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REVIEW OF PHYSICAL AND CHEMICAL METHODS FOR CHARACTERIZATION OF FUELS

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By

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Physical Properties	Bench Tests	Alternate Fuel
Chemical Analysis	Instrumentation	Shale-derived Fuel
Burner Fuel	Coal-derived Fuel	Tar Sand-derived Fuel
		Gasoline
		Diesel
		Turbine
		Cross-reference
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)		
This report provides a tabulation of chemical compounds and physical/chemical properties with methods for their determination based on a review of physical and chemical methods for characterizing liquid mobility fuels. This tabulation is cross-referenced to a list of references organized by preselected categories. A complete bibliography is provided alphabetically by author's last name, both with and without annotations. For ease in utilization and		

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20. ABSTRACT (Cont'd)

updating, a system was developed to facilitate tabulation and recall of references from a word processor in which they are stored. While this tabulation serves as reference material to a program to develop improved analytical and correlative methodology for characterizing fuels, it may be of great utility to personnel developing and analyzing fuels. This tabulation will continue to be expanded and updated periodically.

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FOREWORD

This work was conducted at the U. S. Army Fuels and Lubricants Research Laboratory (USAFLRL) located at Southwest Research Institute, San Antonio, TX under Contracts No. DAAK70-80-C-0001 and DAAK70-82-C-0001 during the period March 1980 through August 1981. Work was funded by the U.S. Army Mobility Equipment Research and Development Command (MERADCOM), Ft. Belvoir, VA, with Mr. F.W. Schaekel (DRDME-GL) serving as contract monitor. Project technical monitor was Mr. M.E. LePera, MERADCOM-DRDME-GL.

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I. BACKGROUND AND INTRODUCTION

Fuel characterization is an important consideration for effective spark ignition, compression ignition, and turbine engine fuel utilization. Military mobility equipment depends upon fuels which provide reliable vehicle operation and performance. Military and federal specifications are designed to help control fuel quality for government use by providing the refiner with a guide which aids in producing an acceptable product. Specifications serve this purpose by listing physical and chemical fuel properties provided with maximum and/or minimum data value requirements which a fuel must meet. Physical and chemical fuel characterization is more extensive in research and development programs using conventional as well as synthetic and biomass-derived fuel forms.

A new comprehensive methodology which can fully characterize a fuel in terms of its performance under specified operational or combustion condition is being sought. In support of this effort, literature pertaining to physical and chemical methods of characterizing fuels has been reviewed. During this review, it was noted that most physical/chemical fuel properties must be determined directly. However, data for some properties could be calculated using correlative methods. A correlative method is an analytical method by which a property can be mathematically determined by using data directly obtained for another property. For example, data from ASTM D 2887 (Boiling Range Distribution of Petroleum Fractions by Gas Chromatography) and ASTM D 3710 (Boiling Range Distribution of Gasoline and Gasoline Fractions by Gas Chromatography) can be used to calculate data for Reid Vapor Pressure and ASTM D 86 (Distillation of Petroleum Products) through mathematical correlation.

This report provides a reference tabulation of over 100 physical and chemical fuel properties, chemical compounds, and compound classes identified during the literature review along with brief outlines of literature-derived methods for their determination. Methods not treated extensively in this review are developmental methods used primarily in areas of research and development such as fuel lubricity, elastomer compatibility, fuel stability, fleet test-

ing, etc. Many methods of this type are not yet standardized, and various approaches using these methods have been and are being used in fuels and fuels-related research. A great deal of literature exists which discusses these developmental procedures' applications and results in detail.(1-7)*

II. DEVELOPMENT AND APPLICATION

In order to tabulate fuel properties and analytical methods for their determination, a computer-assisted literature search for documents was undertaken. Data bases searched included National Technical Information Service, Chemical Abstracts, Society of Automotive Engineers, Engineering Index, Defense Documentation Center, and American Petroleum Institute. Papers were then reviewed, and fuel properties and analytical methods were outlined in tabular form. Papers that did not explain analytical procedures more fully described in other papers, and those that only stated the existence and possibly the value of certain methods were rejected.

A list of references to assist in the selection of analytical methods to be considered and evaluated for the development of an improved analytical methodology, and a bibliography listing alphabetically by author all references included in this study were developed. Both were assigned retrieval codes to allow any number of references to be recalled from a word processor in which they were then stored. The word processor output/printout format could be varied on the basis of selected fields.

Documents continued to be received and reviewed. However, a point was attained where enough information had been accumulated to generate an extensive compilation in the form of five appendices.

Appendix A-1 is an index for Appendix A-2. This appendix alphabetically lists fuel properties and descriptions of analytical methods as they appear in Appendix A-2.

*Underscored numbers in parentheses refer to the list of references at the end of this report.

Appendix A-2 is the outline of chemical compounds and physical/chemical properties with methods for their determination and is tabulated alphabetically by compound or property. Under each heading, method outlines are broken down into seven individual entries. These entries are:

Test:

A method number given in the literature if such exists (e.g., ASTM designation D 2274 on page A-2-75).

Reference:

A reference identifier assigned to the paper in which the method was located during the literature review (e.g., P-95 for test example above).

Description:

A brief description of the analytical method [e.g., Oxidation Stability of Distillate Fuel Oil (Accelerated Method) for test example above].

Test Method:

The method of testing or technique by which the analysis is carried out (e.g., apparatus).

Application:

The type of fuel to which the analytical method applies (e.g., burner, diesel, turbine fuels).

Scope:

The parameter(s) which the analytical method actually measures.

Limitations:

Limitations of the analytical method as stated in the literature (e.g., correlation between test and field storage may vary significantly for test example above).

Appendix B, which has been organized into five distinct categories (D, G, P, S, & T), lists those references according to retrieval codes that serve to cross-reference Appendix A-2 (e.g., using retrieval code P-95, the reference is found on page B-26 which is the document in which ASTM D 2274 was located). The first entry of each citation in Appendix B is the reference identifier. Reference identifiers appear in alphanumeric order throughout the list of references according to categories D, G, P, S, and T with the page for the

start of each category having been given in the index. Each of these categories was developed for the purpose of classifying references according to the substance to which their subject analytical methods apply. Category D includes literature pertaining to methods for analysis of petroleum diesel fuel and/or methods involving the employment of diesel engines. Category G includes literature pertaining to the analysis of petroleum motor and aviation gasolines. Category P is a general category that includes literature discussing properties of hydrocarbon mixtures, heavy distillates, and others which, because of the chemical composition of their subjects of analysis, could not be classified under a more definitive category. Category S, another general category, classifies to some extent literature pertaining to the analysis of alternate fuels such as petroleum-based stocks with extenders and straight alcohols but primarily applies to the analysis of synthetic stocks including shale oil, coal liquid, tar sand crude, and fractions thereof that correspond in boiling range to typical petroleum fractions. Category T heads references pertaining to analysis of petroleum turbine fuels.

Appendices C and D are both bibliographies which list, alphabetically by author, all references considered in this work. Each citation in Appendix C (as opposed to Appendix D) is provided with its corresponding reference identifier and an annotation or brief description of its subject matter. Annotations for references referred to in Appendix A-2 by reference identifier and in Appendix B by reference identifier can be found in Appendix C which is arranged alphabetically according to the name of the author. For example, P-95 is given as the reference identifier (for the test ASTM D 2274) on page A-2-75 in Appendix A-2 and can be found on page B-26 in Appendix B; its annotation can be found on page C-5 under "author unknown" in Appendix C by finding the correct reference identifier number next to the annotations since a number of references in this category have "author unknown." In this particular case, the author is "unknown" since it is a Book of ASTM Standard Methods.

III. UTILIZATION

Practical utilization of this report requires some knowledge of the filing and retrieval code system. All appendices are stored on a word processor; however, citations in Appendices B, C, and D are broken down into identification fields for easy filing and manipulation. Table 1 translates the code system by identifying each field according to field number, retrieval code character, and field description. Figures 1, 2, and 3 are examples of citations with fields labeled as each appears in Appendices B, C, and D, respectively.

Figures 1 through 3 contain reference examples taken from Appendices B, C, and D, respectively, which have various fields (from Table 1) labeled for the purposes of illustration. Referring to the example (taken from Appendix B) in Figure 1, if field 2 is searched by author, all references in this report authored by P.M. Mutsaars can be retrieved. Field 7 relates to analytical methods, the menu of retrieval terms for which are given in Table 1. Field 7 can be searched for "GC" if analytical methods of interest utilizing gas chromatography are sought. All references with "GC" appearing in Field 7 will appear. Any combination of fields searched from 2 through 9 will call out citations, the information for which are similar to the examples in Figures 1 and 2. The information in Fields 1 through 6 is represented by the information in Figure 3 which is an example from Appendix D. The addition of Field 9 to Fields 1 through 6 provides the information in Figure 2, which is an example of a citation from Appendix C.

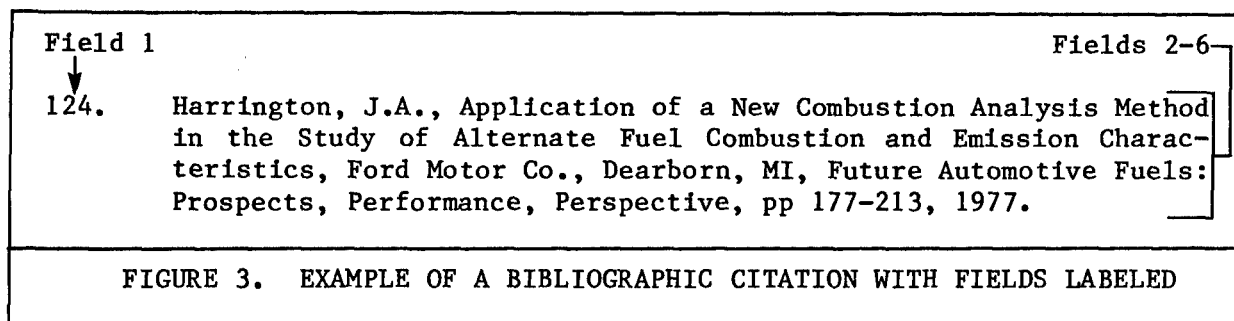
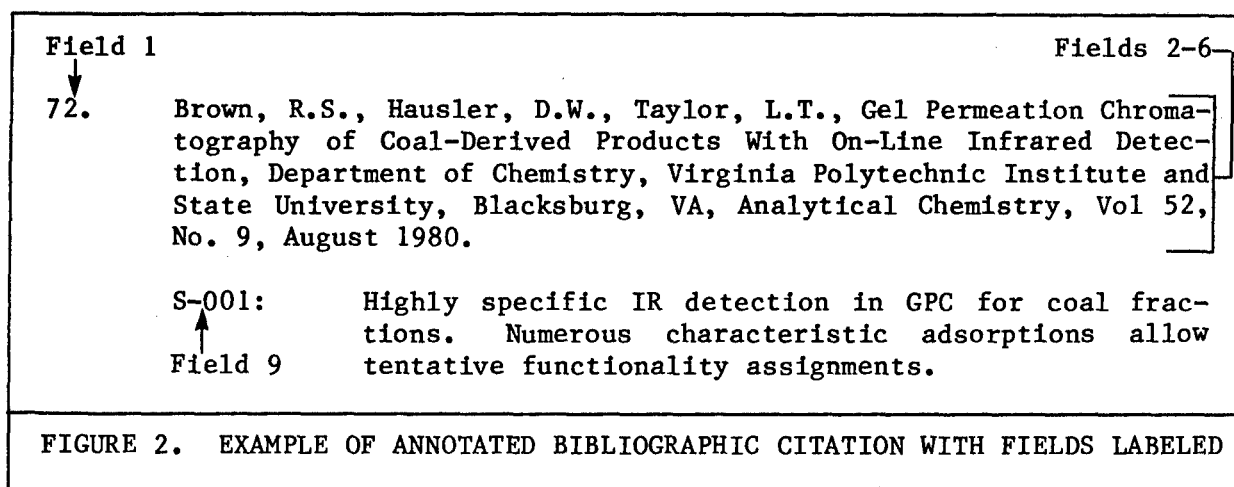
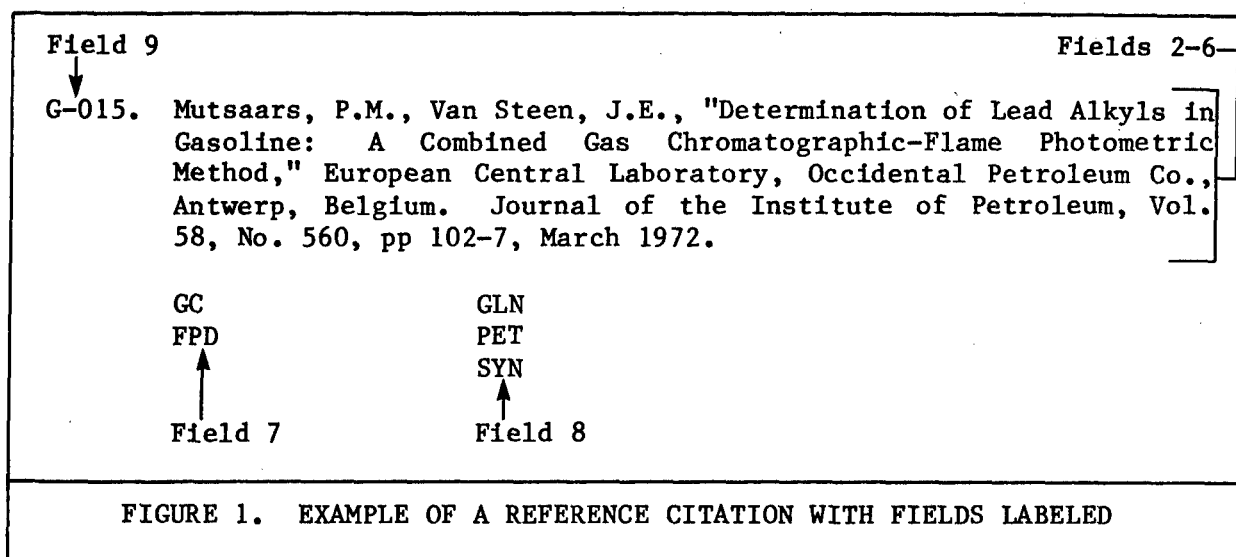
This report is also useful for locating analytical methods of interest directly through the use of the appendices. For example, if a choice of methods for the determination of flash point is desired, eight method descriptions for the property can be found in Appendix A-1 and outlines on the indicated pages (A-2-35 through A-2-37) in Appendix A-2. It is apparent that five of the methods outlined are for determining flash point directly by laboratory apparatus, and three are for its estimation by correlative methods. If a correlative approach utilizing gas chromatographic data is desired, two of the methods are applicable, for which reference identifiers

TABLE 1. WORD PROCESSOR FIELD IDENTIFICATION

<u>Field</u>	<u>Retrieval Code</u>	<u>Description</u>
1	Numeric characters	Machine Source ID Number
2	Alpha characters	Author
3	Alpha characters	Title
4	Alpha characters	Performing organization
5	Alpha characters	Literature source
6	Alphanumeric characters	Month and year
7	Alpha, Various Using the Following Menu	Various Analytical Methods
	GC	Gas chromatography
	LC	Liquid chromatography
	AA	Atomic absorption spectrometry
	XR	X-ray spectrometry
	UV	Ultraviolet spectroscopy
	EQU	Determination by correlation equation
	FIA	Fluorescent indicator adsorption
	WET	Wet chemical method (e.g., titration)
	ENG	Engine test
	ANL	Analyzer
	JFT	JFTOT
	APP	Bench or other apparatus
	NMR	Nuclear magnetic resonance spectrometry
	MS	Mass spectrometry
	COK	Fuel coker
	FPD	Flame photometric detector
	VIS	Visible spectrophotometry
	CM	Combustion microcoulometry
	IR	Infrared spectroscopy
	GPC	Gel permeation chromatography
	ES	Emission spectroscopy
	FE	Flame emission spectroscopy

TABLE 1. WORD PROCESSOR FIELD IDENTIFICATION (Cont'd)

<u>Field</u>	<u>Retrieval Code</u>	<u>Description</u>
7 (Cont'd)	AF	Atomic fluorescence spectroscopy
	BM	Bomb calorimetry
	4B	4-ball wear tester
	SLC	Solid-liquid chromatography
	RPC	Reversed-phase chromatography
	REF	Refractometry
	CAL	Calorimetry
	POT	Potentiometry
	CC	Coordination chromatography
	MSB	Mossbauer spectroscopy
	FS	Flame spectroscopy
	FLS	Fluorescence spectrometry
	IEC	Ion exchange chromatography
	000	Not applicable or unknown
8	Alpha, Various Using the Following Menu	
	DEL	Diesel
	GLN	Gasoline
	TUR	Turbine
	PET	Petroleum
	SYN	Synthetic
	ALT	Alternate
	DIS	Distillate
	COL	Coal-derived
	TAR	Tar sand-derived
	SO	Shale-oil and shale-derived
9	Alphanumeric characters	Reference identifier



P-4 and S-14 are given. Method outlines and retrieval codes evidence the fact that one method applies to petroleum gasoline (P-4), and the other to coal- and shale-derived middle distillate types (S-14). Reference identifiers (P-4 and S-14) are then easily found in Appendix B where the references are given (Pages B-11 for reference P-004 and Page B-35 for reference S-014). Annotations can then be found in Appendix C according to the authors' names (Page C-44 for Walsh, R.P., reference P-004 and Page C-3 for Antoine, A.C., reference S-014).

IV. CONCLUSIONS AND RECOMMENDATIONS

Based on a review of physical and chemical methods for characterizing liquid mobility fuels, a tabulation of chemical compounds and physical/chemical properties with methods for their determination was prepared. This tabulation was cross-referenced using retrieval codes to a list of references which were organized by category (D, G, P, S, and T standing for petroleum diesel fuel, petroleum motor and aviation gasoline, various hydrocarbons, alternate/synthetic fuels, and petroleum turbine fuels, respectively). A complete bibliography (containing 263 citations) was provided in two formats (one containing retrieval codes and annotations while the other was the usual standard form), both of which were organized alphabetically by author's last name. This tabulation serves as reference material to a program designed to develop improved (analytical and correlative) methodology for its characterization of fuels. While this tabulation is not exhaustive nor complete, it is sufficiently extensive that it should be useful to personnel involved both in the development and in the analysis/characterization of liquid mobility fuels. It is recommended that this tabulation should continue to be expanded and updated periodically through continued review of published literature. Readers of this report wishing to call published material (past or very recent) directly to the attention of the authors of this review are encouraged to do so, as this will surely enhance the thoroughness of future updates and utility of this document for its stated purpose.

V. LIST OF REFERENCES

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7. Taylor, W.T. (Editor-Exxon Research and Engineering Company), "Jet Fuel Thermal Stability," NASA Technical Memorandum 79321, Lewis Research Center, Cleveland, OH, November 1978.

APPENDIX A-1

INDEX TO APPENDIX A-2: "CHEMICAL
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WATER OF COMBUSTION

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APPENDIX A-2

PHYSICAL AND CHEMICAL PROPERTIES
OF FUELS WITH METHODS OF THEIR DETERMINATION

ACIDITY

TEST: D 3242
REFERENCE: P-96
DESCRIPTION: Total acidity in aviation turbine fuel
TEST METHOD: Wet
APPLICATION: Aviation turbine fuel
SCOPE: Determination of total acidity 0.000-0.001 mg KOH/g.
LIMITATIONS: None given.

TEST: D 1093
REFERENCE: P-94
DESCRIPTION: Acidity of distillation residues or hydrocarbon liquids (methyl orange ind.)
TEST METHOD: Wet
APPLICATION: Residue from gasoline petroleum solvent or hydrocarbon liquid
SCOPE: Qualitative determination of acidity of distillation residue from gasoline, petroleum solvent, or hydrocarbon liquid.
LIMITATIONS: Phenolphthalein is used in place of orange for basicity test. Qualitative only.

TEST:
REFERENCE: S-6
DESCRIPTION: Qualitative analysis of shale oil acids and bases by porous-layer open tubular gas chromatography and interfaced vapor phase infrared spectrophotometry
TEST METHOD: GC/IR, MS
APPLICATION: Shale oil, shale oil products
SCOPE: Determination of types of shale oil acids and bases. Computerized mass spec for identification of substituted phenolics and pyridine bases, quinolines, and anilines.
LIMITATIONS: GC/IR advantageous over GC/MS with which some ions are difficult to distinguish due to close similarity.

TEST:
REFERENCE: S-22
DESCRIPTION: Analysis of shale oil
TEST METHOD: GC/IR, MS
APPLICATION: Shale oil, shale oil products
SCOPE: Determination of shale oil acids and bases more by presence of acidity or basicity.
LIMITATIONS: Component found by GC, checked for character by IR

TEST: 5101.6
REFERENCE: P-93
DESCRIPTION: Neutrality (Qualitative)
TEST METHOD: Wet
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of hydrocarbon liquid acidity.
LIMITATIONS: Qualitative only.

ACIDITY (Cont'd)

TEST: D 1613
REFERENCE: P-97
DESCRIPTION: Acidity in volatile solvents and chemical intermediates used in paint, varnish, lacquer, and related products
TEST METHOD: Wet
APPLICATION: Methyl fuel
SCOPE: Determination of total acidity.
LIMITATIONS: None given.

ACID NUMBER (NEUTRALIZATION NUMBER)

TEST: D 974
REFERENCE: P-94
DESCRIPTION: Neutralization number by color-indicator titration
TEST METHOD: Wet
APPLICATION: Liquid hydrocarbon fuels soluble in toluene and iso-propanol
SCOPE: Determines acids and bases whose dissociation constants in water are larger than 10^{-9} .
LIMITATIONS: Salts with Ksp greater than 10^{-9} may interfere.

TEST: D 664
REFERENCE: P-94
DESCRIPTION: Neutralization number by potentiometric titration
TEST METHOD: Wet
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Resolves constituents into groups having weak acid, strong acid, or strong base ionization properties provided the dissociation constants of the more strongly acidic or basic compounds are greater than or equal to 1000 times that of the next weaker group.
LIMITATIONS: None given.

TEST: D 3339
REFERENCE: P-96
DESCRIPTION: Total acid number of petroleum products by semi-micro color-indicator titration
TEST METHOD: Wet
APPLICATION: New and used liquid hydrocarbon fuels soluble in toluene and iso-propanol
SCOPE: Determines acids whose dissociation constants are less than or equal to 10^{-9} .
LIMITATIONS: Salts with Ksp greater than 10^{-9} may interfere.

ADDITIVE CONTENT

TEST: D 374
REFERENCE: P-112
DESCRIPTION: P-phenylenediamine type inhibitors in gasoline
TEST METHOD: VIS
APPLICATION: Gasoline
SCOPE: Determination of the alkylated p-phenylenediamines present in the amine form.
LIMITATIONS: Not to be used for determination of phenolic or aminophenolic inhibitors.

AIR CONTENT (ENTRAINED AIR)

TEST:
REFERENCE: S-37
DESCRIPTION: Entrained air in emulsified fuel
TEST METHOD: Wet
APPLICATION: Fuel emulsions
SCOPE: Determination of entrained air.
LIMITATIONS: Volumetric measurement only.

AIR/FUEL RATIO

TEST:
REFERENCE: G-19
DESCRIPTION: Determination of air/fuel ratio by Gerrish and Meem method
TEST METHOD: Engine
APPLICATION: Gasoline
SCOPE: Determination of air/fuel ratio by analysis of CO₂ in exhaust gas, and H/C ratio of fuel.
LIMITATIONS: Since the H/C ratio varies considerably throughout distillation range, it is difficult to estimate its value entering all cylinders.

TEST:
REFERENCE: G-10
DESCRIPTION: Prediction of air/fuel ratio of gasoline from compositional analysis
TEST METHOD: Equations
APPLICATION: Gasoline
SCOPE: Determination of stoichiometric air/fuel ratio using FIA and PONA data.
LIMITATIONS: Statistical correlation, standard errors must be considered.

AIR/FUEL RATIO (Cont'd)

TEST:
REFERENCE: G-19
DESCRIPTION: Determination of air/fuel-vapor ratio
TEST METHOD: GC-FID, Probe, engine
APPLICATION: Distillate fuels, gasoline
SCOPE: Measurement of air/fuel vapor mixture by means of probe-in-cylinder sampling and FID analysis.
LIMITATIONS: Technique not valid for transient engine conditions such as starting, warmup, etc.

ALCOHOL CONTENT

TEST:
REFERENCE: P-30
DESCRIPTION: Alcohols in hydrocarbon liquids
TEST METHOD: GC/FID
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of alcohols content.
LIMITATIONS: Detection limit of 50 ng injected.

TEST:
REFERENCE: P-123
DESCRIPTION: Alcohol content of gasohol by gas-liquid chromatography (direct injection method).
TEST METHOD: GC
APPLICATION: Gasoline/oxygenate blends
SCOPE: Determination of ethanol content by direct injection of sample.
LIMITATIONS: None given.

TEST:
REFERENCE: P-123
DESCRIPTION: Alcohol content of gasohol by gas-liquid chromatography (water extraction method)
TEST METHOD: GC
APPLICATION: Gasoline/oxygenate blends
SCOPE: Determination of ethanol content by aqueous extraction from gasohol followed by injection of extract.
LIMITATIONS: None given.

TEST:
REFERENCE: P-123
DESCRIPTION: Field test for the determination of denatured ethanol in gasohol
TEST METHOD: Wet
APPLICATION: Gasoline/oxygenate blends
SCOPE: Determination of denatured ethanol content.
LIMITATIONS: Ethylene glycol is just as responsive to methanol and water as it is to ethanol, thus these will interfere greatly if present.

ALCOHOL CONTENT (Cont'd)

TEST:
REFERENCE: P-101
DESCRIPTION: Test method for determining the amount of denatured ethanol in gasohol
TEST METHOD: Wet
APPLICATION: Gasoline/oxygenate blends
SCOPE: Determination of denatured ethanol content.
LIMITATIONS: Denaturant must be soluble in ethylene glycol.

TEST:
REFERENCE: P-101
DESCRIPTION: Field test for the detection of methyl alcohol as an adulterant in gasohol
TEST METHOD: Wet
APPLICATION: Gasoline/oxygenate blends
SCOPE: Qualitative detection of methanol in gasohol.
LIMITATIONS: Qualitative field test only, methanol must be present in at least 1% by volume.

ALKYL HALIDE CONTENT

TEST:
REFERENCE: P-30
DESCRIPTION: Alkyl halides in hydrocarbon liquids
TEST METHOD: GC/MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of alkyl halides.
LIMITATIONS: Detection limit of 50 ng injected.

AMIDES CONTENT

TEST:
REFERENCE: P-30
DESCRIPTION: Amides in hydrocarbon liquids
TEST METHOD: GC/MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of amides content.
LIMITATIONS: Detection limit of 50 ng injected.

AMINES CONTENT

TEST:
REFERENCE: P-30
DESCRIPTION: Amines in hydrocarbon liquids
TEST METHOD: GC/MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of amines content.
LIMITATIONS: Detection limit of 50 ng injected.

AMYL NITRATE CONTENT

TEST: D 1839
REFERENCE: P-95
DESCRIPTION: Amyl nitrate in diesel fuels
TEST METHOD: VIS
APPLICATION: Diesel fuels
SCOPE: Determination of weight percent amyl nitrate in diesel.
LIMITATIONS: Applicable to concentration range of 0.1-0.5 wt%. Method may be used to determine amyl nitrate as a cetane improver.

