



Designation: **D4814—15a D4814 – 16**

## Standard Specification for Automotive Spark-Ignition Engine Fuel<sup>1</sup>

This standard is issued under the fixed designation D4814; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

*This standard has been approved for use by agencies of the U.S. Department of Defense.*

### 1. Scope\*

1.1 This specification covers the establishment of requirements of liquid automotive fuels for ground vehicles equipped with spark-ignition engines.

1.2 This specification describes various characteristics of automotive fuels for use over a wide range of operating conditions. It provides for a variation of the volatility and water tolerance of automotive fuel in accordance with seasonal climatic changes at the locality where the fuel is used. For the period May 1 through Sept. 15, the maximum vapor pressure limits issued by the United States (U.S.) Environmental Protection Agency (EPA) are specified for each geographical area except Alaska and Hawaii. Variation of the antiknock index with seasonal climatic changes and altitude is discussed in [Appendix X1](#). This specification neither necessarily includes all types of fuels that are satisfactory for automotive vehicles, nor necessarily excludes fuels that can perform unsatisfactorily under certain operating conditions or in certain equipment. The significance of each of the properties of this specification is shown in [Appendix X1](#).

1.3 The spark-ignition engine fuels covered in this specification are gasoline and its blends with oxygenates, such as alcohols and ethers. This specification does not apply to fuels that contain an oxygenate as the primary component, such as Fuel Methanol (M85). The concentrations and types of oxygenates are not specifically limited in this specification. However, depending on oxygenate type, as oxygenate content increases above some threshold level, the likelihood for vehicle problems also increases. The composition of both unleaded and leaded fuel is limited by economic, legal, and technical consideration, but their properties, including volatility, are defined by this specification. In addition, the composition of unleaded fuel is subject to the rules, regulations, and Clean Air Act waivers of the U.S. Environmental Protection Agency (EPA). With regard to fuel properties, including volatility, this specification can be more or less restrictive than the EPA rules, regulations, and waivers. Refer to [Appendix X3](#) for discussions of EPA rules relating to fuel volatility, lead and phosphorous contents, deposit control additive certification, and use of oxygenates in blends with unleaded gasoline. Contact the EPA for the latest versions of the rules and additional requirements.

1.4 This specification does not address the emission characteristics of reformulated spark-ignition engine fuel. Reformulated spark-ignition engine fuel is required in some areas to lower emissions from automotive vehicles, and its characteristics are described in the research report on reformulated spark-ignition engine fuel.<sup>2</sup> However, in addition to the legal requirements found in this research report, reformulated spark-ignition engine fuel should meet the performance requirements found in this specification.

1.5 This specification represents a description of automotive fuel as of the date of publication. The specification is under continuous review, which can result in revisions based on changes in fuel, automotive requirements, or test methods, or a combination thereof. All users of this specification, therefore, should refer to the latest edition.

NOTE 1—If there is any doubt as to the latest edition of Specification D4814, contact ASTM International Headquarters.

1.6 Tests applicable to gasoline are not necessarily applicable to its blends with oxygenates. Consequently, the type of fuel under consideration must first be identified in order to select applicable tests. Test Method [D4815](#) provides a procedure for determining oxygenate concentration in mass percent. Test Method [D4815](#) also includes procedures for calculating mass oxygen content and oxygenate concentration in volume percent. [Appendix X4](#) provides a procedure for calculating the mass oxygen content of a fuel using measured oxygenate type, oxygenate concentration in volume percent, and measured density or relative density of the fuel.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee [D02](#) on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee [D02.A0.01](#) on Gasoline and Gasoline-Oxygenate Blends.

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<sup>2</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1347.

\*A Summary of Changes section appears at the end of this standard

**TABLE 1 Vapor Pressure and Distillation Class Requirements<sup>A</sup>**

	Vapor Pressure/Distillation Class						ASTM Test Method
	AA	A	B	C	D	E	
Vapor Pressure, <sup>B</sup> at 37.8 °C (100 °F) max, kPa (psi)	54 (7.8)	62 (9.0)	69 (10.0)	79 (11.5)	93 (13.5)	103 (15.0)	D4953, D5191, D5482, or D6378 D86
Distillation Temperatures, °C (°F), at % Evaporated <sup>C</sup>							
10 volume %, max	70. (158)	70. (158)	65 (149)	60. (140.)	55 (131)	50. (122)	
50 volume %							
min <sup>D</sup>	77 (170.)	77 (170.)	77 (170.)	77 (170.)	77 (170.) <sup>E</sup>	77 (170.) <sup>E</sup>	
max	121 (250.)	121 (250.)	118 (245)	116 (240.)	113 (235)	110. (230.)	
90 volume %, max	190. (374)	190. (374)	190. (374)	185 (365)	185 (365)	185 (365)	
End Point, max	225 (437)	225 (437)	225 (437)	225 (437)	225 (437)	225 (437)	
Distillation Residue, volume %, max	2	2	2	2	2	2	D86
Driveability Index, <sup>F</sup> max, °C (°F)	597 (1250.)	597 (1250.)	591 (1240.)	586 (1230.)	580. (1220.)	569 (1200.)	Derived <sup>G,H</sup>

<sup>A</sup> See 1.7 for determining conformance with specification limits in this table. When using this table to determine the conformance of gasoline volatility, the reader is advised to review other applicable national, state, provincial, or local requirements. (For example, in the U.S. these may include the EPA Substantially Similar rule, California Air Resources Board (CARB), Clean Burning Gasoline (CBG), other state or local and pipeline specifications). See Appendix X3 for a summary of applicable U.S. EPA regulations for spark-ignition engine fuels.

