This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: D4814 – 24

Standard Specification for Automotive Spark-Ignition Engine Fuel[1]

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 reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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 September 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, Hawaii, and the U.S. Territories. 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 and where gasoline is the primary component by volume in the blend. The concentrations and types of oxygenates are not specifically limited in this specification. The composition of fuel is limited by economic, legal, and technical consideration, but its properties, including volatility, are defined by this specification. In many countries, regulatory authorities having jurisdiction have set laws and regulations that limit the concentration of oxygenates and certain other compounds found in spark-ignition engine fuel. In the United States, oxygenate types and concentrations are limited to those approved under the U.S. Environmental Protection Agency's (EPA) substantially similar rule (see X3.3.1), waivers, and partial waivers including some restrictions on vehicle and equipment use (see X3.3.2). 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, sulfur content, benzene content, deposit control additive certification, and use of oxygenates in the fuel. 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 Monograph 12 (MONO12) on reformulated spark-ignition engine fuel.[2] However, in addition to the legal requirements found in MONO12, 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 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.

1.7 The following applies to all specified limits in this standard: For purposes of determining conformance with these

[1] 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.

Current edition approved Jan. 1, 2024. Published April 2024. Originally approved in 1988. Last previous edition approved in 2023 as D4814 – 23a. DOI: 10.1520/D4814-24.

[2] MONO12, "U.S. Reformulated Spark-Ignition Engine Fuel and the U.S. Renewable Fuel Standard" is available from ASTM International Headquarters.

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

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TABLE 1 Vapor Pressure and Distillation Class Requirements[A]

	Vapor Pressure/Distillation Class							ASTM Test Method
	AAA	AA	A	B	C	D	E	
Vapor Pressure,[B] at 37.8 °C (100 °F) max, kPa (psi)	51 (7.4)	54 (7.8)	62 (9.0)	69 (10.0)	79 (11.5)	93 (13.5)	103 (15.0)	D4953, D5191, D5482, or D6378
Distillation Temperatures, °C (°F), at % Evaporated[C]								D86 or D7345[D, E]
10 volume %, max	70. (158)	70. (158)	70. (158)	65 (149)	60. (140.)	55 (131)	50. (122)	
50 volume %								
min[F]	77 (170.)	77 (170.)	77 (170.)	77 (170.)	77 (170.)	77 (170.)[G]	77 (170.)[G]	
max	121 (250.)	121 (250.)	121 (250.)	118 (245)	116 (240.)	113 (235)	110. (230.)	
90 volume %, max	190. (374)	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)	225 (437)	
Distillation Residue, volume %, max	2	2	2	2	2	2	2	D86 or D7345[D, E]
Driveability Index,[H] max, °C (°F)	597 (1250.)	597 (1250.)	597 (1250.)	591 (1240.)	586 (1230.)	580. (1220.)	569 (1200.)	Derived[I,J]

[A] 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.
[B] Consult EPA for approved test methods for compliance with EPA vapor pressure regulations.
[C] At 101.3 kPa pressure (760 mm Hg).
[D] Test Method D86 shall be the referee method.
[E] Test Method D7345, results shall be reported as "Predicted D86" as determined by applying the corrections described in Test Method D7345 to convert to D86 equivalent values. The use of Test Method D7345 shall be limited to gasoline and gasoline-ethanol blends up to maximum 20 % by volume ethanol.
[F] For gasolines that may be blended with 1 % to 15 % by volume ethanol or all other gasolines whose disposition with ethanol blending is not known, the minimum 50 % evaporated distillation temperature shall be 77 °C (170. °F) prior to blending with ethanol. For gasoline-ethanol blends that contain 1 % to 15 % by volume ethanol, the minimum 50 % evaporated distillation temperature shall be 66 °C (150. °F) for volatility classes AAA through C. For Classes D and E fuels containing 1 % to 15 % by volume ethanol, the minimum 50 % evaporated distillation temperature shall be 62.8 °C (145.0 °F). For the 62.8 °C (145.0 °F) minimum 50 % evaporated distillation temperature, no allowance shall be made for the precision of the test methods..
[G] 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.
[H] See 5.2.6 for Driveability Index equations for gasoline and gasoline-ethanol blends containing no more than 15 % by volume ethanol.
[I] The DI specification limits are applicable at the fuel manufacturing facility and are not subject to correction for precision of the test method.
[J] 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: $DI_{°C} = (DI_{°F} - 176)/1.8$

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 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.10 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

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)[4]

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

[3] 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.

[4] The last approved version of this historical standard is referenced on www.astm.org.

