

(R) Gasoline, Alcohol, and Diesel Fuel Surrogates for Materials Testing

Foreword—This SAE Recommended Practice is based on the product of the SAE Cooperative Research Program, Project Group 2 which has been extended to cover the current conventional and oxygenated gasolines and diesel fuels. SAE Cooperative Research Project Group 2 was formed by the Oxygenated Fuels Task Force, which is composed of OEM automotive engineering executives. The task of the Oxygenated Fuels Task Force is to identify and prioritize potential areas for pre-competitive cooperative research programs to be administered by SAE. The specific scope of Project Group 2 was to develop and exchange information relative to materials and test methods for use with blends of methanol and gasoline. An SAE Cooperative Research Report titled, "Gasoline/Methanol Mixtures for Materials Testing," was published in September 1990. Information from this report was published as SAE J1681 in September 1993. This revision of SAE J1681 provides information presented in earlier versions and includes additional fluids that can be used to simulate current conventional and oxygenated gasolines and diesel fuels. New in this revision is a listing of "Worldwide Test Fuels." This list is presented in Appendix G.

1. **Scope**—This SAE Recommended Practice presents recommendations for test fluids that can be used to simulate real world fuels. The use of standardized test fluids is required in order to limit the variability found in commercial fuels and fluids. Commercial fuels can vary substantially between manufacturers, batches, seasons, and geographic location. Further, standardized test fluids are universally available and will promote consistent test results for materials testing. Therefore, this document
- Explains commercial automotive fuel components
 - Defines standardized components of materials test fluids
 - Defines a nomenclature for test fluids
 - Describes preparations for test fluids and
 - Recommends fluids for testing fuel system materials

The test fluid compositions specified in Section 7 of this document are recommended solely for evaluating materials. They are not intended for other activities, such as engine development, design verification, or process validation unless agreed upon by the contracting parties. The marketplace test fuels listed in Appendix B of this document can be used for engine, vehicle, or component testing.

Most marketplace fuels contain additives for such purposes as oxidation stability, intake and combustion chamber deposit control, anti-foaming, electrostatics, octane, etc., applied at a parts per million basis. It is not the intention of this document to include a surrogate for the potential effects of these additives. As far as this committee is aware, current additives do not adversely effect fuel system materials. Those contemplating new or improved additives for future application could use the basic test fluids or fuels from this document, inject such additives and use the resulting mixtures to assess whether these new additives might effect fuel system materials.

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For the purposes of this document, the term FUEL is used in conjunction with fully blended hydrocarbon or hydrocarbon oxygenate mixtures for use in commercial automotive engines. The term FLUID is applied to mixtures of specific controlled components used to simulate the effects of fuels.

1.1 Purpose—The purpose of this document is to define standardized surrogate gasoline and diesel mixtures to be used in materials testing, and to publish these compositions. This document also promotes the use of its standardized test fluids to permit consistent results from materials testing and more uniform specification of materials. Formulations in this document are intended to exaggerate the effects of typical severe fuel on materials, as well as to allow the tests to be conducted in a reasonable amount of time.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest version of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1681 MAR93—Gasoline/Methanol Mixtures for Materials Testing
SAE J1748—Methods for Determining Physical Properties of Polymeric Materials Exposed to Gasoline/Oxygenate Fuel Mixture

2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 56—Test Method for Flash Point by Tag Closed Tester
ASTM D 86—Test Method for Distillation of Petroleum Products
ASTM D 93—Flash Point by Pensky-Martens Closed Cup Tester
ASTM D 130—Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test
ASTM D 156—Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method)
ASTM D 287—Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)
ASTM D 323—Test Method for Vapor Pressure of Petroleum Products (Reid Method)
ASTM D 381—Test method for Existent Gum in Fuels by Jet Evaporation
ASTM D 445—Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (the Calculation of Dynamic Viscosity)
ASTM D 471/ISO 1817 and ISO 4639-3—Rubber Hoses and Tubing for Fuel Circuits for Internal Combustion Engines - Part 3, Oxidized Fuel
ASTM D 525—Test Method for Oxidation Stability of Gasoline (Induction Period Method)
ASTM D 611—Test Methods for Aniline Point and Mixed Aniline Point of Petroleum Products and Hydrocarbon Solvents
ASTM D 613—Test Method for Cetane Number of Diesel Fuel Oil
ASTM D 664—Test Method for Acid Number of Petroleum Products by Potentiometric Titration
ASTM D 841—Specification for Nitration Grade Toluene
ASTM D 847—Test Method for Acidity of Benzene, Toluene, Xylenes, Solvent Naphthas, and Similar Industrial Aromatic Hydrocarbons
ASTM D 848—Test Method for Acid Wash Color of Industrial Aromatic Hydrocarbons
ASTM D 849—Test Method for Carbon Strip Corrosion by Industrial Aromatic Hydrocarbons
ASTM D 850—Test Method for Distillation of Industrial Aromatic Hydrocarbons and Related Materials
ASTM D 853—Test Method for Hydrogen Sulfide and Sulfur Dioxide Content (Qualitative) of Industrial Aromatic Hydrocarbons
ASTM D 874—Test Method for Sulfated Ash from Lubricating Oils and Additives
ASTM D 891—Test Methods for Specific Gravity, Apparent, of Liquid Industrial Chemicals
ASTM D 1152-97—Standard Specification for Methanol (Methyl Alcohol)
ASTM D 1193—Specification for Reagent Water

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- ASTM D 1209—Test Method for Color of Clear Liquids (Platinum-Cobalt Scale)
- ASTM D 1266—Test Method for Sulfur in Petroleum Products (Lamp Method)
- ASTM D 1298—Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
- ASTM D 1319—Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption
- ASTM D 1353—Test method for Nonvolatile Matter in Volatile Solvents for Use in Paint, varnish, Lacquer, and Related Products
- ASTM D 1363—Test method for Permanganate Time of Acetone and Methanol
- ASTM D 1364—Test Method for Water in Volatile Solvents (Karl Fischer Reagent Titration Method)
- ASTM D 1612—Test Method for Acetone in Methanol (Methyl Alcohol)
- ASTM D 1613-96—Standard Test Method for Acidity in Volatile Solvents and Chemical Intermediates Used in Paint, Varnish, Lacquer and Related Products
- ASTM D 1722—Test Method for Water Miscibility of Water-Soluble Solvents
- ASTM D 2268—Test Method for Analysis of High-Purity n-Heptane and Isooctane by Capillary Gas Chromatography
- ASTM D 2360—Test Method for Trace Impurities in Monocyclic Aromatic Hydrocarbons by Gas Chromatography
- ASTM D 2500—Test Method for Cloud Point of Petroleum Oils
- ASTM D 2622—Test Method for Sulfur in Petroleum Products by X-Ray Spectrometry
- ASTM D 2699—Test Method for Research Octane Number of Spark-Ignition Engine Fuel
- ASTM D 2700—Test Method for Motor Octane Number of Spark-Ignition Fuel
- ASTM D 2709—Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge
- ASTM D 3120—Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry
- ASTM D 3231—Test Method for Phosphorus In Gasoline
- ASTM D 3237—Test Method for Lead in Gasoline by Atomic Absorption Spectrometry
- ASTM D 3606—Test Method for the Determination of Benzene and Toluene in Finished Motor and Aviation Gasoline by Gas Chromatography
- ASTM D 4045—Test Method for Sulfur in Petroleum Products by Hydrogenolysis and Rateometric Colorimetry
- ASTM D 4052—Test Method for Density and Relative Density of Liquids by Digital Density Meter
- ASTM D 4176—Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)
- ASTM D 4294—Test Method for Sulfur in Petroleum Products by Energy-Dispersive X-Ray Fluorescence Spectroscopy
- ASTM D 4530—Test Method for Determination of Carbon Residue (Micro Method)
- ASTM D 4806—Standard Specification for Denatured Fuel Alcohol for Blending with Gasolines for Use as Automotive Spark Ignition Engine Fuel
- ASTM D 4814—Specification for Automotive Spark-Ignition Engine Fuel
- ASTM D 4815—Test Method for Determination of MTBE, ETBE, TAME, DIPE, tertiary-Amyl Alcohol and C₁ to C₄ Alcohols in Gasoline by Gas Chromatography
- ASTM D 5191—Test Method for Vapor Pressure of Petroleum Products (Mini Method)
- ASTM D 5254—Practice for Minimum Set of Data Elements to Identify a Ground-Water Site
- ASTM D 5441—Test Method for Analysis of Methyl tert-Butyl Ether (MTBE) by Gas Chromatography
- ASTM D 5453—Test Method for the Determination of Total Sulfur in Light Hydrocarbons, Motor Fuels and Oils by Ultraviolet Fluorescence
- ASTM D 5797-96—Standard Specification for Fuel Methanol (M70 - M85) for Automotive Spark Ignition Engines
- ASTM D 5798-98a—Standard Specification for Fuel Ethanol (Ed75 - Ed85) for Automotive Spark Ignition Engines
- ASTM D 6423-99—Standard Test Method for Determination of pH_e of Ethanol. Denatured Fuel Ethanol and Fuel Ethanol (Ed75-Ed85)
- ASTM E 203—Test Method for Water Using Karl Fischer Reagent

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ASTM E 298-98—Standard Test Method for Assay of Organic Peroxides

ASTM E 346—Test Methods for Analysis of Methanol

ASTM as PS122-99—Provisional Standard Specification for BioDiesel Fuel (B100) Blend Stock for Distillate Fuels

2.1.3 ARB PUBLICATION—Available from State of California Air Resources Board in Sacramento.

ARB MLD 16

2.1.4 CEC PUBLICATIONS—Available from Coordinating European Council for the Development of Performance Tests for Transportation Fuels, Lubricants and other Fluids, Madou Plaza - 25th Floor, Place Madou 1, B-1030 Brussels, Belgium

CEC-RF-01-A-80

CEC-RF-08-A-85

2.1.5 DIN PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

DIN 51 604

2.1.6 FEDERAL PUBLICATIONS—Available from the Superintendent of Documents, U. S. Government Printing Office, Mail Stop: SSOP, Washington, DC 20402-9320. <http://www.access.gpo.gov/nara/cfr/cfr-table-search.html>.