<sup>B</sup> Consult EPA for approved test methods for compliance with EPA vapor pressure regulations.

<sup>C</sup> At 101.3 kPa pressure (760 mm Hg).

<sup>D</sup> Gasolines that may be blended with 1 to 10 volume percent ethanol or all other gasolines whose disposition with ethanol blending is not known shall meet a minimum 50 % evaporated distillation temperature of 77 °C (170. °F) prior to blending with ethanol. Gasoline-ethanol blends that contain 1 to 10 volume percent ethanol shall meet a minimum 50 % evaporated distillation temperature of 66 °C (150. °F) after blending.

<sup>E</sup> Gasolines known from the origin to retail that will not be blended with ethanol may meet a minimum 50 % evaporated distillation temperature of 66 °C (150. °F) for volatility classes D and E only. Gasolines meeting these limits are not suitable for blending with ethanol.

<sup>F</sup> Driveability Index (DI) = 1.5 T<sub>10</sub> + 3.0 T<sub>50</sub> + 1.0 T<sub>90</sub> + 1.33 °C (2.4 °F) × Ethanol Volume %, where T<sub>10</sub> = distillation temperature, °C (°F), at 10 % evaporated, T<sub>50</sub> = distillation temperature, °C (°F), at 50 % evaporated, T<sub>90</sub> = distillation temperature, °C (°F), at 90 % evaporated, and 1.33 is the coefficient for the volume % ethanol present when the distillation results are determined in degrees Celsius and 2.4 is the coefficient when distillation results are determined in degrees Fahrenheit.

<sup>G</sup> The DI specification limits are applicable at the refinery or import facility as defined by 40 CFR Part 80.2 and are not subject to correction for precision of the test method.

<sup>H</sup> Since DI is an index and has no units, the standard temperature conversion from U.S. customary to SI units is not appropriate. The following equation is to be used to make the conversion:  $DI_c = (DI_f - 176)/1.8$

1.7 The following applies to all specified limits in this standard: For purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded “to the nearest unit” in the right-most significant digit used in expressing the specification limit, in accordance with the rounding method of Practice E29. For a specification limit expressed as an integer, a trailing zero is significant only if the decimal point is specified. For a specified limit expressed as an integer, and the right-most digit is non-zero, the right-most digit is significant without a decimal point being specified. This convention applies to specified limits in Tables 1, 3, and ~~Table X8.1, X8.1~~, and it will not be observed in the remainder of this specification.

1.8 The values stated in SI units are the standard, except when other units are specified by U.S. federal regulation. Values given in parentheses are provided for information only.

NOTE 2—Many of the values shown in Table 1 were originally developed using U.S. customary units and were subsequently soft-converted to SI values. As a result, conversion of the SI values will sometimes differ slightly from the U.S. customary values shown because of round-off. In some cases, U.S. federal regulations specify non-SI units.

1.9 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>3</sup>

- D86 Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure
- D130 Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
- D287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)
- D381 Test Method for Gum Content in Fuels by Jet Evaporation
- D439 Specification for Automotive Gasoline (Withdrawn 1990)<sup>4</sup>
- D525 Test Method for Oxidation Stability of Gasoline (Induction Period Method)
- D1266 Test Method for Sulfur in Petroleum Products (Lamp Method)
- D1298 Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
- D2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry
- D2699 Test Method for Research Octane Number of Spark-Ignition Engine Fuel

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.

<sup>4</sup> The last approved version of this historical standard is referenced on www.astm.org.

