Designation: D5798 – 17

Standard Specification for Ethanol Fuel Blends for Flexible-Fuel Automotive Spark-Ignition Engines[1]

This standard is issued under the fixed designation D5798; 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 requirements for automotive fuel blends of ethanol and gasoline for use in ground vehicles equipped with ethanol fuel blend flexible-fuel spark-ignition engines. Fuel produced to this specification contains 51 % to 83 % by volume ethanol. This fuel is for use in flexible-fuel vehicles and is sometimes referred to at retail as "Ethanol Flex-Fuel." Appendix X1 discusses the significance of the properties specified.

1.2 The vapor pressure of ethanol fuel blends is varied for seasonal climatic changes. Vapor pressure is increased at lower temperatures to ensure adequate flexible-fuel vehicle operability. Ethanol content and selection of hydrocarbon blendstock are adjusted by the blender to meet these vapor pressure requirements.

1.3 This specification formerly covered Fuel Ethanol (Ed70-Ed85) for Automotive Spark-Ignition Engines, also known commercially as E85. The nomenclature "fuel ethanol" has been changed to "ethanol fuel blends" to distinguish this product from denatured fuel ethanol Specification D4806. To facilitate blending of ethanol fuel blends that meet seasonal vapor pressure requirements, a new lower minimum ethanol content has been established.

1.4 The United States government has established various programs for alternative fuels. Many of the definitions of alternative fuel used by these programs may be more restrictive than the requirements of this specification. See 4.1.2.1 for additional information on alternative fuels containing ethanol.

1.5 The values stated in SI units are to be regarded as the standard.

1.5.1 *Exception*—The values given in parentheses are for information only.

1.6 The following safety hazard caveat pertains only to the test method portion, 8.1.8, of this specification. *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.*

1.7 *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:*[2]

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

D381 Test Method for Gum Content in Fuels by Jet Evaporation

D525 Test Method for Oxidation Stability of Gasoline (Induction Period Method)

D1613 Test Method for Acidity in Volatile Solvents and Chemical Intermediates Used in Paint, Varnish, Lacquer, and Related Products

D1688 Test Methods for Copper in Water

D3231 Test Method for Phosphorus in Gasoline

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products

D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants

D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products

D4306 Practice for Aviation Fuel Sample Containers for

[1] This specification is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is under the direct responsibility of Subcommittee D02.A0.02 on Oxygenated Fuels and Components.

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[2] 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.

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

Tests Affected by Trace Contamination
D4806 Specification for Denatured Fuel Ethanol for Blending with Gasolines for Use as Automotive Spark-Ignition Engine Fuel
D4814 Specification for Automotive Spark-Ignition Engine Fuel
D4953 Test Method for Vapor Pressure of Gasoline and Gasoline-Oxygenate Blends (Dry 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
D5501 Test Method for Determination of Ethanol and Methanol Content in Fuels Containing Greater than 20% Ethanol by Gas Chromatography
D5854 Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products
D6423 Test Method for Determination of pHe of Denatured Fuel Ethanol and Ethanol Fuel Blends
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
D7319 Test Method for Determination of Existent and Potential Sulfate and Inorganic Chloride in Fuel Ethanol and Butanol by Direct Injection Suppressed Ion Chromatography
D7328 Test Method for Determination of Existent and Potential Inorganic Sulfate and Total Inorganic Chloride in Fuel Ethanol by Ion Chromatography Using Aqueous Sample Injection
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
D7795 Test Method for Acidity in Ethanol and Ethanol Blends by Titration
D7923 Test Method for Water in Ethanol and Hydrocarbon Blends by Karl Fischer Titration
E203 Test Method for Water Using Volumetric Karl Fischer Titration
E1064 Test Method for Water in Organic Liquids by Coulometric Karl Fischer Titration

2.2 *Government Standards:*[3]
United States Code of Federal Regulations, Title 40, Part 80

2.3 *SAE Papers:*[4]
SAE 2007–01–4006 A Model for Estimating Vapor Pressures of Commingled Ethanol Fuels

3. Terminology

3.1 For general terminology, refer to Terminology D4175.

3.2 *Definitions:*

3.2.1 *denaturants, n*—materials added to ethanol to make it unsuitable for beverage use under a formula approved by a regulatory agency to prevent the imposition of beverage alcohol tax.

3.2.1.1 *Discussion*—Denaturants are only those materials added by the denaturer to comply with the approved formula; any materials absorbed later are not denaturants. **D4806**

3.2.2 *denatured fuel ethanol*—fuel ethanol made unfit for beverage use by the addition of denaturants under formula(s) approved by the applicable regulatory agency to prevent the imposition of beverage alcohol tax. **D4806**

3.2.3 *ethanol, n*—ethyl alcohol, the chemical compound C_2H_5OH. **D4806**

3.2.4 *finished fuel, n*—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 *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. **D4814**

3.2.6 *hydrocarbon, n*—a compound composed solely of hydrogen and carbon.

3.2.7 *methanol, n*—methyl alcohol, the chemical compound CH_3OH.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *flexible-fuel vehicle, n*—a vehicle designed to operate on either unleaded gasoline or ethanol fuel blends or mixtures of both.

