

FUEL ETHANOL INDUSTRY GUIDELINES, SPECIFICATIONS and PROCEDURES



July 2018

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The Renewable Fuels Association (RFA) is the leading national trade association for the U.S. ethanol industry. Founded in 1981, our mission is to advance the development, production, and use of fuel ethanol by strengthening America's ethanol industry and raising awareness about the benefits of renewable fuels. RFA's primary objective is to promote public policy initiatives that increase the market for renewable ethanol produced from a variety of feedstocks including grains, agricultural wastes, and various biomass feedstock sources. RFA's 300-plus members are working to help America become cleaner, safer, energy independent and economically secure.

The RFA promotes the use of ethanol for fuel in all its legal applications. Denatured Fuel Ethanol (DFE) is currently blended in nearly all the nation's gasoline as E10 (90% gasoline/10% ethanol) with a growing market for E15 (85% gasoline/15% ethanol). Another growing U.S. market for higher levels of ethanol in gasoline blended fuels for use in flexible fuel vehicles (FFV's); Flex Fuels, also known as E85 (51% - 83% ethanol) and mid-level ethanol fuel blends (16% - 50% ethanol). Exports are also growing.

This document focuses on the product quality and integrity of U.S. market DFE for the E10 and E15 gasoline and ethanol/gasoline blends for FFV's with information discussing product specifications and their importance. With a growing export market, we have added a discussion section. Other related issues such as material compatibility, transportation and handling information are discussed as well.

This manual is provided to assist you with the technical information regarding DFE and other ethanol/gasoline blended fuels. Its purpose is to serve as a reference manual providing basic information on ethanol.

All RFA technical publications, other RFA reference materials and staff contact information are available at: www.ethanolrfa.org

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Introduction: Fuel Ethanol as a Blending Component with Gasoline for Spark Ignition Engines

Ethanol addition to commercial gasoline was first allowed by EPA under the “Gasohol Waiver” that became effective on December 16, 1978. That waiver permitted up to 10 % by volume ethyl alcohol (ethanol). Ethanol for use as a transportation fuel has been steadily growing since the 1980’s. The U.S. industry produced 200 million gallons annually in 1981 and has continued steady growth to a record breaking year in 2017 of 15.8 billion gallons. As production grew, ethanol was added to gasoline supplies to replace the octane enhancer’s lead, benzene, toluene, and xylene as they were being removed from the gasoline supply due to toxicity concerns. Ethanol has a blending octane of 113 and is widely used in creating regular octane gasoline from sub-octane base stocks or raising regular octane fuels to the mid-octane level. This addition of ethanol to gasoline to boost octane is an alternative to more severe refining operations making ethanol one of the most cost-effective octane enhancers available to the refiner and blender today.

The Clean Air Act (CAA) in the 1990’s further increased the market share for ethanol blended fuel due to



mandated usage of oxygenated fuels in reformulated gasoline (RFG) in certain areas of the United States. RFG originally required to contain a minimum of 2.0 % by weight oxygen. RFG refers to extensive changes in gasoline properties in ozone non-attainment areas to help reduce carbon monoxide emissions, volatile organic compounds (VOCs), and Oxides of Nitrogen (NOx), which are ozone precursors. The program is also designed to reduce toxic emissions of benzene, 1,3 butadiene, formaldehyde, acetaldehydes, and polycyclic organic matter which pose high cancer risk.

The Energy Policy Act signed into law in August 2005 eliminated the RFG oxygenate

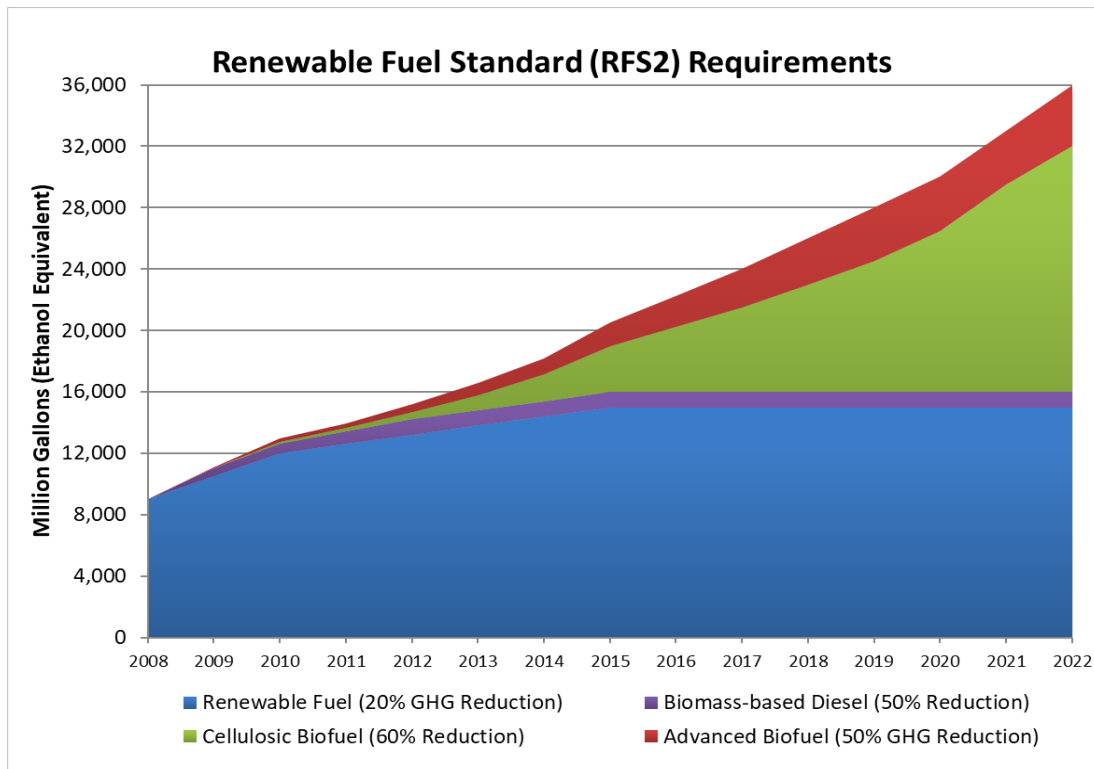
content requirement for fuels and added the Renewable Fuels Standard (RFS) into the energy bill legislation.

Ethanol is the oxygenate most widely used in reformulated gasoline. This is in part due to the use of the other oxygenate MTBE being banned in 25 states and in 2006 the petroleum industry switched to ethanol in their RFG due to concerns about ground water contamination from MTBE.

The RFS was expanded in the Energy Independence and Security Act of 2007 requiring the annual usage of 36 billion gallons of renewable transportation fuels by 2022, such as ethanol of which 15 billion

gallons can be made from corn. The RFS set forth a phase in for renewable fuels volumes and categories beginning with 9 billion gallons in 2008 and ending with 36 billion gallons by 2022.

Year	Conventional Renewable Biofuel	Advanced Biofuel	Cellulosic Biofuel	Biomass Diesel	Undifferentiated Advanced Biofuel	Total RFS
2008	9.0					9.0
2009	10.5	0.6		0.5	0.1	11.1
2010	12.0	0.95	0.1	0.65	0.2	12.95
2011	12.6	1.35	0.25	0.8	0.3	13.95
2012	13.2	2.0	0.5	1.0	0.5	15.2
2013	13.8	2.75	1.0		1.75	16.55
2014	14.4	3.75	1.75		2.0	18.15
2015	15	5.5	3.0		2.5	20.5
2016	15	7.25	4.25		3.0	22.25
2017	15	9.0	5.5		3.5	24.0
2018	15	11.0	7.0		4.0	26.0
2019	15	13.0	8.5		4.5	28.0
2020	15	15.0	10.5		4.5	30.0
2021	15	18.0	13.5		4.5	33.0
2022	15	21.0	16.0		5.0	36.0



The RFS categories of renewable fuels are:

Conventional Biofuels are ethanol produced from corn, and other grains and can include biodiesel from plant oils, although the majority is conventional corn ethanol.

Advanced biofuels are transportation fuels including ethanol and other renewable fuels that are derived from a variety of feedstocks. Advanced biofuels must achieve a 50% reduction in Greenhouse Gases (GHG) compared to gasoline.

Cellulosic biofuels are transportation fuels, including ethanol, that are derived from cellulosic feedstocks such as grasses, trees, agricultural waste and other feedstocks that contain cellulose. Cellulosic biofuels must achieve a 60% GHG reduction.

In 2011 EPA issued a partial waiver to allow the use of up to 15 % ethanol in gasoline for autos model year 2001 and newer, subject to certain conditions described later in this document. EPA denied the waiver for E15 use in all heavy-duty gasoline engines and vehicles, motorcycles, and nonroad engine vehicles and equipment (e.g., boats, snowmobiles, and lawnmowers). The approval of E15 came with numerous regulatory requirements that are not performed for E10. See section on E15 in this document.

In 2014 EPA issued a rule Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards. The Tier 3 program is part of a comprehensive approach to reducing the impacts of motor vehicles on air quality and public health. The program considers the vehicle and its fuel as an integrated system, setting new vehicle emissions standards and a new sulfur standard in fuels of 10 parts per million (ppm) of sulfur by January 1, 2017.

Tier 3 also changed the federal emissions standard test fuel to a test fuel containing 10 % by volume ethanol to better match today's in-use gasoline and to be forward-looking with respect to future ethanol content. The new test fuel specifications apply to new vehicle certification, assembly line, and in-use testing. EPA is also setting test fuel specifications for Flex Fuel (E85) for the first time.

The industry is still evolving and we continue to grow ethanol in the fuel supply. From a vehicle use standpoint, ethanol's 35 % oxygen content per molecule results in more efficient engine system operations with an added benefit of fewer emissions. With its high-octane ratings pure ethanol added to gasoline as an enabler allows extreme cylinder pressures and temperatures, making small engines run cleaner and behave more like larger engines, producing more horsepower and torque. In addition, cooler-running ethanol, when combined with direct-injection and EGR, results in greater horsepower per liter and increased mpg.

In the long term, ethanol's unique properties make it an attractive component of the "fuel of the future" needed for fuel economy and Green House Gas (GHG) compliance for tomorrows automobiles.

American Society for Testing and Materials International <https://www.astm.org/>

There are many entities involved with regulating liquid transportation fuels including Federal agencies like the U.S. EPA and State Regulatory agencies such as the Divisions of Weights and Measures. These organizations are ensuring protection of the environment as well as protection of the consumer. Most of these regulating agencies and the customer will require, at a minimum, that the quality of the products meet ASTM specifications.



The American Society for Testing and Materials International (ASTM) maintains the approved written analytical standard specifications and procedures for assuring that denatured fuel ethanol meets the performance requirements for today's marketplace. Numerous performance quality parameters related to using ethanol as a transportation fuel are important to both engine manufacturers and consumers. The ASTM International Committee D02 on Petroleum Products and Lubricants has 2500 members and over 800 published standards. Each main committee in ASTM International is composed of subcommittees that address specific segments within the general subject area covered by the technical committee. For instance, ethanol and methanol test methods are addressed by the D02.04.OL subcommittee on Gas Chromatography methods. Water and acidity test methods are covered by the D02.06 subcommittee called Analysis of Liquid Fuels and Lubricants. The denatured fuel ethanol and ethanol fuel blends specifications are under Subcommittee D02.A0 on Gasoline and Oxygenated Fuels.

ASTM is not a closed group; the standards are established by consensus with experienced input and cooperation from interested parties in a balanced format. The group responsible for setting and maintaining the standard specifications governing the quality of ethanol is made up of interested parties representing the auto manufacturers, gasoline refiners, ethanol producers, laboratory personnel, government agencies and consumers. ASTM's work is never over; there are periodic reviews of existing standards as well as issues that arise that cause the need to change the standards.

Throughout this document when ASTM standards are mentioned the link to purchase is included. There is also available an online compilation of *ASTM Standards for Denatured Fuel Ethanol and Ethanol Flex Fuels* <https://www.astm.org/BOOKSTORE/COMPS/ETHANOLCMP.htm> with 38 ASTM standards addressing test methods, practices, terminology, and specifications of ethanol. This compilation combines standards from D4806 and its reference documents D4814 and D5798.

Specifications – Denatured Fuel Ethanol (DFE)

Regardless of the blend level, the quality of the ethanol added to gasoline is important. While other standards are available, the most widely accepted industry standard for ethanol for fuel use is *ASTM D4806 Standard Specification for Denatured Fuel Ethanol for Blending with Gasolines for Use as Automotive Spark Ignition Engine Fuel*. The primary quality performance specifications in current version ASTM D4806 are as follows:

**ASTM D4806 Standard Specification for Denatured Fuel Ethanol for
Blending with Gasolines for Use as Automotive Spark Ignition Engine Fuel**

Quality Parameter	Limits	ASTM Test Methods
Ethanol, % by volume, min	92.1	D5501
Methanol, % by volume, max	0.5	D5501
Solvent washed gum, mg/100mL, max	5.0	D381
Water content, % by volume, (% by mass), max	1.0 (1.26)	D7923, E1064 or E203
Inorganic Chloride, mg/kg (mg/L), max	6.7 (5)	D7319 or D7328
Copper, mg/kg, max	0.1	D1688
Acidity, as acetic acid, mg/kg, (% by mass) [mg/L], max	70 (0.0070) [56]	D7795
pHe	6.5 – 9.0	D6423
Sulfur, mg/kg, max	30. **	D5453
Existent Sulfate, mg/kg, max	4	D7318, D7319 or D7328

**** EPA Tier 3 Regulations** reduced this parameter to 10. mg/kg, maximum. There are numerous details to Tier 3 regulatory compliance requirements for denatured fuel ethanol producers and importers. Those details, which also include denaturant approval compliance requirements are found in a separate document “**Tier 3 Motor Vehicle Fuel Standards for Denatured Fuel Ethanol**” found here: http://www.ethanolrfa.org/wp-content/uploads/2018/07/Tier-3-Motor-Vehicle-Fuel-Standards-for-Denatured-Fuel-Ethanol_v2refresh.pdf

A workmanship clause is also part of the specification. The DFE shall be visually free of sediment, suspended or undissolved matter. It shall be clear and bright at the ambient temperature of custody transfer or at a lower temperature agreed upon by purchaser and seller. The product shall be free of any adulterant or contaminant that may render the material



unacceptable for its commonly used applications. Additionally, manufacturers, importers, and others denaturing fuel ethanol shall avoid ethanol (for example, improperly recycled ethanol) or denaturants contaminated by silicon-containing materials. The RFA recommends avoiding silicon-based anti-foaming agents during the ethanol production process. There are many commercially available anti-foaming agents that do not include silicon.

Although D4806 does not indicate the testing frequency for each parameter, buyers often note the testing frequency in their purchase specifications. It's common for buyers to expect ethanol, methanol, water, pH, acidity, inorganic chloride and existent sulfate to be conducted on a per-batch basis. Solvent-washed gum and copper are often allowed to be conducted by a third-party lab on a quarterly oversight basis. Please note there are special sulfur testing requirements for EPA Tier 3 Gasoline Sulfur Regulations.

There are numerous details to this specification, for more complete information refer to the most current ASTM D4806 standard specification. <https://www.astm.org/Standards/D4806.htm>



California Air Resources Board (CARB) per the California Code of Regulations, Title 13 Motor Vehicles, Division 3 Air Resources Board, Chapter 5, Standards for Motor Vehicle Fuels, Article 1, Standards for Gasoline, Sub Article 2 Standards for Gasoline, 2262.9 *Requirements Regarding Denatured Ethanol Intended for Use as a Blending Component in California Gasoline* has additional performance requirements for ASTM D4806 denatured fuel ethanol usage in their state requiring the 10 mg/kg maximum sulfur limit and limits related to the hydrocarbon denaturant used.