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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
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 (Withdrawn 2022)[4]
D3831 Test Method for Manganese in Gasoline By Atomic Absorption Spectroscopy
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_1 to C_4 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 and Manganese in Gasoline by X-Ray Fluorescence 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 and Liquid Fuels (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 and Liquid Fuels (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
D6122 Practice for Validation of the Performance of Multivariate Online, At-Line, Field and Laboratory Infrared Spectrophotometer, and Raman Spectrometer Based Analyzer Systems
D6299 Practice for Applying Statistical Quality Assurance and Control Charting Techniques to Evaluate Analytical Measurement System Performance
D6300 Practice for Determination of Precision and Bias Data for Use in Test Methods for Petroleum Products, Liquid Fuels, and Lubricants
D6304 Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration
D6378 Test Method for Determination of Vapor Pressure (VP_X) of Petroleum Products, Hydrocarbons, and Hydrocarbon-Oxygenate Mixtures (Triple Expansion Method)
D6469 Guide for Microbial Contamination in Fuels and Fuel Systems
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
D7345 Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure (Micro Distillation Method)
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
D7923 Test Method for Water in Ethanol and Hydrocarbon Blends by Karl Fischer Titration
D8148 Test Method for Spectroscopic Determination of Haze in Fuels
D8340 Practice for Performance-Based Qualification of Spectroscopic Analyzer Systems
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

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2.2 *Government Regulations:*

United States Code of Federal Regulations, Title 16 Part 306—Automotive Fuel Ratings, Certification and Posting[5]

United States Code of Federal Regulations, Title 40[5]

United States Code of Federal Regulations, Title 40 Part 1090

Federal Register Vol. 73, April 25, 2008, pp. 22281

Federal Register Vol. 84, June 10, 2019, pp. 26980

California Code of Regulations, Title 17, §60100 – §60114[6]

2.3 *Other Documents:*

API Recommended Practice 1640 Product Quality in Light Product Storage and Handling Operations[7]

CRC Report No. 638 Intermediate-Temperature Volatility Program, 2003[8]

CRC Report No. 666 Intermediate-Temperature E15 Cold-start and Warm-up Vehicle Driveability Program, 2013[8]

CRC Report No. 667 Diesel Fuel Storage and Handling Guide, September 2014[8]

Monograph 12 (MONO12) U.S. Reformulated Spark-Ignition Engine Fuel and the U.S. Renewable Fuel Standard[9]

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 *driveability, n—in vehicles equipped with internal combustion engines*, the quality of a vehicle's performance characteristics under a range of conditions as perceived by the operator.

3.2.2.1 *Discussion*—The operating conditions may include cold starting and warm-up, acceleration, idling, and hot start. The performance characteristics may include engine hesitation, stumble, and stall.

3.2.3 *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**

3.2.4 *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.

3.2.5 *fuel blending facility, n*—any facility, other than a refinery or transmix processing facility where fuel is produced by combining blendstocks or by combining blendstocks with fuel.

3.2.5.1 *Discussion*—Types of blending facilities include, but are not limited to, terminals, storage tanks, plants, tanker trucks, retail outlets, and marine vessels.

3.2.6 *fuel manufacturing facility, n*—any facility where fuels are produced, imported, or recertified.

3.2.6.1 *Discussion*—Fuel manufacturing facilities include refineries, fuel blending facilities, transmix processing facilities, import facilities, and any facility where fuel is recertified.

3.2.7 *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.

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

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

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

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

3.2.12 *oxygenate, n*—a molecule composed solely of carbon, hydrogen, and oxygen.

3.2.12.1 *Discussion*—The fuel described in this standard may contain oxygenates.

3.2.12.2 *Discussion*—In this standard, the oxygenates are low molecular weight alcohols or ethers.

3.2.13 *refinery, n*—a facility where fuels are produced from feedstocks, including crude oil or renewable feedstocks, through physical or chemical processing equipment.

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

3.2.14.1 *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 % by mass oxygen, or more than 0.15 % by 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 3.3 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 percent by mass. Refer to Appendix X4 to calculate mass oxygen content of a fuel using oxygenate concentration in percent by volume.

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

[6] Available from Barclays, 50 California Street, San Francisco, CA 94111.

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

[8] Available from Coordinating Research Council (CRC), 5755 North Point Pkwy #265, Alpharetta, GA 30022, http://www.crcao.org.

[9] Available from ASTM International Headquarters.

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TABLE 2 Detailed Requirements for all Volatility Classes[A,B]

Property	Limit	ASTM Test Method
Lead content, max, g/L (g/U.S. gal)[C]	0.013 (0.05)	D3237 or D5059
Sulfur, max, % by mass	0.0080	D1266, D2622, D3120, D5453, D7039, or D7220
Manganese content, max, mg/L (mg/U.S. gal)[D]	See 6.3	D3831[E]
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

[A] See Appendix X1 for information on Antiknock Index.
[B] See X3.7 for information on U.S. Environmental Protection Agency regulations for benzene in gasoline.
[C] See Appendix X3 for U.S. EPA maximum limits for lead and phosphorus contents in motor vehicle fuel (X3.2.1). Since many jurisdictions outside the U.S. have a different maximum lead content, the reader is advised to review other applicable national, state, provincial, or local requirements.
[D] See X3.8 for information on U.S. EPA and California Air Resources Board regulations for manganese in gasoline.
[E] See Note 8.

4. Ordering Information

4.1 The purchasing agency shall:

4.1.1 State the antiknock index as agreed upon with the seller (see 5.3),

4.1.2 Indicate the season and locality in which the fuel is to be used (see 5.2 and Table 4),

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.

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 seven 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 1 h 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 minimum temperature is the highest temperature of the six coldest consecutive hourly temperature readings of a 24 h day. The 6 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 minimum temperature will be below this value during a month. The 90th percentile 1 h 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.

5.2.1.1 For areas above sea level, the 10th percentile 6 h minimum temperature should be increased by 3.6 °C /1000 m (2 °F/1000 ft) of altitude, and the 90th percentile 1 h 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.

