



FUEL ETHANOL

INDUSTRY GUIDELINES, SPECIFICATIONS AND PROCEDURES

December 2010

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Introduction

The Renewable Fuels Association (RFA) is the national trade association for the U.S. fuel ethanol industry. Membership is comprised of numerous ethanol producers, both large and small, as well as suppliers to the industry and other interested parties. Founded in 1981, the RFA's primary objective is to promote public policy initiatives that increase the market for fuel grade ethanol produced from a variety of feedstocks including grains, agricultural wastes, and various biomass feedstock sources.

As the ethanol industry has grown, so too has the Renewable Fuels Association's areas of responsibility to its membership. Today the RFA not only focuses on legislative/regulatory and public policy type issues but also maintains several committees and task groups to address industry needs. These committees include a technical committee to address various technical issues and to assist with technical industry publications (such as this one). In addition, there are plant and employee safety, environmental, and cellulosic committees monitoring efforts in each of these respective areas. The technical committee also has an E85 task force to deal specifically with E85 issues. Other committees utilize standing and ad hoc task forces and work groups as well. These committees and task forces are comprised of representatives of our member companies, staff, and, when necessary, technical consultants and other interested stakeholders. The RFA provides support for educational outreach programs through its research and education arm, the Renewable Fuels Foundation.

The RFA promotes the use of fuel grade ethanol in all its legal applications¹. Fuel ethanol is blended in nearly all of the nation's gasoline. This includes not only conventional E10 (90% gasoline/10% ethanol), reformulated gasoline (RFG) and fuels that are considered primarily gasoline, but all developing markets such as E85 and mid-level ethanol fuel blends for use in flexible fuel vehicles (FFV's). This document focuses on the product quality and integrity of fuel grade ethanol and gasoline ethanol blends containing up to 10volume % (v%) ethanol. To promote the highest quality fuel possible, the Renewable Fuels Association has put together this information offering a discussion of specifications properties, and their importance, as well as other important related topics. It also advises the reader on important safety procedures and discusses other important documents such RFA's "Implementing an Effective Safety and Health Program for a Fuel Ethanol Facility" which list numerous OSHA guidelines and other information. The purpose of this document is to serve as a condensed technical reference for manufacturers and retailers of fuel grade ethanol and gasoline ethanol blends of up to 10v% ethanol (and blends where gasoline is the primary component), and other interested parties who need such information. All RFA Technical Publications and other RFA Reference materials are available on the RFA website at: www.ethanolrfa.org.

¹ As of October 13, 2010, EPA has approved a partial waiver for E15 use in Model Year 2007 and newer vehicles. RFA is currently assessing the technical and regulatory information in support of the use of E15. This document will be updated accordingly once the information has been assessed.

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Gasoline Ethanol Blends: Introduction

Whether ethanol is used in oxygenated fuels, reformulated gasoline, or conventional gasoline, there are certain technical parameters and issues that must be considered. Those items are covered in the following pages. Ethanol has been added to gasoline since the late 1970s. Since that time U.S. fuel grade ethanol production capacity has grown to over 12 billion gallons per year and production volumes continue to increase. Until the late 1980s ethanol's primary role in the fuels market was that of an octane enhancer and it was viewed as an environmentally sound alternative to the use of lead in gasoline. With its 112.5 blending octane value (R+M)/2, ethanol continues to be one of the most economic octane enhancers available to the refiner or fuel blender.

In the late 1980s some states began to use ethanol and other oxygenates in mandatory oxygenated fuel programs to reduce automobile tailpipe emissions of carbon monoxide (CO). Fuel oxygenates, such as ethanol, add chemical oxygen to the fuel, which promotes more complete combustion thereby lowering CO emissions. Hydrocarbon (HC) exhaust emissions are also often reduced, but to a lesser degree.

The success of these early oxygenated fuel programs led to a similar national program in the 1990 Clean Air Act Amendments. These amendments required that, beginning in November 1992, all CO non-attainment areas implement mandatory oxygenated fuel programs during certain winter months. The oxygenated fuels program has been tremendously successful. Most all of the original non-attainment areas have now achieved compliance, although some continue to require oxygenated fuels to maintain compliance.

The 1990 Clean Air Act Amendments also required that certain ozone non-attainment areas sell Reformulated Gasoline (RFG) beginning January 1, 1995. Other ozone non-attainment areas were allowed to "opt-in" to this program by request of the applicable state's governor. Areas of several states did "opt-in" to this program. In 2009, reformulated gasoline comprised 34% of all gasoline sold. The purpose of the RFG program is to reduce automobile emissions of volatile organic compounds (VOCs), and Oxides of Nitrogen (NOx), which are ozone precursors. The program is also designed to reduce toxic emissions (benzene, 1,3 butadiene, formaldehyde, acetaldehydes, and polycyclic organic matter), which pose high cancer risks.

Compliance with the RFG program is determined through the use of the "Complex Model".† This model, developed by EPA, is a set of mathematical equations that predict the change in emissions levels that occur from various alterations to gasoline. RFG was originally required to contain a minimum of 2.0 weight% (w%) oxygen (on average) and benzene is limited to 1.0 weight % maximum (on average). ††

† Compliance in the State of California is determined through the California Air Resources Board's (CARB) "Predictive Model," which differs somewhat from EPA's Complex Model.

†† The Energy Policy Act of 2005 signed into law in August 2005, removed the RFG oxygenate requirement in California immediately, with the rest of the nation to follow 270 days after enactment. Ethanol is the oxygenate most widely used in reformulated gasoline. This is in part due to the fact that use of the other oxygenate, MTBE, has been 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.

While some ethanol has been blended at the 5.7v% and 7.7v% level, it has historically been blended at the 10v% level to improve water tolerance, achieve best blend properties and to take maximum advantage of available tax credits. At the 10v% level (the highest level currently allowed under EPA regulations) ethanol would add approximately 3.5w% oxygen to the blend.

The requirement to use oxygen for RFG was replaced by a Renewable Fuels Standard (RFS) in the Energy Policy Act of 2005. The first RFS required an increasing amount of renewable transportation fuel use beginning with a 4.0 billion gallon per year usage requirement in 2006 and escalating to 7.5 billion gallons of annual usage requirement in 2012. While some of this requirement was met with Biodiesel, the greater majority of the requirement was met with ethanol due to its much wider availability.

In 2007, Congress passed, and the President signed, the Energy Independence and Security Act of 2007 (EISA 2007). The legislation is expected to dramatically increase the volumes of renewable fuels required under the RFS. EPA recently finalized regulations, which made minor modifications to the volumes in some categories. The Table below shows the RFS requirement for each year as established by EPA.

Year	Conventional Biofuel (bil. gal.)(1)	Advanced Biofuel (bil. gal.) (2)	Cellulosic Biofuel (bil. gal.)(3)	Biomass-based Diesel (bil. gal.)(4)	Total RFS
2008	9				9
2009	10.5	0.6			11.1
2010	12	.95	0.0065	1.15 *	12.95
2011	12.6	1.35	.25	.8	13.95
2012	13.2	2	.5	1	15.2
2013	13.8	2.75	1	a	16.55
2014	14.4	3.75	1.75	a	18.15
2015	15	5.5	3	a	20.5
2016	15	7.25	4.25	a	22.25
2017	15	9	5.5	a	24
2018	15	11	7	a	26
2019	15	13	8.5	a	28
2020	15	15	10.5	a	30
2021	15	18	13.5	a	33
2022	15	21	16	a	36
2023	b	b	b	b	b

* 2009/2010 Combined

a. To be determined by EPA through a future rulemaking but no less than 1.0 billion gallons

b. To be determined by EPA through a future rulemaking

Feedstock definitions for preceding table:

- (1) Conventional Biofuel is ethanol produced from corn, and other grains (also includes biodiesel from plant oils, although the majority is conventional ethanol).
- (2) 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.
- (3) 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.

Based on the RFS requirements, a great majority of the renewable fuel will be produced with feedstocks other than corn and row crops, further improving the already positive carbon footprint of corn based ethanol.

The ethanol industry will expand its production to meet the RFS requirements. In fact, in late 2010 over 88% of the gasoline sold in the U.S. already contained ethanol².

Specifications – Fuel Ethanol

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 is **ASTM D4806 Standard Specification for Denatured Fuel Ethanol for Blending with Gasoline for Use as Automotive Spark Ignition Engine Fuel**. The primary quality specifications contained in ASTM D4806-10a (current version) are as follows:

ASTM D4806

Property	Specification	ASTM Test Method
Ethanol volume %, min	92.1	D5501
Methanol, volume %, max	0.5	D5501
Solvent-washed gum, mg/100 ml max	5.0	D381
Water content, volume %, max	1.0	E203, E1064
Inorganic Chloride content, mass ppm (mg/L) max	10. (8)	D7319, D7328
Copper content, mg/kg, max	0.1	D1688
Acidity (as acetic acid CH ₃ COOH) mass% (mg/L), max	0.007 (56)	D1613
pHe	6.5 to 9.0	D6423
Sulfur, mass ppm, max	30.	D5453, D2622, D3120, D7039
Total Sulfate, mass ppm, max	4	D7318, D7319, D7328

² Jim Jordan and Associates Fuels Blendstock Report, November 26, 2010, Issue 392.