27 CFR 21.24

2.1.7 ISO PUBLICATION—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO 1817—Rubber, vulcanized—Determination of the effect of liquids

2.1.8 NF PUBLICATIONS—Available from ????

NF EN 22719

NF ISO 3991

NF T 60-700

NF T 60-702

NF T 60-703

2.1.9 OTHER PUBLICATIONS

Mazich, Rossi, and Smith, "Macromolecules 25, 6929," (1992)

2.2 Related Publication—The following publication is for information purposes only and is not a required part of this specification.

SAE J1747—Recommended Methods for Conducting Corrosion Tests in Gasoline/Methanol Fuel Mixtures

3. Explanation of Commercial Automotive Fuel Components

3.1 General—Automotive fuels are made from many compounds that are derived from petroleum, natural gas, and biomass. Materials that come into contact with fuel components are affected in different ways. This document identifies the significant components of fuel mixtures and includes those components in recommended testing formulations. A discussion of the fuel components is offered.

3.2 Major Fuel Components

- 3.2.1 ALKANES—The alkane component group includes straight chain, branched chain, and cyclic aliphatic hydrocarbons. The alkanes are often referred to as paraffins and are derived from the naphtha fractions from a refinery or gas processing facility.

Polymeric materials can sorb alkanes, which can in turn cause swelling. Extensive earlier work on rubber materials was performed using the alkane isooctane (2,2,4 - trimethyl pentane).

- 3.2.2 AROMATICS—The aromatics group includes molecules based on the six-member ring compound benzene, and substituted benzenes, such as toluene, and xylenes. The aromatics also include molecules containing additional carbons in various configurations and positions on a benzene molecule.

Polymeric materials can undergo swelling and decomposition when exposed to high concentrations of aromatics. Extensive earlier work on rubber materials was performed using the aromatic toluene, generally in a mixture with the alkane isooctane.

- 3.2.3 OXYGENATES—The oxygenates in fuel blends include lower molecular weight alcohols, such as methanol (MeOH) and ethanol (EtOH). The oxygenates also include ethers such as methyl tertiary - butyl ether (MTBE), ethyl tertiary - butyl ether (ETBE), and tertiary-amyl methyl ether (TAME). The oxygenated compounds are manufactured to create useful fuel components starting with natural gas, certain natural gas liquids, certain refinery and petrochemical intermediates, and alcohols generated from biomass feeds that are readily available to the fuel industry.

Oxygenates in diesel fuel are currently limited to fatty acid methyl esters. In Europe, methyl esters are made from the trans-esterification of rapeseed oil with methanol predominate. These are referred to as rapeseed methyl esters (RME). In the US, vegetable oils (predominantly soybean oil), animal fats, and used cooking oils are reacted with either methanol or ethanol to form fatty acid alkyl esters. The US product is referred to as BioDiesel. These two products are currently being blended into commercial diesel fuels; however, volumes of these products in the market are still small.

Oxygenates can affect polymers (including elastomers and plastics) and polymer systems (including laminates and multi-layered components). Oxygenates and some compounds derived from these oxygenates can also affect metals, especially when moisture is present in the fuel.

3.3 Other Fuel Contaminants/Minor Fuel Components

- 3.3.1 GENERAL—During the manufacturing, transfer, storage, and use of fuels, many chemical reactions can occur to fuels and fuel components. The products of these reactions can in turn affect the properties of the materials that are in contact with the fuels.

Contaminated fuels can represent especially severe environments for polymer, elastomer, plastic, and metal fuel system parts. Several different types of contaminants commonly found in commercial fuels are added to the test fluids described in this document to increase the severity of the test fluids for more rapid materials testing.

- 3.3.2 ACIDS—Organic acids such as formic acid and acetic acid are present in certain fuels along with its corresponding alcohol (MeOH and EtOH, respectively). The acid is formed either in the alcohol production process or due to oxidation of the alcohol during handling, transfer, or storage. Ethanol may also contain trace amounts of sulfuric acid, a strong mineral acid that also originates in the production process.

Organic sulfur-containing acids and corresponding sulfur-containing esters can be formed by sulfur containing gasoline components that react with alcohols, notably ethanol and acetic acid/ethanol mixtures. These acids affect materials that are in contact with the fuel.

An acid/alcohol mixture with some water and salts present (see 3.3.4) is referred to as an "aggressive alcohol." Aggressive alcohol fluids are used in this document to test materials in harsh testing conditions.

- 3.3.3 PEROXIDES—Fuel hydrocarbons can undergo natural oxidation in the presence of heat and oxygen. Unsaturated hydrocarbons, such as olefins, degrade more easily. Organic peroxides form as a result of fuel oxidation (often referred to as auto-oxidation). These peroxides decompose to form free radicals that can chemically attack reactive sites (primarily at carbon double bonds but also hydrogen bonds to the carbon backbone) on polymers and elastomers in the fuel system. Other by-products of these degradation processes are acids that cause corrosion of metal components in the fuel system and gums and varnish that can coat the fuel system.

Although time and temperature alone are capable of decomposing peroxides, transition metals capable of a one electron transition, such as copper, will catalyze the decomposition of organic peroxides thereby accelerating this reaction.

- 3.3.4 IONIC COMPOUNDS—Sodium chloride or salt, is a compound that often makes its way into fuel systems. In fuels that contain moisture, the salt can adversely affect materials, especially metals.

Water has been mentioned in conjunction with several of the components. Water allows and contributes to many reactions concerning fuel components. Many of these reactions adversely affect materials in fuel systems.

- 3.3.5 SULFUR—Commercial gasolines contain varying amounts of sulfur in several forms. Prior to the introduction of reformulated gasoline, the average 1990 sulfur content in U. S. gasolines was 338 ppm. The ASTM D 4814 standard for gasoline allows up to 1000 ppm of total sulfur, the U. S. Federal RFG gasoline specification currently has no limit for total sulfur, and California CARB Phase 2 reformulated gasoline (RFG) regulations allow an average of 30 ppm of total sulfur. Similar restrictions on sulfur are becoming common around the world. In Europe, gasoline sulfur levels will be limited to 50 ppm after 2005.

One process in the refining and gasoline processing industry is the "sweetening" of gasoline components by converting mercaptans ($R - S - H$) to disulfides. Disulfide compounds are in the form of $R_1 - S - S - R_2$, where the groups R_1 and R_2 are generally C_1 to C_4 alkyl radicals. Disulfides can be converted to sulfonic and sulfinic acids in the presence of atmospheric oxygen and water.

Disulfides and their related sulfonic and sulfinic acid oxidation products have significant effects on metals, some elastomers, and some plastics. The stability of fuels and test fluids containing these sulfur compounds is not well understood. Further research is required before sulfur impurities can be recommended for addition to material testing fluid formulations of this document.

Commercial diesel fuels also contain varying amounts of sulfur. The 1996 average sulfur content in U. S. and European diesel fuels was 310 ppm while the application specifications limit sulfur to 500 ppm max. The trend to lower sulfur diesel is underway, with the 2005 European target sulfur content set at 50 ppm. Similar reductions on diesel fuel sulfur are becoming common around the world.

4. **Components of Materials Test Fluids**—Due to the complexity and variability of commercial automotive fuels, they are not suitable for repeatable and reproducible material qualification testing. This document recommends the use of controlled test fluids to simulate commercial fuels. The components of these fluids are described in this section with further details in the appendices.

4.1 Hydrocarbon Fluids

4.1.1 GENERAL—The first component in the materials testing fluid formula is the hydrocarbon fluid. There are several hydrocarbon fluids recommended for materials testing. These test fluids are designed to simulate more severe, real world fuels as described in Section 3. Suppliers and specifications for the hydrocarbon fluids are presented in Appendix A.

4.1.2 FUEL C—Standard ASTM test fluids are described in ASTM D 471/ISO 1817. These fluids are commonly used as the hydrocarbon component of a test fluid. ASTM test fluids are composed of isooctane or mixtures of isooctane and toluene. The ratios of isooctane and toluene vary, and each mixture has a separate letter designation (A through D). Fuel A is 100% isooctane; Fuel B is 70% isooctane, balance toluene; Fuel C is 50% isooctane, balance toluene; and Fuel D is 60% isooctane, balance toluene.

The most notable ASTM test fluid is "Fuel C." Fuel C, as previously mentioned, is a mixture that contains 50 volume percent isooctane and 50 volume percent toluene. Fuel C has been the ASTM fuel most often associated with materials testing since 1980. Fuel C is designated with a "C" in the nomenclature of this document. Suppliers and specifications for isooctane and toluene components are presented in Appendix A.

4.1.3 SURROGATE FUEL C—Since isooctane is a relatively expensive compound, this document now allows use of certain isoparaffin solvents that are suitable substitutes for isooctane. Surrogate Fuel C is a mixture that contains 50 volume percent of the substitute isoparaffin solvent, and 50 volume percent toluene. The substituted isoparaffin fluid is designated as "SC" in the nomenclature of this document. Suppliers and specifications for the substitute isoparaffin solvents are also presented in Appendix A.

The user is cautioned to repeat tests using Fuel C if the results from using Fuel SC fall close to the borderline of allowable material tolerances.

A comparison and validation of two isoparaffin surrogates with isooctane can be found in Appendix F.

4.1.4 REFERENCE GASOLINES—Reference gasolines can be used in place of the hydrocarbon test fluids listed previously, when test fluids more representative of commercial fuels are required. For example, for component subsystem or system design validation, several reference gasolines that are produced for use in vehicles are being recommended for use as hydrocarbon fluids. Suppliers and specifications for the reference gasolines are presented in Appendix B.