- D2700 Test Method for Motor Octane Number of Spark-Ignition Engine Fuel
- D2885 Test Method for Determination of Octane Number of Spark-Ignition Engine Fuels by On-Line Direct Comparison Technique
- D3120 Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry
- D3231 Test Method for Phosphorus in Gasoline
- D3237 Test Method for Lead in Gasoline by Atomic Absorption Spectroscopy
- D3341 Test Method for Lead in Gasoline—Iodine Monochloride Method
- D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
- D4057 Practice for Manual Sampling of Petroleum and Petroleum Products
- D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants
- D4176 Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)
- D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products
- D4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination
- D4806 Specification for Denatured Fuel Ethanol for Blending with Gasolines for Use as Automotive Spark-Ignition Engine Fuel
- D4815 Test Method for Determination of MTBE, ETBE, TAME, DIPE, tertiary-Amyl Alcohol and C<sub>1</sub> to C<sub>4</sub> Alcohols in Gasoline by Gas Chromatography
- D4953 Test Method for Vapor Pressure of Gasoline and Gasoline-Oxygenate Blends (Dry Method)
- D5059 Test Methods for Lead in Gasoline by X-Ray Spectroscopy
- D5188 Test Method for Vapor-Liquid Ratio Temperature Determination of Fuels (Evacuated Chamber and Piston Based Method)
- D5191 Test Method for Vapor Pressure of Petroleum Products (Mini Method)
- D5453 Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence
- D5482 Test Method for Vapor Pressure of Petroleum Products (Mini Method—Atmospheric)
- D5500 Test Method for Vehicle Evaluation of Unleaded Automotive Spark-Ignition Engine Fuel for Intake Valve Deposit Formation
- D5598 Test Method for Evaluating Unleaded Automotive Spark-Ignition Engine Fuel for Electronic Port Fuel Injector Fouling
- D5599 Test Method for Determination of Oxygenates in Gasoline by Gas Chromatography and Oxygen Selective Flame Ionization Detection
- D5842 Practice for Sampling and Handling of Fuels for Volatility Measurement
- D5845 Test Method for Determination of MTBE, ETBE, TAME, DIPE, Methanol, Ethanol and *tert*-Butanol in Gasoline by Infrared Spectroscopy
- D5854 Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products
- D6378 Test Method for Determination of Vapor Pressure (VP<sub>x</sub>) of Petroleum Products, Hydrocarbons, and Hydrocarbon-Oxygenate Mixtures (Triple Expansion Method)
- D6469 Guide for Microbial Contamination in Fuels and Fuel Systems
- D6920 Test Method for Total Sulfur in Naphthas, Distillates, Reformulated Gasolines, Diesels, Biodiesels, and Motor Fuels by Oxidative Combustion and Electrochemical Detection
- D7039 Test Method for Sulfur in Gasoline, Diesel Fuel, Jet Fuel, Kerosine, Biodiesel, Biodiesel Blends, and Gasoline-Ethanol Blends by Monochromatic Wavelength Dispersive X-ray Fluorescence Spectrometry
- D7220 Test Method for Sulfur in Automotive, Heating, and Jet Fuels by Monochromatic Energy Dispersive X-ray Fluorescence Spectrometry
- D7667 Test Method for Determination of Corrosiveness to Silver by Automotive Spark-Ignition Engine Fuel—Thin Silver Strip Method
- D7671 Test Method for Corrosiveness to Silver by Automotive Spark-Ignition Engine Fuel—Silver Strip Method
- D7757 Test Method for Silicon in Gasoline and Related Products by Monochromatic Wavelength Dispersive X-ray Fluorescence Spectrometry
- E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- ~~2.2 Government Standard:~~
- ~~CFR 40 Code of Federal Regulations<sup>5</sup>~~
- ~~2.2 Other Standard: Government Regulations:~~
- ~~CFR 40 Code of Federal Regulations<sup>5</sup>~~
- CCR Title 17, §60100-§60114 California Code of Regulations<sup>6</sup>

<sup>5</sup> Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.

<sup>6</sup> Available from Barclays, 50 California Street, San Francisco, CA 94111.

### 2.3 Other Documents:

[API Recommended Practice 1640 Product Quality in Light Product Storage and Handling Operations](#)<sup>7</sup>  
[CRC Report No. 667 Diesel Fuel Storage and Handling Guide, September 2014](#)<sup>8</sup>

## 3. Terminology

3.1 For general terminology, refer to Terminology [D4175](#).

### 3.2 Definitions:

3.2.1 *antiknock index, n*—the arithmetic average of the Research octane number (RON) and Motor octane number (MON), that is,  $(RON + MON)/2$ .

3.2.2 *dry vapor pressure equivalent (DVPE), n*—value calculated by a defined correlation equation that is expected to be comparable to the vapor pressure value obtained by Test Method [D4953](#), Procedure A. **D4953**

3.2.3 *finished fuel, n*—a homogeneous mixture of blendstocks and fuel additives meeting all specification and regulatory requirements for its intended use at the location where sold.

3.2.4 *gasoline, n*—a volatile mixture of liquid hydrocarbons, generally containing small amounts of additives, suitable for use as a fuel in spark-ignition, internal combustion engines.

3.2.5 *gasoline-alcohol blend, n*—a fuel consisting primarily of gasoline along with a substantial amount (more than 0.35 mass % oxygen, or more than 0.15 mass % oxygen if methanol is the only oxygenate) of one or more alcohols.

3.2.6 *gasoline-ethanol blend, n*—a fuel consisting primarily of gasoline along with a substantial amount (more than 0.35 mass % oxygen) of ethanol. **D4806**

3.2.7 *gasoline-ether blend, n*—a fuel consisting primarily of gasoline along with a substantial amount (more than 0.35 mass % oxygen) of one or more ethers.