In addition to the properties covered in the above table ASTM D4806 contains a workmanship statement in Section 6, which states:

6.1 The denatured fuel ethanol shall be visually free of sediment and suspended matter. It shall be clear and bright at the ambient temperature, or 21° C, whichever is higher.

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

For a more detailed discussion of the importance of these properties, refer to a copy of the specification. Copies of ASTM D4806 and other ASTM specifications and standards may be obtained from:

ASTM
100 Barr Harbor Drive
W. Conshohocken, PA 19428-2959
Publication orders • phone (610) 832-9585 • fax (610) 832-9555
Website: <http://www.astm.org>

The Renewable Fuels Association recommends that all of its member companies adhere to ASTM specifications and guidelines. In addition, the RFA recommends that all its member companies adhere to the additional standards and practices cited below:

Filtering of Product: 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 microns nominal to control any suspended particulates or precipitates.

Corrosion Inhibitors: For more than 20 years, the Renewable Fuels Association (RFA) has recommended that fuel ethanol producers and importers add a corrosion inhibitor to fuel ethanol. The corrosion inhibitor should be included at a treat rate sufficient to provide corrosion protection comparable to that of other available motor fuels while protecting the transportation distribution system from corrosion concerns. RFA is transitioning the recommendation from a general guideline format to an evaluation protocol. This protocol should be considered a transition step as additional information becomes available on the corrosion potential of motor fuels, primarily fuel ethanol.

Prior to publication of this evaluation protocol, the RFA used less stringent criteria focused primarily on the NACE test. RFA then published a list of additives effective in meeting the previous criteria. To allow time for additive manufacturers to complete and submit new test data using this new evaluation protocol, additives previously listed were grandfathered as meeting the criteria of these guidelines for a period of one year from the date of the new evaluation protocol.

NOTE: While the RFA does not endorse any additive or recommend one over another, we have listed and on occasion have published references to corrosion inhibitors that have been demonstrated as sufficiently effective to be acceptable for use. We are discontinuing this type of publication and offering this new guidance for evaluating the effectiveness of corrosion inhibitors.

A full copy of the evaluation protocol can be found in Appendix A – Evaluation Protocol for Corrosion Inhibitors for Fuel Ethanol. The latest version of the evaluation protocol and grandfathered corrosion inhibitors can be found on the RFA website.

Denaturants: To avoid liquor tax implications outlined by the Alcohol and Tobacco Tax & Trade Bureau (TTB), most ethanol producers denature their ethanol with unleaded gasoline or natural gasoline (gas condensates). Because of various regulations and specifications on both fuel grade ethanol and the gasoline to which it is added, selection of the hydrocarbons with which to denature ethanol is very important. For instance, both the Federal Government and the State of California have placed sulfur limits on finished gasoline (30ppm and 10ppm respectively). It should also be noted that while many denaturants are allowed by the TTB, ASTM D4806 specifies the use of natural gasoline, gasoline blend stocks, or unleaded gasoline, as the denaturant. The denaturant level must meet the TTB minimum level specified and cannot exceed the D4806 maximum under IRS guidance. Only a certain portion of the denaturant qualifies for the Volumetric Ethanol Excise Tax Credit (VEETC) (see page 38).

As a result, ethanol producers 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, although no problems were experienced at the retail or consumer vehicle level. 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.

California and Federal Ethanol Requirements: Refiners are currently faced with the need to reduce the sulfur content of their gasoline to comply with federal and state regulations. As such, it is important that the sulfur content of ethanol be kept to very low levels. The Federal Government has adopted a requirement that denatured ethanol used in conventional or reformulated gasoline contains no more than 30 ppm sulfur beginning January 1, 2004. The State of California has adopted requirements that are more stringent and require a lower sulfur level, and that place limits on other compounds.

The California Denatured Ethanol Standards are recapped in the table on the following page.

**California Denatured Ethanol Standards
(In Addition to the Performance Requirements in ASTM D4806)**

Property	Specification Limit	Test Method
Sulfur, ppm max	10	ASTM D5453-93
Benzene, vol% max	0.06*	D5580-95 test results of a sample of the denaturant multiplied by 0.0476
Olefins, vol% max	0.05*	D6550-00 (modified) test results of a sample of the denaturant multiplied by 0.050 (5.00%)
Aromatics, vol% max	1.7*	D5580-95 test results of a sample of the denaturant multiplied by 0.05

* (exceptions may apply – see applicable section of ASTM D4806)

Additionally, the State of California places limits on the denaturants used to denature ethanol that is blended into their gasoline. These requirements are set forth in the following table. These are only applicable when ethanol is denatured at the maximum permitted level of 5.00v%. When used at lower denaturant levels higher concentrations of specified components are allowed.

For example, in the case of benzene the 1.1v% specified is based on 5% denaturant. At 2% denaturant the product could contain 2.5 times that amount, i.e. 2.75v% because it is only 40% of the maximum level and therefore, equates to the 1.1v% benzene level of a 5v% denaturant.

California Denaturant Standards

Property	Specification Limit	Test Method
Benzene, vol% max	1.1	D5580-95
Olefins, vol% max	10	D6550-00 (modified)
Aromatics, vol% max	35	D5580-95

Note that there are exceptions to the above California limits based on the properties of the gasoline to which the ethanol is added. Those producers who distribute ethanol for use in California must meet the above specifications unless otherwise agreed to by a refiner who indicates it can accept nonconforming ethanol for use in its gasoline and still meet the exception rules. If a producer intends to market under such an exception, they should conduct a detailed review of the applicable California regulations. Note that the California denaturant standards were set a number of years ago when the typical denaturant level was 5.0v%. Today fuel grade ethanol is denatured at the 2 to 2.5v% level.

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 Board of Directors 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.

The 2008 Farm Bill (Food Conservation and Energy Act of 2008 – Public Law 110-123) contained a provision that stipulates the full value of the Volumetric Ethanol Excise Tax Credit (VEETC) is only available to blenders when using fuel ethanol denatured at a maximum of 2%. As set forth in the guidance issued by the Internal Revenue Service (the “Service”) on December 31, 2008 (IRS Notice 2009-06), the Service interprets this to mean fuel ethanol with up to 2.5% denaturant. To comply with the denaturant range set forth in the IRS guidance, RFA recommends that all fuel ethanol be produced with an approved denaturant added between 1.96% and 2.5%.

Specifications – Gasoline Ethanol Blends

Ethanol addition to commercial gasoline was first allowed by EPA under the so called “Gasohol Waiver” that became effective on December 16, 1978. That waiver permits up to 10v% ethyl alcohol (ethanol). Although most blenders add 10v% “denatured ethanol,” it is permissible for the blend to contain up to 10v% ethanol plus denaturant.

Although the current blend level is 10v%, work is underway to assess higher blend levels such as E12 and E15. However, the current specifications are focused on E10 and that is the primary objective here. When blend levels higher than E10 (i.e. E10+) are permitted this document will be revised as necessary.

Ethanol will improve a number of properties of the gasoline to which it is added. These properties include octane, oxygen content, volatility, and water solubility. The gasoline related properties of fuel grade ethanol are compared to other available fuel oxygenates in the following table.

Typical Properties of Fuel Grade Ethanol

Gasoline and gasoline/ethanol blends are subject to a variety of federal and state laws and regulations. These include FTC octane posting requirements and EPA Phase II volatility regulations and state fuel quality regulations. In the few remaining carbon monoxide non-attainment areas, these fuels are subject to minimum and/or average oxygen content requirements. Gasolines sold in certain ozone non-attainment areas are required to be reformulated including stricter controls on VOC, NO_x, and toxic emissions profiles.

In addition to the above regulations, some states place certain requirements on fuels including such items as restrictions on Reid Vapor Pressure, distillation characteristics, and in some cases a minimum octane requirement for fuels that are designated as Super or Premium grades. Many states also require that marketers register each grade marketed with the appropriate state agency.

Note that property values may vary slightly depending on ethanol blend levels and the composition and density of the base gasoline to which ethanol is added.