4.1.5 REFERENCE DIESEL FUELS—Reference diesel fuel can be used in place of the hydrocarbon test fluids listed previously, when a diesel test fluid more representative of commercial diesel fuel is required. Reference diesel fuels that are produced for use in diesel engines are being recommended for use as the hydrocarbon fluid for component subsystem or system design validation.

Suppliers and specifications for the reference diesel fuel are also presented in Appendix B.

4.2 Oxygenates

4.2.1 GENERAL—The second (and optional third) formula components of this document are oxygenated compounds. The two oxygenates most commonly found in commercial gasoline fuels in the US are ethanol (EtOH) and methyl tertiary-butyl ether (MTBE). These oxygenates are used in US reformulated gasoline (RFG), California Phase II RFG, Oxy-Fuel and gasohol in the general range of 5 to 10% by volume for ethanol and 5 to 15% by volume for methyl tertiary-butyl ether. Other oxygenates that can be added to gasoline include methanol (MeOH), ethyl tertiary-butyl ether (ETBE), and tertiary-amyl methyl ether (TAME). Of these oxygenates, methanol is generally not found in commercial gasolines sold in the US ETBE and TAME are only occasionally used as the oxygenated component of gasoline at this time.

There are two oxygenates derived from agricultural sources that can be used in diesel fuel. They are rapeseed methyl esters (RME) in Europe and BioDiesel in the US. BioDiesel is composed of methyl and/or ethyl esters of vegetable oils, animal fats, used cooking oils, or combinations of the previous. In order to standardize testing soy methyl esters (SME) derived from the trans-esterification of soybean oil with methanol has been selected as the diesel oxygenate of choice to represent the US market. Soy is the most highly unsaturated of the available oils/esters, which make it potentially the most aggressive test fluid.

- 4.2.2 ETHANOL—The most common source for ethanol is from biomass (corn, grain, sugar cane, etc.) fermentation. Since there are multiple feed sources and several fermentation/purification processes, the minor components of biomass derived ethanols vary greatly. This document recommends the use of synthetic ethanol that has a recognized set of specifications shown in Appendix C. The ethanol and its associated denaturant specified in this document will help to minimize some of the variables in the use of ethanol as a test fluid component.

The document specifies the denaturant that is used in the synthetic ethanol. The denaturant specified is approved by the U. S. Bureau of Alcohol, Tobacco & Firearms (BATF), and will render the ethanol as “completely denatured.” This denaturant is made primarily of heptane isomers, and was chosen so that the denaturant would have a minimal effect on the test fluid. At the same time, the chosen denaturant will allow the testing laboratory to avoid the expenditure of resources on the BATF record keeping requirements associated with non-denatured ethanol or “specially denatured” ethanols.

Ethanol derived from biomass contains a complex set of acid(s) and buffers associated with the acid(s). The buffering process is not fully understood at this time, but acetic acid that is found in biomass derived ethanol has been found to act as a buffer, tending to control the pH of the alcohol when strong acids such as sulfuric acid are present.

A new method analogous to pH, called pH_e , has been developed for use with ethanol. The method for measuring pH_e is ASTM D 6423-99. This method uses special pH electrodes and a pH meter recommended for use with ion specific electrodes to rank ethanols for acid strength on an arbitrary scale. The method was developed to overcome the shortcomings of ASTM D 1613 Acidity method which only measures buffering capacity and cannot distinguish between weak and strong acids. Many ethanol producers are currently using the ASTM D 6423 method to monitor and control strong acids in biomass derived ethanol. ASTM has successfully balloted pH_e specification limits of 6.5 to 9.0 for inclusion into ASTM D 4806.

- 4.2.3 METHYL TERTIARY-BUTYL ETHER (MTBE)—MTBE is the most prevalent oxygenate/octane booster found in current gasoline formulations. MTBE is used worldwide as a replacement for tetraethyl lead, which is legally prohibited from many automotive fuels. Suppliers and specifications for the oxygenated components are presented in Appendix C.
- 4.2.4 METHANOL—The methanol specified is synthetic commercial methanol derived from natural gas. The specifications for methanol found in ASTM D 1152 are recommended by this document. Suppliers and specifications for the oxygenated components are presented in Appendix C.
- 4.2.5 FATTY ACID METHYL-ESTERS—Rapeseed methyl esters (RME) are being used in European diesel fuels. The specifications are found in Appendix C. Fatty acid alkyl esters, referred to as BioDiesel, are starting to be introduced into the U.S. diesel fuel markets. A provisional specification for BioDiesel has been developed by ASTM as PS122-99. Soy methyl ester made to this specification is recommended by this document and can be found in Appendix C.
- 4.2.6 OTHER OXYGENATES—Higher molecular weight alcohols (isopropyl alcohol and tertiary-butyl alcohol) and ethers (diisopropyl ether and ethyl tertiary-amyl ether) may also find some limited usage in commercial gasolines. However, the effects of alcohols on polymers, elastomers, and metals generally decrease as the molecular weight increases.

4.2.7 ALTERNATIVE SPARK IGNITION ENGINE FUELS—Several alternative gasoline fuels are composed primarily of alcohols. The two most common alcohol blends are ethanol (70 to 85%) and methanol (70 to 85%), with the balance composed of a hydrocarbon mixture, such as unleaded gasoline. These alternative fuels currently make up a very small portion of the U. S. market and are specified in ASTM D 5798 and ASTM D 5797 respectively. Alternative fuels are currently used more extensively in markets outside of the U. S. Brazil, for example, uses a hydrated ethanol fuel containing 5 to 7% water and Brazilian gasohol containing approximately 25% anhydrous ethanol in gasoline.

In alternative fuels, more than one oxygenate may be added to a test fluid, but the use of multiple oxygenates is not common in U. S. commercial fuels. The nomenclature of this document (Section 5) provides for fuels containing multiple oxygenates.

4.3 Other Fuel Contaminants/Minor Fuel Components

4.3.1 GENERAL—The organic peroxide, aggressive alcohol, and aggressive water (for hydrocarbons) are the only minor components currently recommended by this document.

4.3.2 AGGRESSIVE ALCOHOL—An “Aggressive” alcohol contains the alcohol, salts, water, and a corresponding organic acid. Aggressive ethanol also contains sulfuric acid, a contaminant found in some commercial biomass derived ethanols. The specifications and suppliers for aggressive alcohol components are found in Appendix D. The formulations for making aggressive alcohols are found in Appendix E.

4.3.3 CORROSIVE WATER FOR METALS TESTING—Corrosive water for hydrocarbons is composed of Reagent Water and salt. Fluids C and SC (or C and SC with MTBE) are the only fluids that can contain Corrosive Water and are used for metals testing only. The formulation used in making corrosive water is also found in Appendix E.

4.3.4 PEROXIDES—Tertiary-butyl hydroperoxide (TBHP) is the recommended organic peroxide to be added into test fluids to simulate and create an oxidized fuel. TBHP is normally sold either as a 70% aqueous solution or as part of a hydrocarbon solution. In order to control the amount of TBHP added, the peroxide content of the TBHP solution must be known. This determination can be performed by the supplier and provided with the product, or the testing laboratory can perform it prior to use. The specifications and suppliers for TBHP are found in Appendix D.

Small amounts of copper, especially cuprous, (Cu^{+1}) compounds are often added to a test fluid that contains organic peroxides to accelerate the decomposition of peroxides into free radicals. Copper compounds are documented in the literature as promoters of free radicals, and their use offers an acceptable method to reduce testing time in sour fuel mixtures. Copper is often found in fuel systems in the form of electrical circuit components, fuel pump motor windings and armatures and in associated wiring. The specifications and suppliers for potentially useful copper compounds are found in Appendix D.

Copper addition to test fluids containing TBHP in prior work was accomplished using a cupric (Cu^{+2}) salt such as copper naphthenate. In the Cupric form, heat and time were required to convert some Cu^{+2} into Cu^{+1} in order to make it available as a catalyst in peroxide decomposition reactions. Results from current and prior testing using cupric salts as a promoter are considered valid. If a suitable cuprous (Cu^{+1}) compound which is both soluble and active can be found, its use will accelerate the formation of free radicals in the test fluid, which in turn accelerates the oxidation of the test fluid and generates quicker results.

It should be noted that adjustments in test time and/or temperature should be made if changing from a test fluid which either contained or did not contain the copper ion. For example, to duplicate tests conducted with the copper ion using a test fluid without the copper ion might require raising the test temperature 10 °C to 20 °C or increasing the exposure time by a factor of 2 to 4 at the same temperature.

4.3.5 FUTURE COMPONENTS—Components, such as sulfur compounds and other contaminants, may be considered in future revisions of this document. These components will be assigned designated formula nomenclatures and specifications.

5. Test Fluid Nomenclature

5.1 **General**—A recommended naming convention for test fluids and fuels is presented in this document. Using these abbreviations uniquely identifies the composition of each fluid. Uniform adaptation of this flexible nomenclature for other test fluids is encouraged.

5.2 **Nomenclature Convention**—The test fluid nomenclature includes the following items, in the specified order:

5.2.1 an abbreviation (X) designating the hydrocarbon fluid used,

5.2.2 an abbreviation (Y_n) designating the oxygenate(s) and the volume percentage(s) of oxygenate(s) used,

5.2.3 an optional suffix (S) designating an optional minor component added to make a more extreme fluid,

5.2.4 the letter "P" at the end indicating the presence of peroxide,

5.2.5 a subscript "A" following the (Y_n) component to designate the presence of minor components making that component aggressive toward the material being tested,

5.2.6 the letter "w" at the end indicating the presence of Corrosive Water.

5.3 Formulas

5.3.1 GENERAL FORMULA—The general formula for a material test fluid is:

$$X (Y_1\%)(Y_2\%)(Y_n\%) S \quad (\text{Eq. 1})$$

where:

X = Hydrocarbon fluid

Y_1 = First optional oxygenate

Y_2 = Second optional oxygenate

Y_n = the nth optional oxygenate

% = Volume percent of oxygenate

S = optional minor constituent such as:

P = the presence of an organic peroxide contaminant which can be added to any fuel mixture.