California Denatured Fuel Ethanol Specifications

(In addition to the performance requirements in ASTM D4806)

Quality Parameter	Limits	ASTM Test Methods
Sulfur, mg/kg, max	10	D5453
Benzene, % by volume, max	0.06	D7576
Aromatics, % by volume, max	1.7	D7576
Olefins, % by volume, max	0.5	D7347

Refer to the section **California Denaturant Standard** on page 10 for limits on the denaturant used and additional information.

Direct analysis can be performed on the denatured fuel ethanol. Another practice for determining sulfur, benzene, olefins, and aromatics content is by calculation based on the results from the denaturant Certificate of Analysis received from the supplier and the denaturant percent by volume used in the batch. For instance, if benzene results on the denaturant Certificate of Analysis are 0.5 % by volume and the ethanol batch is denatured at 2.49 % by volume, the COA for the DFE batch would show benzene results = 0.01 %

The RFA recommends that all member companies adhere to ASTM and CARB specifications and guidelines. In addition, the RFA recommends adhering to the additional standards and practices cited below:

Corrosion Protection

RFA recommends fuel ethanol producers and importers add corrosion inhibitor to fuel ethanol. It is dosed at a treat rate that provides customers with the assurance that all gasoline's blended downstream with our denatured fuel ethanol will provide a sufficient level of corrosion protection to the consumer's automotive fuel system. This addition of corrosion inhibitor also provides protection throughout the storage life of denatured fuel ethanol and blends, such as storage tanks, piping, pumps, and dispensers.

RFA developed a document "**Evaluation Protocol for Corrosion Inhibitors for Fuel Ethanol**" for ethanol manufacturers to determine the appropriate level of corrosion protection available here:

http://www.ethanolrfa.org/wp-content/uploads/2015/11/RFA-Evaluation-Protocol-for-Corrosion-Inhibitors-for-Fuel-Ethanol_V073010a.pdf

It is recommended that these tests be considered by each manufacturing location to confirm the effectiveness of the candidate fuel corrosion additive.

Filtration

The product delivery system dispensing denatured ethanol from plant storage tanks should be equipped with a final filter sized no larger than a maximum of 10-micron nominal to control any suspended particulates or precipitates.

Denaturant and Denaturant Content

Ethanol and its usages are regulated by the Alcohol and Tobacco Tax and Trade Bureau of the U.S. Treasury Department (TTB). Since non-denatured ethanol can be consumed as a beverage, a suitable denaturant must be added to render the product unfit for beverage use. The formula designed for fuel use is Completely Denatured Alcohol (CDA) 20. It requires at a minimum to add 2 gallons of an appropriate denaturant to every 100 gallons of ethanol. The only denaturants allowed by TTB and suitable for ethanol destined for use as a spark ignition fuel are natural gasoline, gasoline blendstocks and unleaded gasoline.

Natural Gasoline is a preferred denaturant and ASTM has developed *D8011 Standard Specification for Natural Gasoline as a Blendstock in Ethanol Fuel Blends or as a Denaturant for Fuel Ethanol* to describe details of usage under these multiple jurisdictions. <https://www.astm.org/Standards/D8011.htm>

Over the years the denaturant content has been imposed by various regulations. The TTB as well as ASTM require a minimum of 1.96 % by volume denaturant content and ASTM has a maximum amount of 5% by volume. The Tier 3 regulations capped the denaturant content at 3 % by volume but the Renewable Fuels Standard for generating a Renewable Identification Number (RIN) is limited to 2 % by volume. If use 3 % denaturant the RIN would be pro-rated.

To comply with the denaturant range, RFA recommends that all denatured fuel ethanol be produced with an approved denaturant added between 1.96 % and 2.49 %. For additional denaturant compliance details, see the “**Tier 3 Motor Vehicle Fuel Standards for Denatured Fuel Ethanol**” document link found on page 7.

Denaturant content is determined by ratio of metered denaturant and ethanol volumes at the time of denaturing. There are no standard test methods or calculation procedures to determine the denaturant content.

California Denaturant Standard

The State of California places limits on the denaturants used to denature ethanol that is blended into their gasoline. Denaturant must be sourced meeting the quality aspects of CARB denaturant standard specification requirements. These requirements are set forth in the following table:

California Denaturant Standard

Quality Parameter	Limits	ASTM Test Methods
Benzene, vol.%, max	1.1	D 5580
Aromatics, vol.%, max	35	D 5580
Olefins, vol.%, max	10	D 6550

Ethanol is routinely commingled when in storage making it difficult to segregate ethanol destined for California from other destinations. As such, in July 2002, the RFA adopted a recommendation that all ethanol distributed for fuel use in the United States, by its member companies, meet the more stringent California specifications as set forth in the above tables.

These are applicable when ethanol is denatured at the maximum permitted level of 5.00 % by volume. When used at lower denaturant levels as we have today higher concentrations of specified components are allowed. For example, in the case of benzene the 1.1 % by volume specified is based on 5 % by volume denaturant. At 2 % by volume denaturant addition the denaturant could contain 2.5 times that amount, i.e. 2.75 % by volume.

Ethanol producers and importers should review the specifications of their denaturant suppliers to assure they do not contribute to levels above the recommended limit for sulfur and other specified ingredients. In addition, denaturants should be free of any silicon containing materials (i.e. silicone from spent solvents, some anti-foaming agents, and sealants). Silicon contamination has led to fouled vehicle components such as spark plugs, oxygen sensors, and catalytic converters.

Some fuel additives commonly used in petroleum, such as drag reducing agents (DRA) used to increase pipeline flow rates, may not be soluble in ethanol. There have been instances in the past where denaturants containing DRA have caused filter plugging at plants. Producers should be sure that denaturant suppliers provide suitable documentation that unacceptable quantities or insoluble fuel additives like DRA are not present in their product.

Conversion of Units

If necessary to evaluate the specification limits from ASTM D4806 in alternate unit's information below may be used as a quick conversion guide.

Parameter	% Volume	% Mass	ppm (mg/L)	ppmw (mg/kg)
Ethanol	92.1	92.5		
Acidity	0.0056	0.0070		
Water	1.0	1.26 *		
Inorganic Chloride			5	6.7
Copper			0.08	0.1
Sulfate			3.2	4

*Based on denaturant content of 1.96 - 2.5 % by volume and denaturant density range 0.60 to 0.74 at 60°F

All conversions for mass and volume based on the equation from ASTM D5501 section 13.5:

$$V_i = (M_i \times D_s) / D_i$$

V_i = volume % of component i
 M_i = mass % of component i
 D_i = relative density at 15.56°C (60°F) of component i
 D_s = density of sample (solution) at 15.56°C (60°F)

Ethanol / Water Solutions

It is also valuable to know ethanol and water physical mixing properties. A volume of alcohol at a defined temperature, when mixed with an equal volume of water at the same temperature, will produce a resultant mixture with a total volume less than the sum of the component parts if measured at the same temperature. When making aqueous volumetric blends of alcohol this "shrinkage" of resultant volume must be considered.

Volume % Ethanol + Volume % Water \neq 100%

Weight % Ethanol + Weight % Water = 100%

Specifications – Gasoline / Ethanol Blends

Gasoline and gasoline / ethanol blends are subject to a variety of federal and state laws and regulations from numerous agencies. These include a wide range of technical aspects such as FTC octane postings, EPA regulations for volatile organic compounds, sulfur, nitrogen oxides and toxic emissions profiles. Some states have certain requirements on fuels including such items as restrictions on vapor pressure, distillation characteristics, and in some cases a minimum octane requirement for fuels that are designated as Super or Premium grades. California has several fuel restrictions that are different, and often more stringent, than federal requirements. Many states also require that marketers register each grade marketed with the appropriate state agency. This document is not intended to include these various important regulations as many of these laws can change in a very short time frame. Those involved with blending gasoline and ethanol for retail should consult the most recent versions of the applicable laws and regulations to ensure compliance.

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Most refiners and marketers require that, at a minimum, their spark ignition fuels meet some, or all, of the quality fuel performance parameters set forth in *ASTM D4814 Standard Specification for Automotive Spark-Ignition Engine Fuel*. <https://www.astm.org/Standards/D4814.htm> Some refiners have standards that exceed those required by the ASTM specifications.

Another helpful document is an ASTM Research Report *MONO 12 U.S. Reformulated Spark-Ignition Engine Fuel and U.S. Renewable Fuel Standard* which describes numerous Federal and State regulations. https://www.astm.org/DIGITAL_LIBRARY/MNL/SOURCE_PAGES/MONO12.htm

The purpose of the ASTM specification is to provide parameters so that gasoline and gasoline / ethanol blends will perform satisfactorily in a wide range of automotive spark-ignition engines. It should be noted that ASTM standards and specifications are voluntary compliance standards, however, most states adopt as a minimum legal requirement for consumer protection. Whether mandatory or voluntary, the RFA believes adherence to the guidelines contained in ASTM D4814 is important in ensuring the delivery of high quality spark ignition engine fuel to the marketplace.

Properties of Gasoline / Ethanol Blends

To produce gasoline / ethanol blends, ethanol is mixed with a hydrocarbon blendstock for oxygenate blending also known as a “BOB”. The BOB may be formulated to produce U.S. reformulated gasoline after blending with ethanol (commonly known as an RBOB) or the BOB may be formulated to produce conventional oxygenated gasoline “CBOB” to be sold outside of areas requiring reformulated gasoline.

Ethanol will affect several properties of the gasoline to which it is added. For informational purposes a few will be described.

Octane

Octane Number is the standard numerical measure of a gasoline’s resistance to pre-ignition – “knocking” – in the cylinders of gasoline engines. Gasoline engines work by compressing an air-fuel mixture and then igniting the mixture, by means of a spark plug, at a specific instant during the cylinder’s compression stroke. Pre-ignition leads to loss of engine power, poor “drivability”, and possible damage to the engine. The higher the octane number, the more compression the fuel can tolerate without pre-igniting.

The octane of a gasoline or gasoline blendstock is measured by burning it in an “octane engine” – a small, stationary engine – under controlled conditions and various compression ratios and comparing the gasoline’s observed anti-knock performance with that of various standard blends of two compounds: iso-octane (octane number 100) and n-heptane (octane number 0). Test methods for octane are *ASTM D2699 Standard Test Method for Research Octane Number of Spark-Ignition Engine Fuel* <https://www.astm.org/Standards/D2699.htm> and *ASTM D2700 Standard Test Method for Motor Octane Number of Spark-Ignition Engine Fuel* <https://www.astm.org/Standards/D2700.htm>

Research Octane Number (RON) applies to low-load operations, such as city driving, constant speed highway driving. Motor Octane Number (MON) applies to higher-than-normal load operations, such as rapid acceleration, hill climbing, hauling a heavy load. Because it applies to higher load operations, a gasoline’s MON is always less than its RON. The average of the RON and MON., defines the anti-knock index (AKI) of automotive spark-ignition engine fuels, in accordance with Specification D4814. This is more commonly presented as: $AKI = RON + MON/2$

U.S. Octane Standards for finished gasoline are set by States

Gasoline Grade	AKI
Premium	91 - 93
Mid-grade	89
Regular	87

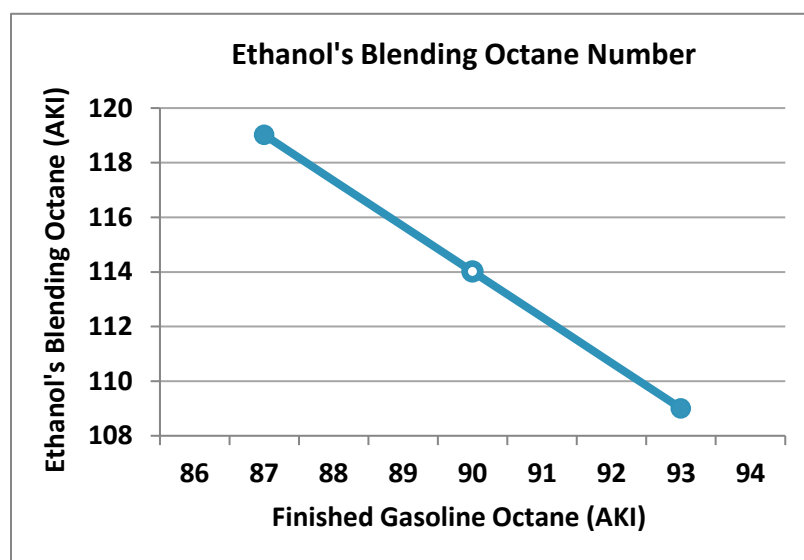


Note: Octane standards are about 2 AKI points lower in some states in the High Plains and Rocky Mountain region.

In the U.S. the AKI is the unit in which octane standards are defined and posted on the retail gasoline pump. However, other countries often post RON at the retail gasoline pump.

Ethanol’s pure component octane number is 100 AKI. But it’s blending octane number is 109-119 AKI, depending on the octane of the finished fuel. Ethanol’s blending octane number is highest when used

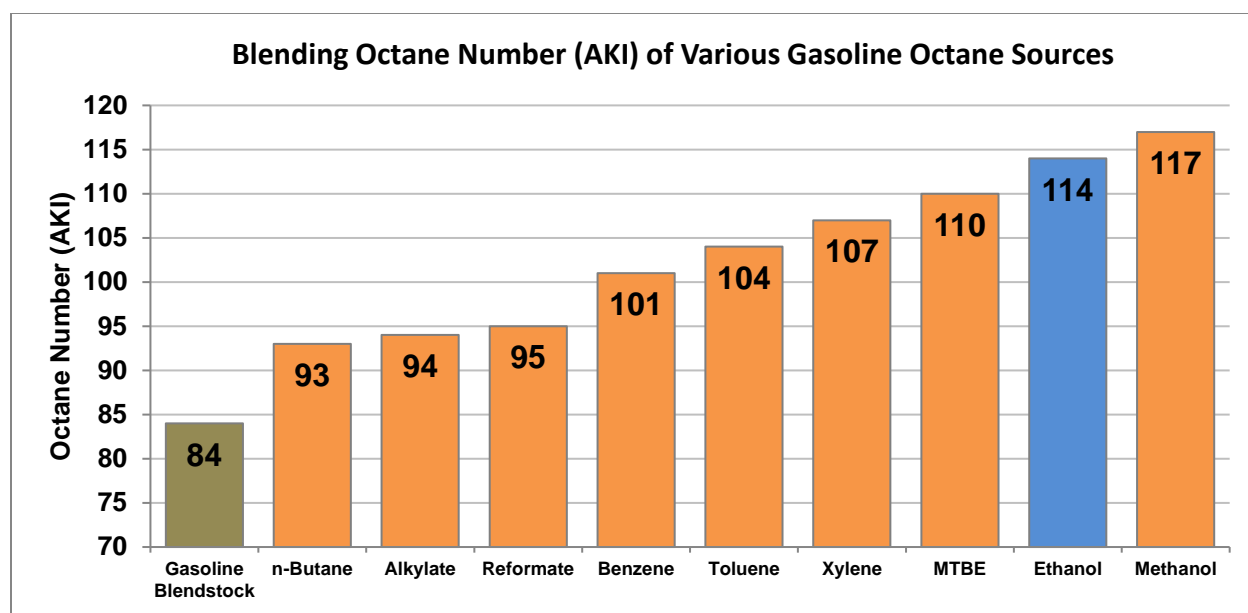
with lower-octane hydrocarbon blendstock.



