

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



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Every effort has been made to ensure that this manual is accurate, complete, and comprehensive at the time of publication. It is intended to be used as a guide and resource document. The authors strongly encourage all parties with an interest in establishing E85 or other ethanol blends fueling systems to engage professional support during installation to ensure fuel integrity and systems compatibility.

This document is not intended for use as a “how to” guide for individuals or organizations performing conversions.

Contents

Abbreviations and Acronyms	2
Introduction	3
Ethanol and E85 Properties, Specifications, and Information	4
Ethanol Blends	5
Hydrocarbons	7
Fuel Additives	7
Fuel Quality	7
Materials Recommendations	8
Storing and Dispensing Ethanol Blends	9
Codes and Regulations	9
UL Listing	10
Retail and Fleet Station Equipment	10
Tanks	11
Pipes	11
Other UST Equipment	12
Aboveground Equipment	12
Signs and Labels	14
E15 Labels	14
E85 Labels	14
Ethanol Blend Quality Assurance	15
Shipping Procedures	15
Safety Procedures	15
Health Considerations	15
Fire Safety Considerations	15
Flexible Fuel Vehicles	16
Checklist for Installing E85 or Blender Pump Dispensing Equipment or Converting Underground Storage Tanks	18
Checklist for Dispensing E15	20
Information Resources	21
Appendix A: Tank Manufacturer Compatibility	22
Appendix B: Pipe and Associated UST Equipment Manufacturer Compatibility	23
Appendix C: Dispenser, Hanging Hardware, Shear Valve and STP Manufacturer Compatibility	29
Appendix D: Various Specifications for Ethanol Fuels	31
Appendix E: Seasonal and Geographical Volatility Classes for E85 (ASTM D5798)	35
Appendix F: Benefits and Limitations of E85	37

Abbreviations and Acronyms

AFDC.....	Alternative Fuels Data Center
API	American Petroleum Institute
AST	aboveground storage tank
ASTM.....	ASTM International
Btu	British thermal unit
CFR	Code of Federal Regulations
CRC	Coordinating Research Council
E10	10% ethanol, 90% gasoline
E15	15% ethanol, 85% gasoline
E85.....	ethanol/gasoline blend containing 51% to 83% ethanol
EPA	U.S. Environmental Protection Agency
FFV	flexible fuel vehicle
NFPA	National Fire Protection Association
NREL.....	National Renewable Energy Laboratory
OSHA	Occupational Safety and Health Administration
RFA	Renewable Fuels Association
UST	underground storage tank

Introduction

This document provides information on ethanol fuel properties, standards, codes, best practices, and equipment information for those who blend, distribute, store, sell, or use E15 (gasoline blended with 10.5% to 15% ethanol), E85 (marketing term for ethanol-gasoline blends containing 51% to 83% ethanol, depending on geography and season), and other ethanol blends.

Ethanol is a renewable, domestically produced fuel made mostly from corn. New production facilities are using biomass feedstocks from agricultural and forestry wastes. Ethanol consumption is driven by both the Renewable Fuel Standards and octane requirements. Several research studies show that ethanol/gasoline blends, and E85 specifically, have the potential to substantially reduce petroleum fuel use and greenhouse gas emissions.¹

E85, also known as flex fuel, is an alternative motor fuel authorized by the Energy Policy Act of 1992, Section 301(2). In 2011, the U.S. Environmental Protection Agency (EPA) approved the use of E15 in conventional light-duty vehicles of model year 2001 and newer. E85, E15, and all mid-level blends between the two require special considerations related to storage, dispensing, handling, and vehicle operation, as compared to gasoline.

Flexible fuel vehicles (FFVs) are capable of operating on E85 or gasoline or any blend of the two. FFVs are available in most vehicle classes, including sedans, minivans, trucks, and sport utility vehicles. According to IHS Automotive, an organization that collects vehicle registration data, there were nearly 17.9 million FFVs registered in the United States as of the end of 2014. The National Highway Traffic Safety Administration establishes corporate average fuel economy standards, and auto manufacturers receive a credit for each FFV sold, which helps them meet the overall regulation. FFV production may be impacted by new EPA requirements starting in 2017 that require vehicle manufacturers to demonstrate that FFVs are using E85. As of October 2015, nearly 3,000 public and private stations across the country offered E85. Current station data are available at afdc.energy.gov/locator/stations/.

Equipment compatibility is important to ensure safe refueling with E15, E85, and other ethanol blends. UL

is an independent safety laboratory that has developed standards for listing refueling equipment. Many standards allow the option to list with specific ethanol blends. All fueling equipment manufacturers offer equipment that is UL listed for E10; many manufacturers offer equipment that is UL listed for use with blends up to E25 and/or equipment listed for use with blends up to E85. Underground storage tank (UST) regulations (40 Code of Federal Regulations [CFR] Part 280.32) allow UST owners to meet compatibility standards by using independent laboratory-certified equipment (UL) or by providing a written affirmative statement from the equipment manufacturer. The appendices provide lists of compatible equipment, including tanks (Appendix A); pipes and associated underground storage tank equipment (Appendix B); and dispensers, hanging hardware, and related equipment (Appendix C).

Federal and state tax incentives may be available to encourage installation of ethanol infrastructure. For a comprehensive list of these programs, visit the Federal and State Laws and Incentives section of the Alternative Fuels Data Center (AFDC) at afdc.energy.gov/laws.

Detailed information on ethanol, including basics, production, distribution, benefits, limitations, and other data, is available at afdc.energy.gov/fuels/ethanol.html.

A Note on Terminology: Flex Fuel and E85

“E85” is a term that technically refers to an ethanol fuel blend containing 15% gasoline and 85% ethanol. By law, ethanol used for blending must contain at least 2% denaturant (a hydrocarbon or hydrocarbons in the gasoline boiling range) to make it unfit for human consumption. ASTM International (ASTM) D5798—a fuel quality standard—previously referred to this ethanol blend as E85. The blend is now referred to as “ethanol flex fuel” or “FFV fuel.” For performance and reliability in various climates and seasons, ASTM D5798 allows a range of ethanol content between E51 to E83. Because of this variation in the allowable ethanol percentage, many in research and industry have begun using the term “flex fuel” rather than “E85.”

1. Michael Wang, MayWu, and Hong Huo, “Life-cycle energy and greenhouse gas emission impacts of different corn ethanol plant types.” *Environ. Res. Lett.* 2 (2007) 024001 (13pp), growthenergy.org/images/reports/Wang_ethanol_emissions.pdf

Ethanol and E85 Properties, Specifications, and Information

Also known as ethyl alcohol or grain alcohol, ethanol (C₂H₅OH) is an oxygenated hydrocarbon compound. In the United States, it is produced primarily from corn. The starch contained in the corn is converted into sugar and fermented to produce ethanol. The remainder of the corn (fiber and germ) is used as feed for livestock. Ethanol can also be produced from cellulose contained in plant-based materials, including corn stover, wheat straw, other agricultural or forestry waste, and municipal waste. Several processes are used for cellulose-derived ethanol, including enzymatic and acid hydrolysis and thermal processes. Cellulose-derived ethanol is expected to be a necessary component in meeting various state and national renewable fuel standards.

While ethanol for beverages and ethanol for fuel are produced through similar processes, fuel ethanol is “denatured” by adding a minimum of 2% hydrocarbons, such as natural gasoline, to make it unfit for human consumption.

Ethanol is a flammable, colorless liquid with a faint alcohol odor. The color of ethanol/gasoline blends depends on the color of the gasoline in the blend. Blends may also have a gasoline-like odor. Descriptive properties of fuel ethanol and E85 are listed in Table 1. Table 2 compares the properties of E85 to those of ethanol and gasoline.

The chemical properties of ethanol must be accommodated to ensure proper engine performance, emissions, fuel economy, and driveability under all operating conditions.

Table 1. Properties of Fuel Ethanol and E85

Property	Comment
Vapor Density	Ethanol vapor, like gasoline vapor, is denser than air and tends to settle in low areas. Ethanol/gasoline blends, including E85, should be treated like gasoline blends with respect to handling and safety.
Solubility in Water	Ethanol is extremely hygroscopic (i.e., attracts water). Water should be removed to the extent possible from fuel ethanol handling, storage, and distribution equipment. A small amount of water is soluble in E85, but at higher concentrations, the gasoline portion will separate from the ethanol/water mixture.
Energy Content	For identical volumes, ethanol contains approximately 30% less energy than gasoline, depending on the gasoline formulation. As a result, vehicle fuel economy of E85 can be expected to be reduced by about 25%, depending on the gasoline formulation and the individual vehicle.
Flame Visibility	A fuel ethanol flame is less bright than a gasoline flame, but is easily visible in daylight.
Specific Gravity	Pure ethanol and ethanol/gasoline blends are slightly denser than gasoline.
Conductivity	Ethanol and ethanol blends have increased electrical conductivity compared to gasoline. This can affect materials compatibility due to increased corrosion of certain metal junctions and exposed electrical connections.
Air-Fuel Ratio	Due to the oxygen content in ethanol, the ideal or “stoichiometric” air-fuel ratio for E85 is a lower value than it is for gasoline (i.e., fewer pounds of air per pound of fuel). FFVs are designed to detect ethanol and properly adjust the air-fuel ratio.
Toxicity	Pure ethanol in small amounts is not toxic and is not considered carcinogenic; however, fuel ethanol and ethanol/gasoline blends must be treated as toxic and carcinogenic due to the addition of hydrocarbons and gasoline.
Flammability	Depending on the hydrocarbon blending component, the vapor concentration in the storage tank head space of many E85 blends can fall into the flammable range. This is a concern primarily at low ambient temperatures.

Table 2. Fuel Properties of Ethanol, Gasoline, and E85

Property	Ethanol	Gasoline	E85*
Chemical Formula	C ₂ H ₅ OH	C ₄ to C ₁₂ Hydrocarbons	C ₄ to C ₁₂ Hydrocarbons and Oxygenated Hydrocarbons
Main Constituents (% by weight)	52 C, 13 H, 35 O	85–88 C, 12–15 H	57 C, 13 H, 30 O
Octane (R+M)/2	113	86–94	95–97
Lower Heating Value (Btu per gallon)	76,300	116,900	83,600–95,450
Miles per Gallon Relative to Gasoline	67%	-	73%**
Reid Vapor Pressure (psi)	2.3	7–16	7–12
Ignition Point—Fuel in Air (%)	3–19	1–8	Varies
Temperature (approx.) (°F)	850	495	Varies
Specific Gravity (60°/65°F)	0.794	0.72–0.78	0.78
Air-Fuel Ratio (by weight)	9	14.7	10
Hydrogen-Carbon Ratio	3.0	1.85	2.75–2.95

*Depends on hydrocarbon blending component properties. **Depends on both vehicle model and percentage ethanol in fuel.

Ethanol vaporizes at a lower temperature and within a narrower temperature range relative to many of the hydrocarbons in gasoline. To ensure proper cold-temperature start-up and warm-up operation in all regions of the United States during all seasons, ethanol is blended with hydrocarbons (typically gasoline) that are more volatile than ethanol. Ethanol has lower energy content than gasoline, which impacts vehicle fuel economy. The impact depends on the level of ethanol in the fuel.

Most transportation fuel sold in the United States is manufactured to ASTM specifications. ASTM International is a voluntary consensus standards organization that creates and maintains fuel quality specifications established by committees composed of vehicle and engine manufacturers, fuel system equipment manufacturers, fuel producers, fuel users, and other interested parties, such as fuel quality regulators. ASTM standards are recognized by federal and most state government agencies as the primary means of ensuring fuel quality.

EPA and most states have passed regulations that require gasoline to meet all or a portion of the ASTM gasoline guidelines. Various specifications for ethanol, E85, and denaturant are available in Appendix D.