3.3.1.1 *Discussion*—In the United States, these vehicles have U.S. EPA emissions certifications using gasoline complying with U.S. EPA requirements and ethanol fuel blends that meet the requirements of Specification D5798.

3.3.2 *hydrocarbon blendstock, n*—a blending component composed of hydrocarbons which boil in the gasoline temperature distillation range and trace amounts of naturally occurring compounds or additives composed of hydrogen, carbon, and other elements such as sulfur, oxygen and nitrogen.

3.3.3 pH_e, *n*—a measure of the acid strength of alcohol fuels.

4. Ordering Information

4.1 The purchasing agency shall:

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

4.1.2 If requested, ensure that the ethanol concentration meets the requirements for an alternative fuel for federal fleets.

[3] A printed copy of the Code of Federal Regulations may be purchased from the U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol Street, N.W., Mail Stop: SDE, Washington, DC 20401 or the online store at http://bookstore.gpo.gov/. The Code of Federal Regulations may be browsed online at http://www.gpoaccess.gov/cfr/index.html.

[4] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

4.1.2.1 The composition of alternative fuels in the United States is regulated by various government agencies and regulations including the U.S. Department of Energy (DOE) and U.S. Environmental Protection Agency (EPA). With regard to fuel properties including volatility, this specification can be more or less restrictive than DOE or EPA rules, regulations and waivers. To qualify as an alternative fuel for federal fleet use in the United States, the ethanol blend is required to meet the U.S. Department of Energy's definition of alternative fuels, enacted under the Energy Policy Act of 1992 (Title III, Sec. 301). For ethanol, the Act defines "alternative fuel" as a mixture containing denatured ethanol at a volume of "85 percent or more (or such other percentage, but not less than 70 percent, as determined by the Secretary, by rule...)." Correcting for denaturant content, a blend of 70 to 85 volume % denatured fuel ethanol contains 68 % to 83 volume % ethanol as measured by Test Method D5501. The U.S. government has other programs and definitions for alternative fuels.

4.1.2.2 Users of this specification are advised to check with the applicable regulatory agency for specific alternative fuel requirements.

5. Ethanol Fuel Blends Performance Requirements

5.1 Ethanol Fuel Blends shall conform to the requirements of Table 1.

5.1.1 The components used to produce Ethanol Fuel Blends are limited to denatured fuel ethanol and hydrocarbon blendstock as defined in 5.2.

5.1.2 The intentional addition of lead or phosphorus compounds to ethanol fuel blends is not permitted.

5.2 Hydrocarbon Blendstock blended with the denatured fuel ethanol shall meet the requirements of Table 2.

5.2.1 The hydrocarbon blendstock may be unleaded gasoline, gasoline blendstock for oxygenate blending (BOB), natural gasoline or other hydrocarbons in the gasoline boiling range.

TABLE 2 Requirements for Hydrocarbon Blendstock

Properties		Test Methods
Distillation, end point, max, °C (°F)	225 (437)	D86
Oxidation stability, minimum, minutes	240	D525
Copper Strip Corrosion, max	No. 1	D130
Silver Strip Corrosion, max	No. 1	D7667, D7671
Vapor pressure	Report[A]	D4953, D5191

[A] While not a requirement of this specification, the blender will need to know the vapor pressure of the hydrocarbon blendstock in order to choose a suitable blend ratio for the components to meet the vapor pressure requirement of a particular volatility class.

5.3 Vapor pressure is varied for seasonal and climatic changes by providing four vapor pressure classes for ethanol fuel blends.

5.3.1 Class 1 encompasses geographical areas with 6-hour tenth percentile minimum ambient temperature of greater than 5 °C (41 °F).

5.3.2 Class 2 encompasses geographical areas with 6-hour tenth percentile minimum ambient temperature of greater than –5 °C (23 °F) but less than or equal to 5 °C (41°F).

5.3.3 Class 3 encompasses geographical areas with 6-hour tenth percentile minimum ambient temperature greater than –13 °C (9 °F) but less than or equal to –5 °C (23°F).

5.3.4 Class 4 encompasses geographical areas with 6-hour tenth percentile minimum ambient temperature less than or equal to –13 °C (9 °F).

5.3.5 There is a 10 % probability that the highest temperature of the six coldest consecutive hourly temperature readings of a 24 h day will be colder than the 6 h tenth percentile minimum ambient temperature.

5.3.6 See 5.4.4 and 5.5.2 for seasonal and geographical distributions.

5.4 *Regulatory and Other Requirements in the United States:*

5.4.1 Ethanol content requirements for ethanol alternative fuel blends can be found in 4.1.2.1.

TABLE 1 Requirements for Ethanol Fuel Blends[A]

Properties	Class 1[B]	Class 2	Class 3	Class 4	Test Methods
Vapor pressure, kPa (psi)	38–62 (5.5–9.0)	48–65 (7.0–9.5) All Classes[C]	59–83 (8.5–12.0)	66–103 (9.5–15.0)	D4953 or D5191
Ethanol Content, volume %		51–83			D5501
Water Content, max, mass %		1.0			E203, E1064, or D7923
Methanol Content, max, volume %		0.5			D5501
Sulfur Content, max, mg/kg		80			D5453 or D7039
Acidity, (as acetic acid CH3COOH), mass % (mg/L) [mg/kg], max		0.005 (40) [50]			D1613 or D7795
Solvent-washed gum content, max, mg/100 mL		5			D381
Unwashed gum content, max, mg/100 mL		20			D381
pH_e		6.5 to 9.0			D6423
Inorganic chloride content, max, mg/kg		1			D7319 or D7328
Copper content, max, mg/L		0.07			D1688

[A] For information on alternative fuels, see 4.1.2.1.
[B] See 5.3.1 for volatility class criteria.
[C] Ethanol content and selection of hydrocarbon blendstock are adjusted by the blender to meet vapor pressure requirements. See X1.3.2 for additional information and guidance for blending.