Comparison of Typical Properties

Property	Denatured Ethanol	Hydrocarbon Gasoline
Oxygen wt.%	33.0	0
Blending Octane (R+M)2	112.5	87.0
Blending Research Octane	129.0	92.0
Blending Motor Octane	96.0	82.0
Blending Vapor Pressure, psi	17.0	7.0-15.0
Energy Content mbtu/gal	78.0-78.3(1)	112.0-115.0
Boiling Point °F	152-174	80 - 437
Density (lb./gal@ 60°F)	6.58	5.8-6.6
Legal Maximum vol% for gasoline blending	10.0% ³	NA

(1) Energy content is given as a range due to potential volume and energy content variations among approved denaturants.

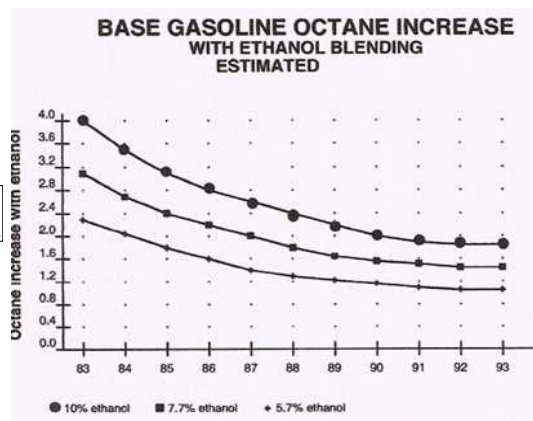
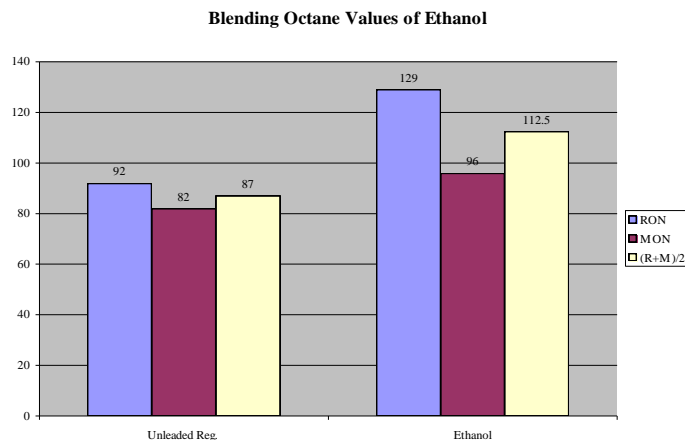
It should also be noted that the State of California, through its Air Resources Board (CARB), has several fuel restrictions that are different, and often more stringent, than federal requirements. Finally, most refiners and marketers require that, at a minimum, their spark ignition fuels meet some, or all, of the parameters set forth in ASTM D4814 "Standard Specification for Automotive Spark-Ignition Engine Fuel" (and where applicable, ASTM Research Report DO2:1347 Research Report on Reformulated Spark-Ignition Engine Fuel). Some refiners have standards that exceed those required by the ASTM specifications.

It would be impossible to try and include all of the state and federal requirements in a brief document such as this. Moreover, many of these laws can change in a short time frame. Those involved in gasoline/ethanol blend programs should check the most recent version of applicable laws and regulations to ensure that they are in compliance.

The purpose of the ASTM specification is to provide parameters so that gasoline and gasoline ethanol blends will perform satisfactorily in as wide a range of automotive spark-ignition engines as possible. It should be noted that ASTM standards and specifications are voluntary compliance standards. However, some states have adopted all, or a portion of, ASTM D4814 into law, making adherence mandatory in those states. Whether mandatory or voluntary, the Renewable Fuels Association believes adherence to the guidelines contained in ASTM D4814 is important in ensuring the delivery of a high quality spark ignition engine fuel. An overview of the primary fuel quality parameters follows:

Octane: Initially, ethanol was almost always added to gasoline at the 10 volume percent level. However, over the past fifteen years environmentally driven fuel specifications, and changes in motor fuel excise tax laws, have, in some cases, allowed ethanol blending at lower levels of 5.7 v% and 7.7 v%. The blending octane value of ethanol is compared to that of gasoline in the bar chart below. The octane response curves appear in the following line graph.

³ As of October 13, 2010, EPA has approved a partial waiver for E15 use in Model Year 2007 and newer vehicles. RFA is currently assessing the technical and regulatory information in support of the use of E15. This document will be updated accordingly once the information has been assessed.



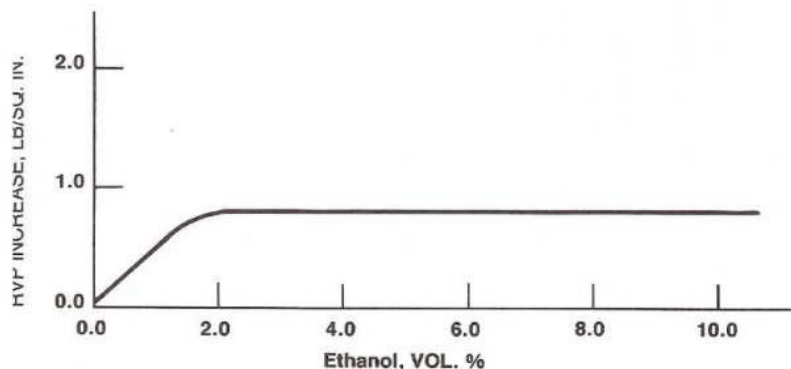
At the 10v% level ethanol will increase octane levels by approximately 2.0 to 3.0 octane numbers (R+M)/2. At the 7.7v% level the octane increase typically ranges from 1.5 to 2.5 octane numbers. At the 5.7v% level, the increase is typically 1.0 to 1.5 octane numbers. In the case of E12 the octane increase is typically 2.4 to 3.6 octane numbers and for E15 it is 3.0 to 4.5 octane numbers. The aforementioned increases are provided as general guidelines. The actual octane increase will vary depending on the octane and, to a lesser degree, the composition of the base fuel. Research Octane Number is increased to a greater degree than Motor Octane Number with increasing ethanol content. The typical blending octane values of ethanol are displayed in the Octane Increase response graph above.

Fuel Volatility: The addition of ethanol to gasoline will generally increase the volatility of the base fuel to which it is added. It will increase the vapor pressure and decrease the 50% distillation point (T50). Because of its effect on T50 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: 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 Phase II 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 9-10v% ethanol are allowed to be up to 1.0 psi higher in vapor pressure. Exclusive of this control period, there are currently no federal restrictions on the vapor pressure of gasoline/ethanol blends except for reformulated gasoline. Reformulated gasoline containing ethanol must meet the applicable RFG requirements for the RFG program.

During the portion of the year when no federal volatility restrictions apply to gasoline, it is still recommended that the vapor pressure increase for gasoline/ethanol blends be no more than 1.0 psi higher than the all-hydrocarbon base fuel. Unless other more volatile blending components are being used, the addition of ethanol should not create a vapor pressure increase above 1.0 psi in conventional gasoline, and in fact the increase is often below 1.0 psi.

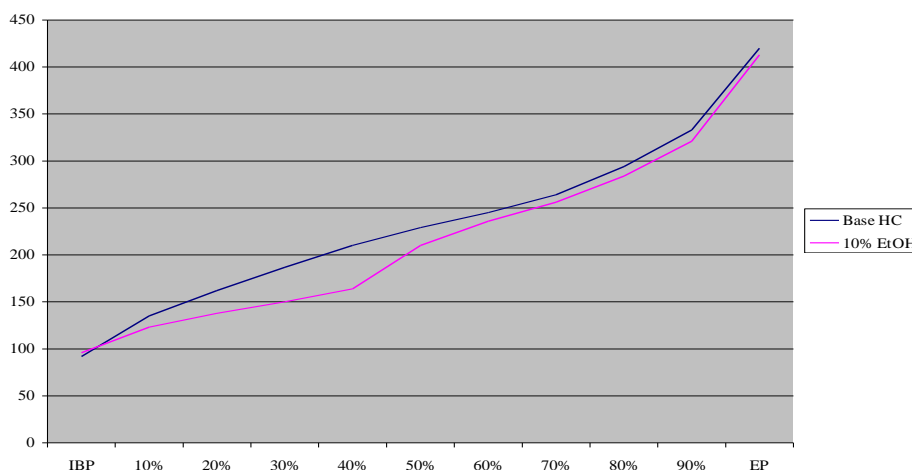
Vapor Pressure Impact of Ethanol



The vapor pressure of a fuel is a measure of its "front end" volatility. Fuels with excessively high vapor pressure may contribute to hot driveability/hot restart problems such as vapor lock. Fuels of too low a volatility may contribute to poor cold starts (long cranking time) and poor warm up performance due to too little vapor being formed.