3.2.8 *gasoline-oxygenate blend, n*—a fuel consisting primarily of gasoline along with a substantial amount (more than 0.35 mass % oxygen, or more than 0.15 mass % oxygen if methanol is the only oxygenate) of one or more oxygenates.

3.2.9 *oxygenate, n*—an oxygen-containing, ashless, organic compound, such as an alcohol or ether, which can be used as a fuel or fuel supplement.

3.2.10 *refinery, n*—a plant at which gasoline or diesel fuel is produced.

<sup>7</sup> Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, <http://www.api.org/pubs>.

<sup>8</sup> Available from Coordinating Research Council (CRC), 5755 North Point Pkwy #265, Alpharetta, GA 30022, <http://www.crc.org>.

#### 3.2.10.1 Discussion—

<https://standards.iteh.ai/catalog/standards/sist/63132af6-3910-467d-b64d-c364b750971c/astm-d4814-16>

This definition is from U.S. CFR 40 Part 80.2. In the federal definition, a plant not only covers the conventional refinery, but also covers oxygenate blending and other facilities where gasoline is produced.

3.2.11 *water tolerance, n*—the ability to absorb small quantities of water without creating a separate phase in the fuel.

#### 3.2.11.1 Discussion—

Improved water tolerance is the ability to absorb larger quantities of water without phase separation.

3.3 *Applicability*—To determine when a fuel contains a substantial amount of an oxygenate, a gasoline-oxygenate blend is defined as a fuel that contains more than 0.35 mass % oxygen, or more than 0.15 mass % oxygen if methanol is the only oxygenate. The definitions in this section do not apply to fuels that contain an oxygenate as the primary component; for example, fuel methanol (M85).

NOTE 3—The criteria in [3-23.3](#) were selected with consideration given to current oxygenate levels in the marketplace, state labeling practices, and consistency with U.S. federal legislation and regulations.

NOTE 4—Refer to Test Method [D4815](#) to calculate the mass oxygen content of a fuel using oxygenate concentration in mass %. Refer to [Appendix X4](#) to calculate mass oxygen content of a fuel using oxygenate concentration in volume %.

## 4. Ordering Information

4.1 The purchasing agency shall:

4.1.1 State the antiknock index as agreed upon with the seller,

4.1.2 Indicate the season and locality in which the fuel is to be used,

4.1.3 Indicate the lead level required ([Table 2](#)), and

4.1.4 State the concentration and types of oxygenates present as agreed upon with the seller.

TABLE 2 Detailed Requirements for all Volatility Classes<sup>A,B</sup>

Property	Limit	ASTM Test Method
Lead content, max, g/L (g/U.S. gal) <sup>C</sup>		
Unleaded	0.013 (0.05)	D3237 or D5059
Leaded	1.1 (4.2)	D3341 or D5059
Sulfur, max, mass %		D1266, D2622, D3120, D5453, D6920, or D7039
Unleaded	0.0080	
Leaded	0.15	
Copper strip corrosion, max	No. 1	D130
Silver strip corrosion, max	No. 1	D7667 or D7671
Solvent-washed gum content, mg/100 mL, max	5	D381
Oxidation stability, minimum, minutes	240.	D525

<sup>A</sup> See Appendix X1 for information on Antiknock Index.

<sup>B</sup> See X3.7 for information on U.S. Environmental Protection Agency regulations for benzene in gasoline.

<sup>C</sup> See Appendix X3 for U.S. EPA maximum limits for lead and phosphorus contents in unleaded gasoline (X3.2.1) and maximum average lead limits for leaded gasoline (X3.2.2). The reader is advised to review other applicable national, state, provincial, or local requirements.

## 5. Performance Requirements

5.1 Some requirements and test methods applicable to automotive spark-ignition engine fuel depend on whether the fuel is a gasoline, or a gasoline-oxygenate blend. Test Methods D4815 and D5599, gas chromatographic test methods, are the recommended procedures to detect the types and amounts of oxygenates. Once the type of fuel is known, the appropriate requirements and test methods can be identified by reference to Table 1, Table 3, and Section 7.

5.2 Volatility of fuels is varied for seasonal climatic changes and conformance to U.S. EPA volatility regulations by providing six vapor pressure/distillation classes and six vapor lock protection classes for fuel. Volatility of fuel is specified by an alphanumeric designation that uses a letter from Table 1 and a number from Table 3.