5.4.2 The denaturant for the denatured fuel ethanol used in making ethanol fuel blends shall meet the requirements of Section 5 in Specification D4806.

5.4.3 Ethanol fuel blends of any volatility class shall meet certain U.S. Environmental Protection Agency (EPA) regulations for unleaded gasoline. See Appendix X2.

5.4.4 The United States seasonal and geographical distribution for the four vapor pressure classes is shown in Table 3.

5.5 *Regulatory and Other Requirements Outside the United States:*

5.5.1 Users of this specification are advised to consult with the applicable regulatory agency for specific requirements for their jurisdictions.

5.5.2 Users of the specification in geographical areas outside the United States need to determine the 6-hour tenth percentile minimum ambient temperatures for their geographic areas and times of year in order to select the appropriate classes of fuel.

6. Workmanship

6.1 The finished fuel blend shall be visually free of sediment, suspended or undissolved matter. It shall be clear and bright at the fuel temperature at the point of custody transfer or at an alternative temperature agreed upon by the purchaser and seller.

NOTE 1—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 Specification D4814, Table X7.1 for guidance.

NOTE 2—Solubility is temperature dependent. As this fuel cools some high molecular weight additives can become insoluble.

6.2 The specification defines only a basic purity for ethanol fuel blends. The product shall be free of any adulterant or contaminant that can render the material unacceptable for its commonly used applications.

6.2.1 Manufacturers and blenders of ethanol fuel blends shall avoid ethanol (for example, improperly recycled ethanol), or denaturants and hydrocarbon blend components contaminated by silicon-containing materials, or both. Silicon contamination of gasoline, denatured ethanol, and their 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. Sampling, Containers, and Sample Handling

7.1 The reader is strongly advised to review all intended test methods prior to sampling to better understand the importance and effects of sampling technique, proper containers, and special handling required for each test method.

7.2 Correct sampling procedures are critical to obtain a sample representative of the lot intended to be tested. Use appropriate procedures in Practice D4057 for manual method sampling and in Practice D4177 for automatic sampling, as applicable.

7.3 The correct sample volume and appropriate container selection are important decisions that can impact test results. Refer to Practice D4306 for aviation fuel container selection for tests sensitive to trace contamination. Refer to Practice D5854 for procedures on container selection and sample mixing and handling. Where practical, ethanol fuel blends should be sampled in glass containers. If samples must be collected in metal containers, do not use soldered metal containers. The soldering flux in the containers and the lead in the solder can contaminate the sample. Plastic containers should be avoided.

7.4 A minimum sample size of about 1 L (1 U.S. qt) is recommended.

8. Test Methods

8.1 Determine the requirements enumerated in this specification in accordance with the test methods listed in Table 1. The scope of some of the test methods listed below does not include ethanol fuel blends. The precision of these test methods can differ from the reported precisions when testing ethanol fuel blends.

8.1.1 *Ethanol Content*—Test Method D5501.

8.1.2 *Vapor Pressure*—Test Method D4953 or D5191.

8.1.3 *Acidity*—Test Method D1613 or D7795.

8.1.3.1 Dissolved carbon dioxide is a known interference and can cause a false high reading when using Test Method D1613. In the absence of dissolved CO_2 Test Method D1613 is an acceptable method. If a sample is known to have dissolved CO_2 or if dissolved CO_2 can be present, Test Method D7795 is the preferred method. In cases of differing results between the two test methods, D7795 shall be the referee method.

8.1.4 pH_e —Test Method D6423.

8.1.5 *Gum Content, Solvent Washed and Unwashed*—Test Method D381.

8.1.6 *Inorganic Chloride Content*—Test Methods D7319 or D7328.

8.1.7 *Water Content*—Test Method E203, E1064, or D7923.

8.1.8 *Copper Content*—Modification of Test Method D1688.

8.1.8.1 The modifications of Test Method D1688, Test Method A (atomic absorption, direct) consists of mixing reagent-grade ethanol (which may be denatured in accordance with TTB Formula 3A or 30) in place of water as the solvent of diluent for the preparation of reagents and standard solutions. However, this shall not be done to prepare the stock copper solution described in the section on Copper Solution, Stock in Test Method D1688. Because a violent reaction can occur between the acid and the ethanol, use water, as specified, in the acid solution part of the procedure to prepare the stock copper solution. Use ethanol for the rinse and final dilution only.

8.1.9 *Sulfur Content*—Test Method D5453 or D7039.

8.1.10 *Methanol Content*—Test Method D5501.