Ethanol Blends

E85

The properties of ethanol for E85 and other ethanol blends must meet ASTM D4806. The ASTM specification for E85 (flex fuel) is ASTM D5798 “Specification for Ethanol Fuel Blends for Flexible-Fuel for Automotive Spark Ignition Engines” (Table 3). The ethanol content of E85 is seasonally adjusted to improve vehicle cold-start and warm-up performance. The ethanol content can range from 51% to 83% by volume. Much like gasoline, the volatility of E85 is also adjusted seasonally and geographically by volatility class by increasing the proportion of light hydrocarbons during colder months. The seasonal and geographical volatility classes are determined by ASTM and are contained in ASTM D5798. (A complete breakdown of geographical and seasonal volatility classes can be found in Appendix E.)

The octane of E85 is much higher than that of gasoline, ranging from 95 to 97 [(R+M)/2], depending on its hydrocarbon content.

E15

EPA defines E15 as gasoline blended with 10.5% to 15% ethanol. In 2011, EPA approved E15 for use in model year 2001 and newer conventional vehicles through a Clean Air Act waiver request based on significant testing and research.² Stations are not required to sell E15.

Vehicles approved for E15 use are:

- FFVs
- Model year 2001 and newer conventional cars, light-duty trucks, and medium-duty passenger vehicles.

Vehicles and engines prohibited from using E15 are:

- All motorcycles
- All vehicles with heavy-duty engines, such as school buses, transit buses, and delivery trucks
- All off-road vehicles, such as boats and snowmobiles

- All engines in off-road equipment, such as lawnmowers and chain saws
- All model year 2000 and older conventional cars, light-duty trucks, and medium-duty passenger vehicles.

E15 does not receive the 1-pound waiver from Reid vapor pressure requirements that E10 receives. This may impact the ability of stations in some regions to sell E15 during summer months.

Blender Pumps

Blender pumps are dispensers that draw fuel from two separate storage tanks to dispense preprogrammed blends of those fuels into vehicles. Many stations have long used blender pumps to create midgrade gasoline from a blend of regular and premium. In ethanol applications, blender pumps allow station owners to blend E85 with conventional gasoline to create mid-level

Table 3. ASTM D5798-11 Standard Specification for Ethanol Fuel Blends for Flexible-Fuel Automotive Spark-Ignition Engines

Property	Value for Class			
	1	2	3	4
ASTM Volatility Class				
Vapor Pressure (psi)	5.5-9.0	7.0-9.5	8.5-12.0	9.5-15.0
	All Classes			
Sulfur (maximum, mg/kg)	80			
Ethanol Content (volume %)	51-83			
Methanol (maximum, volume %)	0.5			
Water (maximum, mass %)	1			
Acidity as Acetic Acid (maximum, mg/kg)	40			
Inorganic Chloride (maximum, mg/kg)	1			
Gum, Unwashed (maximum, mg/100 mL)	20			
Gum, Solvent-Washed (maximum, mg/100 mL)	5			
Copper (maximum, mg/100 mL)	0.07			
Appearance	Product shall be visibly free of suspended or precipitated contaminants (shall be clear and bright).			

2. "E15 (a blend of gasoline and ethanol)", www.epa.gov/otaq/regs/fuels/additive/e15/

Ethanol Production, Blending, and Distribution

- Ethanol is produced at an ethanol plant. Prior to being transported, the fuel must be denatured by adding approximately 2% hydrocarbons, such as natural gasoline, to render it unfit for human consumption. A corrosion inhibitor is also added.
- The denatured ethanol is transported by rail, truck, or barge to the fuel terminal.
- Fuel terminals store gasoline blendstock, ethanol, additives, and other fuels in separate tanks. Terminals are able to supply E10, E85, and other ethanol blends.
- Stations typically contract with fuel terminals and with a fuel marketer or transport company to deliver fuel from the terminal to their station.

ethanol blends. ASTM has developed a standard practice for blending mid-level ethanol fuels for FFVs.³

Blender pumps offer FFV owners a variety of ethanol-blended gasoline products between E15 and E85. E20 (20% ethanol, 80% gasoline) and E30 (30% ethanol, 70% gasoline) are most common. Stations offering blender pump blends to FFV owners are concentrated in the Midwest. The majority of E15 is sold through blender pumps pulling fuel from E10 and E85 tanks.

Hydrocarbons

Unleaded gasoline is typically used to blend E85, but higher-volatility components such as natural gasoline (a high-volatility, low-octane liquid byproduct of natural gas production) can also be used to meet ASTM volatility requirements. These requirements serve to reduce the occurrence of flammable vapor regimes (and explosion hazard) in fuel tanks.

Because of the different types of hydrocarbon components used in E85, its range of vapor flammability in

tanks is wider than that of gasoline. The National Renewable Energy Laboratory (NREL) compared the fuel tank headspace flammability of seven E85 fuel blends, two gasoline samples, and denatured ethanol.⁴ Headspace vapors for the two gasoline samples became flammable when the temperature dropped to approximately -19°C (-2°F) and -25°C (-13°F) or lower. The E85 blends, on the other hand, produced flammable vapors at temperatures below values ranging from -2°C (28°F) to -22°C (8°F). Denatured ethanol was found to be flammable at room temperature and all temperatures down to approximately -6°C (22°F). Therefore, stations should not store denatured ethanol for blending due to the risk of explosion (Table 4).

Fuel Additives

According to EPA regulations, all commercial grades of gasoline must contain minimum specified levels of detergent additives. Other additives may be used by terminals or fuel companies to ensure their fuel meets all customer requirements. ASTM D5798 does not provide specific levels of corrosion inhibitor or deposit control additives for ethanol blends. Ethanol production plants add a corrosion inhibitor at a level that assumes the ethanol will be blended as E10; this level of corrosion inhibitor exceeds what is needed for E85.⁵ Detergents or deposit control additives may be needed to ensure deposits do not form in the vehicle fuel injection system. The Alcohol and Tobacco Tax and Trade Bureau requires that a minimum of 1.96% to a maximum of 2.5% denaturant be added to make ethanol unfit for human consumption. Usually the denaturant is natural gasoline. Blenders or terminals should actively engage additive manufacturers to determine whether the additives will remain soluble with various concentrations of ethanol and gasoline.

Fuel Quality

NREL and the Coordinating Research Council (CRC) collaborated to survey E85 quality in 2008–2009, 2011, and 2014 and mid-level blends from blender pumps in 2012 and 2013. These surveys have shown improvement in E85 quality, likely as a result of the reduction

3. ASTM D7794 - 14 Standard Practice for Blending Mid-Level Ethanol Fuel Blends for Flexible-Fuel Vehicles with Automotive Spark-Ignition Engines, www.astm.org/Standards/D7794.htm

4. D. Gardiner, M. Bardon, and G. Pucher. "An Experimental and Modeling Study of the Flammability of Fuel Tank Headspace Vapors from High Ethanol Content Fuels." NREL/SR-540-44040 National Renewable Energy Laboratory (NREL) Golden, CO (US). October 2008. www.nrel.gov/docs/fy09osti/44040.pdf

5. "E85 Fuel Ethanol Industry Guidelines, Specifications, and Procedures." Renewable Fuels Association. March 2009

Table 4. Flammability Limits of Gasoline and Ethanol

Fuel Gas	Lower Explosive or Flammable Limit (LEL/LFL) (% in air)	Upper Explosive or Flammable Limit (UEL/UFL) (% in air)
Gasoline	1.4	7.6
Ethanol	3.3	19

in minimum ethanol content allowed in D5798, which raises the vapor pressure of the finished blend. The blender pump survey showed that the vapor pressure of E20 blends was statistically similar to that of the gasolines tested. Additional E85 CRC fuel quality survey data can be obtained from the CRC.⁶

Materials Recommendations

As with all motor fuels, it is important to maintain proper fuel handling and housekeeping practices to minimize contamination. Certain materials commonly used with gasoline may be incompatible with mid- and high-level alcohol blends.^{7,8} Some materials may degrade over time, potentially leading to equipment problems. They may also contaminate the fuel, which may adversely affect vehicle fuel system operation or cause component malfunction and lead to degraded driveability and performance.

Ethanol blends may impact metallic and elastomer materials in fueling systems. To address these issues, manufacturers have upgraded materials and developed products that are compatible with blends up to E25 or with blends up to E85. Many elastomer materials (primarily used as hoses and seals) have been changed in fueling equipment to accommodate a range of fuels

(including ethanol blends and ultra-low sulfur diesel) and in anticipation of additional alternative fuels entering the market. Only ethanol-compatible materials should be used in storage and dispensing systems.

E85 acts like a cleaning agent and will initially mobilize sludge in storage tanks. E85 can also cause corrosion of some soft metals and reduce the tensile strength of some nonmetallic materials. Zinc, brass, lead, and aluminum have shown sensitivity to degradation with E85. Terne-plated steel (lead-tin alloy coating), which has been commonly used for vehicle fuel tanks, and lead-based solder are also incompatible with E85. Use of these metals should be avoided. Unplated steel, stainless steel, black iron, and bronze have shown acceptable resistance to E85 corrosion. Blends below E25 do not cause corrosion of metals (unless accompanied by a separate aqueous phase).

Nonmetallic materials that degrade when in contact with fuel ethanol include natural rubber, polyurethane, cork gasket material, leather, polyvinyl chloride, nylon 6/6, methyl-methacrylate plastics, and certain thermoplastic and thermoset polymers. Blends below E25 may impact elastomers, and contact with E85 causes some elastomers to swell. Nonmetallic materials successfully used for transferring and storing ethanol include thermoset-reinforced fiberglass, thermoplastic piping, and thermoset-reinforced fiberglass tanks (as listed for this application by UL).

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6. E-85: Alleman, "National Survey of E85 Quality," CRC Report No. E-85, November 2009, www.crao.org
 E-85-2: Alleman, "National 2010-2011 Survey of E85: CRC Project E-85-2," NREL/TP-5400-52905, December 2011, www.nrel.gov/docs/fy12osti/52905.pdf
 E-85-3: Alleman, "Survey of Flex Fuel in 2014: CRC Project E-85-3," NREL/TP-5400-63505, July 2015, www.nrel.gov/docs/fy15osti/63503.pdf
 E-95-1: Alleman, "Blender Pump Fuel Survey: CRC Project E-95," NREL/TP-5400-51863, July 2011, www.nrel.gov/docs/fy11osti/51863.pdf
 E-95-2: Williams and Alleman, "Blender Pump Fuel Survey: CRC Project E-95-2," NREL/TP-5400-60627, May 2014, www.nrel.gov/docs/fy14osti/60627.pdf
7. Michael Kass and Timothy J. Theiss. "Compatibility Study for Plastic, Elastomeric, and Metallic Fueling Infrastructure Materials Exposed to Aggressive Formulations of Ethanol-Blended Gasoline." Oak Ridge National Laboratory. May 2012
8. Coordinating Research Council. CRC Reports No. E-65-3, Fuel Permeation; No. E-67, Ethanol Effects on Exhaust Emissions; and Nos. E-79 and E-79-2, Study of E85 in the U.S.

Storing and Dispensing Ethanol Blends

Codes and Regulations

Ethanol blends are subject to the same regulations and codes as transportation fuels. Blends above E10 are subject to additional requirements. This section focuses on federal requirements. Stations considering blends above E10 should contact their state and local authorities to identify other regulations and requirements.

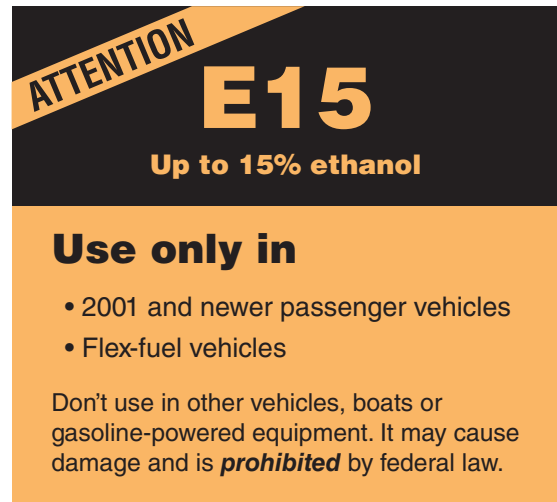
EPA's Office of Underground Storage Tanks (OUST) regulates underground storage tanks (USTs) per Code of Federal Regulation (CFR) Title 40 Subtitle 1 Subchapter 1 Parts 280-282. The federal UST regulation was updated in October 2015 with section CFR 280.32 and provides clarity to the 1988 compatibility requirement by specifying additional compatibility requirements for owners and operators wishing to store certain regulated substances, including gasoline containing more than 10 percent ethanol (and diesel containing greater than 20 percent biodiesel). All portions of a UST system must be compatible with the fuel stored. Demonstrations of compatibility must be provided for tank, piping, containment sumps, pumping equipment, release detection equipment, spill equipment, and overfill equipment.

