




Increasing Biofuel Deployment and Utilization through Development of Renewable Super Premium: Infrastructure Assessment

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NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
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Technical Report
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Preface

This summary report offers a preliminary assessment of the impacts of mid-level ethanol blends (E25 or E25+) on refueling infrastructure. Interviews were conducted with industry stakeholder groups, station inspectors, refueling equipment manufacturers, and other experts. This report also summarizes the patchwork of regulations that cover some, but not all, equipment that is an important aspect in deployment of alternative fuels into the existing infrastructure. It also covers advancements in compatibility and availability of equipment for use with various ethanol blends.

Acknowledgments

This work is sponsored by the U.S. Department of Energy's Bioenergy Technologies Office. The National Renewable Energy Laboratory and Oak Ridge National Laboratory would like to thank staff from the following organizations for their time informing this report: Advantage Earth Products, AOC Resins, BP, the U.S. Environmental Protection Agency's Office of Underground Storage Tanks, Franklin Fueling, Gilbarco, Henderson Consulting, Husky, the National Association of Convenience Store Owners, NOV Fiberglass Systems, NUPI, Omega Flex, OPW, Parker, Petroleum Equipment Institute, The SourceNA, Underwriters Laboratory, Veyance, and Wayne.

List of Acronyms

AHJ	authority having jurisdiction
DOE	U.S. Department of Energy
E10	10% denatured ethanol; 90% hydrocarbon blendstock for oxygen blending
E15	15% denatured ethanol, 85% gasoline
E25	25% denatured ethanol, 75% gasoline
E30	30% denatured ethanol, 70% gasoline
E85	marketing term for high-blend ethanol 51%–83%
EPA	U.S. Environmental Protection Agency
FFV	flex fuel vehicle
FRP	fiber-reinforced plastic
HDPE	high density polyethylene
NACS	National Association of Convenience Store Owners
NBR	acrylonitrile butadiene rubber
NREL	National Renewable Energy Laboratory
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
OUST	Office of Underground Storage Tanks
PEI	Petroleum Equipment Institute
PET	polyester terephthalate
PVDF	polyvinylidenedifluoride
RFA	Renewable Fuels Association
RSP	renewable super premium
STP	submersible turbine pump
UL	Underwriters Laboratories
ULSD	ultra-low sulfur diesel
UST	underground storage tank
vol%	percent by volume

Summary

This report evaluates infrastructure implications for a high-octane fuel, i.e., a blend of 25% denatured ethanol and 75% gasoline (E25) or higher (E25+), for use with a new high-efficiency type of vehicle. E25+ is under consideration due to federal regulations requiring the use of more renewable fuels and improvements in fuel economy. The existing transportation fuel infrastructure may not be completely compatible with a mid-level ethanol blend (blends above E15 up to E50). It is anticipated that a mid-level ethanol blend will face many of the same hurdles as E15, and a fuel above E25 will face additional barriers. Three questions need to be considered when introducing a new fuel to existing infrastructure: Is the infrastructure it compatible? Is it listed by a third party? Is it approved?

A significant amount of research and regulatory action has addressed these concerns with positive progress towards enabling the use of ethanol blends above 10% ethanol (E10) in existing and upgraded equipment. The U.S. Environmental Protection Agency's Office of Underground Storage Tanks biofuels guidance allowed tank and associated equipment manufacturers to issue statements of compatibility (EPA 2011). This has resulted in the determination that the majority of existing tanks are capable of storing blends of up to E85 (a marketing term for high-blend ethanol [51%–83%]) or E100 (denatured fuel ethanol). Past research on ethanol fuels and issues with the introduction and use of ultra-low sulfur diesel led refueling equipment manufacturers to upgrade sealing materials in their products for safe and reliable performance over a range of fuels. However, although gasoline equipment is being designed to be more robust across a broader range of fuels, the Petroleum Equipment Institute stated that new stations are not opting to install E25 or E85 listed or manufacturer-approved equipment due to the greater cost of such equipment and the expectation of low demand for ethanol blends above E10.

The general consensus among industry groups and equipment manufacturers is that it will be easier and less costly to deploy fuel containing ethanol up to E25 than an E25+ fuel. Increasing the blend level will be met with reluctance by manufacturers, who have not yet profited from the development of E25 and E85 products. Equipment manufacturers interviewed in this study suggested a blend above E25 could use their E85 products. While this would be practical because this equipment is available, it is challenging for the marketplace as the price differential between E10 and E25 equipment is negligible compared with the price premium for E85-listed products. Table ES-1 summarizes estimated minimum costs for offering E10+ fuels at a retail station.

