



Designation: **D7794 – 18a D7794 – 20**

Standard Practice for Blending Mid-Level Ethanol Fuel Blends for Flexible-Fuel Vehicles with Automotive Spark-Ignition Engines¹

This standard is issued under the fixed designation D7794; 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.

1. Scope*

1.1 This practice applies to the blending of automotive spark-ignition engine fuels with ethanol concentrations greater than those suitable for conventional-fuel vehicles and less than the minimum ethanol content specification limits of Specification **D5798**. These mid-level ethanol fuel blends are for use in flexible-fuel vehicles and are sometimes referred to at retail as “Ethanol Flex Fuel.”

1.2 These mid-level ethanol fuel blends are only suitable for use in ground flexible-fuel vehicles equipped with spark-ignition engines. Flexible-fuel vehicles are designed to operate on gasoline or gasoline-ethanol blends that meet the requirements of Specification **D4814**, ethanol fuel blends that meet the requirements of Specification **D5798**, or any combination of these. In the United States, these vehicles are certified by the U.S. EPA as emissions compliant with these types of fuels.

1.3 The mid-level ethanol fuel blend shall be blended from either:

1.3.1 Denatured fuel ethanol conforming to the requirements of Specification **D4806** with a reduced limit on inorganic chloride content that will ensure no more than 1 mg/kg inorganic chloride in the finished fuel and from spark-ignition engine fuel conforming to Specification **D4814** (often at a distribution terminal or bulk plant), or

1.3.2 Ethanol fuel blends conforming to Specification **D5798** and from spark-ignition engine fuel conforming to Specification **D4814** (often at a retail site).

1.4 This practice describes the required procedures for blending various mid-level ethanol fuel blends for flexible-fuel vehicles at the bulk distribution point or retail/commercial delivery site. These requirements may be applied at other points in the production and distribution system when provided by agreement between the purchaser and the supplier.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *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.*

1.7 *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

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

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

D4815 Test Method for Determination of MTBE, ETBE, TAME, DIPE, tertiary-Amyl Alcohol and C₁ to C₄ Alcohols in Gasoline by Gas Chromatography

¹ This practice is under the jurisdiction of ASTM Committee **D02** on Petroleum Products, Liquid Fuels, and Lubricants and is 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

- D5191 Test Method for Vapor Pressure of Petroleum Products and Liquid Fuels (Mini Method)
 - D5501 Test Method for Determination of Ethanol and Methanol Content in Fuels Containing Greater than 20 % Ethanol by Gas Chromatography
 - D5599 Test Method for Determination of Oxygenates in Gasoline by Gas Chromatography and Oxygen Selective Flame Ionization Detection
 - D5798 Specification for Ethanol Fuel Blends for Flexible-Fuel Automotive Spark-Ignition Engines
 - D5842 Practice for Sampling and Handling of Fuels for Volatility Measurement
 - D5854 Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products
 - D6469 Guide for Microbial Contamination in Fuels and Fuel Systems
 - 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
 - D7794 Practice for Blending Mid-Level Ethanol Fuel Blends for Flexible-Fuel Vehicles with Automotive Spark-Ignition Engines
 - D7923 Test Method for Water in Ethanol and Hydrocarbon Blends by Karl Fischer Titration
- 2.2 *Other Standards:*³
- 16 CFR United States Code of Federal Regulations, Title 16, Part 306
 - 40 CFR United States Code of Federal Regulations, Title 40, Part 86

3. Terminology

3.1 For general terminology, refer to Terminology **D4175**.

3.2 *Definitions:*

3.2.1 *automotive fuel rating, n*—the automotive fuel rating required under the amended Octane Certification and Posting Rule (or as amended, the Fuel Rating Rule), 16 CFR, Part 306.

3.2.1.1 *Discussion*—

Under this Rule, sellers of liquid automotive fuels, including alternative fuels, must determine, certify, and post an appropriate automotive fuel rating. The automotive fuel rating for gasoline is the antiknock index (octane rating). The automotive fuel rating for alternative liquid fuels consists of the common name of the fuel along with a disclosure of the amount, expressed as a minimum percentage by volume, of the principal component of the fuel. For alternative liquid automotive fuels, a disclosure of other components, expressed as a minimum percentage by volume, may be included, if desired. This is applicable in the United States.

3.2.2 *conventional-fuel vehicle, n*—a vehicle designed to operate on spark-ignition engine fuel that complies with Specification **D4814**.

3.2.3 *denatured fuel ethanol, n*—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.