9. Keywords

9.1 acidity; alcohol; automotive spark-ignition engine fuel; chloride; copper corrosion; E85; ether; ethanol fuel blends for flexible-fuel automotive spark-ignition engines; flexible-fuel; hydrocarbon; hydrocarbon blendstock; inorganic chloride; lead; MTBE; oxidation stability; oxygenates; pH_e; phosphorus;

TABLE 3 United States Seasonal and Geographical Volatility Specifications for Ethanol Fuel Blends

NOTE 1—This schedule, subject to agreement between the purchaser and the seller, denotes the vapor pressure class of the fuel at the time and place of bulk delivery to fuel-dispensing facilities for the end user. Shipments should anticipate this schedule.

NOTE 2—Where alternative classes are listed, either class is acceptable; the option shall be exercised by the seller.

NOTE 3—This schedule was developed using actual (versus altitude-adjusted) 6 h tenth percentile minimum ambient temperatures.

State	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Alabama	2	2	2	2	2/1	1	1	1	1	1/2	2	2
Alaska												
Southern Region	4	4/3	3	3/2	2	2/1	1	1/2	2/3	3	3/4	4
South Mainland	4	4	4	4	4/2	2	2/1	1/2	2/3	3/4	4	4
Arizona												
N of 34° Latitude	3	3	3	3/2	2	2/1	1	1	1/2	2/3	3	3
S of 34° Latitude	2	2	2	2/1	1	1	1	1	1	1/2	2	2
Arkansas	3	3	3/2	2/1	1	1	1	1	1/2	2	2/3	3
California[A]												
North Coast	2	2	2	2	2/1	1	1	1	1	1/2	2	2
South Coast	2	2	2	2	2/1	1	1	1	1	1/2	2	2
Southeast	2	2	2	2	2/1	1	1	1	1	1/2	2	2
Interior	2	2	2	2	2	2/1	1	1	1	1/2	2	2
Colorado												
E of 105° Longitude	4	4/3	3	3/2	2	2/1	1	1	1/2	2/3	3	3/4
W of 105° Longitude	4	4	4/3	3	3/2	2	2/1	1/2	2/3	3/4	4	4
Connecticut	4	4	4/3	3/2	2	2/1	1	1	1/2	2	2/4	4
Delaware	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
District of Columbia	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
Florida												
N of 29° Latitude	2	2	2	2/1	1	1	1	1	1	1/2	2	2
S of 29° Latitude	2	2/1	1	1	1	1	1	1	1	1	1/2	2
Georgia	3	3/2	2	2/1	1	1	1	1	1	1/2	2	2/3
Hawaii	1	1	1	1	1	1	1	1	1	1	1	1
Idaho	4	4	4/3	3/2	2	2	2/1	1/2	2	2/3	3/4	4
Illinois												
N of 40° Latitude	4	4	4/3	3/2	2	2/1	1	1	1/2	2/3	3/4	4
S of 40° Latitude	4	4/3	3	3/2	2/1	1	1	1	1/2	2/3	3/4	4
Indiana	4	4	4/3	3/2	2/1	1	1	1	1/2	2/3	3/4	4
Iowa	4	4	4	4/2	2	2/1	1	1	1/2	2/3	3/4	4
Kansas	4	4/3	3	3/2	2	2/1	1	1	1/2	2/3	3/4	4
Kentucky	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
Louisiana	2	2	2	2/1	1	1	1	1	1	1/2	2	2
Maine	4	4	4	4/2	2	2/1	1	1/2	2	2/3	3/4	4
Maryland	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
Massachusetts	4	4	4/3	3/2	2	2/1	1	1	1/2	2	2/4	4
Michigan												
Lower Michigan	4	4	4/3	3/2	2	2/1	1	1/2	2	2/3	3/4	4
Upper Michigan	4	4	4	4/3	3/2	2/1	1	1/2	2	2/3	3/4	4
Minnesota	4	4	4	4/3	3/2	2/1	1	1/2	2	2/4	4	4
Mississippi	2	2	2	2/1	1	1	1	1	1	1/2	2	2
Missouri	4	4/3	3	3/2	2/1	1	1	1	1/2	2/3	3	3
Montana	4	4	4	4/3	3/2	2	2/1	1/2	2/3	3/4	4	4
Nebraska	4	4	4/3	3/2	2	2/1	1	1/2	2	2/3	3/4	4
Nevada												
N of 38° Latitude	4	4	4/3	3/2	2	2	2/1	1/2	2	2/3	3/4	4
S of 38° Latitude	2	2	2	2/1	2/1	1	1	1	1	1/2	2	2
New Hampshire	4	4	4/3	3/2	2	2/1	1	1/2	2	2/3	3/4	4
New Jersey	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
New Mexico												
N of 34° Latitude	4	4/3	3	3/2	2	2/1	1	1	1/2	2/3	3	3/4
S of 34° Latitude	3	3	3/2	2/1	1	1	1	1	1	1/2	2/3	3
New York												
N of 42° Latitude	4	4	4	4/2	2	2/1	1	1/2	2	2/3	3/4	4
S of 42° Latitude	4	4	4/3	3/2	2/1	1	1	1	1/2	2	2/3	3/4
North Carolina	3	3	3/2	2	2/1	1	1	1	1/2	2/3	3	3
North Dakota	4	4	4	4/3	3/2	2/1	1	1/2	2	2/4	4	4
Ohio	4	4	4/3	3/2	2	2/1	1	1	1/2	2/3	3/4	4
Oklahoma	3	3	3	3/2	2/1	1	1	1	1/2	2	2/3	3
Oregon												
E of 122° Longitude	4	4/3	3	3/2	2	2	2/1	1/2	2	2/3	3	3/4
W of 122° Longitude	3	3/2	2	2	2	2/1	1	1	1/2	2	2	2/3
Pennsylvania												
N of 41° Latitude	4	4	4	4/2	2	2/1	1	1/2	2	2/3	3/4	4
S of 41° Latitude	3	3	3	3/2	2/1	1	1	1	1/2	2	2/3	3
Rhode Island	3	3	3	3/2	2/1	1	1	1	1/2	2	2/3	3
South Carolina	2	2	2	2/1	1	1	1	1	1	1/2	2	2
South Dakota	4	4	4	4/2	2	2/1	1	1/2	2	2/3	3/4	4

