Title: "The Standing of Fischer-Tropsch Diesel in an Assay of Fuel Performance and Emissions"

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ABSTRACT

Two Fischer-Tropsch feedstocks, one from hydrocracking of Arge wax, the other a straight-run product from modern DOE slurry reactor technology, were distilled into a diesel range cut (350°-650°F) for comparison with other diesel stocks. Three petroleum diesel fuel components, representative of different feed sources and processing histories as well as the F-T diesel samples were distilled into narrow cutpoint fractions of similar boiling point petroleum samples included straight-run diesel, light coker gas oil, and light cycle oil. Each stock was cut into 6 to 8 fractions. The overall goal was to select stocks and to create fractions for analysis to determine the composition and properties that control combustion characteristics of each sample. Laboratory tests included hydrocarbon type, density, elemental composition, aromatic composition, and other properties. Combustion characteristics included ignition performance in a constant volume combustion apparatus (CVCA) and exhaust gas composition. The CVCA ignition delay time measurements were calibrated to provide predictions of the cetane number. The results are discussed in terms of the effects of the measured properties on the ignition quality with emphasis on the distribution of cetane number across the distillation range of the various components.

INTRODUCTION

Indirect coal liquids pose opportunities for diesel fuel both as a BTU source for motive force and as a high cetane, low emission component for exhaust emissions control. The increasingly stringent restrictions on emissions from diesel fuel-powered vehicles pose a challenge for both existing petroleum fuels and proposed fuels from alternative sources. The EPA regulation limit governing particulates reduced to 0.25 g/bhp-hr in 1991 for trucks and to 0.1 g/bhp-hr for city buses in 1993. In 1994, the limit will drop to 0.1 g/bhp-hr for all vehicles. It is expected that Canada will adopt the same limits at a later date and Mexico will have similar standards for urban vehicles. EPA has not prescribed the method for meeting the emissions requirements for diesel engines. Engine manufacturers have performed significant development on cleaner engines without meeting the proposed standard in all cases. EPA issued regulations that limit sulfur content of diesel fuel to 0.05 weight percent and imposed a minimum 40 cetane index to "cap" aromatics content at present levels.[1] The California Air Resources Board has also announced regulations that control diesel fuel sulfur content to less than 0.05 weight percent plus aromatics to less than 10 volume percent.

The available data indicate that sulfur, aromatic, and cetane number control will add significantly to the cost of producing diesel fuel. Moreover it is believed that the cost will increase further since the legislative forces driving forward the quality of gasoline generally have adverse effects on the quality of diesel fuel feed and blending stocks. These factors, and the ultimately limited supply of petroleum, place continued importance on the potential role of coal liquids in transportation fuel. This report presents the results to date of the work in progress on a Diesel Fuel Assay* with emphasis on the status of the F-T components. With the broad objective of relating diesel exhaust emissions and performance to chemical composition and physical properties, the more specific concerns of the effect of alkane branching and aromatic substituents will be addressed later. The choice of starting materials will give insight about source and upgrading method as they affect ignition quality and emissions from different samples meeting the same limits on sulfur and aromatics, but with different processing histories.

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OBJECTIVE

This paper emphasizes a portion of the Diesel Fuel Assay comparing the two F-T diesels with the results for the larger project, the overall objective of which is to determine the relationships between the fuel feedstocks and fuel processing, and the fuel properties, composition, and combustion and emissions characteristics in a diesel engine. The preliminary objectives in the work included producing a consistent set of performance, emission, and composition measurements on a matrix of diesel fuel components distinguished by source and processing history emphasizing aromatics.

APPROACH

The approach for achieving these objectives was as follows: the petroleum components were reduced in sulfur and aromatic content by pilot plant hydrogenation before distillation into selected ranges of boiling points. The resulting fractions of all feedstocks and products were analyzed for chemical composition and physical properties that would be most revealing for ignition quality and particulate generation. All samples then are tested for engine performance and emissions.

BACKGROUND

It has been observed that sulfur and aromatics concentrations increase with boiling point. For example, lower concentrations of aromatics and sulfur typically occur in D-1 fuel whose boiling range of 300°- 550°F is lower than D-2 fuel with 350°-650°F. What has not been shown is which of the highest boiling components are most responsible for particulate emissions or which components of refinery streams would benefit the most from processing to reduce emissions precursors. The approach used for determining the effects of fuel composition on engine behavior has been to blend or measure full boiling range fuels for engine tests. For instance, the work at the University of Wisconsin[2] and Pennsylvania State University[3] found little effect on performance and emissions attributable to fuel composition. Other studies had different results. Weidmann found that fuel properties have a small, measurable effect on emissions using a VW 1.67 liter, 4-cylinder engine.[4] Hydrocarbon emissions were found to be a function of fuel cetane number with volatility exerting a stronger influence for low cetane number fuels. Particulate formation was a strong function of fuel density and distillation range.

The work of Ullman[5-6] demonstrated that dominant fuel parameters affecting diesel engine performance and emissions are the sulfur content, the cetane number and the aromatics content. Recently reported work by Miyamoto et al[7], McCarthy et al[8], and Nikanjam[9] all confirmed these findings, with the general consensus that sulfur content has a significant effect on the particulate emissions, and the cetane number may be the dominant factor in controlling both the particulate and the NOx emission. Very recent work by Cowley *et al.*,[10] indicates that these trends are correct.

Two F-T liquids are considered in the current work against the background of the petroleum stocks. The approach will attempt to improve on the resolution of previous studies done with full-boiling test fuels by examining the five starting materials in narrow fractions of the diesel fuel boiling range. We will then correlate the resulting measurements to emissions and performance indicators.

MATERIALS AND PROCESSING

Fischer-Tropsch Liquids - The first material was provided by the DOE Office of Coal Conversion. The production and properties of the F-T distillate are fully described in the report of DOE Project 125501, "Arge Wax Hydrocracking Study." An imported Arge wax was subjected to hydrocracking to produce liquid in the distillate boiling range. In the Assay, this material is designated F-T1.

The second F-T sample was made by Air Products under DOE Contract.[12] The materials were supplied as hydrocarbon liquid and light wax. These samples were combined in a ratio of 1.6:1 according to their proportion

in production. This material, being lower in boiling range than the Arge wax, contained light process oils and oxygenates. From this mixture a 350°-650°F straight run diesel sample was distilled, designated F-T2.

Both F-T liquids were fractionated into controlled boiling range samples. Batches of about 40 liters were distilled in a stainless steel distillation column under vacuum. These samples were reserved for laboratory and engine testing.

Petroleum Stocks and Products - Of the refinery streams blended into diesel fuel, the higher boiling and more aromatic ones are implicated in particulate and hydrocarbon emissions. Accordingly, feedstocks for this study were chosen to include products from resid conversion and gas oil cracking. The test components chosen were:

- full-boiling straight-run diesel (SRD)
- light cycle oil from catalytic cracking (LCO)
- light coker gas oil (LCGO)

The parentheses enclose the abbreviated designations used in this paper. These materials were examined by the same laboratory and engine tests as the two F-T samples with the addition of pilot plant processing to make additional samples with controlled sulfur and aromatics concentration.

Processing. The three petroleum feedstocks were processed to reduce sulfur and aromatics then distilled into analytical samples. The processing and distillation sequence is as shown in Figure 1. The LCO and LCGO were hydrogenated at two severities to reduce sulfur to 0.05 M% and aromatic concentration to 10V% (per ASTM D1319). The SRD was naturally low in sulfur and was hydrotreated at one severity to reduce aromatics to 10V%.

The hydrotreating was performed in the pilot plant of the U.S. DOE Alternative Fuel Center at Southwest Research Institute.** The reactor was a fixed bed (7.5 foot x 2 inch diameter) containing 1.56 gallons of Criterion Trilobe HDN 60 nickel molybdenum catalyst. The feedstocks were preheated and fed to the top of the reactor bed combined with hydrogen gas. After the reactor, two stages of pressure letdown and product separation removed unreacted hydrogen and byproduct gases. The hydrogen was cleaned and recycled. The product was stripped to remove light ends and dissolved gases.

Distillation. Efforts to resolve fuels, such as these, into the individual components have been partially successful in the laboratory. The number of components is extremely large, however, and it is therefore not possible to study the combustion of each individual component and all of the possible interactions among the various components. A more practical approach, and the one used in this project, is to separate the fuels into a reasonable number of fractions by boiling range that can be studied in detail.

Each of the five feedstocks and the five hydrotreated products were distilled under vacuum into congruent (corresponding cut point) boiling range fractions. The following boiling point ranges were selected for the cuts:

Fraction 1	Fraction 2	Fraction 3	Fraction 4	Fraction 5	Fraction 6	Fraction 7
IBP - 440°F	440° - 480°F	480° - 520°F	520° - 560°F	560° - 600°F	600° - 640°F	640° - EP

Approximately 40 liters of each material were charged to a stainless steel kettle and column, which was operated along the lines of a ASTM D1160 distillation. The actual ranges of the sample fractions differed from these ideal cuts and boiling range comparisons should be made among the cuts of closest temperature range rather than sample number. With the original five materials, the processed products, and all their fractions, eighty samples comprised the test fuel matrix for the Diesel Assay.

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SAMPLE TESTING

Laboratory Evaluation. As shown in Figure 1, the five basestocks, five hydrotreated products, and their distillation fractions were characterized by a schedule of physical and chemical tests and by combustion experiments. The results appear in the Appendix as Tables A1 through A10. A more complete discussion appears in reference 13. The set of laboratory measurements listed in the tables are being applied to each of the 80 fractions made by vacuum distillation. The list includes two measures of aromatic content, D1319 and the UV method.[4] The fluorescent indicator analysis (ASTM D1319) is widespread in its use and included in emissions regulations. It is regularly applied to diesel fuel samples, although the method is designed for depentanized gasoline, and relies on measurements of column length taken up by saturates, olefins, and aromatics made visible by fluorescent dye. The volume percent aromatics determined this way can be affected by cycloparaffins or polar materials. The low aromatic content and high cycloparaffin content of the F-T1 as well as the oxygenates in F-T2 made the results of D1319 unreliable for these samples.

The UV method compares sample absorbance at selected wavelengths with reference spectra of solutions of aromatics composed of representative compounds in the diesel boiling range. Since the absorbance is proportional to the aromatic rings, weight percent aromatic carbon is reported without regard to substituents. Both methods are indirect; so instrumental analysis by GC/MS and NMR are indicated.

The hydrocarbon type determinations by ASTM D2425 are presented in Tables A11 through A15. This method requires a separation of each sample into polar and nonpolar fractions and so is quite laborious. For this reason, groups of samples were mixed to represent the middle portion of the boiling range in some cases as noted on the tables. It was believed that little information would be lost by combining similar samples in this way. This presumption was verified by measuring all samples for the low aromatic straight-run diesel. In these tables the usual D2425 report for saturates and aromatics was simplified into a unified listing of hydrocarbon types for each sample.

The next set of results concern the nuclear magnetic resonance spectroscopic examination of the samples. The work was performed at the University of Utah Chemistry Department. Table A16 lists the regions of chemical shift into which the responses for the samples were divided. The instrumental procedures for the integration of these samples included:

1. Long acquisition time (at) is used to guarantee the necessary digital resolution.
2. Wide spectral width (sw = 20000 → 40ppm) is used to guarantee that all protons are equally excited.
3. Long d1 delay used to let protons fully recover between pulses.

The procedure for making the quantitative integration of the NMR spectra was as follows: Each spectrum was first phased manually to have as flat a baseline as possible. Next the spectrum was individually referred to the observed TMS line. Then the spectrum was accurately divided into 5 chemical shift regions (Table A16). The baseline was again corrected with the TMS line also covered by a segment of integration line. Integration was taken after the segment has been removed.

The results for all samples are reported in Table 17. As the reproducibility of manual phasing could not be well guaranteed, there is certain variability (uncertainty) with each value reported in the table. Repeated integration on selected spectra and the variability was estimated as around 1.0 percent. For example, 30.5 should be read as 30.5 + 1.0 percent.

COMBUSTION EXPERIMENTS

Absolute Cetane Number. Ignition quality was determined in a constant volume combustion apparatus (CVCA) that uses a small quantity of sample injected into a volume of hot air to simulate the conditions in a compression ignition engine cylinder for estimated cetane number. The CVCA is shown in Figure 2. The equipment consists of the constant volume combustion bomb, a single-shot fuel injection system, and a data

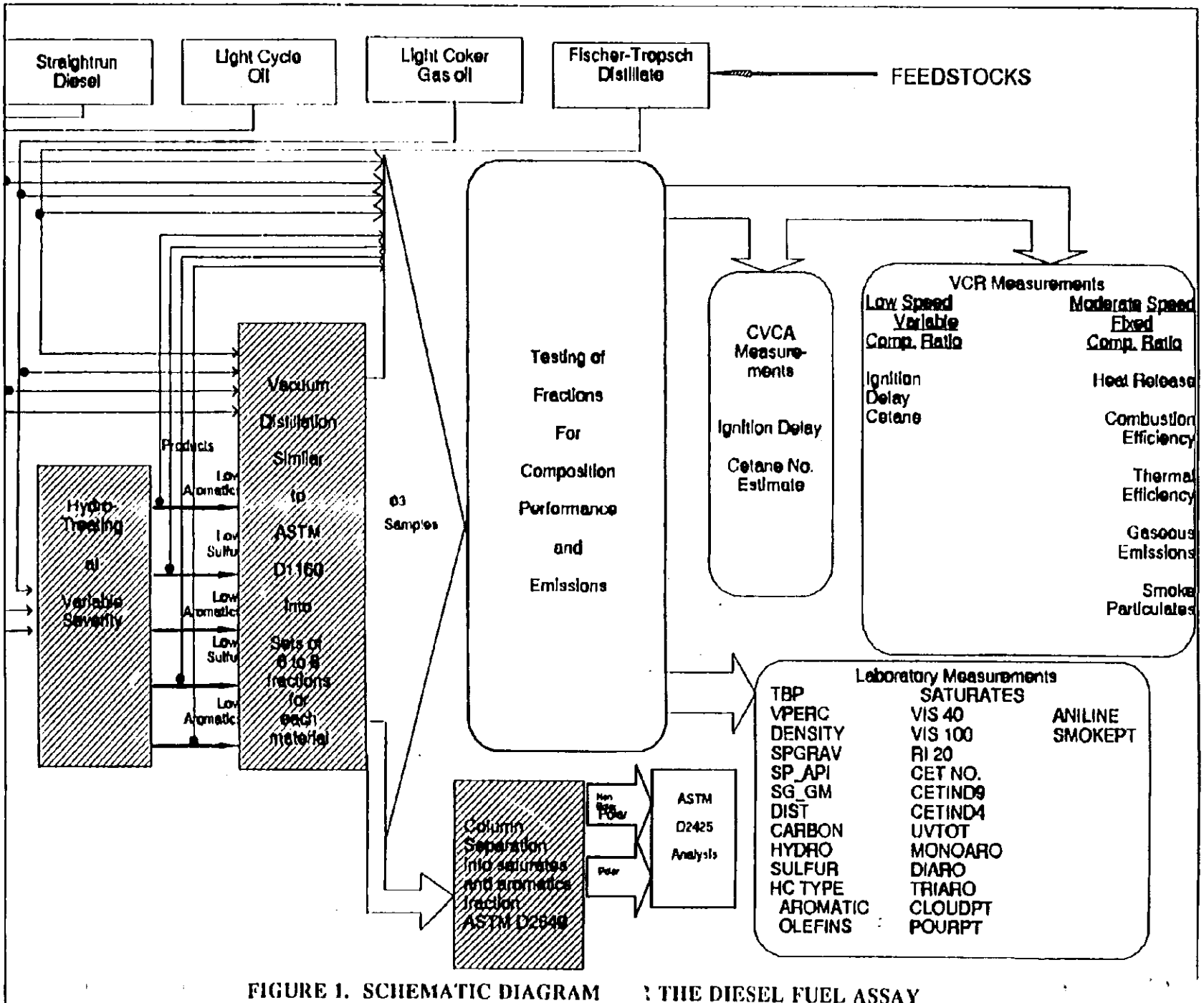

FIGURE 1. SCHEMATIC DIAGRAM OF THE DIESEL FUEL ASSAY

acquisition system to monitor the various temperatures and pressures as the fuel is injected into the bomb, ignites, system. The pressures in the bomb is measured and used to determine the ignition delay and the combustion rates.