Owners of USTs switching to store blends containing greater than E10 (or greater than B20) must:

- Notify their implementing agency (usually a state office) 30 days prior to switching fuels to store an E10+ (or B20+) blend.

Owners of USTs storing greater than E10 (or greater than B20) must demonstrate compatibility through either:

- A nationally recognized, independent testing laboratory certification or listing for the equipment used for the fuel stored; or
- Approval from the equipment or component manufacturer for use with the fuel stored. This statement affirming compatibility must be in writing and list the specific ranges of biofuel blend with which the equipment or component is compatible.



Contact the Renewable Fuels Association for free labels.

Owners of USTs storing greater than E10 (or greater than B20) may also use another option determined by the implementing agency to be no less protective of human health and the environment.

Owners of USTs storing fuels containing greater than E10 (or greater than B20) must maintain records demonstrating compatibility as long as the fuel is stored.

The Petroleum Equipment Institute maintains a website with manufacturer letters affirming compatibility with a specific range of biofuel blend. Use of appropriate letters by station owners satisfies the federal code requirement.⁹

EPA's Office of Transportation and Air Quality developed additional requirements for E15 to reduce the risk of misfueling because the fuel is only approved for use in light-duty vehicles and trucks 2001 and newer. Stations selling E15 (defined as 10.5% to 15% ethanol) must adhere to the following requirements:

- An EPA-approved E15 label must be affixed to the dispenser.

⁹ "PEI Resources", www.pei.org/ust-component-compatibility-library

- An EPA-approved Misfueling Mitigation Plan (available free from Renewable Fuels Association [RFA])¹⁰ must be adopted.
- Product transfer documents must accompany all deliveries of fuel for E15 use.
- The retail station must participate in the fuel quality survey; register at www.rfgsa.org.
- Ethanol in E15 must meet ASTM D4806. Reid vapor pressure is limited to 9.0 psi in the summer.
- Stations must use EPA-approved dispenser and hose configurations. Options include:
 - A dedicated E15 hose
 - A shared E0/E10/E15 hose, which requires a purchase of four gallons minimum (“four gallons minimum” label must be displayed)
 - A dedicated dispenser selling E10 or less.

The Occupational Safety and Health Administration (OSHA) regulates some fuel-dispensing equipment. Its regulations applicable to service stations have not been updated in decades and therefore do not specifically address biofuels. OSHA is planning to update these standards to address new fuels in the marketplace.

OSHA 1910.106 (g)(3)(iv) and (g)(3)(vi)(a) require dispensers and nozzles to be listed by a third party for specific fuels.

OSHA 1910.106(b)(1)(i)(b) and (c)(2)(ii) require tanks, piping, valves, and fittings other than steel to use sound engineering design for materials used; however, there is no listing requirement. OSHA 1910.106(b)(1)(iii) covers steel tanks and requires sound engineering and compliance with UL 58 and American Petroleum Institute (API) Standards 650 and 12B as applicable.

Local authorities having jurisdiction typically adopt fire codes from one of two organizations, the National Fire Protection Association (in particular, Code 30A, which includes language on alternative compliance to address new fuels) and the International Code Council. These organizations provide standard codes for retail stations that are accepted or modified to meet local requirements.

Other organizations developing best practices and codes include API, Fiberglass Tank and Pipe Institute, NACE International, National Conference on Weights and Measure, National Leak Prevention Association, Petroleum Equipment Institute, and Steel Tank Institute.

UL Listing

UL is the primary third-party safety certification laboratory servicing the refueling equipment industry globally. There are many standards covering individual products in the fueling system and many different approaches to evaluating safety. In the past, some standards that provided listings for specific fuels were limited to petroleum products, but were then revised to handle low levels of ethanol blends. Over time, many UL standards provided the option for equipment manufacturers to list their products for gasoline and gasoline/ethanol blends above E10. While some UL standards allow manufacturers to select which fuels to list for, there is a trend towards revising standards to require equipment to be listed for all fuel types—this means equipment would be listed for use with gasoline, diesel, E85, and other commercial fuels. Depending on the standard, UL allows listing for E10 (all equipment); E25 (dispensers, hanging hardware); E85 (most equipment); and E100 (tanks and pipes). A summary of applicable UL standards for refueling equipment is available in Appendix F.

Retail and Fleet Station Equipment

A service station consists of many interconnected pieces of refueling equipment necessary to deliver fuel to vehicles. There are approximately 60 pieces of equipment at a station designed to handle fuel and vapor (Figure 2). The equipment delivering fuel to a vehicle includes tanks, pipes, submersible turbine pump, dispenser, and hanging hardware. The remainder and majority of equipment are used to prevent, detect, and contain releases. Equipment includes overfill protection, leak detection, shear valves, fill and vapor caps and adaptors, containment sumps, and all associated fittings and accessories for these equipment types. Figure 2 provides a diagram and equipment list. This handbook provides checklists detailing key items to consider when adding or converting equipment to dispense E15 and E85 (pages 20 and 21).

¹⁰ Renewable Fuels Association. “E15 Misfueling Mitigation Plan” March 2, 2012. www3.epa.gov/otaq/regs/fuels/additive/e15/documents/rfa-model-e15-misfueling-mitigation-plan.pdf

Tanks

Most existing tanks are compatible with ethanol blends above E10. Appendix A lists tank manufacturers and the compatibility of their equipment with ethanol blends. All existing steel tank companies have issued signed letters stating compatibility with up to E100 per federal requirements. Tanks are listed under UL 58, which does not expose tanks to test fluids. The listing covers all flammable fuels. All Steel Tank Institute members who fabricate regulated fuel USTs in the United States have UL 58 listings. The Steel Tank Institute conducted independent testing and determined that steel tanks are compatible with all ethanol blends.

Xerxes and Containment Solutions manufacture fiberglass tanks, and both have E100 listing for their products under UL 1316. Per federal requirements, Containment Solutions issued a letter stating that all tanks it has manufactured are compatible with all ethanol blends. Xerxes and Owens Corning (which no longer manufactures tanks) have issued letters stating that compatibility depends on tank wall type and the year manufactured.

Aboveground Tanks: Aboveground storage tanks (ASTs) are uncommon at retail stations. Steel ASTs can be used to store blends above E10. ASTs are typically constructed of stainless steel or carbon steel. The use of galvanized metal tanks or plastic tanks is not recommended. It is important to check with local and national fire codes to determine appropriate tank construction. Many jurisdictions will require two-hour fire-rated tank technology to dispense fuels from ASTs into motor vehicles. The construction of the tank may determine where the dispenser can be mounted and how close the tank can be to nearby buildings and property lines.

Cleaning Tanks: If a tank is compatible with blends above E10, it must be cleaned prior to storing a higher ethanol blend. During fuel storage, debris and moisture can build up over time to form sludge known as water bottoms in a tank. Because ethanol is soluble in water, when E85 or another ethanol blend is introduced to an existing tank, the ethanol will mix with the water bottoms, and the solvent action of ethanol will remove any sludge buildup and contaminate the fuel. More than 25 years of experience in handling low-level ethanol blends has helped the industry understand how to address the accumulation of debris and water in the fuel distribution and storage system. However, proper

housekeeping procedures should be instituted to limit debris and water contamination.

There are several methods for cleaning sludge from storage tanks, which are listed below. It is possible to inspect a tank prior to cleaning by using a camera with a remote that is inserted into a tank. It is important to note that all of the methods should be completed by a qualified company familiar with cleaning petroleum storage tanks.

- **Optic Sweep:** This patented system uses a fiber optic camera and controllable probe with an extraction device that can visually inspect and clean fuel storage tank bottoms at any fuel level with no tank down-time. The optic sweep can locate and remove water, sludge, bacteria, rust particles, and sediment while customers continue to pump.
- **Steam Cleaning:** A person physically enters the tank, steam cleans it, and removes sludge. Care must be taken to properly dry the tank.
- **Filter Agitator:** An agitating device is lowered into the tank. The fuel and any debris are agitated and circulated. A filtration system removes the suspended debris.
- **Chemical Solvents:** Chemical solvents are used to remove scale and debris. Liquid and debris are then pumped from the tank and disposed of.

Choosing the appropriate cleaning technique will depend upon the type of fuel that has been stored in the tank, availability of the service, and state and local environmental regulations.

Pipes

All existing pipe companies have UL 971 listing for ethanol blends up to E100. Appendix B provides a list of compatible pipes. Installed pipes are evenly split between fiberglass and flexible plastic pipes. Fiberglass was the primary pipe type for decades. NOV is the only existing company providing fiberglass piping in this market and provides a 30-year warranty. Flexible pipes entered the marketplace in the 1990s after the EPA Office of Underground Storage Tanks recommended development of jointless pipes. These manufacturers include Advantage Earth Products, Brugg Pipesystems, Franklin Fueling, NUPI, Omega Flex, and OPW. Both Franklin Fueling and Omega Flex require the use of stainless steel pipe fittings for blends above E10. A typical warranty for flexible pipes is 10 years.



Figure 1. Dispenser and Hanging Hardware.

Photo by Charles Bensinger, NREL 13531

Other UST Equipment

Stations have a significant amount of equipment underground and in the tank to receive fuel deliveries and to detect, prevent, and contain leaks. This equipment includes, but is not limited to, sumps and accessories, manholes, flexible connectors, fill caps and adaptors, entry fittings, overfill prevention, leak detection, sensors, drop tubes, and vents. Appendix B provides a list of UST equipment and its compatibility with ethanol blends. If a manufacturer or specific model number is missing, please contact the manufacturer directly to determine if the equipment is compatible with specific ethanol blends.

Aboveground Equipment

There are multiple dispenser options to sell ethanol blends above E10. Options include retrofitting an existing dispenser with an E25 UL-listed kit (Gilbarco sells retrofit kits), purchasing a UL-listed E25 dispenser (minimal cost

over conventional E10 dispenser), or purchasing a UL-listed E85 blender pump dispenser (higher cost but more options for fuel offerings). Both Gilbarco and Wayne sell UL-listed E25 and E85 dispensers (Appendix C).

There are two opportunities that are expected to lead to significantly more E25 and E85 UL-listed dispensers by late 2017. The U.S. Department of Agriculture's Biofuels Infrastructure Partnership provided grants of \$100 million with an expectation of installing approximately 5,000 E85 blender pump dispensers at 1,600 stations. Credit card companies are requiring retail stations to upgrade their dispenser payment systems to receive chip and pin credit cards by October 2017—or liability for fraudulent purchases will shift to the retailer/owner. Industry efforts will focus on encouraging retailers who have to replace equipment to select UL listed E25 or E85 dispensers.

The dispenser filter is the last line of defense before the fuel reaches a vehicle's tank. Typically, a 30-micron filter is used with diesel fuel, and a 10-micron filter is used with gasoline and low-level ethanol blends. E85 dispensers should use filters with a nominal rating of 50% for particles 5 microns or larger and an absolute rating of 99% for particles 10 microns or larger. These ratings mean the filter can capture the given percentage of the particles of the stated size.

Hanging hardware includes hoses, nozzles, breakaways, and swivels. Both Husky and OPW offer UL listed E25 and E85 nozzles, swivels, and breakaways. Veyance offers UL-listed E85 hose.

Shear valves are an important piece of safety equipment that cut off the flow of fuel from the UST to the dispenser to prevent a release in the event of an accident dislodging the dispenser or fire. UL-listed E85 shear valves are available from Franklin Fueling and OPW.

Submersible turbine pumps draw fuel from the tank and into piping that delivers the fuel to the dispenser. Both Veeder-Root and Franklin Fueling offer UL-listed E85 pumps.

Appendix C lists E10+ UL-listed and manufacturer-approved dispenser, hanging hardware, shear valves, and submersible turbine pumps.