ANILINE POINT

TEST: D 611
REFERENCE: P-94
DESCRIPTION: Aniline point and mixed aniline point of petroleum products and hydrocarbon solvents
TEST METHOD: Wet
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of aniline point and mixed aniline point of a fuel which gives an indication of the aromatic content hence the ignition quality of the fuel. Product of aniline point and API gravity gives an indication of fuel calorific value.
LIMITATIONS: Aniline point must be below the bubble point of the aniline-sample mixture. Test for mixed aniline point of sample not applicable to samples having aniline points below temperatures at which aniline will crystallize from the aniline-sample mixture.

TEST:
REFERENCE: P-29
DESCRIPTION: Equation relating aniline point to total naphthene and total aromatic content by vol%
TEST METHOD: Mathematical estimation, displacement chromatograph, MS
APPLICATION: Petroleum kerosene distillates
SCOPE: Equation only.
LIMITATIONS: Statistical correlation.

TEST:
REFERENCE: P-4
DESCRIPTION: Equation relating paraffin carbon number to relative density and aniline point.
TEST METHOD: Mathematical estimation, GLC
APPLICATION: Petroleum middle distillates
SCOPE: Linear equation
LIMITATIONS: Statistical correlations, unreliable when extrapolated, less reliable than theoretically derived models. Merit of this application depends to some extent on the material. Best for gasoline.

ANILINE POINT (Cont'd)

TEST:
REFERENCE: D-4
DESCRIPTION: Equations relating aniline point to blending cetane number.
TEST METHOD: Estimation
APPLICATION: Middle distillate
SCOPE: Linear equation
LIMITATIONS: Equation is constructed for cetane number, not convenient for hand calculation nor linear programming. Mainly for refining application.

API GRAVITY

TEST: D 1298
REFERENCE: P-94
DESCRIPTION: Density, specific gravity, or API gravity of crude petroleum and liquid petroleum product by hydrometer method
TEST METHOD: Hydrometer, equation
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of density, specific gravity, or API gravity of crude and liquid petroleum products and nonpetroleum products normally handled as liquids.
LIMITATIONS: Non-petroleum products must have RVP of 26 lbs or less. Hydrometers graduated in density, specific gravity, or API gravity to be used. Equation relates specific gravity to API gravity and to cetane index (D 976), with aniline point gives calorific value (D 1405).

TEST: D 287
REFERENCE: P-94
DESCRIPTION: Density, specific gravity, or API gravity of crude petroleum and liquid petroleum products by hydrometer method
TEST METHOD: Hydrometer, equation
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of density, specific gravity, or API gravity of crude and liquid petroleum products and nonpetroleum products normally handled as liquids.
LIMITATIONS: Non-petroleum products must have RVP of 26 lbs or less. Hydrometers graduated in API gravity. Equation relates specific gravity to API gravity, and to cetane index (D 976), with aniline point gives calorific value (D 1405).

TEST:
REFERENCE: S-14
DESCRIPTION: Equations for estimating bulk properties of kerosene fuels
TEST METHOD: Equation
APPLICATION: Kerosene fuels
SCOPE: Determination of API gravity from D 2887 data.
LIMITATIONS: Long equation to which data must be fitted.

APPEARANCE, VISUAL

TEST:
REFERENCE: P-8
DESCRIPTION: Visual quality surveillance test
TEST METHOD: Wet
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Visual inspection of purity and cleanliness.
LIMITATIONS: Qualitative only.

AROMATIC CONTENT

TEST: D 936
REFERENCE: P-94
DESCRIPTION: Aromatic hydrocarbons in olefin-free gasolines by silica gel adsorption
TEST METHOD: Adsorption column
APPLICATION: Petroleum based gasoline and other debutanized hydrocarbon mixtures
SCOPE: Total aromatic content of gasolines and debutanized hydrocarbon mixtures.
LIMITATIONS: Samples must distill below 204°C (400°F) and must contain less than 1% olefinic hydrocarbons. Nonaromatic nitrogen and sulfur containing compounds interfere.

TEST: D 2267
REFERENCE: P-95
DESCRIPTION: Aromatics in light naphthas and aviation gasoline by gas chromatography
TEST METHOD: GC
APPLICATION: Light naphthas, avgas
SCOPE: Determination of C_6H_6 , $CH_3-C_8H_6$, C_8 , and heavier aromatics and total aromatics.
LIMITATIONS: Applicable to concentration range from 1.0-30 of individual aromatics of total aromatics.

TEST: D 875
REFERENCE: P-94
DESCRIPTION: Calculation of olefins and aromatics in petroleum distillates from bromine number and acid absorption
TEST METHOD: Calculation
APPLICATION: Petroleum-based straight-run, reformed, cracked, and commercial gasolines, turbine fuel, kerosene
SCOPE: Vol% olefins and aromatics.
LIMITATIONS: Gasolines must have a 90% BP below 200°C (392°F). Turbine fuel and kerosene must boil below 316°C (600°F) and have a bromine number less than 20.

AROMATIC CONTENT (Cont'd)

TEST: D 1319
REFERENCE: P-94
DESCRIPTION: Hydrocarbon types in liquid petroleum products by fluorescent indicator adsorption
TEST METHOD: FIA
APPLICATION: Liquid petroleum fuels
SCOPE: Determines saturates, nonaromatic olefins, and aromatics.
LIMITATIONS: Petroleum fractions must distill below 315°C (600°F). Aromatic olefins some diolefins, and sulfur, nitrogen, or oxygen containing compounds will interfere.

TEST:
REFERENCE: P-29
DESCRIPTION: Equation relating total aromatic content to specific gravity, aniline point, smoke point, and total naphthalene content.
TEST METHOD: Mathematical estimation, displacement chromatography, MS
APPLICATION: Petroleum kerosene distillates
SCOPE: Equation relates total aromatic content to specific gravity, aniline point, smoke point, total naphthenes.
LIMITATIONS: Statistical correlation.

TEST: 394
REFERENCE: P-112
DESCRIPTION: Aromatics in hydrocarbons by gas chromatography
TEST METHOD: GC
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of C_6H_8 , C_7H_8 , and total C_8 aromatics.
LIMITATIONS: None given.

TEST:
REFERENCE: S-2
DESCRIPTION: Aromaticity of coal extract by ^1H and ^{13}C pulsed NMR methods
TEST METHOD: NMR
APPLICATION: Coal extract
SCOPE: Coupling methods and relaxation times for aromatic components.
LIMITATIONS: "Second Moment" analysis fails to account for different relaxation times.

TEST:
REFERENCE: S-44
DESCRIPTION: Shale oil hydrocarbon separation by preparative liquid chromatography and glass capillary gas chromatography.
TEST METHOD: HPLC, GC, MS
APPLICATION: Shale oil
SCOPE: Separation and determination of hydrocarbons.
LIMITATIONS: Some alkenes must be isolated and chromatographed by seive subtraction, others require extensive manipulation.

AROMATIC CONTENT (Cont'd)

TEST:
REFERENCE: S-51
DESCRIPTION: Composition of synthetic fuels
TEST METHOD: GC, SLC
APPLICATION: Synthetic fuels
SCOPE: Discussion of separation techniques.
LIMITATIONS: Study of method and application only.

TEST:
REFERENCE: S-17
DESCRIPTION: Characterization of synthetic liquid fuels
TEST METHOD: GLC, MS, NMR
APPLICATION: Synthetic fuels
SCOPE: Hydrocarbon content determination.
LIMITATIONS: Instruments must be used in combination for complementary analyses.

TEST:
REFERENCE: P-64
DESCRIPTION: Aromatic nitrogen compounds in fossil fuels
TEST METHOD: GC/MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of aromatic nitrogen compounds content.
LIMITATIONS: May need other instrument to confirm composition as to specific compounds.

TEST:
REFERENCE: P-53
DESCRIPTION: Determination of C₈ and heavier molecular weight alkylbenzenes in petroleum naphthas by gas chromatography
TEST METHOD: GC
APPLICATION: Petroleum naphtha
SCOPE: Determination of alkylbenzene content.
LIMITATIONS: Samples in this study contained alkylbenzenes of C₇ and larger but no hydrocarbons larger than n-C₁₅.

TEST:
REFERENCE: G-11
DESCRIPTION: The isolation and determination of aromatics in gasoline by gas chromatography
TEST METHOD: GC
APPLICATION: Gasoline
SCOPE: Determination of aromatics from benzene-C₉+.
LIMITATIONS: CEF column temperature must be held constant during separation. Response factors for most heavier aromatics vary ±3% from unity. No provision for specific determination of aromatics above C₉.

AROMATIC CONTENT (Cont'd)

TEST:
REFERENCE: P-61
DESCRIPTION: Separation of hydroaromatics and polycyclic aromatic hydrocarbons and determination of tetralin and naphthalene in coal-derived solvents
TEST METHOD: HPLC
APPLICATION: Coal derived solvents
SCOPE: Determination of aromatics, indan, naphthalenes, and tetralin.
LIMITATIONS: CEF column temperature must be held constant during separation. Response factors for most heavier aromatics vary $\pm 3\%$ from unity. No provision for specific determination of aromatics above C₉.

TEST: D 1017
REFERENCE: P-94
DESCRIPTION: Benzene and toluene in 250°F and lighter petroleum products by ultraviolet spectrophotometry
TEST METHOD: UV
APPLICATION: Petroleum fuels
SCOPE: Determination of benzene and toluene.
LIMITATIONS: Sample must have boiling range from 38°C-721°C (100°F-250°F). Benzene and toluene specific.

TEST:
REFERENCE: G-4
DESCRIPTION: Internal standards for isolation and determination of aromatics in motor gasoline
TEST METHOD: GC
APPLICATION: Gasoline, motor fuels, non-turbine aviation fuels
SCOPE: Internal standards for quantitative determination of aromatics.
LIMITATIONS: Precise sample volume introduction is not critical. Calibration is not critical. Accuracy is improved.

TEST:
REFERENCE: S-52 (See HYDROCARBON CONTENT Reference S-52)

AROMATIC CONTENT (Cont'd)

TEST:
REFERENCE: P-62
DESCRIPTION: Chemically-bonded aminosilane stationary phase for the high-performance liquid chromatographic separation of polynuclear aromatic hydrocarbons
TEST METHOD: HPLC
APPLICATION: Liquid petroleum fuels
SCOPE: Determination of PAHs on micron bondapak NH₂ column. PAH fractionation first, then reversed-phase HPLC to obtain separation of alkyl homologues.
LIMITATIONS: Good for isolation of compounds prior to analysis of other techniques. Reproducible HPLC fractionation of PAH according to number of condensed aromatic rings.

TEST:
REFERENCE: P-12
DESCRIPTION: Fluorescence detector for analysis of polynuclear arenes by gas chromatography
TEST METHOD: GC/spectrofluorometer
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of polynuclear arenes using GC with a spectrofluorometer as a detector. Measurements are made in the gas phase. Quantum efficiency equation.
LIMITATIONS: Gas phase measurements are more convenient but fluorescence intensity is lower. Stationary phases must neither be fluorescent nor yield fluorescent decomposition products.

TEST: D 3239
REFERENCE: P-96
DESCRIPTION: Aromatic types analysis of gas-oil aromatic fractions by high-ionizing voltage mass spectrometry
TEST METHOD: MS
APPLICATION: Straight-run liquid fuels
SCOPE: Determination of 18 aromatic hydrocarbon types and 3 aromatic tihophenotypes.
LIMITATIONS: Samples must not contain more than 1 wt% sulfur, or more than 5% nonaromatic hydrocarbons.

TEST:
REFERENCE: S-41
DESCRIPTION: Chromatographic and spectrometric methods for the separation, characterization, and identification of alkylphenols in coal-derived solvents
TEST METHOD: GPC, HPLC, UV
APPLICATION: Coal-derived solvents
SCOPE: Separation of alkylphenols by GPC and HPLC. Characterization by ultraviolet spectroscopy.
LIMITATIONS: Additional measure to keep nitrogen bases from eluting with some phenols on GPC must be taken.

AROMATIC CONTENT (Cont'd)

TEST:
REFERENCE: S-16
DESCRIPTION: Monocyclic, dicyclic, and tricyclic aromatics in synthetic jet fuel
TEST METHOD: Column chromatography, ¹H NMR, rotary evaporator
APPLICATION: Jet fuel from coal, shale, tar sands
SCOPE: Aromatic fraction is isolated and concentrated, then divided with CCl₄ and analyzed at 60 MH on ¹H NMR. A first approximation calculated method for % dicyclics is presented.
LIMITATIONS: Naphthalene in aromatic fractions yields wide variations.

TEST: D 3606
REFERENCE: P-96
DESCRIPTION: Benzene and toluene in finished motor and aviation gasoline by gas chromatography
TEST METHOD: GC
APPLICATION: Finished gasolines
SCOPE: Determination of benzene and toluene.
LIMITATIONS: Benzene can be determined up to 5 vol%, toluene up to 20 vol%.

TEST: 394
REFERENCE: P-112
DESCRIPTION: Aromatics in hydrocarbons by gas chromatography
TEST METHOD: GC
APPLICATION: Stabilized liquid hydrocarbon fuels
SCOPE: Total C₈, C₉ and heavier aromatic hydrocarbons content determination.
LIMITATIONS: C₈ aromatics are determined in stabilized liquid hydrocarbons. C₉ and heavier are determined as composite in samples containing hydrocarbons with 11 or fewer carbon atoms/molecule. Lower detection limit for single component is 0.1 vol%.

TEST:
REFERENCE: S-43
DESCRIPTION: High performance liquid chromatographic separation of polycyclic aromatic hydrocarbons on microparticulate pyrrolidone and application to the analysis of shale oil
TEST METHOD: HPLC
APPLICATION: Shale oil
SCOPE: Separation of PAH's in normal and reversed-phase modes.
LIMITATIONS: The pyrrolidone used in the column must be synthesized if not available. Recommended synthesis is presented.

AROMATIC CONTENT (Cont'd)

TEST:
REFERENCE: P-81
DESCRIPTION: Analysis of organic mixtures using the combination of a thermogravimetric analyzer, a gas chromatograph, and infrared spectrophotometer
TEST METHOD: Analyzer, GC/IR
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Analysis of organic mixtures.
LIMITATIONS: Not good for trace analysis.

TEST:
REFERENCE: P-90
DESCRIPTION: Analysis of chlorinated benzene compounds by gas chromatography
TEST METHOD: GC
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Chlorinated benzene determination.
LIMITATIONS: None given.

TEST:
REFERENCE: P-74
DESCRIPTION: High-pressure liquid chromatography fingerprinting of petroleum and petroleum products
TEST METHOD: GC/LC
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Compositional analysis.
LIMITATIONS: Chrysene, benzofluorenes, and benzpyrene not resolved well. Emphasis is more on qualitative determinations.

TEST:
REFERENCE: P-107
DESCRIPTION: Coulometric determination of aromatic nitrogen compounds with electrogenerated chromium (II).
TEST METHOD: Coulometry
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of aromatic nitro compounds by reduction.
LIMITATIONS: Partial reoxidation of reduced species could be responsible for some positive errors. $\pm 1\%$ precision and accuracy established.

TEST:
REFERENCE: S-62
DESCRIPTION: Direct determination of polynuclear aromatic hydrocarbons in coal liquid and shale oil by laser excited Shpol'skii spectrometry
TEST METHOD: Shpol'skii spectrometry
APPLICATION: Coal liquid, shale oil
SCOPE: Determination of polynuclear aromatic hydrocarbons.
LIMITATIONS: "Inner filter effect" may result in quenching of luminescence with syncrudes but the effect is so far unknown concerning refined synthetic fuels.

AROMATIC CONTENT (Cont'd)

TEST:
REFERENCE: P-30
DESCRIPTION: Benzene and substituted benzene in hydrocarbon liquids
TEST METHOD: GC/MS
APPLICATION: Liquid fuels
SCOPE: Determination of aromatic hydrocarbon containing one benzene ring.
LIMITATIONS: One ring compounds only.

TEST:
REFERENCE: P-30
DESCRIPTION: Polynuclear aromatics in hydrocarbon liquids
TEST METHOD: GC/MS
APPLICATION: Liquid fuels
SCOPE: Determination of polynuclear aromatic hydrocarbons.
LIMITATIONS: Detection limit of 10 ng injected.

TEST:
REFERENCE: P-30
DESCRIPTION: Aromatic nitro compounds in hydrocarbon liquids
TEST METHOD: GC/MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of aromatic nitrogen-containing compounds.
LIMITATIONS: Detection limit of 10 ng injected.

TEST:
REFERENCE: P-30
DESCRIPTION: Halogenated aromatic compounds in hydrocarbon liquids
TEST METHOD: GC/MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of aromatic halogen-containing compounds.
LIMITATIONS: Detection limit of 10 ng injected.

TEST:
REFERENCE: P-3
DESCRIPTION: Determination of aromatics in fuels and products of combustion using capillary GC and UV detection.
TEST METHOD: GC/UV
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Detection of PAH's and other aromatics.
LIMITATIONS: None given.

AROMATIC CONTENT (Cont'd)

TEST:
REFERENCE: P-33
DESCRIPTION: Mass spectrographic analysis of N and O compounds in petroleum
TEST METHOD: MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: MS analysis of N, O, S compounds and aromatics
LIMITATIONS: Impossible to indicate magnitude of errors as reliable independent methods are not available. Due to complexity of most samples, corrections for hydrocarbon fractionation have not been incorporated into a general program thus estimated oxygen content tends to be low and hydrocarbon content high.

TEST:
REFERENCE: T-3
DESCRIPTION: Analysis of aromatic types by ultraviolet spectroscopy
TEST METHOD: UV
APPLICATION: Petroleum turbine fuels
SCOPE: Determination of benzenes and naphthalenes by use of equations incorporating two molar extinction coefficients at two different wavelengths.
LIMITATIONS: Total aromatic content in some disagreement with that obtained by FIA and a sulfonation method. Method was originally designed for gasoil and lube oil cuts and there may lie the source of the discrepancy.

ASH CONTENT

TEST: D 482
REFERENCE: P-94
DESCRIPTION: Ash from petroleum products
TEST METHOD: Wet, furnace
APPLICATION: Distillate fuels, residual gas turbine fuels
SCOPE: Determination of ash in fuels.
LIMITATIONS: Method is limited to products which do not contain ash-forming additives such as phosphorous compounds.

AUTOIGNITION TEMPERATURE

TEST: D 2155
REFERENCE: P-95
DESCRIPTION: Autoignition temperature of liquid petroleum products
TEST METHOD: Wet, furnace
APPLICATION: Liquid or semi-liquid fuel
SCOPE: Autoignition temperature at 1 atm pressure using hypodermic syringe injection.
LIMITATIONS: Laboratory method only not for appraisal of fire hazard under actual fire conditions.

AUTOIGNITION TEMPERATURE (Cont'd)

TEST:
REFERENCE: T-13
DESCRIPTION: Development of an experiment for determining the auto-ignition characteristics of aircraft type fuels
TEST METHOD: Apparatus
APPLICATION: Turbine, jet, diesel
SCOPE: Autoignition temperatures with pressure and air flow rate variable.
LIMITATIONS: Scope expansion needed.

BASE NUMBER

TEST: D 2896
REFERENCE: P-95
DESCRIPTION: Total base number of petroleum products by potentiometric perchloric acid titration
TEST METHOD: Potentiometry
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of basic constituents by titration with acid.
LIMITATIONS: Strongly overbased oil additives and nitrogenous polymeric compounds will yield high readings. Soaps, basic salts of polyacidic basis, and salts of heavy metals all have basic characteristics.

TEST: D 974
REFERENCE: P-94
DESCRIPTION: Neutralization number by color-indicator titration
TEST METHOD: Wet
APPLICATION: Liquid hydrocarbon fuels soluble in toluene and iso-propanol
SCOPE: Determines acids and bases whose dissociation constants in water are larger than 10^{-9} .
LIMITATIONS: Salts with Ksp greater than 10^{-9} may interfere.

TEST: D 664
REFERENCE: P-94
DESCRIPTION: Neutralization number by potentiometric titration
TEST METHOD: Wet
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Resolves constituents into groups having weak acid, strong acid, or strong base ionization properties provided the dissociation constants of the more strongly acidic or basic compounds are greater than or equal to 1000 times that of the next weaker group.
LIMITATIONS: None given.

BOILING RANGE

TEST: D 3710
REFERENCE: P-96
DESCRIPTION: Boiling range distribution of gasoline and gasoline fractions by gas chromatography
TEST METHOD: GC
APPLICATION: Gasoline
SCOPE: Boiling range distribution of gasoline components.
LIMITATIONS: Final boiling point must be 260°F(500°F). Response factors must be calculated, drift correction must be considered. Precision depends on shape of curve. Repeatability and reproducibility vary with slope of curve. Correlation equations are provided for RVP and distillate (D 86) predictions.

TEST: D 2887
REFERENCE: P-95
DESCRIPTION: Boiling range distribution of petroleum fractions by gas chromatography
TEST METHOD: GC
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Boiling range distribution of liquid hydrocarbon mixtures.
LIMITATIONS: Applicable to samples with final boiling point 538°C(1000°F). Samples must have boiling range greater than 55°C(100°F) and have sufficiently low vapor pressure to permit sampling at room temperature. Sample may be cooled far below room temperature prior to sampling.

TEST:
REFERENCE: P-23
DESCRIPTION: Correlation of ASTM Method D 2887 boiling range distribution data with ASTM Method D 86 and D 1160 distillation data
TEST METHOD: Equations, calculations
APPLICATION: Petroleum gasoline
SCOPE: Prediction of correlation equations using computerized multiple linear regression analysis, and a slope approach to correlation.
LIMITATIONS: No clear advantage to either method. Computer procedure more successful at upper portion of data, slope procedure at lower. No significant difference in overall ability of either.

TEST:
REFERENCE: S-29
DESCRIPTION: Boiling range of coal liquid by gas chromatography
TEST METHOD: GC
APPLICATION: Coal liquid
SCOPE: Comparable to ASTM D 2887 only with slight GC modifications.
LIMITATIONS: Research still in infancy, viability is being studied.

BOILING RANGE (Cont'd)

TEST:
REFERENCE: G-21
DESCRIPTION: An apparatus for the characterization of gasoline volatility by gas-liquid chromatography
TEST METHOD: GLC/Data processor
APPLICATION: Gasoline
SCOPE: Boiling range of gasoline.
LIMITATIONS: None given.

TEST:
REFERENCE: P-130
DESCRIPTION: Continuous on-stream analysis of boiling characteristics of petroleum fractions
TEST METHOD: Monitor
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Boiling point monitor for continuous analysis from which calibration curves for prediction of RVP, V/L, etc. may be constructed.
LIMITATIONS: Calibration curves are not given, the equations must be developed.

TEST: D 86
REFERENCE: P-94
DESCRIPTION: Distillation of petroleum products
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Distillation-boiling point range.
LIMITATIONS: Higher reading thermometer must be used for turbine fuels with wide boiling ranges. Difficult for products with very high end points (see ASTM D 1160).

TEST: D 1160
REFERENCE: P-94
DESCRIPTION: Distillation of petroleum products at reduced pressures
TEST METHOD: Apparatus, pressure-regulating system
APPLICATION: Petroleum products
SCOPE: Distillation-boiling point range.
LIMITATIONS: Not applicable to products which are totally vaporized at a temperature greater than 400°C(750°F) at pressures down to 1.0 torr.

TEST: D 216
REFERENCE: P-94
DESCRIPTION: Distillation of natural gasoline
TEST METHOD: Apparatus
APPLICATION: Natural gasoline
SCOPE: Distillation-boiling point range.
LIMITATIONS: Natural gasoline only.

BOILING RANGE (Cont'd)

TEST: D 1078
REFERENCE: P-97
DESCRIPTION: Distillation range of volatile organic liquids
TEST METHOD: Apparatus
APPLICATION: Methyl fuel
SCOPE: Distillation-boiling point range.
LIMITATIONS: Thermometer and barometer corrections may be necessary.

TEST:
REFERENCE: S-14
DESCRIPTION: Equations for estimating D 86 data for JP-4 and kerosene fuels from D 2887 data
TEST METHOD: Equations, GC
APPLICATION: Petroleum and synthetic JP-4, kerosene
SCOPE: Estimation of D 86 distillation range from D 2887 data. Methods for calculating API°, flash point, and viscosity are provided.
LIMITATIONS: Equations to which data must be fitted. Standard error of estimated ranges from 2.2-5.1°K.

BROMINE INDEX

TEST: 358
REFERENCE: P-112
DESCRIPTION: Bromine index of liquid butane and petroleum distillates by coulometric titration
TEST METHOD: Coulometric titration
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of bromine index.
LIMITATIONS: Sample must have bromine index below 500.

BROMINE NUMBER

TEST: D 1159
REFERENCE: P-94
DESCRIPTION: Bromine number of petroleum distillates and commercial aliphatic olefins by electrometric titration
TEST METHOD: Electrometric titration
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Bromine number determination.
LIMITATIONS: Distillates must be substantially free of material. Lighter than isobutane and have 90% distillation points under 327°C(620°F). Applicable to all petroleum gasolines and kerosenes without blending agents.

BURNING RATE

TEST:
REFERENCE: S-38
DESCRIPTION: Burning rate of emulsified fuel
TEST METHOD: Wet
APPLICATION: Fuel emulsions, petroleum and synthetic fuels
SCOPE: Burning of fuel as function of time.
LIMITATIONS: None given.

CARBON ATOMS/ALKYL SUBSTITUENT

TEST:
REFERENCE: P-62
DESCRIPTION: Chemically-bonded aminosilane stationary phase for the high-performance liquid chromatographic separation of polynuclear aromatic hydrocarbons
TEST METHOD: HPLC
APPLICATION: Liquid petroleum fuels
SCOPE: Determination of PAHs on micron bondapak NH₂ column. PAH fractionation first, then reversed-phase HPLC to obtain separation of alkyl homologues.
LIMITATIONS: Good for isolation of compounds prior to analysis of other techniques. Reproducible HPLC fractionation of PAH according to number of condensed aromatic rings.

CARBON NUMBER DISTRIBUTION

TEST:
REFERENCE: G-9
DESCRIPTION: Gas chromatographic determination of cyclopentyl-cyclohexyl naphthene splits in the gasoline boiling range
TEST METHOD: FIA/GC
APPLICATION: Gasoline, naphtha
SCOPE: Carbon number distribution for saturates, olefins, aromatics, once separated by FIA. Naphthene, isoparaffin and n-paraffin peaks given for each carbon number.
LIMITATIONS: Method is intended for refining purposes but may be practical to analysis of finished fuels.

TEST:
REFERENCE: P-4
DESCRIPTION: Statistical correlation for carbon number and aniline point
TEST METHOD: Equation, GC
APPLICATION: Gasoline
SCOPE: Equation related n-paraffin carbon number to aniline point and relative density of sample.
LIMITATIONS: Calculation for aniline point given only. Carbon number may be more or less accurate by this method.

CARBON NUMBER DISTRIBUTION (Cont'd)

TEST: D 3238
REFERENCE: P-96
DESCRIPTION: Calculation of carbon distribution and structural group analysis of petroleum oils by the N-D-M method
TEST METHOD: Refractometry, calculation
APPLICATION: Petroleum oils
SCOPE: Carbon distribution and ring content by measurement of refractive index, density, and molecular weight.
LIMITATIONS: Sample should be olefin-free. Method good for calculation of up to 75% carbon atoms in ring structure provided percentage in aromatic rings is not larger than 1.5 times the percentage of naphthanic rings, and up to four rings per molecule with not more than half of them aromatic. Sulfur correction may be necessary.