The CVCA has been used to determine the cetane number of unknown fuels using a technique in which the ignition delay time of the unknown fuels is compared to a calibration of cetane number versus the ignition delay time. The calibration is developed using several different blends of the primary reference fuels, hexadecane and heptamethylnonane. It has been observed in previous studies that the calibrations shift periodically. It has been found, however, that the calibrations can be checked and adjusted using the results of measurements of the 100CN reference fuels. In the work reported here, the calibrations were checked daily, and it was observed that the calibrations did not shift appreciably over the duration of the measurements. The CVCA measurements were the subject of reference 15.

Engine Tests The engine experiments were performed as two distinct sets of experiments. The fuels were all first run the Variable Compression Ratio (VCR) engine to determine the cetane number using the VCR techniques. Next the VCR was used to measure performance and emissions.

Cetane Rating The data from the cetane rating experiments included the compression ratio and cetane number as well as high speed combustion data. The results of the cetane ratings are summarized in Tables A18 through A26. The cetane ratings and emissions data are included for reference. During these experiments the engine was operated at the same speed (1200 rpm), the same injection timing (12°BTDC), and the same air-fuel ratio (28:1) for all tests. The test procedure consisted of running the engine on the test fuel, at the above conditions, and adjusting the compression ratio until combustion started at TDC. The compression ratio was then compared to a calibration equation of cetane number as a function of compression ratio, obtained using several blends of the primary and secondary reference fuels. Figure 3 shows the VCR engine. Each of the test fuels were run in the engine at five different conditions, representative of rated torque, rated power, and part loads at the rated power speed. The basis for selection of these conditions was an extensive engine mapping study that defined the rated torque and rated power points, and the timing settings for best torque and also for the equivalent of a 5 gm/ho-hr NOx level.

Performance and Emissions The Mode 1 condition is representative of rated torque speed and overall equivalence ratio, using an injection timing (3°BTDC) for the controlled NOx condition on a baseline diesel fuel. Mode 2 included the same speed and load conditions as Mode 1, but using the best torque injection timing for each test fuel. Modes 3-5 are part load conditions at the rate power speed, using a fixed timing of 3°BTDC.

These conditions were chosen to hold constant the engine effects which tend to dominate fuel effects in comparisons of emissions.

The majority of the discussion will focus on results obtained in a single cylinder research engine designed at SwRI for use in studying fuel effects on combustion. The engine, described in detail of the basic design in a previous paper[5], was modified for use in this work to be representative of current technology two-valve per cylinder engines.

DISCUSSION

The extensive results presented in the appendix (and engine data on power and combustion efficiency) are in the process of statistical examination at this time. Preliminary results from Mode 1 are discussed here as an overview of the findings. A discussion of other aspects of the Mode 1 results is the subject of reference 17.

Ignition Quality. The results for cetane number measured by VCR engine and CVCA technique are presented in Figure 4. The line of ideal agreement (slope = 1) is the diagonal line. The straight line fit is displaced from the ideal because the CVCA technique uses primary reference standards which behave differently than the secondary reference fuels used in the VCR engine and ASTM D613. It can be observed that the data are highly

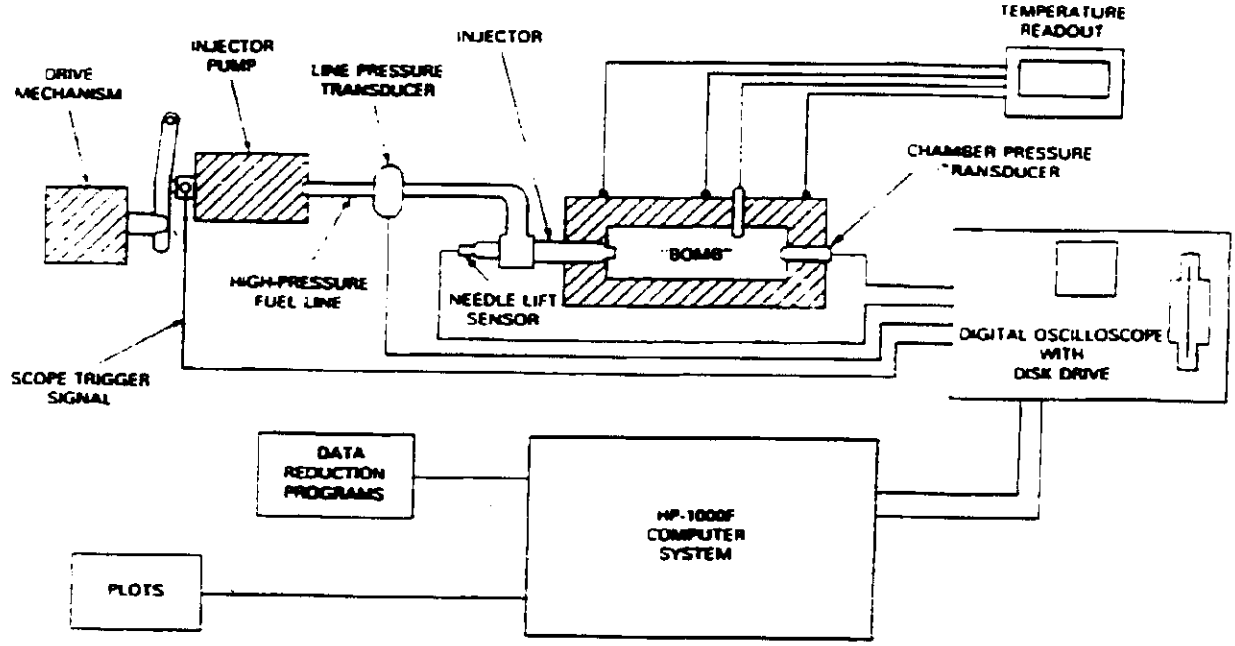

FIGURE 2. CONSTANT VOLUME COMBUSTION APPARATUS

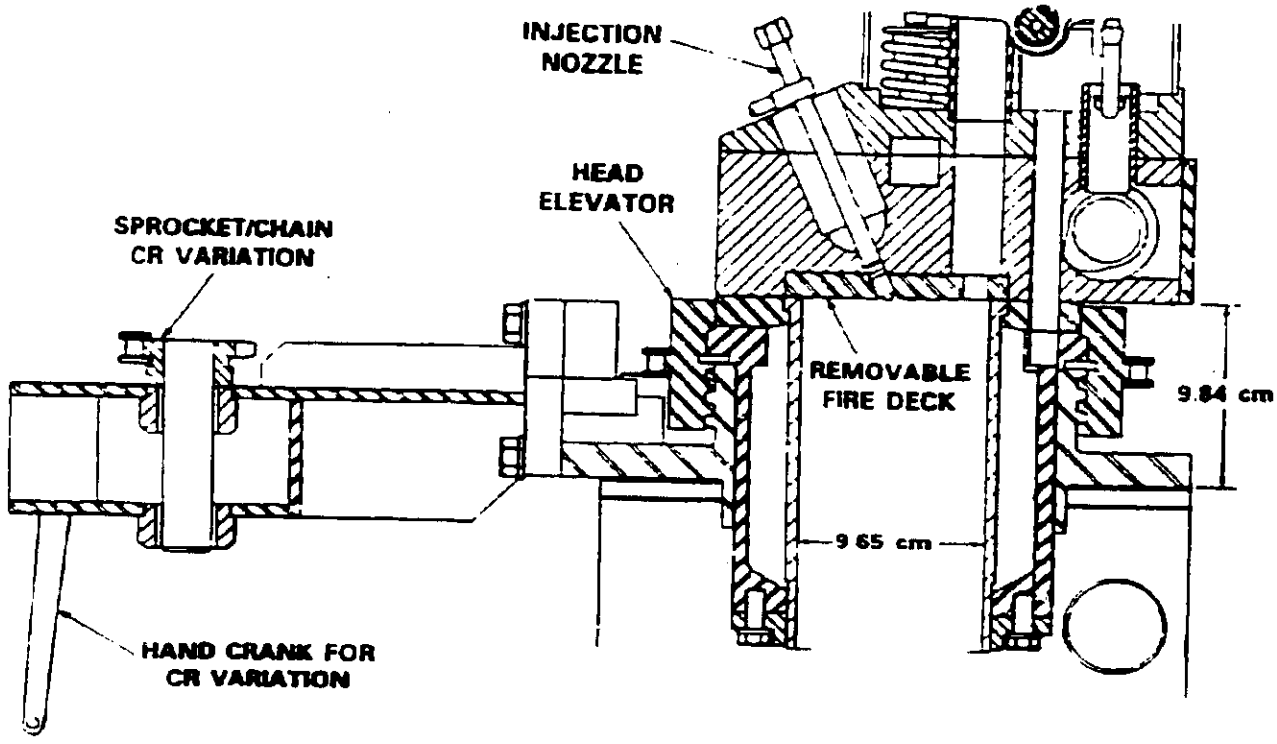

FIGURE 3. VOLUME COMBUSTION RATIO PROFILE SCHEMATIC

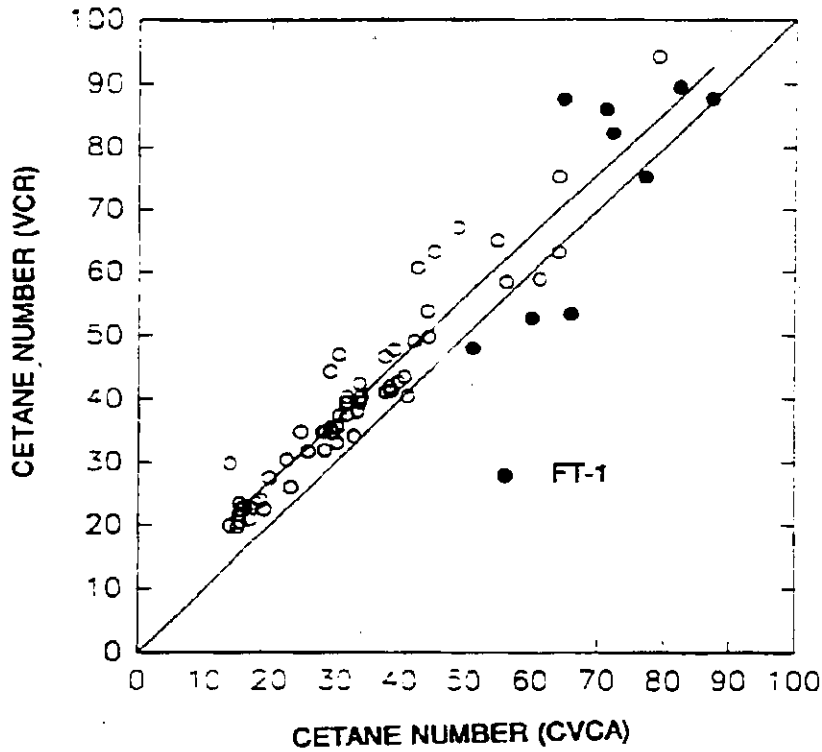

FIGURE 4. CETANE DETERMINATION BY VCR AND CVCA METHODS

correlated by showing both methods, the consistent ignition behavior of the test fuels. The F-T1 points are the solid circle. The F-T2 samples have not yet had the VCR determinations.

When all Mode 1 results are considered, the best regression model for the variation of cetane number as a function of the independent fuel property variables, using linear terms, is

$$CN = -82.897 + 4.74 \times WTPH + 0.0569 \times BPAVG + 0.9309 \times NMRCH2$$

Where,

CN =	Cetane Number
WTPH =	Weight Percent Hydrogen
BPAVG =	Average Boiling Point (°F)
$NMRCH_2$ =	NMR Paraffin and Alkyl Chain

The coefficient of determination (r^2) was 0.88. Further statistical evaluation is in progress.

The effect of boiling range for the straight run diesel (SRD) fuel and the Fischer-Tropsch (FT) distillate are presented in Figure 5. The cetane number of these materials are higher than the other components and all three have a high proportion of the cetane number concentrated in the higher boiling point fractions. Since the sulfur content of the SRD was already very low, hydrotreating was used only to reduce the aromatic content of the fuel. Similar to the other fuels, the processing was more effective in increasing the cetane number of the heavier fractions.