TABLE 3 *Continued*

State	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Tennessee	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
Texas												
N of 31° Latitude	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
S of 31° Latitude	2	2	2	2/1	1	1	1	1	1	1/2	2	2
Utah	4	4/3	3	3/2	2	2/1	1	1	1/2	2/3	3	3/4
Vermont	4	4	4/3	3/2	2	2/1	1	1/2	2	2/3	3/4	4
Virginia	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
Washington												
E of 122° Longitude	4	4/3	3	3/2	2	2	2/1	1	1/2	2/3	3	3/4
W of 122° Longitude	3	3/2	2	2	2	2/1	1	1	1/2	2	2	2/3
West Virginia	4	4/3	3	3/2	2	2/1	1	1/2	2	2/3	3	3/4
Wisconsin	4	4	4	4/2	2	2/1	1	1/2	2	2/3	3/4	4
Wyoming	4	4	4	4/3	3/2	2	2/1	1/2	2	2/4	4	4

[A] Details of State Climatological Division by county as indicated:

California, North Coast—Alameda, Contra Costa, Del Norte, Humbolt, Lake, Marin, Mendocino, Monterey, Napa, San Benito, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, Sonoma, Trinity

California, Interior—Lassen, Modoc, Plumas, Sierra, Siskiyou, Alpine, Amador, Butte, Calaveras, Colusa, El Dorado, Fresno, Glenn, Kern (except that portion lying east of Los Angeles County Aqueduct), Kings, Madera, Mariposa, Merced, Placer, Sacramento, San Joaquin, Shasta, Stanislaus, Sutter, Tehama, Tulare, Tuolumne, Yolo, Yuba, Nevada

California, South Coast—Orange, San Diego, San Luis Obispo, Santa Barbara, Ventura, Los Angeles (except that portion north of the San Gabriel Mountain range and east of the Los Angeles County Aqueduct)

California, Southeast—Imperial, Riverside, San Bernardino, Los Angeles (that portion north of the San Gabriel Mountain range and east of the Los Angeles County Aqueduct), Mono, Inyo, Kern (that portion lying east of the Los Angeles County Aqueduct)

solvent washed gum content; sulfur; vapor pressure; volatility; water

APPENDIXES

(Nonmandatory Information)

X1. SIGNIFICANCE OF SPECIFICATION FOR ETHANOL FUEL BLENDS FOR FLEXIBLE-FUEL AUTOMOTIVE SPARK-IGNITION ENGINES

X1.1 Ethanol

X1.1.1 The ethanol content of ethanol fuel blends is a critical parameter as it affects the capability of the fuel metering system of the flexible–fuel vehicle to establish the proper air/fuel ratio for optimum vehicle operation. Ethanol content can also affect the lubricating properties of the fuel, the water tolerance of the fuel, and the ability to meet cold and cool area volatility requirements.

X1.1.2 The inclusion of impurities, some denaturants, and contaminants, except for the deliberately added hydrocarbons or additives, or both, can impact adversely on the properties and performance of ethanol fuel blends as an automotive spark-ignition engine fuel. The quantities of some of these materials are controlled by specified property limits. The limits on water, methanol, and on types of denaturants, as well as minimums on the amount of ethanol and hydrocarbons limit, but do not prevent, the presence of trace materials.

X1.2 Hydrocarbon Blendstock

X1.2.1 Hydrocarbons are deliberately added to provide higher vapor pressure for improved cold startability and warm up driveability. The addition of hydrocarbon blendstock to fuel ethanol changes its volatility and can affect the flammability of fuel tank vapors.

X1.2.2 Hydrocarbon blendstock used in ethanol fuel blends will be unleaded gasoline, gasoline blendstock for oxygenate blending (BOB), natural gasoline or other hydrocarbons in the gasoline boiling range (Specification D4814). The hydrocarbon blendstock shall be stable and noncorrosive.

X1.2.3 The inclusion of impurities and contaminants, except for the deliberately added denatured fuel ethanol or additives, or both, can impact adversely on the properties and performance of ethanol fuel blends as an automotive spark-ignition engine fuel. The quantities of some of these materials are controlled by specified property limits. The limits on water, types of hydrocarbons as well as minimums on the amount of ethanol and hydrocarbons limit, but do not prevent, the presence of trace materials.