5.2.2 Table 4 *Development*[10]—This volatility schedule was developed based on two decades (1996 – 2015) of 90th percentile 1 h maximum and 6 h minimum temperatures from approximately 300 weather stations and adjusted for altitude. The 90th percentile 1 h maximum temperature and 10th percentile 6 h minimum altitude adjusted temperatures were used to define the volatility classes (vapor pressure class and temperature for a Vapor/Liquid Ratio of 20) for a state or area within a state for each month. While this table was designed for the U.S., the approach utilized can be applied to other geographical areas for seasonal gasoline volatility adjustments.

5.2.2.1 In addition to the ambient temperature determinations, other factors that were considered included, but were not limited to, governmental regulations, geographic proximity, altitude correction in accordance with 5.2.1.1, and regional supply concerns. These recommended classes were then reviewed by a panel of experts to determine if the infrastructure and distribution systems could support the recommended class. Adjustments were made when necessary.

5.2.3 Table 4 *Application*—In the U.S., spark-ignition engine fuel volatility shall meet the schedule and limits in Table 3 and Table 4 on the first day of the month at the point of bulk distribution intended for sale to sites dispensing fuel to the end user during the month. For example, terminals loading tanker trucks should be dispensing fuel in conformance with the in-month volatility requirements on the first day of the month.

[10] For additional information on the development of Table 4, see TR4-EB, *Methodology Used to Update the Gasoline Volatility Schedule for US Seasonal and Geographic Classes*, available from ASTM International.

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TABLE 3 Vapor Lock Protection Class Requirements[A, B, C]

	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

[A] 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).
[B] 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.
[C] 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.

Refiners, importers, shippers, and distributors should anticipate this schedule for conformance with this specification.

5.2.3.1 At sites dispensing fuel to the end user, including retail locations, conformance with the in-month volatility requirements shall occur no later than the 16th day of the month (see below for summer exceptions in the U.S.). From the 1st through the 15th day of the month, the prior or current month volatility properties may be used (see exception for U.S. summertime below). This recognizes the variable turnover time needed for supplies to the end user to be depleted and replenished.

5.2.3.2 The 1.0 psi vapor pressure waiver for gasoline-ethanol blends is not incorporated into Specification D4814. Many states provide a 1.0 psi vapor pressure waiver for gasoline-ethanol blends; however, vapor pressure limits for gasoline-ethanol blends vary among states and in areas with Federally approved State Implementation Plans (SIPs). Contact specific states to determine their vapor pressure limits for gasoline-ethanol blends.

5.2.3.3 *Summer Exceptions*—U.S. EPA limits vapor pressure for gasoline for the regulatory control period of May 1 - September 15 at the refinery and terminal level and from June 1 – September 15 at retail. Refer to 40 CFR 1090 for specific requirements including, but not limited to, timing, gasoline-ethanol blend vapor pressure waivers, and various volatility limits for different gasoline or geographical areas. See Appendix X3 for a summary of U.S. EPA volatility and other fuel quality regulations.

5.2.4 *Multi-Class Designation*—Multi-class volatility designations are created to allow for transitioning or anticipating the transition for seasonal and geographical volatility changes. Allowance is made for the fuel distribution system to use up the prior month's volatility class fuel. This depletion of liquid inventory is facilitated by a multi-class option for a month with a volatility change from the prior month. For months where non-adjacent multi-class volatility designation are listed, either listed class or intermediate class designation are acceptable. The option may be exercised by the seller, but bulk inventories must still meet the required volatility at the first of the month. For example, in Table 4, the volatility for April in Alabama shows C-3/A-3 which means either a C-3, B-3, or A-3 volatility class is allowed. For March, which is D-4/C-3, either volatility class is acceptable. As storage is transitioned between different classes a blend of volatility classes is to be expected. However, for demonstrating conformance with this standard for bulk fuel, a single volatility grade's limits shall be used, not a combination of limits from several classes.

5.2.5 Tables 5-7 contain specific geographic requirements. Consult U.S. EPA regulations under 40 CFR Part 1090 for Federal 7.8 psi vapor pressure areas, RFG covered areas, and Federally approved SIP areas.

5.2.6 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 Methods D86 or D7345 and the ethanol content measured by the test methods shown in 7.1.9. Equations are provided for gasoline and gasoline-ethanol blends containing up to 10 % by volume ethanol and for gasoline-ethanol blends containing greater than 10 % by volume and no more than 15 % by volume ethanol when distillation temperatures are determined in Celsius or Fahrenheit degrees.