CARBON/HYDROGEN RATIO

TEST:
REFERENCE: G-10
DESCRIPTION: Prediction of the combustion properties of gasolines from the analysis of their composition
TEST METHOD: GC, FIA, PONA, Calculation
APPLICATION: Petroleum gasoline
SCOPE: GC used to identify gasoline components. Computer program develops equations for relating properties of fuel to properties of individual components. All properties covered are also related to density, correlation of FIA-PONA to properties.
LIMITATIONS: PONA gives a lower average standard error than FIA when compared with the theoretical computer-derived model. May be applicable to synthetic fuels.

TEST:
REFERENCE: G-19
DESCRIPTION: A technique to characterize quantitatively the air/fuel mixture in the inlet manifold of a gasoline engine
TEST METHOD: Engine, calculation
APPLICATION: Gasoline
SCOPE: H/C ratio (C/H) related to A/F ratio and CO₂ content. Analysis of exhaust gas.
LIMITATIONS: Engine must be warm and running at a steady rate. Ratio must be assumed constant for all cylinders and averaged for boiling range.

CARBON/HYDROGEN RATIO (Cont'd)

TEST:
REFERENCE: P-73
DESCRIPTION: Micro and semimicro procedures for the determination of carbon and hydrogen in organic compounds
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Carbon and hydrogen determination.
LIMITATIONS: Accuracy of $\pm 0.3\%$ when applied to pure compounds, more work is necessary--possibly with GC--for complex mixtures.

TEST:
REFERENCE: G-24
DESCRIPTION: Determination of hydrocarbon-type distribution and hydrogen/carbon ratio of gasoline by nuclear magnetic resonance spectrometry
TEST METHOD: NMR
APPLICATION: Petroleum gasoline
SCOPE: Determination of volume percent aromatics, paraffins, and olefins, and H/C ratio using equations involving integrals of chemical shift regions. Results compared to FIA analyses.
LIMITATIONS: Approximately 1% absolute standard deviation for class determinations. Approximately 12 minutes total analysis time if only spectrum integrals are recorded and a digital integrator used to print out peak areas.

CARBONYL COMPOUNDS CONTENT

TEST:
REFERENCE: P-86
DESCRIPTION: Chromatographic determination of carbonyl compounds as their 2,4-dinitrophenylhydrazones. I. Gas chromatography. II. High pressure liquid chromatography
TEST METHOD: GC, LC
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of compounds containing the C=O group.
LIMITATIONS: Problems of thermal decomposition and column deterioration are not completely eliminated for GC.

TEST:
REFERENCE: P-30
DESCRIPTION: Aldehydes and ketones in hydrocarbon liquids
TEST METHOD: GC/MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of aldehydes and ketones.
LIMITATIONS: Detection limit of 50 ng injected.

CARBONYL COMPOUNDS CONTENT (Cont'd)

TEST:
REFERENCE: S-9
DESCRIPTION: Separation and identification of aldehydes and ketones.
TEST METHOD: Wet, GC, MS, IR
APPLICATION: Shale oil.
SCOPE: Extraction of aldehydes and ketones from shale oil by solid phase precipitation technique with subsequent analysis by GC and MS.
LIMITATIONS: None given for the technique.

CARBOXYLIC ACIDS CONTENT

TEST:
REFERENCE: P-30
DESCRIPTION: Carboxylic acids in hydrocarbon liquids
TEST METHOD: GC/MS, HPLC
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of carboxylic acids.
LIMITATIONS: Detection limit of 50 ng injected for GC/MS, 1-100 microgram/ml (50 microliter injected).

CETANE INDEX

TEST: D 976
REFERENCE: P-94
DESCRIPTION: Calculated cetane index of distillate fuels
TEST METHOD: Calculation, equation
APPLICATION: Petroleum liquid fuels
SCOPE: Cetane index calculation for estimating cetane number from API gravity and mid-boiling point.
LIMITATIONS: For prediction purposes only. Applicable to straight-run and cracked stocks. Not applicable to fuel containing cetane improvers, pure compounds, or synthetic fuels and fuels having volatility below 500°F end point.

CETANE NUMBER

TEST: D 613
REFERENCE: P-98
DESCRIPTION: Ignition quality of diesel fuels by the cetane method
TEST METHOD: Engine
APPLICATION: Diesel fuels
SCOPE: Determination of ignition quality in terms of cetane number.
LIMITATIONS: Engine preparation tedious, quick engine stopping may cause valve warpage. Repeatability has not been assessed. Reproducibility is good.

CETANE NUMBER (Cont'd)

TEST:
REFERENCE: G-1
DESCRIPTION: Octane-cetane relationship of motor gasoline
TEST METHOD: Equations
APPLICATION: Gasoline
SCOPE: Linear relationship between octane and cetane number of automotive gasoline.
LIMITATIONS: Equations determined empirically. Wide variance in gasoline types.

TEST:
REFERENCE: D-4
DESCRIPTION: The development and application of predictive systems for diesel fuel quality
TEST METHOD: Equations
APPLICATION: Diesel fuels
SCOPE: Systems to predict blend cetane number from laboratory inspections of finished fuel. Correlation with aniline point.
LIMITATIONS: Coefficients in equation are regression derived. Method is tedious for hand calculation and awkward for linear programming. Practical for refiner.

CHARACTERIZATION FACTOR

TEST: 375
REFERENCE: P-112
DESCRIPTION: Calculation of UOP characterization factor and estimation of molecular weight of petroleum oils
TEST METHOD: Calculation
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Estimation of characterization factor and average molecular weight.
LIMITATIONS: Molecular weight calculation not applicable to pure hydrocarbons.

TEST:
REFERENCE: D-3
DESCRIPTION: Diesel fuel properties for combustion calculations
TEST METHOD: Calculations
APPLICATION: Petroleum diesel fuel
SCOPE: Estimation of characterization factor from boiling point and specific gravity.
LIMITATIONS: For petroleum diesel but may be possible for synthetic fuel.

CHLORIDE CONTENT

TEST:
REFERENCE: P-99
DESCRIPTION: Trace chloride determination by rate controlled coulometric titration
TEST METHOD: Coulometric titration
APPLICATION: Aqueous solutions
SCOPE: Determination of chloride ion concentration.
LIMITATIONS: Method is an aqueous technique, modification necessary if to be applicable to liquid fuels.

TEST:
REFERENCE: P-115
DESCRIPTION: Determination of chloride in methyl fuel
TEST METHOD: Potentiometry
APPLICATION: Methyl fuel
SCOPE: Determination of chloride ion concentration.
LIMITATIONS: None given.

CHLORINE CONTENT

TEST: D 808
REFERENCE: P-94
DESCRIPTION: Chlorine in new and used petroleum products
TEST METHOD: Bomb, gravimetric analysis
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of total chlorine.
LIMITATIONS: Applicable to concentration range of 0.1-50% chlorine.
Procedure assumes absence of other halogenated compounds.

TEST:
REFERENCE: P-79
DESCRIPTION: Rapid gas chromatographic separation of diastereomeric dihalo butanes, pentanes, and hexanes
TEST METHOD: GC
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Separation of halohydrocarbons.
LIMITATIONS: None given.

TEST:
REFERENCE: P-90
DESCRIPTION: Analysis of chlorinated benzene compounds by gas chromatography
TEST METHOD: GC
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Chlorinated benzene determination.
LIMITATIONS: None given.

CLEANLINESS

TEST:
REFERENCE: D-2
DESCRIPTION: Method for testing fuel cleanliness in the field and in the lab
TEST METHOD: Wet
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of fuel cleanliness by filterability ratio.
LIMITATIONS: None given.

TEST: D 189
REFERENCE: P-94
DESCRIPTION: Conradson carbon residue of petroleum products
TEST METHOD: Distillation apparatus
APPLICATION: Liquid oils and fuels
SCOPE: Determination of carbon residue quantity as an indication of coking tendency.
LIMITATIONS: Samples containing ash-forming constituents will give high results. Samples must be relatively nonvolatile.

TEST: D 524
REFERENCE: P-94
DESCRIPTION: Ramsbottom carbon residue of petroleum products
TEST METHOD: Coking apparatus
APPLICATION: Liquid oils and fuels
SCOPE: Determination of carbon residue quantity as an indication of coking tendency.
LIMITATIONS: Samples containing ash-forming constituents will give high results. Samples must be relatively nonvolatile.

TEST: D 381
REFERENCE: P-94
DESCRIPTION: Existent gum in fuels by jet evaporation
TEST METHOD: Steam-jet/air jet apparatus
APPLICATION: Motor gasoline, avgas, turbine fuel
SCOPE: Determination of washed and unwashed gum content of fuel.
LIMITATIONS: Cleanliness test, not for indication of fuel stability. Antioxidants must be removed by heptane extraction prior to analysis.

CLOUD POINT

TEST: D 2500
REFERENCE: P-95
DESCRIPTION: Cloud point of petroleum oils
TEST METHOD: Wet
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of cloud point.
LIMITATIONS: Sample must be transparent in layers 38 mm thick with cloud point below 49°C(120°F).

COKING TENDENCY

TEST: 3462
REFERENCE: P-93
DESCRIPTION: Coking tendency of oil
TEST METHOD: Apparatus
APPLICATION: Oil, liquid hydrocarbon fuels
SCOPE: Tendency of oils to form solid decomposition products at elevated temperatures.
LIMITATIONS: None given.

COLOR

TEST: D 1500
REFERENCE: P-94
DESCRIPTION: ASTM color of petroleum products (ASTM color scale)
TEST METHOD: Colorimeter
APPLICATION: Petroleum fuels
SCOPE: Color type and intensity determination.
LIMITATIONS: Visual inspection only.

TEST: D 156
REFERENCE: P-94
DESCRIPTION: Saybolt color of petroleum products (Saybolt chromometer method)
TEST METHOD: Chromometer
APPLICATION: Petroleum fuels
SCOPE: Color determination.
LIMITATIONS: Visual inspection only.

TEST: D 2392
REFERENCE: P-95
DESCRIPTION: Color of dyed aviation gasolines
TEST METHOD: Color comparator
APPLICATION: Petroleum aviation gasolines
SCOPE: Color determination.
LIMITATIONS: Acceptability test.

COMPATIBILITY WITH ELASTOMERS

TEST:
REFERENCE: S-38
DESCRIPTION: Emulsified fuel compatibility with elastomers
TEST METHOD: Storage (1 wk)
APPLICATION: Fuel emulsions, liquid hydrocarbon fuels
SCOPE: Determination of elastomer swelling resulting from physical contact with fuel.
LIMITATIONS: Time consuming - 1 week.

TEST:
REFERENCE: S-37
DESCRIPTION: Compatibility of emulsified fuels with elastomers
TEST METHOD: Storage (72 hours)
APPLICATION: Fuel emulsions, liquid hydrocarbon fuels
SCOPE: Determination of elastomer swelling resulting from physical contact with fuel.
LIMITATIONS: Time consuming - three days.

COMPATIBILITY WITH OTHER FUELS

TEST: D 2781
REFERENCE: P-95
DESCRIPTION: Compatibility of fuel oil blends by spot test
TEST METHOD: Paper chromatography
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Degree of wax and asphaltene deposition.
LIMITATIONS: Viscosity of blend must be between 70 and 200 SUS.

CONDUCTIVITY, ELECTRICAL

TEST: D 2624
REFERENCE: P-95
DESCRIPTION: Electrical conductivity of aviation fuels containing a static dissipator additive
TEST METHOD: Electrodes
APPLICATION: Aviation fuels
SCOPE: Determination of electrical conductivity.
LIMITATIONS: Care must be taken to avoid contamination by charge generation. This method is not for a quantitative assessment of dissipator additive.

TEST: D 3114
REFERENCE: P-96
DESCRIPTION: D-C electrical conductivity of hydrocarbon fuels
TEST METHOD: Conductivity cell
APPLICATION: Aviation and other low-conductivity fuels
SCOPE: Electrical conductivity (D-C).
LIMITATIONS: Conductivity of liquids should be between 1000 and 0.01 pS/m.

CONDUCTIVITY, THERMAL

TEST: D 2717
REFERENCE: P-95
DESCRIPTION: Thermal conductivity of liquids
TEST METHOD: Thermal conductivity cell
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Thermal conductivity determination.
LIMITATIONS: Sample must be compatible with borosilicate glass and platinum and have a vapor pressure less than 260 torr (3.86 psi).

CONTAMINANT CONTENT, HYDROCARBON

TEST:
REFERENCE: P-8
DESCRIPTION: Detection of heavy hydrocarbon contamination in aviation gasoline
TEST METHOD: Wet
APPLICATION: Avgas
SCOPE: Detection of hydrocarbon (foreign material) and/or trace quantities of other fuels.
LIMITATIONS: Qualitative only.

TEST:
REFERENCE: G-20
DESCRIPTION: Detection of adulteration of gasolines with kerosenes
TEST METHOD: UV
APPLICATION: Gasoline
SCOPE: Detection and quantitative determination of foreign hydrocarbons in gasoline.
LIMITATIONS: Applicability limited to about 10% kerosene by volume.

CONTAMINANT CONTENT, PARTICULATE

TEST: D 2276
REFERENCE: P-95
DESCRIPTION: Particulate contaminant content in aviation turbine fuels
TEST METHOD: Gravimetric analysis
APPLICATION: Turbine fuel
SCOPE: Evaluation of particulate contaminant content, 2 methods.
LIMITATIONS: None given.

TEST:
REFERENCE: P-100
DESCRIPTION: Method for determination of JP-4 filtration time and total solids (particulate)
TEST METHOD: Gravimetric analysis
APPLICATION: JP-4
SCOPE: Evaluation of particulate contaminants.
LIMITATIONS: Maximum allowable time is 15 minutes.

CONTAMINANT CONTENT, PARTICULATE (Cont'd)

TEST:
REFERENCE: T-9
DESCRIPTION: Filtratio time-solids level test
TEST METHOD: Apparatus
APPLICATION: Determination of filtration time and particulate contaminant level.
LIMITATIONS: None given.

TEST: Gost 10577-78; Method B
REFERENCE: T-2
DESCRIPTION: Determination of particulate matter content in jet fuels
TEST METHOD: Wet
APPLICATION: Turbine fuels
SCOPE: Method B compared with graphical method.
LIMITATIONS: Five liters of fuel needed with correction factor due to gum adherence on filter.

CORROSIVITY

TEST: D 130
REFERENCE: P-94
DESCRIPTION: Detection of copper corrosion from petroleum products by the copper strip tarnish test
TEST METHOD: Tarnish test
APPLICATION: Avgas, turbine, gasoline, diesel
SCOPE: Detection of corrosiveness to copper.
LIMITATIONS: Sample must have RVP no greater than 18 lb. Interpretation by appearance only.

TEST:
REFERENCE: S-37
DESCRIPTION: Compatibility of emulsified fuels with metals
TEST METHOD: Tarnish test
APPLICATION: Fuel emulsions
SCOPE: Detection of corrosiveness to metals.
LIMITATIONS: Interpretation by appearance only.

TEST: D 1616
REFERENCE: P-97
DESCRIPTION: Copper corrosion by mineral spirits (copper strip test)
TEST METHOD: Tarnish test
APPLICATION: Methyl fuel
SCOPE: Detection of corrosiveness to copper.
LIMITATIONS: Interpretation by appearance only.

DE-EMULSIFICATION, RATE OF

TEST: D 1401
REFERENCE: P-94
DESCRIPTION: Emulsion characteristics of petroleum oil and synthetic fluids
TEST METHOD: Wet
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Measurement of ability of petroleum oils or synthetic fluids to separate from water.
LIMITATIONS: Test temperature must be raised to $82 \pm 1^\circ\text{C}$ ($180 \pm 2^\circ\text{F}$) when sample is more viscous than 97 cSt.

TEST:
REFERENCE: S-25
DESCRIPTION: Flow properties of coal/water/oil emulsion
TEST METHOD: Pendulum apparatus
APPLICATION: Coal/water/oil emulsions
SCOPE: Correlation of amount of settling with change in center of mass.
LIMITATIONS: Accuracy within a few percent.

DENSITY

TEST:
REFERENCE: P-85
DESCRIPTION: A new, rapid method for the precise determination of the density of fluids
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of density.
LIMITATIONS: None given.

DEPOSITION TENDENCIES

TEST: D 3711
REFERENCE: P-96
DESCRIPTION: Deposition tendencies of liquids in thin films and vapors
TEST METHOD: Furnace, potentiometry
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of tendency to form deposits on metal surfaces.
LIMITATIONS: Test time 5 hours.

DIENE VALUE

TEST: 326
REFERENCE: P-112
DESCRIPTION: Diene value by maleic anhydride addition reaction
TEST METHOD: Titration
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Measurement of conjugated di-olefin content.
LIMITATIONS: Somewhat empirical as some diolefins do not react completely and some unrelated compounds do.

DIESEL INDEX

TEST: D 1405
REFERENCE: P-94, S-21
DESCRIPTION: Estimation of net heat of combustion of aviation fuels. Diesel index for diesel and aviation fuels
TEST METHOD: Calculation
APPLICATION: Avgas, turbine, diesel fuel
SCOPE: Determination of net heat of combustion using aniline gravity product. Diesel index by aniline-gravity product/100 (S-21, p 52, Note 7).
LIMITATIONS: Calculation may give distorted results with fuels of unusual chemical composition. Aniline-gravity product by itself is purely empirical and is only to be used as a guide when direct measurement is not available.

DROPLET SIZE

TEST:
REFERENCE: S-38
DESCRIPTION: Investigation of emulsion droplet size
TEST METHOD: Microphotography, UFM
APPLICATION: Fuel emulsions
SCOPE: Droplet size determination.
LIMITATIONS: More accurate method needed.

EMULSIFICATION TENDENCY

TEST: 550
REFERENCE: P-93
DESCRIPTION: Emulsification tendencies of petroleum fuels by multiple contact extraction
TEST METHOD: Shaking device
APPLICATION: Petroleum fuels
SCOPE: Tendency of fuel to emulsify when in contact with water.
LIMITATIONS: Rating system only.

EMULSION STABILITY

TEST:
REFERENCE: S-38
DESCRIPTION: Freeze-thaw test for aircraft fuel emulsions
TEST METHOD: Oven, cold box
APPLICATION: Fuel emulsions
SCOPE: Stability of emulsion with temperature change.
LIMITATIONS: None given.

ESTERS CONTENT

TEST:
REFERENCE: P-30
DESCRIPTION: Esters in hydrocarbon liquids
TEST METHOD: GC/MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of esters content.
LIMITATIONS: Detection limit of 50 ng injected.

ETHER CONTENT

TEST:
REFERENCE: P-30
DESCRIPTION: Ethers and haloethers in hydrocarbon liquids
TEST METHOD: GC/FID
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of ethers and haloethers.
LIMITATIONS: Detection limit of 500 ng for ethers, 50 ng for haloethers (injected).

EVAPORATION RATE

TEST:
REFERENCE: S-38
DESCRIPTION: Evaporation loss of aircraft fuel emulsions
TEST METHOD: Thermal gravimetric balance
APPLICATION: Fuel emulsions, petroleum and synthetic fuels
SCOPE: Evaporation rate and dynamic evaporation rate.
LIMITATIONS: None given.

TEST:
REFERENCE: G-16
DESCRIPTION: Analyzer for determining fuel vaporization pressure curves of gasoline and gasoline-alcohol fuels
TEST METHOD: Analyzer
APPLICATION: Gasoline/alcohol blends
SCOPE: Pressure change as a function of sample vaporization is measured. V/L and RVP may be determined.
LIMITATIONS: Too small sample will distort linearity of curve.

FILTERABILITY

TEST:
REFERENCE: S-21
DESCRIPTION: Low temperature filterability of Athabasca tar sand fuels and standard diesel fuels
TEST METHOD: Filter pump
APPLICATION: Petroleum and synthetic fuels
SCOPE: Assess the temperature dependence of fuel filterability.
LIMITATIONS: None given.

TEST:
REFERENCE: S-37
DESCRIPTION: Determination of pressure across a filter
TEST METHOD: Apparatus
APPLICATION: Fuel emulsions
SCOPE: Determination of filter flow characteristics.
LIMITATIONS: Temperature must be maintained at $76^{\circ}\pm 4^{\circ}\text{F}$, yield stress must be measured at 76°F .

TEST:
REFERENCE: T-9
DESCRIPTION: Filtration time-solids level test
TEST METHOD: Apparatus
APPLICATION: Turbine
SCOPE: Determination of filtration time and particulate contaminant level.
LIMITATIONS: None given.

FLAMMABILITY

TEST: 352
REFERENCE: P-93
DESCRIPTION: Effect of evaporation on flammability
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Evaporation effect on flammability.
LIMITATIONS: Simple test, not highly quantitative.

FLASH POINT

TEST: D 3243
REFERENCE: P-96
DESCRIPTION: Flash point of aviation turbine fuels by Setaflash closed tester
TEST METHOD: Apparatus
APPLICATION: Turbine fuel
SCOPE: Determination of flashpoint temperature, or whether or not a fuel will flash at a specified temperature.
LIMITATIONS: Atmosphere pressure correction may be necessary. Results of test should not be used for appraisal of fire hazard under actual fire conditions.

FLASH POINT (Cont'd)

TEST: D 56
REFERENCE: P-94
DESCRIPTION: Flash point by tag closed tester
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of flash point.
LIMITATIONS: Sample must have viscosity below 45 SUS at 37.8°C (100°F) and a flash point below 93°C(200°F). See D 3423.

TEST: D 1310
REFERENCE: P-94
DESCRIPTION: Flash point of liquids by tag open-cup apparatus
TEST METHOD: Apparatus
APPLICATION: Diesel fuel
SCOPE: Determination of flash point.
LIMITATIONS: Not for appraisal of fire hazard under actual fire conditions.

TEST: D 3828
REFERENCE: P-96
DESCRIPTION: Flash point by Setaflash closed tester
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: (See D 3423).
LIMITATIONS: (See D 3423).

TEST: D 93
REFERENCE: P-94, P-2
DESCRIPTION: Flash point by Pensky-Martens closed tester
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of flash point.
LIMITATIONS: Not for appraisal of fire hazard under actual fire conditions.

TEST:
REFERENCE: P-27
DESCRIPTION: Derivation of computer program for estimating flash point
TEST METHOD: Equations, computer program
APPLICATION: Diesel, turbine fuels
SCOPE: Estimation of flash point using computer program. Flash point related to molecular weight, API°, D 86 distillation.
LIMITATIONS: Calculations are lengthy without computer program. Calibration curve is necessary, must use program and lab method for calibration.

FLASH POINT (Cont'd)

TEST:
REFERENCE: P-4
DESCRIPTION: Flash point of middle distillates
TEST METHOD: Equations, GLC
APPLICATION: Petroleum middle distillates
SCOPE: Equations; one relating latent heat of vaporization and vapor pressure and total weight fraction in vapor phase to flash point, a second equation of a calibration curve for flash point estimation.
LIMITATIONS: Flash point calculated by iteration, computer helpful.

TEST:
REFERENCE: S-14
DESCRIPTION: Equations for estimating bulk properties of kerosene fuels
TEST METHOD: Equation
APPLICATION: Kerosene fuels
SCOPE: Estimation of flash point from D 2887 data.
LIMITATIONS: Long equation to which data must be fitted.

FREEZING POINT

TEST: D 2386
REFERENCE: P-95
DESCRIPTION: Freezing point of aviation fuels
TEST METHOD: Apparatus
APPLICATION: Avgas, turbine fuel
SCOPE: Determination of freezing point.
LIMITATIONS: Thermometer correction may be necessary.

TEST:
REFERENCE: P-4
DESCRIPTION: Freezing point of middle distillate
TEST METHOD: Equation, GLC
APPLICATION: Middle distillates
SCOPE: Calculation of freezing point. Relates freezing points of pure hydrocarbon to that of distillate. Correlation with latent heat of fusion provided.
LIMITATIONS: Bias present when compared with experimentally determined freezing point, but can be allowed for statistically.

HEAT OF COMBUSTION

TEST: D 3338
REFERENCE: P-96
DESCRIPTION: Estimation of heat of combustion of aviation fuels
TEST METHOD: Calculation
APPLICATION: Avgas, turbine
SCOPE: Estimation of net heat of combustion. Relates net heat of combustion with aromatic content, API°, volatility.
LIMITATIONS: Method is purely empirical and is only to be used as a guide when direct measurement is not available.

HEAT OF COMBUSTION (Cont'd)

TEST: D 240
REFERENCE: P-94
DESCRIPTION: Heat of combustion of liquid hydrocarbon fuels by bomb calorimeter
TEST METHOD: Calorimeter
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of net and gross heats of combustion.
LIMITATIONS: Thermochemical and heat transfer correlations must be made.

TEST: D 1405
REFERENCE: P-94
DESCRIPTION: Estimation of net heat of combustion of aviation fuels
TEST METHOD: Calculation
APPLICATION: Avgas, turbine
SCOPE: Determination of net heat of combustion using aniline-gravity product.
LIMITATIONS: (See D 3338)

TEST: D 2382
REFERENCE: P-95
DESCRIPTION: Heat of combustion of liquid hydrocarbon fuels by bomb calorimeter (high precision method)
TEST METHOD: Calorimeter
APPLICATION: Liquid hydrocarbon fuels
SCOPE: (See D 240)
LIMITATIONS: (See D 240)

TEST:
REFERENCE: S-34
DESCRIPTION: Calorific value of fuel
TEST METHOD: Calculation
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of calorific value of fuels. Relates calorific value to A/F ratio.
LIMITATIONS: Heteroatoms have some effect on combustion thus the equation given is a good estimation at best.

HEAT OF COMBUSTION (Cont'd)

TEST:
REFERENCE: T-4
DESCRIPTION: Study of estimation methods for heat of combustion of aviation turbine fuels
TEST METHOD: Calculations
APPLICATION: Turbine fuels
SCOPE: Two sets of equations are explored. Relations of aniline point, API°, volume % aromatics, volumetric average of D 86 distillation data to heat of combustion. Also hydrogen content is related to aniline point, API°, volume fraction aromatics, volumetric average of D 86 data.
LIMITATIONS: The two equations may be manipulated to predict heat of combustion from hydrogen content. Care must be taken to choose best equations for optimum precision and accuracy.

TEST:
REFERENCE: T-21, T-22
DESCRIPTION: Enthalpy of combustion of RJ-6 and other turbine fuels
TEST METHOD: Bomb
APPLICATION: Turbine fuels
SCOPE: Enthalpy of combustion measurement with platinum-lined bomb.
LIMITATIONS: None given.

TEST:
REFERENCE: T-23
DESCRIPTION: Combustion character of turbine fuels
TEST METHOD: Calculation
APPLICATION: Turbine fuels
SCOPE: Equation relating net heat of combustion to hydrogen content.
LIMITATIONS: None given.

TEST:
REFERENCE: S-53
DESCRIPTION: Enthalpy measurements for petroleum and coal-derived fuels
TEST METHOD: Bomb, calculations
APPLICATION: Petroleum and coal-derived fuels
SCOPE: Bomb method for petroleum and coal-derived fuels. Equation relating enthalpy to heat capacity, pressure and temperature.
LIMITATIONS: Equations suspect for coal-derived fuels.