Of particular interest is the value of F-T distillate as a cetane blending stock. A blending study was made in which that F-T was blended in different concentrations with each of the three petroleum blendstocks. These stocks included a light cycle oil (LCO), a light coker gas oil (LCGO), and a low sulfur diesel fuel. The cetane number of these blends based on the CVCA technique are plotted in Figure 6 *versus* the concentration of the blendstocks in the F-T fuel. It can be seen that the cetane number appears to blend as a linear function of the

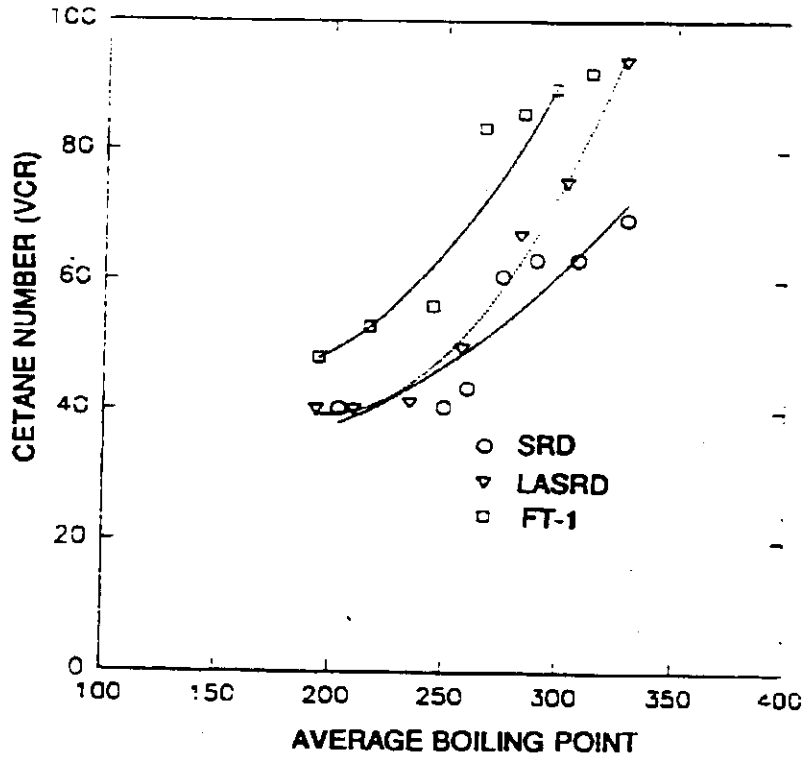

FIGURE 5. EFFECT OF HYDROGENATION BY BOILING RANGE

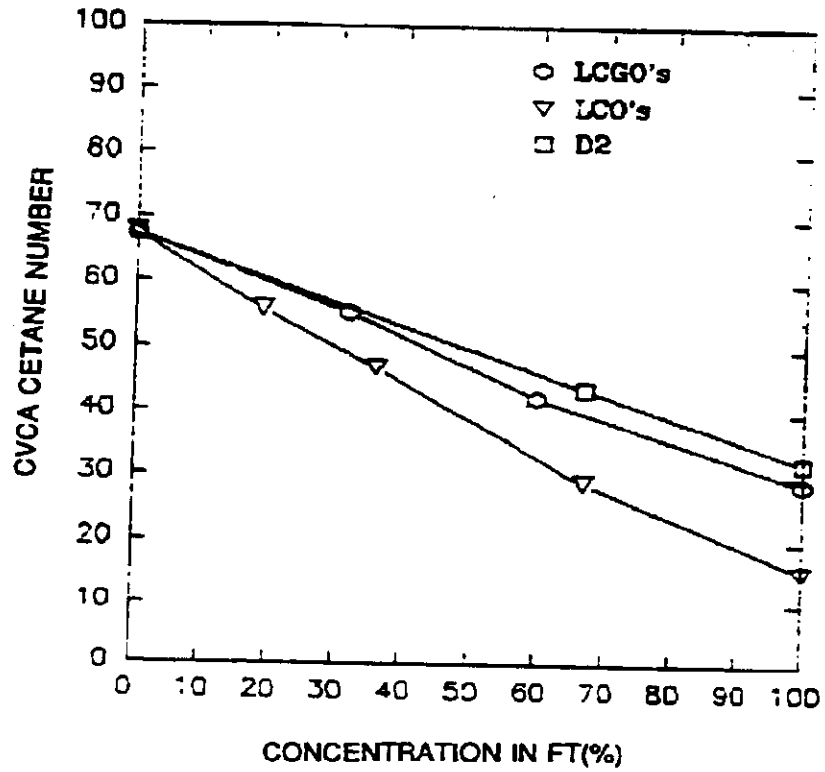

FIGURE 6. CETANE NUMBERS OF BLENDS OF F-T DISTILLATE WITH DIESEL COMPONENTS

concentration for the three materials. While the relationships of Figure 6 are essentially linear, it is interesting to note that the slight nonlinearity apparent on each curve grows as cetane number decreases:

Sample	Neat Cetane Number	Max. Deviation from Linear, %
D-2	32.1	2.1
LCGO	29.2	6.6
LCO	15.9	15.7

These deviations are small enough to permit an approximation of the cetane number of F-T blends as linear combination of the volume weighted values of cetane number for the blend components.

Emissions Measurements The reduction of data for the results presented in the tables in the appendix is far from complete. Of particular note for the F-T materials, statistical analysis of the Bosch Smoke Number measurements indicated that fuel properties exert a significant effect in controlling visible emissions. Fuel structure appears to dominate these relationships, with total aromatic content an important factor at all test conditions. Other important fuel properties are the sulfur content, the aromatic ring structure, and the boiling point distribution. The *order* of importance of these properties varies as the engine load is reduced, with the boiling point distribution and the viscosity becoming more important at the lighter loads, where the injection process might be more affected by the physical properties than at the higher load conditions.

Another area where F-T liquids could have an important role is the control of NO_x emissions. Scatter plots of the NO_x data indicated dominant effects of fuel composition and cetane number at all but the lightest load condition. These trends are demonstrated in the scatter plot of the fuel variables, presented in Figure 7 for the Mode 1 condition. The preliminary statistical analysis showed that the aromatic content and structure of the alkyl groups are important. A linear regression model for the Mode 1 NO_x data is

$$NO_x = 1.196 + 0.0183 \times CN + 0.0806 \times NMRCH + 0.272 \times NMRARO$$

Where,

NO_x =	Nitric Oxide (gm/hp-hr)
CN =	Cetane Number
NMRARO =	NMR Aromatic Ring Protons
NMRCH =	NMR Mid-Alkyl Chain
	NMR Naphthene Proton
	NMR Mid-Chain Proton

(r^2 is 0.72)

CONCLUSION

This paper records work to date on an Assay of Diesel Fuel Composition, Properties, Performance, and Emissions. Emphasis was placed on the relative nature of the two Fischer-Tropsch materials included in the work. The results for the petroleum stocks were fully included to permit this comparison. Work will continue on the interpretation of the experimental results.

It can be observed the F-T diesels showed superior performance by two measures of cetane number determination. F-T1 blended linearly with a wide spectrum of petroleum stocks in cetane number. The study of the results has not yet shown the contributions of aromatics dilution versus paraffin structure in providing this good cetane number behavior.

The smoke emissions are controlled at all load conditions by the aromatic structure of the fuel. Boiling point distribution and cetane number become significant at lighter load conditions where the injection process and ignition are more affected by these properties.

The NO_x emissions are affected at all load conditions by the aromatic content and structure. Also significant are the nature of the chain structures in the fuel and the cetane number.

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[redacted]

TABLE A1. LABORATORY ANALYSES FOR DIESEL FROM FISCHER-TROPSCH ARGE WAX (F-T1)

Test	ASTM Method	Feed FL-1840	Frac. 1 FL-1898	Frac. 2 FL-1899	Frac. 3 FL-1900	Frac. 4 FL-1901	Frac. 5 FL-1902	Frac. 6 FL-1903	Frac. 7 FL-1904
TBP Cut Pts. °F	-		≤400	400-440	440-480	480-520	520-560	560-600	600 +
Yield, V%			0-20	20-31.5	31.5-42.5	42.5-54	54-67	67-82.5	82.5-100
V% of Fraction	-		20%	11.5	11.0	11.5	13.0	15.5	17.5
Density	D 1298								
Sp. Gravity		0.7770	0.7539	0.7632	0.7711	0.7783	0.7852	0.7914	0.7990
°API		50.6	56.2	53.9	52.0	50.3	48.7	47.3	45.6
g/mL		0.7767	0.7536	0.7630	0.7708	0.7780	0.7849	0.7910	0.7986
Distillation, °F	D 86								
IBP/5%		368/396	336/352	386/395	424/436	467/477	511/519	547/555	595/605
10/30%		407/449	355/362	397/404	438/444	478/485	522/526	558/562	607/611
50/70%		502/550	373/388	416/429	453/461	490/496	531/535	566/571	615/619
90/95%		592/606	420/438	452/463	475/482	507/511	545/549	579/583	628/633
EP		620	456	474	488	521	557	589	638
Carbon, W%	D 3178	84.92	84.53	84.68	84.78	85.0	84.95	85.18	84.93
Hydrogen, W%		15.12	15.39	15.44	15.29	15.0	15.20	14.91	15.22
Sulfur, W%	D 2622	0.003	0.001	0.003	0.002	0.003	0.001	0.002	0.003
Hydrocarbon Type	D 1319								
Aromatics	Vol. %	1.1	1.3	-	-	0.9	-	-	1.4
Olefins		1.1	0.6	-	-	0.9	-	-	0.8
Saturates		97.8	98.1	-	-	98.2	-	-	97.8
Vis. @ 40°C	D 445	2.42	1.16	1.48	1.85	2.37	3.11	4.01	5.71
@ 100°C		1.05	0.62	0.74	0.86	1.02	1.24	1.46	1.88
RI @ 20°C	D 1218	1.4342	1.4214	1.4266	1.4303	1.4344	1.4382	1.4411	1.4450
Cetane No.	CVCA	64.8	51.2	60.1	66.0	72.1	77.1	82.3	87.3
Cetane Index	D 976	75.4	62.7	67.9	71.0	73.2	74.9	75.1	74.6
	D 4737	81.4	67.2	73.3	78.9	84.2	90.4	95.4	102.2
UV	TOTAL	0.2	0.4	0.3	0.2	0.2	0.1	0.1	0.1
Aromatics	MONO	0.2	0.4	0.3	0.2	0.2	0.1	0.1	0.1
Analyses	DI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wt% Total Carbon	TRI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloud Pt., °C/°F	D 2500	-20/-4	<-60/-76	-55/-67	-50/-58	-37/-35	-22/-8	-12/10	+1/34
Pour Pt., °C/°F	D 97	-20/-4	<-60/-76	-55/-67	-45/-49	-35/-31	-25/-13	-17/1	-4/25
Aniline Pt. °C/°F	D 611	92.8/199	80.6/178	84.0/183	88.6/192	92.0/198	96.3/205	99.7/212	104.7/221
Smoke Pt., mm	D 1322	+35	+50	+50	+50	+45	+35	+35	N/A

TABLE A2. LABORATORY ANALYSES FOR F-T STRAIGHT RUN PRODUCT (F-T2)

Test	ASTM Method	FL-2095	Frac 1 FL-2115	Frac 2 FL-2116	Frac 3 FL-2117	Frac 4 FL-2118	Frac 5 FL-2119	Frac 6 FL-2120	Frac 7 FL-2121
TBP Cut Points		-	300-400	400-440	440-480	480-520	520-580	580-600	600+
V% of Fraction		-	16.3	10.1	12.0	10.5	18.2	17.3	15.7
Density	D1298								
Sp. Gravity		0.8081	0.7783	0.7936	0.8058	0.8086	0.8104	0.8132	0.8146
°API		43.6	50.3	46.8	44.1	43.5	43.1	42.5	42.2
g/ml		0.8077	0.7780	0.7932	0.8054	0.8082	0.8100	0.8128	0.8142
Distillation									
IBP		363	216	316	358	392	442	482	529
10%		406	274	334	380	424	468	514	557
50%		509	306	354	403	442	489	537	571
90%		588	354	395	442	470	508	553	585
EP		627	392	428	537	522	526	565	603
Carbon, M%	D5291	82.62	79.18	77.78	80.71	82.17	82.03	82.72	84.21
Hydrogen, M%		13.76	13.11	13.27	13.54	13.88	13.39	13.49	13.96
Sulfur, M%	D2628	0.031	0.001	<0.001	0.002	0.001	0.003	0.003	<0.001
Hydrocarbon Type	D1319	Unreliable readings							
Aromatics									
Olefins									
Saturates									
Vis. @ 40°C		2.52 cSt	0.89	1.16	1.58	2.02	2.48	3.14	3.75
@ 100°C		1.08 cSt	0.49	0.61	0.76	0.90	1.07	1.27	1.49
RI @ 20°C		1.4414	1.4196	1.4274	1.4339	1.4381	1.4421	1.4451	1.4476
Cetane No.	CVCA	82.4	34.6	47.0	52.8	66.5	69.2	79.3	94.9
Cetane Index	D976	62.2	28.9	37.3	44.7	51.6	58.6	63.2	65.5
	D4737	64.6	35.3	40.5	46.2	53.8	63.2	72.3	80.1
Ring Carbon	UV								
MONO		1.6	2.0	2.1	2.0	1.5	1.7	2.1	0.8
DI		0.1	0.0	0.0	0.1	1.8	0.1	0.1	0.0
TRI		0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0
Cloud Point	D2500	-5°C	less than -60°C	-54°C	-36°C	-25°C	-12°C	1°C	9°C
Pour Point	D97	-7°C	less than -60°C	-57°C	-37°C	-26°C	-13°C	-1°C	7°C
Aniline Point	D611	43.2	16.2	20.1	21.7	27.2	37.4	50.1	66.1