5.2.6.1 For fuels containing 0 % to 10 % by volume ethanol:

For degrees Celsius:

$$\text{Driveability Index } (DI_C) = 1.5\ T_{10} + 3.0\ T_{50} + 1.0\ T_{90} + 1.33 \times (\text{Ethanol \% by Volume}) \quad (1)$$

For degrees Fahrenheit:

$$\text{Driveability Index } (DI_F) = 1.5\ T_{10} + 3.0\ T_{50} + 1.0\ T_{90} + 2.4 \times (\text{Ethanol \% by Volume}) \quad (2)$$

5.2.6.2 For fuels greater than 10 % and no more than 15 % by volume ethanol:

For degrees Celsius:

$$\text{Driveability Index } (DI_C) = 1.5\ T_{10} + 3.0\ T_{50} + 1.0\ T_{90} + (1.33 + [(\text{Ethanol \% by Volume} - 10)/5] \times (5.26 - 1.33)) \times (\text{Ethanol \% by Volume}) \quad (3)$$

For degrees Fahrenheit:

$$\text{Driveability Index } (DI_F) = 1.5\ T_{10} + 3.0\ T_{50} + 1.0\ T_{90} + (2.4 + [(\text{Ethanol \% by Volume} - 10)/5] \times (9.49 - 2.4)) \times (\text{Ethanol \% by Volume}) \quad (4)$$

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TABLE 4 Schedule of U.S. Seasonal and Geographical Volatility Classes[A]

NOTE 1—See 5.2 for information on the development and use of the table.