HEAT OF COMBUSTION (Cont'd)

TEST:
REFERENCE: S-15
DESCRIPTION: Calculating heating values from elemental compositions of fossil fuels.
TEST METHOD: Equations
APPLICATION: Coal, shale, and petroleum oils.
SCOPE: Boie and Dulong equations examined for accuracy in predicting heating values from elemental composition of crude fuel oils.
LIMITATIONS: Technique given for unrefined liquids only, but may be applicable to fractions. Boie equation is superior.

HEAT OF FUSION, LATENT

TEST:
REFERENCE: P-4
DESCRIPTION: Freezing point of middle distillate
TEST METHOD: GLC, Equation
APPLICATION: Petroleum gasoline, middle distillates
SCOPE: Relation of latent heat of fusion of freezing point.
LIMITATIONS: (See FREEZING POINT Reference P-4)

HETEROCOMPOUNDS CONTENT

TEST:
REFERENCE: P-102
DESCRIPTION: Chemiluminescence detector based on active nitrogen for gas chromatography of hydrocarbons
TEST METHOD: GC/CD
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of halogenated, oxygenated, etc. organic compounds along with simple hydrocarbons.
LIMITATIONS: None given.

TEST:
REFERENCE: S-42
DESCRIPTION: Separation and determination of heteroatomic groups
TEST METHOD: LC, Fourier Transform IR
APPLICATION: Coal-derived fuels
SCOPE: LC separation with IR detection of various compounds.
LIMITATIONS: Normal IR interferences.

HYDROCARBON CONTENT

TEST: D 2427
REFERENCE: P-95
DESCRIPTION: Determination of C₂-C₅ hydrocarbons in gasolines by gas chromatography
TEST METHOD: GC
APPLICATION: Gasoline
SCOPE: Determination of carbon paraffins and mono-olefins in finished gasoline.
LIMITATIONS: Not applicable to determination of cyclic olefins, di-olefins, or acetylenes. Samples should not contain material which boils below that of ethylene.

TEST: D 2425
REFERENCE: P-95
DESCRIPTION: Hydrocarbon types in middle distillates by mass spectrometry
TEST METHOD: MS
APPLICATION: Middle distillates
SCOPE: Determines content of paraffins, noncondensed cycloparaffins, condensed dicycloaraffins, condensed tri-cycloparaffins, alkyl benzenes, indans, tetralins, indenenes, naphthalenes, and tricyclic aromatics in middle distillates.
LIMITATIONS: The given precision data may not be valid for samples which differ appreciably in composition from those with which the method has been tested.

TEST: D 2789
REFERENCE: P-95
DESCRIPTION: Hydrocarbon types in low olefinic gasoline by mass spectrometry
TEST METHOD: MS
APPLICATION: Gasoline
SCOPE: Determination of total paraffins, monocycloparaffins, dicycloparaffins, alkylbenzenes, indans, tetralins, and naphthalenes in gasoline.
LIMITATIONS: Sample must have olefin content less than 3% and a 95% distillation point of less than 411°F.

TEST: D 1319
REFERENCE: P-94
DESCRIPTION: Hydrocarbon types in liquid petroleum products by fluorescent indicator adsorption
TEST METHOD: FIA
APPLICATION: Liquid petroleum fuels
SCOPE: Determines amount saturates, nonaromatic olefins, and aromatics in petroleum fuels.
LIMITATIONS: Petroleum fraction must distill below 315°C(600°F). Aromatic olefins, some diolefins, and sulfur, nitrogen, and oxygen-containing compounds will show up as aromatics.

HYDROCARBON CONTENT (Cont'd)

TEST:
REFERENCE: P-57
DESCRIPTION: Identification and characterization of petroleum fuels using temperature-programmed gas-liquid chromatography
TEST METHOD: GC
APPLICATION: Gasoline, diesel turbine fuels
SCOPE: Determination of fuel type and grade.
LIMITATIONS: Qualitative analysis only, peaks are not identified as to compounds but are used as references.

TEST:
REFERENCE: S-30
DESCRIPTION: An improved method for the analysis of coal liquids
TEST METHOD: LC (charge-transfer) HPLC with refractive index, ultraviolet spectroscopy
APPLICATION: Coal liquids
SCOPE: Determination of hydrocarbons in coal oil. Component elution in HPLC monitored by refractive index and ultraviolet measurements.
LIMITATIONS: Response varies with compound type. Separation is good.

TEST:
REFERENCE: S-28
DESCRIPTION: Mass spectrometric analysis of coal liquid
TEST METHOD: MS
APPLICATION: Coal liquids
SCOPE: Quantitative estimation of saturates relative to aromatics and other saturates by gram sensitivity using MS.
LIMITATIONS: Calibration necessary by pre-determined sensitivity. High temperature ion source needed to decrease sensitivity.

TEST:
REFERENCE: S-39
DESCRIPTION: Isolation and identification of light oil alkanes in shale oil by vapor phase reaction gas chromatography
TEST METHOD: GC, H₂SO₄ reactor, molecular sieve reactor
APPLICATION: Shale²oil
SCOPE: Sulfuric acid reaction subtracts some peaks from the chromatogram enabling fingerprint comparisons between oils produced by different processes. Molecular sieves remove n-alkanes for further comparison.
LIMITATIONS: Crude shale only but possibly may be modified for refined oil analysis.

HYDROCARBON CONTENT (Cont'd)

TEST:
REFERENCE: P-9
DESCRIPTION: Fingerprinting and partial quantification of complex hydrocarbon mixtures by chemical ionization mass spectrometry
TEST METHOD: MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Qualitative assessment of fuel types according to hydrocarbon carbon number resulting from an ionization potential reaction. Partial quantification by calibration curve.
LIMITATIONS: Not good for quantitative determination, must use calibration curve for each component analyzed.

TEST:
REFERENCE: G-13
DESCRIPTION: The analysis of hydrocarbon products from methanol conversion to gasoline using open tubular GC columns and selective olefin absorption
TEST METHOD: GC
APPLICATION: Hydrocarbon liquids
SCOPE: Determination of hydrocarbon types including PONA.
LIMITATIONS: As good as or better than ASTM D 1319. May be applicable to fuel analysis.

TEST:
REFERENCE: D-12, P-25
DESCRIPTION: The application of high-performance liquid chromatography to the analysis of petroleum materials; PTS.1,2.
TEST METHOD: HPLC
APPLICATION: Petroleum middle distillates (diesel fuels)
SCOPE: Determination of saturates and aromatics.
LIMITATIONS: Diesel fuels must be straight-run containing no olefins otherwise a modification is necessary.

TEST:
REFERENCE: P-14
DESCRIPTION: An automated glass capillary gas chromatographic system for routine quantitative analysis
TEST METHOD: GC
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Quantitative analyses of hydrocarbons using two column installation methods and two instrument modifications the second of which uses a computer-initiated syringe pilot signal.
LIMITATIONS: Method 2 column installation and an internal standard gives best quantitative results.

HYDROCARBON CONTENT (Cont'd)

TEST:
REFERENCE: G-9
DESCRIPTION: Gas chromatographic determination of cyclopentyl-cyclohexyl naphthene splits by cetane number in the gasoline boiling range
TEST METHOD: GC, FIA, dehydrogenation reactor
APPLICATION: Gasoline
SCOPE: Sample is split by FIA and injected into GC for reference chromatogram. A portion of saturate fraction is dehydrogenated. Reactions ultimately give determinations of the two naphthenes.
LIMITATIONS: Accurate aromatic value is a by-product of the analysis. Impurities in naphtha may poison catalyst during dehydrogenation of total naphtha in this process is chosen.

TEST: D 1840
REFERENCE: P-95
DESCRIPTION: Naphthalene hydrocarbons in aviation turbine fuels by ultraviolet spectrophotometry
TEST METHOD: UV
APPLICATION: Turbine fuel
SCOPE: Determination of total concentration of naphthalene, acenaphthene, and alkylated derivatives of these hydrocarbons.
LIMITATIONS: Sample must contain not more than 5% of such components and must have end points below 315°C(600°F). Sample must be of straight run origin.

TEST: D 2159
REFERENCE: P-95
DESCRIPTION: Naphthenes in saturates fractions by refractivity intercept
TEST METHOD: Refractometer
APPLICATION: Gasoline
SCOPE: Determination of naphthenes content.
LIMITATIONS: Gasoline must be depentanized (ASTM D 2001) and have end point not exceeding 221°C(430°F).

TEST: D 875
REFERENCE: P-94
DESCRIPTION: Calculation of olefins and aromatics in petroleum distillates from bromine number and acid absorption
TEST METHOD: Calculation
APPLICATION: Petroleum-based straight-run, reformed, cracked, and commercial gasolines, turbine fuel, kerosene
SCOPE: Vol% olefins and aromatics.
LIMITATIONS: Gasolines must have a 90% BP below 200°C (392°F). Turbine fuel and kerosene must boil below 316°C (600°F) and have a bromine number less than 20.

HYDROCARBON CONTENT (Cont'd)

TEST:
REFERENCE: G-5
DESCRIPTION: Hydrocarbon-type analysis of gasoline using stabilized olefin absorption and gas chromatography
TEST METHOD: GC
APPLICATION: Gasoline
SCOPE: Determination of saturates, olefins, and aromatics with GC and olefin absorber column. (Mercuric perchlorate-perchloric acid).
LIMITATIONS: Olefins must be determined by difference. Method at least as good as ASTM D 1319 and does not require any preliminary steps. MP-PA reactivity must be stabilized. Upper bias for aromatics and olefins due to detector response and density distribution.

TEST:
REFERENCE: G-14
DESCRIPTION: Gas chromatographic analysis of gasoline and pure naphtha using packed columns
TEST METHOD: GC, GC/MS
APPLICATION: Gasoline, naphtha
SCOPE: Analysis of complex hydrocarbon mixtures.
LIMITATIONS: Overlappings may be specifically identified by GC/MS. Not able to identify compounds present in less than 0.01% or whose peak is too close to others present in greater amounts. Many olefins and aromatic peaks are overlapped by saturates.

TEST:
REFERENCE: S-16
DESCRIPTION: Alkane concentration of synthetic jet fuels
TEST METHOD: GC/MS
APPLICATION: Synthetic jet fuels
SCOPE: Determination of saturate content.
LIMITATIONS: None given.

TEST:
REFERENCE: G-7
DESCRIPTION: Hydrocarbon type analysis of gasoline by gas chromatography
TEST METHOD: GC
APPLICATION: Gasoline
SCOPE: Analysis of hydrocarbon content.
LIMITATIONS: Humidified helium carrier gas necessary. Absolute accuracy has not been established.

HYDROCARBON CONTENT (Cont'd)

TEST:
REFERENCE: S-32
DESCRIPTION: Characterization of coal-derived liquids and other fossil fuel related materials employing mass spectrometry
TEST METHOD: MS/Computer
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Compositional analysis; correlation of gram sensitivity with mole sensitivity from structure.
LIMITATIONS: None given.

TEST:
REFERENCE: P-65
DESCRIPTION: The effects of T_1 and NOE considerations in quantitative applications of carbon-13 NMR to the analysis of complex hydrocarbon mixtures
TEST METHOD: NMR
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Relation of retention time and Nuclear Overhauser Effect to chemical shift.
LIMITATIONS: NMR theory only no procedure given.

TEST: 501
REFERENCE: P-112
DESCRIPTION: Hydrocarbon types by fluorescent indicator adsorption at elevated temperatures
TEST METHOD: FIA
APPLICATION: Petroleum diesel fuels, gasoline, turbine fuels
SCOPE: Determination of vol% paraffins, olefins, and aromatics.
LIMITATIONS: 2.5 hr analysis time.

TEST:
REFERENCE: S-44
DESCRIPTION: Shale oil hydrocarbon separation by preparative liquid chromatography and glass capillary gas chromatography.
TEST METHOD: HPLC, GC, MS
APPLICATION: Shale oil
SCOPE: Separation and determination of hydrocarbons.
LIMITATIONS: Some alkenes must be isolated and chromatographed by seive subtraction, others require extensive manipulation.

TEST:
REFERENCE: P-80
DESCRIPTION: Determination of normal paraffins in petroleum heavy distillates by urea adduction and gas chromatography
TEST METHOD: GC
APPLICATION: Petroleum heavy distillates
SCOPE: Determination of n-paraffins.
LIMITATIONS: None given.

HYDROCARBON CONTENT (Cont'd)

TEST:
REFERENCE: S-51
DESCRIPTION: Composition of synthetic fuels
TEST METHOD: GC, SLC
APPLICATION: Synthetic fuels
SCOPE: Discussion of separation techniques.
LIMITATIONS: Study of method and application only.

TEST:
REFERENCE: S-17
DESCRIPTION: Characterization of synthetic liquid fuels
TEST METHOD: GLC, MS, NMR
APPLICATION: Synthetic fuels
SCOPE: Hydrocarbon content determination.
LIMITATIONS: Instruments must be used in combination for complementary analyses.

TEST:
REFERENCE: S-52
DESCRIPTION: Quantitative analysis of coal-derived liquids by low-voltage mass spectrometry.
TEST METHOD: MS
APPLICATION: Coal-derived liquids
SCOPE: Quantitative determination of components.
LIMITATIONS: Correction for isotope contributions necessary. Descriptive statement only.

TEST:
REFERENCE: P-84
DESCRIPTION: Comparative relative molar response data on C₅ to C₈ hydrocarbons
TEST METHOD: GC
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of molar response factors for hydrocarbon types.
LIMITATIONS: Inexplicably high response for some C₅ and C₆ hydrocarbons.

TEST:
REFERENCE: P-74
DESCRIPTION: High-pressure liquid chromatography fingerprinting of petroleum and petroleum products
TEST METHOD: GL/LC
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Compositional analysis.
LIMITATIONS: Chrysene, benzofluorenes, and benzpyrene not resolved well. Emphasis is more on qualitative determinations.

HYDROCARBON CONTENT (Cont'd)

TEST:

REFERENCE: P-81

DESCRIPTION: Analysis of organic mixtures using the combination of a thermogravimetric analyzer, a gas chromatograph, and infrared spectrophotometer

TEST METHOD: Analyzer, GC/IR

APPLICATION: Liquid hydrocarbon fuels

SCOPE: Analysis of organic mixtures

LIMITATIONS: Not good for trace analysis.

TEST:

REFERENCE: P-88

DESCRIPTION: Determination of carbon dioxide, hydrogen sulfide, sulfur dioxide, ethane, and propane using a carbon molecular sieve column

TEST METHOD: GC

APPLICATION: Petroleum combustion products

SCOPE: Determination of sulfur light hydrocarbons, carbon dioxide.

LIMITATIONS: Combustion products only.

TEST:

REFERENCE: P-102

DESCRIPTION: Chemiluminescence detector based on active nitrogen for gas chromatography of hydrocarbons

TEST METHOD: GC/CD

APPLICATION: Liquid hydrocarbon fuels

SCOPE: Determination of halogenated, oxygenated, etc. organic compounds along with simple hydrocarbons.

LIMITATIONS: None given.

TEST:

REFERENCE: P-29

DESCRIPTION: Relations between hydrocarbon-type composition of various kerosene distillates, and their properties.

TEST METHOD: Equation, displacement chromatography, MS

APPLICATION: Petroleum based diesel and turbine fuels

SCOPE: Relation of smoke to aromatic and naphthenic content.

LIMITATIONS: Statistical analysis for kerosene distillates.

TEST:

REFERENCE: P-30

DESCRIPTION: Aliphatic hydrocarbons in hydrocarbon liquids

TEST METHOD: GC/FID

APPLICATION: Liquid hydrocarbon fuels

SCOPE: Determination of aliphatic hydrocarbon types.

LIMITATIONS: Detection limit of 5 ng injected.

HYDROCARBON CONTENT (Cont'd)

TEST:
REFERENCE: S-23
DESCRIPTION: Olefin analysis in shale oils.
TEST METHOD: Apparatus, GC
APPLICATION: Shale oil and shale oil fractions
SCOPE: Separation technique followed by simulated distillation, IR, NMR
LIMITATIONS: Difficult to determine olefin types.

TEST:
REFERENCE: P-16
DESCRIPTION: Methods for separating petroleum hydrocarbons.
TEST METHOD: Apparatus, GC, LC, Others
APPLICATION: Light petroleum fractions
SCOPE: Theories of several fractionation methods are described.
LIMITATIONS: Descriptive only, no examples on data given. Applicable to mostly lower boiling fractions.

TEST:
REFERENCE: S-12
DESCRIPTION: High-performance liquid chromatography separation of olefin, saturate, and aromatic hydrocarbons in high-boiling distillates and residues of shale oil.
TEST METHOD: HPLC, Wet
APPLICATION: Shale oil fractions
SCOPE: Separation of hydrocarbon types by HPLC followed by analysis using IR and NMR.
LIMITATIONS: Analysis time approximately 2 hours. Cause of poor reproducibility in some cases is unknown.

TEST:
REFERENCE: S-40
DESCRIPTION: HPLC separation of shale oil distillates and residues
TEST METHOD: HPLC
APPLICATION: Shale oil middle and heavy distillate types
SCOPE: Sample preparation, HPLC preparation, calibration and separations. IR, NMR used to verify separations.
LIMITATIONS: Some poor repeatability which may be due to adsorption of some material on silica gel or loss through handling of small samples. Recovery of separated types generally better than 90%.

HYDROGEN CONTENT

TEST: D 3343
REFERENCE: P-96
DESCRIPTION: Estimation of hydrogen content of aviation fuels
TEST METHOD: Calculation
APPLICATION: Avgas, turbine fuel
SCOPE: Estimation of wt% hydrogen. Relates hydrogen to aniline point, API° volumetric average of distillation data, and volume% aromatics.
LIMITATIONS: Useful as estimation only when direct methods are unavailable (for an in-depth study see Heat of Combustion Reference T-4).

TEST: D 3343
REFERENCE: P-96
DESCRIPTION: Hydrogen content of aviation turbine fuels by low resolution nuclear magnetic resonance spectrometry
TEST METHOD: NMR
APPLICATION: Petroleum turbine fuels
SCOPE: Determination of hydrogen content.
LIMITATIONS: Precision may be affected if method is extended to other liquids as precision evaluation was made for petroleum turbine fuel only.

TEST: D 1018
REFERENCE: P-94
DESCRIPTION: Hydrogen in petroleum fractions
TEST METHOD: Lamp apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of hydrogen content
LIMITATIONS: Sample must be of type that can be burned completely without smoking in a wick lamp.

TEST:
REFERENCE: T-4
DESCRIPTION: Study of estimation methods for heat of combustion of aviation turbine fuels
TEST METHOD: Calculations
APPLICATION: Turbine fuels
SCOPE: Two sets of equations are explored. Relations of aniline point, API°, volume % aromatics, volumetric average of D 86 distillation data to heat of combustion. Also hydrogen content is related to aniline point, API°, volume fraction aromatics, volumetric average of D 86 data.
LIMITATIONS: The two equations may be manipulated to predict heat of combustion from hydrogen content. Care must be taken to choose base equations for optimum precision and accuracy.

HYDROGEN CONTENT (Cont'd)

TEST:
REFERENCE: P-70
DESCRIPTION: Hydrogen content of hydrocarbon fuels by a low-resolution magnetic resonance method
TEST METHOD: NMR
APPLICATION: Liquid petroleum fuels
SCOPE: Determination of hydrogen content.
LIMITATIONS: Good agreement with calculated values for petroleum fuels but may differ for synfuels for which calculations have not been established.

TEST:
REFERENCE: G-24
DESCRIPTION: Determination of hydrocarbon-type distribution and hydrogen/carbon ratio of gasoline by nuclear magnetic resonance spectrometry
TEST METHOD: NMR
APPLICATION: Petroleum gasoline
SCOPE: Determination of volume percent aromatics, paraffins, and olefins, and H/C ratio using equations involving integrals of chemical shift regions. Results compared to FIA analyses.
LIMITATIONS: Approximately 1% absolute standard deviation for class determinations. Approximately 12 minutes total analysis time if only spectrum integrals are recorded and a digital integrator used to print out peak areas.

ICING INHIBITOR CONTENT

TEST:
REFERENCE: P-67
DESCRIPTION: Identification of freezing point depressant anti-icing additives in hydrogen fuels by infrared spectrometry
TEST METHOD: IR
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of icing inhibitors.
LIMITATIONS: Extraction technique somewhat critical for quantitative removal. Hydrogen bonding will have affect on spectra especially for methyl cellosolve.

TEST: 5237.3
REFERENCE: P-93
DESCRIPTION: Fuel system icing inhibitor in hydrocarbon fuels (iodometric method)
TEST METHOD: Titration
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of ethylene glycol monomethyl ether.
LIMITATIONS: Applicable to concentration range of 0.05-0.20 vol%.

ICING INHIBITOR CONTENT (Cont'd)

TEST: 5330.1
REFERENCE: P-93
DESCRIPTION: Fuel system icing inhibitor in hydrocarbon fuels (color-metric method)
TEST METHOD: Wet
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of ethylene glycol methyl ether and glycerol mixtures in fuel.
LIMITATIONS: Applicable to concentration range of 0.04-0.16 vol%.

TEST: 5340.1
REFERENCE: P-93
DESCRIPTION: Fuel system icing inhibitor in hydrocarbon fuels (refractometer method)
TEST METHOD: Refractometer
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of ethylene glycol monomethyl ether and glycerine mixture in fuel.
LIMITATIONS: Applicable to concentration range of 0.05-0.20 vol%.

IGNITION IMPROVER CONTENT

TEST:
REFERENCE: P-103, P-8
DESCRIPTION: Detection of nitrate-type ignition improvers in diesel fuel
TEST METHOD: Filter dish
APPLICATION: Diesel
SCOPE: Determination of presence of nitrate-type cetane improver.
LIMITATIONS: Qualitative only.

IGNITION LIMIT

TEST:
REFERENCE: P-1
DESCRIPTION: Ignition limit of fire-safe fuels
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Ignition limit of fuel by measuring apparatus.
LIMITATIONS: Instrumentation gives some drift, hysteresis, etc. and calibration is necessary.

IRON CONTENT

TEST:
REFERENCE: S-35
DESCRIPTION: Mossbauer spectroscopy in coal and coal hydrogenation products
TEST METHOD: Mossbauer spectroscopy
APPLICATION: Coal liquid
SCOPE: Determination of iron compounds.
LIMITATIONS: Actual method not provided. Trouble in distinguishing some compounds.

TEST:
REFERENCE: P-104
DESCRIPTION: Method for determination of iron in JP-9 fuels
TEST METHOD: AA
APPLICATION: Turbine fuels
SCOPE: Determination of iron compounds.
LIMITATIONS: None given.

KNOCK CHARACTER

TEST: D 2699
REFERENCE: P-98
DESCRIPTION: Knock characteristics of motor fuels by the research method
TEST METHOD: Engine
APPLICATION: Motor gasolines
SCOPE: Research octane number (RON) of fuels for spark ignition engines
LIMITATIONS: Care must be taken in starting and stopping the engine. Adjustments must be made to optimize knock intensity.

TEST: D 2700
REFERENCE: P-98
DESCRIPTION: Knock characteristics of motor and aviation fuels by the motor method
TEST METHOD: Engine
APPLICATION: Avgas, motor gasolines
SCOPE: Motor octane number (MON) of fuels for spark ignition engines.
LIMITATIONS: (Same as D 2699).

TEST: D 2886
REFERENCE: P-98
DESCRIPTION: Knock characteristics of motor fuels by the distribution method
TEST METHOD: Engine
APPLICATION: Avgas, motor gasolines
SCOPE: Distribution octane number (DON) of fuels for spark ignition engines.
LIMITATIONS: (Same as D 2699).

KNOCK CHARACTER (Cont'd)

TEST: D 2885
REFERENCE: P-98
DESCRIPTION: Research and motor octane ratings using on-line analyzers
TEST METHOD: Automatic analyzers
APPLICATION: Motor gasolines
SCOPE: Determination of antiknock quality.
LIMITATIONS: Prototype fuel must be used as standard. Both fuels must be at same temperature. Equations must be used for octane number differences.

TEST: D 909
REFERENCE: P-98
DESCRIPTION: Knock characteristics of aviation fuels by the supercharge method
TEST METHOD: Engine
APPLICATION: Avgas
SCOPE: Supercharge octane number of aviation gasoline-spark ignition type.
LIMITATIONS: Method restricted to testing fuels of 85 ASTM SON and over. (Others same as D 2699).

TEST:
REFERENCE: G-1
DESCRIPTION: Octane-cetane relationship of motor gasoline
TEST METHOD: Equations
APPLICATION: Gasoline
SCOPE: Linear relationship between octane and cetane number of automotive gasoline.
LIMITATIONS: Equations determined empirically. Wide variance in gasoline types.

TEST:
REFERENCE: P-4
DESCRIPTION: Research octane number of motor gasoline
TEST METHOD: GLC, equation
APPLICATION: Petroleum gasoline
SCOPE: Relation of research octane number to volume fractions, weight fractions, volume octane number, and weight octane number by hydrocarbon groups detected by GLC.
LIMITATIONS: The weight and/or vapor blending octane numbers of hydrocarbon groups must be estimated by means of multiple regression analysis from many gasoline samples.

LEAD CONTENT

TEST: D 3237
REFERENCE: P-96
DESCRIPTION: Lead in gasoline by atomic absorption spectrometry
TEST METHOD: AA
APPLICATION: Gasoline
SCOPE: Determination of total lead content of gasoline.
LIMITATIONS: Applicable to concentration range of 2.5-25 mg/liter only and is not specific to lead alkyl type.

TEST: D 3341
REFERENCE: P-96
DESCRIPTION: Lead in gasoline--iodine monochloride method
TEST METHOD: Titration
APPLICATION: Gasoline
SCOPE: Determination of total lead content of gasoline.
LIMITATIONS: Applicable to concentration range of 26-1300 mg/liter only and is not specific to lead alkyl type.

TEST: D 3229
REFERENCE: P-96
DESCRIPTION: Low levels of lead in gasoline by x-ray spectrometry
TEST METHOD: X-ray spectrometry
APPLICATION: Gasoline
SCOPE: Determination of total lead content of gasoline.
LIMITATIONS: Applicable to concentration range of 10-500 mg/liter only and is not specific to lead alkyl type.

TEST: D 3116
REFERENCE: P-96
DESCRIPTION: Trace amounts of lead in gasoline
TEST METHOD: VIS
APPLICATION: Gasoline
SCOPE: Determination of total lead content of gasoline.
LIMITATIONS: Applicable to concentration range of 0.264-26.4 mg/liter only and is not specific to lead alkyl type.

TEST: D 3348
REFERENCE: P-96
DESCRIPTION: Rapid field test for trace lead in unleaded gasoline (colorimetric method)
TEST METHOD: Colorimetry
APPLICATION: Gasoline
SCOPE: Determination of total lead content of unleaded gasoline.
LIMITATIONS: Applicable to concentration range of 2.64-26.4 mg/liter only and is not specific to lead alkyl type.

LEAD CONTENT (Cont'd)

TEST: D 2547
REFERENCE: P-95
DESCRIPTION: Lead in gasoline-volumetric chromate method
TEST METHOD: Wet
APPLICATION: Gasoline
SCOPE: Determination of total lead content of gasoline and other volatile distillates blended with lead alkyls.
LIMITATIONS: Applicable to concentration range of 50-11,000 mg/liter only and is not specific to lead alkyl type.