At the 10 % by volume blend level ethanol (E10) will increase pump octane rating 2 – 4 AKI and for 15 % by volume blend level ethanol (E15) will increase pump octane rating 3 – 5 AKI depending on the octane rating of the base fuel. These increases are provided as general guidelines. The actual octane increase will vary depending on the base octane and, to a lesser degree, the

composition of the base fuel. RON is increased to a greater degree than MON with increasing ethanol content.

Ethanol octane advantage is clear as compared to others. Butane has extremely high volatility, Benzene is a known carcinogen, toluene and xylene are also high toxicity, MTBE is banned in 26 State and methanol is not approved by U.S. automakers. Ethanol is a superior octane booster due to its high RON and blending octane numbers, economic competitiveness and benign effects on the environment and human health.



Fuel Volatility

The addition of ethanol to gasoline will increase the volatility of the base fuel to which it added and decrease the 50 % distillation point (T_{50}). Because of the effect on T_{50} it may also affect the Driveability Index (DI) and the Vapor Lock Protection Class as measured by Temperature for Vapor Liquid Ratio of 20 (TV/L20).

Vapor Pressure

Vapor pressure is a very important physical property of volatile liquids. The vapor pressure of the fuel is a measure of its “front end” volatility. Fuels with excessively high vapor pressure may contribute to hot driveability or hot restart problems such as vapor lock. Fuels of too low vapor pressure may contribute to poor cold starting and poor warm up performance.

ASTM D323 Standard Test Method for Vapor Pressure of Petroleum Products also called Reid Vapor Pressure (RVP) is an accurate test method for measuring the vapor pressure of gasoline. The RVP differs from the true vapor pressure of the sample due to some small sample vaporization and the presence of water vapor and air in the confined space. Measuring vapor pressure of gasoline/ethanol blends uses a Dry Vapor Pressure Equivalent (DVPE).

ASTM D4953 Standard Test Method for Vapor Pressure of Gasoline and Gasoline-Oxygenate Blends (Dry Method) <https://www.astm.org/Standards/D4953.htm> ASTM D4814 defines DVPE as a 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.

ASTM D5191 Standard Test Method for Vapor Pressure of Petroleum Products (Mini Method)

<https://www.astm.org/Standards/D5191.htm> is more precise than Test Method D4953, uses a small sample size (1 mL to 10 mL), and requires about 7 min to complete the test.

An interlaboratory study was conducted in 2008 involving ethanol- gasoline blends containing 25 - 75 % by volume ethanol. The results indicated that the repeatability limits of these samples are within the published repeatability of this test method. D5191 is applicable to ethanol-fuel blends E10 - E83.

Vapor pressure of gasoline and gasoline-oxygenate blends is regulated by various government agencies and generally include limits to ensure products of suitable volatility performance.

Ethanol added to gasoline at a 10 % by volume blend will increase the vapor pressure by 0.6 – 1.3 psi.

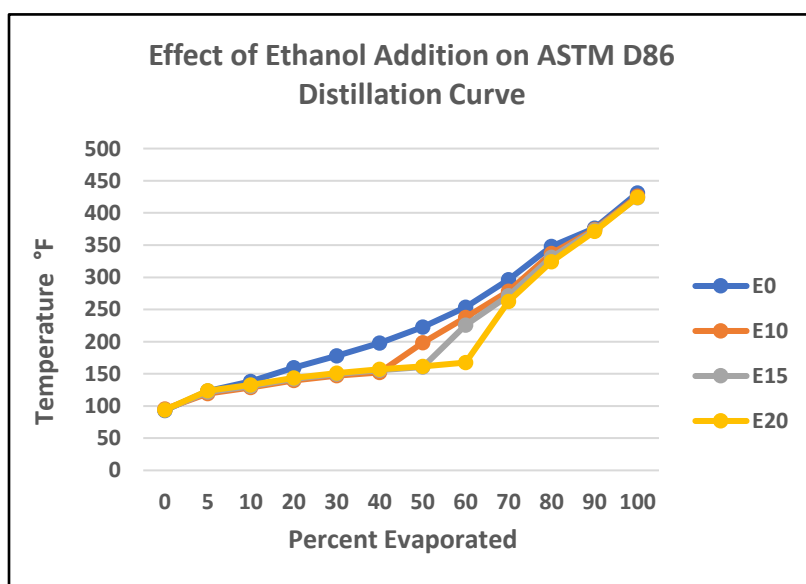
ASTM D4814 specifies a vapor pressure by State (or in some cases, portions of a State) for each month of the year. During the regulatory control period of June 1st to September 15th (at retail), the EPA's volatility restrictions apply. These restrictions require that fuels sold during the control period have a vapor pressure no greater than 9.0 psi or 7.8 psi depending upon the area. During this control period, gasoline/ethanol blends containing only 9 - 10 % by volume ethanol (E10) can be 1.0 psi higher in vapor pressure while ethanol content greater than 10 % up to 15% (E15) is not allowed to be higher in vapor pressure than the base gasoline.

Distillation Properties

ASTM D4814 Standard specification provides guidance on distillation characteristics with a maximum temperature at which 10 %, 90 %, and 100 % by volume (T_{10} , T_{90} , and end point) of a gasoline sample should evaporate.

The T_{50} specification provides a minimum temperature range at which 50% of the sample should evaporate. Ethanol will decrease this temperatures by as much as 10 - 30 °F (-12.2 to -1.1 °C)

The T_{50} would be about the same for E15 but tests have shown that E15 would also lower the T_{70} more than E10.



Data from CRC Report No. 666; Fuel Inspections Table 2

Studies have shown that later model fuel injected cars are less sensitive to gasolines with T₅₀ as low as 150 °F (65.5 °C). Some older vehicles may be more sensitive to low T₅₀ gasolines although this would apply predominantly in warm weather. The lower T₅₀ standard of 150 °F (65.5 °C) allowed by ASTM applies only to cold weather volatility classes of gasoline. While some states may not, in every case, require adherence to the guidelines for T₅₀, it should be noted that there is insufficient data to demonstrate satisfactory hot driveability / hot restart performance at T₅₀ levels below those specified by ASTM D4814.

Driveability Index

ASTM D4814 also includes specifications for a Driveability Index (DI). The DI is based on the relationship between fuel distillation temperatures and vehicle cold start and warm up driveability performance. The DI is indicated by the following formulas when distillation temperatures are performed in Fahrenheit and Celsius:

For degrees Fahrenheit;

$$\text{For E10: } DI = (1.5 \times T_{10}) + (3.0 \times T_{50}) + T_{90} + 2.4 \times (\text{ethanol \% by volume})$$

$$\text{For E15: } DI = (1.5 \times T_{10}) + (3.0 \times T_{50}) + T_{90} + 9.49 \times (\text{ethanol \% by volume})$$

For degrees Celsius;

$$\text{For E10: } DI = (1.5 \times T_{10}) + (3.0 \times T_{50}) + T_{90} + 1.33 \times (\text{ethanol \% by volume})$$

$$\text{For E15: } DI = (1.5 \times T_{10}) + (3.0 \times T_{50}) + T_{90} + 5.26 \times (\text{ethanol \% by volume})$$

where:

T₁₀ = distillation temperature at 10% evaporated

T₅₀ = distillation temperature at 50% evaporated

T₉₀ = distillation temperature at 90% evaporated

The DI is specified as a maximum number for each volatility class ranging from 1200 - 1250 Fahrenheit Scale (569 – 597 Celsius Scale) across the specified volatility classes. In general DIs above those specified tend to be more prone to contribute to poor cold start and/or poor warm up performance, especially in sensitive vehicles.

Vapor Lock Protection Class

ASTM D4814 specification has six Vapor/Liquid (V/L) ratio classes. ASTM defines that the "Vapor-liquid ratio is the ratio of the volume of vapor formed at atmospheric pressure to the volume of fuel tested in

Test Method D2533". The tendency of a fuel to cause vapor lock is indicated by the fuel temperature at a V/L ratio of approximately 20 (T V/L 20). More volatile fuel requires lower temperatures to achieve specified ratios. When blending 10% ethanol it is known that the T V/L 20 volatility parameter decreases from 15 °F (-9.4 °C) for Class 1 fuels to 6 °F (-14.4 °C) for Class 6 fuels.

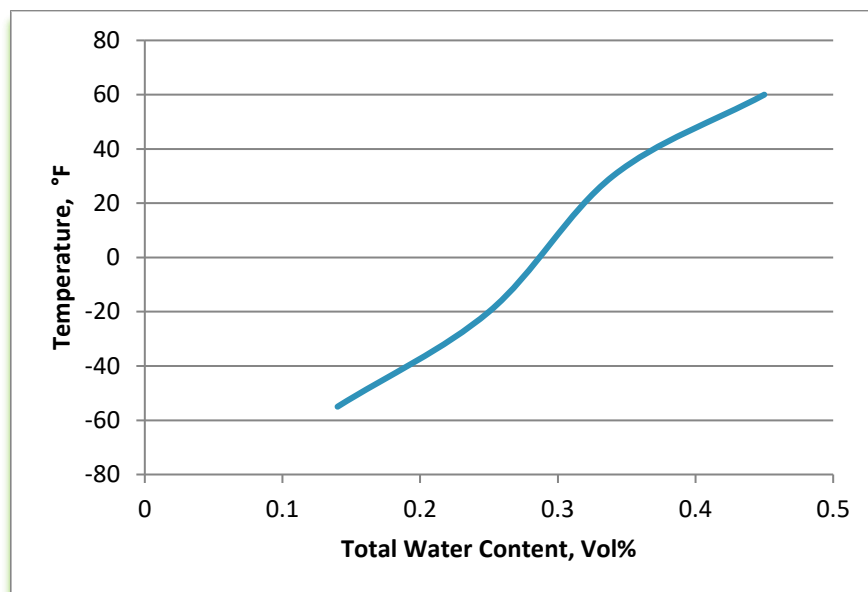
Water Tolerance

Ethanol has an affinity for water. Hence the sensitivity of ethanol gasoline blends to phase separation has been a concern for transporters and distributors and retailers. It is very important that the pipes and storage system be dried out prior to the introduction of ethanol blended fuels. If a gasoline blended with ethanol encounters excessive moisture contamination, the water can pull the ethanol away from the gasoline resulting in tank bottoms comprised of ethanol, water and some hydrocarbon content. This is called Phase Separation.

Phase separation of ethanol blended fuels occurs very rarely, but because the circumstances are different than for gasoline information is important to understand the problem. See section on phase separation on page 45.

The amount of water tolerated by a gasoline blended with ethanol is temperature dependent, with the lower the temperature of the fuel the lower the water tolerance. For instance, at 60 °F (15.5 °C) E10 fuel will tolerate approximately 0.5% volume water but at 10 °F (-12.2 °C) the tolerance is reduced to 0.3%.

Water Tolerance of 10% Ethanol Blended Fuels



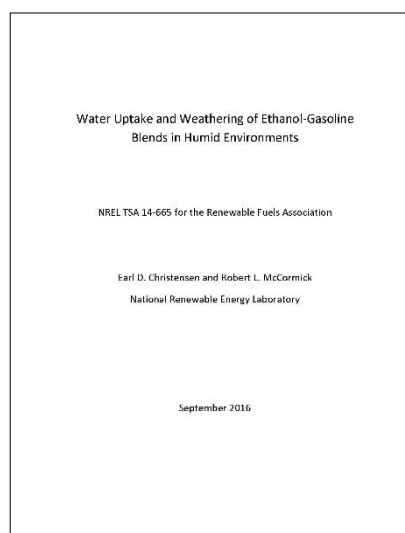
For phase separation to occur, water has exceeded the tolerance level of about 0.5%, either by water coming into the tank or being delivered to the tank, which would not be meeting specification.

Of the alcohols that are used as practical octane enhancers, ethanol blended with gasoline has the highest water tolerance. For instance, it is not necessary to add any gas line anti-freeze to ethanol blended fuels as the ethanol will absorb these trace quantities of water and pull it through the fuel system. Likewise, trace amounts of water in storage tanks are eliminated via the same mechanism. Once the systems have been dried of the excessive moisture this excellent water tolerance of ethanol blends with gasoline handles all normal condensation in bulk storage systems. There are no phase separation problems unless outside water finds its way into the storage tank.

In 2016, the National Renewable Energy Lab (NREL) studied water uptake of gasoline and ethanol/gasoline blends providing fresh insight into a decades-old debate about the impacts of ethanol-blended gasoline on water uptake and “phase separation” in small and off-road engines. The study titled *Water Uptake and Weathering of Ethanol-Gasoline Blends in Humid Environments* found that the petroleum components of ethanol-blended gasoline become degraded and unfit for use in an engine long before the ethanol portion takes up enough water to cause phase separation in the fuel tank. In every case, the hydrocarbon components of the fuel became unfit for use in an engine before water uptake became a concern. Over time, the fuel samples experienced significant loss of volatility, loss of mass, reduced octane rating, increased concentration of sulfur and gum, and other degradations. The study found that ethanol-free gasoline (E0) degraded “to the same degree [as ethanol-blended fuels] during this timeframe...An ethanol-free gasoline stored in the same conditions for the same period would likely be problematic despite a lack of phase separation.”

The research also found that an advantage of ethanol blends is that they do in fact hold more water in suspension without phase separation than the hydrocarbon components of gasoline. The scientists found that “...more ethanol improves the fuel’s resistance to phase separation. This is an advantage that can help keep fuel systems ‘dry’ by moving low levels of water out of the system.”

The full study is available at: <http://www.ethanolrfa.org/wp-content/uploads/2016/09/Evaluation-of-Water-Uptake-by-Ethanol-RFA-09-16.pdf>

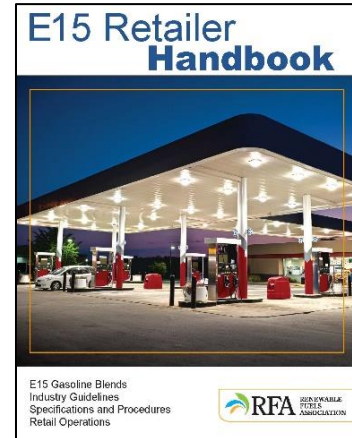


E15: Gasoline / Ethanol Fuel Blend (15% by volume ethanol)

The EPA required a Misfueling Mitigation Plan (MMP) as a condition of the E15 approval process and the conditions must be met before E15 is offered to consumers.

The RFA has developed the “**E15 Retailer Handbook**” to provide fuel retailers with regulatory and technical guidance to legally store and sell E15 ethanol blends. The Handbook provides sample checklists and questions that all potential E15 retailers should contemplate before moving forward with offerings of E15. Specifically, the Handbook offers guidance regarding:

- Labels must be placed on E15 retail dispensers indicating that E15 use is only for MY2001 and newer motor vehicles.
- Product Transfer Documents (PTDs) must accompany all transfers of fuels for E15 use.
- Parties involved in the manufacture of E15 must participate in a survey of compliance at fuel retail dispensing facilities to ensure proper labeling of dispensers.
- RFA has the only submitted and approved “**Model E15 Misfueling Mitigation Plan**”.