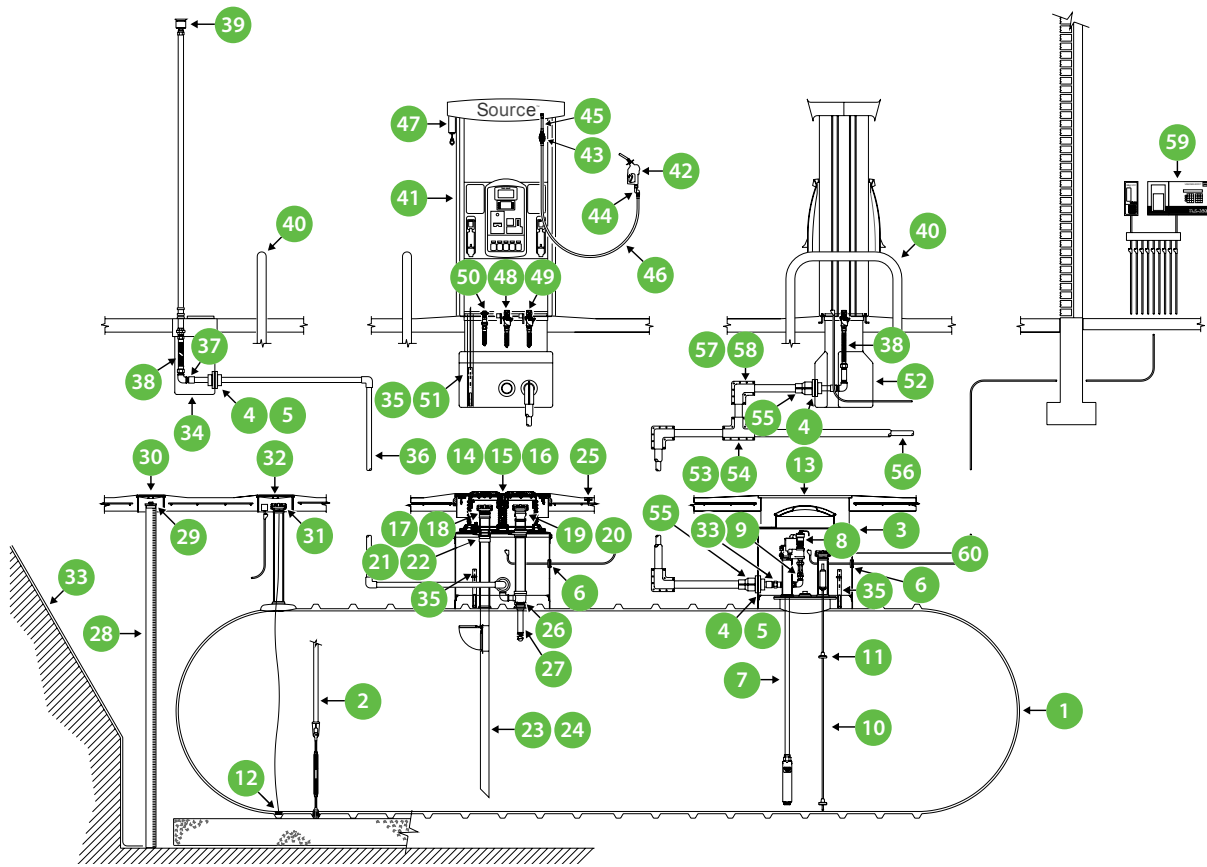


Figure 2. Typical Fuel Dispenser and Underground Storage Piping. Illustration by Source North America

Table 5. Fuel Dispenser and Underground Storage Piping Components

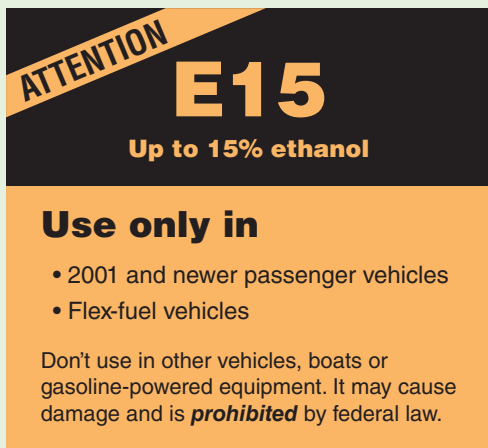
#	Equipment	#	Equipment	#	Equipment
1	Tank	21	Face seal adaptor	41	Dispenser
2	Tank straps	22	Jack screw kit	42	Nozzle
3	Sump and cover (tank)	23	Overfill prevention valve	43	Breakaway
4	Sump entry fitting (boot)	24	Drop tube (often a part of #23)	44	Swivel
5	Sump penetration fittings	25	Fuel grade ID #	45	Whip hose
6	Flexible entry boots	26	Extractor tee	46	Hose
7	Submersible turbine pump	27	Monitoring well screen (pipe)	47	Hose retractor
8	Mechanical line leak detector	28	Ball float vent valve	48	Stabilizer bar kit
9	Ball valve	29	Well cap-monitoring	49	Shear valve
10	Magnetostrictive probe	30	Manhole-monitoring	50	Shear valve-vapor (stage II only)
11	Float kit	31	Interstitial cap	51	Sensor tube
12	Interstitial sensor	32	Manhole	52	Dispenser sump
13	Manhole-composite	33	Roll filter fabric	53	Pipe-secondary containment tee
14	Manhole-multi-port spill containment	34	Transition sump-vent	54	Pipe-product tee
15	Spill bucket	35	Sump sensor	55	Concentric reducer
16	Fuel grade ID tag	36	Pipe	56	Pipe-secondary containment
17	Fill adaptor (top or side)	37	Pipe adaptor	58	Pipe-product elbow
18	Fill cap (top or side)	38	Flexible connector	57	Pipe-secondary containment elbow
19	Vapor adaptor	39	Vent	59	Console
20	Vapor cap	40	Steel bumper	60	Probe cap adaptor

Signs and Labels

The federal government requires dispenser labels for E15 and E85. States and local authorities may require additional labels and signs. Contact the appropriate official in your area to determine the required signage. Labels are available free of charge from the Blend Your Own website (byoethanol.com/dispenser-labels-available.html). API Recommended Practice 1637 states that storage tanks containing E85 must be labeled on all fillboxes and fillbox covers with a bronze pentagon, as shown below at right, and “E85” printed in black or white in the middle of the pentagon. States may have additional labeling requirements.

E15 Labels

Per EPA, an E15 label must be placed on the upper two-thirds of a dispenser. If the dispenser has one nozzle, the E15 label must be placed above the button or control for selecting E15. For a multi-hose dispenser, the label must be placed where it is immediately visible to the consumer. If a common hose is used to dispense E0, E10, and E15, the “four-gallon minimum” sign must be posted on the dispenser.



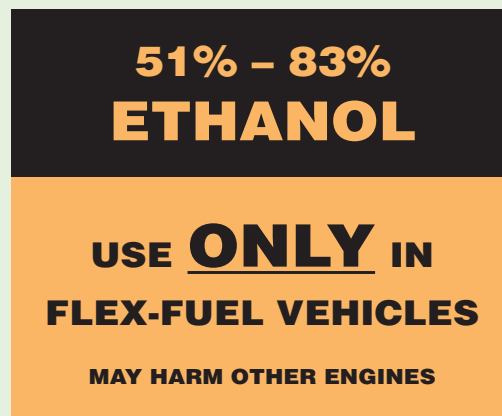
Minimum Fueling Volume 4 Gallons:
Dispensing Less May Violate Federal Law

E85 Labels

E85 labels should be placed on fillboxes and fillbox covers in one of the following ways:

- Paint the decal on the top of the fillbox cover or on the rim of the fillbox
- Attach a tag to the fillpipe adapter
- Screw a tag into the fillbox rim
- Fit a plastic or fiberglass insert into the rim of the fillbox.

In addition, the Federal Trade Commission requires that a small sticker be placed on the face of the fuel dispenser as close as possible to the price per unit of fuel.



The Federal Trade Commission has updated the label to reflect the allowable minimum ethanol content in E85 of 51%.



API Label

Ethanol Blend Quality Assurance

Following the installation of E15, E85, or other blend above E10 equipment, several operational precautions can help assure fuel quality. Periodically checking the fuel properties will avoid damage to vehicles. Some of these checks may be performed in the field, but others may require the services of a specialized laboratory. At a minimum, the following items should be checked every one to two months, depending on how frequently the station is used:

- Electrical conductivity
- Particulate content
- Hydrocarbon content
- Water content
- Reid vapor pressure.

Shipping Procedures

Your fuel provider may be able to recommend a laboratory in your area that can perform periodic fuel quality analysis. To safely and legally ship a sample of fuel, follow all hazardous material shipping requirements and include the following information on the outside of the package:

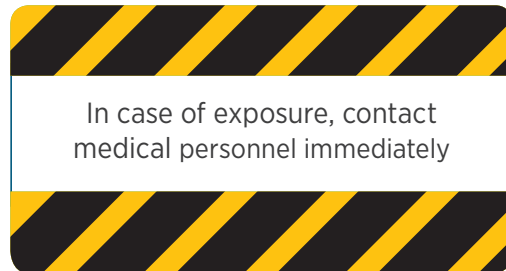
- U.S. Department of Transportation Shipping Name: Alcohol, not otherwise specified or n.o.s. (ethanol, gasoline)
- Identification Number: UN 1987
- Diamond Labels: Flammability 3
- Label: Flammable Liquid
- Arrow Label: This End Up.

Be sure to use ethanol-compatible shipping containers, including the box holding the container, specifically designed for this purpose.

Safety Procedures

Health Considerations

Fuel ethanol should be handled in the same manner as gasoline. Personal exposure should be minimized. Like gasoline, fuel ethanol is flammable and may contain additives that can be harmful even with casual contact. Fuel ethanol is poisonous and should not be ingested.



Exposure to fuel ethanol can occur by inhalation (breathing in its vapors), absorption (contact with the skin or the eyes), or ingestion (swallowing). The various symptoms of exposure to fuel ethanol are shown in Table 5 on page 15.

Fire Safety Considerations

Fighting fuel ethanol fires requires specific equipment, materials, and training. Conventional gasoline fire-fighting methods and chemicals are insufficient for fighting fires fueled by ethanol blends higher than E10. Only foams containing an alcohol-resistant polymer should be used, and only foams classified as AR-AFFF passed all UL requirements. These recommendations should be applied to all ethanol blends.

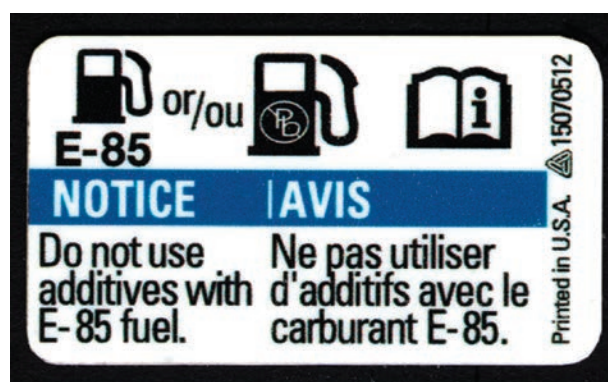
Before constructing any fueling installations, the local fire marshal should be consulted to determine local regulations governing safe fuel ethanol handling procedures.

“Responding to Ethanol Incidents,” a video developed in conjunction with RFA, the International Fire Chiefs Association, General Motors, Independent Liquid

Table 6. First Aid Treatments for Exposure to Fuel Ethanol

Symptoms of Exposure		
<ul style="list-style-type: none"> • Dullness of memory and concentration • Impaired motor coordination • Drowsiness, stupor, and coma. 		
Exposure	First Aid Treatment	Treatment Compared to Gasoline Exposure
Inhalation	Move away from the vapors to fresh air, and contact medical personnel immediately.	Same
Skin Absorption	Immediately wash skin with soap, and flush skin with plenty of water for at least 15 minutes. Remove contaminated clothing, and contact medical personnel.	Same
Eye Absorption	Immediately flush eyes with plenty of water for at least 15 minutes, and contact medical personnel.	Same
Ingestion	Lie down, keep warm, do not induce vomiting, and contact medical personnel immediately.	Different

Terminals Association, ANSUL Innovative Fire Solutions, and Williams Fire and Hazard Control, is a technical presentation directed primarily at ethanol plant operators and first responders. It is a training tool that documents ethanol fire-fighting foam test results and educates viewers on how to deal with ethanol-related spills and fires. The Ethanol Emergency Response Coalition provides the video in several formats as well as other pertinent safety training manuals.¹¹ An example of a material safety data sheet for E85 is available on the AFDC website.¹²



OEMs place labels like these inside FFV fuel doors.