TEST: D 2599
REFERENCE: P-95
DESCRIPTION: Lead in gasoline by x-ray spectrometry
TEST METHOD: X-ray spectrometry
APPLICATION: Gasoline
SCOPE: Determination of total lead content of gasoline.
LIMITATIONS: Applicable to concentration range of 26-1,321 mg/liter only and is not specific to lead alkyl type.

TEST: D 2787
REFERENCE: P-95
DESCRIPTION: Lead and vanadium in gas turbine fuels
TEST METHOD: VIS
APPLICATION: Turbine fuel
SCOPE: Determination of lead and vanadium content.
LIMITATIONS: Care must be taken while handling reagents.

TEST: D 1368
REFERENCE: P-94
DESCRIPTION: Trace concentrations of lead in primary reference fuels
TEST METHOD: VIS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of lead content.
LIMITATIONS: Applicable to concentration range of 1-3 mg/liter only and is not specific to lead alkyl type.

TEST:
REFERENCE: G-18
DESCRIPTION: Determination of tetraethyllead in gasolines by high-performance liquid chromatography
TEST METHOD: HPLC/UV
APPLICATION: Gasoline
SCOPE: Determination of tetraethyllead content.
LIMITATIONS: Short analysis time, sensitive to concentrations as low as 10 mg/imperial gallon. However, although applicable to analysis of other alkylleads, the response factors differ appreciably. Therefore, the method is of no value unless the compound types (lead) present in the sample have been qualitatively assessed.

LEAD CONTENT (Cont'd)

TEST:
REFERENCE: P-31
DESCRIPTION: Atomic absorption spectroscopy used as a specific gas chromatography detector in the determination of lead alkyl types.
TEST METHOD: GC/AA, GC/Furnace
APPLICATION: Gasoline
SCOPE: Comparison of flame and graphite furnace techniques in the determination of tetraalkyllead compounds.
LIMITATIONS: Some tetraalkyllead compounds can react with higher homologs in the column and appear as baseline drifts, so use of an integrator may be tricky. Small variety of lead compounds gives GC/AA the advantage being a fast technique. Larger number of varieties makes GC/furnace useful for detection of these compounds outside the detection limit.

TEST:
REFERENCE: G-2
DESCRIPTION: Analysis of gasoline for antiknock agents with a hydrogen atmosphere flame ionization detector
TEST METHOD: GC/HAFID
APPLICATION: Gasoline
SCOPE: Determination of lead alkyl types.
LIMITATIONS: Good separation due to HAFID and dilution of sample.

TEST:
REFERENCE: P-8
DESCRIPTION: Determination of small amounts of lead in fuels
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of lead content.
LIMITATIONS: Applicable to concentration range of 1-20 mg/liter, not applicable to fuels containing metal salts capable of producing sulfides. Not specific to lead alkyl type.

TEST:
REFERENCE: G-15
DESCRIPTION: Determination of lead alkyls in gasoline; a combined gas chromatographic-flame photometric method
TEST METHOD: GC, FPD
APPLICATION: Gasoline
SCOPE: Determination of lead alkyl types.
LIMITATIONS: None given.

LIQUID HEAT CAPACITY

TEST: D 2890
REFERENCE: P-95
DESCRIPTION: Calculation of liquid heat capacity of petroleum distillate fuels
TEST METHOD: Calculation
APPLICATION: Liquid petroleum fuels
SCOPE: Graphical correlation of Watson characterization factor and distillation data to calculate liquid heat capacity.
LIMITATIONS: Applicable only at temperatures greater than 0°F and no higher than 60°F above the volumetric average boiling point of the fuel.

TEST: D 2766
REFERENCE: P-95
DESCRIPTION: Specific heat of liquids and solids
TEST METHOD: Calorimetry, potentiometry
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of heat capacity or specific heat.
LIMITATIONS: Sample must be compatible with stainless steel and have vapor pressure greater 100 Torr and cannot undergo phase transformation throughout test temperature range.

LUBRICITY

TEST:
REFERENCE: S-38
DESCRIPTION: Lubricity of aircraft fuel emulsions
TEST METHOD: Apparatus
APPLICATION: Fuel emulsions
SCOPE: Wear preventative characteristics of fuel emulsions.
LIMITATIONS: Temperature and time modifications necessary.

TEST:
REFERENCE: T-16
DESCRIPTION: Lubricity characteristics of JP-5 fuels
TEST METHOD: BOCM
APPLICATION: JP-5 and other turbine fuels
SCOPE: Wear preventative characteristics of turbine fuel.
LIMITATIONS: None given.

TEST:
REFERENCE: T-19
DESCRIPTION: Antiwear properties of reactive fuels
TEST METHOD: Apparatus
APPLICATION: Turbine fuel
SCOPE: Antiwear character of fuel mixtures as a function of temperature.
LIMITATIONS: None given.

LUBRICITY (Cont'd)

TEST:
REFERENCE: P-22
DESCRIPTION: Wear characteristics--hydrocarbons
TEST METHOD: 4-Ball tester, equations
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Wear value in relation to carbon number of hydrocarbon types.
LIMITATIONS: Coefficients are derived from pure compounds therefore, compound-type analysis must be made prior to application of equations.

METALS CONTENT (TRACE QUANTITIES)

TEST: D 2788
REFERENCE: P-95
DESCRIPTION: Trace metals in gas turbine fuels
TEST METHOD: AA
APPLICATION: Turbine fuels
SCOPE: Determination of calcium, lead, magnesium potassium, sodium, and vanadium content.
LIMITATIONS: Vanadium analysis requires nitrous oxide-acetylene flame. Calibration curve tedious. Sample may have to be diluted to lower viscosity. Precision of method is still under study.

TEST: D 3605
REFERENCE: P-96
DESCRIPTION: Trace metals in gas turbine fuels by atomic absorption and flame emission spectroscopy
TEST METHOD: AA, FE
APPLICATION: No. 1 and No. 2 gas turbine fuels
SCOPE: Determination of sodium lead, calcium, and vanadium content.
LIMITATIONS: For oil-soluble metals only, not for waterborne contaminants in oil-water emulsions.

TEST:
REFERENCE: P-54
DESCRIPTION: Determination of the vanadium content of hydrotreated petroleum residues by visible spectrometry
TEST METHOD: VIS
APPLICATION: Hydrotreated residual liquid fuels
SCOPE: Determination of vanadium content.
LIMITATIONS: Chemical rearrangements may cause shift of non-vanadium molecules to wavelength used for analysis.

METALS CONTENT (TRACE QUANTITIES) (Cont'd)

TEST:
REFERENCE: P-28
DESCRIPTION: Computer controlled system for the automatic neutron activation analysis of vanadium in petroleum with a Californium-252 source
TEST METHOD: Analyzer, computer
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of vanadium content.
LIMITATIONS: Large samples advisable for homogeneity. Calibration curve must be prepared for each fuel type.

TEST: D 3831
REFERENCE: P-96
DESCRIPTION: Manganese in gasoline by atomic absorption spectrometry
TEST METHOD: AA
APPLICATION: Gasoline
SCOPE: Determination of total manganese content.
LIMITATIONS: Applicable to concentration range of 0.25-30 mg/liter.

TEST:
REFERENCE: S-37
DESCRIPTION: Tentative method for determination of sodium and potassium in emulsified JP-4 fuels
TEST METHOD: AA
APPLICATION: Fuel emulsions
SCOPE: Determination of sodium and potassium content.
LIMITATIONS: Accuracy of method has not been established as of March 1969, method not fully adopted as of March 1969.

MOLAR SPECIFIC VOLUME

TEST:
REFERENCE: D-3
DESCRIPTION: Molar specific volume of diesel fuel
TEST METHOD: Equation
APPLICATION: Diesel fuel
SCOPE: Function relating the volume of a fuel to a specific temperature at a specific pressure.
LIMITATIONS: Extrapolation necessary for specific volume at critical point.

MOLECULAR WEIGHT

<u>TEST:</u>	G-10
<u>REFERENCE:</u>	G-10
<u>DESCRIPTION:</u>	Calculation of average molecular weight
<u>TEST METHOD:</u>	Equation, GC
<u>APPLICATION:</u>	Liquid petroleum fuels
<u>SCOPE:</u>	Calculation of average molecular weight relating density, volume, and molecular weight of components.
<u>LIMITATIONS:</u>	Component analysis must be performed first such as qualitative and quantitative GC. May possibly be applicable to synthetic fuels.
<u>TEST:</u>	D 2503
<u>REFERENCE:</u>	P-95
<u>DESCRIPTION:</u>	Molecular weight of hydrocarbons by thermoelectric measurement of vapor pressure
<u>TEST METHOD:</u>	Osmometer
<u>APPLICATION:</u>	Heavy burner fuel
<u>SCOPE:</u>	Determination of average molecular weight of hydrocarbon oils.
<u>LIMITATIONS:</u>	Applicable to fractions with molecular weights up to 3000 although precision has not been established above 800 M.W. Not applicable to fractions with IBP less than 221°C.
<u>TEST:</u>	676
<u>REFERENCE:</u>	P-112
<u>DESCRIPTION:</u>	Molecular weight by osmometry
<u>TEST METHOD:</u>	Osmometer
<u>APPLICATION:</u>	Heavy burner fuel
<u>SCOPE:</u>	Determination of average molecular weight.
<u>LIMITATIONS:</u>	Same as in ASTM D 2503.
<u>TEST:</u>	375
<u>REFERENCE:</u>	P-112
<u>DESCRIPTION:</u>	Calculation of UOP characterization factor and estimation of molecular weight of petroleum oils
<u>TEST METHOD:</u>	Calculation
<u>APPLICATION:</u>	Liquid hydrocarbon fuels
<u>SCOPE:</u>	Estimation of characterization factor and average molecular weight.
<u>LIMITATIONS:</u>	Molecular weight calculation not applicable to pure hydrocarbons.

NITRILES CONTENT

TEST:
REFERENCE: P-30
DESCRIPTION: Nitriles in hydrocarbon liquids
TEST METHOD: GC/MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of nitriles content.
LIMITATIONS: Detection limit of 50 ng injected.

NITROGEN CONTENT

TEST:
REFERENCE: P-18
DESCRIPTION: Distribution profiles of nitrogen compounds in petroleum by solid-liquid chromatography
TEST METHOD: SLC, UV
APPLICATION: Liquid hydrocarbon fuels
SCOPE: THF and hexane eluents used in SLC. Nitrogen content checked with UV.
LIMITATIONS: Useful for analysis of complex products but is a slow procedure.

TEST:
REFERENCE: P-5
DESCRIPTION: A consideration of standardization of analytical method for determination of total nitrogen in fuel oils
TEST METHOD: Wet, microcoulometry
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Discussion-evaluation of Kjeldahl, Dumas, and micro-coulometric methods of quantitative nitrogen compound analysis.
LIMITATIONS: Large errors due to large samples needed. Low sensitivity to some nitrogen-containing groups. Instrumental parameters critical.

TEST:
REFERENCE: P-6
DESCRIPTION: Statistical design for the optimization of the nitrogen-phosphorus gas chromatographic detector response
TEST METHOD: GC/FIA, GC/NPD
APPLICATION: Liquid hydrocarbon fuels, (hydrocarbon matrix)
SCOPE: Flame ionization and nitrogen-phosphorus detectors compared as to nitrogen detection efficiency. Detector responses analyzed statistically.
LIMITATIONS: FID loses sensitivity to nitrogen-containing compounds, NPD gains sensitivity.

NITROGEN CONTENT (Cont'd)

TEST:
REFERENCE: S-36
DESCRIPTION: Combined gas chromatographic-mass spectrometric analyses of nitrogen bases in light oil from a coal liquifaction product
TEST METHOD: GC/MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Analysis of pyridines, quinolines, and anilines using GC/MS.
LIMITATIONS: None given.

TEST:
REFERENCE: S-6
DESCRIPTION: Qualitative analysis of shale oil acids and bases by porous-layer open tubular gas chromatography and interfaced vapor phase infrared spectrophotometry
TEST METHOD: GC/IR, MS
APPLICATION: Shale oil, shale oil products
SCOPE: Determination of types of shale oil acids and bases. Computerized mass spec for identification of substituted phenolics and pyridine bases, quinolines, and anilines.
LIMITATIONS: GC/IR advantageous over GC/MS with which some ions are difficult to distinguish due to close similarity.

TEST:
REFERENCE: P-51
DESCRIPTION: Characterization of nitrogen bases in high-boiling petroleum distillates
TEST METHOD: GPC, IR, FS, MS, Titrimeter
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Assessment of nitrogen bases by separation and multiple analyses. Total nitrogen data.
LIMITATIONS: Multiple analysis is for the purpose of obtaining total nitrogen data only.

TEST:
REFERENCE: S-3
DESCRIPTION: Determination of the nitrogen content of shale oil furnace oil by refractometry
TEST METHOD: Refractometer
APPLICATION: Synthetic liquid burner fuel
SCOPE: Refractive index of sample is measured, nitrogen is determined by Kjeldahl method, relation is established.
LIMITATIONS: Method applicable only to concentration range established by calibration curve. Care must be taken on establishing this curve due to interfering species. New curve needed for each sample.

NITROGEN CONTENT (Cont'd)

TEST: D 3228
REFERENCE: P-96, P-2
DESCRIPTION: Total nitrogen in lubricating oils by modified Kjeldahl method
TEST METHOD: Titration, apparatus
APPLICATION: Liquid synthetic fuels
SCOPE: Determination of nitrogen in oil.
LIMITATIONS: Applicable to concentration range of 0.03-0.10 wt%.
Not applicable to materials containing N-O or N-N linkage.

TEST: E 258
REFERENCE: P-106, P-2
DESCRIPTION: Total nitrogen in organic materials by modified Kjeldahl method (synthetic fuels)
TEST METHOD: Titration, apparatus
APPLICATION: Liquid synthetic fuels
SCOPE: Determination of nitrogen in oil.
LIMITATIONS: Applicable to concentration of 0.03-0.10 wt%.
Not applicable to materials containing N-O or N-N linkages.

TEST: E 258
REFERENCE: P-106, P-2
DESCRIPTION: Total nitrogen in organic materials by modified Kjeldahl method (hydrogen and methyl fuels)
TEST METHOD: Titration, apparatus
APPLICATION: Liquid hydrogen fuels, methyl fuel
SCOPE: Determination of total nitrogen.
LIMITATIONS: Not applicable to materials containing N-O or N-N linkages.

TEST:
REFERENCE: S-50
DESCRIPTION: Gas chromatography-mass spectroscopy analyses; nitrogen heterocyclics in coal liquids
TEST METHOD: GC/MS, FID
APPLICATION: Coal liquids
SCOPE: Determination of nitrogen heterocyclics content.
LIMITATIONS: As of the data of report, validity has been shown only, calibration curves and reproducibility not given.

NITROGEN CONTENT (Cont'd)

TEST:

REFERENCE: P-107

DESCRIPTION: Coulometric determination of aromatic nitrogen compounds with electrogenerated chromium (II).

TEST METHOD: Coulometry

APPLICATION: Liquid hydrocarbon fuels

SCOPE: Determination of aromatic nitro compounds by reduction.

LIMITATIONS: Partial reoxidation of reduced species could be responsible for some positive errors. $\pm 1\%$ precision and accuracy established.

TEST:

REFERENCE: P-30

DESCRIPTION: Heterocyclic nitrogen compounds in hydrocarbon liquids

TEST METHOD: GC/MS

APPLICATION: Liquid hydrocarbon fuels

SCOPE: Determination of nitrogen-containing aliphatic ring compounds.

LIMITATIONS: Detection limit of 10 ng injected.

TEST:

REFERENCE: S-10

DESCRIPTION: Determination of nitrogen compound distribution in petroleum by gas chromatography with a thermionic detector.

TEST METHOD: GC

APPLICATION: Liquid hydrocarbon fuels

SCOPE: Nitrogen compound determination, comparison with microcoulometry.

LIMITATIONS: NPD-FID working simultaneously give best results, better than microcoulometry.

TEST:

REFERENCE: P-47

DESCRIPTION: GC nitrogen analysis by MS detector

TEST METHOD: GC, MS

APPLICATION: Liquid hydrocarbon fuels

SCOPE: Sample is introduced to GC then to MS set at resolution 3000 such that particular nitrogen-containing fragment ions can be monitored at a nominal mass value.

LIMITATIONS: Applicable to nitrogen compounds with N-C-H bonding only.

NITROGEN CONTENT (Cont'd)

TEST:
REFERENCE: P-33
DESCRIPTION: Mass spectrographic analysis of N and O compounds in petroleum
TEST METHOD: MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: MS analysis of N, O, S compounds and aromatics
LIMITATIONS: Impossible to indicate magnitude of errors as reliable independent methods are not available. Due to complexity of most samples, corrections for hydrocarbon fractionation have not been incorporated into a general program thus estimated oxygen content tends to be low and hydrocarbon content high.

OXYGEN CONTENT

TEST: E 385
REFERENCE: P-108
DESCRIPTION: Oxygen content using a 14-Mev neutron activation and direct-counting technique
TEST METHOD: Neutron generator
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Oxygen content of liquids of the multicomponent type.
LIMITATIONS: Irradiation, delay and counting sequence is major source of error.

TEST: D 3176
REFERENCE: P-109, P-2
DESCRIPTION: Ultimate analysis of coal and coke
TEST METHOD: Equations
APPLICATION: Coal, coke
SCOPE: Oxygen content on as-determined, as received and dry bases.
LIMITATIONS: Estimation only, may aid in analysis of coal-derived fuels.

TEST:
REFERENCE: T-15
DESCRIPTION: Dissolved oxygen in aircraft fuel
TEST METHOD: Bomb
APPLICATION: Turbine
SCOPE: Dissolved oxygen content.
LIMITATIONS: Sampling technique very critical.

OXYGEN CONTENT (Cont'd)

TEST: RK-63-R
REFERENCE: P-60
DESCRIPTION: Determination of dissolved oxygen in liquid hydrocarbons by gas chromatography
TEST METHOD: GC
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of dissolved oxygen content.
LIMITATIONS: Relationship of standard deviation to concentration is not linear. Accuracy of method has not been established.

TEST: 678
REFERENCE: P-112
DESCRIPTION: Dissolved molecular oxygen in oils by the Beckman "Oxygen Analyzer"
TEST METHOD: Polarography
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of dissolved oxygen content.
LIMITATIONS: Applicable to concentration range of 1-200 wt ppm. Measurement must be made on flowing stream sample.

TEST:
REFERENCE: P-30
DESCRIPTION: Heterocyclic oxygen compounds in hydrocarbon liquids
TEST METHOD: GC/MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of oxygen-containing aliphatic ring compounds.
LIMITATIONS: Detection limit of 10 ng injected.

TEST:
REFERENCE: P-48
DESCRIPTION: Oxygen determination by reaction-frontal GC
TEST METHOD: GC
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Sample is pyrolyzed. Oxygen-containing products converted to CO and H₂ and produced CO is converted to CO₂ and H₂O which is analyzed by frontal GC
LIMITATIONS: Different substances render different actual blank values which can cause systematic errors so constant blank values must be established for sample analysis.

OXYGEN CONTENT (Cont'd)

TEST:
REFERENCE: P-33
DESCRIPTION: Mass spectrographic analysis of N and O compounds in petroleum
TEST METHOD: MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: MS analysis of N, O, S compounds and aromatics
LIMITATIONS: Impossible to indicate magnitude of errors as reliable independent methods are not available. Due to complexity of most samples, corrections for hydrocarbon fractionation have not been incorporated into a general program thus estimated oxygen content tends to be low and hydrocarbon content high.

PERFORMANCE CHARACTER

TEST:
REFERENCE: D-13
DESCRIPTION: Use of the jet fuel thermal oxidation tester for predicting diesel fuel performance
TEST METHOD: JFTOT
APPLICATION: Diesel
SCOPE: Performance quality fuel measured by pressure drop.
LIMITATIONS: Can distinguish between fuels well but is time-consuming.

PEROXIDE CONTENT

TEST: D 3703
REFERENCE: P-96
DESCRIPTION: Peroxide number of aviation fuels
TEST METHOD: Titration
APPLICATION: Turbine fuel
SCOPE: Determination of peroxide content.
LIMITATIONS: Returning endpoint type, blue color must disappear for at least 30 seconds.

TEST:
REFERENCE: G-8
DESCRIPTION: Determination of hydroperoxides in petroleum products
TEST METHOD: Reflux, titration
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of hydroperoxide content (hydroperoxide number).
LIMITATIONS: Reducing agents in gasolines may give negative numbers, technique provided to offset this.

PEROXIDE CONTENT (Cont'd)

TEST:
REFERENCE: P-21
DESCRIPTION: Determination of peroxides by I₂ liberation procedures
TEST METHOD: Reflux, titration
APPLICATION: Middle and heavy distillate types
SCOPE: Five methods, each with slight modifications of the other, are given for determinations of various types of organic peroxides. The methods vary as to their application to various peroxides and avoidance of interfering species.
LIMITATIONS: The methods provided should be considered as a group in total analysis as to different peroxide compounds, thus qualitative assessment of peroxide types in the samples may be necessary as a preliminary step. It is possible that equipment setup modifications may facilitate analysis of lighter sample fractions.

PHOSPHORUS CONTENT

TEST: D 3231
REFERENCE: P-96
DESCRIPTION: Phosphorus in gasoline
TEST METHOD: VIS
APPLICATION: Gasoline
SCOPE: Determination of phosphorus content of gasoline.
LIMITATIONS: Applicable to concentration range of 0.2-40 mg/liter. Hydrazine sulfate reagent very unstable.

TEST:
REFERENCE: G-22
DESCRIPTION: Direct determination of phosphorus in gasoline by flameless atomic absorption spectrometry
TEST METHOD: AA, furnace
APPLICATION: Gasoline
SCOPE: Determination of phosphorus content.
LIMITATIONS: Sensitive to 20 ng/90 microliter.

POUR POINT

TEST: D 97
REFERENCE: P-94
DESCRIPTION: Pour point of petroleum oils
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Pour point determination (flow characteristics).
LIMITATIONS: Calibration of thermometer necessary.

PROPAGATION RATE

TEST:
REFERENCE: S-38
DESCRIPTION: Propagation rate of fuel emulsions
TEST METHOD: Wet
APPLICATION: Fuel emulsions, liquid hydrocarbon fuels
SCOPE: Time taken for flame to completely cover surface of fuel.
LIMITATIONS: None given.

RADIATION INTENSITY

TEST: D 1740
REFERENCE: P-95
DESCRIPTION: Luminometer number of aviation turbine fuels
TEST METHOD: Apparatus, equation
APPLICATION: Turbine fuel
SCOPE: Measurement of flame radiation. Correlation with smoke point.
LIMITATIONS: Fuels with high luminometer number may form condensation in apparatus. Fuels with low luminometer number smoke at low readings.

REFRACTIVE INDEX/DISPERSION

TEST: D 1218
REFERENCE: P-94
DESCRIPTION: Refractive index and refractive dispersion of hydrocarbon liquids
TEST METHOD: Refractometer, apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Measurements of refractive index and refractive dispersion.
LIMITATIONS: Sample must be transparent or light colored with refractive index from 1.33-1.50 at temperatures from 20°-30°C (68°-86°F). Sample may not have color darker than ASTM #4 or a bubble point near test temperature.

TEST:
REFERENCE: S-3
DESCRIPTION: Determination of the nitrogen content of shale oil furnace oil by refractometry
TEST METHOD: Refractometer
APPLICATION: Synthetic liquid burner fuel
SCOPE: Refractive index of sample is measured, nitrogen is determined by kjeldahl method, relation is established.
LIMITATIONS: Method applicable only to concentration range established by calibration curve. Care must be taken on establishing this curve due to interfering species. New curve needed for each sample.

SAPONIFICATION NUMBER

TEST: D 94
REFERENCE: P-94
DESCRIPTION: Saponification number of petroleum products
TEST METHOD: Titration
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of amount of saponifiable constituents.
LIMITATIONS: Some compounds in used samples will consume alkali and acids thus yielding a higher value.

SILTING INDEX

TEST: 5350
REFERENCE: P-93
DESCRIPTION: Silting index of hydrocarbon fuels
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Silting tendency resulting from foreign matter.
LIMITATIONS: Rating method only.

SMOKE POINT

TEST: D 1322
REFERENCE: P-94
DESCRIPTION: Smoke point of aviation turbine fuels
TEST METHOD: Lamp
APPLICATION: Turbine fuel
SCOPE: Determination of maximum flame height which can be achieved without smoking, correlation with luminometer number.
LIMITATIONS: Calibration of apparatus or correction factor for sample-standard must be used.

TEST:
REFERENCE: P-29
DESCRIPTION: Relations between hydrocarbon-type composition of various kerosene distillates and their properties
TEST METHOD: Equation, displacement chromatography, MS
APPLICATION: Petroleum based diesel and turbine fuels
SCOPE: Relation of smoke to aromatic and naphthenic content.
LIMITATIONS: Statistical analysis for kerosene distillates.

SOLUBILITY OF GASES IN FUELS

TEST: D 2779
REFERENCE: P-95
DESCRIPTION: Estimation of solubility of gases in petroleum liquids
TEST METHOD: Equations
APPLICATION: Liquid petroleum fuels
SCOPE: Estimation of equilibrium solubility of some common bases.
LIMITATIONS: Density of sample must be between 0.63 and 0.90 at 15.5°C(60°F). Accuracy at 95% confidence level is $\pm 13\%$ of estimated Ostwald coefficient for air.

TEST: D 3827
REFERENCE: P-120
DESCRIPTION: Estimation of solubility of gases in petroleum and other organic liquids
TEST METHOD: Equations
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Estimation of equilibrium solubility of some common gases.
LIMITATIONS: Limited to systems in which polarity and hydrogen bonding are minor. Estimates for fuels are less accurate than those for lubricants.

TEST:
REFERENCE: P-75
DESCRIPTION: Determination of the solubility of gases in low-boiling liquids
TEST METHOD: GC, apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of solubility of non-reactive gases in hydrocarbon liquids.
LIMITATIONS: Accuracy of $\pm 2\%$. Method applicable to liquid which boil below 0°C but may be modifiable.

SPECIFIC COMPOUNDS

TEST:
REFERENCE: P-113
DESCRIPTION: Direct coupling of a liquid chromatograph to a continuous flow hydrogen nuclear magnetic resonance detector for analysis of petroleum and synthetic fuels
TEST METHOD: LC/NMR
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Composition determination by continuous analysis.
LIMITATIONS: Detector sensitivity somewhat limited. Choice of appropriate solvent is limited.

SPECIFIC COMPOUNDS (Cont'd)

TEST:
REFERENCE: P-104
DESCRIPTION: Analysis of grade JP-9 by gas chromatography
TEST METHOD: GC
APPLICATION: JP-9, JP-10
SCOPE: Quantitative determination of the three major constituents of JP-9; methylcyclohexane, norbornadiene, cyclopentadiene.
LIMITATIONS: Response factor needed for each.

TEST:
REFERENCE: S-1
DESCRIPTION: Gel permeation chromatography of coal-derived products with on-line infrared detection.
TEST METHOD: GPC/IR
APPLICATION: Coal liquid, Products
SCOPE: GPC separates coal liquid into rough molecular fractions each of which in turn is characterized according to functional groups by IR.
LIMITATIONS: Compound classification only, not specific to compound type.