5.2.1 The seasonal and geographic distribution of the combined vapor pressure/distillation-vapor lock classes is shown in Table 4. For sea-level areas outside of the United States, the following ambient temperatures are for guidance in selecting the appropriate alphanumeric designation:

Alphanumeric Volatility Designation	10th Percentile 6-h Minimum Daily Temperature, °C (°F)	90th Percentile Maximum Daily Temperature, °C (°F)
A-1	>16 (60.)	≥43 (110.)
B-2	>10. (50.)	<43 (110.)
C-3	>4 (40.)	<36 (97)
D-4	> -7 (20.)	<29 (85)
E-5	≤ -7 (20.)	<21 (69)

The 6-h<sub>6</sub> h minimum temperature is the highest temperature of the six coldest consecutive hourly temperature readings of a 24-h<sub>24</sub> h day. The 6-h<sub>6</sub> h minimum temperature provides information on the cold-soak temperature experienced by a vehicle. The 10th percentile of this temperature statistic indicates a 10 % expectation that the 6-h<sub>6</sub> h minimum temperature will be below this value during a month. The 90th percentile maximum temperature is the highest temperature expected during 90 % of the days, and provides information relative to peak vehicle operating temperatures during warm and hot weather. For areas above sea level, the 10th percentile 6-h<sub>6</sub> h minimum temperature should be increased by 3.6 °C/1000 m (2 °F/1000 ft) of altitude, and the 90th percentile maximum should be increased by 4.4 °C/1000 m (2.4 °F/1000 ft) of altitude before comparing them to the sea level temperature. These corrections compensate for changes in fuel volatility caused by changes in barometric pressure due to altitude. Tables 5-7 show the U.S. federal ozone nonattainment areas at several vapor lock protection levels that require reduced vapor pressure in the summertime. Tables 8-11 show at several vapor lock protection levels the areas that require federal reformulated spark-ignition engine fuel in the summertime. Table 12 shows the areas with restrictive local vapor pressure limits that have been approved under the EPA state implementation plan (SIP).

5.2.2 The EPA vapor pressure regulations can cause the distillation of the fuel to be less volatile, which for some vehicles, results in a worse warm-up driveability performance.

5.2.3 Driveability Index (DI) is intended to provide control of distillation parameters and ethanol content that influence cold start and warm-up driveability. It is a function of the 10 %, 50 %, and 90 % evaporated distillation temperatures measured by Test Method D86 and the ethanol content measured by the test methods shown in 7.1.9.

5.2.4 Test Method D5188 is the method for determining vapor-liquid ratio temperatures by an evacuated chamber method for gasoline-oxygenate blends, as well as for gasoline. The methods for estimating temperature-V/L (see Appendix X2) are applicable for gasoline and gasoline-ethanol blends (1 to 10 volume %), but not for gasoline-ether blends.

**TABLE 3 Vapor Lock Protection Class Requirements<sup>A, B, C</sup>**

	Vapor Lock Protection Class						ASTM Test Method
	1	2	3	4	5	6	
Temperature, °C (°F) for a Vapor-Liquid Ratio of 20, min	54 (129)	50. (122)	47 (116)	42 (107)	39 (102)	35 (95)	D5188
Special Requirements for Area V of D4814 Temperature, °C (°F) for a Vapor-Liquid Ratio of 20, min	54 (129)	50. (122)	47 (116)	47 (116)	41 (105)	35 (95)	D5188

<sup>A</sup> See 1.7 for determining conformance with numerical specification limits in this table. When using this table to determine the conformance of the temperature for a vapor-liquid ratio of 20, the reader is advised to review other applicable national, state, provincial, or local requirements (for example, EPA's "Substantially Similar" rule, CARB regulations, and other state and local regulations).

<sup>B</sup> Gasoline, or blend of oxygenate and gasoline as sold to the consumer, shall meet these limits. Certain gasolines meeting these limits of this table may not be suitable for blending with ethanol.

<sup>C</sup> Gasolines and gasoline-oxygenate blends sold at retail sites located in Area V shown in Fig. X1.2 (generally high elevations) shall use the special limits shown in Row 2 of this table, regardless of ethanol content.

5.3 Antiknock index (AKI) is very important to engine performance. The matching of engine octane requirement to fuel octane level (AKI) is critical to the durability and performance of engines; this cannot be accomplished with a single specified minimum level of antiknock index. Appendix X1 includes a discussion of antiknock indexes of fuels currently marketed and relates these levels to the octane needs of broad groups of engines and vehicles. Also discussed is the effect of altitude and weather on vehicle antiknock requirements.

5.4 Additional fuel requirements are shown in Table 2.

5.5 The properties of gasoline-oxygenate blends can differ considerably from those of gasoline. Consequently, additional requirements are needed for gasoline-oxygenate blends. These requirements involve evaluation of compatibility with plastic and elastomeric materials in fuel systems, corrosion of metals, and especially in the case of gasoline-alcohol blends, water tolerance. Requirements for metal corrosion (other than copper and silver) and material compatibility are not given because test methods and appropriate limits are still under development. When these have been developed, they will be included in this specification.

5.6 Depending on oxygenate type and concentration in the blend, vehicle driveability with gasoline-oxygenate blends can differ significantly from that with gasolines having similar volatility characteristics.