Download the RFA’s E15 Retailer Handbook here: <http://www.ethanolrfa.org/wp-content/uploads/2015/09/RFA-E15-Retailer-Handbook-Update-Jan-20131.pdf>



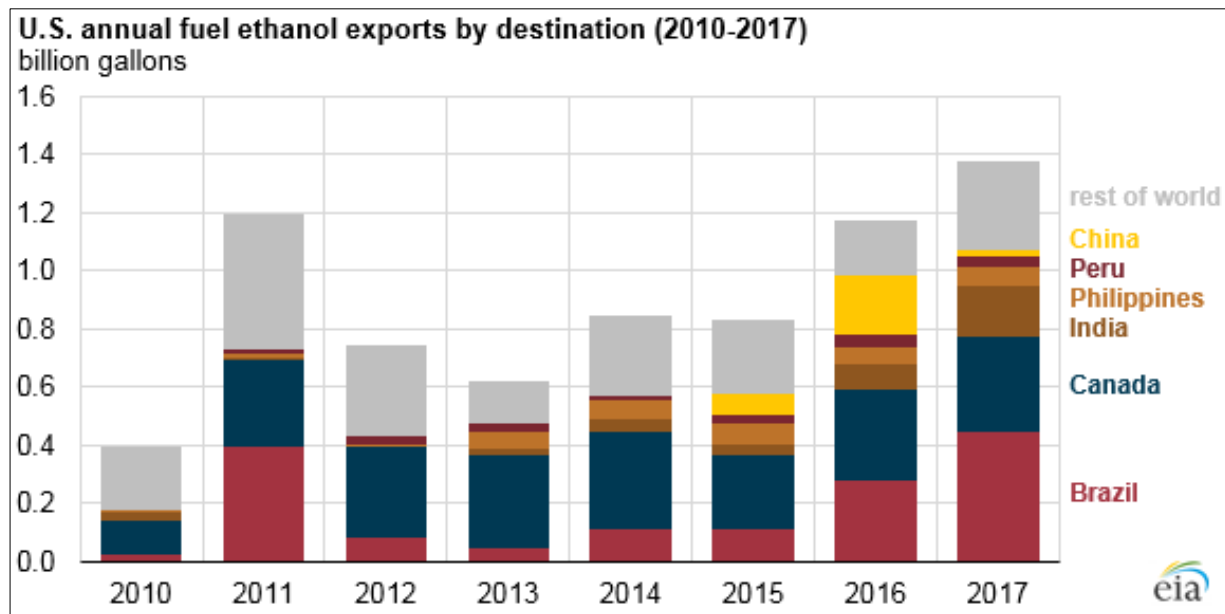
For additional E15 information for fuels registration, reporting, MMP and the compliance survey requirements, visit the EPA website:

<https://www.epa.gov/fuels-registration-reporting-and-compliance-help/e15-fuel-registration>



Exports: Global Marketplace for Ethanol

The U.S. ethanol industry has undergone a dramatic growth in production over the last decade. Most is utilized by the domestic market. However, world trade dynamics began to change in 2009 due to market conditions affecting sugarcane ethanol production, which thereby began to constrain Brazil's ethanol exports. At the same time, U.S. ethanol demand growth in U.S. is constrained due to the saturation of the E10 marketplace and the slow roll-out of recently approved E15. The export market has become a viable outlet for the U.S. corn ethanol operating capacity. U.S. produced ethanol has been exported to many global destinations driven by global demand for Green House Gas (GHG) savings and a low-cost source for octane in the transportation sector.



Specifications and other specified compliance conditions for ethanol can vary by destination country. Always consult the applicable standards and requirements as they can change. Some countries want undenatured product. Only a properly licensed distilled spirits plant can ship undenatured ethanol due to tax concerns. A few countries specifications are listed here for our two largest importers Canada and Brazil.

Canada Denatured Fuel Ethanol Specifications

The Canadian General Standards Board (CGSB) is a federal government organization that offers comprehensive standards development. The specification for denatured fuel ethanol, a blendstock that is used solely as a component of automotive spark-ignition fuels is:



CAN/CGSB 3.516-2017 Denatured Fuel Ethanol for Use in Automotive Spark-Ignition Fuels available here:
http://publications.gc.ca/collections/collection_2017/ongc-cgsb/P29-003-516-2017-eng.pdf

CAN/CGSB 3.516-2017
Denatured Fuel Ethanol for Use in Automotive Spark-Ignition Fuels

Property	Limits	ASTM and CAN/CGSB Test Methods
Ethanol, % by volume, min	92.0	D5501, CAN/CGSB-3.0 No. 14.3
Methanol, % by volume, max	0.5	D5501, CAN/CGSB-3.0 No. 14.3
Solvent washed gum, mg/100mL, max	5.0	D381
Water content, % by volume, max	0.8	D7923, E1064, E203, D6304
Inorganic Chloride, mg/kg, max	10.	D7319, D7328
Copper, mg/L, max	0.1	D1688
Acidity, as acetic acid, mg/kg, (% by mass) [mg/L], max	70 (0.0070) [56]	D1613, D7795
pHe	6.5 – 9.0	D6423
Sulphur, mg/kg, max	until 12/31/2019	D5453, D7039
	begin 1/1/2020	
Sulphate Content, mg/kg, max	4	D7318, D7319, D7328
Benzene, % by volume, max	0.25	CAN/CGSB-3.0 No. 14.3
Aromatics, % by volume, max	2.2	CAN/CGSB-3.0 No. 14.3
Phosphorus, mg/L, max	1.3	D3231
Conductivity, μ S/m, max	500.	D1125
Steel Corrosion, tested after blended with 90% by volume reagent grade iso-octane	B+	NACE TM-0172

Many the quality-related issues focus on denaturant. Canadian buyers also often want the CoA to state that the denatured ethanol does not contain Drag Reducing Agent due to issues experienced at a terminal. Concerns about DRA in ethanol were presented to the CGSB at a May 2009 Meeting.

Denaturants used for CGSB 3.516 ethanol also need to meet three Canadian regulations:

Canadian Denatured and Specially Denatured Alcohol Regulations SOR/2005-22

<http://laws-lois.justice.gc.ca/eng/regulations/SOR-2005-22/FullText.html>

The regulation allows two grades of denaturant: Grade DA-2C, (2 Liter to 5 Liters of petroleum derivative to every 100 Liters) and Grade DA-2F, 1 L to 5 L of gasoline to every 100 L). Natural gasoline falls under the definition of petroleum derivative in the Denatured and Specially Denatured Alcohol Regulations and needs to meet these properties: A volatile, highly flammable liquid that has the characteristic odor of light petroleum distillate. Upon distillation, a maximum of 10% by volume of the liquid shall pass over at or below 35°C or the liquid shall have a vapor pressure at 37.8°C (at a vapor-to-liquid ratio of 4:1) that is < 105 kPa, and a minimum of 95% by volume of the liquid shall pass over at or below 225°C.

Benzene in Gasoline Regulation SOR/97-493

<http://laws-lois.justice.gc.ca/eng/regulations/SOR-97-493/index.html>

Sulphur in Gasoline Regulation SOR/99-23

<http://laws-lois.justice.gc.ca/eng/regulations/SOR-99-236/index.html>

Canada also has a specification for higher ethanol blends.

CAN/CGSB-3.512-2014 Automotive Ethanol Fuel (E50-E85) available here:

http://publications.gc.ca/collections/collection_2017/ongc-cgsb/P29-003-512-2013-eng.pdf

Brazil Specifications – Anhydrous

The National Petroleum Agency (ANP) set specifications for fuel ethanol in Brazil. The current specification for anhydrous ethanol to be blended with gasoline is, ANP Resolution n°19/2015, Anhydrous Ethanol (EAC). The test methods specified are from the Brazilian Association of Technical Standards (NBR) and American Society for Testing and Materials (ASTM). Below is a translated version of the specification table. Brazil also imports undenatured ethanol.



**Brazilian ANP Ethanol Specifications
Resolution ANP #19 – Dated April 15, 2015**

Characteristic	Limits	ASTM and NBR Test Methods
Ethanol content, % by volume, min	98.0	D5501, NBR16041
Methanol, % by volume, max	0.5	NBR16041
Evaporative Residue, mg/100mL, max	5.0	NBR8644
Water content, % by mass, max	0.7	E203, NBR15531, NBR15888
Alcoholic Strength, % by mass, min	99.3	NBR5992, NBR15639
Hydrocarbons, % by volume, max	3	NBR13993
Chlorides, mg/kg, max	1	D7319, D7328, NBR10864
Specific Mass at 20°C, kg/m ³ , max	791.5	D4052, NBR5992, NBR15639
Total Acidity, mg/L, max	30	NBR9866, NBR16047, ISO17315
pHe	6.0 – 8.0	NBR10891
Sulfur, mg/kg, max	Report	D5453
Sulfate, mg/kg, max	4	D7319, D7328, NBR10894
Iron, mg/kg, max	5	NBR11331
Sodium, mg/kg, max	2	NBR10422
Copper, mg/L, max	0.07	NBR11331
Electrical Conductivity, µS/m, max	300	NBR10547, ISO17308

Other countries specifications of interest;

Mexico: The Comision Reguladora de Energia (CRE) issued NOM-016-CRE-2016 at the first ethanol specification and is currently still under development.

China: Standardization Administration of the People’s Republic of China issued the Chinese Standard for Denatured Fuel Ethanol GB 18350-2013 May 1, 2014 for Anhydrous Fuel Grade. The specification follows ASTM D4806 parameters but with a lower water content of 0.8 % by volume, max.

India: The Bureau of Indian Standard (BIS) has specification IS 15464:2004 for Anhydrous Ethanol for use in automotive fuel.

IS 15464 (for Test Methods Refer to Annex of IS 15464 : 2004)

Characteristics	Limits
Ethanol content % by volume at 15.6°C/15.6°C, min	99.6
Methyl Alcohol, mg/L, max	300
Relative Density at 15.6°C/15.6°C, max	0.7956
Conductivity, µS/m, max	300
Residue on Evaporation, % by mass, max	0.005
Copper, mg/L, max	0.1
Aldehyde content (as CH ₃ CHO), mg/L, max	60
Alkalinity	Nil
Acidity (as CH ₃ COOH), mg/L, max	30

Korea: Korean B Grade is an undenatured ethyl alcohol specification. Trends show undenatured ethanol products are greater than 50% of our exports.

B Grade Anhydrous Ethyl Alcohol

Property	Limits	ASTM Test Methods
Alcohol strength, GL at 20°C, min	99.3	Alcoholmeter for GL
Methanol, mg/L, max	80	D5501, GLC
Acetal, mg/l, max	100	GC
Esters (Ethyl Acetate), mg/L, max	120	D5501, GLC
Aldehydes (Acetaldehyde), mg/L, max	100	D5501, GLC
Iso-propanol, mg/L, max	20	D5501, GLC
Total Higher Alcohols, mg/L, max (n-propanol, iso-butanol, iso-amyl alcohol, iso-propanol, n-butanol)	400	D5501, GLC
Cyclohexane and Crotonaldehyde	absent	D5501, GLC
Toluene, Xylene, other Aromatics	absent	GC
Hydrocarbons	absent	D1722
Benzene	absent	UV / GC
1,4 Dioxane	absent	GC MS
Mono Ethylene Glycol	absent	D1296
Dry Extract, mg/L, max	40	D1353
Chlorides, mg/kg, max	1.0	GC
Alkalinity	negative	D1613

All ethanol global specifications have a visual check for clear and bright and free of foreign materials.

Before exporting product always check for the latest standard specifications for ethanol product quality.

The Worldwide Fuel Charter was first established in 1998 to promote greater understanding of the fuel quality needs of motor vehicle technologies and to harmonize fuel quality world-wide in accordance with vehicle needs. It provides recommended fuel specifications for a range of fuel for use with engines designed for different levels of emission control. It also provides a full explanation of the various aspects of fuel quality and their effects on vehicle emissions. Here is a link to the ethanol guidelines.

<http://oica.net/wp-content/uploads/ethanol-guideline-final-26mar09.pdf>

Quality Assurance and Test Methods

RFA has a companion document “**Guidelines for Establishing Ethanol Plant Quality Assurance and Quality Control Programs**” with detailed discussions which includes methods for analyses, sampling, general laboratory procedures and techniques and instruction on quality assurance and quality control practices. The document is found here: <http://www.ethanolrfa.org/wp-content/uploads/2018/07/RFA-QA-QC-Guideline-2018-.pdf>



RFA recommends utilizing ASTM Standard Test Methods to ensure the quality and purity of the ethanol supply and gasoline/ethanol blends. Some are relatively simple tests while others are more sophisticated, requiring laboratory equipment and specialized training. Ethanol producers need to be aware of the significance of these properties and limits. Moreover, various process changes may affect some properties such as inorganic chloride of sulfate. Any time a process change is implemented the producer should run tests to ensure that the finished product still meets the requirements of ASTM D4806. Similar action should be taken in the event of a process upset or temporary malfunctions.

The following provides an overview of the significant properties and common test methods for Denatured Fuel Alcohol:

Water: Karl Fischer analysis is generally the only consistently reliable procedure for the determination of water in denatured ethanol. *ASTM D7923 Standard Test Method for Water in Ethanol and Hydrocarbon Blends by Karl Fischer Titration* may be used to measure water content in denatured fuel ethanol in concentrations 0.05 % to 5.0 % by mass.

ASTM E203 Standard Test Method for Water Using Volumetric Karl Fischer Titration describes the modifications required to run the test in the presence of alcohols. Relative density or specific gravity is needed to convert the Karl Fischer water determination from E203 and *ASTM E1064 Standard Test Method for Water in Organic Liquids by Coulometric Karl Fischer Titration* from a percent by mass to a percent by volume. *ASTM D4052 Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter* are recommended for determination of relative density.

All water sources should be identified, monitored and controlled to prevent phase separation of the blended fuel. Denatured fuel ethanol is hygroscopic and can pick up water from the atmosphere during long-term storage. Prudent precautions to reduce water exposure and monitor the product should be considered if long term storage is expected.

Inorganic Chloride: Low concentrations of chloride ions are corrosive to many metals. Inorganic Chloride content can be determined by *ASTM Test Methods D7319 Standard Test Method for Determination of Existent and Potential Sulfate and Inorganic Chloride in Fuel Ethanol and Butanol by Direct Injection Suppressed Ion Chromatography* and *D7328 Standard Test Method for Determination of Existent and Potential Inorganic Sulfate and Total Inorganic Chloride in Fuel Ethanol by Ion Chromatography Using Aqueous Sample Injection*.

Copper: Copper is a very active catalyst for the 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. Analysis performed *ASTM D1688-17 Standard Test Methods for Copper in Water* with modifications.

Acidity: Very dilute aqueous solutions of low-molecular weight organic acids such as acetic acid (CH₃COOH) are highly corrosive to many metals. It is therefore necessary to keep such acids at a very low level. The acidity method is intended to determine the concentration of organic acids in ethanol. However, carbon dioxide (CO₂) is very soluble in ethanol, and in the presence of water it converts to carbonic acid. RFA recommends *ASTM D7795 Standard Test Method for Acidity in Ethanol and Ethanol Blends by Titration* as the preferred method. *ASTM D1613 Standard Test Method for Acidity in Volatile Solvents and Chemical Intermediates Used in Paint, Varnish, Lacquer, and Related Products* 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 CO₂ converted to carbonic acid will be titrated as an "acid." The presence of dissolved CO₂ will thus create a high bias in the acidity results and can incorrectly indicate that the sample is above the maximum allowed acidity. Test Method D1613 is an acceptable test method if utilizing the removal step for any dissolved CO₂. If a sample is known to have dissolved CO₂ or in cases of differing results between the two test methods, Test Method D7795 shall be the referee method.

pHe: When the pHe of ethanol used as a fuel for automotive spark-ignition engines is below 6.5, fuel pumps can malfunction because of film forming between the brushes and commutator, fuel injectors can fail from corrosive wear, and excessive engine cylinder wear can occur. When the pHe is above 9.0, fuel pump plastic parts can fail. ASTM Designation: *ASTM D6423 Standard Method for Determination of pHe of Ethanol, Denatured Fuel Ethanol, and Fuel Ethanol Blends*.