And while storage tanks may be compatible with these blends, a typical station will have three storage tanks: one dedicated to diesel and the other two storing regular and premium gasoline to offer regular, mid-grade (made by blending from the two tanks), and premium. In some instances, a station may have a tank dedicated to mid-grade storage that could be used to store an ethanol blend. Incorporating a new ethanol blend into the system presents a challenge to the station operator's business model and cash flow. A station would need to decide between using an existing tank or adding a new tank.

Perhaps the most significant barrier is that stations are not required to keep records of equipment. This makes it difficult to determine if existing equipment is compatible with various ethanol blends. In addition, retail station owners have concerns about their liability in the event of misfueling. Small, independent retailers (which represent 63% of the stations) are unlikely to

have the capital needed to purchase equipment to handle blends above E10. Large ownership groups (owners of many stations, hypermarkets) are concerned with vague codes and regulations. Some chains are risk averse and may not consider carrying an alternative fuel until it reaches some threshold where many of their competitors are selling it. A fuel is viewed as "convenient" if it is available at 20% of stations according to past studies (Greene 1998, Greene et al. 2008, Melaina et al. 2013, Nicholas et al. 2004).

Table ES-1. Minimum Costs for One E10+ Refueling Position at a Station

	Station Costs for One Refueling Position at a Station	
Equipment	**E15–E25**	**E26–E83**
Use an existing tank		
Dispenser[a]	$2,100	$23,500
Hanging hardware & shear valve	$835	$926
Tank cleaning cost	$1,500	$1,500
Total (using an existing tank)	$4,435	$25,926
New tank[b]	$95,000	$95,000
Total (with a new tank)	$97,935	$119,426

[a] Assumes E15 and E25 use a UL-listed retrofit kit on an existing dispenser and E25+ requires an E85 dispenser.
[b] Installed tank and all associated tank equipment cost at an existing station; tank costs are the same regardless of fuel costs; tank at a new station is $75,000.

Source: Refueling equipment distributors, manufacturers, and Petroleum Equipment Institute

Table of Contents

List of Figures

List of Tables

1 Background

1.1 Renewable Super Premium Project Description Rationale

The renewable fuel standard[1] established a 36-billion-gallon annual target for renewable fuel consumption by 2022, but the future path toward compliance is not clear. Because nearly all gasoline sold already contains 10% ethanol (E10), the United States is essentially at the "blend wall," meaning that the only available expansion opportunities for ethanol as a vehicle fuel are in selling more E15 and E85 (a marketing term for high-blend ethanol 51%–83%, also known as flex-fuel). However, consumption of blends above E10 is limited and estimated to account for less than 1% of ethanol consumption.

Additionally, federal law requires carbon dioxide emissions from vehicles to drop by more than 50% by 2025. Automakers are pursuing a complete portfolio of technologies to achieve these emission reductions, including lightweighting, improved aerodynamics, hybridization, and improvements in engine efficiency. Engine efficiency improvements may involve increased compression ratio, direct injection, turbocharging and downsizing/downspeeding. While the 2025 targets are expected to be met with existing marketplace fuels, a lower cost pathway – or a pathway towards lower carbon dioxide levels in the future – may be the introduction of more highly knock resistant fuels that enable compression ratio, turbocharging, and downsizing/downspeeding to be taken significantly farther than is possible with current fuels.

Recently published data from U.S. Department of Energy (DOE) laboratories and vehicle manufacturers and discussions with the U.S. Environmental Protection Agency (EPA) suggest the high potential of a new "renewable super premium" (RSP) fuel with 20–40 volume percent (vol%) ethanol to enable significant increases in engine efficiency. This mid-level ethanol content fuel, with a research octane number of around 100, appears to enable efficiency improvements in a properly designed engine/vehicle system sufficient to more than offset the lower energy density (Jung et al. 2013). This would negate the tank mileage (range) loss typically seen with ethanol blends in gasoline and un-optimized ethanol-tolerant vehicles.