A = a subscripted "A" following the alcohol component indicating the presence of an aggressive alcohol.

w = a lower case "w" component indicating the presence of Corrosive Water added to a hydrocarbon fluid or MTBE containing hydrocarbon fluid.

5.3.2 HYDROCARBON NOMENCLATURE—Letter designations for the recommended hydrocarbon fluids in the nomenclature of this document are:

C = ASTM Fuel C (50% Toluene and 50% Isooctane)

SC = ASTM Surrogate Fuel C (50% Toluene and 50% substitute isoparaffin solvent)

D_{EPA2} = EPA Certification No. 2 low sulfur reference diesel fuel

Commercial reference gasoline names as shown in Appendix B and their industry abbreviations may be used as the hydrocarbon fluid nomenclature of this document.

5.3.3 OXYGENATE NOMENCLATURE—Letter designations for the more common oxygenates in the nomenclature of this document are:

- M = methanol
- E = ethanol
- ME = methyl tertiary-butyl ether
- EE = ethyl tertiary-butyl ether
- TE = tertiary-amyl methyl ether
- RME = rapeseed methyl esters
- SME = soybean methyl esters (this is the recommended version of BioDiesel).

5.4 **Examples**—Examples utilizing this naming convention are presented as follows:

EXAMPLE 1—C(E10) = 90 volume % Fuel C + 10 volume % ethanol.

EXAMPLE 2—SC(M25)_A = 75 volume % Surrogate Fuel C + 25 volume % aggressive methanol.

EXAMPLE 3—C(E25)(ME15) = 60 volume % Fuel C + 25 volume % ethanol + 15 volume % methyl tertiary butyl ether.

EXAMPLE 4—C(ME15)P = 85 volume % Fuel C + 15 volume % methyl tertiary butyl ether + tertiarybutyl hydroperoxide (an auto-oxidized fuel).

EXAMPLE 5—C(E10)AP = 90 volume % Fuel C + 10 volume % aggressive ethanol + tertiary butyl hydroperoxide (an auto-oxidized fuel).

EXAMPLE 6—D_{EPA2} (RME20) = 80 volume % Certification diesel + 20 volume % rapeseed methylesters.

EXAMPLE—SC_w = Surrogate Fuel C with Corrosive Water (for metals testing).

6. Preparation of Test Fluids

6.1 **General**—Each of the test fluids used in this document shall be made from components as specified in the appendices of this document.

Most of the test fluids are flammable liquids and should be stored, handled, and used only after consulting the appropriate Material Safety Data Sheets.

All liquid components of test fluids are specified in terms of volume percent. Test fluids should be well mixed before use. Inverting a closed container 24 times assures complete mixing.

Phase separated fluids should be handled such that the relative amounts of the two phases are not changed during transfer.

Fluids and/or components prepared in advance should be stored in tightly sealed containers to prevent evaporation or contamination.

Transfer of hydrocarbon fluids from container to container can generate static charges. The charges can discharge via a spark and cause subsequent ignition of the fluid or its vapor. Grounding methods for the containers are recommended.

Hydrocarbons and oxygenated compounds are volatile and release vapors. Vapor tight containers are recommended to prevent possible vapor ignition and personal exposure to the compounds present in the test fluids.

The following steps are recommended for preparing these blends:

- a. Determine the volume of fluid to be blended.
- b. Determine the volume or weight of each component required.
- c. Add the required volumes of hydrocarbon and/or oxygenate(s).
- d. Add the contaminants (peroxide solution, aggressive components, etc.).
- e. Mix well before use.

Mixing can be accomplished with a stirrer that constantly mixes the fluid as components are added in the blending container.

6.2 Hydrocarbon Fluids

- 6.2.1 GENERAL—ASTM reference fluids and surrogate reference fluids should be premixed according to the formulations. Reference fluids are used as obtained from the suppliers.
- 6.2.2 CORROSIVE WATER—Corrosive water is used to make corrosive hydrocarbon fluids such as Cw and SCw, or corrosive MTBE containing hydrocarbon fluids such as SC(ME15)w and C(ME15)w.

A Corrosive Water stock solution provides 100 ppm chloride ion per liter of water. Previous versions of this document also included Na_2SO_4 and NaHCO_3 . These two constituents have been judged to not contribute significantly to metal corrosion. In fact, it was determined that NaHCO_3 helped to neutralize acids that were added to make aggressive alcohol.

The detailed formulation used in making Corrosive Water is found in Appendix E.

6.3 Alcohols

- 6.3.1 GENERAL—Methanol and ethanol should be purchased to conform to the properties shown in Appendix C. Reagent Water is added to purchased alcohols prior to their use in materials testing fluid blends as described in this document. This is done to simulate the water content commonly found in fuel grade methanol and ethanol. The amount of water required is determined by difference between the total water content required and the water content of the product as received, determined by Karl Fisher titration.
- 6.3.2 METHANOL—Methanol used in materials testing fluids should be adjusted by adding Reagent Water to the methanol, as received, to obtain a test fluid component that contains 0.3 wt % total water content.
- 6.3.3 ETHANOL—Ethanol for use in materials testing fluids should be adjusted by adding Reagent Water to the ethanol, as received, to obtain a test fluid component that contains 1.0 wt % total water content.

Alcohols are hygroscopic, absorbing moisture from the air. For this reason, alcohol containers should be tightly sealed after the water content has been adjusted and measured.

- 6.3.4 AGGRESSIVE ALCOHOLS—Aggressive MeOH and EtOH formulations are stated in Appendix E.

6.4 Peroxides

- 6.4.1 GENERAL—It is recommended that the peroxide solution be refrigerated at approximately 7 °C (45 °F) to minimize decomposition. It is also recommended that the peroxide solution be analyzed periodically to determine the actual peroxide content over time.

- 6.4.2 TERTIARY-BUTYL HYDROPEROXIDE—Tertiary-butyl hydroperoxide (TBHP) in an aqueous solvent must conform to the properties shown in Appendix D. The weight percent of TBHP in solution should be provided by the supplier or be determined using ASTM E 298. In order to simulate an oxidized fuel, 50 millimoles (mMol) of TBHP is added per liter of the test fluid. The amount of TBHP solution required to obtain a concentration of 50 mMol TBHP per liter of test fluid is calculated using Equation 2:

$$\text{grams of TBHP solution to make 1.0 L of test fluid} = \frac{(50 \text{ mMol TBHP}) \times (90 \text{ mg/mMol TBHP})}{(\text{wt fraction of TBHP in solution}) \times (1000 \text{ mg/g})} \quad (\text{Eq. 2})$$

According to this equation, 6.43 g of 70% TBHP solution is required per liter of test fluid.

- 6.4.3 COPPER ION—The use of copper compounds to create copper ions in solution is optional for this document. The specifications, and suppliers for organic copper salts are found in Appendix D. The final test fluid should contain 0.01 mg of Cu per liter.

If copper ions are used, simply dissolve the correct amount of one of the compounds listed in Appendix D.

The amount of copper compound required to give 0.01 g copper per liter of test fluid can be calculated from the Equation 3, where the weight percent copper is obtained from the supplier's specification for the copper compound or it is determined by testing:

$$(0.01 \text{ mg Cu}) \div [(\text{wt \% Cu in copper compound}) \times (0.01)] = \text{mg Cu compound to be used} \quad (\text{Eq. 3})$$

The addition of copper should be made with adequate mixing immediately AFTER blending the TBHP into the test fluid. Mixing the cuprous ions into the concentrated TBHP solution is NOT recommended.

7. Recommended Fluids for Materials Testing

7.1 Fluids for Testing Fuel System Materials

- 7.1.1 GENERAL—While this document establishes a system of methods and nomenclature capable of creating and naming an infinite variety of potential test fluid recipes, it is not the intention that materials should be tested in all potential fluids. The test fluids that the document recommends as a minimum to evaluate all candidate materials are listed in this section.

The recommended fluids are designed to simulate typical, severe, real world conditions that can be encountered. The selected fluids are intended to:

- Minimize the testing required to rigorously evaluate fuel system materials,
- Reduce variability in test fluids listed in materials specifications, and
- Standardize testing of fuel system materials.

The final choice of materials to be selected and the test fluids to be used to qualify these materials are dependent on the application as well as the specific design of the component. It will likely involve the cooperative efforts of the component engineer, materials engineer, and the suppliers.

- 7.1.2 FLUIDS TO QUALIFY MATERIALS FOR WORLDWIDE, BASIC, GASOLINE, AND DIESEL FUEL SYSTEM APPLICATIONS—The four test fluids that are representative of severe general gasoline fuels in marketplaces, worldwide include:

C(M15) _A	or	SC(M15) _A ,
C(ME15)	or	SC(ME15), and
CP	or	SCP
Cw	or	SCw for metals testing only (see 7.2.4)

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Testing in these fluids alone is sufficient for qualifying materials for consideration in general fuel system applications.

Note that a fuel mixture containing methanol is recommended (CM15) whereas methanol is rarely found in commercial fuels. This fuel has been used for years in the automotive industry and continues to be a valid test fluid because methanol creates effects on materials which are representative of worst case marketplace fuels whether they contain methanol or not. Ethanol and higher alcohols, which may be more common in fuels, usually create significantly smaller effects on fuel system materials.

Diesel fuel is usually less chemically aggressive; therefore, materials qualified in these four test fluids can also be used in diesel fuel applications without being tested in additional fluids.

7.1.3 FLUIDS TO QUALIFY MATERIALS FOR DEDICATED, ALCOHOL BASED FUEL SYSTEM APPLICATIONS—Materials to be qualified for use in fuel systems intended for dedicated alcohol fueled vehicles (E100 to E85 or M100 to M85 fuels) must be tested in the following test fluids:

- a. All fluids designated in 7.1.2, and
- b. Either: C(M85)_A, SC(M85)_A, C(E85)_A, or SC(E85)_A (depending on the intended marketplace alcohol fuel: ethanol or methanol).

