



Designation: **D5798—13 D5798 – 13a**

Standard Specification for Ethanol Fuel Blends for Flexible-Fuel Automotive Spark- Ignition Engines¹

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 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 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. 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.*

2. Referenced Documents

2.1 ASTM Standards:²

D86 Test Method for Distillation of Petroleum Products 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, Petroleum Products, and Lubricants

D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products

D4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination

¹ This specification is under the jurisdiction of ASTM Committee **D02** on Petroleum Products 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

- 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)
- D5190 Test Method for Vapor Pressure of Petroleum Products (Automatic Method) (Withdrawn 2012)³
- 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 pH of Ethanol, Denatured Fuel Ethanol, and Fuel Ethanol (Ed75-Ed85)
- D7319 Test Method for Determination of Existent and Potential Sulfate and Inorganic Chloride in Fuel Ethanol 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
- 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*:⁴
- United States Code of Federal Regulations, Title 40, Part 80
- 2.3 *SAE Papers*:⁵
- 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 C₂H₅OH. **D4806**

3.2.4 *gasoline, n*—a volatile mixture of liquid hydrocarbons, generally containing small amounts of additives, suitable for use as a fuel in spark-ignition, internal combustion engines. **D4814**

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

3.2.6 *methanol, n*—methyl alcohol, the chemical compound CH₃OH.

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.

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.

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).

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)	59–83 (8.5–12.0)	66–103 (9.5–15.0)	D4953, D5190, or D5191
		All Classes ^C			
Ethanol Content, volume %		51–83			D5501
Water Content, max, mass %		1.0			E203 or E1064
Methanol Content, max, volume %		0.5			D5501
Sulfur Content, max, mg/kg		80			D5453
Acidity, (as acetic acid CH ₃ COOH), mass % (mg/L), max		0.005 (40)			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.

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, D5190, 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.

5.3.3 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-hour day will be colder than the 6-hour tenth percentile minimum ambient temperature.

5.3.6 See 5.4.4 and 5.5.2 for seasonal and geographical distributions.

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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.

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 Ethanol fuel blends shall be visually free of sediment and suspended matter. They shall be clear and bright at the ambient temperature or 21°C (70°F), whichever is higher.

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. ~~There Test Method D7757 is no ASTM approved test method a procedure for determining silicon compounds in gasoline, gasoline-oxygenate blends, denaturants, hydrocarbon blend components, or denatured fuel ethanol, although some laboratories are possibly using non-ASTM test methods, 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 US 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, D5190, 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 CO₂ Test Method D1613 is an acceptable method. If a sample is known to have dissolved CO₂ or if dissolved CO₂ 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 or E1064.

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

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-hour 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