Flexible Fuel Vehicles

Nearly all gasoline-fueled passenger cars and light-duty trucks sold in the United States in the last 20 years have been designed to operate on E10, and EPA has approved E15 for use in conventional gasoline vehicles of model year 2001 and newer. Flexible fuel vehicles (FFVs) feature modifications that allow them to safely and effectively operate on higher-level ethanol blends. FFVs can run on E85, gasoline, or any blend of the two, without adverse effects on fuel system and engine materials,

onboard diagnostics systems, or driveability. Original equipment manufacturers (OEMs) identify FFVs with a label inside the fuel door that indicates E85 and gasoline capability.

The list of fuel-system and engine components that must be modified for FFVs is extensive. These modifications address the different chemical properties and lower energy content in ethanol blends. Examples include hoses and other rubber components, such as fuel pump and fuel pressure regulator diaphragms and fuel injector

11. "Ethanol Emergency Response Coalition", www.ethanolresponse.com

12. Speedway E85. MSDS Solution Center. May 25, 2011. www.afdc.energy.gov/uploads/publication/SSA_MSDS.pdf

O-rings, to address possible leakage and permeation of fuel vapor. Modified electrical wiring and connectors are required for submersed components, such as the fuel-level sensor and fuel pump. Increased evaporative emissions carbon canister capacity, a modified fuel tank vapor pressure sensor, and modified engine valve and valve seat materials may also be required. Both metal and plastic fuel tanks must be designed to accommodate E85 because traditional terneplated steel fuel tanks and monolayer high-density polyethylene fuel tanks are not compatible with E85.

FFVs determine the concentration of ethanol in the fuel through the use of either a fuel sensor or a computer calculation based on oxygen sensor information. Many 2006 and later model year FFVs have eliminated the fuel sensor in favor of the computer calculation method. The engine control computer adjusts engine fueling rate for the oxygen content and reduced energy content of ethanol in order to maintain the proper air/fuel ratio under the various engine operating loads and conditions. The vaporization characteristics of ethanol require modified engine fueling strategies under engine cold-start and warm-up conditions as well.

If E85 is used in a conventional vehicle, it may negatively affect fuel system materials and components, and lead to leaks or failures. Driveability, performance, and emissions may also be negatively affected, leading the onboard diagnostics system to trigger the service engine light and set diagnostic codes related to lean engine operation.

Converting a conventional vehicle to an FFV is complicated and costly due to required modifications of the fuel system, engine, and the control system. EPA has established rules and guidelines for vehicle conversions for alternative fuel use. Each engine family must be certified separately with EPA, a process that includes filing the necessary paperwork and conducting required emission testing at a laboratory capable of performing EPA testing methods. Comprehensive information on EPA's certification procedures for alternative fuel conversions is available on EPA's website.¹³

In the U.S. marketplace, FFVs are available in dozens of models, from several manufacturers. Many of these vehicles are available at no additional cost compared to conventional gasoline-fueled vehicles, but some FFVs carry a nominal additional charge. For a list of FFVs available from original equipment manufacturers, visit FuelEconomy.gov or the Alternative Fuels Data Center Light-Duty Vehicle Search.¹⁴

Federal and state governments have established regulations for the purpose of advancing the use of all forms of alternative transportation fuels. For a list of these programs, visit the Federal and State Laws and Incentives section of the AFDC website at afd.energy.gov/laws.

13. "Alternative Fuel Conversion", www.epa.gov/otaq/consumer/fuels/altfuels/altfuels.htm

14. "Alternative Fuel and Advanced Vehicle Search", www.afdc.energy.gov/vehicles/search/light/

Checklist for Installing E85 or Blender Pump Dispensing Equipment or Converting Underground Storage Tanks

Dispensing Equipment

- _____ Notify your installer to review the applicable codes (generally NFPA 30A or International Fire Code 2012), then contact the local authority having jurisdiction, usually the building code office or local fire marshal, to determine whether there are any local code issues that should be addressed.
- _____ Notify the nearest fire department (and/or local first responders) that the site will soon be dispensing alcohol-blended fuels. Verify that fire extinguishers and other onsite safety equipment (necessary to respond to leaks, spills, fires, etc.) are ethanol compatible.
- _____ Notify implementing agency (usually a state office) 30 days prior to storing E85.
- _____ Determine compatibility of existing UST equipment—compare station equipment records with Appendices A, B, and C in this document. Replace incompatible UST equipment. Install UL-listed E85 dispenser, hanging hardware, and shear valve. Keep compatibility equipment records.
- _____ Use a 5–10-micron alcohol-compatible dispenser filter. Do not use 10-micron gasoline or 30-micron diesel filters.
- _____ Do not store or use denatured ethanol or any gasoline/ethanol blend with more than 83% ethanol by volume at a retail facility.
- _____ Calibrate the dispenser meter at the time of conversion or new installation and two weeks later to verify meter accuracy with E85.
- _____ Label the dispenser with all E85 logos, cautionary labels, and trade commission decals. Use nozzle covers stating that E85 is not gasoline or diesel. Add logos for blender pump fuels and indicate that they are for FFVs only. Consider using hangtags, pump toppers, and other signage to educate your customers. Price sign inserts, curb-side signs, and decals are available from industry associations.
- _____ Train site operators and emergency response personnel responsible for this location on ethanol fuel safety procedures and the differences relative to gasoline.

Underground Tanks

- _____ Notify your licensed installer (some states do not require installers to have a license) and the state UST program of your intent to dispense E85. Print a copy of the statement of compatibility from your tank manufacturer (see Appendix A for tank compatibility and links to letters stating compatibility).
- _____ Notify your UST insurance carrier to determine whether it has additional requirements for E85 fuels.
- _____ Obtain an amended insurance certificate showing coverage of E85 storage and dispensing.

Checklist continued on next page

- _____ If using an existing tank, clean the tank of all water and sediment. Ensure no water is present, to protect the quality of your ethanol-blended fuels and your customers' vehicles (see API Publication 2015, "Cleaning Petroleum Storage Tanks," and NFPA 326, "Standard for the Safeguarding of Tanks and Containers for Entry, Cleaning, or Repair," 2010 Edition).
- _____ Ensure all visible fittings and connections at the top of the tank are tight (no vapors escape, and no water enters).
- _____ Ensure the sump and spill containment covers will prevent water from entering the system. Identify the E85 fill port and paint the access cover according to API RP 1637. Make certain transport drivers cannot make fuel deliveries to the wrong fill pipe.
- _____ As a precaution to address residual sludge and gum deposits that will be dissolved by ethanol, industry recommends the tank to be filled to 80% of capacity and kept as full as possible for seven to 10 days. The residual impurities will be more diluted in a larger quantity of E85, reducing the risk of vehicle problems. This practice is also likely to expose any problems related to sludge and gum deposits during the initial inspection period.
- _____ Conduct a precision test of the tank system (0.1 gallon/hour leak rate) with an automatic tank gauging system within seven days after the tank is filled, to confirm the integrity of the system and that the leak detection equipment is operating properly. Report any fail results as required by the authority having jurisdiction.

Maintenance

- _____ Check for water regularly. Ensure that no water is contaminating your fueling system. If water is suspected or detected, track down its source and fix the problem immediately. The best way to guard against contamination is to properly clean and maintain the fueling system. Confirm no leaks exist in the tank fill cap and containment reservoir before beginning your E85 operation.
- _____ If the product seems to pump slowly, check and replace filters. Persistently clogged filters could indicate moisture or another source of contamination.
- _____ If installing a blender pump, ensure that the ethanol content is updated in the control system for each fuel delivery since the percentage changes according to geography and season.

Checklist for Dispensing E15

Nearly all E15 is sold from blender pumps drawing from E85 and E15. Follow the Checklist for Dispensing E85 and the additional steps for E15 sales.

- _____ Contact marketing/branding and state your intention to sell E15.
- _____ Contact your insurance company to determine any requirements impacting coverage related to E15 sales.
- _____ Adopt the RFA E15 Misfueling Mitigation Plan, as approved by EPA.¹⁵
- _____ Register for the RFG Survey Association's E15 retail survey at www.rfgsa.org.
- _____ EPA has approved the following dispenser hose configurations for dispensing E15:
 - Dedicated E15 hose
 - Common E15/E10/E0 hose; this configuration includes additional requirements:
 - Minimum 4-gallon purchase (label required); or
 - At least one fueling position with a dedicated E10 hose.
- _____ Dispenser options include using a UL-listed E25 retrofit kit or using an existing dispenser or purchasing a new UL E25 or E85 dispenser.
 - Purchase and install E25 or E85 hanging hardware.
- _____ Calibrate the dispenser meter at the time of conversion or new installation and two weeks later to verify meter accuracy with E15.
- _____ Label the dispenser with the required EPA E15 label; if E10 and E15 are dispensed from the same hose, add a label stating the 4-gallon minimum fueling volume. Consider using hangtags, pump toppers, and other signage to educate your customers. Price sign inserts, curbside signs, and decals are available from industry associations, including the Blend Your Own website (www.byoethanol.com or www.ethanolretailer.com).
- _____ Train site operators and emergency response personnel responsible for this location on ethanol fuel safety procedures and the differences relative to gasoline.

¹⁵. "Renewable Fuels Association. "E15 Misfueling Mitigation Plan" March 2, 2012. www3.epa.gov/otaq/regs/fuels/additive/e15/documents/rfa-model-e15-misfueling-mitigation-plan.pdf

Information Resources

General

- Alternative Fuels Data Center
www.afdc.energy.gov
- California Air Resources Board Fuels Programs
www.arb.ca.gov/fuels/fuels.htm
- EPA Office of Transportation and Air Quality
www.epa.gov/otaq/
- National Renewable Energy Laboratory
www.nrel.gov
- American Coalition for Ethanol
www.ethanol.org
- Blend Your Own
www.byoethanol.com
- Clean Fuels Development Coalition
www.cleanfuelsdc.org
- Ethanol Retailer
www.ethanolretailer.com
- Governors' Biofuels Coalition
www.governorsbiofuelscoalition.org
- Growth Energy
www.growthenergy.org
- National Corn Growers Association
www.ncga.com
- Renewable Fuels Association
www.ethanolrfa.org

Ethanol Fuel Codes and Safety

- International Code Council
www.iccsafe.org
- National Fire Protection Association
www.nfpa.org
- Occupational Safety & Health Administration
www.osha.com

Standards

- ASTM International
www.astm.org
- American Petroleum Institute
www.api.org

- California Air Resources Board Fuels Programs
www.arb.ca.gov/fuels/fuels.htm
- EPA Office of Transportation and Air Quality
www.epa.gov/otaq/
- EPA Office of Underground Storage Tanks
www.epa.gov/ust
- UL
www.ul.com

Equipment

- Fiberglass Tank and Pipe Institute
www.fiberglasstankandpipe.com
- Petroleum Equipment Institute
www.pei.org/ust-component-compatibility-library
- Steel Tank Institute
www.steeltank.com

Flexible Fuel Vehicles

- Alternative Fuels Data Center
www.afdc.energy.gov/vehicles/flexible_fuel.html
- Alliance of Automobile Manufacturers
www.autoalliance.org

Emissions

- Alliance of Automobile Manufacturers
www.autoalliance.org
- California Air Resources Board Fuels Programs
www.arb.ca.gov/fuels/fuels.htm
- Coordinating Research Council
www.crao.com
- EPA Office of Transportation and Air Quality
www.epa.gov/otaq/
- National Renewable Energy Laboratory
www.nrel.gov
- SAE International
www.sae.org