7.1.4 FLUIDS TO QUALIFY MATERIALS FOR ALCOHOL BASED, FLEXIBLE FUELED VEHICLE FUEL SYSTEM APPLICATIONS—Materials to be qualified for use in fuel systems intended for flexible fueled vehicles (gasoline, E85, or M85) should be tested in the intended marketplace alcohol fuel (ethanol or methanol) as follows:

- a. All fluids designated in 7.1.2,
- b. C(E15)_A or SC(E15)_A (if applicable) and
- c. C(M30)_A or SC(M30)_A or C(E30)_A or SC(E30)_A and
- d. C(M50)_A or SC(M50)_A or C(E50)_A or SC(E50)_A and
- e. C(M85)_A or SC(M85)_A or C(E85)_A or SC(E85)_A and
- f. C(M20)_A(ME15) or SC(M20)_A(ME15) or C(E20)_A(ME15) or SC(E20)_A(ME15).

The purpose for testing with the six additional fluids indicated in this section is to identify the fluid composition that causes the greatest effect on the material being evaluated. The worst case fluid should then be used exclusively for all subsequent testing of that material. This allows all materials to be compared at their individual worst to indicate suitability for use in a particular application.

7.1.5 FLUIDS TO QUALIFY MATERIALS FOR DIESEL FUEL ONLY APPLICATIONS—Materials previously qualified in gasoline systems and tested in fluids designated in 7.1.2, will qualify for diesel fuel applications. To qualify for diesel fuel only applications, candidate materials need only be tested in D_{EPA2} (EPA certification No. 2 diesel fuel). Testing in RME or BioDiesel and their mixtures with diesel fuel may also be required.

7.1.6 FURTHER QUALIFICATION OF MATERIALS IN MARKETPLACE FUELS—In addition to the basic fuel compatibility testing specified previously, component or automotive original equipment manufacturers may require further testing in marketplace representative fluids or fuels. These include:

- a. Test fluids that simulate marketplace fuels which are all fluids designated in 7.1.2, and
- b. Test fuels that represent typical marketplace fuels (see Appendix B):
 - a. EPA certification gasoline
 - b. California certification gasoline
 - c. GM test fuel 1 (TF-1)
 - d. GM test fuel 2 (TF-2)
 - e. Brazilian Gasohol (with 25% Biomass Ethanol)
 - f. D_{EPA2} (EPA certification No. 2 diesel fuel)

- g. D_{EPA2} (RME20) (20% RME in No. 2 reference diesel fuel)
- h. D_{EPA2} (SME20) (20% SME in No. 2 reference diesel fuel)

7.2 Material Qualification Testing for Fuel Compatibility

- 7.2.1 GENERAL—The purpose of this testing is initial screening of material coupon samples to determine their compatibility with intended marketplace fuels. Use of the test fluids outlined in 7.1 permits simplified testing with standardized chemicals and assures repeatable test results.

Careful attention should be paid to the mechanisms of failure or incompatibility discovered by this testing. For example, the aggressive fluid mixtures may cause one type of degradation while auto-oxidized (peroxide) fluid may cause another. If the extent of degradation is significant for each fluid, then both fluid types must be considered as worst case for further evaluations.

- 7.2.2 POLYMERS (PLASTICS AND THERMOPLASTIC ELASTOMERS)—Flexural modulus and/or tensile modulus should be used as a screening test for polymers. The test fluid that causes the greatest reduction in modulus should be used for all subsequent testing and/or for inclusion in the specification of the material when intended for fuel system applications.

- 7.2.3 ELASTOMERS (RUBBER)—Swelling should be used as the screening test for elastomers. The test fluid that causes the greatest amount of swelling should be used for all subsequent testing and/or for inclusion in the specification of the material when intended for fuel system applications.

- 7.2.4 METALS AND THEIR PROTECTIVE COATINGS—The primary concern for metals is corrosion. Test exposure of the material or component should reflect actual use conditions. Tests should include immersion of the material or component in the fluid and exposure of the material or component to the vapor phase above the fluid. Note that in some test fluids, phase separation can occur. Exposure to the water-rich “lower” phase may be the most difficult environment for metals. The test design should include exposure of the metal to such a water-rich phase if this circumstance exists. Test specimens should be examined for corrosion or any obvious chemical attack after exposure to the vapor phase, the fluid phase, and the water-rich phase.

Metals should be tested for resistance to corrosion by placing the test specimen in a container filled with enough mixture of fluid C or SC and Corrosive Water to expose the lower end to water phase and the top end to vapor phase. The test fluid mixture should contain enough Corrosive Water to create a second phase layer thick enough to contact the lower 10 to 20% of the test specimen. In addition, the container should be only partially filled with test fluid mixture so that the top 20 to 30% of the test specimen is exposed to vapor phase only. The Corrosive Water formulation is found in Appendix A.

- 7.2.5 OTHER REQUIREMENTS—A material’s properties, including its fuel compatibility, can be strongly influenced by the part design and the manufacturing processes used to convert the raw material into a finished component. The task of assessing fuel compatibility and suitability of a material for use in a fuel system is not complete unless the material is re-evaluated after conversion into the intended component using the test fluids or test fuels identified as worst case. However, as emphasized earlier in the document (see “Scope”), it is not intended that the TEST FLUIDS listed in this document be used for product or process validation of devices (e.g., fuel pumps, injectors, etc.) assembled from materials so qualified. Product validation should only be conducted using the TEST FUELS specified in this document.

8. **Listing of Worldwide Test Fuels** —Test fluids and fuels that have been used worldwide for materials testing are listed in Appendix G for reference only.

9. Summary of the Appendices

Appendix A: Specifications for Hydrocarbon Fluids

- Specifications for ISOCTANE AND TOLUENE
- Specifications for REFERENCE FUEL GRADE TOLUENE
- Specifications for TOLUENE Nitration Grade
- Specifications for ISOCTANE (2,2,4 - trimethyl pentane)
- Specifications for MIXED OCTANE ISOMERS (Isopar C)
- Specifications for MIXED OCTANE ISOMERS (Soltrol 10)

Appendix B: Specifications and Suppliers for Reference Gasolines and Diesel Fuel

- Specifications for EPA CERTIFICATION GRADE GASOLINE
- Specifications for CARB PHASE 2 REFORMULATED CERTIFICATION GRADE GASOLINE
- Specifications for TF-1 GASOLINE
- Specifications for TF-2 GASOLINE
- Specifications for BRAZILIAN E 22 GASOLINE
- Specifications for EPA CERTIFICATION NO. 2 DIESEL FUEL

Appendix C: Suppliers and Specifications for Oxygenates

- Specifications for METHANOL, Commercial Grade
- Specifications for ETHANOL, Synthetic
- Specifications for METHYL TERTIARY-BUTYL ETHER, (MTBE), High Purity Grade
- Specifications for RAPESEED METHYL ESTERS (RME)
- Specifications for SOY METHYL ESTERS (SME)

Appendix D: Specifications and Suppliers of Other Chemicals For Materials Testing

- Specifications for TERTIARY-BUTYL HYDROPEROXIDE, 70% Solution
- Specifications for GLACIAL ACETIC ACID, ACS Reagent Grade
- Specifications for FORMIC ACID, ACS Reagent Grade
- Specifications for SODIUM CHLORIDE, Crystalline, ACS Reagent Grade
- Specifications for Copper Salts for Adding Copper Ions to Peroxide Test Fluids
- Specifications for SULFURIC ACID, 95 to 98%, ACS Reagent Grade
- Specifications for REAGENT WATER

Appendix E: Formulations for Aggressive Alcohols and Corrosive Water

- Aggressive Methanol
- Aggressive Ethanol
- Corrosive Water

Appendix F: Test Results Validating the Use of Isooctane Surrogates

Appendix G: Worldwide Test Fluids and Test Fuels

APPENDIX A

SPECIFICATIONS FOR HYDROCARBON FLUIDS

A.1 Specifications for ISOCTANE AND TOLUENE from ASTM D 471—See Table A1.

TABLE A1—SPECIFICATIONS FOR ISOCTANE AND TOLUENE FROM ASTM D 471

	ASTM Isooctane	ASTM n-Heptane	ASTM 80 O.N. Blend
ASTM-IP MOTOR OCTANE NO. ⁽¹⁾	—	—	NOMINAL ± 0.1
ISOCTANE, ⁽²⁾ %	NOT LESS THAN 99.75	NOT GREATER THAN 0.10	—
N-HEPTANE, ⁽²⁾ %	NOT GREATER THAN 0.10	NOT LESS THAN 99.75	—
LEAD CONTENT, ⁽³⁾ G/GAL	NOT GREATER THAN 0.002	NOT GREATER THAN 0.002	—

1. DETERMINED IN ACCORDANCE WITH ASTM D 2700-IP236.

2. DETERMINED IN ACCORDANCE WITH ASTM D 2268.

3. TO BE DETERMINED IN THE CERTIFICATION TEST IN ACCORDANCE WITH ASTM D 3237-97.

A.2 Specifications for Reference Fuel Grade Toluene¹

Toluene, % not less than 99.5⁽¹⁾⁽²⁾

1. Determined in accordance with ASTM D 2360.

2. In addition to determining nonaromatic hydrocarbons, a calibration for trace benzene and trace xylenes must be made to aid in the determination of monocyclic aromatic hydrocarbons other than toluene.

A.3 Specifications for Toluene Nitration Grade—See Table A2.