State	Jan.	Feb.	Mar.	Apr.	May[B]	June	July	Aug.	Sept. 1–15	Sept. 16–30	Oct.	Nov.	Dec.
Alabama	D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-3	A-2	A-2	A-3	A-3/C-3	C-3	C-3/D-4	D-4
Alaska	E-6	E-6	E-6	E-6	E-6/D-4	D-4	D-4	D-4	D-4	D-4/E-6	E-6	E-6	E-6
Arizona:[C]													
N 34° Latitude and E111° Longitude	D-4	D-4/C-3	C-3	C-3/A-2	A-2 (B-2)	A-1	A-1	A-2	A-2	A-2/B-2	B-2/C-3	C-3/D-4	D-4
Remainder of State	D-4	D-4/C-3	C-3/B-2	B-2/A-2	A-2 (B-2)	A-1[C]	A-1[C]	A-1[C]	A-2[C]	A-2	A-2/B-2	B-2/C-3	C-3/D-4
Arkansas	E-5/D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-3	A-2	A-2	A-3	A-3/C-3	C-3	C-3/D-4	D-4/E-5
California:[C,D]													
North Coast	E-5/D-4	D-4	D-4	D-4/A-3	A-3 (C-3)	A-2[C]	A-2[C]	A-2[C]	A-2[C]	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
South Coast	D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-2[C]	A-2[C]	A-2[C]	A-2[C]	A-2/B-2	B-2/C-3	C-3/D-4	D-4
Southeast	D-4	D-4/C-3	C-3/B-2	B-2/A-2	A-2 (B-2)	A-1[C]	A-1[C]	A-1[C]	A-1[C]	A-1	A-1/B-2	B-2/C-3	C-3/D-4
Interior	E-5/D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-2[C]	A-2[C]	A-2[C]	A-2[C]	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
Colorado	D-4	D-4/C-3	C-3	C-3/A-3	A-2 (C-3)	A-1[C]	A-1[C]	A-2[C]	A-2[C]	A-2/B-2	B-2/C-3	C-3/D-4	D-4
Connecticut	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3[C]	A-3[C]	A-3[C]	A-3[C]	A-3/D-4	D-4	D-4/E-5	E-5
Delaware	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3[C]	A-3[C]	A-3[C]	A-3[C]	A-3/C-3	C-3/D-4	D-4/E-5	E-5
District of Columbia	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-3[C]	A-3[C]	A-3[C]	A-3[C]	A-3/C-3	C-3/D-4	D-4	D-4/E-5
Florida	D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-2	A-2	A-3	A-3	A-3/C-3	C-3	C-3/D-4	D-4
Georgia	D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-2	A-2	A-2	A-3	A-3/C-3	C-3	C-3/D-4	D-4
Hawaii	C-3	C-3	C-3	C-3	C-3	C-3	C-3	C-3	C-3	C-3	C-3	C-3	C-3
Idaho:													
N 46° Latitude	E-5	E-5	E-5/D-4	D-4/A-3	A-3 (C-3)	A-3	A-2	A-2	A-2	A-2/C-3	C-3/D-4	D-4/E-5	E-5
S 46° Latitude	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-2	A-2	A-2	A-2	A-2/B-2	B-2/D-4	D-4/E-5	E-5
Illinois:													
N 40° Latitude	E-5	E-5	E-5/D-4	D-4/A-3	A-3 (C-3)	A-3[C]	A-3[C]	A-3[C]	A-3[C]	A-3/C-3	C-3/D-4	D-4/E-5	E-5
S 40° Latitude	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-3[C]	A-3[C]	A-3[C]	A-3[C]	A-3/C-3	C-3/D-4	D-4	D-4/E-5
Indiana[C]	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-3[C]	A-3[C]	A-3[C]	A-3[C]	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Iowa	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-3	A-3	A-3	A-3	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Kansas[C]	E-5	E-5/D-4	D-4/C-3	C-3/A-2	A-2 (C-3)	A-2[C]	A-2[C]	A-2[C]	A-2[C]	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
Kentucky	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-3[C]	A-3[C]	A-2[C]	A-3[C]	A-3/C-3	C-3/D-4	D-4	D-4/E-5
Louisiana	D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-2	A-2	A-2	A-3	A-3/C-3	C-3	C-3/D-4	D-4
Maine	E-5	E-5	E-5	E-5/A-4	A-4 (D-4)	A-3	A-3	A-3	A-3	A-4/D-4	D-4	D-4/E-5	E-5
Maryland	E-5	E-5/D-4	D-4	D-4/A-4	A-3 (D-4)	A-3[C]	A-3[C]	A-3[C]	A-3[C]	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Massachusetts	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3[C]	A-3[C]	A-3[C]	A-3[C]	A-3/D-4	D-4	D-4/E-5	E-5
Michigan[C]	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3	A-3	A-3	A-3	A-3/D-4	D-4	D-4/E-5	E-5
Minnesota	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3	A-3	A-3	A-3	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Mississippi	D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-3	A-2	A-2	A-3	A-3/C-3	C-3	C-3/D-4	D-4
Missouri[C]	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-3[C]	A-2[C]	A-2[C]	A-3[C]	A-3/C-3	C-3/D-4	D-4	D-4/E-5
Montana	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-3	A-2	A-2	A-2	A-2/C-3	C-3/D-4	D-4/E-5	E-5
Nebraska	E-5	E-5	E-5/D-4	D-4/A-3	A-3 (C-3)	A-2	A-2	A-2	A-2	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
Nevada:													
N 38° Latitude	E-5/D-4	D-4	D-4	D-4/A-3	A-2 (C-3)	A-2[C]	A-1[C]	A-2[C]	A-2[C]	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
S 38° Latitude	D-4	D-4/C-3	C-3	C-3/A-2	A-2 (B-2)	A-1	A-1	A-1	A-2	A-2/B-2	B-2/C-3	C-3/D-4	D-4
New Hampshire	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3[C]	A-3[C]	A-3[C]	A-4[C]	A-4/D-4	D-4	D-4/E-5	E-5
New Jersey	E-5	E-5	E-5/D-4	D-4/A-4	A-3 (D-4)	A-3[C]	A-3[C]	A-3[C]	A-3[C]	A-3/D-4	D-4	D-4/E-5	E-5
New Mexico:													
N 34° Latitude	D-4	D-4/C-3	C-3	C-3/A-2	A-2 (B-2)	A-1	A-1	A-2	A-2	A-2/B-2	B-2/C-3	C-3/D-4	D-4
S 34° Latitude	D-4/C-3	C-3	C-3/B-2	B-2/A-2	A-2 (B-2)	A-1	A-1	A-1	A-2	A-2/B-2	B-2/C-3	C-3	C-3/D-4
New York	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3[C]	A-3[C]	A-3[C]	A-3[C]	A-3/D-4	D-4	D-4/E-5	E-5
North Carolina	D-4	D-4	D-4	D-4/A-3	A-3 (C-3)	A-2	A-3	A-3	A-3	A-3/C-3	C-3/D-4	D-4	D-4
North Dakota	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3	A-2	A-2	A-3	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Ohio	E-5	E-5/D-4	D-4	D-4/A-4	A-3 (D-4)	A-3	A-3	A-3	A-3	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Oklahoma	E-5/D-4	D-4	D-4/C-3	C-3/A-3	A-2 (C-3)	A-2	A-2	A-2	A-2	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
Oregon:													
E122° Longitude	E-5	E-5/D-4	D-4	D-4/A-4	A-3 (D-4)	A-2	A-2	A-2	A-2	A-2/C-3	C-3/D-4	D-4/E-5	E-5
W 122° Longitude	E-5	E-5/D-4	D-4	D-4/A-4	A-3 (D-4)	A-3[C]	A-2[C]	A-2[C]	A-2[C]	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Pennsylvania	E-5	E-5	E-5/D-4	D-4/A-3	A-3 (D-4)	A-3[C]	A-3[C]	A-3[C]	A-3	A-3/D-4	D-4	D-4/E-5	E-5
Rhode Island	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3[C]	A-3[C]	A-3[C]	A-4	A-4/D-4	D-4	D-4/E-5	E-5
South Carolina	D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-2	A-2	A-3	A-3	A-3/C-3	C-3/D-4	D-4	D-4
South Dakota	E-5	E-5	E-5/D-4	D-4/A-3	A-3 (C-3)	A-2	A-2	A-2	A-2	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
Tennessee	E-5/D-4	D-4	D-4	D-4/A-3	A-3 (C-3)	A-3	A-2	A-2	A-3	A-3/C-3	C-3	C-3/D-4	D-4/E-5
Texas:[C]													
E 99° Longitude	D-4	D-4/C-3	C-3	C-3/A-2	A-2 (C-3)	A-2[C]	A-2[C]	A-2[C]	A-2[C]	A-2/B-2	B-2/C-3	C-3/D-4	D-4
W 99° Longitude	D-4	D-4/C-3	C-3/B-2	B-2/A-2	A-2 (B-2)	A-1[C]	A-2[C]	A-2[C]	A-2[C]	A-2/B-2	B-2/C-3	C-3	C-3/D-4
Utah	E-5/D-4	D-4	D-4	D-4/A-3	A-2 (C-3)	A-1[C]	A-1[C]	A-2[C]	A-2[C]	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5