Appendix A: Tank Manufacturer Compatibility

Table A1: Tank Manufacturer Compatibility with Ethanol Blends					
	E10	E100		E10	E100
Manufacturer	✓	✓		<i>Continued from below</i>	
FIBERGLASS^a					
Containment Solutions	✓	✓		Highland Tank	✓ ✓
Owens Corning (single wall 1965-1994)	✓	✗		J.L. Houston Co.	✓ ✓
Owens Corning (double wall 1965-July 1, 1990)	✓	✗		Kennedy Tank and Manufacturing Co., Inc.	✓ ✓
Owens Corning (double wall July 2, 1990-December 31, 1994)	✓	✓		Lancaster Tanks and Steel Products	✓ ✓
Xerxes (single wall prior to February 1981)	✗	✗		Lannon Tank Corporation	✓ ✓
Xerxes (single wall February 1981-June 2005)	✓	✗		Mass Tank Sales Corp.	✓ ✓
Xerxes (single wall since July 2005)	✓	✓		Metal Products Company	✓ ✓
Xerxes (double wall prior to April 1990)	✓	✗		Mid-South Steel Products, Inc.	✓ ✓
Xerxes (double wall April 1990 and after)	✓	✓		Modern Welding Company	✓ ✓
STEEL^b				Newberry Tanks & Equipment, LLC	✓ ✓
Acterra Group Inc.	✓	✓		Plasteela	✓ ✓
Caribbean Tank Technologies Inc.	✓	✓		Service Welding & Machine Company	✓ ✓
Eaton Sales & Service LLC	✓	✓		Southern Tank & Manufacturing Co., Inc.	✓ ✓
General Industries	✓	✓		Stanwade Metal Products	✓ ✓
Greer Steel, Inc.	✓	✓		Talleres Industriales Potosinos, S.A. de C.V.	✓ ✓
Hall Tank Co.	✓	✓		Tanques Antillanos C. x A.	✓ ✓
Hamilton Tanks	✓	✓		Watco Tanks, Inc.	✓ ✓
				We-Mac Manufacturing Company	✓ ✓

Letters stating compability:

a. Petroleum Equipment Institute

www.pei.org/ust-component-compatibility-library

b. Steel Tank Institute

www.steeltank.com/FabricatedSteelProducts/ShopFabricatedTanks/SteelandAlternativeFuels/tabid/465/Default.aspx

Appendix B: Pipe and Associated UST Manufacturer Compatibility

Table B1. Pipe Manufacturer Compatibility with Ethanol Blends			
Manufacturer	Product	Model	Ethanol Compatibility
<i>Piping—All Companies have UL 971 listing for E100</i>			
Advantage Earth Products	Piping	1.5", 2", 3", 4"	E0-E100
Brugg	Piping	FLEXWELL-HL, SECON-X, NITROFLEX, LPG	E0-E100
Franklin Fueling	Piping	Franklin has third-party certified piping compatible with up to E85. Contact manufacturer for specific part numbers.	E0-E85
OPW	Piping	FlexWorks, KPS, Pisces (discontinued)	E0-E100
NOV Fiberglass	Piping	RedThread IIA, Ameron Dualoy	E0-E100
NUPI	Piping	Smartflex	E0-E100
OMEGAFLEX	Piping	DoubleTrac (brass and stainless steel fittings)	E0-E100

Letters stating compatibility:

Petroleum Equipment Institute

www.pei.org/ust-component-compatibility-library

Appendix B: Pipe and Associated UST Manufacturer Compatibility

Table B2. Associated UST Manufacturer Compatibility with Ethanol Blends			
Manufacturers introduce and discontinue models over time. If you do not see your equipment on this list please contact the manufacturer. Note X in these lists can be substituted for any value.			
Federal code requires compatibility of this equipment with specific fuels. This is achieved through either third-party listing or a letter from the manufacturer stating compatibility. Husky has UL listing for E85. The following companies have issued letters stating compatibility: Bravo, Morrison Brothers, Vaporless Manufacturing, Veeder-Root, and Western Fiberglass. Please contact other manufacturers for a compatibility letter or to inquire if they have UL E85 listed products. Compatibility letters are available at: www.pei.org/ust-component-compatibility-library			
Manufacturer	Product	Model	Ethanol Compatibility
Bravo Systems	Fiberglass fittings	Series F, FF, FPE, FR, Retrofit-S, D-BLR-S, D-INR-S, FLX, FLX-INR, FPS, TBF	E0-E100
Bravo Systems	Spill buckets	B3XX	E0-E100
Bravo Systems	Tank sumps & covers	B4XX	E0-E100
Bravo Systems	Transition sumps	B5XX, B6XX, B7XX, B8XX	E0-E100

Table B2 continued on next page

Appendix B: Pipe and Associated UST Manufacturer Compatibility

Table B2 (continued). Associated UST Manufacturer Compatibility with Ethanol Blends			
Manufacturer	Product	Model	Ethanol Compatibility
Bravo Systems	Under dispenser containment sumps	B1XXX, 7XXX, B8XXX, B9XXX	E0-E100
Cimtek	Filter	300MB-10, 300MB-30, 400MB-10, 400MB-30, 475XLMB-10	E0-E15
Cimtek	Filter	300BHA-01, 400BHA-01, 400BHA-05, 800BHA-01	E0-E85
Clay and Bailey	AST emergency vent	354, 365, 366, 367, 368, 369, 370	E0-E85
Clay and Bailey	AST manhole	API-650	E0-E85
Clay and Bailey	AST overfill prevention valve	1228	E0-E85
Clay and Bailey	AST spill containment	all	E0-E85
Clay and Bailey	Fill cap	94, 232, 233, 234, 235, 254	E0-E85
Franklin Fueling	All	Franklin has third-party certified equipment compatible with up to E85. Contact manufacturer for specific part numbers.	
Husky	Pressure vacuum vents	4620, 4885, 5885, 11730, 11735, 11740	E0-E85
Morrison Bros	Anodized farm nozzle	200S	E0-E85
Morrison Bros	Anti-syphon valve	912	E0-E85
Morrison Bros	AST adaptor	927	E0-E85
Morrison Bros	Ball valves	691BSS	E0-E85
Morrison Bros	Caps	305C	E0-E85
Morrison Bros	Clock gauge with alarm	918	E0-E85
Morrison Bros	Clock gauges	818	E0-E85
Morrison Bros	Combination vent/ overfill alarm	922	E0-E85
Morrison Bros	Diffuser	539TO, 539TC	E0-E85
Morrison Bros	Double tap bushing	184	E0-E85
Morrison Bros	Drop tubes	419A	E0-E85
Morrison Bros	Emergency vents	244	E0-E85

Table B2 continued on next page

Appendix B: Pipe and Associated UST Manufacturer Compatibility

Table B2 (continued). Associated UST Manufacturer Compatibility with Ethanol Blends			
Manufacturer	Product	Model	Ethanol Compatibility
Morrison Bros	Expansion relief valve	076DI, 078DI	E0-E85
Morrison Bros	External emergency valves	346DI, 346FDI, 346SS, 346FSS	E0-E85
Morrison Bros	Extractors	560/561/562/563	E0-E85
Morrison Bros	Flame arrester	351S	E0-E85
Morrison Bros	Float vent valves	317	E0-E85
Morrison Bros	Frost proof drain valve	128DIS	E0-E85
Morrison Bros	In-line check valve	958	E0-E85
Morrison Bros	Internal emergency valves	272DI, 72HDI	E0-E85
Morrison Bros	Overfill alarm	918TCP	E0-E85
Morrison Bros	Overfill prevention valve	9095A-AV, 9095SS	E0-E85
Morrison Bros	Series tank monitor adaptor and cap kits	305XPA	E0-E85
Morrison Bros	Solenoid valves (3" must be all teflon version)	710SS	E0-E85
Morrison Bros	Spill containers	515/516/517/518	E0-E85
Morrison Bros	Strainer	285	E0-E85
Morrison Bros	Swing check valves	246ADI, 246DRF	E0-E85
Morrison Bros	Tank monitor adaptor and cap kits	305XPA	E0-E85
Morrison Bros	Vapor recovery adaptor	323	E0-E85
Morrison Bros	Vapor recovery caps	323C	E0-E85
Morrison Bros	Vent-double outlet (small UST)	155	E0-E85
Morrison Bros	Vent-pressure vacuum	548, 748, 749	E0-E85
Morrison Bros	Vent-updraft	354	E0-E85
National Environmental Fiberglass	Sumps-dispenser	All	E0-E85
National Environmental Fiberglass	Sumps-tank	All	E0-E85
National Environmental Fiberglass	Sumps-transition	All	E0-E85

Table B2 continued on next page

Appendix B: Pipe and Associated UST Manufacturer Compatibility

Table B2 (continued). Associated UST Manufacturer Compatibility with Ethanol Blends

Manufacturer	Product	Model	Ethanol Compatibility
OPW	AST anti-siphon valve	199ASV	E0-E85
OPW	AST ball valve	21BV SS	E0-E85
OPW	AST check valve	175, 1175	E0-E85
OPW	AST emergency shut off valve	178S	E0-E85
OPW	AST emergency vent	201, 202	E0-E85
OPW	AST emergency vent	301	E0-E85
OPW	AST mechanical gauge	200TG	E0-E85
OPW	AST overfill prevention valve	61fSTOP A or M versions	E0-E85
OPW	AST overfill prevention valve	61fSTOP	E0-E25
OPW	AST pressure vacuum vent	523V, 623V	E0-E100
OPW	AST solenoid valve	821	E0-E25
OPW	AST spill container	211-RMOT, 331, 332	E0-E85
OPW	AST swing check valve	all	E0-E85
OPW	AST tank alarm	444TA	E0-E85
OPW	AST vapor adaptor	1611AVB-1625	E0-E100
OPW	AST vapor cap	1711T-7085-EVR, 1711LPC-0300	E0-E100
OPW	Ball float vent valve	53VML, 30MV	E0-E100
OPW	Check valve	70, 70S	E0-E100
OPW	Dispenser sumps & accessories	FlexWorks	E0-E100
OPW	Drop tube	61FT	E0-E25
OPW	Drop tube	61T, 61TC, 61TCP	E0-E15
OPW	Drop tube	61TSS	E0-E100
OPW	Extractor fittings and plug	233, 233VP	E0-E100
OPW	Face seal adaptor (threaded riser adaptor)	FSA	E0-E100
OPW	Fill adaptor-side	61AS	E0-E100

Table B2 continued on next page

Appendix B: Pipe and Associated UST Manufacturer Compatibility

Table B2 (continued). Associated UST Manufacturer Compatibility with Ethanol Blends			
Manufacturer	Product	Model	Ethanol Compatibility
OPW	Fill adaptor-top	633T, 633TC	EO-E100
OPW	Fill Cap	634TT-7085-EVR, 634LPC, 634TT-4000	EO-E100
OPW	Fill cap-side	62TT	EO-E100
OPW	Fill-swivel adaptor	61SALP-MA, 61SALP-1020-EVR	EO-E100
OPW	Flexible connectors	FCxx	EO-E100
OPW	Float kit	61SOK-0001	EO-E15
OPW	Jack screw	61JSK, 71JSK	EO-E100
OPW	Manhole	Conquistador, Fiberlite, 104A, 104FG, 104C, 6110,6120	EO-E100
OPW	Monitoring well cap kit	634TTM	EO-E100
OPW	Monitoring well probe cap	62M, 116M, 62M-MA	EO-E100
OPW	Multi-port spill containment	6511, 6421, 6511, 6521, 6561, 6571, Fiberlite	EO-E100
OPW	Overfill prevention valve	71SOM, 61SOM, 61SOCM-4000	EO-E100
OPW	Overfill prevention valve	71SO, 71SO-C, 71SO-CT, 61SOC, 61SOP, 61SOR	EO-E15
OPW	Pressure vacuum vent	523V, 623V	EO-E100
OPW	Spill container (bucket)	1-2100, 1SC-2100, 1C-2100,1C-2200, EDGE, '1-2105, 101-BG2100	EO-E100
OPW	Tank bottom protectors	6111, 61TP	EO-E15
OPW	Tank sumps & accessories	Fiberlite, FlexWorks	EO-E100
OPW	Transition sumps & accessories	FlexWorks	EO-E100
OPW	Vapor adaptor	1611AV, 1611AVB	EO-E100
OPW	Vapor Cap	1711T-7085-EVR, 1711LPC	EO-E100
OPW	Vapor-swivel adaptor	61VSA-MA, 61VSA-1020-EVR	EO-E100
Vaporless Manufacturing	Leak detector	99LD-2000/2200/3000 without stainless steel tubing/fittings	EO-E20
Vaporless Manufacturing	Leak detector	99LD-2000/2200/3000 with stainless steel tubing/fittings	EO-E100