TABLE A2—SPECIFICATIONS FOR TOLUENE NITRATION GRADE⁽¹⁾

Parameter	Units	Conditions	Minimum	Maximum	Test Method
TOLUENE	wt /wt %		99.5		ASTM D 2360 MOD.
NITRATION TOLUENE			PASSES 99.5		ASTM D 841
DISTILLATION RANGE	°C	Including 110.6 °C	PASSES	1.0	ASTM D 850
NON AROMATICS	wt /wt %			1.5	ASTM D 2360 MOD.
SPECIFIC GRAVITY	—	15 °C (60 °F)	0.869	0.873	ASTM D 4052
COLOR	Pt - Co		0.869	20	ASTM D 1209
ACIDITY	—		NONE	20	ASTM D 847
ACID WASH COLOR	—		NONE	2	ASTM D 848
COPPER CORROSION	—		1 A	2	ASTM D 849
H ₂ S + SO ₂	—		NONE		ASTM D 853
BENZENE	PPM			300	ASTM D 2360
NON-VOLATILE MATTER	MG. / 100 mL			1.0	ASTM D 1353
APPEARANCE	—		BRIGHT & CLEAR		ASTM D 4176 MOD.

1. U.S. Suppliers: Specified Fuels and Chemicals
Various Chemical Distributing Companies
Various Laboratory Supply Companies

Trade Name: Nitration Grade Toluene

1. Determined in accordance with ASTM D 2360.

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A.4 Specifications for Isooctane (2,2,4, - trimethyl pentane)—See Table A3.

TABLE A3—SPECIFICATIONS FOR ISOCTANE (2,2,4, - TRIMETHYL PENTANE)⁽¹⁾

Parameter	Units	Conditions	Typical	Minimum	Maximum	Test Method
NON-VOLATILE MATTER	MG./1000 mL.		0.16			ASTM D 381
SULFUR CONTENT	PPM		<1			ASTM D 3120
LEAD	grams / gal.		0.000		0.002	ASTM D 3237
COMPOSITION	LV%					
2,2,4 TRIMETHYL PENTANE			99.95	99.75		ASTM D 2268
OTHER OCTANES			0.04			
n HEPTANE			0.01		0.1	

1. U.S. Suppliers: Phillips Petroleum Company
Specified Fuels and Chemicals
Various Chemical Distributing Companies
Various Laboratory Supply Companies

Trade Name: Isooctane, Primary Reference Fuel (PRF)

A.5 Specifications for Mixed Octane Isomers (Isopar C)—See Table A4.

TABLE A4—SPECIFICATIONS FOR MIXED OCTANE ISOMERS (ISOPAR C)⁽¹⁾

Parameter	Units	Conditions	Typical	Minimum	Maximum	Test Method
ANILINE POINT	°C		77	80		ASTM D 611
	°F			170.6	176	
APPEARANCE				BRIGHT & CLEAR		ASTM D 4176 MOD.
AROMATICS	vol/vol %				0.02	ASTM D 1319
BULK ODOR	—			PASS		PANEL
COLOR	SAYBOLT UNITS			30		ASTM D 156
DISTILLATION						ASTM D 86
INITIAL B P	°C (°F)			96 (204.8)		
DRY POINT	°C (°F)				107 (224.6)	
NON-VOLATILE MATTER	MG. /100 mL				1.0	ASTM D 1353
SPECIFIC GRAVITY	—	15 °C (60 °F)		0.694	0.701	ASTM D 4052 / 1298
SULFUR CONENT	PPM				5	ASTM D 4045 MOD.
COMPOSITION	LV %					
2,2,4 TRIMETHYL PENTANE			79			TYPICAL G. C.
OTHER BRANCHED OCTANES			17			TYPICAL G. C.
BRANCHED HEPTANES			4			TYPICAL G. C.

1. U.S. Suppliers: Exxon Chemical Company
Specified Fuels and Chemicals
Various Chemical Distributing Companies
Various Laboratory Supply Companies

Trade Name: Isopar C

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A.6 Specifications for Mixed Octane Isomers (Soltrol 10)—See Table A5.

TABLE A5—SPECIFICATIONS FOR MIXED OCTANE ISOMERS (SOLTROL 10)⁽¹⁾

Parameter	Units	Conditions	Typical	Minimum	Maximum	Test Method
ANILINE POINT	° F		170.6			ASTM D 611
AROMATICS	vol/vol %		NIL			G.C.
BULK ODOR	---		PASS			PANEL
COLOR	SAYBOLT UNITS			30		ASTM D 156
DISTILLATION	°F					ASTM D 86
INITIAL B P	°F		204	200		
5%	°F		205	202		
10%	°F		206			
50%	°F		208			
90%	°F		212			
95%	°F		215	219		
DRY POINT	°F		218	220		
NON-VOLATILE MATTER	MG. / 100 mL		0.5		1.0	ASTM D 1353
SPECIFIC GRAVITY	---	15 °C (60 °F)		0.694	0.701	ASTM D 4052 / 1298
API GRAVITY	° API	60 °F	70.6			
SULFUR CONENT	PPM					ASTM D 4045 MOD.
	PPM		<1		10	ASTM D 3120
COMPOSITION	L V %					G. C.
2,2,4 TRIMETHYL PENTANE			62			
OCTANES			10			
HEPTANES			28			
REID VAPOR PRESSURE	PSIA	100 °F	2.2			ASTM D 323
FLASH POINT	° F		13			ASTM D 56
KARI - BUTANOL VALUE	—	27.9				

1. U.S. Suppliers: Phillips Petroleum Company
 Specified Fuels and Chemicals
 Various Chemical Distributing Companies
 Various Laboratory Supply Companies

Trade Name: Soltrol 10

APPENDIX B

SPECIFICATIONS AND SUPPLIERS FOR REFERENCE GASOLINES AND DIESEL FUEL

B.1 Specifications and Suppliers for Reference Gasolines and Diesel Fuel—See Tables B1 through B6.

TABLE B1—SPECIFICATIONS FOR EPA CERTIFICATION GRADE GASOLINE⁽¹⁾
U.S. ENVIRONMENTAL PROTECTION AGENCY
40 CFR 86.307 (A) (1)

Parameter	Units	Specifications Minimum	Specifications Maximum	ASTM Test Method
OCTANE, RESEARCH		96		D 2699
PB (ORGANIC)	GRAMS/U.S. GAL	0.00	0.05	
DISTILLATION RANGE:				
IBP	°F	75	95	D 86
10 PCT POINT	°F	120	135	D 86
50 PCT POINT	°F	200	230	D 86
90 PCT POINT	°F	300	325	D 86
EP			415	D 86
SULFUR	WT %		0.1	D 1266
PHOSPHORUS	GRAMS/U.S. GAL		0.005	
RVP	PSIG	8.0	9.2	D 323
COMPOSITION:				
OLEFINS	%		10	D 1319
AROMATICS	%		35	D 1319
SATURATES	%		BALANCE	D 1319

1. U.S. Suppliers: Specified Fuels and Chemicals
 BP/Amoco
 Trade name: EEE
 Indolene

TABLE B2—SPECIFICATIONS FOR CARB PHASE 2 REFORMULATED
CERTIFICATION GRADE GASOLINE⁽¹⁾
CALIFORNIA AIR RESOURCE BOARD REGULATIONS SECTION 2262, 2252 - 54

Parameter	Units	Specifications Minimum	Specifications Maximum	ASTM or ARB Test Method
SULFUR	PPM		80	D 2622
OXYGEN	VOL %	1.80	2.7	D 4815
DISTILLATION RANGE:				
50 PCT POINT	° F		220	D 86
90 PCT POINT	° F		330	D 86
RVP	PSIG		7.0	D 323
COMPOSITION:				
OLEFINS	%		10.0	D 1319
AROMATICS	%		35	D 1319
BENZENE	VOL %		1.2	D 3606
				ARB MLD 16
PHOSPHORUS	GRAMS/U.S. GAL		0.005	D 3231
LEAD	GRAMS/U.S. GAL		0.05	D 3237
MANGANESE	GRAMS/U.S. GAL		0	—

1. U.S. Suppliers: Specified Fuels and Chemicals
 Trade Name: C A RB Phase 2

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TABLE B3—SPECIFICATIONS FOR TF-1 GASOLINE⁽¹⁾

Parameter	Units	Specifications Minimum	Specifications Maximum	ASTM or ARB Test Method
SULFUR	PPM		500	D 2622, D 3120, OR D 5453
METHANOL	VOL %		0	D 4815
ETHANOL	VOL %	9.5	10.5	D 4815
MTBE	VOL %		0	D 4815
DISTILLATION RANGE:				
10 PCT POINT	°F		158	D 86
50 PCT POINT	°F	170	250	D 86
90 PCT POINT	°F		374	D 86
END POINT	°F		437	D 86
RVP	PSIG	8.0	9.0	D 5191
COMPOSITION:				
OLEFINS	VOL %		15.0	D 1319
AROMATICS	VOL %	45.0	50.0	D 1319
GUM CONTENT, WASHED	MG/100ML		5.0	D 381
OXIDATION STABILITY	MINUTES	960		D 525
OCTANE (R+M/2)	- - -	91.0		D 2699/2700
WATER	VOL %		0.1	D 2709
LEAD	GRAMS/U.S. GAL		0.005	D 3237
APPEARANCE	—	CLEAR, BRIGHT, FREE	OF UNDISSOLVED WATER	VISUAL

1. U.S. Suppliers: Specified Fuels and Chemicals
Trade Name: General Motors Test Fuel 1 (TF-1)

TABLE B4—SPECIFICATIONS FOR TF-2 GASOLINE⁽¹⁾

Parameter	Units	Specifications Minimum	Specification Maximum	ASTM or ARB Test Method
SULFUR	PPM		500	D 2622, D 3120, or D 5453
METHANOL	VOL %	4.5	5.5	D 4815
ETHANOL	VOL %	2.0	3.0	D 4815
MTBE	VOL %		0	D 4815
DISTILLATION RANGE:				
10 PCT POINT	°F		158	D 86
50 PCT POINT	°F	170	250	D 86
90 PCT POINT	°F		374	D 86
END POINT	°F		437	D 86
RVP	PSIG	8.0	9.0	D 5191
COMPOSITION:				
OLEFINS	VOL %		15.0	D 1319
AROMATICS	VOL %	45.0	50.0	D 1319
GUM CONTENT, WASHED	MG/100 ML		5.0	D 381
OXIDATION STABILITY	MINUTES	960		D 525
OCTANE (R+M/2)	—	91.0		D 2699/2700
WATER	VOL %		0.1	D 2709
LEAD	GRAMS/U.S. GAL		0.005	D 3237
APPEARANCE	—	CLEAR, BRIGHT, FREE	OF UNDISSOLVED WATER	Visual