#### 5.7 Water Tolerance:

5.7.1 The term water tolerance is used to indicate the ability of a gasoline-oxygenate blend to dissolve water without phase separation. This may not be a problem with gasoline-ether blends, but it is of primary concern for alcohol-containing blends, as blends of gasoline with low-molecular weight alcohols generally will dissolve about 0.1 to 0.7 mass % of water under normal conditions, depending on the nature and amount of the alcohol(s) used, the specific hydrocarbons present, and the temperature of the blend. Additional information on water tolerance is provided in Appendix X8.

5.7 Deposit control additives are added to fuel to help keep carburetors, fuel injectors, and intake valves clean. In the United States, deposit control additives are required to be certified by the EPA as summarized in X3.5. Each additive is certified for use at a lowest additive concentration (LAC), which is the lowest level certified to be effective in preventing deposit formation. All parties who blend deposit control additives into fuel must complete mandatory volume additive reconciliation (VAR) accounting to establish that the product was additized at a concentration that was at least equal to the LAC. The user of this document outside the U.S. should consult the regulatory authorities in those countries for similar deposit control requirements.

5.7.1 In the United States, deposit control additives are required to be certified by the EPA as summarized in X3.5. Each additive is certified for use at a lowest additive concentration (LAC), which is the lowest level certified to be effective in preventing deposit formation. All parties who blend deposit control additives into fuel must complete mandatory volume additive reconciliation (VAR) accounting to establish that the product was additized at a concentration that was at least equal to the LAC.

5.7.2 Outside the U.S., the user of this document should consult the regulatory authorities in those countries for similar deposit control requirements.

## 6. Workmanship

6.1 The finished fuel shall be visually free of undissolved water, sediment, and suspended matter; it shall be clear and bright at the ambient temperature or 21 °C (70 °F), whichever is higher, fuel temperature at the point of custody transfer or at a lower temperature agreed upon by the purchaser and seller.







**TABLE 5 U.S. Ozone Nonattainment Areas Requiring Volatility Class AA-3**

NOTE 1—See 40 CFR Part 81.300 for description of the geographic boundary for each area.

Alabama—Jefferson and Shelby counties
California <sup>A</sup> —Alameda, Contra Costa, Marin, Monterey, Napa, San Francisco, San Benito, San Mateo, Santa Clara, Santa Cruz, and Solano (part) counties
Georgia <sup>A</sup> —Cherokee, Clayton, Cobb, Coweta, DeKalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Henry, Paulding, and Rockdale counties
Georgia—Cherokee, Clayton, Cobb, Coweta, DeKalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Henry, Paulding, and Rockdale counties
Louisiana—Ascension, Beauregard, Calcasieu, East Baton Rouge, Iberville, Jefferson, Lafayette, Lafourche, Livingston, Orleans, Point Coupee, Saint Bernard, Saint Charles, Saint James, Saint Mary, and West Baton Rouge parishes
Missouri—Franklin, Jefferson, Saint Charles, and Saint Louis counties; and the city of St. Louis
North Carolina—Gaston and Mecklenburg counties
Oregon—Clackamas (part), Marion (part), Multnomah (part), Polk (part), and Washington (part) counties
Tennessee—Davidson, Rutherford, Shelby, Sumner, Williamson, and Wilson counties
Texas—Hardin, Jefferson, and Orange counties
Virginia—Smyth County (part)

<sup>A</sup> See Table 12 for local vapor pressure limits.

**TABLE 6 U.S. Ozone Nonattainment Areas Requiring Volatility Class AA-2**

NOTE 1—See 40 CFR Part 81.300 for description of the geographic boundary for each area.

Alabama—Jefferson and Shelby counties
Arizona <sup>A</sup> —Maricopa County
Arizona <sup>A</sup> —Maricopa County
California <sup>A</sup> —Alameda, Butte, Contra Costa, Fresno, Kern (part), Kings, Madera, Marin, Merced, Monterey, Napa, San Benito, San Francisco, San Joaquin, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, Stanislaus, Tulare, and Yuba counties
Colorado—Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, Jefferson, Larimer (part), and Weld (part) counties
Georgia <sup>A</sup> —Cherokee, Clayton, Cobb, Coweta, DeKalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Henry, Paulding, and Rockdale counties
Georgia—Cherokee, Clayton, Cobb, Coweta, DeKalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Henry, Paulding, and Rockdale counties
Kansas <sup>A</sup> —Johnson and Wyandotte counties
Louisiana—Ascension, Beauregard, Calcasieu, East Baton Rouge, Iberville, Jefferson, Lafayette, Lafourche, Livingston, Orleans, Point Coupee, Saint Bernard, Saint Charles, Saint James, Saint Mary, and West Baton Rouge parishes
Missouri—Franklin, Jefferson, Saint Charles, and Saint Louis counties; and the city of St. Louis
Nevada—Washoe County
North Carolina—Gaston and Mecklenburg counties
Tennessee—Davidson, Rutherford, Shelby, Sumner, Williamson, and Wilson counties
Texas—Hardin, Jefferson, and Orange counties
Utah—Davis and Salt Lake counties

<sup>A</sup> See Table 12 for local vapor pressure limits.

damage, engine failing to start or failing to operate properly. A separated water-rich phase can be observed as a haze, as water droplets or as a distinct lower layer. This lower aqueous phase can be corrosive to many metals and the engine cannot operate on it. Similarly, the upper hydrocarbon phase may no longer meet volatility and antiknock properties. See Appendix X8 for additional information on water haze and phase separation.