Table B2 continued on next page

Appendix B: Pipe and Associated UST Manufacturer Compatibility

Table B2 (continued). Associated UST Manufacturer Compatibility with Ethanol Blends

Manufacturer	Product	Model	Ethanol Compatibility
OPW	Fill adaptor-top	633T, 633TC	E0-E100
Vaporless Manufacturing	Overfill prevention valve	OPF-2/3 with stainless steel tubing/fittings	E0-E100
Veeder-Root	Continuous interstitial tank system	P/N 857280-100, 857280-200, 857280-30X	E0-E15
Veeder-Root	Electronic line leak detector	Series 8484, 8590	E0-E15
Veeder-Root	Ground water monitoring	P/N 794380-621, 794380-622, 794380-624	E0-E15
Veeder-Root	Interstitial and secondary containment monitoring	P/N 794380-XXX, 794390-XXX, 847990-00X, 857080-XXX	E0-E15
Veeder-Root	Interstitial and secondary containment monitoring	P/N 794380-321, 794380-323, 794380-333, 794380-344, 794380-345, 794380-351, 794380-430	E0-E85
Veeder-Root	Magnetostrictive probe	Mag Plus Series 8463XX, Mag Series 8473XX	E0-E15
Veeder-Root	Tall tank probe	Mag-FLEX 889560-XXX, MAGXL-XXX	E0-E90
Veeder-Root	Vapor monitoring	P/N 394390-700	E0-E15
Western Fiberglass	Co-flex piping	all	E0-E100
Western Fiberglass	Cuff fittings	all	E0-E100
Western Fiberglass	Sumps (dispenser, tank, transition, vapor, vent)	all	E0-E100
Western Fiberglass	Co-flow hydrostatic monitoring systems	all	E0-E100

Letters stating compability:

Petroleum Equipment Institute

www.pei.org/ust-component-compatibility-library

Appendix C: Dispenser, Hanging Hardware, Shear Valve, and Submersible Turbine Pump Manufacturer Compatibility

Table C. Dispenser, Hanging Hardware, Shear Valve, and Submersible Turbine Pump Manufacturer Compatibility			
Manufacturers introduce and discontinue models over time. If you do not see your equipment on this list please contact the manufacturer.			
Manufacturer	Product	Model	Ethanol Compatibility
UL E25 and E85 Listed Equipment			
Gilbarco	Dispenser	An option on remote control dispenser Models NAO, NA1, NA2, NA3, NG1, NG6, NLO, NL1, NL2, and NL3. Models NG1, NG6, and NLO-NL3 are X+1 configurations where X is a number of blendable grades running through one hose on each side and the +1 indicates a dedicated, independent, set of hydraulics. E25 may only be on the +1 side (no ethanol blending). For such split-type dispensers, the independent non-E25 hydraulics may be constructed.	E0-E25
Gilbarco	Dispenser	An option on remote control dispenser Models NAO, NA1, NA2, NA3, NN0, NN1, NN2, NN3, G1, G6, L0, L1, L2, and L3 and NJ4. Models NG1, NG6, and NLO-NL3 are X+1 configurations where X is a number of blendable grades running through one hose on each side Model NJ4 is a 3+2 grade (double blender) with two distinct fuel trees as described above, and the +1 indicates a dedicated, independent, set of hydraulics. Hydraulics trees marked as suitable for E85 are suitable for blending mid-level grades.	E0-E85
Wayne	Dispenser	Ovation2 B12//9 and B23//9	E0-E25
Wayne	Dispenser	Ovation 2 EB23/4, EB23/5/M Dual Blender, EB23/5/M5 Double Dual Blender; Helix 3-1-1 H(W/LU)43-43E, 3-1-1 H(W/LU)45-43E/M5 Dual Blender, 3-1-1 H(W/LU)35-33E Double Dual Blender	E0-E85
Franklin Fueling	Shear valve	Franklin has third-party certified shear valves compatible with up to E85. Contact manufacturer for specific part numbers.	E0-E85
Franklin Fueling	Submersible turbine pump	Franklin has third-party certified STPs compatible with up to E85. Contact manufacturer for specific part numbers.	E0-E85
Husky	Nozzle	X E25, X E25 Cold Weather, XS E25, XS E25 Cold Weather	E0-E25
Husky	Nozzle	X E85, X E85 Cold Weather, XS E85, XS E85 Cold Weather	E0-E85
Husky	Breakaway	E25 Safe-T-Breaks	E0-E25
Husky	Breakaway	E85 Safe-T-Breaks	E0-E85

Table C continued on next page

Appendix C: Dispenser, Hanging Hardware, Shear Valve, and Submersible Turbine Pump Manufacturer Compatibility

Table C (continued). Dispenser, Hanging Hardware, Shear Valve, and Submersible Turbine Pump Manufacturer Compatibility

Manufacturers introduce and discontinue models over time. If you do not see your equipment on this list please contact the manufacturer.

Manufacturer	Product	Model	Ethanol Compatibility
UL E25 and E85 Listed Equipment			
OPW	Balance Adaptor	28CS	E0-E25
OPW	Breakaway	66V-0492	E0-E85
OPW	Breakaway	66V-030RF	E0-E25
OPW	Nozzle	11BP*E85	E0-E85
OPW	Nozzle	11AP*E25 and 11BP*E25 Series Nozzles	E25
OPW	Swivel	241TPS-75RF	E25
OPW	Swivel	241TPS-0492	E0-E85
OPW	Shear valve	10 series	E0-E100
OPW	Shear valve vapor	60VS	E0-E100
Manufacturer approved; equipment is not UL listed for blends above E10			
Veyance	Hose	Flexsteel Futura Ethan-ALL	E0-E85
Husky	Swivel	E85	E0-E85
IRPCO	Hose dispenser	Steelflex Ultra Hardwall, Softwall (2 Braid, 4SP), Marina	E0-E15
IRPCO	Hose transfer	Kanapower ST, RED FLEXTRA, FLEXWING Versafuel	E0-E15
Veeder-Root	Submersible turbine pump	Redjacket Maxxum 410763-XXX (MXP300JX-XXX or MXP500JX-XXX)	E0-E20
Veeder-Root	Submersible turbine pump	Redjacket AG models	E0-E100
Veyance	Hose dispenser	Flexsteel Futura	E0-E15

Appendix D: Various Specifications for Ethanol Fuels

Table D1. Listing of ASTM Specifications for Ethanol and E85	
ASTM D4806	Standard Specification for Denatured Fuel Ethanol for Blending with Gasoline for Use as Automotive Spark-Ignition Engine Fuel
ASTM D5798	Standard Specification for Ethanol Fuel Blends for Flexible-Fuel Automotive Spark-Ignition Engines
ASTM D7328	Standard Test Method for Determination of Existent and Potential Inorganic Sulfate and Total Inorganic Chloride in Fuel Ethanol by Ion Chromatography Using Aqueous Sample Injection
ASTM D6423	Standard Test Method for Determination of pH of Ethanol, Denatured Fuel Ethanol, and Fuel Ethanol
ASTM D5501	Standard Test Method for Determination of Ethanol and Methanol Content in Fuels Containing Greater than 20% Ethanol by Gas Chromatography
ASTM D4814	Standard Specification for Automotive Spark-Ignition Engine Fuel
ASTM D7794	Standard Practice for Blending Mid-Level Ethanol Fuel Blends for Flexible-Fuel Vehicles with Automotive Spark-Ignition Engines

ASTM D4806 standard sets guidelines for purity and other important properties for ethanol that is to be blended into gasoline. Major ethanol producers often establish additional guidelines that may exceed ASTM requirements. In addition, RFA has established specifications and quality standards for ethanol manufactured by its member companies (RFA Recommended Practice 911201). RFA Publication No. 96050117, "Fuel Ethanol: Industry Guidelines, Specifications and Procedures," also contains helpful information on fuel ethanol specifications.

Table D2. ASTM D4806 Standard Specification for Denatured Fuel Ethanol for Blending with Gasoline for Use as Automotive Spark-Ignition Engine Fuel		
Product Characteristic	Specification	ASTM Test Method
Ethanol, volume %, minimum	92.1	D5501
Methanol, volume %, maximum	0.5	D5501
Solvent-washed gum, mg/100 mL, maximum	5.0	D381
Sulfur, mass ppm, maximum	30	D2622, D3120, D5453, or D7039
Water content, volume %, maximum	1.0	E203 or E1074
Sulfate, mass ppm, maximum	4	D7318, D7319, or D7328
Denaturant content, volume %, minimum volume %, maximum	1.96 2.5	
Reactive Sulfur	Negative, "sweet"	GPA 1138
Inorganic chloride content, mass ppm (mg/L), maximum	10. (8)	D7319 or D7328
Copper content, mg/kg, maximum	0.1	D1688

Table D2 continued on next page

Appendix D: Various Specifications for Ethanol Fuels

Table D2 (continued). ASTM D4806 Standard Specification for Denatured Fuel Ethanol for Blending with Gasoline for Use as Automotive Spark-Ignition Engine Fuel

Product Characteristic	Specification	ASTM Test Method
Acidity (as acetic acid, CH ₃ COOH), mass % (mg/L), maximum	0.007 (56)	D1613 or D7795
pHe	6.5-9.0	D6423
Appearance	Visibly free of suspended or precipitated contaminants (clear and bright)	

Table D3. California Denatured Ethanol Standards (In Addition to the Performance Requirements in ASTM D4806)

Property	Specification Limit	ASTM Test Method
Sulfur, ppm, maximum	10	D5453-93
Benzene, volume %, maximum	0.06	D7576-10 test results of a sample of the denaturant multiplied by 0.0500 or the denaturant fraction, whichever is less
Olefins, volume %, maximum	0.5	D7347-07e1 test results of a sample of the denaturant multiplied by 0.0500 or the denaturant fraction, whichever is less
Aromatics, volume %, maximum	1.7	D7576-10 test results of a sample of the denaturant multiplied by 0.0500 or the denaturant fraction, whichever is less

California has promulgated additional specifications for denatured ethanol and the denaturant hydrocarbon that apply to ASTM D4806.

Table D4. California Denaturant Standards

Property	Specification Limit	ASTM Test Method
Benzene, volume %, maximum	1.1	D5580-02 (2007)
Olefins, volume %, maximum	10	D6550-10
Aromatics, volume %, maximum	35	D5580-02 (2007)

Appendix D: Various Specifications for Ethanol Fuels

Table D5. ASTM D8011 – Regulatory Requirements Pertaining to Natural Gasoline Used as a Denaturant and Hydrocarbon Blendstock for Ethanol Fuel Blends

Properties	Denaturant		Hydrocarbon Blendstock for Ethanol Fuel Blends		Test Methods
	For Use in the United States	For Use in California	For Use in the United States	For Use in California	
Distillation Temperatures, C (°F), at % Evaporated					D86, D7096
10% by volume, min	36 (97) ^A				
50% by volume, max	69 (156) ^A			100 (213) ^B	
90% by volume, max	98 (209) ^A			152 (305) ^B	
Sulfur, mg/kg, max	330 ^C				D1266, D2622, D3120, D5453, D6920, D7039, or D7220
Benzene, % by volume, max		1.1 ^D		1.10 ^E	D5580
Olefins, % by volume, max		10.0 ^D		10.0 ^E	D6550
Aromatics, % by volume, max		35.0 ^D		35.0 ^E	D5580

^ANo specific test method is referenced in the Alcohol and Tobacco Tax and Trade Bureau (TTB) of the U.S. Treasury Department and Revenue Canada regulations. At the time the TTB and Revenue Canada limits were created, Test Method D86 was the standard test method for these parameters.