X1.3 Vapor Pressure

X1.3.1 The addition of volatile hydrocarbons is required for adequate cold startability. The addition of hydrocarbon blendstocks that are too volatile can contribute to hot fuel handling problems. Higher vapor pressures are required at colder ambient temperatures while lower volatility fuels are less prone to hot fuel handling problems at higher (summertime) ambient temperatures. Excessive vapor pressure contributes to evaporative emissions. Lower and upper limits on vapor pressure for

the four volatility classes are used to define the acceptable range of volatile components to ensure adequate vehicle performance.

X1.3.2 The following four charts can be used to estimate the vapor pressure of ethanol fuel composition. Figs. X1.1 and X1.2 are in SI units and Figs. X1.3 and X1.4 are in United States customary units. The charts enable blenders who know the vapor pressure of the gasoline component to estimate the correct proportion of gasoline and denatured fuel ethanol to achieve the vapor pressure required in this specification. These curves were developed using the predictive equations found in SAE paper 2007-01-4006.

X1.4 Acidity

X1.4.1 Very dilute aqueous solutions of organic acids, such as acetic acid, are highly corrosive to a wide range of metals and alloys. It is therefore necessary to keep such acids at a very low level.

X1.4.1.1 The acidity method is intended to determine the concentration of organic acids in ethanol. However, carbon dioxide is very soluble in ethanol, and in the presence of water it converts to carbonic acid. Test Method D1613 has an option to use either water or alcohol as solvent. Since ethanol is completely soluble in water, water is added to the sample and the mixture is titrated with aqueous sodium hydroxide solution. Dissolved CO_2, converted to carbonic acid will be titrated as an 'acid'. The presence of dissolved CO_2 will thus create a high bias in the acidity results. If there is sufficient dissolved CO_2, Test Method D1613 can incorrectly indicate that the sample is above the maximum allowed acidity in the specification. In the absence of any dissolved CO_2, Test Method D1613 is an acceptable method. If a sample is known to have dissolved CO_2 or if dissolved CO_2 is expected to be present, Test Method D7795 is the preferred test method. In cases of differing results between the two test methods, Test Method D7795 shall be the referee test method.

X1.5 pH_e

X1.5.1 When the pH_e of ethanol fuel blends used in automotive spark-ignition engines is below 6.5, fuel pumps can malfunction as a result of a film forming between the brushes and commutator, fuel injectors can fail from corrosive wear, and excessive engine cylinder wear can occur. When the pH_e is above 9.0, fuel pump plastic parts can fail.

X1.6 Gum Content, Solvent Washed and Unwashed

X1.6.1 The test for solvent washed gum content measures the amount of residue after the evaporation of the fuel and following a heptane wash. The heptane wash removes the heptane-soluble, nonvolatile material, such as additives, carrier oils used with the additives, and diesel fuel. Unwashed gum content consists of fuel-insoluble and fuel-soluble gum. The fuel-insoluble portion can clog fuel filters. Both can be deposited on surfaces when the fuel evaporates.

X1.6.2 Solvent washed gum can contribute to deposits on the surface of carburetors, fuel injectors, and intake manifolds, ports, valves, and valve guides. The impact of solvent washed gum on malfunctions of modern engines that can operate on ethanol fuel blends has not been fully established but is based on limited experience gained with high alcohol fuels in field tests and from historic gasoline limits. Performance effects depend on where the deposits form; the presence of other deposit precursors, such as airborne debris, blowby and exhaust gas recirculation gases; oxidized engine oil; and the amount of deposit.

X1.6.3 The difference between the unwashed and solvent washed and gum content values can be used to assess the presence and amount of nonvolatile material in the fuel. Additional analytical testing is required to determine if the material is additive, carrier oil, diesel fuel, and so forth.

X1.6.4 The unwashed gum content limit is intended to limit high-boiling contaminants, like diesel fuel, that can affect

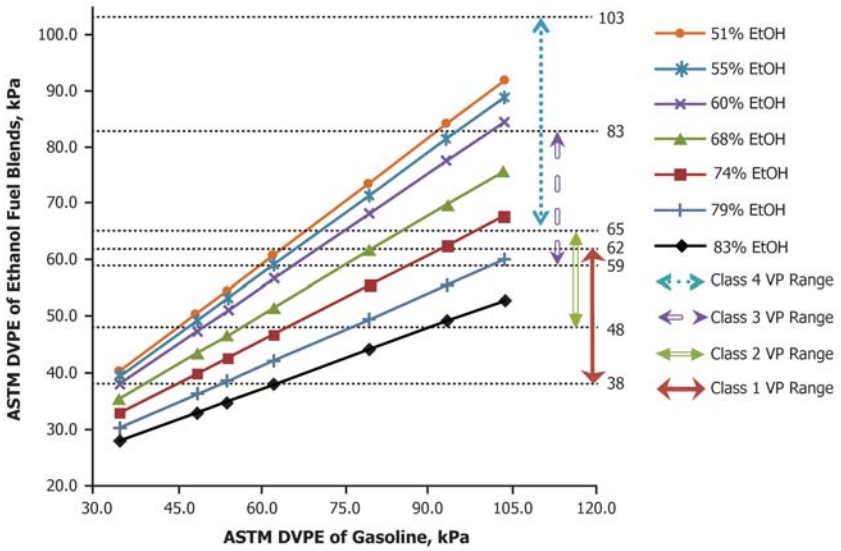

FIG. X1.1 Estimated Ethanol Fuel Blend Vapor Pressure as a Functions of Gasoline Vapor Pressure and Ethanol Content, kPa