1. U.S. Suppliers: Specified Fuels and Chemicals
Trade Name: General Motors Test Fuel 2 (TF-2)

TABLE B5—SPECIFICATIONS FOR BRAZILIAN E 22 GASOLINE⁽¹⁾

Parameter	Units	Specifications Minimum	Specifications Maximum	Typical	ASTM Test Method
SULFUR	PPM	350	650		D4294
ETHANOL	VOL %	21.0	23.0		D4815
DISTILLATION RANGE:					D86
10 PCT POINT	°F		150	132	
50 PCT POINT	°F		220	162	
95 PCT POINT	°F			329	
END POINT	°F		400	358	
RVP	PSIG		9.0	7.0	D 5191
LEAD	G/GAL			0.01	D 3237
COMPOSITION:					
AROMATICS	%		30	20	D 1319
OLEFINS	%		15.0	10.0	D 1319

1. NOTE—This fluid has been designed to be similar to Brazilian gasohol containing 22% biomass ethanol.

U.S. Suppliers: Specified Fuels and Chemicals
Trade Name: Brazilian E 22

TABLE B6—SPECIFICATIONS FOR EPA CERTIFICATION NO. 2 DIESEL FUEL⁽¹⁾
U.S. ENVIRONMENTAL PROTECTION AGENCY
40 CFR 86.1313 (B) (2)

Parameter	Units	Specifications Minimum	Specifications Maximum	ASTM Test Method
CETANE NUMBER	—	42	48	D 613
DISTILLATION RANGE:				
IBP	°F	350	390	D 86
10 PCT POINT	°F	410	450	D 86
50 PCT POINT	°F	480	530	D 86
90 PCT POINT	°F	570	620	D 86
EP	°F	620	680	D 86
GRAVITY	° API	32	37	D 287
SULFUR	WT %	0.03	0.05	D 2622
COMPOSITION:				
AROMATICS	VOL %	28	35	D 1319
PARAFFINS, NAPHTHENES, OLEFINS	VOL %	BALANCE	BALANCE	D 1319
FLASHPOINT	°F	130		D 93
VISCOSITY	CST	2.0	3.2	D 445

1. U.S. Suppliers: Specified Fuels and Chemicals
Trade Name: Low Sulfur Reference Diesel - 4

APPENDIX C

SUPPLIERS AND SPECIFICATIONS FOR OXYGENATES

C.1 *Suppliers and Specifications for Oxygenates*—See Tables C1 through C5.TABLE C1—SPECIFICATIONS FOR METHANOL, COMMERCIAL GRADE⁽¹⁾

Parameter	Units	Conditions	Minimum	Maximum	Test Method
METHANOL	WT /WT PERCENT		99.85		ASTM E 346
SPECIFIC GRAVITY	—	20 °C/20 °C		0.7928	ASTM D 891
DISTILLATION RANGE	°C	Not More Than:		1.0	
DISTILLATION RANGE	°C	RANGE 64.6 ±		0.1	
COLOR	APHA			5	ASTM D 1209
ACIDITY	WT /WT PERCENT	AS ACETIC ACID		0.003	ASTM D 1613
ACETONE	WT /WT PERCENT			0.003	ASTM D 1612
NON-VOLATILE MATTER	WT /WT PERCENT			0.001	ASTM D 1353
PERMANGANATE TIME	MINUTES	at 15 °C	50		ASTM D 1363
ETHANOL	WT./WT PERCENT			0.003	ASTM D 1612
WATER	VOL/VOL PERCENT			0.10	ASTM D 1364
HYDROCARBONS	CLOUDINESS		None		ASTM D 1722
	OPALESCEENCE		None		
APPEARANCE			Clear		VISUAL
APPEARANCE			Colorless		VISUAL

1. Meets:
Federal Grade A,
ASTM D 1152 and
USP (NF XVI) Standards

U.S. Suppliers; Specified Fuels and Chemicals
 Various Chemical Distributing Companies
 Various Laboratory Supply Companies

Trade Name: Methanol

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TABLE C2—SPECIFICATIONS FOR ETHANOL, SYNTHETIC⁽¹⁾

Parameter	Units	Conditions	Minimum	Maximum	Test Method
ETHANOL	PROOF	15.6 ° (60 °F)	199.8		
	WT PERCENT	16 °C (61 °F)	99.9		
WATER	VOL/VOL PERCENT			0.10	ASTM D 1364
SPECIFIC GRAVITY	—	15.6 °C (60 °F)		0.7942	ASTM D 4052
	—	20 °C (68 °F)		0.7910	
	—	77/77 °F		0.7876	
ACIDITY	WT/WT PERCENT	AS ACETIC ACID		0.0025	ASTM D 1613
COLOR	PT - CO			10	ASTM D 1209
NON-VOLATILE MATTER	GRAMS PER 100 ML			0.0025	ASTM D 1353
PERMANGANATE TIME	MINUTES	AT 15 °C	30		ASTM D 1363
DENATURANT CDA 20: RUBBER HYDROCARBON SOLVENT	VOL/VOL PERCENT		2.0		27 CFR 21.24

1. U.S. Suppliers: Specified Fuels and Chemicals
Various Chemical Distributing Companies
Various Laboratory Supply Companies

Trade Name: Ethyl Alcohol, USP, Dehydrated and Denatured to BATF CDA 20

TABLE C3—SPECIFICATIONS FOR METHYL TERTIARY-BUTYL ETHER,
(MTBE) HIGH PURITY GRADE⁽¹⁾

Parameter	Units	Conditions	Minimum	Maximum	Test Method
MTBE	WT /WT PERCENT		99.9		ASTM D 5441
WATER	WT /WT PERCENT			0.15	ASTM E 203
METHANOL	WT /WT PERCENT			0.05	ASTM D 5254
TERT BUTYL ALCOHOL	WT /WT PERCENT		NONE		ASTM D 5441
C4 HYDROCARBONS	WT /WT PERCENT		NONE		ASTM D 5441
C5 + HYDROCARBONS	WT /WT PERCENT		NONE		ASTM D 5441
UNKNOWN	WT /WT PERCENT		NONE		ASTM D 5441
REID VAPOR PRESSURE	PSIA	100 °F		11.0	ASTM D 323

1. U.S. Suppliers: Lyondell Chemical Company
Specified Fuels and Chemicals
Various Chemical Distributing Companies
Various Laboratory Supply Companies

Trade Name: High Purity MTBE

TABLE C4—SPECIFICATIONS FOR RAPESEED METHYL ESTERS (RME)⁽¹⁾

Parameter	Units	Minimum	Maximum	Test Method
ESTER CONTENT	WT %	98.9 ° (210 °F)		
IODINE NUMBER			120	ISO 3991
FLASH POINT (PMCC)	°C (°F)	210		ASTM D 93
ACID VALUE	MG KOH/GM		0.5	ASTM D 664
WATER CONTENT	WT %		0.2	ASTM D 2709

1. U.S. Suppliers: Specified Fuels and Chemicals
Various Laboratory Supply Companies

Trade Name: Rapeseed Methyl Esters

TABLE C5—SPECIFICATIONS FOR SOY METHYL ESTERS (SME)⁽¹⁾
In accordance with ASTM PS121-99, Provisional Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels

Parameter	Units	Minimum	Maximum	Test Method
ESTER CONTENT	WT %	96.5	—	
FLASH POINT (PMCC)	°C	100	—	ASTM D 93
WATER AND SEDIMENT	VOL %		0.05	ASTM D 2709
KINEMATIC VISCOSITY, 40 °C	MM ² /S	1.9	6.0	ASTM D 445
SULFATED ASH	% MASS	—	0,020	ASTM D 874
SULFUR	% MASS	—	0.05	ASTM D 2622
COPPER STRIP CORROSION	-	—	NO. 3	ASTM D 130
CETANE	-	40	—	ASTM D 613
CLOUD POINT	°C	REPORT	—	ASTM D 2500
CARBON RESIDUE (100% SAMPLE)	% MASS	—	0.050	ASTM D 4530
ACID NUMBER	MG KOH/GM	—	0.8	ASTM D 664
FREE GLYCERIN	% MASS	—	0.020	GC
TOTAL GLYCERIN	% MASS	—	0.240	GC

1. U.S. Suppliers: Specified Fuels and Chemicals
Various Laboratory Supply Companies
Ag Environmental Company

Trade Name: Soy Methyl Esters
Soy Diesel

APPENDIX D

SPECIFICATIONS AND SUPPLIERS OF OTHER CHEMICALS FOR
MATERIALS TESTING SPECIFICATIONS FOR TERTIARY-BUTYL HYDROPEROXIDE,

D.1 Specifications and Suppliers of Other Chemicals for Materials Testing—See Tables D1 through D7.

