONDITIONS

PRESSURE - PSIG	250	TEMPERATURE °F	950
LHSV - VOL/VOL-HR	1.88	CATALYST VOLUME CC	50
MATERIAL BALANCE %	101.76	FORCE BALANCED ON	OIL PRODUCT
HYDROGEN RATIO SCF/BBL	4260	OIL PRODUCT RATE G/HR	57.77
OIL FEED RATE G/HR	74.80	TAIL GAS RATE G/HR	23.44
HYDROGEN FEED RATE G/HR	6.41	WATER PRODUCT G/HR	---

YIELD: G/100G OIL FEED

HYDROGEN	2.71[A]	1.16[B]	WATER	---
METHANE	1.94			
ETHANE	2.46			
PROPANE	2.66			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	1.63	.90				2.53
C_5	1.13	1.01	.23			2.37
C_6	1.49	.96	1.98	1.30	4.41	10.13
C_7	1.22	1.75	1.75	3.53	14.36	22.61
C_8	.67	1.20	1.44	1.76	16.50	21.57
C_9	.40	1.08	.63	1.27	17.39	20.77
TOTAL	6.54	6.89	6.02	7.86	52.67	79.98

UNIDENTIFIED $C_4 - C_9$ 0.0 $C_{10}+$ 10.13

HYDROGEN YIELD SCF/BBL 1350[A] 580[B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	87.1	12.9				100.0
HYDROGEN		8.57				8.57
TOTAL	87.1	21.48				108.57
PRODUCTS						
LIQUID	68.78	8.46				77.23
HC GAS	16.69	3.28				19.97
HYDROGEN		11.27				11.27
NH_3						
H_2O						
H_2S						
TOTAL	85.47	23.01				108.47

A From Hydrogen Mass Balance B From Elemental Balance

COED
HYDROCRACKATE NAPHTHA
HYDROTREATED FEED
TO
REFORMING

Carbon	87.3
Hydrogen	12.7

	NORM PARAF	ISO PARAF	CYCLO PENT	CYCLO HEXANE	AROMATIC
C_4	0.3				
C_5	0.4		0.6		
C_6	1.1	0.6	3.7	4.9	1.6
C_7	1.5	4.6	4.5	8.1	10.8
C_8	2.4	1.3	4.9	6.0	9.2
C_9	1.0	0.8	0.9	2.0	11.8
C_{10}^+	17.2				

HYDROPROCESSING DATA

DATE 3-12-76 DATA BOOK NO. 103-8-2
RUN, SAMPLE NO. 103-8-2-2
PROCESS: REFORMING
CATALYST: CYANAMID AERO PHF-4
FEED: COED HYDROTREATED HYDROCRACKATE NAPHTHA

REACTOR CONDITIONS

PRESSURE - PSIG	500	TEMPERATURE °F	968
LHSV - VOL/VOL-HR	1.86	CATALYST VOLUME CC	50
MATERIAL BALANCE %	98.97	FORCE BALANCED ON	NOT DONE
HYDROGEN RATIO SCF/BBL	4250	OIL PRODUCT RATE G/HR	57.44
OIL FEED RATE G/HR	74.25	TAIL GAS RATE G/HR	22.31
HYDROGEN FEED RATE G/HR	6.33	WATER PRODUCT G/HR	---

YIELD: G/100G OIL FEED

HYDROGEN	1.46 A	1.96 B	WATER	---
METHANE	1.07			
ETHANE	2.06			
PROPANE	3.08			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	1.78	1.19				2.97
C_5	.98	1.47	.32			2.78
C_6	1.32	1.95	1.07	.12	8.90	13.37
C_7	.58	1.75	.33	.10	26.35	29.11
C_8	.12	.47	.19	.02	21.41	22.22
C_9	.37	.15	.03	.00	13.51	14.06
TOTAL	5.16	6.98	1.96	.23	70.18	84.51

UNIDENTIFIED $C_4 - C_9$ 0.05 C_{10}^+ 6.60

HYDROGEN YIELD SCF/BBL 727 A 976 B

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	87.3	12.7				100.0
HYDROGEN		8.53				8.53
TOTAL	87.3	21.23				108.53
PRODUCTS						
LIQUID	69.73	7.64				77.36
HC GAS	16.93	3.10				20.03
HYDROGEN		9.99				9.99
NH_3						
H_2O						
H_2S						
TOTAL	86.65	20.72				107.38

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 3-16-76 DATA BOOK NO. 103-8-2
RUN, SAMPLE NO. 103-8-2-3
PROCESS: REFORMING
CATALYST: CYANAMID AERO PHF-4
FEED: COED HYDROTREATED HYDROCRACKATE NAPHTHA