TABLE A3. LABORATORY ANALYSES FOR STRAIGHT RUN DIESEL

Test	ASTM Method	Feed FL-1627	Frac. 1 FL-1793	Frac. 2 FL-1794	Frac. 3 FL-1795	Frac. 4 FL-1796	Frac. 5 FL-1797	Frac. 6 FL-1798	Frac. 7 FL-1799	Frac. 8 FL-1800
TBP Cut Pts. F			<400	400-440	440-480	480-520	520-560	560-600	600-640	640+
Cut Range, V%			0-11.5	11.5-20.5	20.5-28.5	28.5-45	45-61.5	61.5 75.5	75.5-86.5	86.5-100
Yield, V%			11.5	9.0	8.0	16.5	16.5	14.0	11.0	13.5
Sp. Gr. @ 60 F	D 1298	0.8458	0.8146	0.8445	0.8483	0.8483	0.8448	0.8473	0.8586	0.8633
Gravity, API		35.8	42.2	36.1	35.3	35.3	36.0	35.5	33.3	32.4
Density, g/mL		0.8453	0.8142	0.8440	0.8479	0.8479	0.8443	0.8469	0.8582	0.8629
Distillation, F	D86									
IBP/5%		353/428	282/324	452/464	476/484	502/509	536/542	570/576	610/616	657/663
10/30%		466/523	338/377	465/473	486/492	514/518	544/546	578/581	617/620	666/669
50/70%		551/581	404/425	480/488	498/506	523/527	550/555	584/589	622/626	673/677
90/95%		635/657	452/462	501/506	516/521	542/550	564/568	597/602	634/638	687/691
EP		672	475	515	529	556	576	610	643	698
Carbon, W%	D3178	86.82	86.64	87.08	87.14	87.10	87.06	86.27	86.47	86.38
Hydrogen, W%		13.31	12.82	12.49	12.44	12.56	12.69	13.59	13.41	13.89
Sulfur, W%	D2622	0.052	0.007	0.013	0.018	0.026	0.043	0.073	0.121	0.111
HC Type, V%	D1319									
Aromatics		23.6	23.4	24.5	25.0	25.4	23.3	22.9	23.7	too heavy
Olefins		1.0	1.1	1.0	1.5	1.6	1.6	1.1	1.2	too heavy
Saturates		74.7	75.5	74.5	73.5	73.0	75.1	76.0	75.1	too heavy
Vis. cSt @ 40 C	D445	3.52	1.26	2.28	2.60	3.18	3.85	5.00	6.86	10.41
cSt @ 100 C		1.34	0.58	0.99	1.10	1.25	1.42	1.70	2.08	2.79
RI @ 20 C	D1218	1.4718	1.4550	1.4717	1.4742	1.4737	1.4713	1.4726	1.4787	1.4873
Cetane No.	CVCA	56.2	33.9	41.1	40.5	42.5	45.1	54.2	-	-
Cetane Index	D976	52.6	41.4	44.8	46.0	49.0	52.8	54.5	52.7	52.0
	D4737	54.6	41.5	45.1	47.0	52.2	59.3	64.8	66.2	80.7
Aromatic C W%	UV									
Total		11.4	12.3	13.5	13.3	12.5	10.9	8.7	9.3	17.2
Mono-aromatic		4.3	7.9	4.6	4.4	4.3	4.0	3.2	3.1	5.7
Di-aromatic		5.8	4.4	8.6	8.5	7.4	5.7	3.7	3.5	6.2
Tri-aromatic		1.3	0.1	0.4	0.4	0.8	1.2	1.8	2.7	5.2
Cloud Pt., C/ F	D2500	1/34	-43/-47	-28/-18	-21/-6	-14/7	-6/21	6/43	12/54	36/97
Pour Pt., C/ F	D97	-1/30	-45/-49	-25/-13	-18/0	-12/10	-3/27	6/43	15/59	39/102
Aniline Pt., C/ F	D611	73.0/163	54.4/130	62.4/144	64.4/148	68.6/155	75.0/167	80.1/176	82.1/180	88.4/191
Smoke Point, mm	D 1322	17.2	19.5	15.7	15.0	15.3	15.8	16.2	NA	NA

TABLE A4. LABORATORY ANALYSES FOR LOW AROMATICS STRAIGHT RUN DIESEL

Test	ASTM Method	Feed FL-1873	Frac. 1 FL-1876	Frac. 2 FL-1877	Frac. 3 FL-1878	Frac. 4 FL-1879	Frac. 5 FL-1880	Frac. 6 FL-1881	Frac. 7 FL-1882	Frac. 8 FL-1883
TBP Cut Pts.°F			IBP-400	400-440	440-480	480-520	520-560	560-600	600-640	640 +
Cut Range, V%			0-5	5-15	15-24.5	24.5-39.5	39.5-56	56-73.5	73.5-87	87-100
Yield, V%			5	10	9.5	15	16.5	17.5	13.5	13
Sp. Gr. @ 60°F	D 1298	0.8280	0.7892	0.8251	0.8373	0.8368	0.8304	0.8246	0.8314	0.8373
Gravity, °API		39.4	47.8	40.0	37.5	37.6	38.9	40.1	38.7	37.5
Density, g/mL		0.8276	0.7888	0.8247	0.8368	0.8364	0.8300	0.8242	0.8310	0.8368
Distillation, °F	D 86									
IBP/5%		262/380	201/212	361/381	427/438	474/480	520/528	559/567	605/613	659/670
10/30%		442/507	241/258	386/396	440/445	482/489	530/534	567/573	615/618	673/677
50/70%		539/572	278/297	404/418	452/461	494/500	538/544	577/580	620/624	683/688
90/95%		622/644	323/334	438/447	474/480	510/515	552/557	587/591	631/635	699/705
EP		664	351	455	488	526	562	597	641	715
Carbon W%	D 3178	85.99	86.61	86.26	86.07	86.00	85.87	85.80	85.62	85.68
Hydrogen, W%		14.86	13.62	14.03	13.91	14.01	14.37	14.50	14.67	14.53
Sulfur, W%	D 2622	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
HC Type, V%	D 1319									
Aromatics		9.8	22.7	14.6	14.9	12.5	9.1	7.6	7.6	NA
Olefins		0.6	0.7	0.9	0.9	2.7	1.8	1.0	2.8	NA
Saturates		89.6	76.9	84.5	84.2	84.8	89.1	91.4	89.6	NA
Vis. cSt @ 40°C	D 445	3.17	0.75	1.53	2.12	2.81	3.46	4.35	5.89	8.70
cSt @ 100°C		1.29	0.45	0.75	0.96	1.16	1.32	1.58	1.94	2.54
RI @ 20°C	D 1218	1.4580	1.4403	1.4557	1.4610	1.4608	1.4576	1.4565	1.4595	NA
Cetane No.	CVCA	61.3	23.1	31.7	38.6	44.3	48.8	64.2	79.1	.
Cetane Index	D 976	57.7	13.0	37.4	42.6	49.3	56.7	62.1	61.7	60.5
	D 4737	60.1	23.8	38.1	42.7	51.3	64.1	78.4	81.5	82.2
Aromatic, °C, V%	UV									
Total		3.3	7.7	5.8	5.0	3.6	2.6	1.5	1.1	0.8
Mono-aromatic		3.0	7.7	5.6	4.6	3.2	2.2	1.3	0.9	0.6
Di-aromatic		0.3	0.1	0.3	0.4	0.4	0.3	0.2	0.2	0.2
Tri-aromatic		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloud Pt., °C/°F	D 2500	1/34	<-78/-108	-53/-63	-34/-29	-20/-4	-9/16	0/32	15/59	26/79
Pour Pt., °C/°F	D 97	-3/27	< 78-108	-51/-60	-33/-27	-18/0	-7/19	3/37	16/61	28/82
Aniline Pt.,°C/°F	D 611	80.8/177	35.4/96	47.0/117	64.0/147	72.7/163	81.0/178	88.6/191	93.2/200	101.7/215
Smoke Point, mm	D 1322	25.5	20.5	21.5	21.2	21.9	25.9	29.6	NA	NA

TABLE A5. LABORATORY ANALYSES FOR LIGHT COKER GAS OIL								
	ASTM Method	Feed FL-1440	Frac. 1 FL-1546	Frac. 2 FL-1547	Frac. 3 FL-1548	Frac. 4 FL-1549	Frac. 5 FL-1550	Frac. 6 FL-1551
TBP Cut Pts. °F	-	-	330-440	440-480	480-520	520-560	560-600	600-651
Cut Range, V%			0-25	25-42.7	42.7-59.7	59.7-75.8	75.8-88.8	88.8-100
Yield, V%	-	-	25.0	17.7	17.0	16.1	13.0	11.2
Sp. Gravity @ 60°F	D 1298	0.8676	0.8403	0.8565	0.8740	0.8871	0.8927	0.9094
Gravity, °API		31.6	36.9	33.7	30.4	28.0	27.0	24.1
Density, g/mL		0.8671	0.8398	0.8561	0.8735	0.8867	0.8922	0.9089
Distillation, °F	D 86							
IBP/5%		385/420	379/391	440/445	480/485	521/529	559/564	599/601
10/30%		435/462	395/403	446/451	486/491	530/533	565/569	603/606
50/70%		492/528	410/417	456/462	495/500	537/541	571/574	609/614
90/95%		574/590	429/436	473/478	508/512	547/551	580/583	624/635
EP		608	461	491	526	565	595	645
Carbon, W%	D 3178	85.18	85.36	85.70	85.68	85.77	85.96	85.82
Hydrogen, W%		12.58	13.16	12.46	12.35	12.09	12.27	11.97
Sulfur, W%	D 2622	1.41	1.16	1.08	1.36	1.48	1.32	1.33
HC Type, V%	D 1319							
Aromatics		52.4	29.1	31.8	38.7	46.4	49.0	too heavy
Olefins		5.9	18.0	17.0	15.8	12.7	14.9	too heavy
Saturates		41.7	52.9	51.2	45.5	40.9	36.1	too heavy
Vis. cSt @ 40°C	D 445	2.56	1.46	2.01	2.77	3.97	5.64	10.08
cSt @ 100°C		1.10	0.73	0.90	1.11	1.40	1.69	2.40
RI @ 20°C	D 1218	1.4797	1.4629	1.4729	1.4831	1.4907	1.4942	Too dark
Cetane No.	CVCA	29.0	25.6	27.9	30.1	29.1	32.8	31.7
Cetane Index	D 976	39.3	33.3	37.0	37.9	39.2	40.6	38.8
	D 4737	38.7	32.0	31.9	35.6	37.5	41.2	41.2
Aromatic °C, W%	UV							
Total		15.7	11.4	13.8	14.4	15.1	14.7	15.2
Mono-aromatic		8.4	9.1	8.6	7.1	6.7	6.2	5.6
Di-aromatic		5.9	1.6	4.4	6.3	7.2	6.6	6.1
Tri-aromatic		1.4	0.6	0.8	1.0	1.3	1.7	3.5
Cloud Point, °C/°F	D 2500	Too dark	-65/-85	-54/-65	-38/-36	-27/-17	-21/-6	Too dark
Pour Point, °C/°F	D 97	-30/-22	-65/-85	-55/-67	-38/-36	-27/-17	-21/-6	-5/23
Aniline Point, °C/°F	D 611	47.6/118	43.4/110	46.7/116	46.2/115	49.0/120	53.4/128	Too dark
Smoke Point, mm	D 1322	13.3	16.6	16.7	12.4	11.9	11.0	NA

TABLE A6. LABORATORY ANALYSES FOR LOW SULFUR LIGHT COKER GAS OIL

Test	ASTM Method	Feed FL-1442	Frac. 1 FL-1862	Frac. 2 FL-1863	Frac. 3 FL-1864	Frac. 4 FL-1865	Frac. 5 FL-1866	Frac. 6 FL-1867
TBP Cut Pts.°F			<400	400-440	440-480	480-520	520-560	560+
Cut Range, V%			0-13.5	13.5-29.0	29.0-48.5	48.5-66.5	66.5-82.0	82-100
Yield, V%			13.5	15.5	19.5	18.0	15.5	18.0
Sp. Gr. @ 60°F	D 1298	0.8463	0.8184	0.8299	0.8403	0.8524	0.8628	0.8697
Gravity, °API		35.7	41.4	39.0	36.9	34.5	32.5	31.2
Density, g/mL		0.8458	0.8180	0.8295	0.8398	0.8520	0.8623	0.8692
Distillation, °F	D 86							
IBP/5%		380/416	337/354	379/395	421/430	462/472	500/510	558/565
10/30%		427/454	360/374	399/407	432439	473/478	512/518	567/572
50/70%		476/511	389/405	415/425	447/456	484/492	523/529	577/584
90/95%		552/572	427/441	442/453	473/481	504/512	539/543	598/607
EP		599	457	467	492	526	550	624
Carbon W%	D 3178	86.85	86.48	86.43	86.59	86.99	86.74	86.72
Hydrogen, W%		13.31	13.66	13.59	13.54	13.18	13.17	12.96
Sulfur, W%	D 2622	0.04	0.007	0.009	0.014	0.024	0.041	0.052
HC Type, V%	D 1319							
Aromatics		27.5	22.1	22.9	24.7	28.2	32.5	31.2
Olefins		2.1	1.9	1.8	1.9	1.9	1.6	1.3
Saturates		70.4	76.0	75.3	73.4	69.9	65.9	67.5
Vis. cSt @ 40°C	D 445	2.31	1.26	1.52	1.90	2.52	3.45	5.81
cSt @ 100°C			0.58	0.76	0.87	1.06	1.30	1.58
RI @ 20°C	D 1218	1.4676	1.4537	1.4596	1.4646	1.4716	1.4771	1.4810
Cetane No.	CVCA	33.3	28.2	29.5	29.2	30.4	33.7	37.8
Cetane Index	D 976	43.5	36.4	38.0	40.7	42.7	44.5	47.2
	D 4737	43.5	37.4	38.2	40.5	42.7	45.5	52.6
Aromatic °C, W%	UV							
Total		10.5	10.0	10.9	10.2	11.0	11.2	11.4
Mono-aromatic		8.2	9.4	9.8	8.4	8.2	7.7	7.2
Di-aromatic		2.3	0.6	1.1	1.8	2.8	3.4	3.5
Tri-aromatic		0.0	0	0	0	0	0.1	0.7
Cloud Pt., °C/°F	D 2500	35	<-65/-85	-62/-80	-48/-54	-38/-36	-27/-17	-5/23
Pour Pt., °C/°F	D 97	-38/-36	<-65/-85	-6/-80	-45/-49	-35/-31	-27/-17	-2/28
Aniline Pt., °C/°F	D 611	58.6/137	51.7/125	53.5/128	56.2/133	58.2/137	61.2/142	69.6/157
Smoke Point, mm	D 1322	16.2	19.1	18.3	16.7	15.5	14.7	14.1