Appearance: Turbidity or evidence of precipitation normally indicates contamination. Fuel components can encounter conditions in the bulk distribution system that could cause the material to fail a workmanship visual evaluation. Some fuel components can contain dirt or rust particles during distribution. Terminals or bulk plants can address these issues with proper operating procedures: for

example, by allowing sufficient time for the dirt or particles to settle in the tank, by filtration or by other means.

Existent Sulfate: The presence of small amounts of inorganic sulfates in denatured fuel ethanol under the right conditions can contribute to turbine meter deposits and the premature plugging of fuel dispensing pump filters in the fuel distribution system. The sulfates also have been shown to cause fuel injector sticking resulting in engine misfiring and poor driveability in automobiles. Existent sulfate content can be determined by *ASTM D7319 Standard Test Method for Determination of Existent and Potential Sulfate and Inorganic Chloride in Fuel Ethanol and Butanol by Direct Injection Suppressed Ion Chromatography* or *D7328 Standard Test Method for Determination of Existent and Potential Inorganic Sulfate and Total Inorganic Chloride in Fuel Ethanol by Ion Chromatography Using Aqueous Sample Injection* or *ASTM D7318 Standard Test Method for Existent Inorganic Sulfate in Ethanol by Potentiometric Titration*. Potential Sulfate is also important and is a variation of these test methods.

Sulfur: EPA Federal Tier 3 Motor Vehicle and Emissions Standards and Gasoline Sulfur Control Requirements establish sulfur standards for gasoline and denatured fuel ethanol blended into gasoline. Sulfur contaminates the catalytic converter necessary for reducing emissions of hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NOx). The recommended ASTM test method for determining the sulfur content of ethanol is *ASTM D5453 Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons, Motor Fuels and Oils by Ultraviolet Fluorescence*.

Methanol / Ethanol: Small amounts of methanol can be produced in the ethanol production process. Methanol at high concentrations can be corrosive to components of the fuel system and has a greater effect on increasing vapor pressure than does ethanol. The limit is set to prevent methanol corrosion and the incremental effect on vapor pressure. The limit is also to prevent methanol from being used as a denaturant.

The ethanol content is important in determining the blend ratios for adding denatured fuel ethanol into the finished gasoline. The ethanol content of denatured fuel ethanol will vary based on levels of denaturant, water and the minor components common to ethanol production. *ASTM D5501 Standard Test Method for Determination of Ethanol Content of Denatured Fuel Ethanol by Gas Chromatography* is used to determine both methanol and ethanol content.

Test Methods (non-ASTM)

RFA recommends marketing product meeting ASTM D4806 utilizing ASTM standard test methods to ensure the quality and purity of the denatured fuel ethanol product but we recognize that not all terminals have these capabilities. We feel these tests are obsolete but include here for reference. These are considered relatively simple field tests that can be utilized when time and laboratory equipment are not suitable for the ASTM D4806 test methods.

Visual Clarity: Ethanol, when viewed in a clear glass container should be clear (clear to very pale straw color) and visibly free of haze and any suspended particles.

Apparent Proof / Specific Gravity / API Gravity:

Apparent proof can be determined with the use of proofing hydrometers. A 185 – 206 proof scale hydrometer and hydrometer cylinder can be purchased through your local laboratory equipment supplier.



The addition of denaturant will result in higher proof readings than would have been obtained on the pure ethanol prior to denaturing. The use of alcohol proofing hydrometers for pure ethanol/water only solutions is a well know accepted technique. It can be utilized for denatured fuel ethanol but the quantity and type of denaturant used will affect the proofing results. Proofing tables will vary slightly among producers for these reasons. Some purchasers of denatured fuel ethanol will require a specification of minimum 200 proof and maximum 203 proof. It is noted that the denatured fuel ethanol product can meet the established requirements of ASTM D4806 but fall below the 200-proof customer specific requests when the denaturant level is on the low side of the specification at 2% volume and the water content approaches the maximum tolerance of the ASTM D4806 specification.

The apparent proof is a hydrometer reading at 60°F. If product temperature is not 60°F then a correction table is used found here. https://www.ttb.gov/foia/Gauging_Manual_Tables/Table_1.pdf

Some terminals may also test for API Gravity. The specified API Gravity range is API 46° - 49°, corresponding to the specific gravity range of 0.7972 – 0.7839. If the terminal does not have temperature compensation abilities an allowance of +/- 0.6° is suitable for variability of the test method.

Equation for converting API gravity to Specific Gravity at 60°F:

$$SG = 141.5 / (API\ Gravity + 131.5)$$

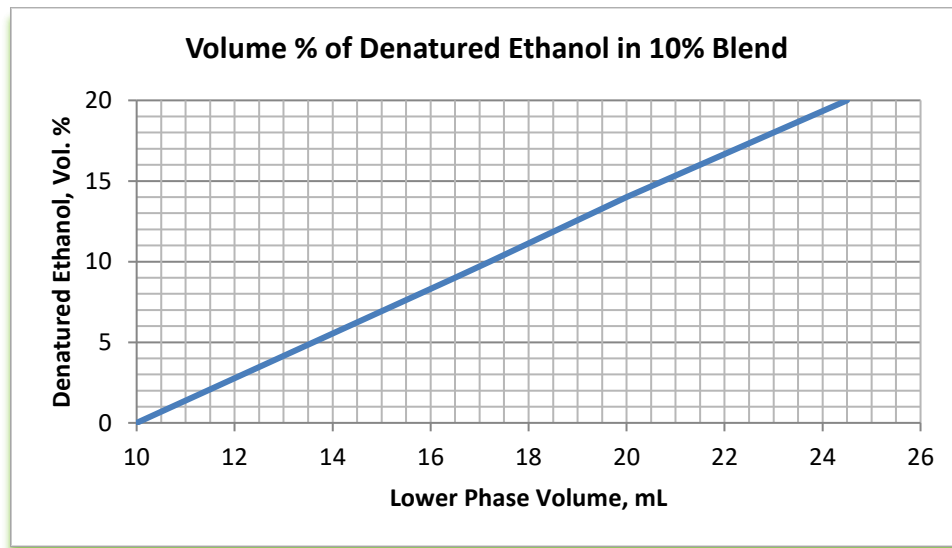
Equation for converting Specific Gravity to API Gravity at 60°F:

$$API\ Gravity = (141.5 / SG) - 131.5$$

Determination of Denatured Fuel Ethanol Content in Blends - Water Extraction Method:

Place 100 mL of the ethanol blend fuel to be tested in a 100-mL glass graduated cylinder with stopper. Pipette additional 10 mL of water into the cylinder. Place stopper and shake vigorously for one minute. Allow to rest and separate. Read the volume of the alcohol/water layer at the bottom of the cylinder. Use the graph below to determine the denatured fuel ethanol content.

Example: A reading of 17.2 mL of the bottom layer volume is 10% denatured alcohol in the blend.



Source: Chevron Research Corporation, Richmond, California

ASTM D4815 Standard Test Method for Determination of MTBE, ETBE, TAME, DIPE, tertiary-Amyl Alcohol and C1 to C4 Alcohols in Gasoline by Gas Chromatography is a more accurate laboratory test for determining the ethanol content of gasoline/ethanol blends. Blenders may also wish to consult *ASTM D4814 Standard Specification for Automotive Spark-Ignition Engine Fuel* for other test procedures relative to gasoline/ethanol blends.

Ethanol Fuel Blends; E85 / Ethanol Flex Fuel

While denatured fuel ethanol is most widely recognized for its use as an additive blend component in E10 or E15 gasoline/ethanol blends this application produces a finished fuel with ethanol as the primary component.



There is growing awareness and use of ethanol fuel blends known as flex fuel or commonly called E85 which can range from 51 – 83 % by volume ethanol content in hydrocarbons, depending on the season and geographic region. E85 is currently restricted for use to Flexible Fuel Vehicles (FFVs). There are

several issues regarding E85 quality, including the quality of the ethanol, the quality of the hydrocarbon portion of the blend, and the quality of the finished blend. In addition, adequate treatment with certain additives and proper care during transport and delivery, as well as proper procedures for conversion and housekeeping, are also necessary.

It is advised to check with other regulatory agencies, the EPA, the U.S. Department of Energy (DOE) for specific alternative fuel requirements and States also can have individual requirements. The State of California has specific regulatory quality parameters found in *13 CCR § 2292.4 Specifications for E-85 Fuel Ethanol*.

For most the product quality and integrity of E85 is governed by *D5798 Standard Specification for Ethanol Fuel Blends for Flexible-Fuel Automotive Spark-Ignition Engines*.

<https://www.astm.org/Standards/D5798.htm>

The vapor pressure of ethanol fuel blends is varied by Class for seasonal climatic changes. The addition of hydrocarbons is required for adequate vehicle cold start. 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 temperatures. Ethanol content and selection of the hydrocarbon blendstock are adjusted by the blender to meet these vapor pressure requirements. The volatility class by State and Month is identified in the specification. The following is a summary of the performance requirements:

D5798 Standard Specification Requirements for Ethanol Fuel Blends (E85)

Properties	Class 1	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 or D5191
All Classes					
Ethanol Content, % by volume	51–83			D5501	
Water Content, % by mass, max	1.0			E203, E1064, or D7923	
Methanol Content, % by volume, max	0.5			D5501	
Sulfur Content, mg/kg, max	80			D5453 or D7039	
Acidity, (as acetic acid), % by mass (mg/L) [mg/kg], max	0.005 (40) [50]			D1613 or D7795	
Solvent-washed gum content, mg/100 mL, max	5			D381	
Unwashed gum content, mg/100 mL, max	20			D381	
pH _e	6.5 to 9.0			D6423	
Inorganic chloride content, mg/kg, max	1			D7319 or D7328	
Copper content, mg/L, max	0.07			D1688	

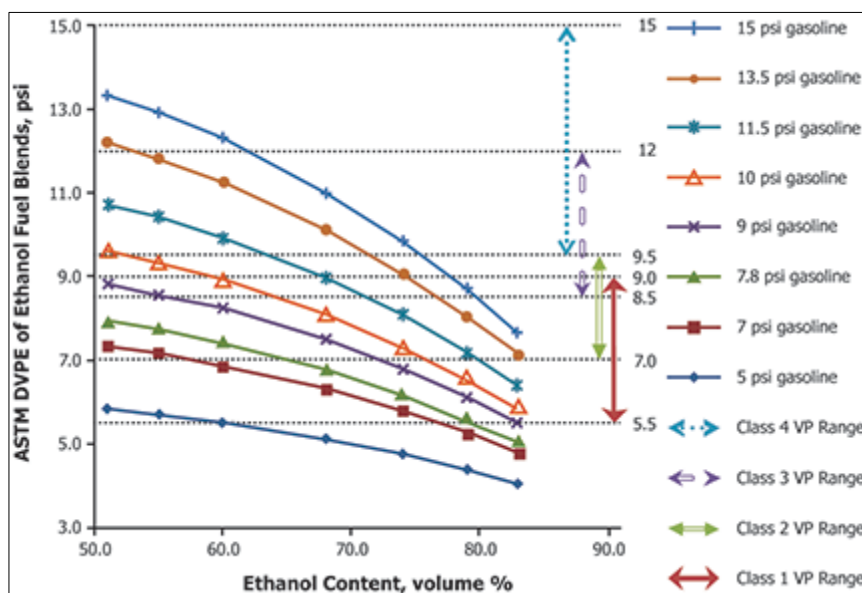
The hydrocarbon blendstock blended with the denatured fuel ethanol shall meet the requirements:

D5798 Standard Specification Requirements for Hydrocarbon Blendstock

Properties	Limits	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	D4953, D5191

ASTM has developed *D8011 Standard Specification for Natural Gasoline as a Blendstock in Ethanol Fuel Blends or as a Denaturant for Fuel Ethanol* to describe details of usage under these multiple jurisdictions. <https://www.astm.org/Standards/D8011.htm>

This chart, developed using the predictive equations found in SAE paper 2007-01-4006, 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.



The ASTM D5798 specification has very detailed information regarding the importance of each performance property requirement. Each E85

manufacturer should evaluate their own operation and process to set a testing frequency to ensure adherence to the ASTM standards. The RFA “Guidelines for Establishing Ethanol Plant Quality Assurance and Quality Control Programs,” discussed earlier may prove useful in setting up a fuel quality and oversight program.

Fuel Additives for Ethanol Fuel Blends

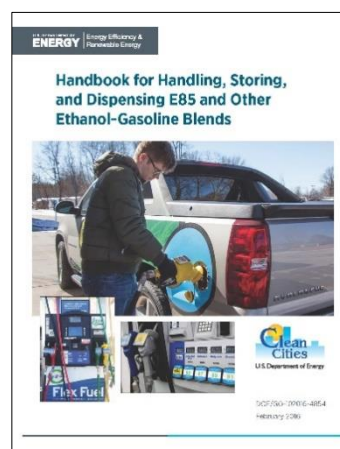
ASTM D5798 does not contain guidelines for additives such as corrosion inhibitors or detergents/deposit control additives. Work in this area is ongoing. As such, the RFA has not yet prepared a formal recommendation for additives to be used in E85. Blenders or terminals should actively engage additive manufacturers to determine whether the additives will remain soluble with various concentrations of ethanol and gasoline. The following discussion provides information on the issues.

Corrosion Inhibitors: Nearly all ethanol producers add a corrosion inhibitor at a level sufficient to treat the entire finished gallon of E10. This level would over-treat a gallon of E85. However, since E85 is typically made from ethanol in common storage and E10 is the primary blend, this is unavoidable now.

Detergents/Deposit Control Additives: According to EPA regulations, all commercial grades of gasoline must contain minimum specified levels of detergent additives. Other additives may be used by terminals or fuel companies to ensure their fuel meets all customer requirements. Studies have shown that E85 may, in some cases, lead to development of fuel injector and/or intake valve deposits. Preliminary work indicates that this may be a result of no detergents in the ethanol portion of the blend in combination with high levels of corrosion inhibitor. This can be addressed through the addition of detergents/deposit control additives. If an additive is used, the blender must rely on information from the additive manufacturer. In addition to effectiveness, it should be confirmed that any additive selected will remain soluble in varying blend levels of gasoline and ethanol, and that the additive meets the “no harm” criteria, meaning it will not interact with other gasoline additives present in a manner that would cause problems or reduce the effectiveness of other additives. Common gasoline additives may not be compatible with E85. The recommended treat rate of any additive should not be exceeded.

For further information the Department of Energy Office of Energy Efficiency & Renewable Energy has put together compatible information offering a discussion of other important topics related to Ethanol-Gasoline Blends (E85) such as;

- ✓ Materials Recommendations / Storing and Dispensing Ethanol Blends / Codes and Regulations
- ✓ Retail and Fleet Station Equipment / Tank Manufacturer Compatibility
- ✓ Associated UST Equipment Manufacturer Compatibility
- ✓ Checklists for Installing E85, Blender Pump Dispensing Equipment or Converting Underground Storage Tanks



“Handbook for Handling, Storing, and Dispensing E85 and Other Ethanol-Gasoline Blends”

https://www.afdc.energy.gov/uploads/publication/ethanol_handbook.pdf

Mid-Level Ethanol Fuel Blends / Ethanol Flex Fuel

ASTM has a helpful standard practice for blending; *D7794 Practice for Blending Mid-Level Ethanol Fuel Blends for Flexible-Fuel Vehicles with Automotive Spark-Ignition Engines*

<https://www.astm.org/Standards/D7794.htm>

The 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. Typically considered for 16 – 50% by volume ethanol content gasoline blends. These mid-level ethanol fuel blends are for use in flexible-fuel vehicles and are sometimes referred to at retail as ethanol flex fuel.