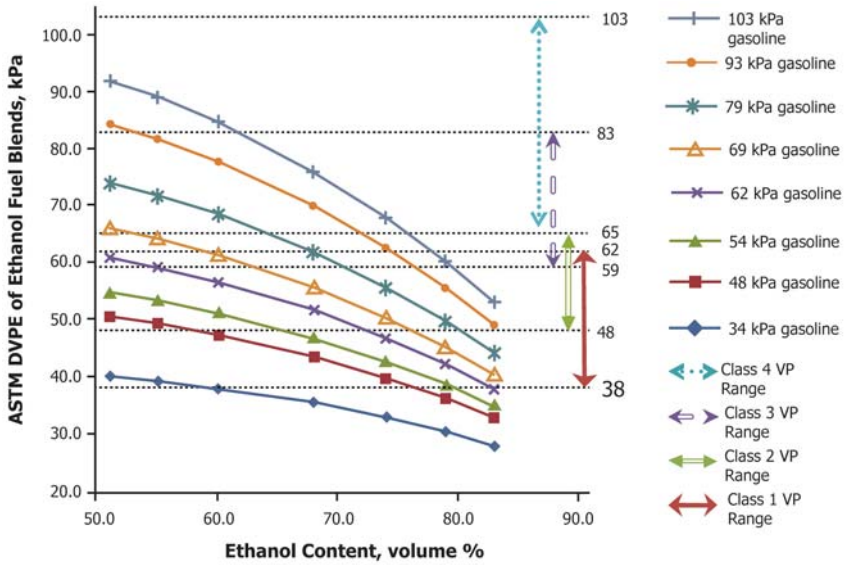

FIG. X1.2 Estimated Ethanol Fuel Blend Vapor Pressure as a Function of Ethanol Content and Gasoline Vapor Pressure, kPa

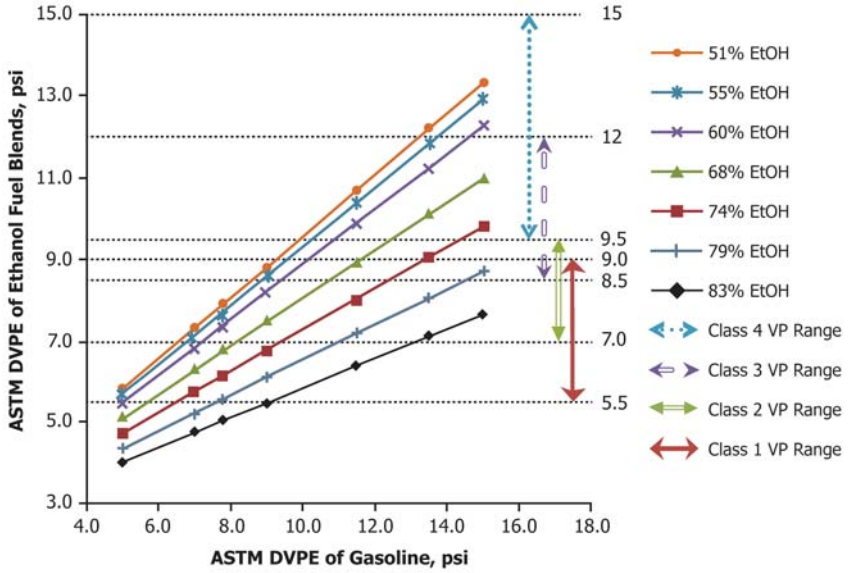

FIG. X1.3 Estimated Ethanol Fuel Vapor Pressure as a Function of Gasoline Vapor Pressure and Ethanol Content, psi

engine performance, yet allow the use of appropriate levels of deposit control additives with carrier oils in ethanol fuel blends.

X1.6.5 Because the precision statements for Test Method D381 were developed using only data on hydrocarbons, they may not be applicable to ethanol fuel blends.

X1.7 Inorganic Chloride

X1.7.1 Inorganic (ionic) chloride is corrosive to many metals, and it is desirable to minimize inorganic chloride compounds in ethanol fuel blends.

X1.7.2 An inorganic chloride limit of 1 mg/kg, maximum, has been found to be adequate in protecting fuel system components.

X1.8 Lead

X1.8.1 Most vehicles equipped to operate on ethanol fuel blends are equipped with exhaust catalysts that control emissions of aldehydes (formaldehyde and acetaldehyde) as well as regulated emissions. Lead compounds deactivate the catalyst and are therefore limited to trace amounts.

X1.9 Phosphorus

X1.9.1 Like lead, phosphorus deactivates exhaust catalysts and is limited to trace amounts.

X1.10 Appearance

X1.10.1 Turbidity, phase separation, or evidence of precipitation normally indicates contamination.