TEST:
REFERENCE: S-27
DESCRIPTION: Determination of individual organic compounds in shale oil
TEST METHOD: Wet, HPLC, GC, GC/MS
APPLICATION: Shale Oil
SCOPE: Acid/base extraction and HPLC separation followed by HPLC analysis of fractions obtained. GC and GC/MS analysis of compounds in unfractionated shale oil.
LIMITATIONS: GC/MS analysis of straight sample has great advantage over GC internal standard method and preparatory extraction/separation techniques.

SPECIFIC GRAVITY

TEST: D 1217
REFERENCE: P-94
DESCRIPTION: Density and specific gravity of liquids by Bingham pycnometer
TEST METHOD: Pycnometer
APPLICATION: Diesel, turbine fuels
SCOPE: Measurement of density or specific gravity.
LIMITATIONS: Sample must boil between 90-110°C (194-230°F).

SPECIFIC GRAVITY (Cont'd)

TEST: D 941
REFERENCE: P-94
DESCRIPTION: Density and specific gravity of liquids by Lipkin bicapillary pycnometer
TEST METHOD: Pycnometer
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Measurement of density or specific gravity.
LIMITATIONS: Sample must have a vapor pressure of less than 600 mm Hg and a viscosity of less than 15 cSt at 20°C.

TEST:
REFERENCE: P-29
DESCRIPTION: Relations between hydrocarbon-type composition of various kerosene distillates and their properties
TEST METHOD: Equation
APPLICATION: Kerosene distillates
SCOPE: Relation between specific gravity, smoke point, and total aromatic and naphthenic content.
LIMITATIONS: Statistical analysis of data.

TEST: D 891
REFERENCE: P-97
DESCRIPTION: Specific gravity of industrial aromatic hydrocarbons and related materials.
TEST METHOD: Balance, hydrometer, pycnometer
APPLICATION: Methyl fuel
SCOPE: Determination of specific gravity.
LIMITATIONS: None given.

SPONTANEOUS HEATING VALUE

TEST: D 3523
REFERENCE: P-96
DESCRIPTION: Spontaneous heating values of liquids and solids (differential Mackey test)
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Non-adiabatic determination of spontaneous heating value. Qualitative indication of degree of self heating which may occur due to sample exposure.
LIMITATIONS: Applicable to samples which are not completely volatile at test temperature.

STABILITY, HYDROLYTIC

TEST: 3457.1
REFERENCE: P-93
DESCRIPTION: Hydrolytic stability of finished oil
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of resistance of a finished oil for fuel to reaction when in contact with water.
LIMITATIONS: Qualitative overall but some weight changes and value changes can be assessed.

STABILITY, LOW TEMPERATURE

TEST: 3459
REFERENCE: P-93
DESCRIPTION: Low temperature stability of finished fluid blends
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of gelling, crystallization, or solidification.
LIMITATIONS: Inspection test only.

STABILITY, OXIDATION

TEST: D 873
REFERENCE: P-94
DESCRIPTION: Oxidation stability of aviation fuels (potential residue method)
TEST METHOD: Bomb
APPLICATION: Avgas, motor gasoline, turbine fuel
SCOPE: Deposit forming tendencies under accelerated aging conditions. Indicative of storage stability.
LIMITATIONS: None given.

TEST: D 2274
REFERENCE: P-95
DESCRIPTION: Oxidation stability of distillate fuel oil (accelerated method)
TEST METHOD: Apparatus
APPLICATION: Burner, diesel, turbine fuels
SCOPE: Insolubles-forming tendency.
LIMITATIONS: Correlation between the test and field storage may vary significantly.

TEST: D 525
REFERENCE: P-94
DESCRIPTION: Oxidation stability of gasoline (induction period method)
TEST METHOD: Bomb
APPLICATION: Gasoline
SCOPE: Stability of gasoline (breakpoint determination).
LIMITATIONS: (Same as D 2274).

STABILITY, TEMPERATURE

TEST:
REFERENCE: S-37
DESCRIPTION: Temperature stability of emulsified fuels
TEST METHOD: Wet
APPLICATION: Fuel emulsions
SCOPE: Determination of highest and lowest temperature at which an emulsified fuel remains in the thickened state.
LIMITATIONS: None given.

STABILITY, THERMAL

TEST: D 1660
REFERENCE: P-94
DESCRIPTION: Thermal stability of aviation turbine fuels
TEST METHOD: Coker
APPLICATION: Turbine fuel
SCOPE: Tendency to deposit decomposition products.
LIMITATIONS: Acceptability on pass-fail basis.

TEST:
REFERENCE: T-6
DESCRIPTION: Research recommendations for testing jet fuel thermal stability
TEST METHOD: Various
APPLICATION: Turbine fuel
SCOPE: Procedure for thermal stability research.
LIMITATIONS: Merely a set of directions. Nothing standardized.

TEST: 3466
REFERENCE: P-93
DESCRIPTION: Thermal stability of low volatility gas turbine aviation fuels
TEST METHOD: Coker
APPLICATION: Turbine fuel
SCOPE: Tendency to deposit decomposition products. Flow rate and pressure differ from these of ASTM D 1660.
LIMITATIONS: Pass-fail method only.

TEST:
REFERENCE: P-60
DESCRIPTION: Thermal stability of hydrocarbon fuels
TEST METHOD: Bomb, VIS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of threshold failure temperature as an indication of stability.
LIMITATIONS: Good correlation with coker method for fuels having stability below 475°F.

STABILITY, THERMAL (Cont'd)

TEST:
REFERENCE: P-39
DESCRIPTION: Procedures for evaluating the stability of distillate fuel oils
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Two accelerated tests for determining the thermal stability of a fuel.
LIMITATIONS: Inspection tests only.

TEST: 500
REFERENCE: P-93
DESCRIPTION: Induction system deposit (ISD) tendencies of motor gasoline
TEST METHOD: Apparatus
APPLICATION: Gasoline
SCOPE: Determination of motor gasolines to form deposits in the induction system region of spark-ignition engines.
LIMITATIONS: None given.

TEST:
REFERENCE: G-3
DESCRIPTION: A bench technique for evaluating the induction system deposit tendencies of motor gasolines.
TEST METHOD: Apparatus
APPLICATION: Petroleum gasolines, possibly synthetic
SCOPE: Bench apparatus sprays fuel onto a heated tube whose weight change represents deposit tendencies.
LIMITATIONS: Correlatable to but not necessarily representative of deposit tendencies of gasoline in an engine.

STABILITY, THERMAL OXIDATIVE

TEST: D 3241
REFERENCE: P-96
DESCRIPTION: Thermal oxidation stability of aviation turbine fuels (JFTOT procedure)
TEST METHOD: JFTOT
APPLICATION: Turbine fuel
SCOPE: Tendency to deposit decomposition products within fuel system.
LIMITATIONS: Precision data have not yet been established.

STABILITY, THERMAL OXIDATIVE (Cont'd)

TEST:
REFERENCE: T-14
DESCRIPTION: Determination of the effect of pretest ratings of jet fuel thermal oxidation tester tubes on post-test ratings using the tube deposit rater.
TEST METHOD: JFTOT, TDR
APPLICATION: Turbine fuel
SCOPE: Deposit tendencies using a more precise tube rater.
LIMITATIONS: Calibration method needed for low tube ratings.

TEST:
REFERENCE: T-5
DESCRIPTION: Thermal oxidative stability test for JPTS jet fuel
TEST METHOD: JFTOT
APPLICATION: Turbine fuel
SCOPE: Deposit tendency measurement using different temperature and pressure than ASTM D 3241.
LIMITATIONS: The effect of pressure changes near the fuel bubble point are large and tend to scatter data. Also, some pressure effects well above bubble point. These phenomena are not yet clearly understood.

STABILITY, VIBRATION

TEST:
REFERENCE: S-38
DESCRIPTION: Vibration stability of fuel emulsions
TEST METHOD: Vibration machine
APPLICATION: Fuel emulsions
SCOPE: Penetration measured before and after vibration.
LIMITATIONS: None given.

SULFUR CONTENT

TEST: D 1323
REFERENCE: P-94
DESCRIPTION: Mercaptan sulfur in aviation turbine fuels (amperometric and potentiometric methods)
TEST METHOD: Amperometric and potentiometric titrations
APPLICATION: Turbine fuels
SCOPE: Determination of mercaptan sulfur.
LIMITATIONS: Applicable to concentration range of 0.003-0.01 wt% mercaptan sulfur. Elemental sulfur greater than 0.005 wt% will interfere. Hydrogen sulfide will interfere, removal procedure provided.

SULFUR CONTENT (Cont'd)

<u>TEST:</u>	D 3227
<u>REFERENCE:</u>	P-96
<u>DESCRIPTION:</u>	Mercaptan sulfur in gasoline, kerosene, aviation turbine, and distillate fuels
<u>TEST METHOD:</u>	Potentiometric titration
<u>APPLICATION:</u>	Liquid hydrocarbon fuels
<u>SCOPE:</u>	(See SULFUR CONTENT Test D 1323)
<u>LIMITATIONS:</u>	(See SULFUR CONTENT Test D 1323)
<u>TEST:</u>	D 2785
<u>REFERENCE:</u>	P-95
<u>DESCRIPTION:</u>	Trace quantities of total sulfur (Wickbold and Beckman combustion apparatus)
<u>TEST METHOD:</u>	Apparatus, titration
<u>APPLICATION:</u>	Liquid hydrocarbon fuels
<u>SCOPE:</u>	Determination of total sulfur.
<u>LIMITATIONS:</u>	Applicable to concentration range of 2-25 ppm in volatile liquids. Sample must not contain more than 1000 ppm halogens, 2 ppm barium, 0.01 ppm lead or appreciable ash-forming substances. Primarily for organic liquids.
<u>TEST:</u>	D 1552
<u>REFERENCE:</u>	P-94
<u>DESCRIPTION:</u>	Sulfur in petroleum products
<u>TEST METHOD:</u>	Furnace, apparatus
<u>APPLICATION:</u>	Diesel, turbine, and burner fuels
<u>SCOPE:</u>	Two procedures for determination of total sulfur.
<u>LIMITATIONS:</u>	Sample must boil about 177°C(350°F) and contain not less than 0.06% sulfur. Nitrogen in excess of 0.1% may interfere.
<u>TEST:</u>	D 1266
<u>REFERENCE:</u>	P-94
<u>DESCRIPTION:</u>	Sulfur in petroleum products (lamp method)
<u>TEST METHOD:</u>	Apparatus, titration, gravimetric analysis
<u>APPLICATION:</u>	Liquid hydrocarbon fuels
<u>SCOPE:</u>	Determination of total sulfur.
<u>LIMITATIONS:</u>	Applicable to concentrations above 0.002 wt% sulfur although a procedure is provided for concentrations down to 5 ppm. Blending procedure provided as high sulfur content products cannot be burned satisfactorily. High concentrations of acid or base-forming elements will interfere with titrations. Correction provided for small acid concentration formed from combustion of lead antiknock fluids.

SULFUR CONTENT (Cont'd)

TEST: D 129
REFERENCE: P-94
DESCRIPTION: Sulfur in petroleum products (general bomb method)
TEST METHOD: Bomb
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of total sulfur
LIMITATIONS: Restricted to samples of low volatility that do not produce residues which are insoluble in dilute hydrochloric acid. Sample cannot contain lead compounds.

TEST: D 2622
REFERENCE: P-95
DESCRIPTION: Sulfur in petroleum products (x-ray spectrographic method)
TEST METHOD: X-ray spectrometer
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of total sulfur.
LIMITATIONS: Applicable concentration range will vary to some extent depending on sample nature and instrumentation used. At best, sulfur can be determined in essentially paraffinic samples at concentrations greater than 0.0010 wt%.

TEST:
REFERENCE: G-17
DESCRIPTION: Determination of total sulfur in gasoline by gas chromatography with a flame photometric detector
TEST METHOD: GC/FPD
APPLICATION: Gasoline
SCOPE: Determination of total sulfur.
LIMITATIONS: Imprecision in small sample injection volume is main source of error. Response of FPD is low, but fortunately is constant.

TEST:
REFERENCE: P-56
DESCRIPTION: Determination of hydrogen sulfide, carbonyl sulfide, and sulfur dioxide in gases and hydrocarbon streams by gas chromatography/flame photometric detection.
TEST METHOD: GC/FPD
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of sulfur compounds.
LIMITATIONS: Due to interference and overlapping, several different columns must be used for identification of the four compounds. Major source of error in determination is in emission and flow rates of the diluent gas. H_2S and SO_2 show more variability than COS and CS_2 due to reactivity of those compounds.

SULFUR CONTENT (Cont'd)

TEST:
REFERENCE: P-7
DESCRIPTION: Determination of sulfur by electrolytic conductivity type analyzer
TEST METHOD: GC/analyzer
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of sulfur content by combustion of sample and ratio of SO_2/CO_2 produced.
LIMITATIONS: Presence of some hydrocarbon types; particularly aromatics, can affect the carbon/hydrogen ratio and introduce small errors (analyzer assumes constant mass). Analysis time app. 15 min/sample.

TEST: 600
REFERENCE: P-93
DESCRIPTION: Ditertiary-butyl disulfide in reference diesel fuels
TEST METHOD: TLC
APPLICATION: Diesel fuel
SCOPE: Determination of DTBDS in reference diesel.
LIMITATIONS: Qualitative with sensitivity of 0.035 wt% sulfur.

TEST:
REFERENCE: P-92
DESCRIPTION: Sulfur FPD flow optimization and response normalization with a variable exponential function device
TEST METHOD: GC/FPD, equations
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of sulfur content.
LIMITATIONS: Proportionally factor is critically dependent upon flow parameters of the detector flame.

TEST:
REFERENCE: P-88
DESCRIPTION: Determination of carbon dioxide, hydrogen sulfide, sulfur dioxide, ethane, and propane using a carbon molecular sieve column
TEST METHOD: GC
APPLICATION: Petroleum combustion products
SCOPE: Determination of sulfur light hydrocarbons, carbon dioxide.
LIMITATIONS: Combustion products only.

TEST:
REFERENCE: P-52
DESCRIPTION: Determination of low levels of sulfur in organics by combustion microcoulometry
TEST METHOD: Combustion microcoulometry
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of sulfur compounds, a recommended procedure compared with a pyrolysis procedure.
LIMITATIONS: None given.

SULFUR CONTENT (Cont'd)

TEST:
REFERENCE: P-30
DESCRIPTION: Mercaptans, sulfides, and disulfides in hydrocarbon liquids
TEST METHOD: GC/MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Sulfur compounds determination.
LIMITATIONS: Detection limit of 50 ng injected.

TEST:
REFERENCE: P-30
DESCRIPTION: Heterocyclic sulfur compounds in hydrocarbon liquids
TEST METHOD: GC/MS
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of sulfur-containing aliphatic ring compounds.
LIMITATIONS: Detection limit of 10 ng injected.

TEST:
REFERENCE: P-43
DESCRIPTION: Hydrogenolysis of thiophene and acyclic sulfur on Raney nickel
TEST METHOD: Apparatus, GC
APPLICATION: Known hydrocarbon mixtures only
SCOPE: Model sulfur compounds undergo hydrogenolysis, reaction products which identify compounds are analyzed by GC.
LIMITATIONS: Not applicable to unknown hydrocarbon mixtures or multicomponent hydrocarbon fluids (such as fuels) where interferences have not been researched.

TEST:
REFERENCE: P-46
DESCRIPTION: Sulfur compound characterization on high-boiling petroleum fractions
TEST METHOD: Distillation apparatus, MS
APPLICATION: Burner fuels - petroleum, probably synthetic
SCOPE: Heavier ends are obtained by subjecting crude oil to isothermal distillation, vacuum fractionation, molecular and bruch still distillation. Seven resulting fractions and residue are analyzed by mass spectrometry for sulfur types.
LIMITATIONS: Method applied to heavy ends but may be applicable to lighter fractions of petroleum and synthetic crudes.

SULFUR CONTENT (Cont'd)

TEST:

REFERENCE: G-23

DESCRIPTION: Sulfur group determination in straight-run gasolines by potentiometry

TEST METHOD: Potentiometry

APPLICATION: Straight-run petroleum gasolines

SCOPE: Three methods discussed for the determination of mercaptan/elemental, disulfide, and sulfide sulfur.

LIMITATIONS: Free sulfur is determined by first potential change with mercaptan content estimated by difference. Mercaptan and disulfide interface in sulfide determination and must be subtracted out, however, analysis at low temperatures will help eliminate this inconvenience.

TEST:

REFERENCE: P-33

DESCRIPTION: Mass spectrographic analysis of N and O compounds in petroleum

TEST METHOD: MS

APPLICATION: Liquid hydrocarbon fuels

SCOPE: MS analysis of N, o, S compounds and aromatics

LIMITATIONS: Impossible to indicate magnitude of errors as reliable independent methods are not available. Due to complexity of most samples, corrections for hydrocarbon fractionation have not been incorporated into a general program thus estimated oxygen content tends to be low and hydrocarbon content high.

TEST:

REFERENCE: S-5

DESCRIPTION: Determination of elemental sulfur in bitumen

TEST METHOD: Wet, extraction, UV

APPLICATION: Tar sand bitumen only

SCOPE: Elemental sulfur is extracted with naphtha then diluted with cyclohexane and read on UV at 262 nm. An extraction of S⁰ from cyclohexane is performed with aqueous Na₂S and read at 262 nm. A calibration curve for each method was preconstructed, and the differential absorption at this wavelength is related to the amount of elemental sulfur in the sample.

LIMITATIONS: Cyclohexane portion can be measured with reasonable accuracy, however, heating and cooling the sodium sulfide solution results in some color change and unpredictable dissolution rendering quantitative interpretation rather uncertain.

SULFUR CONTENT (Cont'd)

TEST:
REFERENCE: P-42
DESCRIPTION: Sulfur compound distribution in petroleum by reactor or pyrolysis GC with a sulfur detector
TEST METHOD: Pyrolyzer, dealkylation reaction, GC
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Dealkylation of condensed thiophenes by catalytic reactor or noncatalytic pyrolysis. Nonthiophenic converted to H_2S in same manner and all analyzed by GC.
LIMITATIONS: With the catalytic reactor, all H_2S is deposited on metal ports disallowing separation of nonthiophenes. However, peak area provides data in relative weight percent and can be normalized to 100%. With pyrolyzer, above 790°C increasing the temperature yields decreasing recoverable sulfur.

TEST:
REFERENCE: P-32
DESCRIPTION: Elemental sulfur analysis by high-speed liquid chromatography
TEST METHOD: LC with styrene-divinylbenzene-packed columns
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Elemental sulfur is retained quantitatively on column packing until all other components have eluted.
LIMITATIONS: Presence of large quantities of hydrogen sulfide will interfere due to trailing effect in column no problem with small quantities.

TEMPERATURE, CRITICAL

TEST: D 2889
REFERENCE: P-95
DESCRIPTION: Calculation of true vapor pressures of petroleum distillate fuels
TEST METHOD: Estimation from curve
APPLICATION: Liquid petroleum fuels
SCOPE: Estimation of critical temperature from bubble point curve and known true vapor pressure.
LIMITATIONS: Estimation only, practicability questionable.

TEMPERATURE, DECOMPOSITION

TEST: D 2879
REFERENCE: P-95
DESCRIPTION: Vapor pressure-temperature relationship and initial decomposition temperature of liquids by isoteniscope
TEST METHOD: Isoteniscope
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of decomposition temperature of mixed hydrocarbons and its relationship to vapor pressure.
LIMITATIONS: Liquids must be compatible with borosilicate glass and have a vapor pressure between 1.0 Torr and 760 Torr.

TEMPERATURE, REACTION THRESHOLD

TEST: D 2883
REFERENCE: P-95
DESCRIPTION: Reaction threshold temperature of liquid and solid materials
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Pre-flame, cool flame and hot flame R.T.T. and incipient reaction temperature.
LIMITATIONS: Cooperative data not available for statement of precision at present time.

TENSION, INTERFACIAL

TEST: D 2285
REFERENCE: P-95
DESCRIPTION: Interfacial tension of electrical insulating oils of petroleum origin against water by the drop-weight method.
TEST METHOD: Tensiometer
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Tension of oil or fuel against water.
LIMITATIONS: Sludge interferes.

TEST: D 971
REFERENCE: P-94
DESCRIPTION: Interfacial tension of oil against water by the ring method
TEST METHOD: Tensiometer
APPLICATION: Liquid hydrocarbons fuels, oils
SCOPE: Tension of oil or fuel against water, indication of hydrophilic compounds.
LIMITATIONS: Apparatus may need calibration for ring used.

TENSION, SURFACE

TEST: D 3825
REFERENCE: P-96
DESCRIPTION: Dynamic surface tension by the fast-bubble technique
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of specific free energy of liquid-gas surface.
LIMITATIONS: Applicable to liquids with vapor pressures up to 225 Torr (30 kPa) and kinematic viscosities up to 4.0 mm²/s (4.0 cSt) at the test temperature.

VAPOR PRESSURE

TEST:
REFERENCE: P-122
DESCRIPTION: Application of GC distillation to motor gasoline blending
TEST METHOD: GC, equations
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Equations relating boiling point and vol% of a fraction to RVP.
LIMITATIONS: Correction factor amounts to RVP of about 0.1 unit difference from experimentally determined RVP.

TEST: D 2889
REFERENCE: P-95
DESCRIPTION: Calculation of true vapor pressure of petroleum products distillate fuels
TEST METHOD: Calculation
APPLICATION: Liquid petroleum fuels
SCOPE: Calculation of true vapor pressure based on ASTM D 86 distillation data and critical temperature.
LIMITATIONS: Method not applicable to samples which reach decomposition temperature prior to 90% distillation point or have a boiling range of less than 100°F between the 10% and 90% distilled temperatures.

TEST: D 2551
REFERENCE: P-95
DESCRIPTION: Vapor pressure of petroleum products (micromethod)
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of total pressure exerted in vacuo by air-containing, volatile, nonviscous petroleum products at preselected V/L ratios and temperatures. Correlation with Reid vapor pressure.
LIMITATIONS: Applicable within the range of 34.-117 kPa. Apparatus must be able to measure small samples within 1% sensitivity. Different correlation factors differ for different units, especially for a multiunit apparatus.

VAPOR PRESSURE (Cont'd)

TEST: D 323
REFERENCE: P-94
DESCRIPTION: Vapor pressure of petroleum products (Reid method)
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels, oxygenated liquid hydrocarbon fuels, methyl fuel
SCOPE: Determination of the absolute vapor pressure of volatile nonviscous petroleum products.
LIMITATIONS: None given.

TEST:
REFERENCE: P-129
DESCRIPTION: Reid vapor pressure of hydrocarbon mixtures
TEST METHOD: Equation
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Equation for partial pressures of components in a mixture. Total gives RVP.
LIMITATIONS: None given.

TEST:
REFERENCE: P-130
DESCRIPTION: Continuous on-stream analysis of boiling characteristics of petroleum fractions
TEST METHOD: Monitor
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Boiling point monitor for continuous analysis from which calibration curves for prediction of RVP, V/L, etc. may be constructed.
LIMITATIONS: Calibration curves are not given, the equations must be developed.

TEST:
REFERENCE: P-45
DESCRIPTION: Estimation of vapor pressure of petroleum from GC data
TEST METHOD: GC, calculations
APPLICATION: Petroleum distillate fractions, possibly synthetic-based fuels also
SCOPE: GC gives fractions of components from which mole fractions, partial pressures, and total pressures are calculated.
LIMITATIONS: Modifications necessary for very light and very heavy ends.

VAPOR/LIQUID RATIO

TEST: D 2533
REFERENCE: P-95
DESCRIPTION: Vapor-liquid ratio of gasoline
TEST METHOD: Apparatus
APPLICATION: Gasoline
SCOPE: Measurement of vapor volume from a given volume of gasoline at atmospheric pressure.
LIMITATIONS: Temperature of bath must be carefully controlled.

TEST: D 439
REFERENCE: P-94
DESCRIPTION: Estimating temperature V/L values (spec. for gasoline)
TEST METHOD: Calculations
APPLICATION: Petroleum gasoline
SCOPE: Three methods of estimation given for V/L. Computer method, linear equation method, nomogram method, relation to distillation data and Reid vapor pressure also given.
LIMITATIONS: Not applicable to all gasoline blending stocks or specially blended fuels. To be used only when D 2533 is inconvenient.

TEST:
REFERENCE: P-4
DESCRIPTION: Vapor/liquid ratio of motor gasoline
TEST METHOD: Equations
APPLICATION: Petroleum gasoline
SCOPE: Two equations given to aid in the estimation of V/L ratio. Relates vapor pressure, atmospheric pressure, moles of vapor and liquid, and sample volume to V/L ratios.
LIMITATIONS: Computer optimized relation. May be modifiable for V/L=20 since it is given as V/L=36.

TEST:
REFERENCE: G-16
DESCRIPTION: Analyzer for determining fuel vaporization pressure curves of gasoline and gasoline-alcohol fuels
TEST METHOD: Analyzer
APPLICATION: Gasoline/alcohol blends
SCOPE: Pressure change as a function of sample vaporization is measured. V/L and RVP may be determined.
LIMITATION: Too small sample will distort linearity of curve.

VAPOR/LIQUID RATIO (Cont'd)

TEST: 1011
REFERENCE: P-93
DESCRIPTION: Vapor-liquid ratio of gasoline (alternate method)
TEST METHOD: Nomograph
APPLICATION: Petroleum gasoline
SCOPE: Determination of V/L ratio from RVP and distillation data.
LIMITATIONS: Approximation only.

TEST:
REFERENCE: P-121
DESCRIPTION: V/L ratios of pure hydrocarbon mixtures
TEST METHOD: Equations
APPLICATION: Liquid hydrocarbon fuel
SCOPE: Appendix provides an equation for estimating V/L=20 at 120°F and 130°F from mole fraction of components.
LIMITATIONS: Activity corrections must be interpolated from given table for vol% aromatics.

VAPORIZATION PRESSURE

TEST:
REFERENCE: G-16
DESCRIPTION: Analyzer for determining fuel vaporization pressure curves of gasoline and gasoline-alcohol fuels
TEST METHOD: Analyzer
APPLICATION: Gasoline/alcohol blends
SCOPE: Pressure change as a function of sample vaporization is measured. V/L and RVP may be determined.
LIMITATIONS: Too small sample will distort linearity of curve.

VISCOSITY

TEST: D 445
REFERENCE: P-94
DESCRIPTION: Kinematic viscosity of transparent and opaque liquids and the calculation of dynamic viscosity
TEST METHOD: Viscometer, calculation
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of kinematic viscosity, calculation of dynamic viscosity, relation to density.
LIMITATIONS: Temperature and timing critical.

VISCOSITY (Cont'd)

TEST: D 2161
REFERENCE: P-95
DESCRIPTION: Conversion of kinematic viscosity to Saybolt Universal viscosity or to Saybolt Furol viscosity
TEST METHOD: Equations, tables
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Conversion of viscosity units. Computer calculation provided.
LIMITATIONS: None given.

TEST:
REFERENCE: S-25
DESCRIPTION: Flow properties of coal/water/oil emulsion
TEST METHOD: Apparatus
APPLICATION: Coal/water/oil emulsions
SCOPE: No detailed procedure. Mention of comparison of apparatus, Poiseuille equation.
LIMITATIONS: 1% error due to pressure and collection techniques.