Distillation Properties: ASTM D4814 also provides guidance on distillation characteristics. Table 1 of D4814 provides a maximum temperature at which 10v%, 90v%, and 100v% (T_{10} , T_{90} , and end point) of a gasoline sample should evaporate. The specification also provides a temperature range at which 50% (T_{50}) of the sample should evaporate. This range provides a minimum of 150°F - 170°F and a maximum of 230°-250°F depending on the volatility class. Ethanol will depress the T_{50} point of the gasoline to which it is added. As an example, adding 10v% ethanol to a gasoline with a T_{50} of 210°F can result in a blend with a T_{50} of 180°-185°F.

Ethanol Effect on Distillation Curve



The T_{50} would be about the same for E15 but tests have shown that E15 would also lower the T_{60} and T_{70} more than E10. Studies have shown that later model fuel injected cars are less sensitive to gasolines with T_{50} as low as 150°F. Some older vehicles may be more sensitive to low T_{50} gasolines although this would apply predominantly in warm weather. The lower T_{50} standard of

150°F allowed by ASTM applies only to cold weather volatility classes of gasoline. While some states may not, in every case, require adherence to the aforementioned 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 formula:

$$DI = (1.5 \times T_{10}) + (3.0 \times T_{50}) + T_{90} + (2.4^{\circ}F \times v\% \text{ ethanol})$$

DI = driveability index
T₁₀ = distillation temperature at 10% evaporated
T₅₀ = distillation temperature at 50% evaporated
T₉₀ = distillation temperature at 90% evaporated
v% = volume percent ethanol

The DI is specified as a maximum for each volatility class ranging from 1250 for volatility class AA and A down to 1200 for volatility class E. These numbers are based on the Fahrenheit Scale. Generally speaking, 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: The ASTM D4814 Standard also specifies "Vapor Lock Protection Class Requirements" in Table 3 of the standard specification. The six vapor lock protection classes are based on the Vapor/Liquid Ratio (V/L) of the fuel.

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 D 2533." The tendency of a fuel to cause vapor lock, as evidenced by loss of power during full throttle acceleration, is indicated by the gasoline temperature at a V/L of approximately 20 (TV/L20). Therefore, some refiners and petroleum companies also utilize a specification for Vapor-Liquid Ratio. More volatile fuels require lower temperatures to achieve specified ratios. More detailed information on V/L is contained in ASTM D4814. Currently there is some debate about the accuracy of TV/L20 in predicting hot driveability problems at higher altitudes. Ongoing tests are being conducted to determine the accuracy of TV/L20 in predicting hot driveability problems in modern vehicles at higher altitudes.

Oxygen Content: Ethanol is usually blended at 10v% but is sometimes blended at 7.7v% in those former CO non-attainment areas that continue to require oxygenated fuel programs (at 2.7w% oxygen) as part of their compliance maintenance measures. When oxygenates were required in reformulated gasoline (prior to 2006) it was sometimes blended at 5.7v% to meet the 2.0w% oxygen requirement. Today most RFG contains ethanol but usually at the 10v% level. Denatured ethanol contains approximately 33.0w% oxygen. Due to differences in gasoline density compared to ethanol density, the most popular blend ratios yield the following approximate oxygen contents.

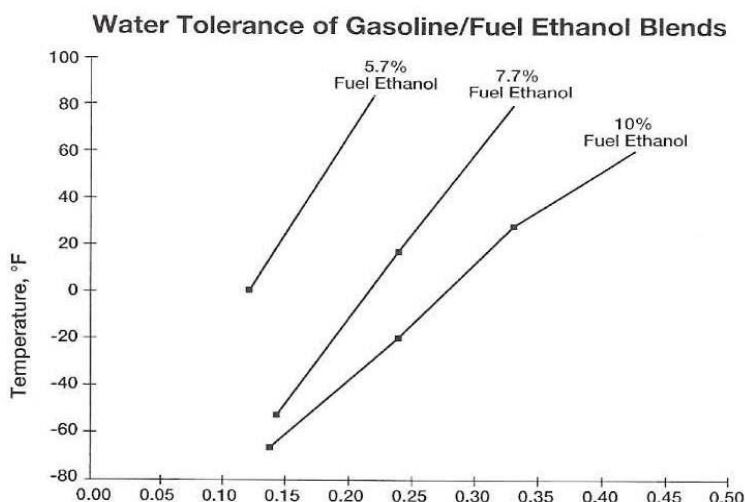
Volume % Denatured Ethanol and Corresponding Fuel Oxygen Content

5.7% by volume	2.00% by weight
7.7 % by volume	2.70% by weight
10.0% by volume.....	3.50% by weight
12% by volume.....	4.20% by weight
15% by volume.....	5.25% by weight
20% by volume.....	7.00% by weight

The final oxygen content of a gasoline/ethanol blend is affected by the content of the ethanol and its denaturant level and moisture content, as well as the Specific Gravity (relative density) of the gasoline to which it is being added. The EPA has issued guidance documents on calculating oxygen content. It should also be noted that when blending gasoline/ethanol blends under the "gasohol waiver" an oxygenate free base gasoline must be used. EPA has, however, ruled that gasolines containing up to 2v% MTBE, due to inadvertent commingling or contamination, may be used as the base fuel for gasoline/ethanol blends containing up to 10v% ethanol. MTBE is now banned in over 25 states and has largely been eliminated from the gasoline pool.

NOTE: Some states such as California may have rules and regulations, specific to their state, which deviate from Clean Air Act Amendments and EPA guidelines.

Water Tolerance: Ethanol has an affinity for water. For instance, it is not necessary to add any gas line antifreeze to a gasoline/ ethanol blend since the ethanol will absorb trace amounts of water and pull it through the fuel system. Likewise, trace amounts of water in underground storage tanks are eliminated via the same mechanism. In normal operations ethanol protects against the buildup of water in vehicle tanks and underground storage tanks.



Under normal conditions ethanol blends have the beneficial effect of entraining and removing small amounts of moisture from retail storage tanks and vehicle fuel systems. However, ethanol's affinity for water also necessitates that steps be taken to eliminate excessive moisture from the fuel

storage and delivery system. If a gasoline/ethanol blend encounters excessive moisture contamination, the water can pull the ethanol out of the blend resulting in tank bottoms comprised of water, ethanol, and some hydrocarbon content. The amount of water tolerated by a gasoline/ethanol blend is dependent upon the product temperature: the lower the temperature, the lower the water tolerance. For instance, at 60°F, a 10v% ethanol blend will tolerate approximately 0.5% water. However at 10°F that tolerance is reduced to approximately 0.3%.

Gasoline Detergents: Gasoline ethanol blends, like other gasolines are subject to EPA's gasoline detergency requirements. The RFA recommends that gasoline ethanol blends contain the appropriate detergent/deposit control additive at levels to provide detergency performance comparable to other gasolines. Prior to EPA detergent requirements, the RFA Technical Committee routinely reviewed available additives to determine their effectiveness and provided recommendations. Today, EPA regulations require that the additives be registered with EPA and documentation of their effectiveness must be available for EPA review. Because of this, the RFA no longer makes recommendations on such additives for E10 blends. The blender should, however, be sure they are utilizing a properly registered detergent/deposit control additive that is in compliance with EPA regulations.

Corrosion Inhibitors: Fuel grade ethanol routinely contains corrosion inhibitors in accordance with RFA recommendations (see page 7).

Retail Conversion Procedures

As mentioned, ethanol is infinitely soluble in water and the sensitivity of gasoline/ethanol blends to water requires certain precautionary steps to prevent phase separation. These steps include drying out wholesale storage tanks and proper preparation of retail storage tanks and dispensers. In addition, transport drivers should exercise proper precautions when making deliveries.

The Renewable Fuels Association and its member companies intend to prepare a more detailed guide on all aspects of properly implementing and maintaining a gasoline/ethanol blend program. The guide will be available in the future. It will provide more expanded guidance. We have excerpted the check lists that will conclude each chapter for Retail Unit procedures, Terminal Operations, and Transportation Issues and included them on the following pages.

Retail Pump Labeling: The Federal Trade Commission, 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." Retail pump labels for ethanol blended fuels are available from the Renewable Fuels Association at no charge by contacting the Market Development team at info@ethanolrfa.org or (402) 391-1930.