D7794 describes the required procedures for blending various mid-level ethanol fuel blends for flexible-fuel vehicles at the bulk distribution point or retail delivery site. Typically, these flex fuels are blended using a blender pump at retail. Mid-level ethanol fuel blend shall be blended from either:

- ✓ ASTM D4806 Denatured Fuel Ethanol with a reduced limit on inorganic chloride content that assures ≤ 1 mg/kg inorganic chloride in the finished fuel and ASTM D4814 spark-ignition engine fuel, or
- ✓ ASTM D5798 Ethanol Blended Fuel and ASTM D4814 spark-ignition engine fuel

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



Materials Compatibility Information for Commonly Used Materials with Ethanol and Gasoline / Ethanol Blended Fuels

Please consult with the manufacturer of any product choice for a service application as these are generalized recommendations.

Storage Tanks

The mild steel used in product terminals tanks is compatible for storage of denatured fuel ethanol and gasoline / ethanol blended fuels. The interior of some older steel tanks may have been epoxy lined to prevent small leaks and extend the service life. Most liner materials are compatible with ethanol blended fuels but some are not. Steel tanks coated with a standard, general-purpose epoxy lining or polyester resin based materials in the late 1970's and early 1980's is not suitable for ethanol or ethanol blended fuels. If a tank has been relined the manufacturer of the lining material should be consulted. There are currently suitable epoxy compounds for lining tanks storing ethanol and ethanol/gasoline blends.

In general fiberglass tanks are not suitable due to the resin being softened by the ethanol. Improvements made since 1981 have allowed the manufacturers to warranty this type of tank for 10% ethanol/gasoline blends. It is recommended that the manufacturer of a fiberglass tank be consulted. Fiberglass warranty statement excerpts from Owens-Corning (now Containment Solutions) & ZCL | Xerxes®:

Containment Solutions, Inc www.containmentsolutions.com Containment Solutions provides a 30-year warranty for single wall tanks for storage of blended fuels containing up to 10% ethanol. A 30-year warranty is provided for double wall tanks for storage of fuels containing up to 100% ethanol.

ZCL | Xerxes® <https://www.zcl.com/en/> Since July 1980 Xerxes has provided a 30-year warranty for single wall tanks for storage of blended fuels containing up to 10% ethanol. A 30-year warranty, available since April 1, 1990, has been provided for double wall tanks for storage of fuels containing any concentration of ethanol.

Metals

Carbon steel, stainless steel and bronze are suitable for ethanol and ethanol blends.

Aluminum is suitable for intermittent contact with ethanol or ethanol blended fuels, such as transport equipment, but not recommended in dispensing equipment where ethanol content is greater than 10%.

Galvanized Zinc is not recommended.

Pumps

For denatured fuel ethanol the preferred materials for seals are carbon and ceramic. Teflon materials are recommended for the packing construction. A petroleum equipment supplier should be able to determine if existing terminal pumps are compatible with ethanol. Gasoline pumps (both above ground and submersible) should handle gasoline/ethanol blends with no problems.

Meters

Meters for ethanol should have O-rings and seals designed to withstand ethanol' solvent action. Consult a meter manufacturer for recommendations. Gasoline meters are being used for ethanol blended fuels with no adverse wear or leakage problems. When first using meters for ethanol blended fuels it is recommended to recalibrate after two weeks of use to assure meter is working properly.

Pipe Sealant

Teflon tape is the best sealant to use when sealing pipe connections. Be careful to avoid alcohol based pipe sealants as they may be softened and washed away by denatured fuel ethanol or ethanol blends.

Filters

Screens and filters used at both the terminal and retail facility are generally compatible with denatured fuel ethanol and gasoline / ethanol blended fuels. A 10-micron nominal filter is recommended for the ethanol loadout and retail dispenser. A #40 mesh screen in the transfer line is recommended for terminal operations. Be alert that paper filters may use shellac as an adhesive and ethanol will dissolve shellac. There would be a manufacturer warning on the box about using with alcohol containing fuels.

Plastics, Elastomers and Other Materials

Materials not significantly affected include, leather, nylon, paper, polyethylene, polypropylene and acetal (Delrin®) and Teflon®.

It is difficult to generalize about elastomer compounds. Fluorel®, Viton® and Polysulfide Rubber are recommended. Other elastomer choices depend on the application of where the product is used. Viton® is preferred for static seals and gaskets while Buna N® and neoprene provide better performance in dynamic uses like hoses and gaskets.

Because of softening problems, pure rubber and urethane rubber are not recommended.

Materials not suitable for use are cork, due to shrinking, and polyurethane, due to softening. Fiberglass-reinforced polyester and epoxy resins have also been reported to be softened by ethanol blends.

Compatibility of Commonly Used Material with Denatured Fuel Ethanol and Gasoline / Ethanol Blends		
	<u>Recommended</u>	<u>Not Recommended</u>
Metals:	Aluminum ⁽¹⁾ Carbon Steel Stainless Steel Bronze	Zinc-galvanized (ethanol only)
Elastomers:	EPDM Buna-N [®] (hoses & gaskets) Butly 11 [®] Flourosilicone ⁽²⁾ Flourel Neoprene (hoses & gaskets) Polysulfide Rubber Natural Rubber (ethanol only) Viton [®] Viton [®] B+ Specific Formulation Viton [®] GF-S Viton [®] GFLT Viton [®] Extreme RTP Simriz [®] Kalrez [®] Chemraz [®]	Buna-N [®] (seals only) Neoprene (seals only) Urethane rubber Nitrite NBR Nitrite, Hyd, HNBR
Polymers:	Acetal Nylon Polypropylene Teflon [®] ⁽²⁾ Fiberglass reinforced plastic ⁽²⁾	Polyurethane ⁽²⁾ Alcohol- based pipe dope
⁽¹⁾ aluminum is not recommended for continual contact applications but is suitable for intermittent contact such as transport equipment ⁽²⁾ manufacturer of specific product should be consulted		

Ethanol Temperature Volume Correction Factors (VCF)

Table for Correction of Volume to 60 °F for Denatured Fuel Ethanol

Temperature °F	Factor	Temperature °F	Factor	Temperature °F	Factor
-10	1.0441	27	1.0208	64	0.9975
-9	1.0435	28	1.0202	65	0.9968
-8	1.0428	29	1.0195	66	0.9962
-7	1.0422	30	1.0189	67	0.9956
-6	1.0416	31	1.0183	68	0.9950
-5	1.0409	32	1.0176	69	0.9943
-4	1.0403	33	1.0170	70	0.9937
-3	1.0397	34	1.0164	71	0.9931
-2	1.0391	35	1.0157	72	0.9924
-1	1.0384	36	1.0151	73	0.9918
0	1.0378	37	1.0145	74	0.9912
1	1.0372	38	1.0139	75	0.9905
2	1.0365	39	1.0132	76	0.9899
3	1.0359	40	1.0126	77	0.9893
4	1.0353	41	1.0120	78	0.9887
5	1.0346	42	1.0113	79	0.9880
6	1.0340	43	1.0107	80	0.9874
7	1.0334	44	1.0101	81	0.9868
8	1.0328	45	1.0094	82	0.9861
9	1.0321	46	1.0088	83	0.9855
10	1.0315	47	1.0082	84	0.9849
11	1.0309	48	1.0076	85	0.9842
12	1.0302	49	1.0069	86	0.9836
13	1.0296	50	1.0063	87	0.9830
14	1.0290	51	1.0057	88	0.9824
15	1.0283	52	1.0050	89	0.9817
16	1.0277	53	1.0044	90	0.9811
17	1.0271	54	1.0038	91	0.9805
18	1.0265	55	1.0031	92	0.9798
19	1.0258	56	1.0025	93	0.9792
20	1.0252	57	1.0019	94	0.9786
21	1.0246	58	1.0013	95	0.9779
22	1.0239	59	1.0006	96	0.9773
23	1.0233	60	1.0000	97	0.9767
24	1.0227	61	0.9994	98	0.9761
25	1.0221	62	0.9987	99	0.9754
26	1.0214	63	0.9981	100	0.9748

Denatured Fuel Ethanol sales are metered gallons. The gross gallons can be adjusted to net 60 °F gallons by using the above table. Example: 29,292 gallons at 65 °F is to be corrected to volume at 60 °F

$$29,292 \times 0.9968 = 29,198 \text{ net gallons at } 60 \text{ }^\circ\text{F}$$

Denatured Fuel Ethanol coefficient of expansion is 0.00063 per °F.

EPA Standardized Volume – Volume Correction Factor for RINs

The Renewable Fuel Standard has a regulatory requirement to standardize a volume of a batch to a temperature of 60 °F for the purposes of generating Renewable Identification Numbers (RINs).

For ethanol, the following formula shall be used:

$$V_{s,e} = V_{a,e} \times (-0.0006301 \times T + 1.0378)$$

Where:

$V_{s,e}$ = Standardized volume of ethanol at 60 °F, in gallons

$V_{a,e}$ = Actual volume of ethanol, in gallons

T = Actual temperature of the batch, in °F

American Petroleum Institute (API) Ethanol-Gasoline Project Group for VCF

API performed a study of the VCF and in late 2011 published, API MPMS Chapter 11.3.3, Miscellaneous Hydrocarbon Product Properties – Ethanol Density and Volume Correction Factors.

The standard includes implementation procedures for both pure (99+%) and denatured fuel ethanol, providing VCF coefficients as follows.

For volume or density correction from observed temperature to 60 °F, the implementation procedure given in API MPMS Ch. 11.1-2004 shall be used. Pure and denatured fuel grade ethanol's are considered "special applications" (formerly known as Table 6C or Table 54C) with a coefficient of 0.000599/°F or 0.001078/°C for pure ethanol and 0.000603/°F or 0.001085/°C for Denatured Ethanol.

The standard also notes "However, if occasional table differences of 0.001% (1 in 100,000 volume units) are acceptable to all parties, commodity group Refined Products (formerly known as Table 6B) with an API gravity of 50.47 (pure) and 50.61 (denatured) may be used in lieu of the 6C table".



Conversion Procedures to Ethanol Blended Fuels



Terminal / Ethanol Storage

There are steps that should be taken to properly prepare a terminal storage tank for storing denatured fuel ethanol.

The volume and number of the tanks need to be sized to match requirements of anticipated delivery frequencies. A fixed roof with floating internal cover is recommended. To minimize vapor losses, install a Pressure/Vacuum Vent (16-ounce pressure / 1-ounce vacuum) on the tank. To minimize water vapor ingestion into the tank a desiccant drier system may be desired depending upon local humidity conditions and daily temperature changes. A flame arrestor

should be placed in the vapor return line (loading rack back to vapor process unit) and may also be used on the outlet vent lines.

Confirm that the tank is designed to tolerate this pressure prior to installing. Experience shows that evaporation losses during storage are generally equal to or lower than for gasoline due to ethanol having a low vapor pressure and the higher-pressure vent minimizes vapor losses.

Consult with the petroleum equipment supplier with the proper selection and the fittings for the tank.

Since ethanol will loosen rust, varnish and gums from previously used tanks, it is important to clean loose materials and be completely dry prior to introduction of ethanol. A 40 – 80 mesh screen filter should be installed in the transfer line, between the tank and the loading rack or blending unit, prior to the pump.

It is best practice to have a certified inspector perform API Standard 653 internal and external storage tank inspections at 5-year and 10-year intervals (or more frequent if necessary) for tanks storing denatured fuel ethanol.

Some terminal tankage in fuel grade ethanol service has experienced Stress Corrosion Cracking (SCC). Though these incidents have been few and isolated events; it is now common practice to coat tank bottoms and the first 3 to 6 feet of the tank shell with a phenolic epoxy coating as well as the undersides of the floating roof. See API Technical Report 939-D and 939-E for additional information.

Blending Systems: There are a variety of blending system options including Sequential, Ratio Blending, Ratio Proportional Blending, Non- Proportional in Line Blending, and Side Stream Blending. It is recommended that an engineering assessment and cost analysis be conducted to determine the best system for a given application since selection criteria is terminal specific.

Spill / Run-Off Management: Ethanol that is dissolved in water will pass through the oil water separator. Therefore, spill and run-off areas should be separated from hydrocarbon products. Check with the authority having jurisdiction for proper procedures for disposing of ethanol water mixtures.

Safety: The fire protection system (e.g. foam/deluge system) should be upgraded with proper sprinkler heads. Many times, insurance companies have specific requirements for emergency mitigation equipment.

Terminal and Transportation Personnel Communication and Training

Once changes are made, terminal personnel should be apprised of the proper operation of new equipment and handling of new products. To provide orientation to the terminal personnel a few helpful suggestions of information to communicate are:

- ✓ Equipment orientation
- ✓ Cover all new or modified procedures
- ✓ Cover safety and firefighting information
- ✓ Post the Safety Data Sheet (SDS) (available from ethanol supplier)
- ✓ Cover product receipt procedure
- ✓ Cover any procedure regarding product inspection and/or sample retention
- ✓ Advise maintenance personnel of conversion and potential for filter/screen plugging
- ✓ Test affected meters and recalibrate if needed (10 to 14 days after initial conversion)

Transportation personnel should also be advised of product changes and any related procedures. Training should:

Inbound Ethanol Delivery

- ✓ Cover product delivery procedures
- ✓ Cover applicable firefighting & safety procedures
- ✓ Safety Data Sheet (MSDS) (available from ethanol supplier)
- ✓ Placard requirements
- ✓ Discuss approved prior commodities hauled

Outbound Blended Product Delivery

- ✓ Cover information on new terminal blending equipment
- ✓ Cover splash blending procedure (if applicable)
- ✓ Cover color codes (API or company specific color codes)
- ✓ Discuss need to test for water bottoms and what procedures to follow when water bottoms are present. Any level of water above 1/4" should be removed.
- ✓ Assuming no water bottoms are present, the load can be dropped per normal procedure.

Conversion Procedures

- ✓ Review conversion procedures
- ✓ Review any special requirements & resulting increase in transportation demands
- ✓ Stress importance of no water bottoms
- ✓ Cover importance of accurate blend ratios

Retail Conversion to Ethanol Blended Fuels

As mentioned, water is infinitely soluble in ethanol but not gasoline. The presence of 0.5% water will cause phase separation problems that are difficult to remedy. A tank with a history of water bottom growth is certain to cause problems until the root cause of water entering the tank is remedied. The water can enter the underground tank through a faulty gasket, loose fill cap or a leak in the tank itself. The tank must be properly prepared by replacing the gasket, tasking step to keep ground water from accumulation around the fill cap and repairing or replacing a leaking tank. Make sure the tank is in watertight condition prior to conversion.

Other preparations prior to introducing ethanol blends are ordering a few things you will need.

Order a waterfinder paste that can be used for detecting phase separation in ethanol blended fuels. The conventional waterfinder pastes for gasoline do not work well for ethanol blended fuels. Local petroleum equipment suppliers usually carry the pastes. Be sure to specify that the paste is suitable for ethanol blends. Order dispenser filters if the dispensers are not equipped with filters. A 10-micron size is recommended.