TEST:
REFERENCE: S-29
DESCRIPTION: Viscosity measurement of coal liquid
TEST METHOD: Viscometer
APPLICATION: Coal liquid
SCOPE: Viscosity determination with modified Brookfield viscometer.
LIMITATIONS: Viscosity of samples over 300 cP increases with time while being tested.

TEST:
REFERENCE: S-38
DESCRIPTION: Viscosity of emulsified aircraft fuel (JP-4) (modified ASTM D 1092)
TEST METHOD: Viscometer
APPLICATION: Fuel emulsions
SCOPE: Viscosity determination using smaller capillary diameter.
LIMITATIONS: Unknown to date.

VISCOSITY (Cont'd)

TEST: D 88
REFERENCE: P-110
DESCRIPTION: Saybolt viscosity of liquid hydrocarbon fuels
TEST METHOD: Viscometer
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of viscosity.
LIMITATIONS: Sample may need preheating.

TEST:
REFERENCE: S-14
DESCRIPTION: Equations for estimating bulk properties of kerosene fuels
TEST METHOD: Equations
APPLICATION: Kerosene fuels
SCOPE: Estimation of viscosity from D 2887 data.
LIMITATIONS: Long equation to which data must be fitted.

TEST:
REFERENCE: P-133
DESCRIPTION: Predicting viscosity of crude oil fractions
TEST METHOD: Equations
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Several equations provided, one in particular is useful relating viscosity to free energy of activation of viscous flow.
LIMITATIONS: Sketchy, not all parameters explained well.

TEST:
REFERENCE: S-13
DESCRIPTION: Viscosity of coal-derived liquids.
TEST METHOD: Wet, viscometer, equations
APPLICATION: Middle and higher boiling liquid hydrocarbon mixtures.
SCOPE: Viscosity changes of coal-derived liquids as function of concentration of asphaltenes, pentene and toluene insolubles, etc.
LIMITATIONS: No mention as to a test for purity.

WATER AND SEDIMENT

TEST: D 2709
REFERENCE: P-95
DESCRIPTION: Water and sediment in distillate fuels by centrifuge
TEST METHOD: Centrifuge
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of free water and sediment.
LIMITATIONS: Temperature control critical. Precision of method has not been determined.

WATER AND SEDIMENT (Cont'd)

TEST: D 1796
REFERENCE: P-95
DESCRIPTION: Water and sediment in crude oils and fuel oils by centrifuge
TEST METHOD: Centrifuge
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of water and sediment content.
LIMITATIONS: Temperature control critical.

WATER CONTENT

TEST: D 95
REFERENCE: P-94
DESCRIPTION: Water in petroleum products and bituminous materials by distillation
TEST METHOD: Distillation apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of water content.
LIMITATIONS: Not applicable to bitumenous emulsions.

TEST: D 1744
REFERENCE: P-95
DESCRIPTION: Water in liquid petroleum products by Karl Fischer reagent
TEST METHOD: Apparatus, titration
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Determination of water content.
LIMITATIONS: Applicable to concentration range of 50-1000 ppm. Free alkali, oxidizing and reducing agents, mercaptans, some basic nitrogen compounds, or other materials which react with iodine will interfere.

TEST: D 3240
REFERENCE: P-96
DESCRIPTION: Undissolved water in aviation turbine fuels
TEST METHOD: Apparatus
APPLICATION: Turbine fuels
SCOPE: Measurement of undissolved water.
LIMITATIONS: Amount of free water in sample is sensitive to temperature and may adhere on container walls thus giving inaccurate rating. Additives in fuel may affect calibration of test.

WATER CONTENT (Cont'd)

TEST: E 203
REFERENCE: P-106
DESCRIPTION: Water using Karl Fischer reagent
TEST METHOD: Apparatus, titration
APPLICATION: Methyl fuel
SCOPE: Measurement of free water and water of hydration.
LIMITATIONS: Concentration of reagent, titration technique, apparatus, quantity of water titration and nature of material being analyzed all have some bearing upon sensitivity, precision, and accuracy.

TEST:
REFERENCE: P-111
DESCRIPTION: Removal of water in the distillation of hydrocarbon mixtures
TEST METHOD: Wet
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Removal of water prior to or during distillation.
LIMITATIONS: Not highly quantitative.

TEST:
REFERENCE: P-68
DESCRIPTION: Water content in turbine fuel by detector
TEST METHOD: Apparatus
APPLICATION: Petroleum turbine fuels
SCOPE: Determination of water content by UV illumination.
LIMITATIONS: Water contents that do not match any of the standards must be interpolated. Method may be applicable to synthetic turbine fuels.

WATER OF COMBUSTION

TEST:
REFERENCE: G-10
DESCRIPTION: Prediction of water of combustion from gasoline compositional analysis
TEST METHOD: Equations, GC
APPLICATION: Petroleum gasoline
SCOPE: Prediction of water of combustion from FIA and PONA analysis, composition of gasoline being first established by GC.
LIMITATIONS: Statistical analysis by multiple regression. Standard errors must be considered.

WATER REACTION

TEST: D 1094
REFERENCE: P-94
DESCRIPTION: Water reaction of aviation fuels
TEST METHOD: Wet
APPLICATION: Avgas, turbine fuels
SCOPE: Determination of presence of water-miscible components.
LIMITATIONS: Qualitative test only--based on appearance.

WATER SEPARATION

TEST: D 2550
REFERENCE: P-95 (ASTM)
DESCRIPTION: Water separation characteristics of aviation turbine fuels
TEST METHOD: Water separometer
APPLICATION: Turbine fuels
SCOPE: Measurement of ease with which a fuel will release entrained or emulsified water when passed through a coalescing medium. Measures presence of surfactant agents.
LIMITATIONS: Some fuels may develop electrostatic charge which will require nitrogen blanket during testing.

TEST: 3255.2
REFERENCE: P-93
DESCRIPTION: Water separation characteristics of aviation turbine fuels
TEST METHOD: Water separometer
APPLICATION: Turbine fuels
SCOPE: Ability of fuel to release entrained or emulsified water. Use of separation index as rating of this ability.
LIMITATIONS: Electrostatic charge buildup is possible unless special care is taken.

WATER TOLERANCE

TEST:
REFERENCE: P-101
DESCRIPTION: Test method for determining the water tolerance of gasohol.
TEST METHOD: Wet, apparatus
APPLICATION: Gasoline/oxygenate blends
SCOPE: Determination of gasohol absorbance of water.
LIMITATIONS: Sample must be transparent in layers 38 mm thick and have a cloud point below 49°C(120°F).

WATER TOLERANCE (Cont'd)

TEST:
REFERENCE: P-114
DESCRIPTION: Proposed water tolerance test for gasohol
TEST METHOD: Wet
APPLICATION: Gasoline/oxygenate blends
SCOPE: Determination of gasohol absorbance of water. Equation relating vol% aromatics and wt% water content to cloud point, and a pass/fail field test are provided.
LIMITATIONS: Must be run in laboratory where sample could be exposed to large temperature differential which may cause phase separation on test jar. Sample must not be agitated to equilibrate temperature as some methanol will not resolubilize.

WAX APPEARANCE POINT

TEST: D 3117
REFERENCE: P-96
DESCRIPTION: Wax appearance point of distillate fuels
TEST METHOD: Apparatus
APPLICATION: Liquid hydrocarbon fuels
SCOPE: Detection of separated solids.
LIMITATIONS: Applicable range of $(-26 \rightarrow +2)^{\circ}\text{C}$ $(-15 \rightarrow +35)^{\circ}\text{F}$. Not applicable to oils through which stirrer cannot be seen.

YIELD STRESS

TEST:
REFERENCE: S-38
DESCRIPTION: Modified yield stress method
TEST METHOD: Apparatus
APPLICATION: Fuel emulsions
SCOPE: Yield stress of aircraft fuel emulsion.
LIMITATIONS: Accuracy and reproducibility not yet fully assessed.

TEST:
REFERENCE: S-37
DESCRIPTION: Method for determining the yield stress of emulsified JP-4 fuels by cone penetration
TEST METHOD: Penetrometer
APPLICATION: Fuel emulsions
SCOPE: Yield stress of fuel emulsions by low and room temperature methods, worked and related methods.
LIMITATIONS: None given.

APPENDIX B

**LIST OF REFERENCES ACCORDING TO CATEGORY
WITH RETRIEVAL CODES**

LIST OF REFERENCES ACCORDING TO CATEGORY WITH
RETRIEVAL CODES

List of References According to Category D
With Retrieval Codes

D-001. Redundant or otherwise unuseful candidate references were rejected, and for this reason not all reference numbers appear in sequence. Although the bulk of obtained literature is listed, acquisition of literature is still continuing. These sources, when obtained and reviewed, will be assigned numbers to replace those missing.

D-002. Creason, A., Miller, G.M., Kelley, P., Foster, W.E., "Diesel Fuel Filterability Study, MFA Oil Co., Columbia, MO, February 1973.

WET

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D-003. Williams, T.J., "Diesel Fuel Properties for Combustion Calculations," University of Wales Institute of Science and Technology, International Journal of Mechanical Science, Vol. 13, pp 803-12, July 1971.

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D-004. Hanlon, J.V., Maxwell, W.B., Ponder, R.M., "The Development and Application of Predictive Systems for Diesel Fuel Quality presented at National Fuels and Lubricants Meeting, September 17-18, 1969, New York City, NY," Ethyl Corporation, Ferndale, MI, National Petroleum Refiners Association, Washington, DC, September 1969.

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D-005. Frame, E.A., "High-Sulfur Fuel Effects in a Two-Cycle, High-Speed Army Diesel Engine, AFLRL No. 105," U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, May 1978.

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D-006. Moffitt, J.V., Owens, E.C., Wright, B.R., Weatherford, W.D., Jr., "Diesel Engine Endurance Test With Water-Containing Fire-Resistant Fuel, AFLRL No. 94," U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, September 1979.

000

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SYN

D-007. Owens, E.C., Wright, B.R., "Engine Performance and Fire-Safety Characteristics of Water-Containing Diesel Fuels, AFLRL Report No. 83," U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, December 1976.

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D-008. Johnston, A.A., Springer, K., Johnson, D., Newman, F.M., "Toxicity of Engine Exhaust Gases Diesel-Bromochloromethane Fuel Blend, AFLRL No. 51," U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, February 1975.

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D-011. Tyler, J.C., Gray, J.T., Weatherford, W.D., Jr., "An Investigation of Diesel Fuel Composition--Exhaust Emission Relationships," U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, October 1974.

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D-012. Fodor, G.E., Newman, F.M., "The Application of High-Performance Liquid Chromatography to the Analysis of Petroleum Materials. Part 2. Quantitative Hydrocarbon-Type Analysis of Middle Distillate Fuels," U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, May 1975.

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D-013. LePera, M.E., McCaleb, F., "Use of the Jet Fuel Thermal Oxidation Tester (JFTOT) for Predicting Diesel Fuel Performance," U.S. Army Mobility Equipment Research and Development Command, Fort Belvoir, VA, March 1978.

JFT

DEL
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D-014. Irish, G.E., "Letter to Mr. D.K. Lawrence, Amoco Oil Co., Naperville, IL," Union Oil Co. of California, Brea, CA, April 1980.

ENG

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D-015. Stavinocha, L.L., Newman, F.M., "Design and Evaluation of Diesel Exhaust Processors for the Analysis of CO and UBH with Vortex Concentration Sensors, AFLRL No. 45 (Final Report)," U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, October 1974.

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D-016. Baker, L.A., "Alternate Fuels for Medium-Speed Diesel Engines, SAE Technical Paper Series #800330," Southwest Research Institute, San Antonio, TX, Society of Automotive Engineers, Inc., Warrendale, PA, February 1980.

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D-017. Nagalingam, B., Sridhar, B.T., Panchapakesan, W.R., Gopalakrishnan, K.V., Murthy, B.S., "Surface Ignition Initiated Combustion of Alcohol in Diesel Engines--A New Approach, SAE Technical Paper Series #800262," Internal Combustion Engines Lab, Indian Institute of Technology, Madras, India, Society of Automotive Engineers, Inc., Warrendale, PA, February 1980.

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D-018. Purohit, G.P., Housman, J., "Gasification of Diesel Fuel for a Low-Emission, High Efficiency System, SAE Technical Paper Series #800264," Jet Propulsion Laboratory, California Institute of Technology, Society of Automotive Engineers, Inc., Warrendale, PA, February 1980.

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SYN

D-019. Tuteja, A.D., Clark, D.W., "Comparative Performance and Emission Characteristics of Petroleum, Oil Shale, and Tar Sands Derived Diesel Fuels, SAE Technical Paper Series #800331," Detroit Diesel Allison, Detroit, MI, Society of Automotive Engineers, Inc., Warrendale, PA, February 1980.

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D-020. Author Unknown, "ASTM Standard Specification for Diesel Fuel Oils, D 975," American Society for Testing and Materials, 1916 Race St., Philadelphia, PA, 1979 Annual Book of ASTM Standards, Part 23, 1979.

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D-021. Berg, P.S., Holmes, E., Bertilsson, B.I., "The Utilization of Different Fuels in a Diesel Engine With Two Separate Injection Systems," Volvo Truck Corp., Goteborg, Sweden, Proceedings to the Third International Symposium on Alcohol Fuels Technology, Alisomar, CA, pp II-29, 1-8, May 1979.

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- G-001. Bowden, J.N., "Octane-Cetane Relationship AFLRL Report No. 33," U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, March 1974.

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- G-002. DuPuis, M.D., Hill, H.H., "Analysis of Gasoline for Antiknock Agents with a Hydrogen Atmosphere Flame Ionization Detector," Department of Chemistry, Washington State University, Pullman, WA, Analytical Chemistry, Vol. 51, No. 2, pp 292-5, February 1979.

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- G-003. Johnston, A.A., Dimitroff, E., "A Bench Technique for Evaluating the Induction System Deposit Tendencies of Motor Gasolines," U.S. Army Fuel and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, Society of Automotive Engineers, Inc., New York, NY, Presented at Fuels and Lubricants Meeting, Houston, TX, November 1966.

- G-004. Stavinoha, L.L., "Internal Standards for the Isolation and Determination of Aromatics in Motor Gasolines, AFLRL Report No. 22," U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, February 1973.

GC

GLN

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- P-060: Program to determine factors responsible for JP fuel storage instability. Small scale thermal stability test procedure. Stability is related to dissolved oxygen in fuel. Thermal stability quality of a West Texas hydrotreated kerosene investigated.
51. Baker, L.A., Alternate Fuels for Medium-Speed Diesel Engines, SAE Technical Paper Series #800330, Southwest Research Institute, San Antonio, TX, Society of Automotive Engineers, Inc., Warrendale, PA, February 1980.

- D-016: Tests were performed on a two-stroke medium-speed test engine in an attempt to define the ability of this engine class to operate on alternate fuels. Cetane number, viscosity, and distillation range were varied independently of other properties by blending various fuel components. No single fuel property could be classified as the primary variable affecting performance and emissions but rather the combined influence of several variables.
52. Baudino, J.H., Chloupek, F.J., Crowley, A.W., Analyzer for Determining Fuel Vaporization Pressure Curves of Gasoline and Gasoline-Alcohol Fuels, Atlantic Richfield Co., Harvey Technical Center, Harvey, IL, Analytical Chemistry, Vol. 49, No. 4, pp 2368-71, December 1977.
- G-016: An analyzer was developed for measuring a nonequilibrium volatility characteristic of fuels while the sample vaporizes under conditions of constant volume, temperature, and initial reduced pressure. The characteristic is the pressure increase with time resulting from vaporization.
53. Bayer, F.L., Goodley, P.C., Gordon, M., Rapid Gas Chromatographic Separation of Diastereomeric Dihalo-Butanes, Pentanes, and Hexanes, Department of Chemistry, Murray State University, Murray, KY, Journal of Chromatographic Science, Vol. 11, pp 443-6, August 1973.
- P-079: Separation of various diastereomeric isomers by use of different GC columns.
54. Bechtold, R., Pullman, B., Driving Cycle Comparisons of Energy Economies and Emissions From an Alcohol and Gasoline Fueled Vehicle, U.S. Department of Energy and University of Santa Clara, Proceedings of the Third International Symposium on Alcohol Fuels Technology, Alisomar, CA, pp III-48, 1-13, May 1979.
- G-033: Study for comparisons of energy economy and exhaust emissions from internal combustion of methanol, ethanol, and gasoline in motor vehicles.
55. Beery, G.T., Clodfelter, R.G., Gandee, G.W., Morris, J.T., McCoy, J.R., Assessment of JP-8 as a Replacement Fuel for the Air Force Standard Jet Fuel JP-4. Part I: Assessment of JP-8/JP-4 Fuel in Noncombat Environment, AFAPL-TR-74-71, Part I., Air Force Aero Propulsion Laboratory and Aeronautical Systems Division, Wright-Patterson Air Force Base, OH, June 1975.
- T-008: Assessment of JP-8 as a replacement for JP-4 in the U.S. Air Force. Problems such as crash fire safety, storage, lab testing, flight testing, and cost are discussed.
56. Berg, P.S., Holmes, E., Bertilsson, B.I., The Utilization of Different Fuels in a Diesel Engine With Two Separate Injection Systems, Volvo Truck Corp., Goteborg, Sweden, Proceedings to the Third International Symposium on Alcohol Fuels Technology, Alisomar, CA, pp II-29, 1-8, May 1979.

- D-021: The Swedish Methanol Development Company investigated the possibility of using methanol as a diesel engine fuel. Since this proved successful, ethanol was tried. To maximize the total energy balance, including fuel production, testing was done with different ethanol/water concentrations to establish minimum need for acceptable combustion.
57. Bergner, P., Eberius, H., Pokorny, H., Flame Quenching and Exhaust Hydrocarbons in a Combustion Bomb as a Function of Pressure, Temperature, and Equivalence Ratio for Methanol and Other Alcohols, DFVLR-Institut für Phys. Chemie der Verbrennung, Stuttgart, Germany, Proceedings of the Third International Symposium on Alcohol Fuels Technology, Aliso Viejo, CA, pp I-13, 1-11, May 1979.
- S-056: The influence of pressure, temperature, and air/fuel ratio on the content of unburnt hydrocarbons in flame gases was investigated. Fuels used were propane, methanol and ethanol.
58. Bird, W.L., Kimball, J.L., Application of GC Distillation to Motor Gasoline Blending, Exxon Corp., Baton Rouge, LA, presented at the Symposium on Correlations of ASTM D 2887 With Physical Properties of Petroleum Fractions, Dallas, TX, December 1973.
- P-122: Mathematical models have been developed and applied to refinery gasoline blending operations that allow RVP and ASTM distillation properties to be predicted from GC analysis.
59. Block, M.G., Callen, R.B., Stockinger, J.H., The Analysis of Hydrocarbon Products Obtained From Methanol Conversion to Gasoline Using Open Tubular GC Columns and Selective Olefin Absorption, Mobil Research and Development Corporation, Paulsboro, NJ, Journal of Chromatographic Science, Vol. 15, pp 504-12, November 1977.
- G-013: Conditions of analysis are given for hydrocarbon determination. Method is highly reproducible, accurate, and sensitive to compositional changes.
60. Blosser, E.R., Develop an Operational System for Evaluating and Testing Methods and Instruments for Determining the Effects of Fuels and Fuel Additives on Automobile Emissions, Battelle Memorial Institute, Columbus Laboratories, Columbus, OH. Sponsored by Chemistry and Physics Laboratory, National Environmental Research Center, Research Triangle Park, NC, February 1973.
- P-011: Chemical and physical properties of unused glass fiber filter used in analysis, and chemical analyses of collected automobile exhaust particulates were performed in order to account for observed weight variations in exhaust particulates. No clear indication of a single cause of the weight variation was found.
61. Bockrath, B.C., LaCount, R.B., Noceti, R.P., Viscosity of Coal-Derived Liquids, Pittsburgh Energy Research Center, U.S. Energy Research and Development Administration, Pittsburgh, PA and Chemistry and Physics Department, Waynesburg College, Waynesburg, PA, Fuel Processing Technology, Vol. 1, pp 217-26, October 1977.

- S-013: A coal liquid can be separated into various insoluble/soluble fractions of which viscosities can be compared and related.
62. Boldt, K., Hall, B.R., Significance of Tests for Petroleum Products, ASTM STP 7C, Union Oil Company of California and American Petroleum Institute, American Society for Testing and Materials, Philadelphia, PA, January 1977.
- P-019: The significance of standard ASTM test methods for various petroleum products for the purpose of safety in handling, and performance in power generation is described.
63. Boreham, G.R., Armstrong, W.G., The Use of New Analytical Techniques in Control and Research, London Research Council, London, UK, I.S.E. Journal, pp 228-252, March 1965.
- P-117: Techniques such as GC, TLR, IR, UV, MS, x-ray, and specialized problems associated with these are discussed as apply to petroleum and other analyses.
64. Bowden, J.N., Octane-Cetane Relationship AFLRL Report No. 33, U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, March 1974.
- G-001: Regression correlations were developed which related octane number to cetane number for the purpose of replacing diesel fuels with some gasolines in the event of diesel fuel shortage.
65. Bowden, J.N., Trends in Properties of Unleaded Gasolines, AFLRL No. 57, U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, March 1975.
- G-006: Gasolines on the market during 1973 and 1974 were compared with those sold during 1971 and 1972 with respect to physical/chemical specification properties.
66. Bowden, J.N., Storage Stability of Federal Specification Gasoline, U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, Final Report AFLRL No. 34, July 1974.
- G-003: A technique which utilizes a bench apparatus designed to simulate the valve and port area of an engine intake system, can determine the induction system deposit tendencies of gasoline with good correlation to real engines.
67. Bowden, J.N., Wimer, W.W., Universal Fuel Requirements, AFLRL Report No. 67, U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, May 1975.
- P-027: Requirements for a fuel which can operate in any engine at any location in any climate are suggested. Computer programs were developed for blending to yield a fuel with the desired properties.

68. Bradley, M.P.T., Kennard, C.E., Volatility Control by ASTM D 2887, The Standard Oil Company, OH--presented at ASTM D-2, RD IV, Section L Symposium, Dallas, TX, December 1973.
- P-132: Summary of a study to correlate fuel volatility-related properties to ASTM D 2887 data.
69. Bradley, R.P., Kerosene Type Aviation Turbine Fuel Properties Survey, AFAPL-TR-74-7, Air Force Propulsion Laboratory, Wright-Patterson Air Force Base, OH, April 1974.
- T-012: Survey was conducted to determine the physical properties and in particular the thermal stabilities of kerosene-type jet fuels by the use of JFTOT, ASTM-CRC Fuel Coker, and the Minex III test devices. Limited data indicate high degree of correlation between the Coker and Minex III, moderate degree between the JFTOT and Minex III, and a low degree between the Coker and the JFTOT.
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- T-005: Results of JFTOT and ASTM-CRC Fuel Coker testing of Thermally Stable Jet Fuel (JPTS) were compared. It was concluded that the JFTOT, when used in conjunction with the Alcor Mark 8A Tube Deposit rater, is suitable for use with JPTS fuels.
71. Brandberg, A.R.L., Economics of Methanol in Motor Fuel--Value and Cost of Production, Swedish Methanol Development Co., Sweden, Proceedings of the Third International Symposium on Alcohol Fuels Technology, Alisomar, CA, pp I-14, 1-12, May 1979.
- S-058: This paper discusses the contributing economic and technical factors in the institution of methanol as a component of motor fuel.
72. Brown, R.S., Hausler, D.W., Taylor, L.T., Gel Permeation Chromatography of Coal-Derived Products With On-Line Infrared Detection, Department of Chemistry, Virginia Polytechnic Institute and State University, Blacksburg, VA, Analytical Chemistry, Vol. 52, No. 9, August, 1980.
- S-001: Highly specific IR detection in GPC for coal fractions. Numerous characteristic adsorptions allow tentative functionality assignments.
73. Brown, R.S., Hausler, D.W., Taylor, L.T., Carter, R.C., Fourier Transform Infrared Spectrometric Detection in Size-Exclusion Chromatographic Separation of Polar Synfuel Material, Virginia Polytechnic Institute and State University, Blacksburg, and Old Dominion University, Norfolk, VA, Analytical Chemistry, Vol. 53, No. 2, pp 197-201, February 1981.
- S-042: Application of FTIR detection to the size separation of various SRC fractions previously separated on a silica column allows simultaneous monitoring of multiple functionalities.

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- P-073: A procedure for determining C/H ratio, in samples difficult to analyze, by employing small quantities of samples is outlined and discussed.
75. Bunker, J.W., Thomas, K.P., Dorrence, S.M., Compound Types and Properties of Utah and Athabasca Tar Sand Bitumen, Department of Energy, Laramie Energy Technology Center, Laramie, WY, Fuel, Vol. 58, pp 183-95, March 1979.
- S-008: Methods for bitumen extraction, separation, and functional group analysis are presented for geographical characterization of bitumen.
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- P-012: A GC gas phase fluorescence detector has been developed for analysis of polynuclear arenes. Gas phase measurements are easier to make and less susceptible to light scattering by the solvent than liquid phase measurements but at the expense of fluorescence intensity.
77. Burke, F.P., Winschel, R.A., Wooton, D.L., Liquid Column Fractionation: A Method of Solvent Fractionation of Coal Liquefaction and Petroleum Products, Conoco Coal Development Co., Research Division, Library, PA and Ashland Petroleum Co., Research and Development Department, Ashland, KY, Fuel, Vol. 58, pp 539-41, July 1979.
- S-026: A method for solvent fractionation which is more rapid and reproducible than former techniques is described. Applications of method are given.
78. Butler, R.D., Hydrogen Content of Hydrocarbon Fuels by a Low-Resolution Nuclear Resonance Method, AFAPL-TR-77-61, Air Force Aero Propulsion Laboratory, Wright-Patterson Air Force Base, OH, August 1977.
- P-070: A low resolution NMR technique for determination of hydrogen content of aircraft and missile fuels. Instrument parameters, calibration, operating procedure, analysis results and analysis of unknown fuel samples are discussed.
79. Butler, R.D., Martel, C.R., A System for the Computation of Aircraft Fuels Properties from GC Data, Air Force Aero Propulsion Laboratory, Wright-Patterson Air Force Base, OH for Symposium on "Correlations of ASTM D 2887 With Physical Properties of Petroleum Fractions"--American Society for Testing and Materials, Dallas, TX, December 1973.