The prospects of such a fuel are additionally attractive because it can be used legally in flex-fuel vehicles (FFVs) on the road today. Some FFV owners want more options for ethanol blends due to frequency of fill-ups or for other reasons of consumer choice. Thus, the current FFV fleet can serve as a bridge by providing a market for the new fuel today so that future vehicles can have improved efficiency through optimization on the new fuel. In this way, RSP can simultaneously enable compliance with future greenhouse gas / fuel economy standards as well as renewable fuel standard compliance by creating a growing market for an ethanol blend beyond E10. Today, with gasoline at the E10 level, neither the advantageous nor disadvantageous properties of ethanol are particularly noticeable. At high-level blends ("E85") for FFVs, the potential benefits from high research octane number and other knock resistance properties of ethanol cannot offset the loss of tank mileage (the octane number benefits are non-linear and diminish at blends greater than 40% ethanol [E40]).

Argonne National Laboratory, the National Renewable Energy Laboratory (NREL), and Oak Ridge National Laboratory (ORNL) are collaborating on a scoping study to address key issues and opportunities with RSP. The topics being considered in this project include this

[1] Revised in 2007 as a part of the Energy Independence and Security Act

infrastructure assessment, a market analysis of the economic and regulatory barriers associated with introducing RSP in the market, a well-to-wheels analysis of the greenhouse gas profiles associated with RSP, quantifying the knock resistance properties of RSP, and the impact of RSP on legacy FFVs and optimized, dedicated vehicles.

Compatibility with refueling infrastructure is often cited as a barrier to introducing alternative transportation fuels. This study was conducted by NREL and ORNL and builds on their experience with E15 and E85 and interactions with the retail fuels industry and equipment manufacturers. The scope of this report is limited to retail stations and does not assess the logistics of getting additional ethanol to terminals. It is assumed that because ethanol is already stored at terminals, additional ethanol for RSP can be delivered to the terminal and also to the retail station. In this study, RSP refers to the mid-level ethanol, high-octane blend of fuel whereas E25 or E30, etc., refers to the specific volume of denatured ethanol blended in the finished fuel.[2]

1.2 Ethanol Background

The use of ethanol in motor fuels has grown dramatically over the past decade, principally through the expansion and availability of E10. Although E85 and E15 are both legal fuels, the overwhelming majority of all fuel ethanol is used in the form of E10. In 2004, E10 was about 30% of the gasoline market, growing to 50% in 2007 and over 95% by 2011 (RFA 2005, 2008, 2012). As evidenced by a significant increase in ethanol exports, the United States probably hit the blend wall in late 2012 or sometime in 2013 (White 2014). With the rapid growth of E10 nationally, some problems in the existing infrastructure did occur. Anecdotal evidence indicated that when ethanol was initially introduced into the infrastructure, the ethanol removed “rust plugs” in metal underground storage tanks (USTs), and some dispensers developed leaks, especially in pipe sealants, seals, and gaskets. These issues have largely been resolved by equipment manufacturers with upgraded materials to address E10 and also ultra-low sulfur diesel (ULSD).[3] This recent transition and the introduction of E15 into the market can be used to offer some perspective on the introduction of RSP.

It is conceivable that FFVs could consume significant quantities of additional ethanol. Fuel quality standard ASTM D5798-11 was revised to redefine E85 as “fuel for FFVs” and allows the ethanol content to range from 51% to 83% ethanol to ensure performance across seasons and geography (AFDC 2014a). As of October 2014, there were over 2,400 public E85 stations in 47 states (AFDC 2014b). Of these stations, 342 have blender pumps providing several mid-level ethanol fuel choices for FFV owners. According to Polk data, there were over 17.4 million FFVs nationwide. Based on Energy Information Administration data, average 2012 E85 use per FFV was calculated at 13.4 gallons for the year (NACS 2014a). Likely causes are lack of availability of E85 fueling stations, E85 energy content translating to lower vehicle range, and pricing that may not fully compensate for the lower energy content. The renewable fuel standard is tracked through a system of renewable identification numbers, which have market values. There have been price spikes for ethanol renewable identification numbers, which resulted in lower E85

[2] Denatured ethanol is E98; 2% denaturant is added to prevent human consumption and avoid alcohol sales tax.
[3] The introduction of ULSD with lower sulfur and less lubricity led to some issues with sealing materials similar with E10 in gasoline. Thus manufacturers have upgraded materials in their product to handle a variety of transportation fuels.

prices, in turn leading to higher sales, illustrating the potential to increase sales of higher-level ethanol blends when the pricing is favorable (White 2014).