REACTOR CONDITIONS

PRESSURE - PSIG	500	TEMPERATURE °F	968
LHSV - VOL/VOL-HR	2.04	CATALYST VOLUME CC	50
MATERIAL BALANCE %	99.37	FORCE BALANCED ON	NOT DONE
HYDROGEN RATIO SCF/BBL	3920	OIL PRODUCT RATE G/HR	64.40
OIL FEED RATE G/HR	81.29	TAIL GAS RATE G/HR	22.73
HYDROGEN FEED RATE G/HR	6.39	WATER PRODUCT G/HR	---

YIELD: G/100G OIL FEED

HYDROGEN	1.55 [A]	1.97 [B]	WATER	---
METHANE	.85			
ETHANE	1.64			
PROPANE	2.63			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	1.54	1.02				2.56
C_5	.91	1.40	.46			2.77
C_6	1.44	2.04	1.46	.13	8.94	14.01
C_7	.66	2.06	.48	.17	25.60	28.97
C_8	.19	.62	.21	.04	21.02	22.08
C_9	.45	.17	.08	.02	14.11	14.84
TOTAL	5.20	7.31	2.69	.36	69.67	85.23

UNIDENTIFIED $C_4 - C_9$ .03 $C_{10}+$ 7.37

HYDROGEN YIELD SCF/BBL 772 [A] 981 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	87.3	12.7				100.0
HYDROGEN		7.86				7.86
TOTAL	87.3	20.56				107.86
PRODUCTS						
LIQUID	71.31	7.91				79.22
HC GAS	15.72	2.82				18.54
HYDROGEN		9.41				9.41
NH_3						
H_2O						
H_2S						
TOTAL	87.03	20.14				107.17

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 3-17-76 DATA BOOK NO. 103-8-2
RUN, SAMPLE NO. 103-8-2-4
PROCESS: REFORMING
CATALYST: CYANAMID AERO PHF-4
FEED: COED HYDROTREATED HYDROCRACKATE NAPHTHA

REACTOR CONDITIONS

PRESSURE - PSIG	500	TEMPERATURE °F	968
LHSV - VOL/VOL-HR	2.05	CATALYST VOLUME CC	50
MATERIAL BALANCE %	99.00	FORCE BALANCED ON	NOT DONE
HYDROGEN RATIO SCF/BBL	3922	OIL PRODUCT RATE G/HR	64.50
OIL FEED RATE G/HR	81.80	TAIL GAS RATE G/HR	22.86
HYDROGEN FEED RATE G/HR	6.44	WATER PRODUCT G/HR	---

YIELD: G/100G OIL FEED

HYDROGEN	1.58[A]	1.90[B]	WATER	---
METHANE	.88			
ETHANE	1.68			
PROPANE	2.64			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	1.58	.99				2.58
C_5	.96	1.37	.48			2.81
C_6	1.54	2.11	1.47	.11	9.02	14.26
C_7	.68	2.29	.33	.14	25.52	28.97
C_8	.19	1.40	.22	.04	20.32	22.16
C_9	.46	.22	.11	.09	13.23	14.11
TOTAL	5.42	8.39	2.61	.38	68.10	84.89

UNIDENTIFIED $C_4 - C_9$ .03 $C_{10}+$ 7.17

HYDROGEN YIELD SCF/BBL 787[A] 947[B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	87.3	12.7				100.0
HYDROGEN		7.88				7.88
TOTAL	87.3	20.58				107.88
PRODUCTS						
LIQUID	70.88	9.97				78.85
HC GAS	15.64	2.82				18.47
HYDROGEN		9.45				9.45
NH_3						
H_2O						
H_2S						
TOTAL	86.52	20.24				106.77

A From Hydrogen Mass Balance B From Elemental Balance

HYDROPROCESSING DATA

DATE 3-18-76 DATA BOOK NO. 103-8-2
RUN, SAMPLE NO. 103-8-2-5
PROCESS: REFORMING
CATALYST: CYANAMID AERO PHF-4
FEED: COED HYDROTREATED HYDROCRACKATE NAPHTHA

REACTOR CONDITIONS

PRESSURE - PSIG	500	TEMPERATURE °F	968
LHSV - VOL/VOL-HR	2.06	CATALYST VOLUME CC	50
MATERIAL BALANCE %	98.99	FORCE BALANCED ON	NOT DONE
HYDROGEN RATIO SCF/BBL	3890	OIL PRODUCT RATE G/HR	64.95
OIL FEED RATE G/HR	82.13	TAIL GAS RATE G/HR	22.71
HYDROGEN FEED RATE G/HR	6.42	WATER PRODUCT G/HR	---