NOTE 6—Finished fuel should be resistant to phase separation or undissolved matter at the lowest temperatures to which it is likely to be subjected, dependent on the time and place of its intended use. See Table X8.1 for guidance.

NOTE 7—Solubility is temperature dependent. As this fuel cools, water or water-alcohol and some high molecular weight additives can become insoluble.

**TABLE 7 U.S. Ozone Nonattainment Areas Requiring Volatility Class AA-1**

NOTE 1—See 40 CFR Part 81.300 for description of the geographic boundary for each area.

Arizona<sup>A</sup>—Maricopa County  
 California<sup>A</sup>—Imperial and Kern (part) counties  
 Texas<sup>A</sup>—El Paso County

<sup>A</sup> See Table 12 for local vapor pressure limits.

**TABLE 8 U.S. Federal RFG Areas Requiring Volatility Class A-3**

NOTE 1—See 40 CFR Part 81.300 for description of the geographic boundary for each area.

NOTE 2—No waiver for gasoline-ethanol blends.

Connecticut—All counties  
 Delaware—All counties  
 Illinois<sup>A</sup>—Cook, Du Page, Grundy (part), Jersey, Kane, Kendall (part), Lake, Madison, McHenry, Monroe, St. Clair, and Will counties  
 Indiana<sup>A</sup>—Lake and Porter counties  
 Kentucky—Boone, Bullitt (part), Campbell, Jefferson, Kenton, and Oldham (part) counties  
 Maryland—Cecil County  
 Massachusetts—All counties  
 New Hampshire—Hillsborough, Merrimack, Rockingham, and Strafford counties  
 New Jersey—All counties  
 New York—Bronx, Dutchess, Essex (part), Kings, Nassau, New York, Orange, Putnam, Queens, Richmond, Rockland, Suffolk, and Westchester counties  
 Pennsylvania—Bucks, Chester, Delaware, Montgomery, and Philadelphia counties  
 Rhode Island—All counties  
 Wisconsin—Kenosha, Milwaukee, Ozaukee, Racine, Washington, and Waukesha counties

<sup>A</sup> See Table 12 for local vapor pressure limits.

**TABLE 9 U.S. Federal RFG Areas Requiring Volatility Class AA-3**

NOTE 1—See 40 CFR Part 81.300 for description of the geographic boundary for each area.

NOTE 2—No waiver for gasoline-ethanol blends.

District of Columbia  
 Maryland—Anne Arundel, Baltimore, Calvert, Carroll, Charles, Frederick, Harford, Howard, Kent, Montgomery, Prince George's, and Queen Anne's counties  
 Texas—Brazoria, Chambers, Collin, Dallas, Denton, Fort Bend, Galveston, Harris, Liberty, Montgomery, Tarrant, and Waller counties  
 Virginia—Arlington, Charles City, Chesterfield, Fairfax, Hanover, Henrico, James City, Loudoun, Prince William, Stafford, and York counties and independent cities of Alexandria, Chesapeake, Colonial Heights, Fairfax, Falls Church, Hampton, Hopewell, Manassas, Manassas Park, Newport News, Norfolk, Poquoson, Portsmouth, Richmond, Suffolk, Virginia Beach, and Williamsburg

6.2 Fuel to be used in this test shall not be cooled below about 15 °C (59 °F) or its temperature at the time the sample was taken, whichever is lower, as cooling of gasoline-oxygenate blends can produce changes in appearance that are not reversed on rewarming. The finished fuel shall also be free of any adulterant or contaminant that can render the fuel unacceptable for its commonly used applications.

6.3 The finished fuel shall also be free of any adulterant or contaminant that may render the fuel unacceptable. Manufacturers and blenders of gasoline and gasoline-oxygenate blends shall avoid gasoline blending stocks (for example, purchased used toluene solvents) or denatured fuel ethanol (for example, improperly recycled ethanol) contaminated by silicon-containing materials, or both. Silicon contamination of gasoline and gasoline-oxygenate blends has led to fouled vehicle components (for example, spark plugs, exhaust oxygen sensors, catalytic converters) requiring parts replacement and repairs. Test Method D7757 for its commonly used applications. is a procedure for determining silicon content but no specification limits have been established for silicon.

**TABLE 10 U.S. Federal RFG Areas Requiring Volatility Class AA-2**

NOTE 1—See 40 CFR Part 81.305 for description of the geographic boundary for each area.