Converting to Ethanol Fuel Blends: A 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 hopes to provide 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 on 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 state authorities of intentions to offer ethanol blended fuels. Many times there is a registration requirement for offering E85. Information on conversion techniques and regulatory requirements for motor fuels may also be available.
- Verify tank material compatibility.
Tank Manufacturer: _____
Year of Construction: _____
Is tank older than 1981? Has tank been lined? What is the lining material?
Document material compatibility with manufacturer certification.
- 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:

- Equip pump or dispenser with 10 micron ethanol compatible filter. Water slug filters are optional. 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

(Printed Name, Signature)

(Date)

NOTE: Be sure that you are using a water finder paste suitable for use with ethanol blends. Two suppliers of such pastes are:

SAR-GEL Water Paste
Sartomer USA, Inc.
502 Thomas Jones Way
Exton, PA 19341
(610) 363-4100
www.sartomer.com/sargel

Gasoil All Purpose Water Finding Paste
Gasoil Chemicals
4520 Richmond Road
Cleveland, OH 44128
(216) 464-6440
www.gsasupplyco.com

Conversion Procedures for Terminal/Ethanol Storage

There are a number of steps that should be taken to properly prepare a terminal storage tank for storing denatured fuel grade ethanol. These include the following:

Tankage: Obviously, the tank needs to be sized to volume requirements and the size and frequency of anticipated deliveries. Tank design should be a fixed roof with a floating internal cover. 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.

Fuel grade ethanol tankage should be diked separately from petroleum product storage tanks. This is necessary to prevent storm water runoff from the separate products from mingling. 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 (AHJ) 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.

Material Compatibility: Obviously, ethanol compatible materials should be used on all equipment that is modified or altered.

Terminal Personnel - Orientation Check List

Once all changes are made, terminal personnel should be apprised of the proper operation of new equipment and handling of new products.

- Equipment orientation
- Cover new or modified procedures (accounting, etc.)
- Cover safety and firefighting information
- Issue/post Material Safety Data Sheet (MSDS) (available from your 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 - Orientation Check List

Transportation personnel should also be advised of product changes and any related procedures as provided in the following check list.

Inbound Ethanol Delivery

- Cover product delivery procedures
- Cover applicable firefighting & safety procedures
- Issue Material Safety Data Sheet (MSDS) (available from your 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

Materials Compatibility Information

Most materials used in retail gasoline dispensing systems are totally compatible with gasoline/ethanol blends. Equipment used to dispense denatured ethanol (e.g. terminal meters) should be designed to withstand the solvent action of ethanol. The following discusses each major equipment category.

Tanks

The mild steel used in finished product terminal tanks is compatible with both ethanol and

gasoline/ethanol blends. Underground tanks at the retail facility may be made of mild steel or fiberglass reinforced plastic. Both steel tanks and fiberglass tanks (manufactured after 1981) designed for gasoline storage are compatible with gasoline/ethanol blends containing up to ten volume percent ethanol. The RFA has letters on file to this effect from both Fluid Containment (formerly Owens Corning Fiberglass) and Xerxes Corporation, the two major fiberglass tank manufacturers. Some higher blend concentrations may require a tank constructed of a special chemical resin.

The interior of some older steel tanks may have been lined to prevent small leaks and extend useful life. Most of those lining materials are compatible with gasoline/ethanol blends but some are not. In particular general epoxy or polyester resin based materials used in the late 1970s and earlier 1980s are not compatible with gasoline/ethanol blends. If a tank has been relined the manufacturer of the lining material should be consulted.

Pumps

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

Pipe Sealants

For pipes carrying neat ethanol, teflon tape is the best sealant. For retail facilities dispensing gasoline/ethanol blends, alcohol based pipe sealant should be avoided. Suitable sealants include:

- Scotch Brand Pipe Sealant with Teflon, No. 4178
- Loctite Pipe Sealant with Teflon, No. 592
- Permatex Seals Pipes, No. 804

Meters

Meters for neat ethanol should have internal o-rings and seals designed to withstand ethanol's solvent action. Consult your meter manufacturer for recommendations. Gasoline meters have been used for gasoline/ethanol blends with no accelerated wear or leakage problems. When first converting to an ethanol program, it is advisable to recalibrate the meters after 10-14 days to ensure that the change of product has not caused any meters to malfunction.

Filters

Filters and screens used at both the terminal and retail facility are compatible with gasoline/ethanol blends. A 10 micron (nominal) filter is recommended for the retail dispenser. A #40 mesh screen in the transfer line is recommended for terminal operations. When stations are first converted to gasoline/ethanol blends the solvent action of the ethanol may loosen built up lacquer on the tank walls and sediment in the bottom of the tank. This may result in the need for a filter change shortly after conversion. Once the system is clean, filter life will be similar to that when using any gasoline.

Nozzles

Gasoline/ethanol blends have been dispensed through all major brands of nozzles for a number of years without problem. As with hose manufacturers, the nozzle manufacturers have indicated their products are suitable for use with gasoline/ethanol blends containing up to 10v% ethanol.

Other Materials

There are a number of materials that may be suitable for use with ethanol and gasoline/ethanol blends. However, such suitability may depend on the application and it is therefore difficult to generalize. The table on the following page lists various recommended and non-recommended materials.

Compatibility of Commonly Used Materials With Denatured Fuel Ethanol and Gasoline Ethanol Blends

Recommended

Not Recommended

Metals

Aluminum (note 1)

Zinc-galvanized (ethanol only)

Carbon steel

Stainless Steel

Bronze

Elastomers

EPDM

Buna-N® (hoses & gaskets)

Buna-N (seals only)

Butyl 11®

Neoprene (seals only)

Fluorosilicone (consult manufacturer)

Urethane rubber

Fluorel

Nitrite NBR

Neoprene (hoses & gaskets)

Nitrite, Hyd, HNBR

Polysulfide rubber

Natural rubber (ethanol only)

Viton®

Viton® B+ Specific Formulation

Viton® GF-S

Viton® GFLT

Viton® Extreme RTP

Simriz®

Kalrez®

Chemraz®

Polymers

Acetal

Polyurethane (note 2)

Nylon

Alcohol-based pipe dope (recently applied) (note 1)

Polypropylene

Teflon® (consult manufacturer)

Fiberglass reinforced plastic (note 2)

(1) The information on materials listed in this table may not be applicable to Ed85. For specific recommendations on materials compatibility with Ed85, see RFA publication "E85 Fuel Ethanol Industry Guidelines, Specifications and Procedures." Also aluminum is not recommended for continual contact applications but is suitable for intermittent contact such as transport equipment.

(2) The manufacturer of the specific material should be consulted.

Handling and Receipt of Fuel Grade Ethanol Deliveries

Inbound Ethanol Deliveries

Procedures for delivery of inbound 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. (See page 11)

Barge

Procedures for receiving barge shipments vary from terminal to terminal depending on whether or not 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

Many terminals receive product by rail, typically in up to 29,000-30,000 gallon capacity railcars. Whether the equipment belongs to the customer or the supplier, 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 tank car has been spotted, the grounding equipment should be affixed to the tankcar frame. You may then open the dome cover. Next check the main outlet valve, which should be completely closed. (Valve handles are located either on top near the dome, or at the bottom of the car near the outlet.) Most equipment will be equipped with an outlet cover, which contains a small safety plug. Once the main valve is closed, you can remove the safety plug. Any evidence of ethanol in the main outlet cover indicates the valve is open or has been open.

Unloading: 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. After proper connections are made, open the main outlet valve and engage your unloading pump. Once the tank car is unloaded, close the main outlet valve, close and secure the dome cover and the large outlet cover. Advise railroad when empty car is ready for routing. Suppliers should provide a "Return Bill of Lading" to ensure prompt forwarding of the car. Caution - ethanol is a flammable liquid. Handle with the same safety precautions as gasoline. Avoid sparks and flames. It is advisable to wear safety goggles when unloading ethanol. If ethanol contacts the body or face, flush with water. See Material Safety Data Sheet (MSDS).

Transport Trucks

The most common method of ethanol delivery for a number of terminals is by transport truck (typically 7800-8200 gallons). While equipment suitable for transportation of gasoline is

acceptable for handling ethanol, a few extra precautionary steps should be taken. Truck compartment(s) should be clean and dry before loading. Avoid contamination from water, leaded fuels such as racing gasoline/AV gas, or diesel, etc. Always ground the truck during loading and unloading operations. Hoses must be purged. It is best to have pumped ethanol or unleaded gasoline prior to pumping ethanol to avoid contamination. Before the first delivery to the ethanol storage system, make certain that the lines and pump are clean. 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.

Ethanol is a flammable liquid. Handle with the same safety precautions as gasoline. 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, because they can cause headaches, dizziness, and nausea. If you are delivering to a terminal not within your own control, you should contact the terminal manager to verify their unloading hours and procedures. Fuel Grade Ethanol (E95 - E99) should be placarded as NA 1987 / UN 1987 with the preferred proper shipping name of either: Denatured Alcohol, NA 1987 or Alcohol N.O.S., UN 1987.

Low level ethanol/ gasoline blends (i.e., E1 to E10) should be placarded as UN 1203 with the preferred proper shipping name of Gasohol, UN 1203 or Gasoline, UN 1203.