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TABLE 4 *Continued*

State	Jan.	Feb.	Mar.	Apr.	May[B]	June	July	Aug.	Sept. 1–15	Sept. 16–30	Oct.	Nov.	Dec.
Vermont	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3	A-3	A-3	A-4	A-4/D-4	D-4	D-4/E-5	E-5
Virginia	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-3[C]	A-3[C]	A-3[C]	A-3[C]	A-3/C-3	C-3/D-4	D-4	D-4/E-5
Washington:													
E 122° Longitude	E-5	E-5	E-5/D-4	D-4/A-4	A-3 (D-4)	A-3	A-2	A-2	A-3	A-3/C-3	C-3/D-4	D-4/E-5	E-5
W 122° Longitude	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-4	A-3	A-3	A-4	A-4/D-4	D-4	D-4/E-5	E-5
West Virginia	E-5	E-5/D-4	D-4	D-4/A-4	A-3 (D-4)	A-3	A-3	A-3	A-3	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Wisconsin	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3[C]	A-3[C]	A-3[C]	A-3[C]	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Wyoming	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-2	A-2	A-2	A-2	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5

[A] For the period May 1 through September 15, the specified vapor pressure classes shall meet U.S. EPA volatility regulations. Reformulated gasoline is limited to a maximum vapor pressure of 7.4 psi during the summer EPA regulatory control period. Under EPA regulations at 40 CFR 1090.215(b), from May 1 through September 15, certain gasoline-ethanol blends in conventional gasoline areas are allowed a 1.0 psi higher vapor pressure. Other requirements apply to the ethanol waiver. See Appendix X3 for additional U.S. federal volatility and other regulations. The 1.0 psi vapor pressure waiver for gasoline-ethanol blends is not incorporated into Specification D4814. Many states provide a 1.0 psi vapor pressure waiver for gasoline-ethanol blends; however, vapor pressure limits for gasoline-ethanol blends vary among states and in areas with Federally approved State Implementation Plans (SIPs). Contact specific states to determine their vapor pressure limits for gasoline-ethanol blends.

[B] Values in parentheses are permitted for retail stations and other end users.

[C] See Tables 5-7 for specific area requirements. Consult U.S. Environmental Protection Agency regulations under 40 CFR Part 1090 for Federal 7.8 psi vapor pressure areas, RFG covered areas, and Federally approved SIP areas.

[D] Details of State Climatological Division by CARB air basin and county as indicated (Descriptions of the California Air Basins are found in the California Code of Regulations):

California, North Coast—CARB North Coast, Lake County, San Francisco Bay Area, and North Central Coast Air Basins (Alameda, Contra Costa, Del Norte, Humboldt, Lake, Marin, Mendocino, Monterey, Napa, San Benito, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, Sonoma, and Trinity Counties and part of Solano County).

California, interior—CARB Northeast Plateau, Sacramento Valley, Mountain Counties, Lake Tahoe, and San Joaquin Valley Air Basins (Amador, Butte, Calaveras, Colusa, El Dorado, Fresno, Glenn, Kings, Lassen, Madera, Mariposa, Merced, Modoc, Nevada, Placer, Plumas, Sacramento, San Joaquin, Shasta, Sierra, Siskiyou, Stanislaus, Sutter, Tehama, Tulare, Tuolumne, Yolo, and Yuba Counties, and parts of Kern and Solano Counties).

California, South Coast—CARB South Central Coast, San Diego, and South Coast Air Basins (Los Angeles, Orange, San Diego, San Luis Obispo, Santa Barbara, and Ventura Counties, and parts of Riverside and San Bernardino Counties).

California, Southeast—CARB Great Basin Valleys, Salton Sea, and Mojave Desert Air Basins (Alpine, Imperial, Inyo, and Mono Counties, and parts of Kern, Los Angeles, Riverside, San Bernardino Counties).

TABLE 5 U.S. Ozone Nonattainment Areas Requiring Volatility Class AA[A]

NOTE 1—See 40 CFR Part 1090.215(a)(2) for Federal 7.8 psi vapor pressure areas during the summer EPA regulatory control period.

Colorado—Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, Jefferson, Larimer (part), and Weld (part) Counties
Nevada—Washoe County
Oregon—Clackamas (part), Marion (part), Multnomah (part), Polk (part), and Washington (part) counties
Texas—Hardin, Jefferson, and Orange Counties
Utah—Davis and Salt Lake Counties

[A] Refer to Tables 3 and 4 for Vapor Lock Protection Requirements.

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TABLE 6 U.S. Federal RFG Areas Requiring Volatility Class AAA[A, B]

NOTE 1—See 40 CFR Part 1090.285 for RFG covered areas.

NOTE 2—No waiver for gasoline-ethanol blends in RFG areas during the summer EPA regulatory control period.

California—El Dorado (part), Fresno, Kern, Kings, Los Angeles, Madera, Merced, Orange, Placer (part), Riverside (part), Sacramento, San Bernardino (part), San Diego, San Joaquin, Solano (part), Stanislaus, Sutter (part), Tulare, Ventura, and Yolo Counties
Colorado—Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, Jefferson, Larimer (part), and Weld (part) Counties
Connecticut—All Counties
Delaware—All Counties
District of Columbia
Illinois—Cook, Du Page, Grundy (part), Jersey, Kane, Kendall (part), Lake, Madison, McHenry, Monroe, St. Clair, and Will Counties
Indiana—Lake and Porter Counties
Kentucky—Bullitt (part), Jefferson, and Oldham (part) Counties
Maryland—Anne Arundel, Baltimore, Calvert, Carroll, Cecil, Charles, Frederick, Harford, Howard, Kent, Montgomery, Prince George's, and Queen Anne's Counties and the City of Baltimore
Massachusetts—All Counties
Missouri—Franklin, Jefferson, Saint Charles, and Saint Louis counties; and the City of St. Louis
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
Texas—Brazoria, Chambers, Collin, Dallas, Denton, Ellis, Fort Bend, Galveston, Harris, Johnson, Kaufman, Liberty, Montgomery, Parker, Rockwall, Tarrant, Waller, and Wise 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
Wisconsin—Kenosha, Milwaukee, Ozaukee, Racine, Washington, and Waukesha Counties