3.2.4 *ethanol, n*—ethyl alcohol, the chemical compound $\text{CH}_3\text{CH}_2\text{OH}$.

3.2.5 *ethanol fuel blend, n*—a high concentration ethanol-based fuel for flexible-fuel spark-ignition engines and vehicles; an automotive spark-ignition engine fuel composed of hydrocarbon and ethanol blendstocks for flexible-fuel vehicles with ethanol concentrations greater than those used for conventional-fuel vehicles.

3.2.5.1 *Discussion*—

Ethanol fuel blends are often referred to as Ethanol Flex Fuel or EXX, where XX represents the nominal percentage by volume of denatured fuel ethanol in the finished fuel.

3.2.6 *flexible-fuel vehicle, n*—a vehicle designed to operate on both gasoline and ethanol fuel blends and can operate on any mixture of both.

3.2.6.1 *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 Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, <http://dodssp.daps.dla.mil>.

3.2.6.2 Discussion—

Flex-fuel vehicle and FFV are commonly used synonyms for flexible-fuel vehicle.

3.2.6.3 Discussion—

The fuels may also contain anti-oxidants, corrosion inhibitors, metal deactivators, and dyes but do not contain lead additives. A jurisdiction may set limits on lead content from all sources **D5798**

3.2.7 *fuel blending dispenser, n*—a device for measuring and dispensing fuel, conforming to the standards established by the applicable regulatory jurisdictions, that can volumetrically combine two different base products into newly formed blended products that may be dispensed through a single hose or multiple hose dispenser configuration.

3.2.8 *fuel ethanol, n*—a grade of ethanol with other components common to its production (including water) that do not affect the use of the product as a component for automotive spark-ignition engine fuels. **D4806**

3.2.8.1 Discussion—

The common components do not include denaturant.

3.2.9 *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**

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

~~3.2.11 *mid-level ethanol fuel blend, n*—an automotive spark-ignition engine fuel with an ethanol concentration greater than those suitable for conventional-fuel vehicles and less than the minimum ethanol content limit of Specification **D5798**.~~

~~3.2.11.1 Discussion—~~

~~Mid-level ethanol fuel blends are often referred to as EXX, where XX represents the nominal percentage of denatured fuel ethanol.~~

3.3 Definitions of Terms Specific to This Standard:

3.3.1 *mid-level ethanol fuel blend, n*—an automotive spark-ignition engine fuel made by blending a **D4814** fuel and a **D5798** fuel according to Practice **D7794**.

3.3.1.1 Discussion—

Ethanol fuel blends are often referred to as Ethanol Flex Fuel or EXX, where XX represents the nominal percentage by volume of ethanol in the finished fuel.

4. Summary of Practice

4.1 This practice provides procedures for blending automotive spark-ignition engine fuels with ethanol concentrations greater than those suitable for conventional-fuel vehicles and less than the minimum ethanol content limit of Specification **D5798**. It addresses in detail the various factors which need to be considered when blending. These considerations include selection of fuel components for blending and general handling information.

5. General Requirements

5.1 The fuel blending components specified in this practice shall meet the performance requirements of Specifications **D4814**, and either **D5798** or **D4806** and all applicable regulatory fuel requirements.

5.2 The blending party, being responsible for the finished product, shall be provided, at the time of delivery of the fuel, on product transfer documents, an invoice, bill of lading, shipping paper, or other documentation, a declaration of the product type and grade of the fuels that are the intended fuel blending components. It is recommended that the blending party conduct testing and inspections to determine applicable properties that are necessary to ensure the blending of compliant mid-level ethanol fuel blends.

5.3 Product transfer documents alone may not be sufficient to demonstrate conformance. A Certificate of Analysis representative of the fuel being delivered is recommended to ensure compliance.

5.4 The fuel blender or testing analyst, or both, is warned that some requirements and test methods applicable to automotive spark-ignition engine fuels depend on whether the fuel is a gasoline, a gasoline-ethanol blend, or ethanol fuel blend. Once the

amount of ethanol is known for the gasoline or gasoline-ethanol blend component and for the Specification **D5798** ethanol fuel blend or Specification **D4806** fuel ethanol component, the appropriate blending ratios can be determined for the blending of the two components.

5.4.1 Test Method **D5501** shall be used for determination of the volume percent ethanol for the fuel ethanol component (that is, high concentration ethanol) and to verify the mid-level blend fuel, and Test Methods **D4815** or **D5599** shall be used for the gasoline or gasoline-ethanol blend component (that is, low concentration ethanol).