TABLE A7. LABORATORY ANALYSES FOR LOW AROMATICS LIGHT COKER GAS OIL

Test	ASTM Method	Feed FL-1443	Frac. 1 FL-1597	Frac. 2 FL-1598	Frac. 3 FL-1599	Frac. 4 FL-1600	Frac. 5 FL-1601	Frac. 6 FL-1602	Frac. 7 FL-1603
TBP Cut Pts. °F	-	-	326-400	400-440	440-480	480-520	520-560	560-600	600-746
Cut Range, V%			0-8.5	8.5-24	24-42.3	42.3-58.4	58.4-73.4	73.4-85.9	85.9-100
Yield, V%	-	-	8.5	15.5	18.3	16.1	15.0	12.5	14.0
Sp. Gr. @ 60°F	D 1298	0.8393	0.8203	0.8265	0.8324	0.8418	0.8490	0.8498	0.8522
Gravity, °API		37.1	41.1	39.7	38.5	36.6	35.1	35.0	34.5
Density, g/mL		0.8388	0.8198	0.8261	0.8319	0.8413	0.8486	0.8494	0.8518
Distillation, °F	D 86								
IBP/5%		412/429	358/371	394/401	429/436	466/472	498/506	537/547	585/594
10/30%		436/464	374/382	404/410	437/442	474/479	508/512	548/552	595/599
50/70%		491/526	390/400	417/425	448/453	483/491	516/522	556/560	602/610
90/95%		576/597	414/421	440/449	468/477	503/509	530/536	566/570	622/632
EP		612	430	466	485	520	546	574	644
Carbon, W%	D 3178	86.29	86.22	86.40	86.53	86.53	86.66	86.42	86.73
Hydrogen, W%		13.69	13.50	13.52	13.51	13.41	13.35	13.41	13.58
Sulfur, W%	D 2622	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	0.002	0.002
HC Type, V%	D 1319								
Aromatics		10.4	10.5	9.1	8.7	10.2	11.9	13.0	14.3
Olefins		0.4	0.7	0.5	0.6	0.5	0.7	0.9	1.0
Saturates		89.2	88.8	90.4	90.7	89.3	87.4	86.1	84.7
Vis. cSt @ 40°C	D 445	2.67	1.35	1.58	1.98	2.61	3.37	4.63	7.10
cSt @ 100°C		1.10	0.69	0.78	0.90	1.08	1.28	1.55	2.07
RI @ 20°C	D 1218	1.4608	1.4509	1.4539	1.4569	1.4616	1.4652	1.4662	1.4676
Cetane No.	CVCA	37.7	28.2	30.5	31.7	33.7	39.0	44.1	54.9
Cetane Index	D 976	48.0	36.1	39.7	43.6	46.2	47.9	51.7	53.8
	D 4737	49.2	36.6	39.9	44.0	47.2	50.6	57.7	65.9
Aromatic °C, W%	UV								
Total		3.3	4.5	3.9	3.5	3.4	3.3	2.7	2.2
Mono-aromatic		3.0	4.3	3.7	3.3	3.1	2.9	2.3	1.8
Di-aromatic		0.3	0.2	0.2	0.3	0.4	0.4	0.4	0.4
Tri-aromatic		0	0	0	0	0	0	0	0
Cloud Pt., °C/°F	D 2500	-28/-18	<-48/-54	<-48/-54	<-48-54	-41/-42	-31/-24	-21/-6	-4/25
Pour Pt., °C/°F	D 97	-33/-27	<-48/-54	<-48/-54	<-48/-54	-37/-35	-28/-18	-17/1	-4/25
Aniline Pt., °C/°F	D 611	71.2/160	57.4/135	62.9/145	66.0/151	69.5/157	73.0/163	79.7/175	88.6/191
Smoke Point, mm	D 1322	23.1	25.9	23.8	23.5	22.4	21.0	22.1	NA

TABLE A8. LABORATORY ANALYSES FOR LIGHT CYCLE OIL

Test	ASTM Method	Feed FL-1538	Frac. 1 FL-1555	Frac. 2 FL-1556	Frac. 3 FL-1557	Frac. 4 FL-1558	Frac. 5 FL-1559	Frac. 6 FL-1560	Frac. 7 FL-1561
TBP Cut Pts. °F	-		367-440	440-480	480-520	520-560	560-600	600-640	640-689
Cut Range, V%			0-8.9	8.9-18.1	18.1-38	38-53	53-67.3	67.3-79	79-100
Yield, V%	-		8.9	9.2	19.9	15.0	14.3	11.7	21.0
Sp. Gr. @ 60°F	D 1298	0.9490	0.8849	0.9147	0.9321	0.9440	0.9541	0.9685	0.9979
Gravity, °API		17.6	28.4	23.2	20.3	18.4	16.8	14.6	10.3
Density, g/mL		0.9485	0.8844	0.9142	0.9316	0.9434	0.9536	0.9679	0.9973
Distillation, °F	D 86								
IBP/5%		367/457	382/384	442/444	477/481	508/514	542/546	578/582	616/636
10/30%		476/509	384/397	447/455	483/486	515/518	548/550	583/586	643/645
50/70%		536/573	410/424	459/464	490/492	522/525	552/556	588/591	651/658
90/95%		634/656	443/449	473/479	499/503	531/534	562/566	596/601	677/709
EP		689	460	492	518	544	575	614	734
Carbon, W%	D 3178	88.84	89.00	89.36	88.63	89.80	89.97	89.41	88.67
Hydrogen, W%		9.84	10.74	10.08	9.69	9.65	9.70	9.41	9.18
Sulfur, W%	D 2622	0.69	0.16	0.35	0.45	0.41	0.32	0.57	1.85
HC Type, V%	D 1319								
Aromatics		75.5	76.6	74.1	77.2	81.7	80.8	81.0	75.0
Olefins		3.6	2.7	5.4	5.1	4.5	3.0	3.0	1.8
Saturates		20.9	20.7	20.5	17.7	13.8	16.2	16.0	23.2
Vis. cSt @ 40°C	D 445	3.16	1.25	1.73	2.14	2.78	3.74	5.47	11.38
cSt @ 100°C		1.20	0.65	0.81	0.94	1.09	1.31	1.64	2.40
RI @ 20°C	D 1218	1.5537	1.5047	1.5279	1.5431	1.5532	1.5572	1.5641	1.5866
Cetane No.	CVCA	15.5	15.2	17.0	- -	13.9	15.6	16.3	19.1
Cetane Index	D 976	26.1	20.2	22.6	23.8	25.5	26.7	26.9	24.9
	D 4737	23.8	19.3	17.5	17.0	18.1	19.5	19.7	17.6
Aromatic °C, W%	UV								
Total		43.7	42.5	55.3	57.2	60.6	46.1	41.2	46.7
Mono-aromatic		6.3	26.7	14.5	6.8	5.1	3.3	4.9	6.4
Di-aromatic		28.3	15.0	39.8	49.6	53.9	37.2	25.2	11.8
Tri-aromatic		9.1	0.8	1.0	0.8	1.6	2.2	6.3	19.6
Cloud Pt., °C/°F	D 2500	-10/14	<-65/-85	-45/-49	-40/-40	-35/-31	-22/-8	-8/18	9/48
Pour Pt., °C/°F	D 97	-12/10	<-65/-85	-45/-49	-40/-40	-35/-31	-22/-8	-9/16	9/48
Aniline Pt., °C/°F	D 611	9.8/50	-5/23	0.5/33	1.3/34	2.0/36	6.5/44	17.3/63	34.0/93
Smoke Point, mm	D1322	6.2	7.2	6.0	6.2	6.0	5.1	5.4	4.1

TABLE A9. LABORATORY ANALYSES FOR LOW SULFUR LIGHT CYCLE OIL

Test	ASTM Method	Base FL-1615	Frac. 1 FL-1850	Frac. 2 FL-1851	Frac. 3 FL-1852	Frac. 4 FL-1853	Frac. 5 FL-1854	Frac. 6 FL-1855	Frac. 7 FL-1856
TBP Cut Pts. °F			400-440	440-480	480-520	520-560	560-600	600-640	640+
Cut Range, V%			0-12.3	12.3-28	28-48.5	48.5-65	65-79.1	79.1-89.1	89.1-100
Yield, V%			12.3	15.7	20.5	16.5	14.1	10.0	10.9
Sp. Gr. 60°F		0.9200	0.8849	0.9082	0.9153	0.9230	0.9352	0.9484	0.9497
Gravity, °API		22.3	28.4	24.3	23.1	21.8	19.8	17.7	17.5
Density, g/mL		0.9195	0.8844	0.9077	0.9147	0.9225	0.9347	0.9478	0.9491
Distillation, °F	D 86								
IBP/5%		392/436	317/356	422/440	458/469	495/502	533/541	593/593	641/645
10/30%		462/491	370/403	444/456	472/478	503/510	543/549	595/599	650/655
50/70%		518/554	424/444	467/479	488/498	519/529	557/565	603/609	663/673
90/95%		614/642	469/481	502/516	521/533	549/559	579/585	617/622	702/727
EP		682	510	5[illegible]	548	572	595	630	738
Carbon, W%	D 3178	89.08	88.79	89.36	89.16	89.40	89.69	89.80	89.41
Hydrogen, W%		10.65	11.03	10.10	11.07	11.04	10.78	10.50	10.86
Sulfur, W%	D 2622	0.026	0.005	0.002	0.003	0.004	0.006	0.040	0.114
HC Type, V%	D 1319								
Aromatics		73.1	69.1	73.6	76.0	76.0	76.7	76.3	Too dark
Olefins		-	0.6	1.0	1.2	2.0	1.0	1.0	
Saturates		26.9	30.3	25.4	22.8	22.0	22.3	22.7	
Vis. cSt @ 40°C	D 445	2.96	1.39	1.99	2.34	2.95	4.11	6.41	13.87
cSt @ 100°C		1.16	0.70	0.88	0.99	1.02	1.39	1.85	2.89
RI @ 20°C	D 1218	1.5249	1.4980	1.5125	1.5185	1.5264	1.5358	1.5466	1.5505
Cetane No.	CVCA	17.9	14.0	15.4	15.7	17.3	18.6	19.9	-
Cetane Index	D 976	29.8	23.1	25.3	26.9	29.2	30.4	30.9	32.1
	D 4737	28.6	21.6	22.1	23.4	25.1	26.0	27.7	35.5
Aromatic °C, W%	UV								
Total		35.8	29.1	35.4	35.8	36.8	34.1	32.8	31.9
Mono-aromatic		16.6	23.3	22.9	20.4	16.7	11.8	6.8	2.4
Di-aromatic		15.0	5.8	12.5	15.1	19.0	19.6	17.5	9.5
Tri-aromatic		4.2	0	0	0.3	1.2	2.7	8.6	20.1
Cloud Pt., °C/°F	D 2500	+12/-11	<-65/-85	-60/-76	-43/-45	-31/-24	-18/0	-3/27	too dark
Pour Pt., °C/°F	D 97	-25/-13	<-65/-85	-58/-72	-43/-45	-30/-22	-18/0	0/32	16/61
Aniline Pt., °C/°F	D 611	16.6/62	<8/46	8/46	8/46	14.0/57	17.0/63	29.2/85	552.2/126
Smoke Point	D 1322	7.1	8.7	7.1	7.1	7.3	7.1	5.4	NA

TABLE A10. LABORATORY ANALYSES FOR LOW AROMATICS LIGHT CYCLE OIL

Test	ASTM Method	Feed FL-1562	Frac. 1 FL-1566	Frac. 2 FL-1567	Frac. 3 FL-1568	Frac. 4 FL-1569	Frac. 5 FL-1570	Frac. 6 FL-1571	Frac. 7 FL-1572
TBP Cut Pts. °F	-		326-400	400-440	440-480	480-520	520-560	560-600	600-746
Cut Range, V%			0-11.3	11.3-25.2	25.2-43	43-61.3	61.3-76.4	76.4-86.4	86.4-100
Yield, V%	-		11.3	13.9	17.8	18.3	15.1	10.0	13.6
Sp. Gr. @ 60°F	D 1298	0.8628	0.8483	0.8628	0.8681	0.8713	0.8740	0.8708	0.8453
Gravity, °API		32.5	35.3	32.5	31.5	30.9	30.4	31.0	35.9
Density, g/mL		0.8623	0.8479	0.8623	0.8676	0.8708	0.8735	0.8703	0.8448
Distillation, °F	D 86								
IBP/5%		390/419	340/354	402/411	439/444	472/476	511/513	543/546	599/603
10/30%		433/463	362/372	412/416	446/450	477/482	514/517	547/550	606/613
50,70%		488/518	384/396	422/426	454/459	486/490	520/523	552/556	620/636
90/95%		581/617	406/411	434/439	470/474	499/501	530/534	561/565	669/694
EP		657	419	453	488	514	544	574	715
Carbon W%	D 3178	86.49	86.67	86.78	86.73	86.73	86.68	86.55	86.07
Hydrogen, W%		13.55	13.19	13.26	13.04	13.08	13.04	13.07	13.80
Sulfur, W%	D 2622	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
HC Type, V%	D 1319								
Aromatics		10.10	12.6	9.1	11.7	11.6	9.9	10.3	8.1
Olefins		0.6	0.8	0.9	0.8	0.7	0.9	1.1	0.9
Saturates		89.3	86.6	90.0	87.5	87.7	89.2	88.6	91.0
Vis. cSt @ 40°C	D 445	2.66	1.33	1.75	2.17	2.71	3.50	4.47	7.02
cSt @ 100°C		1.11	0.70	0.84	1.12	1.12	1.32	1.54	2.15
RI @ 20°C	D 1218	1.4708	1.4621	1.4681	1.4716	1.4736	1.4750	1.4741	1.4645
Cetane No.	CVCA	38.4	22.4	24.5	30.1	31.4	39.6	42.1	77.2
Cetane Index	D 976	40.1	24.6	28.8	33.3	37.4	40.9	45.0	56.9
	D 4737	39.8	24.6	26.7	31.2	35.5	40.5	47.3	72.6
Aromatic °C, W%	UV								
Total		3.5	5.6	3.6	4.1	3.9	2.9	2.5	1.4
Mono-aromatic		3.1	5.4	3.4	3.7	3.4	2.5	2.0	1.0
Di-aromatic		0.4	0.2	0.2	0.4	0.5	0.4	0.5	0.4
Tri-aromatic		0	0	0	0	0	0	0	0
Cloud Pt., °C/°F	D 2500	-13/9	>-50/-58	>-50/-58	>-50/-58	>-50/-58	-40.5/-41	-25.5/-8	+12/54
Pour Pt., °C/°F	D 97	-19/-2	>-50/-58	>-50/-58	>-50/-58	>-50/-58	-41/-42	-27.5/-18	+9/48
Aniline Pt., °C/°F	D 611	63.6/146	43.0/109	49.3/121	53.7/129	58.5/137	66.3/151	73.6/164	93.3/200
Smoke Point, mm	D 1322	20.4	19.5	19.8	19.3	18.1	18.5	19.3	NA