^BLimits set by the California Air Resources Board (CARB) utilize Test Method D86-99.

^CEPA, effective January 1, 2017, establishes a limit of 330 ppm sulfur in denaturant.

^DCalifornia regulations (title 13 CCR 2262.9) establish limits of 1.10 % by volume benzene, 10.0% by volume olefins, and 35.0% by volume aromatics for the denaturant used to produce denatured fuel ethanol. The regulatory limits assume the maximum denaturant content of 5.00% by volume is contained in the denatured fuel alcohol. The regulations allow the limits to be adjusted if lower denaturant concentrations are used.

^ECalifornia regulations (title 13 CCR 2292.4) sets a maximum content of benzene, olefins, and aromatics for the hydrocarbon blendstock used to produce ethanol fuel blends.

Appendix D: Various Specifications for Ethanol Fuels

Table D6. Specifications for Fuel Ethanol Denaturants

Under 27 CFR 19.1005(b), the following materials are approved to render spirits unfit for beverage use and thus acceptable for withdrawal from alcohol fuel plants as fuel alcohol.

1. The materials listed in 27 CFR 19.10 05(c), in the quantities specified there.
2. The following additional materials, in the following quantities, corresponding to the following specifications:

Material	Quantity Added to 100 Gallons of Distilled Spirits	Specifications
Natural gasoline	2 gallons or more	<ol style="list-style-type: none"> 1. Natural gasoline (drip gas) is a mixture of butane, pentane, and hexane hydrocarbons extracted from natural gas. 2. Distillation range: No more than 10% of the sample may distill below 97° F; at least 50% shall distill at or below 156° F; and at least 90% shall distill at or below 209° F.
Ethyl tertiary-butyl ether (ETBE)	2 gallons or more	N/A
Raffinate	2 gallons or more	<ol style="list-style-type: none"> 1. Octane (R+M/2): 66-70 2. Distillation, in degrees F: <ul style="list-style-type: none"> • 10%: 120-150 • 50%: 144-180 3. API gravity: 76-82 4. Reid vapor pressure: 5-11 • 90%: 168-200 • End point: 216-285
Naphtha	2 gallons or more	<ol style="list-style-type: none"> 1. API gravity @ 60/60 degrees F: 64-70 2. Lb/gal: 5.845-6.025 3. Density: .7022-.7238 4. Reid vapor pressure: 8 P.S.I.A. max. 5. Copper corrosion: 17. Saybolt Color: 28 Min. 6. Distillation, in degrees F: <ul style="list-style-type: none"> • I.B.P.: 85 max. • 10%: 130 max. • 50%: 250 max. • 90%: 340 max. • End point: 380
Straight run gasoline (TTB Rul. 2008-2)	2 gallons or more	<ol style="list-style-type: none"> 1. Straight run gasoline is a mixture consisting predominantly (greater than 60% by volume) of C4, C5, C6, C7 and/or C8 hydrocarbons, and is either (1) a petroleum distillate coming straight from an atmospheric distillation unit without being cracked or reformed or (2) a condensate coming directly from an oil/gas recovery operation. 2. API gravity: 72° min., 85° max. 3. Reid vapor pressure: 15 psi max. 4. Sulfur: 120 ppm max. 5. Benzene: 1.1% by volume max. 6. Distillation, in degrees F: <ul style="list-style-type: none"> • 10%: 97 min., 158 max. • 50%: 250 max. • Final boiling point: 437°F max.
Toluene	5 gallons or more	See 27 CFR 21.132

Source: U.S. Department of the Treasury Alcohol and Tobacco Tax and Trade Bureau, www.ttb.gov/pdf/authorized_denaturants_fuel_alcohol.pdf

Appendix E: Seasonal and Geographical Volatility Classes for E85 (ASTM D5798)

Table E1. Seasonal and Geographical Volatility Classes for E85 (ASTM D5798)												
State and Fuel-Marketing Region	Volatility Class by Month											
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Alabama	2	2	2	2	2/1	1	1	1	1	1/2	2	2
Alaska - Southern Region	4	4/3	3	3/2	3/2	2/1	1	1/2	2/3	3	3/4	4
South Mainland	4	4	4	4	4/2	2	2/1	1/2	2/3	3/4	4	4
Arizona - North of 34°	3	3	3	3/2	2	2/1	1	1	1/2	2/3	3	3
South of 34°	2	2	2	2/1	1	1	1	1	1/2	2	2	2
Arkansas	3	3	3/2	2/1	1	1	1	1	1/2	2	2/3	3
California - North Coast	2	2	2	2	2	1	1	1	1	1/2	2	2
South Coast	2	2	2	2	2	1	1	1	1	1/2	2	2
Southeast	2	2	2	2	2	1	1	1	1	1/2	2	2
Interior	2	2	2	2	2	1	1	1	1	1/2	2	2
Colorado - East of 105° longitude	4	4/3	3	3/2	2	2/1	1	1	1/2	2/3	3	3/4
West of 105° longitude	4	4	4/3	3	3/2	2	2/1	1/2	2/3	3/4	4	4
Connecticut	4	4	4/3	3/2	2	2/1	1	1	1/2	2	2/4	4
Delaware	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
District of Columbia	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
Florida - North of 29° latitude	2	2	2	2/1	1	1	1	1	1	1/2	2	2
South of 29° latitude	2	2/1	1	1	1	1	1	1	1	1	1/2	2
Georgia	3	3/2	2	2/1	1	1	1	1	1	1/2	2	2/3
Hawaii	1	1	1	1	1	1	1	1	1	1	1	1
Idaho	4	4	4/3	3/2	2	2	2/1	1/2	2	2/3	3/4	4
Illinois - North of 40° latitude	4	4	4/3	3/2	2	2/1	1	1	1/2	2/3	3/4	4
South of 40° latitude	4	4/3	3	3/2	2/1	1	1	1	1/2	2/3	3/4	4
Indiana	4	4	4/3	3/2	2/1	1	1	1	1/2	2/3	3/4	4
Iowa	4	4	4	4/2	2	2/1	1	1	1/2	2/3	3/4	4
Kansas	4	4/3	3	3/2	2	2/1	1	1	1/2	2/3	3/4	4
Kentucky	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
Louisiana	2	2	2	2/1	1	1	1	1	1	1/2	2	2
Maine	4	4	4	4/2	2	2/1	1	1/2	2	2/3	3/4	4
Maryland	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
Massachusetts	4	4	4/3	3/2	2	2/1	1	1	1/2	2	2/4	4
Michigan - Lower	4	4	4/3	3/2	2	2/1	1	1/2	2	2/3	3/4	4
Upper	4	4	4	4/3	3/2	2/1	1	1/2	2	2/3	3/4	4
Minnesota	4	4	4	4/3	3/2	2/1	1	1/2	2	2/4	4	4

Table E1 continued on next page

Appendix E: Seasonal and Geographical Volatility Classes for E85 (ASTM D5798)

Table E1 (continued). Seasonal and Geographical Volatility Classes for E85 (ASTM D5798)												
State and Fuel-Marketing Region	Volatility Class by Month											
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mississippi	1/2	2	2	2/1	1	1	1	1	1	1/2	2	2
Missouri	4	4/3	3	3/2	2/1	1	1	1	1/2	2/3	3	3
Montana	4	4	4	4/3	3/2	2	2/1	1/2	2/3	3/4	4	4
Nebraska	4	4	4/3	3/2	2	2/1	1	1/2	2	2/3	3/4	4
Nevada - North of 38° latitude	4	4	4/3	3/2	2	2	2/1	1/2	2	2/3	3/4	4
South of 38° latitude	2	2	2	2/1	2/1	1	1	1	1	1/2	2	2
New Hampshire	4	4	4/3	3/2	2	2/1	1	1	?	2	2/3	3
New Jersey	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
New Mexico - North of 34° latitude	4	4/3	3	3/2	2	2/1	1	1	1/2	2/3	3	3/4
South of 34° latitude	3	3	3/2	2/1	1	1	1	1	1	1/2	2/3	3
New York - North of 42° latitude	4	4	4	4/2	2	2/1	1	1/2	2	2/3	3/4	4
South of 42° latitude	4	4	4/3	3/2	2/1	1	1	1	1/2	2	2/3	3/4
North Carolina	3	3	3/2	2	2/1	1	1	1	1/2	2/3	3	3
North Dakota	4	4	4	4/3	3/2	2/1	1	1/2	2	2/4	4	4
Ohio	4	4	4/3	3/2	2	2/1	1	1	1/2	2/3	3/4	4
Oklahoma	3	3	3	3/2	2/1	1	1	1	1/2	2	2/3	3
Oregon - East of 122° longitude	4	4/3	3	3/2	2	2	2/1	1/2	2	2/3	3	3/4
West of 122° longitude	3	3/2	2	2	2	2/1	1	1	1/2	2	2	2/3
Pennsylvania - North of 41° latitude	4	4	4	4/2	2	2/1	1	1/2	2	2/3	3/4	4
South of 41° latitude	3	3	3	3/2	2/1	1	1	1	1/2	2	2/3	3
Rhode Island	3	3	3	3/2	2/1	1	1	1	1/2	2	2/3	3
South Carolina	2	2	2	2/1	1	1	1	1	1	1/2	2	2
South Dakota	4	4	4	4/2	2	2/1	1	1/2	2	2/3	3/4	4
Tennessee	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
Texas - North of 31° latitude	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
South of 31° latitude	2	2	2	2/1	1	1	1	1	1	1/2	2	2
Utah	4	4/3	3	3/2	2	2/1	1	1	1/2	2/3	3	3/4
Vermont	4	4	4/3	3/2	2	2/1	1	1/2	2	2/3	3/4	4
Virginia	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
Washington - East of 122° longitude	4	4/3	3	3/2	2	2	2/1	1	1/2	2/3	3	3/4
West of 122° longitude	3	3/2	2	2	2	2/1	1	1	1/2	2	2	2/3
West Virginia	4	4/3	3	3/2	2	2/1	1	1/2	2	2/3	3	3/4
Wisconsin	4	4	4	4/2	2	2/1	1	1/2	2	2/3	3/4	4
Wyoming	4	4	4	4/3	3/2	2	2/1	1/2	2	2/4	4	4

Appendix F: UL Testing Standards for Refueling Equipment

Table F. UL Testing Standards for Refueling Equipment		
UL Testing Standard	Equipment Covered	Test Fluid (or listing)
UL 58	Underground steel tanks (no test fluids)	No test fluid
UL 1746	External Corrosion Protection Systems for USTs (option to test with up to E100)	Option up to E100
UL 1316	Underground fiberglass tanks (option to test with up to E100)	Option up to E100
UL 971	Pipes and pipe fittings non-metallic (option to test with up to E100)	Option up to E100
UL 971A	Pipes and pipe fittings metallic (option to test with up to E100)	Option up to E100
UL 2447	Sumps: tank, dispenser, transition, fill/vent, spill buckets Sump fittings: penetration, termination, internal, test and monitoring Sump accessories: frames/brackets, covers/lids, & chase pipe	Requires E25 and E85
UL 2039	Flexible Connectors	Requires E25 and E85
UL 87	Dispensers	E10 listing only
UL 87A	Dispensers	Requires E25 and E85
UL 25	Meters	E10 listing only
UL 25A	Meters	Requires E25 and E85
UL 330	Hose and hose assemblies	E10 listing only
UL 330A	Hose and hose assemblies	Requires E25 and E85
UL 331	Filters	E10 listing only
UL 331A	Filters	Requires E25 and E85
UL 428	Submersible turbine pump	E10 listing only
UL 428A	Submersible turbine pump	Requires E25 and E85
UL 567	Breakaway, swivels, pipe connection fittings	E10 listing only
UL 567A	Breakaway, swivels, pipe connection fittings	Requires E25 and E85
UL 842	Shear valve	E10 listing only
UL 842A	Shear valve	Requires E25 and E85
UL 2586	Nozzles	E10 listing only
UL 2586A	Nozzles	Requires E25 and E85

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