5.5 In order to ensure the presence of no more than 1 mg/kg inorganic chloride in the finished fuel or in Specification **D5798**, the ethanol component specified herein shall meet all the requirements of Specification **D4806** with a more restrictive inorganic chloride limit as determined in Test Methods **D7319** and **D7328**. The hydrocarbon blending component specified herein shall meet all the requirements of Specification **D4814**.

5.6 Mid-level ethanol fuel blends shall be visually free of water, sediment, and suspended matter. It shall be clear and bright at the point and condition of custody transfer and display no indication of phase separation.

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

6. Blending Procedures

6.1 This practice includes procedures for blending mid-level ethanol fuel blends at the bulk distribution terminal and at retail using a fuel blending dispenser.

6.2 A fuel blending plan shall be developed describing the necessary actions needed to achieve the targeted mid-level ethanol fuel blends and performance expectations of flexible-fuel vehicles.

6.2.1 Blending plans utilizing new equipment installation or conversion of existing equipment depend on thorough preparation and planning for the entire fuel system.

6.2.2 The investigation and design of the wetted fuel system starts with a review of the flow of the fuel from receipt through retail delivery ensuring materials compatibility with the blending components and the blended mid-level ethanol fuel blends.

6.2.3 Fuel storage and blending systems shall be approved by the jurisdictions in charge of storage tanks, fuel dispensers, and associated equipment.

6.2.4 If a single hose blending dispenser is used, the entire dispenser shall be dedicated to serving flexible-fuel vehicles. If a multiple hose dispenser configuration is used, one hose may be dedicated to E0 or E10 fuel, and one or more additional hoses may be dedicated to mid-level ethanol fuel blends.

6.2.5 Documentation of the findings and changes made during the system review may prove beneficial for the fuel blender's future reference.

6.2.6 The plan should include a strategy for handling the variability in ethanol and gasoline content in fuels being delivered and shall take into consideration the design and operational abilities of the blending meters that will be used.

6.2.7 This review should apply to the initial handling point at the terminal, through the distribution and transport system, and ultimately to the end point—the retail point of sale.

6.3 Determination of Blending Component Properties:

6.3.1 It is the responsibility of the suppliers of fuels that will be used for blending mid-level ethanol fuel blends to provide the blending parties with product transfer documents that contain, at a minimum, the information required by all applicable regulatory agencies. In the United States, this includes, among other items, a product description and the applicable Automotive Fuel Rating. The fuel supplier is responsible for ensuring that the product transfer documents are a true and accurate representation of the materials being supplied. Because product transfer documents are not always required to contain all information necessary for the blending party to accurately determine compliance with the final blend, the blending party must be prepared to either obtain a Certificate of Analysis from the fuel supplier(s), arrange for specific purchase specifications with their supplier(s), or have a sample of each component tested periodically to determine the ethanol content using Test Methods **D4815** or **D5599** for gasoline or gasoline-ethanol blends, and Test Method **D5501** for Specification **D5798** ethanol fuel blend, the resulting mid-level ethanol fuel blend, or for Specification **D4806** denatured fuel ethanol. For Specification **D4806** denatured fuel ethanol, the blending party shall also determine that the inorganic chloride content does not exceed a level that would result in finished mid-level ethanol fuel blend that would have more than the specified 1 mg/kg maximum of Specification **D5798**.

6.3.2 The blending party should be aware that the spark-ignition engine fuel (Specification **D4814**) used may contain ethanol up to the maximum concentrations permitted by fuel specifications and regulations, and that this content may change over time. Likewise, ethanol fuel blends (Specification **D5798**) may change in ethanol content depending upon the month and location of the intended sale of the ethanol fuel. These changes must be taken into account when preparing blending formulas for mid-level ethanol fuel blends.

6.3.3 The blending party shall also be aware that denatured fuel ethanol for fuel blending (Specification **D4806**) contains from 1.96% to 5.0% by volume %-hydrocarbons as denaturant (most often 2.0% to 2.5% by volume %-denaturant). This hydrocarbon content must also be taken into account when preparing blending formulas for mid-level ethanol fuel blends.

6.4 Blending Formula:

6.4.1 The formula used for blending mid-level ethanol fuel blends is based on the lever arm rule for binary components used to make a blend. To make such a blend, gasoline or gasoline-ethanol blend (Specification **D4814**) will be used to provide the hydrocarbon portion, and either ethanol fuel blend (Specification **D5798**) or denatured fuel ethanol (Specification **D4806**) will provide the ethanol portion. Blending calculations shall be based on “gross” gallons; (not temperature compensated net gallons).