TABLE D1—SPECIFICATIONS FOR TERTIARY-BUTYL HYDROPEROXIDE, 70% SOLUTION⁽¹⁾

Parameter	Units	Conditions	Minimum	Maximum	Test Method
ACTIVE OXYGEN	WT. PERCENT		12.2		ASTM E 298
TERT. BUTYL HYDROPEROXIDE	WT PERCENT		69.0	71.0	ASTM E 298
DI ALKYL PEROXIDES	WT PERCENT			0.10	G. C.
KETONES	WT PERCENT		NONE	0.20	G. C.
OTHER HYDROPEROXIDES	WT PERCENT		NONE	1.00	G. C.
OTHER ORGANICS	WT PERCENT		NONE	0.40	G. C.
TERT BUTYL ALCOHOL	WT PERCENT		NONE	0.50	G. C.
WATER, FREE PHASE	VOL PERCENT			0.7	Centrifuge
WATER BY DIFFERENCE	VOL PERCENT		BALANCE		

1. U.S. Suppliers: Lyondell Chemical Company
Elf Atochem
Various Chemical Distributing Companies
Various Laboratory Supply Companies

Trade Name: TBHP, tert-Butyl Hydroperoxide 70% Solution

**TABLE D2—SPECIFICATIONS FOR GLACIAL ACETIC ACID,
ACS REAGENT GRADE⁽¹⁾**

Parameter	Units	Minimum	Maximum
ACETIC ACID	WT PERCENT	99.7	
ACETIC ANHYDRIDE	WT PERCENT		0.01
ACETALDEHYDE	WT. PERCENT		0.005
COLOR	APHA		10
RESIDUE AFTER EVAPORATION	PPMW		10
HEAVY METALS (AS, PB)	PPMW		500
ACS SPECIFICATIONS		PASSES	

1. U.S. Suppliers: Various Chemical Distributing Companies
Various Laboratory Supply Companies

Trade Name: Glacial Acetic Acid

**TABLE D3—SPECIFICATIONS FOR FORMIC ACID,
ACS REAGENT GRADE⁽¹⁾**

Parameter	Units	Minimum	Maximum
FORMIC ACID	WT PERCENT	88.0	
ACETIC ACID	WT PERCENT		0.4
ACETALDEHYDE	WT PERCENT		0.005
COLOR	APHA		15
RESIDUE AFTER EVAPORATION	PPMW		20
HEAVY METALS (AS, PB)	PPMW		5
ACS SPECIFICATIONS		PASSES	

1. U.S. Suppliers: Various Chemical Distributing Companies
Various Laboratory Supply Companies

Trade Name: Formic Acid

**TABLE D4—SPECIFICATIONS FOR SODIUM CHLORIDE, CRYSTALLINE,
ACS REAGENT GRADE⁽¹⁾**

Parameter	Units	Minimum	Maximum
SODIUM CHLORIDE	WT PERCENT	99.0	
IODIDE	WT PERCENT		0.002
BROMIDE	WT PERCENT		0.01
SULFATE	WT PERCENT		0.003
RESIDUE INSOLUBLE MATTER	PPMW		50
ACS SPECIFICATIONS		PASSES	

1. U.S. Suppliers: Various Chemical Distributing Companies
Various Laboratory Supply Companies

Trade Name: Salt
Table Salt
Sodium Chloride

**TABLE D5—SPECIFICATIONS FOR COPPER SALTS FOR ADDING COPPER IONS
TO PEROXIDE TEST FLUIDS**

Parameter	Available from
COPPER NAPHTHENATE	AVAILABLE FROM HULS/VEBA
COPPER CYCLOHEXANEBUTYRATE	AVAILABLE FROM KODAK
CUPRIC ACETATE	AVAILABLE FROM BAKER CHEMICAL

**TABLE D6—SPECIFICATIONS FOR SULFURIC ACID, 95 TO 98%,
ACS REAGENT GRADE⁽¹⁾**

Parameter	Units	Minimum	Maximum
SULFURIC ACID	WT PERCENT	95.0	98.0
RESIDUE AFTER IGNITION	PPMW		4
COLOR	APHA		8
HEAVY METALS (AS PB)	PPMW		0.5

1. U.S. Suppliers: Various Chemical Distributing Companies
Various Laboratory Supply Companies

Trade Names: Concentrated Sulfuric Acid

TABLE D7—SPECIFICATIONS FOR REAGENT WATER⁽¹⁾

Parameter	Units	Minimum	Maximum
CONDUCTIVITY	μ S/CM @ 25 °C		10
RESISTIVITY	M Ω -CM @ 25 °C	10	
SODIUM	μ G / L		5
CHLORIDE	μ G / L		5

1. Meets ASTM D 1193-91 Type II grade

Trade Names: Reagent Water
Megaohm Water

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APPENDIX E

FORMULATIONS FOR AGGRESSIVE ALCOHOLS AND CORROSIVE WATER AGGRESSIVE METHANOL

E.1 Formulations for Aggressive Alcohols and Corrosive Water—See Tables E1 through E3.

E.1.1 Aggressive Methanol—The components to make 1.0 L or 1.0 gal of Aggressive Methanol are shown in Table E1.

TABLE E1—AGGRESSIVE METHANOL

Component	Units	1.0 Liter	1.0 Gallon
METHANOL, COMMERCIAL GRADE	GM	792.4	2995.3
REAGENT WATER	GM	2.330	8.808
SODIUM CHLORIDE	GM	0.004	0.014
FORMIC ACID	GM	0.046	0.173

E.1.2 Aggressive Ethanol—The components to make 1.0 L or 1.0 gal of Aggressive Ethanol are shown in Table E2.

TABLE E2—AGGRESSIVE ETHANOL⁽¹⁾

Component	Units	1.0 Liter	1.0 Gallon
ETHANOL, SYNTHETIC	GM	816.0	3084.5
DEIONIZED WATER	GM	8.103	30.631
SODIUM CHLORIDE	GM	0.004	0.014
SULFURIC ACID	GM	0.021	0.080
GLACIAL ACETIC ACID	GM	0.061	0.230

1. NOTE—To minimize esterification reactions, the sulfuric acid should be blended into the Reagent Water prior to mixing with ethanol

E.1.3 Corrosive Water—The components to make 1.0 L or 1.0 gal of Corrosive Water are shown in Table E3.

TABLE E3—CORROSIVE WATER⁽¹⁾

Component	Units	1.0 Liter	1.0 Gallon
SODIUM CHLORIDE	GM	0.165	0.624
REAGENT WATER	GM	1000	3780

1. NOTE—All materials for these formulations are specified in Appendices C and D.

APPENDIX F

TEST RESULTS VALIDATING THE USE OF ISOCTANE SURROGATES

F.1 Two isoparaffin surrogates, Soltrol 10 and Isopar C, were tested on materials and compared with isooctane. Solvent uptake tests on loosely crosslinked isoprene were performed to determine polymer swelling after exposure to these three hydrocarbons.

Swelling tests were performed on crosslinked isoprene with exposures of 42.5 and 66.5 hours, at 40 °C. Additional testing was done on High Density Polyethylene (HDPE) with exposure of 450 hours, at 40 °C and on Natural Rubber with exposure of 450 hours, at 40 °C.

The results of these tests are indicated in Table F1.

TABLE F1—COMPARISON OF THE EFFECT OF ISO-OCTANE VERSUS MIXED OCTANE ISOMERS ON NATURAL RUBBER

Material Solvent	Solvent Uptake, Weight Fraction ⁽¹⁾ Crosslinked Polyisoprene	Solvent Uptake, Percent Weight Increase ⁽²⁾ High Density Polyethylene	Solvent Uptake, Percent Weight Increase ⁽²⁾ Natural Rubber
ISOCTANE	2.07	5.96	72.7
SOLTROL 10	2.23	6.64	89.0
ISOPAR C	2.15	6.21	79.4
ASTM FUEL C	4.00	—	—
SURROGATE C1 (50% SOLTROL 10 + 50% TOLUENE)	4.09	—	—
SURROGATE C2 (50% ISOPAR C + 50% TOLUENE)	4.04	—	—

1. Weight fraction is defined as the difference in weight before and after exposure of the polymer to the solvent, divided by the original weight of the polymer tested. Polymer preparation is described by Mazich, Rossi, and Smith in Macromolecules 25, 6929 (1992). Testing courtesy of Ford Motor Company.
2. Testing performed on 1 x 2 in samples suspended in the test fluid. Testing courtesy of Solvay Automotive.

APPENDIX G

WORLDWIDE TEST FLUIDS AND TEST FUELS

G.1 Worldwide Test Fluids and Test Fuels—See Table G1.

TABLE G1—WORLDWIDE TEST FLUIDS AND TEST FUELS

Identification	Name	Major Ingredient	Paraffinic (vol %)	Olefinic (vol %)	Aromatic (vol %)	Oxygenate (vol %)	Other (vol %)
AUTO-OIL	U.S. Industry Avg. (Summer)	Full range distillate gasoline.	58 mixed C ₄ - C ₁₀	9.2 mixed	32 mixed	none	1.5 Benzene, 8.7 psig RVP 165 °C (330 °F) T ₉₀
U.S. EPA CERTIFICATION FUEL	Specified Fuels & Chem. EEE; Indolene Clear	Full range distillate gasoline.	64 mixed C ₄ - C ₁₀	4.6 mixed	29.9 mixed	none	.5 Benzene, 9.0 psig RVP 154 °C (309 °F) T ₉₀
CALIFORNIA PHASE II REFORMULATED		Full range distillate gasoline	74 mixed C ₄ - C ₁₀	4.0 mixed	22 mixed	15 MTBE or 5 Methanol or 7 Ethanol	.8 max. Benzene, 7.8 psig RVP, 143 °C (290 °F) T ₉₀
ASTM D 471 ('79) / ISO 14469	Ref. Fuel A	Iso-Octane	100				
	Ref. Fuel B	Iso-Octane	70		30		
	Ref. Fuel C		Iso-Octane 50		Toluene 50		
	Ref. Fuel D	Iso-Octane	60		40		
	Ref. Fuel E		Iso-Octane		Toluene		
	Ref. Fuel F	Grade #2 Diesel Fuel			100		
	Ref. Fuel G	Ref. Fuel D			Toluene		
	Ref. Fuel H	Ref. Fuel C				15 anhydrous denatured Ethanol	
	Ref. Fuel I	Ref. Fuel C				15 anhydrous denatured Ethanol	
	Ref. Fuel K	Ref. Fuel C				15 anhydrous denatured Methanol	
DIN 51 604	FAM A (11/82)	Toluene	30	15	50	5 anhydrous denatured Methanol	
	FAM B (03/84)	84.5 FAM A	Iso-Octane	Di-Isobutylene	Toluene	5 Ethanol	
	FAM C (03/84)	40 FAM A				15 Methanol	0.5 Water
ISO 1817 (03/85)	Liquid A	ASTM Fuel A				58 Methanol	2.0 Water