[A] Refer to Tables 3 and 4 for Vapor Lock Protection Requirements.
[B] Gasoline designated as California gasoline or used in areas subject to the California reformulated gasoline regulations must comply with those regulations under Title 13, California Code of Regulations, sections 2250-2273.5.

TABLE 7 U.S. Federally Approved State Implementation Plan Areas Requiring More Restrictive Maximum Vapor Pressure Limits[A]

Arizona—Maricopa County, Pinal(part), and Yavapai (part)–48.2 kPa (7.0 psi) max June 1 - Sept. 30, 62.0 kPa (9.0 psi) max Oct. 1 - Mar. 31 and May, 69.0 kPa (10.0 psi) max Apr.[B(Apr. only),C]
California—48.26 kPa (7.00 psi) max April 1, May 1, or June 1 - Sept. 30 or Oct. 31 depending on air basin[D]
Indiana—Clark and Floyd counties area – 53.8 kPa (7.8 psi) max May 1 terminal/June 1 retail - Sept. 15[B]
Michigan—Lenawee, Livingston, Macomb, Monroe, Oakland, Saint Clair, Washtenaw, and Wayne counties–48.2 kPa (7.0 psi) max June 1 - Sept 15
Texas—El Paso County–48.2 kPa (7.0 psi) max May 1 terminal/June 1 retail - Sept. 15
Texas—Anderson, Angelina, Aransas, Atascosa, Austin, Bastrop, Bee, Bell, Bexar, Bosque, Bowie, Brazos, Burleson, Caldwell, Calhoun, Camp, Cass, Cherokee, Colorado, Comal, Cooke, Coryell, De Witt, Delta, Ellis, Falls, Fannin, Fayette, Franklin, Freestone, Goliad, Gonzales, Grayson, Gregg, Grimes, Guadalupe, Harrison, Hays, Henderson, Hill, Hood, Hopkins, Houston, Hunt, Jackson, Jasper, Johnson, Karnes, Kaufman, Lamar, Lavaca, Lee, Leon, Limestone, Live Oak, Madison, Marion, Matagorda, McLennan, Milam, Morris, Nacogdoches, Navarro, Newton, Nueces, Panola, Parker, Polk, Rains, Red River, Refugio, Robertson, Rockwall, Rusk, Sabine, San Jacinto, San Patricio, San Augustine, Shelby, Smith, Somervell, Titus, Travis, Trinity, Tyler, Upshur, Van Zandt, Victoria, Walker, Washington, Wharton, Williamson, Wilson, Wise, and Wood counties–53.8 kPa (7.8 psi) max May 1 terminal/June 1 retail - October 1

[A] Refer to Tables 3 and 4 for Vapor Lock Protection Requirements
[B] A 1.0 psi higher vapor pressure is allowed for gasoline-ethanol blends containing 9 % to 10 % by volume ethanol. For the Arizona Cleaner Burning Gasoline program, the 1.0 psi higher vapor pressure applies during April only.
[C] See Arizona Revised Statutes (ARS) §49–541 for boundaries of Arizona Cleaner Burning Gasoline. The Cleaner Burning Gasoline program does not apply to facilities located within Native American Tribal Lands.
[D] Gasoline designated as California gasoline or used in areas subject to the California reformulated gasoline regulations must comply with those regulations under Title 13, California Code of Regulations, sections 2250-2273.5.

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where:

T_{10} = distillation temperature at 10 % evaporated,
T_{50} = distillation temperature at 50 % evaporated, and
T_{90} = distillation temperature at 90 % evaporated.

5.2.7 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* ($T_{V/L=20}$) (see Appendix X2) are applicable for gasoline and gasoline-ethanol blends (1 % to 15 % by volume), but not for gasoline-ether blends.

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 The denatured fuel ethanol used in gasoline-ethanol blends shall conform to the requirements of Specification D4806.

5.5 Additional fuel requirements are shown in Table 2.

5.6 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.

5.7 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.

5.8 Deposit control additives are added to fuel to help keep carburetors, fuel injectors, and intake valves clean.

5.8.1 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.

5.8.2 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 fuel temperature at the point of custody transfer or at a lower temperature agreed upon by the purchaser and seller.

NOTE 5—Test Method D4176, D6304, D7923, or D8148 can be helpful for evaluating the product. Although Test Methods D6304 and D7923 are quantitative methods to measure dissolved and/or entrained water in fuels, knowing these quantities can help determine if undissolved water may appear in fuels at lower temperatures. See X8.1.1 for additional information on these standard test methods.