TABLE A11. COMPONENT HYDROCARBON COMPOSITION BY GC/MS

Hydrocarbon Type, Wt%/V%	SRD Feed 1627	SRD #1 1793	SRD #2/3/4 1794-96	SRD #5/6 1797/98	SRD #7 1799	SRD #8 1800	LCO Feed 1538	LCO #1/2 1555/56	LCO #3/4/5 1557-59	LCO #6 1560	LCO #7 1561
Paraffins	50.1/54.6	46.7/50.0	44.7/47.1	56.2/57.2	50.8/54.0	45.8/49.6	17.6/21.2	25.0/27.9	27.8/31.9	23.1/25.3	18.6/22.5
Monocycloparaffins	15.1/15.7	20.5/20.7	18.6/18.6	14.2/14.0	14.5/14.8	20.1/20.8	7.3/8.5	12.8/13.6	5.4/5.9	3.6/3.9	6.9/7.9
Dicycloparaffins	5.8/5.7	5.4/5.0	7.4/6.7	4.4/4.0	5.4/5.1	5.8/5.6	1.4/1.5	1.1/1.0	5.7/5.7	5.3/5.0	2.2/2.4
Tricycloparaffins	1.7/1.6	2.5/2.1	2.0/1.7	2.0/1.7	2.7/2.4	2.5/2.2	0/0	0/0	0.3/0.3	1.0/0.9	0.7/0.7
Alkylbenzenes	6.0/5.5	12.5/12.0	7.0/7.0	4.4/4.8	4.8/4.7	5.0/4.6	10.6/11.3	27.1/26.5	13.1/13.2	6.2/6.0	2.5/2.7
Indans/Tetralins	3.1/2.6	4.0/3.5	3.8/3.7	2.0/2.1	2.3/2.1	2.6/2.2	1.6/1.5	4.2/4.0	0/0	0/0	0.9/0.9
Indenes	3.7/3.0	0.6/0.5	4.5/4.2	3.5/3.4	3.1/2.6	2.9/2.3	1.8/1.6	2.5/2.3	1.9/1.7	0.3/0.3	0/0
Naphthalene	0.3/0.2	1.5/1.1	0.7/0.5	0.1/0.1	0/0	0/0	0.5/0.4	3.0/2.4	0.4/0.3	0.2/0.1	0/0
Naphthalenes, alkyl	7.1/5.6	5.5/4.5	8.0/7.4	5.7/5.5	4.4/3.8	4.0/3.2	31.2/28.0	22.1/20.1	28.0/24.9	11.2/10.5	14.0/12.7
Acenaphthenes	3.5/2.8	0.6/0.5	2.2/2.0	3.9/3.7	5.0/4.2	3.8/3.0	12.8/11.5	1.6/1.5	11.7/10.4	24.8/23.1	12.6/11.4
Acenaphthylenes	2.4/2.1	0.1/0.1	1.1/1.1	2.7/2.9	4.2/4.0	4.0/3.5	9.4/9.4	0.7/0.7	5.6/5.5	20.7/21.4	16.6/16.7
Tricyclic Aromatics	1.0/0.7	0/0	0/0	0.6/0.6	2.8/2.3	3.6/2.9	5.7/5.0	0/0	0/0	3.8/3.5	25.1/22.3
Total Saturates	72.8/77.5	75.1/77.8	72.7/74.2	76.8/77.0	73.4/76.4	74.2/78.2	26.4/31.2	38.9/42.5	39.3/43.9	33.0/35.2	28.3/33.4
Total Aromatics	27.2/22.5	24.9/22.2	27.3/25.8	23.2/23.0	26.6/23.6	25.8/21.8	73.6/68.8	61.1/57.5	60.7/56.1	67.0/64.8	71.7/66.6

TABLE A12. COMPONENT HYDROCARBON COMPOSITION BY GC/MS

Hydrocarbon Type, Wt%/V%	LoA SRD Feed 1873	LoA SRD #1 1876	LoA SRD #2 1877	LoA SRD #3 1878	LoA SRD #4 1879	LoA SRD #5 1880	LoA SRD #6 1881	LoA SRD #7 1882	LoA SRD #8 1883
Paraffins	57.2/60.2	23.3/25.0	37.7/40.2	40.7/44.0	49.3/53.2	59.4/62.6	64.6/67.6	62.6/65.5	60.9/63.9
Monocycloparaffins	16.9/16.8	38.8/39.1	32.1/32.2	20.4/20.9	18.6/18.8	16.4/16.4	21.0/20.5	21.2/20.8	23.7/23.2
Dicycloparaffins	11.3/10.3	0.8/0.8	14.8/13.6	16.8/15.7	12.4/11.7	8.8/8.1	4.7/4.5	6.6/6.0	7.2/6.5
Tricycloparaffins	6.2/5.2	0/0	2.2/1.8	5.5/4.8	4.9/4.3	5.1/4.3	3.1/2.7	3.7/3.1	3.3/2.8
Alkylbenzenes	4.5/4.1	37.1/35.1	7.6/7.3	7.3/6.7	6.6/5.7	4.8/4.4	3.2/2.5	2.9/2.4	2.3/1.9
Indans/Tetralins	2.3/2.0	0/0	5.3/4.7	7.7/6.5	5.5/4.2	2.2/1.8	1.1/0.7	0.8/0.5	0.7/0.5
Indenes	1.4/1.1	0/0	0.1/0.1	0.8/0.7	2.7/2.0	2.2/1.7	1.5/0.9	0.9/0.6	0.7/0.5
Naphthalene	0/0	0/0	0.1/0.1	0.2/0.2	0.0	0.2/0.1	0.1/0	0/0	0/0
Naphthalenes, alkyl	0.2/0.2	0/0	0.1/0.1	0.5/0.4	0.1/0	0.6/0.4	0.5/0.3	0.7/0.5	0.5/0.3
Acenaphthenes	0.1/0.1	0/0	0/0	0.1/0.1	0.1/0.1	0.2/0.2	0.2/0.1	0.4/0.3	0.4/0.3
Acenaphthylenes	0/0	0.0	0/0	0/0	0/0	0.1/0.1	0/0	0.1/0.1	0.1/0.1
Tricyclic Aromatics	0/0	0.0	0/0	0/0	0.0	0/0	0/0	0.0	0.1/0.1
Total Saturates	91.4/92.5	62.9/64.9	86.8/87.7	83.4/85.5	85.1/88.0	89.8/91.4	93.4/95.4	94.1/95.5	95.1/96.4
Total Aromatics	8.6/7.5	37.1/35.1	13.2/12.3	16.6/14.5	14.9/12.0	10.2/8.6	6.6/4.6	5.9/4.5	4.9/3.6

TABLE A13. COMPONENT HYDROCARBON COMPOSITION BY GC/MS

Hydrocarbon Type, Wt%/V%	LoS LCO Feed 1615	LoS LCO #1 1850	LoS LCO #2/3 1851/52	LoS LCO #4/5 1853/54	LoS LCO #6 1855	LoS LCO #7 1856	LoA LCO Feed 1562	LoA LCO #1/2 1566/67	LoA LCO #3/4 1568/69	LoA LCO #5/6 1570/71	LoA LCO #7 1572
Paraffins	27.8/31.5	22.5/24.9	28.0/31.0	28.7/30.5	29.1/33.5	29.3/32.6	23.0/25.2	4.1/4.2	13.5/14.9	30.9/34.1	55.1/57.8
Monocycloparaffins	11.1/11.9	17.7/18.2	10.9/11.5	9.3/9.4	8.5/9.3	7.5/8.0	30.3/31.6	54.6/57.3	42.3/43.8	16.2/16.8	20.2/20.0
Dicycloparaffins	3.0/2.9	5.2/4.9	4.1/3.9	2.2/2.0	2.5/2.5	3.5/3.5	22.6/21.6	31.9/31.0	24.4/23.3	16.0/15.3	8.6/7.8
Tricycloparaffins	0.0	0.1/0.1	0.4/0.3	0.1/0.1	0.1/0.1	1.5/1.4	14.1/12.3	0/0	8.9/7.9	26.6/23.6	8.0/6.8
Alkylbenzenes	18.5/18.4	31.5/30.4	22.7/21.9	13.7/13.0	6.6/6.6	2.4/2.4	4.7/4.6	7.0/5.6	5.2/5.1	3.8/3.9	2.4/2.3
Indans/Tetralins	7.5/6.9	15.4/14.7	13.4/12.7	4.5/4.6	0.2/0.2	2.6/2.6	3.7/3.3	2.3/1.7	4.7/4.2	3.2/3.1	1.1/1.1
Indenes	3.7/3.3	2.2/2.0	3.9/3.6	5.5/5.4	2.9/2.6	1.3/1.2	1.3/1.1	0/0	0.8/0.7	2.6/2.4	1.6/1.5
Naphthalene	0.8/0.6	0.1/0.1	0.1/0.1	0.6/0.5	0.1/0.1	0/0	0/0	0/0	0/0	0/0	0/0
Naphthalenes, alkyl	9.2/8.0	4.3/3.8	10.3/9.1	12.9/12.3	5.4/4.7	5.3/4.8	0.1/0.1	0/0	0/0	0.3/0.2	1.2/1.1
Acenaphthenes	9.4/8.1	0.9/0.8	4.8/4.3	14.5/13.9	21.3/18.6	12.5/11.3	0.1/0.1	0/0	0.1/0	0.4/0.3	0.9/0.8
Acenaphthylenes	6.4/6.2	0.1/0.1	1.2/1.2	7.7/8.1	17.5/16.9	14.9/15.0	0.1/0.1	0/0	0/0	0.2/0.2	0.7/0.7
Tricyclic Aromatics	2.5/2.1	0/0	0.2/0.2	0.1/0.1	5.7/4.9	19.1/17.2	0/0	0/0	0/0	0/0	0.2/0.2
Total Saturates	41.9/46.4	45.5/48.1	43.4/46.9	40.4/42.1	40.3/45.4	41.8/45.5	90.0/90.7	90.6/92.5	89.1/89.8	89.6/89.7	91.9/92.4
Total Aromatics	58.1/53.6	54.5/51.9	56.6/53.1	59.6/57.9	59.7/54.6	58.2/54.5	10.0/9.3	9.4/7.5	10.9/10.2	10.4/10.3	8.1/7.6

TABLE A14. COMPONENT HYDROCARBON COMPOSITION BY GC/MS

Hydrocarbon Type, Wt%/V%	LCGO Feed 1440	LCGO #1 1546	LCGO #2/3 1547/48	LCGO #4/5 1549/50	LCGO #6 1551	LoS LCGO Feed 1442	LoS LCGO #1/2 1862/63	LoS LCGO #3/4 1864/65	LoS LCGO #5 1866	LoS LCGO #6 1867
Paraffins	24.9/28.3	27.6/29.6	27.7/29.8	23.4/24.5	22.6/24.4	26.8/29.7	32.6/35.0	33.8/35.9	32.5/33.6	34.9/36.3
Monocycloparaffins	25.7/27.7	38.3/38.6	28.2/28.8	24.0/24.3	19.0/19.9	26.8/28.2	35.4/35.8	25.5/25.6	24.0/23.5	21.6/21.3
Dicycloparaffins	10.5/10.5	10.9/10.0	11.1/10.2	9.1/8.5	11.0/10.6	13.0/12.5	9.6/8.9	12.1/11.0	9.8/8.7	10.1/9.0
Tricycloparaffins	3.2/2.9	1.8/1.5	4.2/3.6	4.2/3.7	4.2/3.8	4.0/3.5	0.4/0.4	3.1/2.6	3.6/3.0	4.0/3.3
Alkylbenzenes	8.5/8.0	9.8/9.9	9.0/9.1	10.0/10.3	8.7/8.9	9.9/9.4	11.8/11.2	7.5/7.9	7.2/7.6	7.3/7.7
Indans/Tetralins	8.5/7.3	8.1/7.5	8.8/8.5	5.1/5.3	4.6/4.6	10.7/9.3	9.0/7.8	12.4/12.0	9.3/9.9	5.6/5.9
Indenes	6.4/5.2	1.2/1.1	6.1/5.6	8.8/8.6	4.8/4.5	6.0/5.0	0.3/0.2	4.0/3.7	8.4/8.5	7.0/7.0
Naphthalene	0.7/0.5	0.5/0.4	0.2/0.1	0.2/0.2	0/0	0/0	0.3/0.2	0/0	0.7/0.6	0.2/0.2
Naphthalenes, alkyl	5.1/4.1	0.8/0.7	3.4/3.1	6.9/6.6	7.4/6.8	1.6/1.3	0.5/0.4	1.2/1.1	2.6/2.6	3.3/3.2
Acenaphthenes	3.8/3.1	0.7/0.6	0.6/0.6	4.7/4.5	9.0/8.2	0.8/0.6	0/0	0.2/0.2	1.2/1.2	3.2/3.2
Acenaphthylenes	2.2/1.9	0.1/0.1	0.4/0.4	2.8/3.0	6.2/6.3	0.4/0.4	0/0	0/0	0.7/0.8	2.3/2.5
Tricyclic Aromatics	0.5/0.4	0/0	0.2/0.2	0.6/0.6	2.3/2.1	0.1/0.1	0/0	0.1/0	0/0	0.4/0.4
Total Saturates	64.3/69.5	78.7/79.7	71.2/72.4	60.7/61.0	56.9/58.6	70.5/74.0	78.1/80.1	74.5/75.0	69.9/68.8	70.6/69.9
Total Aromatics	35.7/30.5	21.3/20.3	28.8/27.6	39.3/39.0	43.1/41.4	29.5/26.0	21.9/19.9	25.5/25.0	30.1/31.2	29.4/30.1

TABLE A15. COMPONENT HYDROCARBON COMPOSITION BY GC/MS

Hydrocarbon Type, Wt%/V%	LoA LCGO Feed 1443	LoA LCGO #1/2 1597/98	LoA LCGO #3/4 1599/1600	LoA LCGO #5/6 1601/02	LoA LCGO #7 1603	FT Feed 1840	FT #1/2/3 1898-1900	FT #4/5/6 1901-03	FT #6 1903	FT #7 1904
Paraffins	32.5/35.0	26.6/28.6	31.9/34.3	36.9/39.6	43.7/46.4	89.5/90.7	94.8/95.2	83.3/84.2	89.3/90.4	88.1/89.5
Monocycloparaffins	35.3/36.5	49.6/50.4	40.0/40.7	29.2/29.6	29.0/28.3	7.3/6.9	4.3/4.1	14.0/13.4	8.5/8.0	9.7/9.0
Dicycloparaffins	13.9/13.4	13.3/12.4	14.0/13.2	15.0/13.9	14.6/13.6	0/0	0/0	1.9/1.7	1.0/0.8	0.3/0.2
Tricycloparaffins	3.1/2.8	0.7/0.6	3.1/2.7	8.4/7.2	6.3/5.4	0/0	0/0	0/0	0/0	0/0
Alkylbenzenes	8.8/7.7	6.5/5.5	5.1/4.5	3.9/3.8	2.6/2.3	2.7/2.1	0.7/0.6	0.5/0.5	0.7/0.5	1.6/1.1
Indans/Tetralins	4.1/2.9	3.0/2.2	4.4/3.5	3.2/2.9	0.9/0.7	0.1/0.0	0.2/0.1	0.1/0.1	0.1/0.1	0/0
Indenes	1.3/0.9	0.2/0.1	1.4/1.1	3.0/2.6	2.5/1.9	0.4/0.3	0/0	0/0	0.1/0	0.4/0.2
Naphthalene	0.1/0.1	0.1/0.1	0.1/0.1	0/0	0.5/0.3	0/0	0/0	0/0	0/0	0/0
Naphthalenes, alkyl	0.6/0.4	0/0	0/0	0.3/0.2	0/0	0/0	0/0	0/0	0/0	0/0
Acenaphthenes	0.1/0.1	0/0	0/0	0.2/0.2	0/0	0/0	0/0	0/0	0/0	0/0
Acenaphthylenes	0/0	0/0	0/0	0.1/0.1	0/0	0/0	0/0	0/0	0.3/0.2	0/0
Tricyclic Aromatics	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Total Saturates	84.8/86.9	90.2/92.0	89.0/90.8	89.4/90.3	93.5/94.7	96.8/97.6	99.1/99.3	99.2/99.3	98.8/99.2	98.0/98.6
Total Aromatics	15.2/12.2	9.8/8.0	11.0/9.2	10.6/9.7	6.5/5.3	3.2/2.4	0.9/0.7	0.6/0.6	1.2/0.8	2.0/1.4