YIELD: G/100G OIL FEED

HYDROGEN	1.66 [A]	1.99 [B]	WATER	---
METHANE	.86			
ETHANE	1.59			
PROPANE	2.51			

	PARAFFIN		NAPHTHENE		AROMATIC	TOTAL
	NORMAL	ISO	CYCLO C_5	CYCLO C_6		
C_4	1.49	.89				2.39
C_5	.99	1.30	.53			2.82
C_6	1.42	1.85	1.88	.15	9.43	14.74
C_7	.86	2.74	.48	.21	27.08	31.36
C_8	.26	.88	.28	.08	22.00	23.50
C_9	.53	.29	.14	.13	12.00	13.10
TOTAL	5.56	7.95	3.32	.56	70.51	87.91

UNIDENTIFIED $C_4 - C_9$ .02 $C_{10}+$ 4.33

HYDROGEN YIELD SCF/BBL 827 [A] 991 [B]

ELEMENTAL MATERIAL BALANCE - WEIGHT

FEED	CARBON	HYDROGEN	NITROGEN	OXYGEN	SULFUR	TOTAL
OIL	87.3	12.7				100.0
HYDROGEN		7.82				7.82
TOTAL	87.3	20.52				107.82
PRODUCTS						
LIQUID	71.11	7.97				79.08
HC GAS	15.42	2.74				18.16
HYDROGEN		9.48				9.48
NH_3						
H_2O						
H_2S						
TOTAL	86.53	20.19				106.72

A From Hydrogen Mass Balance B From Elemental Balance

STEAM COIL CRACKING OF VARIOUS COED FRACTIONS

	COED STRAIGHT RUN NAPHTHA				COED STRAIGHT RUN MID-DISTILLATE				COED HYDROCRACKED NAPHTHA				COED HYDROCRACKED MID-DISTILLATE			
Temperature °F	1427	1472	1517	1562	1427	1472	1517	1562	1427	1472	1517	1562	1427	1472	1517	1562
Res. Time Sec.	1.69	1.65	1.57	1.58	1.88	1.85	1.77	1.74	1.63	1.66	1.56	1.60	1.91	1.93	1.70	1.73
Steam/Oil Ratio	0.31	0.30	0.30	0.30	0.33	0.33	0.32	0.33	0.30	0.28	0.30	0.30	0.33	0.32	0.31	0.34
Product Pattern, wt. %																
Hydrogen	0.7	0.8	1.0	1.2	0.7	0.8	0.9	1.1	0.8	0.9	1.0	1.1	0.8	1.0	1.2	1.4
Methane	10.4	12.0	13.4	15.3	8.9	10.8	12.1	13.6	10.5	11.1	11.7	14.4	7.6	9.6	9.5	10.2
Ethylene	13.5	15.4	17.3	18.5	9.8	10.9	11.8	12.9	14.9	15.5	16.4	16.6	11.5	12.4	12.6	12.0
Ethane	3.7	3.2	2.6	2.4	4.1	3.4	2.9	2.6	3.9	3.2	2.8	2.3	4.2	3.7	3.2	2.5
Propylene	8.4	7.3	6.0	5.0	7.0	5.7	4.5	4.4	9.0	7.4	6.2	4.6	8.6	6.7	6.4	3.9
Propane	0.5	0.5	0.3	0.3	0.7	0.4	0.1	0.1	0.4	0.3	0.2	0.1	0.7	0.4	0.3	0.1
1,3 Butadiene	1.9	2.1	2.0	1.3	0.9	1.0	0.8	0.5	1.2	1.2	1.2	0.7	1.8	1.4	1.3	0.6
Other C_4's	1.5	1.2	1.0	0.7	1.4	1.3	0.8	0.5	1.6	1.0	0.7	0.4	2.8	1.8	1.5	0.5
C_5-410°F Non-Aromatic	16.6	13.1	11.1	8.3	2.4	1.9	0.9	1.2	7.0	5.4	3.5	1.9	6.1	6.5	6.4	6.8
Benzene	10.0	10.6	12.9	13.7	4.0	5.1	6.3	6.1	10.4	11.8	12.4	13.8	3.2	4.2	4.6	8.0
Toluene	9.6	8.9	8.6	7.6	3.0	3.9	4.1	3.5	15.1	15.1	13.9	12.3	3.2	3.2	3.8	4.2
C_8Aromatics	9.1	8.0	6.8	6.1	2.4	3.1	3.0	2.9	10.4	9.7	8.8	7.1	3.1	3.0	3.6	3.5
C_9-410°F Aromatics	6.5	6.0	4.3	4.5	3.4	4.1	4.4	3.8	5.4	5.7	4.3	3.9	5.6	4.5	5.2	4.7
$C_{10}{}^+$	7.5	10.8	12.6	14.9	51.1	47.4	47.2	46.7	9.5	11.5	16.6	20.6	41.0	41.5	40.7	41.4

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