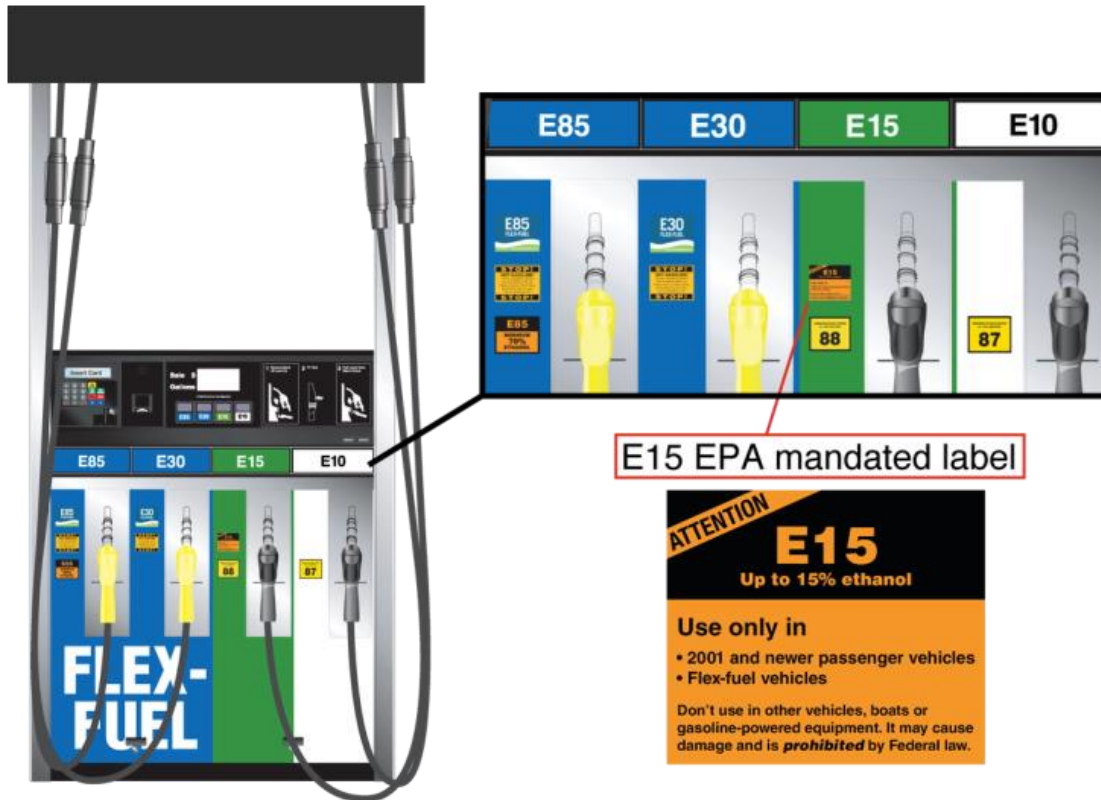
Because ethanol blends will soften gums and varnishes and loosen the rust, it becomes mandatory to use dispenser filters. The filter will protect the loosened rust from reaching the customers fuel tank. Place these in service prior to conversion to ethanol blends.

Follow company policy and safety procedures prior to making any physical changes. Pumps should be shut down during initial delivery as an extra consumer protection precaution.

The preferred conversion technique is to completely empty the tank by dispensing as much gasoline as possible and then pumping the water bottom until the tank is empty. The water bottom must be disposed of in accordance with state and federal environmental regulations. The ethanol blended fuel can now be introduced to the tank. It is recommended that the tank be filled to 80 - 90% so the ethanol can absorb any residual trace amounts of water left in the tank. Keep the tank as full as possible for a few weeks. Purge all pumps that will be dispensing the ethanol blended fuel until the product is clear and bright and the ethanol content is 10%. After all the dispensers have been flushed and checked for fuel quality the product is now ready for retail.



Consumer Pump Labeling



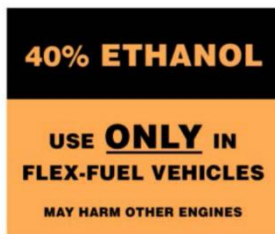
Order appropriate decals and labels for the pump, such as contains ethanol and octane stickers. Check with state labeling law regulations as they may vary. The Federal Trade Commission (FTC), as listed in the Code of Federal Regulations Title 16, Part 306, provides guidance for retail fuel pump labeling. Additionally, most states adopt fuel labeling requirements as listed in NIST Handbook 130, “Engine Fuels, Petroleum Products, and Automotive Lubricants Regulation.” Handbook 130 states that the type of oxygenate must be disclosed using the word “with” or “containing.”

Consumer Pump Labeling (E16 -E83)

In 2016 the FTC issued a final rulemaking in 16 CFR Part 306 Automotive Fuel Ratings, Certification and Posting with regards to pump labeling requirements for Ethanol Flex Fuels which they defined as ethanol blends above 10% to a maximum of 83%.

The final rule adopts tiered labeling for Ethanol Flex Fuels with options to provide fewer burdens to retailers. Specifically, retailers must post labels for mid-level blends with the exact ethanol concentration or may round to the nearest multiple of 10 (e.g., “40% Ethanol” could have ethanol content of 35 – 44 % by volume). For high-level blends (E51 – E83), retailers may post the exact

percentage of ethanol concentration, round to the nearest multiple of 10, or indicate that the fuel contains “51% to 83% Ethanol.”



LABEL SIZE: Labels must be 3 inches wide by 2.5 inches long using Helvetica or another similar type.

LABEL PLACEMENT: Labels must be placed on each face of the pump where the specific ethanol blend is offered for sale to the consumer.



Retail pump labels for ethanol blended fuels are available from the RFA at no charge by contacting the Market Development team at info@ethanolrfa.org

Retail Station On-going Maintenance after Conversion

Keep fill caps secured always and monitor fill opening and driveway covers for standing water. If standing water is found correct immediately to prevent water contamination. During winter months clear away the snow buildup to prevent melting snow from leaking into the fill opening.



Monitor the pump rate for any slowing and replace the filter if lower pump rates are occurring. This will only occur within a few days after conversion.

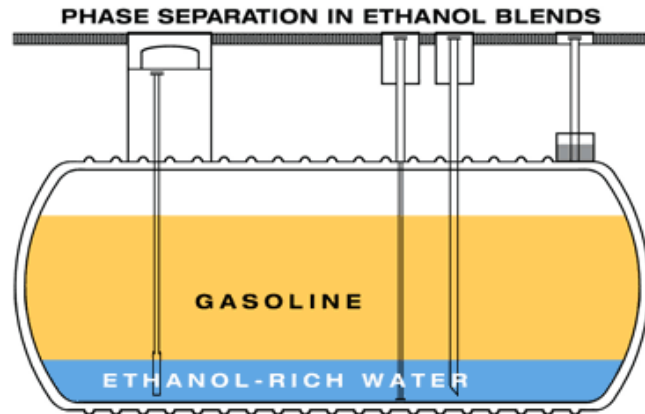
Monitor the water bottoms, with appropriate water paste designed for ethanol blended fuels, daily. If water bottoms are detected, follow the recommended phase separation guidelines.

Phase Separation

Water bottoms or phase separation of ethanol blended fuels occurs very rarely, but because the circumstances are different than for gasoline this information is important to understand the problem.

Water bottoms are not normally present in ethanol blended fuel tanks. If there is a bottom layer in the storage tank detected with the water paste designed for ethanol blends, it means that a phase separation has occurred.

For phase separation to occur, water has exceeded the tolerance level of about 0.5%, either by water coming into the tank or being delivered to the tank, which would not be meeting specification. Depending on the conditions, about 40 -60% of the ethanol will be pulled away from the gasoline by the water. It will also likely render the top gasoline portion out of specification due to lower octane rating.



If phase separation is detected using the proper water paste:

- Immediately stop sales from the tank.
- Determine the root cause of the problem, either water entering the tank or recent delivery was contaminated. Remove the water bottoms until only gasoline is being pumped. Dispose of these bottoms in accordance with state and federal laws and handle as flammable material.
- Carefully monitor the tank for new water bottoms. After the bottom layer is removed, test the remaining upper layer for ethanol content.
- Reintroduce good product after careful math calculations relative to tank contents, ethanol concentration and delivered volumes. A fortified ethanol/gasoline blend may be necessary for delivery to make the final concentration in the tank of 10% volume ethanol.
- Sales can resume when quality is confirmed. Keep the tank as full as possible for a few weeks monitoring for water bottoms daily.

Checklist for Retail Stations

Introducing ethanol fuel blends is a strategic move for many retailers. A thorough investigation and implementation plan is the key to a successful new fuel introduction. This checklist provides essential step by step information. Each of these steps should be evaluated thoroughly when preparing retail storage tanks and dispensers. In addition, station employees and transport drivers should be notified early in the process and trained on the properties of the new fuel blends. Each step should be documented as a reference for future considerations.

System Investigation and Preparation

- ✓ Notify necessary authorities of intentions to offer ethanol blended fuels. Information on conversion techniques and regulatory requirements for motor fuels may also be available.

- ✓ Verify tank material compatibility. Is tank older than 1981? Has tank been lined? What is the lining material? Document material compatibility with manufacturer certification.
Tank Manufacturer: _____ Year of Construction: _____
- ✓ Verify material of construction of submersible pumps and piping for ethanol compatibility. Document material compatibility with manufacturer certification.
- ✓ Verify compatibility of tank gauging system, including water and leak detection equipment. Document material compatibility with manufacturer certification.
- ✓ Verify compatibility of system overflow and spill containment system. Document material compatibility with manufacturer certification.
- ✓ Verify compatibility of dispensing system, this includes valves, hoses, nozzles, swivels, etc. Only use steel or nickel-plated nozzles and swivels. Document material compatibility with manufacturer certification.
- ✓ Review safety listing requirements and contact fire marshal or local authority having jurisdiction for system requirements and inspection.
- ✓ Investigate tank system for water problems and correct. Review history of water problems and initiate any necessary corrective action. Install rain caps on tank opening such as vent lines to prevent rain water entry.
- ✓ Check for tilted tanks. Inspect both tank openings (may need to remove tank gauging equipment).
- ✓ Inspect tank for cleanliness and residue. Clean tank and remove water bottom, if necessary.
- ✓ Verify a tight seal on fill caps and proper water run-off from man hole covers. Plug any holes in the fill line box.
- ✓ Verify safety equipment for effectiveness with ethanol fuel blends. Utilize Alcohol Resistant Film Forming Foam (AR-AFFF) or dry chemical that is effective.
- ✓ Modify inventory system for new fuel. Obtain fuel density and temperature compensation factors if necessary.
- ✓ Train employees on new fuel properties.
- ✓ Notify local authorities and emergency response personnel of ethanol fuel blend offering.
- ✓ Notify insurance carrier of new fuel blend.

Pre- Delivery

- ✓ Place on pump or dispenser with 10-micron ethanol compatible filter. Water slug filters are optional. Always remember; SAFETY FIRST - SHUT OFF BREAKER.
- ✓ Recheck for water bottoms and remove any present.
- ✓ Issue alcohol compatible paste. Discard any old incompatible pastes.
- ✓ Procure proper pump labels.
- ✓ Confirm any applicable accounting procedures.

First Delivery

- ✓ Check for water. Water bottoms must be removed before first delivery of ethanol blends.
- ✓ Follow normal delivery procedures and ensure that accurate tank gauge and dispenser readings are taken.
- ✓ Verify with transport driver correct product and compartment for correct tank.
- ✓ Pumps should be shut down during initial delivery.
- ✓ Purge lines from tanks to dispensers.
- ✓ Install required decals and if necessary change octane decals. Also repaint manhole covers to proper color code (for example, API color code).
- ✓ Fill tanks to at least 80% of capacity. Keep as full as possible for 7 to 10 days.
- ✓ Test for water bottoms at the beginning of each shift for the first 48 hours after initial delivery.

Post Delivery and Ongoing Maintenance

- ✓ Check for water introduction daily. No level is acceptable.
- ✓ Replace filters if pump / dispenser is running slow.
- ✓ Check pump calibration two weeks after initial load conversion

Handling and Receipt of Fuel Grade Ethanol Deliveries

Procedures for delivery of ethanol should encompass barge, rail, and transport truck. The following provides a brief overview of the considerations for each mode of delivery. In all cases, delivery equipment that has not been cleaned prior to use should conform to the recommendations for prior commodities hauled.

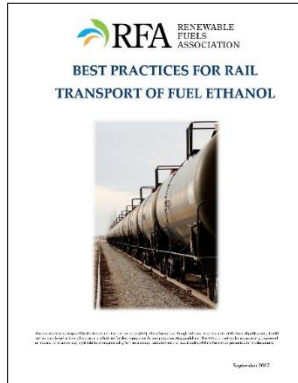
Ethanol is a flammable liquid. Handle with care. Avoid sparks and flames. It is advisable to wear safety goggles when handling ethanol. If ethanol contacts the body or face, flush with water. Use good ventilation. Avoid breathing vapors, which can cause headaches, dizziness, and nausea. If delivering to a customer terminal, you should contact the terminal manager to verify their unloading hours and procedures.

Barge

Procedures for receiving barge shipments vary from terminal to terminal depending on if an independent company is involved. Each company should conduct a review with the appropriate terminal manager to establish procedures that are specific to the terminal involved. Such a review should address safety, product integrity, assurance of full measure and minimizing any demurrage on equipment, as well as proper scheduling and inventory levels.

Rail

It is estimated that 70 % of U.S. Ethanol is transported to the marketplace by rail. Many terminals receive product by rail, typically in 30,000-gallon capacity rail tank cars.



RFA has a document publication “**Best Practices for Rail Transport of Fuel Ethanol**” covering the numerous regulatory requirements for persons handling a hazardous material for transportation in commerce found in Department of Transportation (DOT) Code of Federal Regulations (CFR) Title 49. The document is available here: <http://www.ethanolrfa.org/wp-content/uploads/2017/10/RFA-Best-Practices-for-Rail-Transport-of-Fuel-Ethanol-2017.pdf>

The document presents general guidelines for the ethanol industry to promote improved regulatory compliance and to communicate industry best practices for the continued safe transport of ethanol via rail. In general, there are certain procedures that should be followed.

Inspection: If there is any indication of damage, leakage, tampering, or theft, the delivering railroad and supplier should be notified to ascertain appropriate action. Suppliers should use numerically identified seals, and write the numbers on the bill of lading. It should be verified that these numbers correspond on arrival.

After the railcar is spotted:

1. Attach the grounding equipment to the frame of the railcar. Always Safety First.
2. Open the dome cover.
3. Check the main outlet valve to be certain that it is completely closed. This valve may be found on top near the dome or at the bottom of the railcar near the outlet. Most equipment will have an outlet cover that contains a small safety plug. Remove this safety plug and inspect. Any evidence of ethanol in the main outlet cover means the main outlet valve is or has been open. Do not remove main outlet cover until main valve is closed.

Off-loading:

1. Remove the main outlet cover and connect a tank car coupling assembly (45° elbow recommended) to the down leg. Use of a coupler such as an OPW 156-M allows reducers to be utilized with the elbow.
2. After proper connections are made, open the main outlet valve and start the off-loading pump.
3. Once the railcar is empty, close the main outlet valve. Close and secure the dome cover and the large outlet cover. Contact railroad when railcar is ready for return. Suppliers should provide a "Return Bill of Lading" to ensure prompt forwarding of the car.