TABLE A16. PROTON NMR CHEMICAL SHIFT ASSIGNMENTS			
Proton Type	Abbreviated Symbol	Description	Chemical Shift Region, (ppm, delta)
1. Alkane methyl	CH_3	Terminal paraffin chain protons	0.5 - 1.05
2. Gamma methyl	CH_3	Terminal alkyl chain protons at least three carbons from an aromatic ring	0.5 - 1.05
3. Alkane methylene	CH_2	Mid-paraffin chain proton with no branching	1.05 - 1.4
4. Beta methyl	CH_2	Terminal alkyl proton exactly two carbons from an aromatic ring	1.05 - 1.4
5. Gamma methylene	CH_2	Mid-alkyl chain proton at least three carbons from an aromatic ring	1.05 - 1.4
6. Alkane methine	CH	Mid-chain proton with branching	1.4 - 2.0
7. Cycloalkane methylene	CH	Cycloalkane (naphthene) proton	1.4 - 2.0
8. Beta methylene	CH	Mid-alkyl chain proton exactly two carbons from an aromatic ring	1.4 - 2.0
9. Alpha methyl	ALP	Terminal alkyl chain on carbon adjacent to an aromatic ring	2.0 - 4.4
10. Alpha methylene	ALP	Alkyl chain proton on carbon adjacent to an aromatic ring	2.0 - 4.4
11. Alpha methine	ALP	Alkyl proton on carbon adjacent to an aromatic ring with branching	2.0 - 4.4
12. Aromatic	ARO (DI & MONO)	All aromatic ring protons on di or mono-ring compounds	6.2 - 9.2

TABLE A17. PER CENT OF TOTAL PROTON RESONANCE INTENSITY FOR VARIOUS CHEMICAL SHIFT RANGES

	Chemical Shift Ranges in ppm referred to TMS				
SAMPLE NO.	0.5-1.05	1.05-1.4	1.4-2.0	2.0-4.4	6.2-9.2*
1440-F	30.5	33.3	17.1	14.9	4.2
1442-F	33.0	38.2	15.4	9.5	3.9
1546-F	33.6	30.8	17.3	14.9	3.4
1538-F	11.9	27.4	5.8	29.8	25.1
1538	13.0	27.3	5.5	29.3	24.9
1546-F	33.3	31.4	17.7	14.1	3.5
1547-F	33.5	31.5	16.4	14.7	3.9
1548-F	31.6	33.2	16.2	14.5	4.5
1549-F	30.1	35.2	15.8	14.6	4.3
1550-F	29.8	35.6	15.7	14.3	4.6
1551-F	27.5	36.9	15.6	14.6	5.4
1569-F	36.9	32.4	25.0	4.0	1.7
1570-F	36.8	35.5	23.4	3.1	1.2
1571-F	35.0	39.9	20.8	3.3	1.0
1572-F	27.1	56.5	13.2	2.5	0.6
1603-F	39.9	46.2	12.7	0.4	0.8
1615-F	16.6	29.1	11.4	27.0	15.9
1627-F	27.9	53.9	8.8	4.9	4.5
1793-F	32.1	44.9	10.9	6.5	5.5
1794-F	31.7	45.6	10.3	6.6	5.8
1795-F	30.2	46.6	10.5	7.3	5.4
1796-F	29.2	49.1	9.7	7.0	5.0
1797-F	28.6	53.3	9.0	6.1	4.0
1798-F	27.6	55.5	8.4	5.1	3.4
1799-F	24.7	57.1	9.1	5.5	3.6
1800-F	23.4	55.9	10.6	6.2	3.8

* This range contains the resonance from the residual protons in the solvent $CDCl_3$, corresponding to approximately 0.3%.

TABLE A17. PER CENT OF TOTAL PROTON RESONANCE INTENSITY FOR VARIOUS CHEMICAL SHIFT RANGES
(Continued)

	Chemical Shift Ranges in ppm referred to TMS				
1840-F	37.2	59.3	2.8	0.3	0.4
1850-F	18.8	24.3	13.9	27.7	15.3
1851-F	16.4	25.2	13.4	29.2	15.8
1852-F	15.4	26.7	12.8	28.9	16.1
1853-F	17.1	28.2	11.1	27.6	16.0
1854-F	14.3	30.0	10.3	28.1	17.3
1855-F	14.7	33.6	8.6	25.8	17.3
1856-F	14.8	41.7	8.3	20.2	15.0
1862-F	37.2	36.3	14.3	8.2	4.0
1863-F	36.7	36.9	14.6	8.0	3.8
1864-F	36.0	37.2	14.6	8.5	3.7
1865-F	35.3	37.6	14.2	8.9	4.0
1866-F	32.5	39.3	14.8	9.8	3.6
1867-F	32.3	41.5	13.9	8.7	3.6
1898-F	41.4	53.3	3.2	0.1	2.0
1899-F	38.6	56.8	3.4	0.4	0.8
1900-F	37.4	58.4	3.2	0.5	0.5
1901-F	36.2	60.3	2.4	0.0	1.1
1902-F	32.2	62.8	4.2	0.6	0.2
1903-F	33.4	63.1	2.5	0.3	0.7
1904-F	31.7	64.7	2.9	0.4	0.3
1443-F	33.3	38.8	20.5	6.0	1.3
1555-F	16.5	24.4	7.5	31.9	19.6
1556-F	15.7	26.1	6.1	28.6	23.5
1557-F	13.1	25.7	5.6	30.1	25.4
1558-F	12.6	25.4	5.0	31.6	25.5
1559-F	11.6	27.1	5.5	31.9	24.0

* This range contains the resonance from the residual protons in the solvent $CDCl_3$ corresponding to approximately 0.3%.

TABLE A17. PER CENT OF TOTAL PROTON RESONANCE INTENSITY FOR VARIOUS CHEMICAL SHIFT RANGES (Continued)

	Chemical Shift Ranges in ppm referred to TMS				
1560-F	13.2	29.4	5.5	29.1	22.8
1561-F	12.5	33.7	4.7	24.2	25.0
1562-F	35.9	35.0	23.9	3.7	1.5
1566-F	39.6	24.9	27.9	4.8	2.8
1567-F	41.9	25.4	27.9	3.1	1.7
1568-F	39.5	28.7	26.3	3.7	1.9
1597-F	43.8	33.3	17.5	3.3	2.2
1598-F	40.9	35.0	18.5	4.0	1.6
1599-F	40.3	36.7	17.8	3.9	1.3
1600-F	38.7	38.3	17.8	4.0	1.2
1601-F	41.5	39.7	15.2	2.2	1.3
1602-F	37.1	42.7	16.1	3.3	0.9
1873-F	31.0	52.1	12.5	2.9	1.5
1876-F	34.3	37.9	13.9	9.1	4.7
1877-F	34.9	39.8	17.1	5.3	2.9
1878-F	34.4	46.7	13.7	3.5	1.7
1879-F	34.5	41.4	16.9	4.9	2.4
1880-F	31.4	52.3	12.4	2.9	1.1
1881-F	30.5	57.6	9.6	1.6	0.7
1882-F	27.4	61.3	9.4	1.4	0.6
1883-F	27.9	59.9	10.3	1.2	0.7

* This range contains the resonance from the residual protons in the solvent $CDCl_3$ corresponding to approximately 0.3%.

TABLE A18. COMBUSTION ANALYSES FOR FISCHER-TROPSCH DIESEL (FT1)

Properties	FT 1 FEED 1840	FT1 #1 1898	FT1 #2 1899	FT1 #3 1900	FT1 #4 1901	FT1 #5 1902	FT1 #6 1903	FT1 #7 1904
VCR Cetane No.	87.8	48.1	52.9	53.5	82.4	86.0	89.6	87.3
CVCA Cetane No.	64.8	51.2	60.1	66.0	72.1	71.1	82.3	87.3
M1 CO	6.29	6.15	5.67	4.68	4.97	5.87	4.32	5.83
M1 HC	2.45	3.40	2.12	1.92	1.83	2.06	1.98	2.44
M1 NOx	3.54	3.34	3.37	3.59	3.43	3.30	3.58	3.20
M1 Smoke	2.00	1.83	2.05	1.80	1.85	2.00	2.10	2.60
M2 CO	5.43	6.24	5.91	4.65	4.56	6.35	4.94	5.66
M2 HC	2.03	2.94	1.91	1.36	1.06	1.41	1.78	1.24
M2 NOx	3.53	3.49	3.35	3.51	3.57	3.18	3.32	3.27
M2 Smoke	2.00	2.30	2.00	1.85	1.90	2.00	2.30	2.00
M3 CO	5.50	7.25	6.42	6.60	5.26	6.55	4.82	6.17
M3 HC	1.55	2.27	1.74	1.71	1.35	1.33	1.43	1.87
M3 NOx	3.33	2.91	3.50	3.57	3.34	3.21	3.43	3.34
M3 Smoke	1.90	1.75	1.75	2.00	4.25	1.70	2.00	2.05
M4 CO	3.95	4.44	4.04	3.94	4.08	3.93	3.48	-
M4 HC	3.71	5.49	3.63	2.79	2.06	1.55	2.07	-
M4 NOx	2.97	4.35	3.77	3.75	3.61	3.97	3.36	-
M4 Smoke	0.90	0.80	1.00	1.00	0.90	1.20	1.25	-
M5 CO	4.95	4.60	4.15	4.54	4.35	4.89	4.56	-
M5 HC	7.21	6.92	5.72	3.28	1.45	1.52	2.30	-
M5 Nox	3.62	5.00	4.25	4.30	4.20	4.48	3.64	-
M5 Smoke	0.60	0.60	0.60	J	0.70	0.95	1.00	-

TABLE A19. COMBUSTION ANALYSES FOR STRAIGHT RUN DIESEL

Properties	SRD Feed 1627	SRD #1 1793	SRD #2 1794	SRD #3 1975	SRD #4 1796	SRD #5 1797	SRD #6 1798	SRD #7 1799	SRD #8 1800
VCR Cetane No.	58.5	40.3	40.5	43.5	60.7	63.3	63.3	69.4	-
CVCA Cetane No.	56.2	33.9	41.1	40.5	42.5	45.1	64.2	-	-
M1 CO	5.21	5.39	5.59	6.65	4.70	0.93	1.00	0.87	-
M1 HC	2.42	3.41	2.99	1.72	2.38	0.37	0.43	0.38	-
M1 NOx	3.48	3.49	3.78	3.87	3.90	5.29	5.62	5.67	-
M1 Smoke	2.30	2.50	2.80	2.50	2.03	3.70	2.65	2.40	-
M2 CO	5.01	6.27	-	5.50	5.20	0.89	1.01	0.82	-
M2 HC	2.01	3.11	-	1.31	1.65	0.47	0.59	0.34	-
M2 NOx	3.64	3.63	-	3.99	3.98	6.34	6.49	6.39	-
M2 Smoke	2.40	2.60	-	2.40	2.50	3.00	2.10	2.30	-
M3 CO	6.18	6.14	4.89	5.41	5.08	0.76	0.78	0.92	-
M3 HC	1.15	2.21	1.96	1.56	1.37	0.38	0.47	0.32	-
MC NOx	3.55	3.65	3.39	3.83	4.02	6.23	6.33	6.16	-
M3 Smoke	2.60	2.40	2.50	2.15	2.75	1.60	1.05	1.25	-
M4 CO	3.78	3.57	3.96	4.06	2.18	1.68	1.95	-	-
M4 HC	6.46	2.74	2.04	3.42	0.57	0.46	0.53	-	-
M4 NOx	4.45	3.62	4.91	4.23	6.14	5.30	5.26	-	-
M4 Smoke	1.30	1.60	1.00	1.50	1.60	1.25	1.25	-	-
M5 CO	5.19	5.73	5.35	5.34	5.36	3.77	4.15	-	-
M5 HC	7.01	6.27	3.45	3.80	2.71	0.85	0.95	-	-
M5 Nox	4.95	3.94	5.76	4.62	6.98	5.27	5.36	-	-
M5 Smoke	0.90	1.20	0.80	1.40	1.70	1.15	1.35	-	-