The RFA Plant and Employee Safety Committee suggests the following as guidelines for manufacturers identifying ethanol blended fuels for shipments:

Ethanol Concentration	Preferred Proper Shipping Name
E1 to E10	Gasohol, UN 1203 or Gasoline, UN 1203
E11 to E94	Ethanol and Gasoline mixture, UN 3475
E95 to E99	Denatured Alcohol, NA 1987 or Alcohols n.o.s., UN 1987
E100	Ethanol, UN 1170 or Ethyl Alcohol, UN 1170

Note that for fuel grade ethanol (E95 – E99) the hazmat description should lead first responders to Guide 127 of the Emergency Response Handbook. This will ensure use of the proper fire fighting foam (AR-AFFF).

The Use of the NAR logo represents the Ethanol Industry’s commitment to eliminating Non Accidental Releases in transportation.



Pipeline: Fuel ethanol is now being shipped commercially on the Central Florida Pipeline (Kinder Morgan). A great deal of research is in progress to determine the best practices for commercial shipments of fuel grade ethanol and / or gasoline ethanol blends on existing fungible

systems. Magellan Midstream Partners has proposed a dedicated fuel ethanol pipeline that would originate in the Midwest and deliver product to the East Coast. 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 pipeline policies of any pipeline they may use.

Transportation Equipment and Prior Commodities Recommendations

To ensure that ethanol remains on specification until delivery, transportation procedures are very important.

Transportation Equipment: 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. The RFA has been advised that some of our member companies have, upon inspection, had to reject barges (that had supposedly been properly cleaned) due to the presence of caustic soda.

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

All Equipment: Prior commodities that are acceptable in barges, rail cars, and trucks 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, prior commodities such as vegetable oil, linseed oil, lube oils, or distillates as well as all grades of glycol require a **Group I Wash**. Toluene, acetone, heavier alcohols, hexane, kerosene, and diesel fuel require a **Group III Strip**. Caustic soda and caustic potash, as well as sulfuric acid and calcium chloride, require a **Group IV Rinse**. Again **all barges**, regardless of prior commodities, should be inspected. An excellent reference on tank cleaning is Dr. Verwey's Tank Cleaning Guide, 7th Edition available from:

Silliker Laboratories Group, Inc.
900 Maple Road, Suite 1W
Homewood, IL 60430
Phone: 708-957-7878
<http://www.silliker.com/drverwey/html/silliker/tankcleaningguide.php>

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

Cleaning Instructions for Fuel Grade Ethanol Truck Shipments

This 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 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 up 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 Grade Ethanol Railcar Shipments

This procedure is to be used as a guideline for the washing/cleaning of railcars. Typical railcars hauling ethanol-related products are constructed of carbon steel. The prior contents of an empty

railcar 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.
If performing a product rinse only, inspect railcar for cleanliness and any cleanliness deficiency then place seals on all vessel openings.

Steam/Wash

7. 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.
8. Apply detergent/cleaner/degreaser, whichever is necessary, to vessel.
9. 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.
10. 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 Grade Ethanol Barge Shipments

This 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 in order 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.

* 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 in order 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.

Ethanol Temperature Correction Factors

Fuel grade ethanol is typically sold on a net gallon basis, i.e., temperature corrected to 60°F. This is also standard procedure for most petroleum products. However, fuel grade ethanol has a different coefficient of expansion than petroleum products and requires different conversion tables than gasoline.

The coefficient of expansion for fuel grade ethanol is 0.00063/F°. This corresponds approximately to API temperature correction table 6B (General Products) for API Gravity 51.5°. The following table provides the temperature correction factors to convert a fuel grade ethanol volume to 60°F.

Fuel Ethanol
Table for Correction of Volume to 60°F

Temp °F	Factor	Temp °F	Factor	Temp °F	Factor
-10	1.0441	28	1.0202	66	0.9962
-9	1.0435	29	1.0195	67	0.9956
-8	1.0428	30	1.0189	68	0.9950
-7	1.0422	31	1.0183	69	0.9943
-6	1.0416	32	1.0176	70	0.9937
-5	1.0409	33	1.0170	71	0.9931
-4	1.0403	34	1.0164	72	0.9924
-3	1.0397	35	1.0157	73	0.9918
-2	1.0391	36	1.0151	74	0.9912
-1	1.0384	37	1.0145	75	0.9905
0	1.0378	38	1.0139	76	0.9899
1	1.0372	39	1.0132	77	0.9893
2	1.0365	40	1.0126	78	0.9887
3	1.0359	41	1.0120	79	0.9880
4	1.0353	42	1.0113	80	0.9874
5	1.0346	43	1.0107	81	0.9868
6	1.0340	44	1.0101	82	0.9861
7	1.0334	45	1.0094	83	0.9855
8	1.0328	46	1.0088	84	0.9849
9	1.0321	47	1.0082	85	0.9843
10	1.0315	48	1.0076	86	0.9836
11	1.0309	49	1.0069	87	0.9830
12	1.0302	50	1.0063	88	0.9824
13	1.0296	51	1.0057	89	0.9817
14	1.0290	52	1.0050	90	0.9811
15	1.0283	53	1.0044	91	0.9805
16	1.0277	54	1.0038	92	0.9798
17	1.0271	55	1.0031	93	0.9792
18	1.0265	56	1.0025	94	0.9786
19	1.0258	57	1.0019	95	0.9779
20	1.0252	58	1.0013	96	0.9773
21	1.0246	59	1.0006	97	0.9767
22	1.0239	60	1.0000	98	0.9761
23	1.0233	61	0.9994	99	0.9754
24	1.0227	62	0.9987	100	0.9748
25	1.0221	63	0.9981	101	0.9742
26	1.0214	64	0.9975		
27	1.0208	65	0.9968		

Gross gallons can be adjusted to net gallons at 60°F with the preceding table. For instance, if 8,000 gross gallons with a temperature of 76°F were converted to net gallons, this would equate to

7,919.2 net gallons as follows:

$$8,000 \times 0.9899 = 7919.2$$

Tables may vary slightly among ethanol producers. This is because of potential small differences in gravity as well as the possible rounding of the coefficient of expansion (e.g., 0.0006 instead of 0.00063). The applicable ethanol supplier should be consulted to obtain copies of their temperature correction table and to determine if they differ from the previous table.

EPA Guidance – Volume Correction for RINs: In the case of Renewable Identification Numbers (RINs) there are also directions for standardizing volume calculations. The EPA guideline for standardizing volumes for RINs under the Renewable Fuel Standard 2 (RFS2, 40CFR80.1126) state:

Standardization of volumes. In determining the standardized volume of a batch of renewable fuel for purposes of generating RINs under this paragraph (f), the batch volumes shall be adjusted to a standard temperature of 60°F.

- (i) For ethanol, the following formula shall be used:

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

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.

Quality Assurance and Test Methods

There are several test methods that can be employed to ensure the quality and purity of your ethanol supply and gasoline/ethanol blends. Some are relatively simple field tests while others are more sophisticated, requiring laboratory equipment and specialized training. The following provides an overview of the more common test methods.

Ethanol

Visual Clarity: Ethanol, when viewed in a clear, glass container should be clear (clear to very pale straw color) and visibly free of any suspended particles. This is a very simple though somewhat subjective test.

API Gravity/Specific Gravity: The RFA Technical Committee has been advised that some terminals will also test for API Gravity. Among companies utilizing this test, of which we are aware, the specified API Gravity Range is API 46° to 49°. This corresponds to a Relative Density (Specific Gravity) range of 0.7972 to 0.7839 (the Specific Gravity / Relative Density scale is inverse to the API Gravity scale. This should not be a problem for properly denatured, uncontaminated ethanol that was at least 197 proof before denaturing. Note that terminals using API Gravity as a quality control procedure consider API Gravity outside the above specified range

as necessitating further examination. API Gravity outside the range is generally not used as a sole reason to reject a load.

Finally some terminals are utilizing instruments that are not temperature compensated to account for the reproducibility of the test method. Consequently terminals will usually allow +/- 0.6 API units for test variability. For those who may not be familiar with the API Gravity/Specific Gravity conversion formulas they are provided below:

For converting API gravity to Specific gravity at 60°F

$$\frac{141.5}{(131.5 + \text{API}^\circ)} = \text{Specific Gravity}$$

For converting specific gravity to API gravity at 60°

$$\frac{141.5}{\text{specific gravity}} - 131.5 = \text{API Gravity}$$

Note that at the current time, RFA does not offer a recommended practice guideline for API Gravity or Specific Gravity. These issues, if applicable, are currently addressed between customer and supplier.

Obsolete Field Tests: Over the years other test methods that have been used have become obsolete. These include a refractive index test method to determine purity and an “Apparent Proof” test which uses a proof hydrometer to determine a density in “apparent proof” units. The test methods are available on the Technical Committee’s page of the RFA’s website.