6.4.2 The formula is:

$$FG = \frac{(FEE - FEML)}{(FEE - FEG)} \quad (1)$$

where:

FG = fraction of gasoline to be used to make the mid-level ethanol fuel blend,

$(1 - FG)$ = fraction of the ethanol fuel or denatured fuel ethanol to be used to make the mid-level ethanol fuel blend,

FEE = fraction of ethanol in either the ethanol fuel blend (Specification **D5798**) or denatured fuel ethanol (Specification **D4806**),

$FEML$ = the desired fraction of ethanol in the targeted mid-level ethanol fuel blend, and

FEG = the fraction of ethanol in the gasoline.

6.4.3 *Example 1, Bulk Distribution Terminal Blending*—The following example is used to make mid-level ethanol fuel blends at a terminal or bulk plant.

6.4.4 Assume that an E30 mid-level ethanol fuel blend is desired to be made from straight gasoline and denatured fuel ethanol at the terminal, thus $FEML = 0.30$.

6.4.5 The gasoline in terminal storage has no ethanol content, thus FEG in **Eq 1** is 0.0.

6.4.6 The ethanol content in the denatured fuel ethanol at the terminal is determined to be ~~97.5 volume %~~, 97.5 % by volume, or $FEE = 0.975$.

6.4.7 For this example, we use **Eq 1**.

$$FG = \frac{(0.975 - 0.30)}{(0.975 - 0.0)} = 0.692$$

6.4.7.1 Thus the fraction of gasoline for this blend is 0.692 or ~~69.2 volume %~~, 69.2 % by volume. And the fraction of denatured fuel ethanol is $1 - 0.692 = 0.308$ or ~~30.8 volume %~~, 30.8 % by volume.

6.4.8 *Example 2, Retail Station Blending*—The following example is used to make mid-level ethanol fuel blends at retail stations using fuel blending dispensers. Analysis of the ethanol content of the gasoline and the ethanol fuel blends is known from the supplier.

6.4.9 Assume that an E30 mid-level ethanol fuel blend is desired to be made from gasoline with ~~10-10 % by volume %~~ denatured fuel ethanol (E10) and ethanol fuel blend at the retail site, thus $FEML = 0.30$.

6.4.10 The (E10) gasoline in the retail tank storage has ~~9.7-9.7 % by volume %~~ ethanol content as reported by the fuel supplier, thus FEG in **Eq 1** is 0.097.

6.4.11 The ethanol fuel blend at the site is reported by the supplier to contain ~~72.5-72.5 % by volume %~~ ethanol, so the ethanol content in the denatured ethanol $FEE = 0.725$.

6.4.12 For this example, again we use **Eq 1**.

$$FG = \frac{(0.725 - 0.30)}{(0.725 - 0.097)} = 0.677$$

6.4.12.1 Thus the fraction of gasoline for this blend is 0.677 or ~~67.7 volume %~~, 67.7 % by volume. And the fraction of ethanol fuel is $1 - 0.677 = 0.323$ or ~~32.3 volume %~~, 32.3 % by volume.

6.4.13 *Example 3, Retail Station Blending*—The following example is used to make mid-level ethanol fuel blends at retail stations using blending dispensers. In this case we have a bill of lading from the terminal listing the denatured fuel ethanol contents in the ethanol fuel blend and the gasoline.

6.4.14 Assume that an E50 mid-level ethanol fuel blend is desired to be made from gasoline with ~~10-10 % by volume %~~ denatured fuel ethanol (E10) and ethanol fuel blend at the retail site, thus $FEML = 0.50$.

6.4.15 The E10 gasoline from the terminal has ~~9.5-9.5 % by volume %~~ ethanol content assuming that the denatured fuel ethanol blend had ~~5.0-5.0 % by volume %~~ denaturant (see **6.3.3**); thus $FEG = 0.095$.

6.4.16 The ethanol fuel blend is reported from the supplier to be made from ~~70-70 % by volume %~~ denatured fuel ethanol and ~~30-30 % by volume %~~ gasoline. Since denatured fuel ethanol contains hydrocarbon denaturant, we must account for this hydrocarbon to get the true ethanol content in the ethanol fuel. The denatured fuel ethanol contains about ~~95%95 %~~ pure ethanol (see **6.3.3**). Thus the ethanol content in the ethanol fuel is 0.095 (~~70 volume %~~) = ~~66.5 volume %~~, (70 % by volume) = 66.5 % by volume, thus $FEE = 0.665$.

6.4.17 For this example, again we use **Eq 1**.