TABLE A20. COMBUSTION ANALYSES FOR LOW AROMATICS STRAIGHT RUN DIESEL

Properties	LoA SRD Feed 1873	LoA SRD #1 1876	LoA SRD #2 1877	LoA SRD #3 1878	LoA SRD #4 1879	LoA SRD #5 1880	LoA SRD #6 1881	LoA SRD #7 1882	LoA SRD #8 1883
VCR Cetane No.	58.9	40.3	40.3	41.3	49.8	67.1	75.3	93.0	-
CVCA Cetane No.	61.3	23.1	31.7	38.6	44.3	48.8	64.2	79.1	-
M1 CO	7.37	3.18	5.69	5.26	5.57	5.43	4.70	2.17	-
M1 HC	2.14	8.75	3.45	3.39	1.08	1.99	1.03	0.80	-
M1 NOx	3.31	4.51	3.86	3.47	3.31	3.60	3.39	2.48	-
M1 Smoke	2.55	1.70	2.65	2.15	2.35	1.90	2.40	1.10	-
M2 CO	5.48	3.24	5.68	5.65	5.01	5.69	6.25	6.96	-
M2 HC	1.86	7.20	2.87	2.38	1.28	1.31	1.24	1.37	-
M2 NOx	3.50	5.40	3.38	3.76	3.55	3.49	3.26	3.39	-
M2 Smoke	2.60	1.80	2.50	2.35	2.35	1.95	2.20	2.35	-
M3 CO	5.01		4.78	4.91	5.23	5.67	4.40	5.68	-
M3 HC	1.70	-	1.95	1.96	1.33	1.02	1.36	1.27	-
MC NOx	3.57	-	3.75	3.79	3.52	3.62	3.70	3.59	-
M3 Smoke	2.30	-	2.15	2.10	2.15	2.00	1.80	2.00	-
M4 CO	-	-	4.02	3.73	3.99	3.54	3.56	-	-
M4 HC	-	-	4.52	2.44	1.15	1.78	1.66	-	-
M4 NOx	-	-	4.42	4.45	4.17	4.20	4.05	-	-
M4 Smoke	-	0.95	1.20	1.00	0.90	1.10	1.00	-	-
M5 CO	-	-	4.77	4.86	4.74	4.59	4.47	-	-
M5 HC	-	-	5.31	1.33	1.50	1.70	1.79	-	-
M5 Nox	-	-	5.14	4.74	4.48	4.64	4.40	-	-
M[illegible]moke	-	0.80	1.80	0.85	0.80	0.90	0.80	-	

TABLE A21. COMBUSTION ANALYSES FOR LIGHT COKER GAS OIL							
Properties	**LCGO Feed 1440**	**LCGO #1 1546**	**LCGO #2 1547**	**LCGO #3 1548**	**LCGO #4 1549**	**LCGO #5 1550**	**LCGO #6 1551**
VCR Cetane No.	44.3	31.8	34.8	33.1	35.5	34.2	37.6
CVCA Cetane No.	29.0	25.6	27.9	30.1	29.1	32.8	31.7
M1 CO	7.97	5.43	4.55	6.11	4.89	5.60	5.80
M1 HC	3.63	2.60	3.18	1.88	0.98	1.52	1.23
M1 NOx	3.82	3.71	3.97	4.04	3.89	3.89	4.05
M1 Smoke	2.10	2.10	2.35	2.50	2.10	2.30	1.80
M2 CO	6.41	5.17	4.26	5.84	4.38	5.98	4.94
M2 HC	2.18	3.01	2.67	2.31	0.91	1.55	1.18
M2 NOx	4.78	4.12	4.35	4.40	4.18	4.10	4.36
M2 Smoke	2.20	2.50	2.20	2.50	2.35	2.40	1.90
M3 CO	5.80	7.32	5.65	4.63	4.87	4.50	5.17
M3 HC	1.07	2.36	2.09	1.71	1.02	1.50	1.17
MC NOx	3.91	3.76	4.11	3.95	3.83	3.82	3.98
M3 Smoke	1.80	2.40	2.45	2.20	2.20	2.20	2.80
M4 CO	3.30	4.73	4.00	3.83	3.51	3.74	-
M4 HC	2.86	7.30	5.95	3.27	1.85	1.22	-
M4 NOx	4.95	4.26	5.20	4.36	4.37	4.25	-
M4 Smoke	0.50	1.10	1.15	1.10	1.45	1.35	-
M5 CO	7.59	6.15	6.73	6.62	6.04	8.96	-
M5 HC	13.73	7.22	6.31	2.58	3.55	2.10	-
M5 Nox	6.22	6.09	5.30	5.59	5.29	5.46	-
M5 Smoke	0.80	0.40	0.90	1.00	1.40	1.60	-

TABLE A22. COMBUSTION ANALYSES FOR LOW SULFUR LIGHT COKER GAS OIL							
Properties	**LoS LCGO Feed 1442**	**LoS LCGO #1 1862**	**LoS LCGO #2 1863**	**LoS LCGO #3 1864**	**LoS LCGO #4 1865**	**LoS LCGO #5 1866**	**LoS LCGO #6 1867**
VCR Cetane No.	38.1	31.9	34.6	34.8	47.0	39.5	41.1
CVCA Cetane No.	33.3	28.2	29.5	29.2	30.4	33.7	37.8
M1 CO	5.72	5.48	5.13	4.55	7.05	4.13	5.36
M1 HC	1.79	3.74	2.29	1.76	2.14	1.08	1.69
M1 NOx	3.74	3.86	3.76	3.73	3.38	4.00	3.90
M1 Smoke	2.15	2.40	2.10	2.05	2.70	2.20	2.40
M2 CO	4.95	6.28	5.12	4.47	6.70	4.60	6.02
M2 HC	1.31	4.71	2.13	1.72	1.50	0.72	1.58
M2 NOx	4.15	4.45	4.08	4.16	3.93	4.07	3.71
M2 Smoke	2.30	2.10	2.20	2.00	2.85	2.10	2.10
M3 CO	4.32	5.73	4.55	4.57	6.14	4.16	5.14
M3 HC	1.51	2.30	1.73	1.58	1.25	0.97	1.63
MC NOx	3.71	3.36	3.84	3.74	3.70	3.80	3.69
M3 Smoke	1.95	2.15	2.15	2.00	2.65	2.15	2.50
M4 CO	3.92	3.54	3.34	3.90	3.16	3.42	-
M4 HC	6.09	3.97	3.85	2.34	1.09	1.51	-
M4 NOx	3.79	4.66	4.44	4.39	4.54	3.72	-
M4 Smoke	1.40	1.20	1.25	1.30	1.10	1.60	-
M5 CO	5.66	5.47	4.95	5.27	4.68	5.68	-
M5 HC	7.37	6.94	4.98	4.73	1.18	3.07	-
M5 Nox	4.55	5.51	5.09	4.69	5.22	3.85	-
M5 Smoke	1.30	0.80	0.75	1.00			

TABLE A23. COMBUSTION ANALYSES FOR LOW AROMATICS LIGHT COKER GAS OIL

Properties	LoA LCGO Feed 1443	LoA LCGo #1 1597	LoA LCGO #2 1598	LoA LCGO #3 1599	LoA LCGO #4 1600	LoA LCGO #5 1601	LoA LCGO #6 1602	LoA LCGO #7 1603
VCR Cetane No.	46.7	34.8	37.4	39.5	42.4	47.7	53.9	65.1
CVCA Cetane No.	37.7	28.2	30.5	31.7	33.7	39.0	44.1	54.9
M1 CO	4.59	4.49	4.52	4.79	5.95	5.67	5.75	5.27
M1 HC	2.78	4.38	2.33	2.44	1.94	1.49	1.40	1.32
M1 NOx	3.77	4.00	3.48	3.89	3.39	3.66	3.47	3.68
M1 Smoke	2.30	1.90	2.40	2.10	2.25	2.30	2.70	2.50
M2 CO	4.59	5.27	5.96	4.42	5.78	5.72	6.99	5.62
M2 HC	2.78	4.51	3.81	2.27	1.17	0.95	1.47	1.51
M2 NOx	3.77	4.43	3.89	3.78	3.58	3.83	3.54	3.63
M2 Smoke	2.30	2.10	2.40	2.10	2.25	2.25	2.10	2.20
M3 CO	5.54	6.10	6.29	5.77	4.59	4.49	5.08	5.04
M3 HC	1.81	2.36	1.68	2.50	1.46	0.92	1.31	1.09
MC NOx	3.78	3.76	3.36	4.79	3.51	3.57	3.31	3.53
M3 Smoke	2.30	2.25	2.90	2.00	2.10	2.10	3.10	2.40
M4 CO	3.80	3.84	3.86	3.21	3.44	3.58	3.70	-
M4 HC	6.89	4.88	5.17	1.76	1.86	1.91	1.33	-
M4 NOx	4.73	3.77	4.43	4.38	4.06	3.28	4.26	-
M4 Smoke	1.85	1.30	0.95	1.00	1.20	1.60	1.10	-
M5 CO	4.90	4.82	4.50	4.69	4.28	5.23	4.97	-
M5 HC	7.07	6.23	6.02	2.48	1.50	3.17	1.67	-
M5 Nox	5.14	4.36	4.79	4.95	4.46	3.48	4.52	-

TABLE A24. COMBUSTION ANALYSES FOR LIGHT CYCLE OIL

Properties	LCO Feed 1538	LCO #1 1555	LCO #2 1556	LCO #3 1557	LCO #4 1558	LCO #5 1559	LCO #6 1560	LCO #7 1561
VCR Cetane No.	23.4	19.7	20.8	-	19.9	20.4	22.9	22.5
CVCA Cetane No.	15.5	15.2	17.0	-	13.9	15.6	16.3	19.1
M1 CO	-	-	-	-	-	-	6.38	9.56
M1 HC	-	-	-	-	-	-	0.87	1.92
M1 NOx	-	-	-	-	-	-	9.49	8.18
M1 Smoke	-	-	-	-	-	-	1.70	9.00
M2 CO	4.69	3.96	3.70	-	-	4.72	4.23	4.09
M2 HC	1.75	3.62	3.04	-	-	0.47	0.63	0.67
M2 NOx	13.43	13.72	14.08	-	-	14.16	11.23	11.08
M2 Smoke	2.95	1.80	2.10	-	-	1.80	1.70	4.00
M3 CO	-	-	-	-	-	-	1.89	-
M3 HC	-	-	-	-	-	-	0.55	-
MC NOx	-	-	-	-	-	-	8.89	-
M3 Smoke	-	-	-	-	-	-	0.85	-
M4 CO	-	-	-	-	-	-	-	-
M4 HC	-	-	-	-	-	-	-	-
M4 NOx	-	-	-	-	-	-	-	-
M4 Smoke	-	-	-	-	-	-	-	-
M5 CO	-	-	-	-	-	-	-	-
M5 HC	-	-	-	-	-	-	-	-
M5 Nox	-	-	-	-	-	-	-	-
M5 Smoke	-	-	-	-	-	-	-	-

TABLE A25. COMBUSTION ANALYSES LOW SULFUR LIGHT CYCLE OIL								
Properties	LoS LCO Feed 1615	LoS LCO #1 1850	LoS LCO #2 1851	LoS LCO #3 1852	LoS LCO #4 1853	LoS LCO #5 1854	LoS LCO #6 1855	LoS LCO #7 1856
VCR Cetane No.	23.4	29.8	21.6	22.5	22.7	23.9	27.4	35.0-
CVCA Cetane No.	17.9	14.0	15.4	15.7	17.3	18.6	19.9	-
M1 CO	7.73	-	-	4.47	5.74	2.84	1.81	1.79
M1 HC	2.30	-	-	1.31	1.71	0.47	0.32	0.41
M1 NOx	5.53	-	-	6.64	6.40	8.60	7.93	6.66
M1 Smoke	2.70	-	-	1.60	2.23	1.90	1.45	2.50
M2 CO	4.66	5.07	4.06	6.24	5.25	1.93	1.67	1.90
M2 HC	1.51	3.22	2.57	2.76	1.31	0.63	0.28	0.47
M2 NOx	6.83	12.52	12.60	7.90	8.05	10.83	9.62	8.15
M2 Smoke	1.85	2.20	1.70	2.20	2.20	1.80	2.00	1.90
M3 CO	5.81	-	-	4.92	4.85	1.39	1.39	1.13
M3 HC	1.57	-	-	1.12	2.13	0.29	0.29	0.33
MC NOx	4.45	-	-	4.67	4.92	7.68	7.72	7.49
M3 Smoke	2.64	-	-	2.60	2.40	1.15	1.25	0.85
M4 CO	12.29	-	-	21.47	14.00	8.78	5.09	3.82
M4 HC	5.50	-	-	6.31	4.27	1.05	0.77	0.92
M4 NOx	6.82	-	-	7.34	8.60	8.39	8.22	6.82
M4 Smoke	0.30	-	-	0.35	0.33	0.75	0.95	1.05
M5 CO	-	-	-	-	-	-	8.77	-
M5 HC	-	-	-	-	-	-	1.50	-
M5 Nox	-	-	-	-	-	-	6.91	-
M5 Smoke	-	-	-	-	-	0.95	0.85	-

TABLE A 26. COMBUSTION ANALYSIS FOR LOW AROMATICS LIGHT CYCLE OIL								
Properties	**LoA LCO Feed 1562**	**LoA LCO #1 1566**	**LoA LCO #2 1567**	**LoA LCO #3 1568**	**LoA LCO #4 1569**	**LoA LCO #5 1570**	**LoA LCO #6 1571**	**LoA LCO #7 1572**
VCR Cetane No.	41.9	30.4	34.8	35.6	39.3	42.7	49.1	75.3
CVCA Cetane No.	38.4	22.4	24.5	30.1	31.4	39.6	42.1	77.2
M1 CO	1.16	4.40	1.42	1.14	1.21	0.95	5.30	2.48
M1 HC	0.87	3.65	2.97	2.65	0.53	0.44	1.66	2.93
M1 NOx	5.54	3.62	5.83	6.05	5.94	5.79	3.66	2.01
M1 Smoke	2.10	2.20	1.90	2.10	2.50	1.70	2.40	1.20
M2 CO	1.07	4.25	1.46	1.20	1.14	0.91	5.13	5.35
M2 HC	2.17	4.47	3.23	2.99	2.58	0.53	1.45	1.48
M2 NOx	6.86	4.28	7.41	7.15	7.05	6.64	3.97	3.45
M2 Smoke	1.90	2.20	2.10	2.10	2.10	2.10	2.40	2.50
M3 CO	0.97	6.21	1.05	0.88	0.90	0.83	5.05	6.27
M3 HC	0.81	2.28	1.85	1.62	0.39	0.62	1.34	1.16
MC NOx	5.76	3.56	6.36	6.41	6.13	6.27	3.30	3.29
M3 Smoke	1.45	6.00	1.05	0.85	0.95	1.25	2.20	4.50
M4 CO	2.10	4.03	2.28	2.22	2.17	2.51	4.06	3.16
M4 HC	2.33	6.59	4.58	4.20	2.52	0.96	2.82	1.10
M4 NOx	5.57	4.08	6.00	5.56	5.70	5.50	3.79	4.03
M4 Smoke	0.85	1.60	1.05	1.05	0.85	1.45	1.25	1.60
M5 CO	5.16	7.95	5.33	4.80	5.30	4.42	4.79	-
M5 HC	6.08	9.10	6.57	3.12	0.94	3.66	1.61	-
M5 Nox	4.20	8.17	6.23	5.76	5.96	3.40	4.51	-
M5 Smoke	1.20	0.85	0.85	0.85	0.85	1.10	1.40	-