Ethanol Content: ASTM Test Method D5501 Standard Test Method for Determination of Ethanol Content of Denatured Fuel Ethanol By Gas Chromatography can be used to determine ethanol content. Copies of the ASTM test procedure can be obtained from ASTM at the address listed on page 8.

Most independent laboratories are capable of performing this test. You may also wish to consult ASTM D4806 for a list of other relevant laboratory test procedures for fuel grade ethanol.

pHe Level: Work by the auto manufacturers and others has indicated that low pHe ethanol (in both E10 and E85 blends) can contribute to accelerated corrosion of certain fuel system parts. While the ASTM Standards limit total acidity, as acetic acid, to 0.007 mass percent (56 mg/L), this standard is not always sufficient to limit more aggressive sulfuric based acids. Ethanol meeting the ASTM acidity standard may still be of low pHe.

ASTM has developed a test method to monitor "pHe". This test method measures acid strength and reports a pHe value. (NOTE: A pHe value is not directly comparable to pH values for water solutions.) The ASTM pHe test method is designated and titled as: ASTM Designation: D6423 Standard Method for Determination of pHe of Ethanol, Denatured Fuel Ethanol, and Fuel Ethanol (Ed75-Ed-85). As with the other ASTM standards mentioned in this document, ASTM D6423 can

be obtained from ASTM at the contact information on page 8.

Sulfur Content: As noted on page 9, requirements to lower the sulfur content of gasoline have led to the sulfur content of ethanol being an important issue. ASTM has a sulfur specification for denatured ethanol in ASTM D4806 and California has its own applicable regulation regarding the sulfur content of denatured ethanol.

At the current time, industry consensus indicates the most appropriate ASTM test method for determining the sulfur content of ethanol to be ASTM D5453 Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons, Motor Fuels and Oils by Ultraviolet Fluorescence. This is the test method specified in California regulations. The most recent copy of ASTM D4806 should be consulted for applicable sulfur limitations and appropriate test procedures.

Total Sulfate Content: Small amounts of inorganic sulfates can, under some circumstances, contribute to deposits in meter and dispensing pumps as well as causing automotive fuel injectors to stick. Test methods to measure for total sulfates include ASTM D7318, ASTM D7319, and ASTM D7328.

Inorganic Chloride: Very low levels of chloride ions can be corrosive to many metals. Inorganic Chloride content can be determined by ASTM Test Methods D7319 and D7320.

Note: Ethanol producers need to be aware of why these properties are limited. 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.

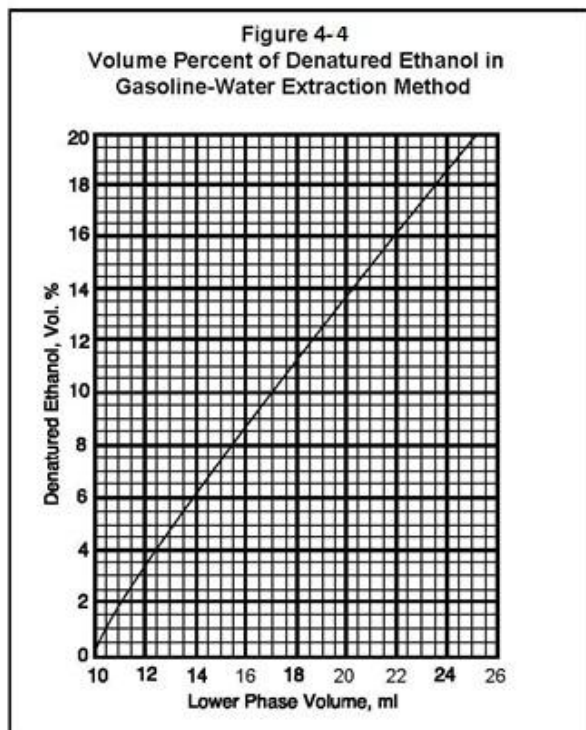
Gasoline Ethanol Blends

Ethanol Content: The approximate ethanol content of a gasoline ethanol blend can be tested by the "Water Extraction Test". This procedure is as follows.

Determination of Alcohol Content in Blends-Water Extraction Method

Place 100ml. of the gasoline/ethanol blend in 100 ml. glass stoppered graduated cylinder. Pipette 10 ml. of water into the cylinder and shake thoroughly for about one minute. Set aside for 2 minutes. Read the volume of the alcohol-water layer on the bottom and compare to the graph below to read the alcohol content.

For example, a reading of 17.2 ml. lower phase volume by this test is 10v% alcohol in the blend. (See chart)



ASTM D4815: There is also a more accurate laboratory test for determining the ethanol content of gasoline/ethanol blends, ASTM D4815 Test Method for determination of MTBE, ETBE, TAME, DIPE, tertiary-Amyl Alcohol and C1 to C4 Alcohols by Gas Chromatography.

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.

Summary of Safety and Fire Fighting Procedures

Although ethanol does not present any danger beyond those of other flammable products, it is important that pertinent safety and fire fighting details be covered with appropriate personnel.

Material Safety Data Sheets (MSDS) should be provided to all personnel who come in, or may come in, contact with ethanol. A current MSDS is available from your ethanol supplier.



Safety is the top priority of America's ethanol industry and those who transport and bring ethanol to the marketplace. It is with this commitment in mind that the Ethanol Emergency Response Coalition (EERC) has compiled and released the Complete Training Guide for Ethanol Emergency Response, to help prepare ethanol producers, transporters and first responders who may experience or come in contact with an ethanol-related emergency.

This complete training package includes two DVD's, an instructor's guide, interactive workshops and seven modules and PowerPoint presentations, each focusing on a specific and important aspect of ethanol response. Guidelines are also given for fire departments and first responders that have ethanol production facilities in their communities.

The complete guide to emergency response is available on the EERC website at www.ethanolresponse.com. The DVD's are also available on the RFA website.



Another important safety organization is TRANSCAER®.

TRANSCAER® (Transportation Community Awareness and Emergency Response) is a voluntary national outreach effort that focuses on assisting communities prepare for and respond to a possible hazardous material transportation incident. TRANSCAER® members consist of volunteer representatives from the chemical manufacturing, transportation, distributor, and emergency response industries, as well as government.

TRANSCAER®

- Promotes safe transportation and handling of hazardous materials
- Educates and assists communities near major transportation routes about hazardous materials
- Aids community emergency response planning for hazardous material transportation incidents

Information on TRANSCAER® activities can be found on their website at www.transcaer.com.

Fire Related Emergencies: Ethanol blended fuels present the same type of flammability hazard as other transportation fuels, however ethanol's polar solvent nature may be a new consideration. A review of the fire response equipment at all levels of the distribution chain will ensure the appropriate tools are available in the event of an emergency. This review includes a check of appropriateness of the larger response equipment such as structural protection that includes fire fighting foams through the small incident response tools such as fire extinguishers.

Ethanol blended fuels with greater than 10% ethanol require the use of a Polar Solvent or Alcohol Resistant (AR) type of foam, commonly known as an AR-AFFF. Traditional AFFF foams have limited to no ability to extinguish fire emergencies when the ethanol content is above 10% by volume. AR type foams work on all alcohol variations of ethanol and gasoline blended fuels and would be the best use of fire response equipment. It should be mentioned that dry chemical fire extinguishing agents may also work on ethanol blended fuels, however the dry chemical manufacturer must be consulted for appropriateness.

Another excellent resource is "RFA's document "Implementing an Effective Safety and Health Program for a Fuel Ethanol Facility" which list numerous OSHA guidelines and other information.

Technical End Note: While many of the recommendations in this recommended practice also applies to E85 and mid-level blends such as E20 and E30, the RFA has developed separate guides specifically for those fuels.

- For E85 refer to: Publication #090301 – “E85 Fuel Ethanol Industry Guidelines, Specifications and Procedures”
- For Mid-Level Blends refer to: Publication #090526 - “Guidelines and Best Practices for Blending Mid Level Ethanol Blends”

Tax Incentives

Recognizing the many public policy benefits of ethanol the federal government, as well as some state governments, offers certain tax incentives for the production and/or use of ethanol for transportation

The Volumetric Ethanol Excise Tax Credit (VEETC) signed into law October 2004, and modified by the 2008 Farm Bill, currently allows blenders to claim a \$0.45 per gallon tax benefit on each gallon of ethanol used. The VEETC replaces the former motor fuels tax exemption for ethanol. There are various requirements under the regulations for VEETC. The IRS has issued guidance in the form of *Fuel Tax Guidance, IRS Notice 2005-04*. See the IRS website at: <http://www.irs.gov/pub/irs-regs/15383804.pdf>. The RFA has also issued guidance and additional information is available on RFA's website.