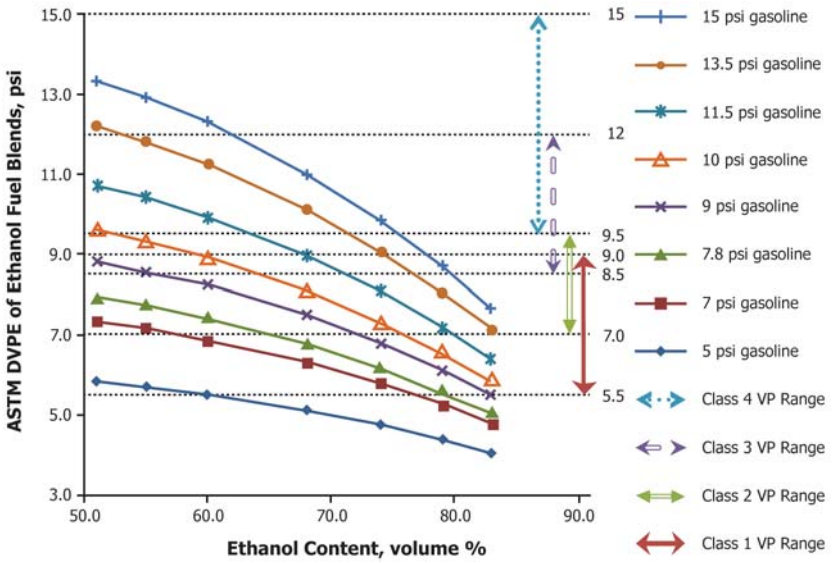

FIG. X1.4 Estimated Ethanol Fuel Vapor Pressure as a Function of Ethanol Content and Gasoline Vapor Pressure, psi

X1.10.2 Fuels and fuel components can encounter conditions in the bulk distribution system that could cause the material to fail a workmanship visual evaluation. Some fuels and components can commonly contain undissolved water or rust particles during distribution. Terminals can address these issues with proper operating procedures, for example, by allowing sufficient time for the water or particles to settle in the tank, by filtration, or by other means.

X1.11 Water

X1.11.1 The solubility of hydrocarbon in ethanol fuel blends and blends with gasoline as may occur in multifuel-capable vehicles decreases with lowering temperature and increasing water content. Separation of the hydrocarbon from the fuel will adversely affect cold starting and driveability and denaturing. Phase separation of this type indicates that the ethanol fuel blend is contaminated with water or other materials far in excess of what is allowed by this specification. Water may affect the calibration of some types of composition sensors of multifuel-capable vehicles. Water also reduces the energy content of the fuel and thus adversely affects fuel economy and power. Because some degree of water contamination is practically unavoidable in transport and handling, and because the ethanol fuel blends are miscible with water, the water content of ethanol fuel blends are limited to reduce the potential for problems.

X1.11.2 Test Method D7923 is intended for measuring water content of gasoline or other hydrocarbon blendstock, denatured fuel ethanol, and ethanol fuel blends. This test method is not applicable to samples that are phase separated.

X1.12 Copper

X1.12.1 Copper is a very active catalyst for low-temperature oxidation of hydrocarbons. Experimental work has shown that copper concentrations higher than 0.012 mg/kg in commercial gasolines can significantly increase the rate of gum formation.

X1.13 Sulfur

X1.13.1 The limit on sulfur content is included to protect against engine wear, deterioration of engine oil, corrosion of exhaust system parts, and exhaust catalyst deactivation.

X1.14 Methanol

X1.14.1 The limit on methanol content is included to protect against engine and fuel system wear, corrosion, and deterioration.

X2. SUMMARY OF U.S. EPA REGULATIONS APPLICABLE TO ETHANOL FUEL BLENDS FOR FLEXIBLE-FUEL AUTOMOTIVE SPARK-IGNITION ENGINES

X2.1 EPA Lead and Phosphorus Regulations

X2.1.1 *Unleaded Fuel*—The intentional addition of lead or phosphorus compounds to unleaded fuel is not permitted by the EPA. EPA regulations limit their maximum concentrations to 0.05 g lead/U.S. gal (0.013 g/L) and 0.005 g of phosphorus/U.S. gal (0.0013 g/L) (see Test Method D3231), respectively.

X2.1.2 *Leaded Fuel*—EPA regulations after December 31, 1995 prohibit the sale, supply, dispensing, transporting, or introducing into commerce a fuel for use in any motor vehicle which is produced with the use of lead additives or which contains more than 0.05 g lead/U.S. gal (0.013 g/L).

X2.1.2.1 The regulations define motor vehicle to include any self-propelled vehicle designed for transporting persons or property on a street or highway.

X2.1.2.2 The regulations do not prohibit the use of lead additives in fuel used in aircraft, racing cars, and nonroad engines, such as farm equipment engines and marine engines.

SUMMARY OF CHANGES

Subcommittee D02.A0 has identified the location of selected changes to this standard since the last issue (D5798 – 15) that may impact the use of this standard. (Approved July 1, 2017.)

(1) Added Test Method D7923 to Section 2, Referenced Documents.
(2) Revised Table 1 and subsection 8.1.7 to include reference to Test Method D7923.
(3) Added new subsection X1.11.2, describing Test Method D7923 as not applicable to samples that are phase separated.