NOTE 2—No waiver for gasoline-ethanol blends.

California<sup>A</sup>—El Dorado (part), Los Angeles, Orange, Placer (part), Riverside (part), Sacramento, San Bernardino (part), San Diego, Solano (part), Sutter (part), Ventura, and Yolo Counties  
 Texas—Brazoria, Chambers, Collin, Dallas, Denton, Fort Bend, Galveston, Harris, Liberty, Montgomery, Tarrant, and Waller counties

<sup>A</sup> See Table 12 for local vapor pressure limits.

**TABLE 11 U.S. Federal RFG Area Requiring Volatility Class AA-1**

NOTE 1—See 40 CFR Part 81.300 for description of the geographic boundary for each area.

NOTE 2—No waiver for gasoline-ethanol blends.

California<sup>A</sup>—Los Angeles (part), Riverside (part), and San Bernardino (part) counties

<sup>A</sup> See Table 12 for local vapor pressure limits.

6.3.1 Manufacturers and blenders of gasoline and gasoline-oxygenate blends shall avoid gasoline blending stocks (for example, purchased used toluene solvents) or denatured fuel ethanol (for example, improperly recycled ethanol) contaminated by silicon-containing materials, or both. Silicon contamination of gasoline and gasoline-oxygenate blends has led to fouled vehicle components (for example, spark plugs, exhaust oxygen sensors, catalytic converters) requiring parts replacement and repairs. Test Method D7757 is a procedure for determining silicon content but no specification limits have been established for silicon.

**7. Test Methods**

7.1 The requirements of this specification shall be determined in accordance with the methods listed below. The scopes of some of the test methods listed below do not include gasoline-ethanol blends or other gasoline-oxygenate blends. Refer to the listed test methods to determine applicability or required modifications for use with gasoline-oxygenate blends. The precision of these test methods can differ from the reported precisions when testing gasoline-ethanol blends or other gasoline-oxygenate blends.

7.1.1 *Distillation*—Test Method D86.

7.1.2 *Vapor-Liquid Ratio*—Test Method D5188 is an evacuated chamber method for determining temperatures for vapor-liquid ratios between 8 to 1 and 75 to 1. For this specification, it is conducted at a ratio of 20 to 1. It may be used for gasoline and gasoline-oxygenate blends.

7.1.3 *Vapor Pressure*—Test Methods D4953, D5191, D5482, or D6378.

7.1.3.1 When using Test Method D6378, determine VP<sub>4</sub> at 37.8 °C (100 °F) using a sample from a 1 L container and convert to DVPE (D5191 equivalence) using the following equation:

$$\text{Predicted DVPE} = VP_{4, 37.8\text{ }^\circ\text{C}} - 1.005 \text{ kPa} (0.15 \text{ psi}) \tag{1}$$

$$\text{Predicted DVPE}_C = VP_{4, 37.8\text{ }^\circ\text{C}} - 1.005 \text{ kPa} \tag{1}$$

$$\text{Predicted DVPE}_F = VP_{4, 100\text{ }^\circ\text{F}} - 0.15 \text{ psi} \tag{2}$$

7.1.4 *Corrosion, for Copper*—Test Method D130, 3 h at 50 °C (122 °F).

7.1.5 *Solvent-Washed Gum Content*—Test Method D381, air jet apparatus.

7.1.6 *Sulfur*—Test Methods D1266, D2622, D3120, D5453, D6920, D7039, or D7220. With Test Method D3120, fuels with sulfur content greater than 100 ppm (0.0100 mass %) must be diluted with isooctane. The dilution of the sample may result in a loss of precision. Test Method D3120 cannot be used when the lead concentration is greater than 0.4 g/L (1.4 g/U.S. gal).

7.1.7 *Lead*—Test Methods D3341 or D5059 (Test Methods A or B). For lead levels below 0.03 g/L (0.1 g/U.S. gal), use Test Methods D3237 or D5059 (Test Method C).

7.1.8 *Oxidation Stability*—Test Method D525.

7.1.9 *Oxygenate Detection*—Test Methods D4815, D5599, or D5845. These test methods are designed for the quantitative determination of methyl *tert*-butyl ether (MTBE), ethyl *tert*-butyl ether (ETBE), *tert*-amyl methyl ether (TAME), diisopropyl ether (DIPE), methyl alcohol, ethyl alcohol, and *tert*-butyl alcohol. In addition, Test Methods D4815 and D5599 are designed for the quantitative determination of *n*-propyl alcohol, *isopropyl* alcohol, *n*-butyl alcohol, *sec*-butyl alcohol *isobutyl* alcohol, and *tert*-pentyl alcohol. Results for all of these test methods are reported in mass %. Test Method D4815 includes procedures for calculating oxygenate concentration in volume % and mass oxygen content using the mass % oxygenate results.

7.1.10 *Corrosion, for Silver*—Test Methods D7667 or D7671.