- T-024: Discussion of the potential for developing a methodology for fuel quality control by use of sophisticated gas chromatography. A GC system and associated problems are presented.
80. Bye, R., Paus, P.E., Solberg, R., Thomassen, Y., Atomic Absorption Spectroscopy Used as a Specific Gas Chromatography Detector. Comparison of Flame and Graphite Furnace Techniques in the Determination of Tetraalkyllead Compounds, Central Institute for Industrial Research and Department of Chemistry, University of Oslo, Oslo 3, Norway, Atomic Absorption Newsletter, Vol. 17, No. 6, November 1978.
- P-031: A GC/AA and a graphite furnace method for the determination of tetraalkyllead compounds in gasoline are compared and their advantages are discussed.
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- P-084: Presentation of new or relative molar response for C₅ to C₈ hydrocarbons as an aid to means of measuring specific peak area in GC analysis.
82. Cassidy, R.M., A Selective Method for Elemental Sulfur Analysis by High-Speed Liquid Chromatography, General Chemistry Branch, Atomic Energy of Canada Ltd., Chalk River Nuclear Laboratories, Chalk River, Ont., Journal of Chromatography, Vol. 117, pp 71-9, 1976.
- P-032: High-speed liquid chromatography utilizing a styrene-divinylbenzene packed column can be used to determine free sulfur content in oil and in aqueous media due to selective interaction of free sulfur with the packing material.
83. Clay, D.A., Rogers, C.H., Jungers, R.H., Determination of Total Sulfur in Gasoline by Gas Chromatography With a Flame Photometric Detector, United States Environmental Protection Agency Environmental Monitoring and Support Laboratory, Analytical Chemistry Branch, Research Triangle Park, NC, Analytical Chemistry, Vol. 49, No. 1, pp 126-8, January 1977.
- G-017: Analysis time is less than 5 minutes with a detector limit of 0.002 wt% and a repeatability of $\pm 10\%$. Main source of error is imprecision of small sample volume injection.
84. Collins, M.H., A Technique to Characterize Quantitatively the Air/Fuel Mixture in the Inlet Manifold of a Gasoline Engine, Shell Research Ltd.,
- G-019: Method provides estimates of the weights of both air and fuel entering individual cylinders.
85. Costa Neto, C., Pinto, R.C.P., Macaira, A.M.P., Separation and Identification of Aldehydes and Ketones From an Irati Oil Shale Bitumen. Use of the Solid Phase Extractor Technique, Instituto de Química, Universidade Federal do Rio de Janeiro, Brasil, 1978.

- S-009: A method to separate bitumen into sets of substances that contain a common functional group, or into sets of substances that contain equal functional groups.
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- P-089: The utility of the plasma chromatograph in identifying GC effluents is discussed.
87. Creason, A., Miller, G.M., Kelley, P., Foster, W.E., Diesel Fuel Filterability Study, MFA Oil Co., Columbia, MO, February 1973.
- D-002: A study by MFA Oil Company for the testing of diesel fuel filterability with test results is described. A test method for determining filterability in the lab is also given.
88. Cropper, W.P., New Type Sulfur Analyzer Developed, Standard Oil Company of Indiana, Naperville, IL, Oil and Gas Journal, pp 71-5, December 1979.
- P-007: By employing the principle of electrolytic conductivity and a ratio technique, a Standard oil of Indiana on-line sulfur analyzer measures weight percent sulfur in distillates of various densities without use of a density compensation device.
89. Crowley, R.J., Siggia, S., Uden, P.C., Class Separation and Characterization of Shale Oil by Liquid Chromatography and Capillary Column Gas Chromatography, Department of Chemistry, University of Massachusetts, Amherst, MA, Analytical Chemistry, Vol. 52, No. 8, pp 1224-8, July 1980.
- S-061: Separation of shale oil aliphatics, aromatic, and polar fractions is achieved within 30 min. by normal phase partition HPLC. Characterization is then carried out by fused silica and glass wall coated tubular capillary GC and high pressure LC.
90. Cukor, P., Lanning, E.W., Analysis of Organic Mixtures Using the Combination of a Thermogravimetric Analyzer, a Gas Chromatograph and an Infrared Spectrophotometer, Bayside Research Center, GTE Laboratories Inc., Bayside, NY, Journal of Chromatographic Science, Vol. 9, pp 487-92, August 1971.
- P-081: Unknown samples are pyrolyzed, volatile products put through GC, column effluent is split into two streams to TCD and FID, and finally analyzed by IR.
91. DiCorcia, A., Samperi, R., Capponi, G, Gas Chromatographic Analysis of Gasoline and Pure Naphtha Using Packed Columns, Istituto di Chimica Analitica dell' Universita' di Roma, Rome, Italy, Journal of Chromatography, Vol. 160, pp 147-54, 1978.
- G-014: The analysis of very complex hydrocarbon mixtures can be carried out on a specially packed GC column, overlapping can be specifically identified by GC/MS.

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S-039: A precolumn reactor of sulfuric acid supported on diatomite serves to subtract alkenes, aromatics, and functional group compounds within the shale oil GC profile.

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S-044: Compound class separation of alkanes, alkenes, and aromatics takes place on silica gel and silica gel/silver nitrate. Further characterization of hydrocarbon classes is achieved by glass capillary GC and vapor phase molecular sieve 5A subtraction techniques.

94. Dominguez, J.A.G., Munoz, J.G., Sanchez, E.F., Molera, M.J., Retention of Methane in Gas-Liquid Chromatography-New Evaluation Methods of Mathematical Dead Time, Instituto de Quimica Fisica "Rocasolano", Madrid, Spain, Journal of Chromatographic Science, Vol. 15, pp 520-7, November 1977.

P-017: Methane is retained by normal liquid phases even at high temperatures thus causing erroneous adjusted retention times in the C_6-C_{16} n-paraffin range. Four methods for correcting retention data are presented.

95. Dooher, H.P., Feasibility Study of Using a Coal/Water/Oil Emulsion as a Clean Liquid Fuel. Phase 2. Second Year, Adelphi University, Adelphi Research Center, Inc., Garden City, NY, December 1977.

S-025: Attempt to correlate viscosity of emulsion as measured by pumping it through a section of pipe to that measured by a "Roto-visco". Some equipment problems mentioned.

96. Drashel, H.V., Sulfur Compound Type Distributions in Petroleum Using an In-Line Reactor or Pyrolysis Combined With Gas Chromatography and a Microcoulometric Sulfur Detector, Esso Research Laboratories, Humble Oil and Refining Co., Baton Rouge, LA, Analytical Chemistry, Vol. 41, No. 4, pp 569-76, April 1969.

P-042: Determination of S compound types by dealkylation of condensed thiophenes using an in-line catalytic reactor or noncatalytic pyrolysis. Reaction products are separated by GC and S compounds quantitated by Dohrmann microcoulometry. Data agrees well with HRMS analysis.

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- G-022: Lanthanum nitrate solution is inserted via a graphite furnace followed by direct addition of gasoline. The organic matrix is charred prior to atomization of the phosphorus. Each determination requires less than 2 min.
98. DuPuis, M.D., Hill, H.H., Analysis of Gasoline for Antiknock Agents with a Hydrogen Atmosphere Flame Ionization Detector, Department of Chemistry, Washington State University, Pullman, WA, Analytical Chemistry, Vol. 51, No. 2, pp 292-5, February 1979.
- G-002: HAFID can be used as a selective GC detector for the determination of lead alkyl antiknock agents in gasolines with no interference from overlapping chromatographic peaks of hydrocarbons.
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- P-092: Optimum flow characteristics of the sulfur FPD to maximize relative sensitivity and exponential proportionality factor "n" is described. Also described is a simple electronic device which monitors the sulfur FPD output signal.
100. Eggertson, T.T., Nygard, N.R., Nickoley, L.D., Estimation of the Vapor Pressure of Petroleum Distillate Fractions from Gas Chromatographic Data, Cal/Ink Division, Flint Ink Corp., Berkeley, CA, Analytical Chemistry, Vol. 52, No. 13, pp 2069-72, November 1980.
- P-045: Vapor pressure is computed as a summation of the partial pressures for carbon number groups in the chromatogram, each partial pressure being derived as the product of mole fraction determined from the chromatogram, and saturation pressure, calculated from the Antoine equation.
101. Elder, J., A New, Rapid Method for the Precise Determination of the Density of Fluids, Mettler Instrument Corporation, Princeton, NJ, Presented at the 25th Pittsburgh Conference, Pittsburgh, PA, March 1974.
- P-085: Theory, description and experimental procedure of the Mettler/ Paar Digital Density Meter are given.
102. Ernst, E.D., Laboratory Test Techniques for Evaluating the Thermal Protection of Materials When Exposed to Various Heat Sources, AFML-TR-74-118, University of Dayton, Dayton, OH, Research Institute for Air Force Materials Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, OH, March 1974.

- P-040: Techniques are described which provide a measure of a materials thermal protection against human skin burns.
103. Fishel, D.L., Longo, T.T., Jr., Gas Chromatography--Mass Spectrometry Analyses: Heterocycles in Coal Liquids, Chemistry Department and Liquid Crystal Institute, Kent State University, Kent, OH, Advanced Mass Spectrometry, Vol. 7B, pp 1323-9, 1978.
- S-050: A computerized GC/MS system for the analysis of indoles and quinolines in coal liquids is described, and analytical results are discussed.
104. Fodor, G.E., Newman, F.M., The Application of High-Performance Liquid Chromatography to the Analysis of Petroleum Materials. Part 2. Quantitative Hydrocarbon-Type Analysis of Middle Distillate Fuels, U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, May 1975.
- D-012: Quantitative hydrocarbon type analysis of straight-run, olefin-free diesel fuels was accomplished using HPLC.
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- P-025: Elution volumes for several hydrocarbon types can be determined by HPLC.
106. Ford, D.C., The Evaluation of Reformate Analysis by Gas Chromatography, Sinclair Research, Inc., Harvey, IL, July 1966.
- P-076: Development of GC reformate analysis from inception of reforming technique through constant temperature thermal conductivity chromatogram to temperature-programmed GC/FID using capillary columns. Tables included.
107. Ford, D.C., Miller, W.H., Thren, R.C., Wertzler, R., Correlation of D 2887 Boiling Range Distribution Data With D 86 Distillation Data, Atlantic Richfield Co., Harvey, IL and Philadelphia, PA,
- P-127: Two methods employing correlation equations for boiling range distribution and distillation.
108. Frame, E.A., High-Sulfur Fuel Effects in a Two-Cycle, High-Speed Army Diesel Engine, AFLRL No. 105, U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, May 1978.
- D-005: Study to determine the effects of increasing fuel sulfur content on engine wear. Test details and results are given.
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- S-048: Study of the role of N compounds in sediment formation and structure, and compounds that inhibit or accelerate formation.
110. Freudenthal, J., Gramberg, L.G., Pulse-Counting Techniques in Organic Mass Spectrometry, National Institute of Public Health, Laboratory of Toxicology, Netherlands, Analytical Chemistry, Vol. 49, No. 14, pp 2205-8, December 1977.
- P-063: Pulse-counting techniques in MS are described with which it is possible to make accurate measurements in gas chromatographic peaks of only a few seconds wide with an accuracy of better than 1 ppm for most substances.
111. Gallegos, E.J., Analysis of Heavy Distillates, Residues..., Research Services Department, Chevron Research Co., Richmond, CA, Chromatographic Science, Vol. 11, pp 163-85, 1979.
- P-069: Chapter compares basic differences in performance of the more important pyrolyzers currently in use, followed by a short review of vapor phase pyrolysis of purer hydrocarbons. A review of recent applications for PCG to the analysis of petroleum residue, coals, shales, and sediments is presented also.
112. Gallegos, E.J., Medium-Resolution Mass Spectrometry as a Nitrogen Compound Specific Detector, Chevron Research Company, Richmond, CA, Analytical Chemistry, Vol. 53, No. 2, pp 187-9, February 1981.
- P-047: GC/MS with MS set at about 300 resolution is used in the multiple ion detection mode to monitor the intensity of the CH_2N^+ ion at m/g 28. Practicability of this system is demonstrated² by use of N compound mixtures gasoline, and coals.
113. Gibbs, L.M., Proposed Water Tolerance Test for Gasohol, Chevron Research Co., 576 Standard Ave, Richmond, CA, Letter to Mr. P.D. Hobson, May 1980.
- P-114: Problems of water tolerance test for "gasohol" is discussed and a room temperature modification is suggested. Finally, a go/no-go test method procedure is given.
114. Gleason, C.C., Oller, T.L., Shayeson, M.W., Bahr, D.W., Evaluation of Fuel Character Effects on the F101 Engine Combustion System, AFAPL-TR-79-2018 CEEDO-TR-79-07, General Electric Co., Aircraft Engine Group, Cincinnati, OH, Air Force Aero Propulsion Laboratory, Wright-Patterson Air Force Base, OH, June 1979.
- T-023: Results of a program to determine the effects of broad variations in fuel properties on the performance, emissions, and durability of an engine are presented.
115. Good, W.D., Scott, D.W., Smith, N.K., Bechtold, S.L., Osborn, A.G., Thermodynamics of Organic Compounds, Department of Energy, Bartlesville Energy Technology Center, Bartlesville, OK, September 1978.

- P-072: Thermodynamic properties measured for pure organic compounds which are constituents of present and will probably be of future high-energy fuels.
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- S-034: A broad comparison is made of the net calorific values of a wide variety of gaseous liquid and solid fuels including potential alternatives against a background of conventional fuels.
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- T-015: Thermal stability of jet fuel is characterized by quantification of deposit formation as determined by the Advanced Aircraft Fuel System Simulator under cyclic and steady state conditions. A good correlation was established between coker preheater tube data and the Simulator steady state test data.
118. Goww, T.H., Removal of Water in the Distillation of Hydrocarbon Mixtures, Chevron Research Co., 576 Standard Ave., Richmond, CA, Analytical Chemistry, Vol. 49, No. 12, pp 1887-8, October 1977.
- P-111: Procedures for removing entrained water from hydrocarbon mixtures prior to distillation are given.
119. Grabel, L., Lubricity Characteristics of JP-5 Fuels, NAPC-LR-79-6, Naval Air Propulsion Center, Trenton, NJ, March 1979.
- T-016: Discussion of jet fuel lubricity deterioration with increase in crude oil sulfur content, a recommended lubricity improver additive, and a test method for fuel lubricity with discussion of results.
120. Grabel, L., Lubricity Properties of High Temperature Jet Fuel, NAPTC-PE-112, Naval Air Propulsion Test Center, Linden, NJ, August 1977.
- T-017: Description and test method of the Ball-on-Cylinder Machine (BOCM) which can distinguish between good and poor lubricity fuels and detect known beneficial effects of corrosion inhibitors on poor lubricity fuel. Parameters affecting fuel lubricity are also presented.
121. Gryaznov, A.P., Rozhkov, G.V., Investigation of the Antiwear Properties of Reactive Fuels, Khimaya i Teknologiya Topliv i Masel, No. 4, pp 67-60, 1964.
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- D-018: Two-stage combustion concept for production of gasified diesel fuel in a self-contained engine/combustor system to alleviate the particulates and emissions problem. First, fuel is partially oxidized and converted to hydrogen-rich gas. The gas is then combined with air and burned to completion in the engine. Cost of concept implementation would be quite high.
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- S-057: A theoretical approach to the problem of cold starting and warm-up driveability of engines which utilize pure alcohols or alcohol/gasoline blends as fuels.
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- S-019: Magic-angle spinning at 2 KHz is shown to remove chemical shift anisotropy to a sufficient degree to resolve aromatic and aliphatic ^{13}C NMR spectral regions.

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- S-015: Two equations are given for calculating syncrude and oil heating value from C, H, N, S, and O content. Tables.
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- P-067: Infrared method developed to identify and determine freezing point depressant anti-icing additives in hydrocarbon fuels by using the -OH stretching bands of the additives in dilute solutions.
198. Roof, R.W., Yates, H., Prediction of Selected Jet Fuel Test Results Using ASTM Test Method D 2887 Data With Multiple Linear Regression Analysis; Master's Thesis, Graduate Education Division, School of Systems and Logistics, Air Force Institute of Technology, Wright-Patterson Air Force Base, OH, June 1978.
- T-020: Attempt to correlate aniline-gravity products, RVP, water separator index, and API gravity with ASTM D 2887 data. Except for API gravity, results were less than acceptable.
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- S-017: Analytical separation and spectroscopic techniques used for petroleum crudes were extended and modified to characterize coal liquids, tar sand bitumens and shale oils.
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- P-006: Combined use of factorial and simplex experimental designs for optimization of NPD operating variables is discussed, and the applicability of the NPD to the detection of nitrogen compounds in fractions of a coal liquefaction product oil is illustrated.
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- S-003: Refractive index can be used to determine nitrogen content and is adaptable to process control.
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- S-033: Separation methods of N compounds by modified API-USBM procedures are presented and advantages are discussed.
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- P-061: Development of a correlation factor which relates the $\log k^1$ values for PAHs, alkyl-substituted aromatic hydrocarbons, and hydroaromatics to certain structural features.
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- G-023: Elemental, mercaptan, sulfide, and disulfide sulfur are determined by potentiometric titration utilizing a silver chloride reference electrode.
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- T-010: Compilation and review of literature surveys, interviews, etc. on or relating to the subject of supersonic jet fuel deterioration.
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- P-003: Capillary GC equipped with a UV detector set at 250 nm can effectively separate complex mixtures of PAHs.
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- P-074: HPLC (silica gel-heptane) system separates hydrocarbon classes and with IR and UV detection gives information on sample composition. Interpretations of HPLC chromatograms on various different samples are given.
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- P-009: Neat liquid fossil fuels can be "fingerprinted" using modified chemical ionization mass spectrometry. Prior fractionation or separation is not required, and the technique can be extended to the partial quantification aromatic and olefinic components.
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- P-066: Purpose of program was to determine, analytically and experimentally, the extent to which the autoignition delay times of liquid hydrocarbons could be reduced by molecular structure modifications or by use of homogeneous additives and heterogeneous catalysts.
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- G-010: Equations obtained by applying multiple correlation analysis to data calculated for commercial and experimental gasolines. Statistical analysis is based on FIA and PONA data.
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- T-003: Ultraviolet determination of total aromatic hydrocarbon content in fuels and differentiation of hydrocarbons with benzene and naphthalene rings.
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- P-137: GC/MS profiles compared with historical libraries of GC/MS data for the validation of analytical procedures, determination of variation among controls, and rapid detection of novel components in new mixtures.
222. Smith, N.K., Enthalpy of Combustion of RJ-6, Department of Energy, Bartlesville Energy Technology Center, Bartlesville, OK, April 1979.
- T-021: Report on measurement of enthalpy of combustion of ramjet fuel RJ-6 by combustion calorimetry.
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- S-016: Straight-chain alkane content determined by GC and GC/MS and aromaticity by ¹H NMR for synthetic jet fuels and compared with those for petroleum. Relations between chemical composition and freezing point, heating value, smoke point, and kinematic viscosity are attempted.

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T-013: Test apparatus developed to determine autoignition characteristics of aircraft fuels. Independent variables are temperature, pressure, flow rate, and fuel/air ratio.

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G-004: Potential thermal standards were investigated for determination of aromatics in gasoline in order to eliminate problems associated with direct calibration.

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G-005: The addition of a dual column valve, olefin absorber column, and humidified carrier gas, extends the capability of a GC technique used to isolate the aromatic and the saturate/olefin fractions of gasoline. Advantages are compared to those of conventional techniques.

229. Stavinocha, L.L., Hydrocarbon Type Analysis by Gas Chromatography, AFLRL Report No. 15, U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, July 1972.

G-007: The technique and parameters affecting olefin absorber reactivity were evaluated based on results from analyses of a standard and two gasoline samples.

230. Stavinocha, L.L., Memorandum to File No. 10-5857-121--Fuel Analysis in Support of Rapid Qualification Testing, U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, May 1980.

P-134: Memorandum to justify the use of GC as a viable tool in development of correlative analytical methodology. Also included is the agenda of ASTM Committee D-2 on Petroleum Products and Lubricants held June 22-27, 1980.

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- G-011: GC parameters and operating conditions are outlined. Provisions for extending the procedure to higher boiling-point materials are discussed.
232. Stavinocha, L.L., Newman, F.M., Design and Evaluation of Diesel Exhaust Processors for the Analysis of CO and UBH with Vortex Concentration Sensors, AFLRL No. 45 (Final Report), U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, October 1974.
- D-015: Processors were designed to measure diesel exhaust constituents. Processors are diagrammed, methods of operations and measurement are outlined, and evaluations are discussed.
233. Stein, M., Recover Aromatics With NFM, Heinrich Koppers Gml H. Essen, Germany, Hydrocarbon Processing, pp 139-41, April 1973.
- P-077: Discussions of two Koppers processes utilizing N-formyl-morpholine as a solvent to recover aromatics from petroleum products.
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- S-024: Tar sand diesel fuels were used successfully despite less than optimal cloud points, flash points, and cetane numbers.
235. Strigner, P.L., Wisniowski, H.U., Kallio, N.N., Low Temperature Filterability of Athabasca Tar Sands Fuels and Standard Diesel Fuels, Division of Mechanical Engineering, National Research Council, Canada, January 1974.
- S-021: Bench and cold room rig tests were performed with Athabasca tar sand fuels to determine their filterability in locomotive fuel systems at low temperatures. Results compared with standard diesel fuels.
236. Stuckey, C.L., The Analysis of Aromatic Hydrocarbons in the 325-435°F Boiling Fraction of Crude Oil by Open Tubular Column GC, Research and Development Department, Continental Oil Co., Ponca City, OK, Journal of Chromatographic Science, Vol. 9, pp 575-6, September 1971.
- P-078: Technique for isothermal separation of aromatics from saturates by GLC using two open tubular columns operating in tandem.

237. Sutton, D.G., Westburg, K.R., Melzer, J.E., Chemiluminescence Detector Based on Active Nitrogen for Gas Chromatography of Hydrocarbons, The Aerospace Corporation, El Segundo, CA, Analytical Chemistry, Vol. 51, No. 9, pp 1399-1401, August 1979.

P-102: Saturated and unsaturated compounds are detectable by monitoring an intense spectroscopic feature at 383 to 388 nm. Method is applicable to compounds with or without halogen constituents.

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G-009: A portion of gasoline saturate fraction previously isolated and analyzed for specific compound groups is dehydrogenated and reanalyzed. The cyclopentyl naphthenes are not affected by dehydrogenation, while the nongeminal cyclohexyl naphthenes are converted to aromatics.

239. Szetela, E.J., Chiappetta, L., External Fuel Vaporization Study, Phase I Report, United Technologies Research Center, East Hartford, CT for National Aeronautics and Space Administration, Lewis Research Center, June 1980.

P-124: Theory of heat exchanger to measure thermodynamic properties of fuel is discussed.

240. Tackett, L., Bradley, R.P., Determination of the Effect of Pretest Ratings of Jet Fuel Thermal Oxidation Tester Tubes on Post-Test Ratings Using the Tube Deposit Rater AFAPL-TR-77-53, Air Force Aero Propulsion Laboratory, Wright-Patterson Air Force Base, OH, June 1977.

T-014: Discussion of the effect of pretest ratings of JFTOT tubes and proposal of a method for improving JFTOT results by accounting for pretest condition of tubes.

241. Taylor, W.T., Frankenfeld, J.W., Development of High Stability Fuel-- Final Report for Phase II, Exxon Research and Engineering Co., Government Research Laboratory, Linden, NJ, December 1975.

P-058: Program for development of a high-stability JP-5 physically similar to present day JP-5. Various methods and analyses pertinent to development are presented.

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S-007: Increase in viscosity according to interaction between acid, neutral, and base components in coal correlates with ¹H NMR downfield chemical shift of the OH signal of o-phenylphenol as a function of added asphaltene concentration. Results suggest

that when oil and asphaltene are present together, hydrogen bonding involving phenolic-OH is one of the mechanisms by which oil-asphaltene interactions are achieved, and are in part responsible for the viscosity increase of coal liquids.

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- S-029: This study identifies the equipment, describes the techniques, and shows the precision of data obtained in the laboratory for coal liquefaction analyses. Several techniques under development are also presented.
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- P-046: Describes the preparation of S compound concentrates boiling from 225°-400°C and reports the S types detected in these concentrates by low voltage MS. Major constituents are pointed out. Methods should be applicable to high-boiling distillates.
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- D-019: Performance and emissions characteristics of shale- and tar sand-derived diesel fuels were compared with those of petroleum D-2. Slight differences are attributed to physical/chemical properties. No significant NO_x contribution to emissions due to fuel-bound nitrogen was observed.
246. Tyler, J.C., Gray, J.T., Weatherford, W.D., Jr., An Investigation of Diesel Fuel Composition--Exhaust Emission Relationships, U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, TX, October 1974.
- D-011: Investigation conducted to study effects of hydrocarbon composition and additive content of diesel fuels on exhaust pollutant emissions. A two-cylinder, four stroke cycle Onan diesel engine-generator unit was used and seven different fuel blends of varying aromatic contents and cetane numbers were investigated.
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- S-022: Various modes of high-resolution GC are assessed for different fractions of shale oil, MS and IR are used for further identification.

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Layer Open Tubular Gas Chromatography and Interfaced Vapor Phase In-
frared Spectrophotometry, Department of Chemistry, University of Mass-
achusetts, Amhurst, MA, Analytical Chemistry, Vol. 51, No. 1, pp 38-43,
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individual phenolic and heterocyclic N base compounds. Vapor
phase IR provided informative spectra for microgram component
peaks.

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Reaction-Frontal Gas Chromatography, Institute of Analytical Chemistry,
Czechoslovak Academy of Sciences, Brno, Czechoslovakia, Analytical
Chemistry, Vol. 53, No. 2, pp 164-7, February 1981.

P-048: Method is based on pyrolysis of sample, conversion of O-con-
taining products to CO and oxidation of H_2 to H_2O and CO to CO_2
on CuO at 650°C.

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Lubricants Research Laboratory, Southwest Research Institute, San An-
tonio, TX, March 1969.

S-037: Essential property requirements were developed based on know-
ledge of emulsified fuels and test methods adopted, adapted or
developed.

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Energy Technology Center, Bartlesville, OK, December 1977.

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its hydrocarbon and functional compound composition. It was
separated using various conventional techniques and character-
ized by MS.

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Products, Research Department, Standard Oil Company of Indiana, Whiting,
IN, Analytical Chemistry, Vol. 25, No. 6, pp 923-5, June 1953.

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tish Petroleum Company, Ltd., Sunbury-on-Thames, Middlesex, United
Kingdom, Hydrocarbon Processing, pp 153-8, September 1971.

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freezing point, vapor pressure and other physical properties of
fuels if the fuel composition on an individual component basis
is known.

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- S-036: Nitrogen base components produced during the catalytic hydrodesulfurization of coal were isolated by precipitation with HCl and analyzed by GC/MS.
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- P-052: Oxidative combustion-microcoulometry for determination of sulfur is described. Organic sulfur is converted to SO_2 and is independent of matrix or function type. Coking problems associated with high-boiling products are avoided.
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- D-003: The relation of diesel fuel composition to its thermodynamic properties is discussed. Methods presented cover the whole range of states required. A computer program for property evaluation is described.
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- P-001: Information to illustrate the nature of the experimental problem, and the method and apparatus designed for obtaining flammability limits.
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- P-062: Bondapak NH_2 provides distinct separation of PAHs due to alkyl groups on the rings which has little effect on retention. PAHs are eluted according to number of condensed rings.
259. Yang, Y., D'Silva, A.P., Fassel, V.A., Iles, M., Direct Determination of Polynuclear Aromatic Hydrocarbon in Coal Liquids and Shale Oil by Laser Excited Shpol'skii Spectrometry, Ames Laboratory and Department of Chemistry, Iowa State University, Ames, IA, Analytical Chemistry, Vol. 52, No. 8, pp 1350-1, July 1980.

- S-062: Tunable, dye laser excitation of Shpol'skii effect spectra provides a potentially useful means of determining PAH compounds directly in coal liquids and shale oil without prior isolation of the PAH fraction by other techniques.
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- S-002: ^{13}C spectra analyzed to evaluate carbon aromaticity. Correlation between carbon aromaticity and reciprocal of the square of the shorter component in spin-spin relaxation time which was obtained by ^1H NMR was observed.
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APPENDIX D
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