The 2008 Farm Bill contained a provision that stipulates the full value of the Credit (VEETC) is only available to blenders when using fuel ethanol denatured at a maximum of 2%. As set forth in the guidance issued by the Internal Revenue Service on December 31, 2008, the Service interprets this to mean fuel ethanol with up to 2.5v% denaturant (IRS Notice 2009-06). The RFA therefore, recommends that denatured ethanol be produced with an approved denaturant added between 1.96v% and 2.5v%. This recommended practice will be reviewed and revised, as needed, when the IRS issues additional guidance on this issue.

Small Ethanol Producer Tax Credit: The 2005 Energy Policy Act expanded the definition of a small ethanol producer to include plants of up to 60,000,000 gallon annual production capacity. Plants defined as "small ethanol producers" are eligible for a production incentive of 10 cents per gallon on the first 15 million gallons of ethanol produced each year.

The Alternative Fuel Infrastructure Tax Credit is available for the cost of alternative fueling equipment placed into service after December 31, 2005. Qualified alternative fuels include ethanol as E85. The credit amount is based on a percentage of the cost of the equipment. For more information see IRS Form 8911 and/ or Form 3800, which are available via the IRS website (Reference Public Law 111-5, Section 1123, and 26 U.S. Code 30C and 38B) www.irs.gov/ or by phone at (800) 829-1040.

Other Documents Available From the Renewable Fuels Association **(www.ethanolrfa.org)**

The RFA has developed and/or obtained a number of documents useful to those with interests in ethanol and gasoline/ethanol blends. These are available through the RFA website or from RFA member companies.

Changes in Gasoline IV – The Auto Technician’s Guide to Spark Ignition Engine Fuel Quality (2009)

E85 Fuel Ethanol Industry Guidelines, Specifications, and Procedures
RFA Publication # 090301 (March 2009)

Guidelines and Best Practices for Blending Mid-Level Ethanol Blends
RFA Publication # 090616, (June 2009)

Handbook for Handling, Storing, & Dispensing E85
U.S. Dept of Energy (DOE / GO – 10 2008 – 2450, (April 2008)

Guidelines for Establishing Ethanol Plant Quality Assurance and Quality Control Programs
RFA Publication # 040301, (August 2004)

DVD – Complete Training Guide to Ethanol Emergency Response (EERC 2009)

Best Practices for Rail Transport of Fuel Ethanol
RFA Publication (November 2009)

Implementing an Effective Safety and Health Program for a Fuel Ethanol Facility
RFA Publication

Appendix A

Evaluation Protocol for Corrosion Inhibitors

for

Fuel Ethanol

Evaluation Protocol for Corrosion Inhibitors for Fuel Ethanol

For more than 20 years, the Renewable Fuels Association (RFA) has recommended that fuel ethanol producers and importers add a corrosion inhibitor to fuel ethanol. The corrosion inhibitor should be included at a treat rate sufficient to provide corrosion protection comparable to that of other available motor fuels while protecting the transportation distribution system from corrosion concerns. RFA is transitioning the recommendation from a general guideline format to an evaluation protocol. This protocol should be considered a transition step as additional information becomes available on the corrosion potential of motor fuels, primarily fuel ethanol.

The RFA Evaluation Protocol for Corrosion Inhibitors provides an evaluation technique for ethanol manufacturers to determine appropriate level of corrosion protection for the fuel produced. This protocol may be used with denatured or undenatured ethanol intended for use as a spark ignition engine fuel. The RFA recommends that each of the below tests be considered by each manufacturing location to confirm the effectiveness of the candidate fuel corrosion additive. Corrosion concerns are expected to vary from fuel to fuel as no two ethanol production plants or processes are identical. Corrosion inhibitors may also assist in altering pH levels of fuel ethanol. Ultimately, it is the responsibility of the ethanol manufacturer to address the fuel's corrosion potential.

Prior to publication of this evaluation protocol, the RFA used less stringent criteria focused primarily on the NACE test. RFA then published a list of additives effective in meeting the previous criteria. To allow time for additive manufacturers to complete and submit new test data using this new evaluation protocol, additives previously listed should be grandfathered as meeting the criteria of these guidelines for the period of one year from the date of this publication.

NOTE: While the RFA does not endorse any additive or recommend one over another, we have listed and on occasion have published references to corrosion inhibitors that have been demonstrated to us as sufficiently effective to be acceptable for use. We are discontinuing this type of publication and offering this guidance for evaluating the effectiveness of corrosion inhibitors.

Evaluation of Fuel Ethanol as an Unleaded Gasoline Additive

For evaluation of fuel ethanol intended for E10 (10% Denatured Fuel Ethanol/ 90% Unleaded Gasoline) or desired fuel blend ratio, the following protocol is suggested:

- Secure the motor fuels for the evaluation.
 - Un-additized, unleaded gasoline that meets the requirements of ASTM D4814 Standard Specification for Automotive Spark-Ignition Engine Fuel with the exception of exhibiting a “C” rating by the NACE Standard Test Method TM0172-2001 should be used as the gasoline blendstock. Confirmation of the gasoline characteristics should be provided.

- Fuel ethanol, either denatured or undenatured, that represents typical production from the ethanol manufacturing plant process also meeting ASTM D4806 Standard Specification for Denatured Fuel Ethanol for Blending with Gasolines for Use as Automotive Spark- Ignition Engine Fuel should be used as the fuel ethanol blendstock. Confirmation of the fuel ethanol characteristics should be provided.
- Blend the desired gasoline/ ethanol fuel ratio, in this case 10% fuel ethanol and 90% unleaded gasoline, with the candidate corrosion inhibitor utilizing the recommended treat rate. Determine the corrosion rating with test method NACE TM0172-2001. The fuel blend with candidate corrosion inhibitor must meet a NACE Standard Test rating of B+ (less than 5% surface rust) or better for the recommended treat rate to be acceptable. ○ The corrosion inhibitor supplier should clearly state the acceptable treat rate, including a maximum inclusion level.
- Determine the corrosion rating using NACE TM0172-2001 of the same desired gasoline/ ethanol fuel ratio blend after 120 days of storage to emulate expected shelf life. The fuel blend with candidate corrosion inhibitor must again meet a NACE Standard Test rating of B+ (less than 5% surface rust) or better for the recommended treat rate after 120 days of storage to be acceptable. Sample should be stored under laboratory ambient conditions, in a non metal container, protected from UV light and following all safety precautions.
- An optional analysis may be performed to confirm the effective treat rate for the candidate corrosion inhibitor and gasoline/ ethanol fuel blend. Utilizing the desired blend ratio determine the NACE Standard test rating at 75% of the recommended fuel additive treat rate. The fuel blend with 75% treat rate of corrosion inhibitor should not reach the B+ NACE Standard Test rating for the recommended treat rate after 120 days of storage.

Evaluation Specific to Fuel Ethanol

Evaluation specific to the fuel ethanol may also be necessary.

- Determine the buffering capacity of the corrosion inhibitor using ASTM D6423 Standard Test Method for Determination of pHe of Ethanol, Denatured Fuel Ethanol and Fuel Ethanol. To determine that the corrosion inhibitor has adequate pHe buffering capability to meet the pHe requirements of the most current version or the ASTM D 4806 Standard Specification for Denatured Fuel Ethanol for Blending with Gasolines for Use as Automotive Spark-Ignition Engine Fuel specification, analyze fuel ethanol before and after treatment with the candidate corrosion inhibitor.
 - Fuel ethanol should also meet the ASTM D4806 pHe requirements after 120 days storage to emulate expected shelf life. Sample should be stored under laboratory ambient conditions, in a non metal container, protected from UV light and following all safety precautions.
- Secure a statement of solubility from the corrosion inhibitor supplier demonstrating the fuel ethanol/ gasoline blends and treat rate tested are completely soluble. RFA recommends the

Modified MOBIL Filterability Test, or an equivalent test correlating to real world data, for this evaluation. The Filterability Test can be provided upon request.

- Secure a statement of “no harm” from the corrosion inhibitor supplier.

Corrosion inhibitor suppliers should provide the treatment guidelines including recommendations for storage, handling and additization information. Additionally, the fuel additive supporting information should include precautions, suggestions, limits, calculation tools, cost estimates and/or a recommendation for verification of consistent fuel additive addition. Safety information such as a Material Safety Data Sheet (MSDS) should also be available.

Additional Considerations

In the past, fuel additive chemistries have been identified that have proven to be insoluble in high concentrations of fuel ethanol, such as poly isobutylene amine (PIBA). It is critical that fuel producers are aware of all fuel additives that are present, whether intentionally added by the fuel ethanol, denaturant or gasoline producer or seller, or by the logistic systems transporting these fuels.

If you should have any questions or would like to comment on this issue, please don't hesitate to contact Kristy Moore directly at 309-830-6154.
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