6.1.1 *Avoiding Water Haze and Phase Separation*—Finished spark-ignition engine fuel should not contain a separate water or water-alcohol phase at the time it is introduced into a vehicle or equipment fuel tank or under the conditions the fuel is used. Water that is dissolved in fuel at the point of use does not generally cause engine problems. However, if excess water is present in spark-ignition fuel, a separate phase, either 'free water' or a water-alcohol mixture, can form. Either condition can lead to engine 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.

6.2 The finished fuel shall also be free of any adulterant or contaminant that can render the fuel unacceptable for its commonly used applications.

6.2.1 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.

6.2.2 Manufacturers and blenders of gasoline and gasoline-oxygenate blends shall avoid gasoline blending stocks or denatured fuel ethanol contaminated by chloride salts. Chloride salts can contribute inorganic chloride ions to the blend component or the finished fuel. Contamination of the blend components or the finished fuel with inorganic chlorides has led to corrosion issues with vehicle fuel and emissions systems requiring parts replacement and repairs. Approved standard test methods are not available to determine the concentration of inorganic chloride in spark-ignition engine fuels.

6.3 For markets where vehicles meeting U.S. Tier 2, Euro 5, or more stringent emissions standards are required or in widespread use, MMT shall be limited in automotive spark-ignition engine fuel to a maximum manganese concentration of 0.25 mg/L, until such time as data are produced to support its

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use at higher concentrations, and incorporated into this specification. (See Note 8.)

NOTE 8—This level represents the lower limit of the Test Method D3831 scope.

7. Test Methods

7.1 The requirements of this specification shall be determined in accordance with the methods listed in 7.1 or predicted by the application of a multivariate spectroscopic test method conforming to Practice D8340 as described in 7.2. The scopes of some of the test methods listed in 7.1 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 Methods D86 or D7345.

7.1.1.1 When using Test Method D7345, results shall be reported as "Predicted D86" as determined by applying the corrections described in Test Method D7345 to convert to Test Method D86 equivalent values. In case of dispute, Test Method D86 shall be the referee method.

7.1.1.2 The use of Test Method D7345 shall be limited to gasoline and gasoline-ethanol blends up to maximum 20 % by volume ethanol.

7.1.1.3 The Driveability Index is calculated using distillation information from the test methods above.

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_4 at 37.8 °C (100 °F) using a sample from a 1 L container and convert to DVPE (Test Method D5191 equivalence) using the following equation:

$$Predicted\ DVPE_C = VP_{4\ 37.8\ °C} - 1.005\ \text{kPa} \quad (5)$$

$$Predicted\ DVPE_F = VP_{4\ 100\ °F} - 0.15\ \text{psi} \quad (6)$$

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, D7039, or D7220. With Test Method D3120, fuels with sulfur content greater than 100 mg/kg (0.0100 % by mass) must be diluted with *iso*octane. The dilution of the sample may result in a loss of precision.

7.1.7 *Lead*—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, *iso*propyl alcohol, *n*-butyl alcohol, *sec*-butyl alcohol *iso*butyl alcohol, and *tert*-pentyl alcohol. Results for all of these test methods are reported in percent by mass. Test Method D4815 includes procedures for calculating oxygenate concentration in percent by volume and mass oxygen content using the percent by mass oxygenate results.

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

7.1.11 *Manganese*—Test Method D3831. (See Note 8.)

7.1.12 Antiknock Index (AKI) is calculated using Research Octane Number (Test Methods D2699 or D2885) and the Motor Octane Number (Test Methods D2700 or D2885).

7.2 The application of Multivariate Spectroscopic Test Methods to predict property results that would be obtained if tested by the methods listed in 7.1 (primary test methods) shall conform to Practice D8340. Practice D8340 is a Standard Practice for Performance-Based Qualification of Spectroscopic Analyzer Systems to allow the use of spectroscopic analysis for predicting physical, chemical, and performance properties of liquid petroleum products and fuels that are otherwise measured by primary test methods. The predicted properties obtained by a spectroscopic test method conforming to Practice D8340 may be used in lieu of the test methods listed in 7.1 for confirmation of specification conformance. In case of dispute, the test methods listed in 7.1 of Specification D4814 shall be used.

7.2.1 Liquid petroleum products and fuels is defined in Practice D8340 as being inclusive of biofuels, renewable fuels, blendstocks, alternative blendstocks, and additives.

7.2.2 Practice D8340 covers the qualification of on-line, at-line, or laboratory infrared or Raman analyzers.

7.2.3 The user of the spectroscopic test method is responsible for demonstrating at/within a specified minimum frequency that the spectroscopic test method provides results in agreement to the primary test method result within the Practice D6122 local validation limits or the primary test method reproducibility, whichever is the more stringent.

7.2.3.1 Practice D6122 is a continual validation process with a minimum frequency requirement.

7.2.3.2 Practice D8340 provides methodology to establish the lower/upper prediction limits associated with the Predicted Primary Test Method Result with a specified degree of confidence that would contain the Primary Test Method Result (if tested by the Primary Test Method).

7.2.3.3 Practice D8340 requires the identification of spectral outliers, which is a sample whose spectrum differs from the spectra of samples in the calibration set by certain criteria. Samples resulting in spectral outliers are not used in analyzer validation.

7.2.3.4 Spectroscopic analyzer system data shall not be used to confirm conformance and release if it is determined that the sample is a spectral outlier or if the analyzer system is failing validation for the property of interest.

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