The Use of the Non-Accidental Release (NAR) logo represents the Ethanol Industry's commitment to eliminating in transportation.



Transport Trucks

Another common method of ethanol delivery for many terminals is by transport truck (typically 8000 gallons). While equipment suitable for transportation of gasoline is acceptable for handling ethanol, a few extra precautionary steps should be taken.

1. Tank trucks or truck compartments must be dry before loading the denatured fuel ethanol product. Avoid contamination from water, leaded fuels such as racing gasoline or aviation gasoline, or diesel, etc.
2. Ground the truck during loading or off-loading operations. **Always Safety First.**
3. Hoses must be purged. It is best to have pumped ethanol or gasoline prior to pumping or have dedicated hoses.
4. Before the delivery to the receiving tank system, make certain tanks, lines and pump are clean and suitable for the job. Check receiving storage tank to assure delivery will fit and not overflow.
5. Reassure the grounding of the truck. Ethanol is a flammable liquid.
6. Use good ventilation and avoid breathing vapors.

Some acrylic sight glasses in tanker trucks may not be compatible with denatured ethanol. It may be necessary to switch to an acrylic sight glass with greater chemical resistance.



Prior hauls can be checked on the previous Bill of Lading. Acceptable prior hauls include ethanol, denatured fuel ethanol, gasoline and natural gasoline only. Equipment used to haul other commodities, such as diesel fuel, should not be used unless equipment has been properly cleaned. The extent of the cleaning will depend on the prior haul. Cleaning procedures are included in this document.

Pipeline

Fuel ethanol is now being shipped commercially on the Central Florida Pipeline (Kinder Morgan). Best practices development is necessary for commercial shipments of fuel grade ethanol and / or gasoline ethanol blends on existing fungible systems. Each pipeline has proprietary procedures, product codes, safety procedures, and shipping requirements. Therefore, as shipments of fuel ethanol by pipeline increase, it will be necessary for shippers to become familiar with the pipelines policies.

Ethanol is a Hazardous Material

Department of Transportation (DOT), Pipeline and Hazardous Materials Safety Administration (PHMSA) govern the requirements of classification, labeling and packaging of hazardous material transported in commerce.

For fuel ethanol to be fit for its ultimate end use as an ignitable fuel for spark ignition engines, it must also be classified as a flammable material. The DOT defines the chemical and physical characteristics of flammable liquids in 49 CFR §173.120. Typical fuel ethanol meeting ASTM D4806 Standard Specification for Denatured Fuel Ethanol for Blending with Gasolines for use as an Automotive Spark-Ignition Engine Fuel per DOT regulation is a Class 3 Flammable Liquid.

Class 3 Definitions (per 49 CFR §173.120)	
Flammable Liquid	“For the purpose of this subchapter, a flammable liquid (Class 3) means a liquid having a flash point of not more than 60°C (140°F), or any material in a liquid phase with a flash point at or above 37.8°C (100°F) that is intentionally heated and offered for transportation or transported at or above its flash point in a bulk packaging...”
Combustible Liquid	“For the purpose of this subchapter, a combustible liquid means any liquid that does not meet the definition of any other hazard class specified in this subchapter and has a flash point above 60°C (140°F) and below 93°C (200°F).”
Flash Point	“Flash point means the minimum temperature at which a liquid gives off vapors within a test vessel in sufficient concentration to form an ignitable mixture with air near the surface of the liquid...”

Also within the Class 3 designation there is a requirement to assign a packing group (§173.121). The packing group is assigned using the initial boiling point and its flash point of the flammable liquid.

Class 3 Packing Groups		
Packing Group	Flash Point (Closed Cup)	Initial Boiling Point
I		<=35°C (95°F)
II	<23°C (73°F)	>35°C (95°F)
III	>=23°C, <=60°C (140°F)	>35°C (95°F)

For Denatured Fuel Ethanol:

Initial Boiling Point (ASTM D86) 162.5°F (72.5°C) @ 760 mm Hg
Flash Point (ASTM D3278, Closed Cup) 19.4 °F (- 7°C)

For Ethanol (Undenatured):

Initial Boiling Point (ASTM D86) 173°F (78°C) @ 760 mm Hg
Flash Point (ASTM D3278, Closed Cup) 57 °F (14°C)

Ethanol typically is Packing Group II.

Flex Fuel (E85), depending on the hydrocarbon used and the ethanol concentration, should have a known initial boiling point determined to assure PGII prior to transport.

For additional safety information refer to the example **Safety Data Sheets** for Ethanol and Denatured Fuel Ethanol;

http://www.ethanolrfa.org/wp-content/uploads/2016/02/SDS-Example_Ethanol.pdf

http://www.ethanolrfa.org/wp-content/uploads/2016/02/SDS-Example_DFE.pdf

Placarding Recommendations

The RFA Plant and Employee Safety Committee previously provided this safety information to raise awareness of ethanol related transport and provide the industry guidance for proper shipping names and placarding for various ethanol blended fuels. Consistent labeling and marking of ethanol while in transit will help to improve the first response community’s ability to recognize ethanol shipments.



Improper placarding can result in serious fines and penalties that quickly stack up when occurring on multiple cars.

The following table lists the most commonly used placards by members of the RFA.

Ethanol Volume % Content in Blend (Exx)	Commodity	Identification Numbers
E100 (undenatured)	Ethanol or Ethyl alcohol or Ethanol solutions or Ethyl alcohol solutions	UN1170
E95 – E98 (ASTM D4806 denatured fuel ethanol)	Alcohols, n.o.s.	UN1987
E95 – E98 (Canadian transport)	Denatured alcohol	NA1987
E11 – E83 (ethanol fuel blends)	Ethanol and gasoline mixture or Ethanol and motor spirit mixture or Ethanol and petrol mixture <i>with more than 10% ethanol</i>	UN3475
E1 – E10 (retail fuels)	Gasoline	UN1203

Transportation Prior Commodities Recommendations

To ensure that ethanol remains on specification until delivery, transportation procedures are very important. Some transportation equipment used to deliver ethanol may have seen prior use delivering other commodities such as caustic soda, distillate, or other products that could contaminate the load.

Regardless of the prior commodity believed to be hauled, all transport equipment should be inspected before loading. If caustic soda or other unacceptable commodities are present, they should be rejected. Galvanized or epoxy coated surfaces should be investigated prior to transporting ethanol.

Prior commodities hauled that are acceptable in transport equipment include ethanol, fuel grade denatured ethanol, unleaded gasoline, unleaded RBOB, unleaded CARBOB, and natural gasoline.

Equipment used to haul other commodities should not be used unless the equipment has been properly cleaned. The extent of cleaning necessary depends on the prior commodity. In general, a **Group I Wash** is utilized for prior commodities such as vegetable oil, linseed oil, lube oils, or distillates as well as all grades of glycol require. A **Group III Strip** for Toluene, acetone, heavier alcohols, hexane, kerosene, and diesel fuel and a **Group IV Rinse** for Caustic soda and caustic potash, as well as sulfuric acid and calcium chloride. An excellent reference on tank cleaning is Dr. Verwey's Tank Cleaning Guide.

The following provides a general discussion of the cleaning procedures for transport trucks, rail cars, and barges.

Cleaning Instructions for Fuel Ethanol Truck Shipments

This example procedure is to be used as a guideline for the washing/cleaning of truck trailers. Typical trailers hauling ethanol-related products are constructed of stainless steel or aluminum. Trailers vary in the number of compartments, and some trailers have baffles in the compartments. The prior contents of an empty trailer will need to be discussed with the cleaning contractor before any work is initiated to cover any special cleaning requirements, special hazards of the prior cargo, and any other general concerns.

All safety procedures must be adhered to where applicable.

1. Complete a pre-wash inspection consisting of:
 - a. Check trailer for contaminants
 - b. Check for any rust or damage to trailer
 - c. Check previous Bill of Lading for prior content documenting.
2. Open top manway for a visual inspection of the compartment. Wing nuts should be opened slowly to allow pressure to exhaust before completely removing any wing nut.
 - a. If a visible heel of product exists, contact supervisor for correct disposition.

3. Insert spinner head or rotating nozzle-cleaning head into a compartment of the trailer. Multiple compartment trailers will need to repeat this procedure for each compartment being washed.
4. Clean the dome lid, vent caps, latches, and the rest of the crow's nest area with hot (>180 °F) water.
5. Remove all the hoses from the hose tubes and carefully remove the caps and plugs from the hoses. Allow any remaining product to drain into the wastewater collection.
6. Hook the hoses together and hook them to the discharge of the trailer placing the open end into the wastewater collection.
7. Open the product valve, and if so equipped, the safety valve. Make sure there is not any solid product blocking the discharge.
8. Start the wash cycle
 - a. Wash cycle must consist of a minimum of >180 °F water, heel rinse not recycled ~ 100 psi pressure wash.
 - b. A detergent is not recommended. If detergent is used, steps must be taken to verify the detergent has been completely rinsed.
 - c. Repeat rinse cycle if odor remains in compartment.
9. Clean the underside of the dome lid, and replace gasket as necessary.
10. After the wash cycle, the compartments, hoses, and pump must be dried by using forced air apparatus. Air must be oil-free.
11. Close the trailer, place hoses in compartments and replace discharge caps.
12. All entry points to the trailer should be sealed with tamper-evident, identifiable seals, and all seals accounted for on the wash ticket.
13. The wash ticket should include: the wash facility name and contact information, trailer information, date/ time of wash, duration of the wash cycle from start to finish, prior contents of trailer washed out, seals installed on cleaned trailer, and signature of person completing the wash.

Cleaning Instructions for Fuel Ethanol Rail Tank Car Shipments

This example procedure is to be used as a guideline for the washing/cleaning of rail tank cars. Typical rail tank cars hauling ethanol-related products are constructed of carbon steel. The prior contents of an empty rail tank car need to be discussed with the cleaning contractor before any work is initiated to cover any special cleaning requirements, special hazards of the prior cargo, and any other general concerns. All safety procedures must be adhered to where applicable. Air used for blowing compartment dry must be oil-free. Compartment product heel must not be rinsed into the wash water return cycle.

Inspection

1. Open manway for a visual inspection of the interior.
2. Inspect interior for cleanliness and any cleanliness deficiency. If performing an inspection only place seals on all vessel openings.

Strip

3. Remove the residual product out of the railcar with strong suction, which can include pumps, mechanical vacuums, etc. Be sure to open the eduction valves to release any product in the piping. Properly dispose of any residual material.
4. Hook up air hose to railcar piping and blow dry. Blow interior dry with air horns/movers, etc. If performing a product strip only, inspect railcar for cleanliness and any cleanliness deficiency, then place seals on all vessel openings.

Rinse

5. Drop the Butterworth or rotating nozzle-cleaning head in through the manway to fully rinse the interior. Water used in cleaning must be heated to >140 °F, and pressurized to approximately 100 psi, and not recycled.
6. Hook up air hose to railcar piping and blow completely dry. Blow interior completely dry with air horns/movers, etc.
7. If performing a product rinse only, inspect railcar for cleanliness and any cleanliness deficiency then place seals on all vessel openings.

Steam/Wash

8. If steam is necessary, place a steam hose with a distribution nozzle in each compartment for a minimum of 30 minutes. This process needs to make the shell interior of the railcar compartment sweat out the prior contents.
9. Apply detergent/cleaner/degreaser, whichever is necessary, to vessel.
10. Use the Butterworth or rotating nozzle cleaning head again through the manway to fully rinse the interior. Be sure to hook up the water source to eduction tube to rinse piping.
11. Hook up air hose to railcar piping and blow completely dry. Blow interior completely dry with air horns/movers, etc. If performing a product steam/wash only, inspect trailer for cleanliness and any deficiency, then place seals on all vessel openings.

Cleaning Instructions for Fuel Ethanol Barge Shipments

This example procedure is to be used as a guideline for the washing/cleaning of barges. Typical barges hauling ethanol are constructed of carbon steel. The prior contents of an empty barge need to be discussed with the cleaning contractor before any work is initiated to cover any special cleaning requirements, special hazards of the prior cargo, and any other general concerns. All safety procedures must be adhered to where applicable. Air used for blowing compartment dry must be oil-free.

Inspection

1. Open all manways and ullage/gauge holes for a visual inspection of the interior.
2. Inspect cargo piping, compartments, etc. for cleanliness and any cleanliness deficiency. If performing an inspection only, place seals in the following locations: one on each compartment manway, each stripping line cap, each ullage/gauge port, all cargo valves and blinds on both ends of header.

Strip

3. Remove the residual product out of the barge compartment with strong suction, which can include pumps, mechanical vacuums, etc. Be sure to open the compartment cargo valves to release any product in the cargo piping into the sumps. Properly dispose of any residual material.
4. Hook up air hose to barge piping and blow dry. Blow interior dry with air horns/movers, etc. If performing a product strip only, inspect cargo piping, compartments, etc. for cleanliness and any cleanliness deficiency. Place seals in the following locations: one on each component manway, each stripping line cap, each ullage/gauge port, all cargo valves, and blinds on both ends of header.

Rinse

5. Drop the Butterworth or rotating nozzle-cleaning head in through the ullage/gauge port or manway to fully rinse the compartments. Be sure to hook up the water source to cargo piping, pinching back the compartment valve to flood the piping. Rinse to compartment sumps. Water used in cleaning must be heated to >140 °F, and pressurized to approximately 100 psi, and not recycled.
6. Manually strip compartment floors and sumps with squeegees, stripping pumps, hoses, etc.
7. Hook up air hose to cargo piping and blow completely dry. Blow compartments, etc.
 - If performing a product rinse only, inspect cargo piping, compartments, etc. for cleanliness and any cleanliness deficiency. Place seals in the following locations: one on each compartment manway, each stripping line cap, each ullage/gauge port, all cargo valves, and blinds on both ends of header.

Steam/Wash

8. If steam is necessary, place a steam hose with a distribution nozzle in each compartment for a minimum of 30 minutes. The process needs to make the steel interior of the barge compartment sweat out the prior contents.
9. Apply detergent/cleaner/degreaser, whichever is necessary, to each compartment.
10. Use the Butterworth or rotating nozzle cleaning head again through the ullage/gauge port and/or manway to fully rinse the compartments. Be sure to hook up the water source cargo piping, pinching back the compartment valve to flood the piping. Be sure to fully rinse the compartments, with a minimum of 4500 gallons, to compartment sumps.
11. Manually strip compartment floors and sumps with squeegees, stripping pumps, hoses, etc.
12. Hook up air hose to cargo piping and blow completely dry. Blow compartments completely dry with air horns/movers, etc.

Emergency Response / Fire Fighting Procedures

To ensure the continued safety of ethanol industry employees, community neighbors, and the first responders tasked with confronting ethanol incidents, the Renewable Fuels Association has worked with partners to develop award winning Ethanol Emergency Response training programs.

Knowledge of fighting a gasoline fire is not enough to successfully fight a denatured fuel ethanol or an ethanol blended fuel fire.

Ethanol chemistry, being a polar solvent means it is soluble in water, makes it different than gasoline with choices of foam and firefighting techniques. Only alcohol resistant (AR-AFFF) foam is successful in most applications. Other types of foams commonly used will dissolve into the liquid rather than forming an extinguishing blanket.



RFA just completed the newly updated 2017 version of the Training Guide to Ethanol Emergency Response. The updated program has been approved by the American Chemical Council (ACC) and is now part of the TRANSCAER® National Training Tour. Additional information and the classroom portion (DVD or download) available here:

<http://www.ethanolresponse.com/>