According to the Renewable Fuels Association (RFA), at the start of 2014 there were 65 stations selling E15 with plans for ownership groups Murphy USA and MAPCO to start selling the blend at some of their stations in late 2014 (White 2014). Additionally, RFA estimates that consumers have driven over 100 million miles with E15.[4]

The National Association of Convenience Store Owners (NACS) conducts consumer surveys and looked into consumer knowledge and potential use of E15 (NACS 2014b). Only 20% of consumers were reported to be very or somewhat familiar with E15 while nearly 60% stated they were very likely or somewhat likely to purchase E15 if it were the same price as gasoline. The reasons consumers cited for considering buying E15 included: better for the environment, better fuel economy, to support renewable fuel use, and to reduce petroleum use. The top responses for consumers unwilling to use E15 included: worried it would damage their vehicle, decrease in fuel economy, and manufacturer does not authorize vehicle to use it.

E15 and Station Reluctance

The following issues were identified by NACS as applicable to stations considering selling E15 (NACS 2013). These concerns may also apply to mid-level ethanol blends.

Exposure to liability: EPA allows the sale and use of E15 in vehicles model year 2001 and newer. Station ownership groups are concerned about the approval for only certain engine types, which could confuse consumers and lead to fines for stations. There have been concerns about misfueling and who is responsible—examples include a consumer refilling with E15 in an older vehicle or filling a canister for use with small engines, which use is not approved by EPA. There is a provision in the Clean Air Act that allows stations to be sued for misfueling whether intentional or not. Fines can be up to $37,500 per day. Retailers are somewhat less concerned about misfueling of E85 because FFVs are a specialized vehicle type; this could also be the case for a specific high-octane fuel and vehicle.

Occupational Safety and Health Administration (OSHA) requirements: OSHA rules require the use of third-party listed products for specific fuels for the dispenser, breakaway, and nozzle and sound engineering for tanks and pipes. Industry groups have suggested that not meeting federal requirements opens up the possibility of a station losing tank insurance and failing to meet bank loan agreements. Costs to upgrade to compatible equipment (dispenser retrofit kit and compatible hanging hardware) are also a concern.

Vapor pressure: Federal, state, and local air control regulations require fuels to meet certain volatility standards. In particular, EPA limits the vapor pressure of gasoline to 9 psi in the summer months (and to lower levels in reformulated gasoline areas). Blends of 10 vol% ethanol are allowed 1 psi higher vapor pressure, the so-called "1-pound waiver." E15 is not afforded the same "1-pound waiver" rule as E10, which means E15 cannot be sold in certain locations at

[4] RFA assumptions provided by Robert White are based on average station sales volumes and that 12% of sales at each station are E15 and that the average light-duty vehicle has a fuel economy of 20 miles per gallon.

certain times of the year, or E15 has to be blended with a lower-volatility gasoline blendstock for oxygen blending (a product not typically available at blending terminals).

Additional issues include the auto industry's viewpoint on E15 and whether consumers void their warranty if they refuel with E15. There are also concerns on where to store E15 as many stations only have one tank storing regular and one storing premium.

1.3 Station Data and Ownership

Overall, the total number of retail stations has declined by 20% since 1996 (AFDC 2014c). However, approximately 1,600 new retail stations open annually (NACS 2014c). Some statistics from NACS 2013 Annual Report show some of the challenges in reaching various station owner types and their ability to afford equipment upgrades and installations (NACS 2013):

1.3.1 Station Ownership

- There are 152,995 fueling stations.
- Fifty-eight percent are single-store owners/operators.
- Major oil companies own 0.4% of stations.
- Approximately 50% of stations sell branded fuel.
- Eighty percent of transportation fuels are sold at convenience stores.
- Sales per convenience store average 128,000 gallons per month (4,000 gallons/day).
- Transportation fuels are 71% of sales at a convenience store, but only 36% of profits.
- Average markup (gross margin) for gasoline is $0.184/gallon.
- Average profit per convenience stores in 2012 was $48,000 with most profit coming from selling products in the store.[5]
- There are at least 40 million fill-ups per day.
- Light-duty vehicles consumed on average 453 gallons per year with an average efficiency of 23.5 miles per gallon traveling an average of 29.1 miles per day.

One of the challenges in introducing a new fuel to the marketplace is outreach because so many stations are single owner. Stations would want to ensure they maintain insurance and bank loans—a common concern when considering dispensing alternative fuels from existing infrastructure. As evidenced in Figure 1, after single-store owners, the next highest percentage of ownership—almost 15%—is ownership groups with more than 500 stations.

[5] Communicated by John Eichberger of NACS on March 3, 2014.

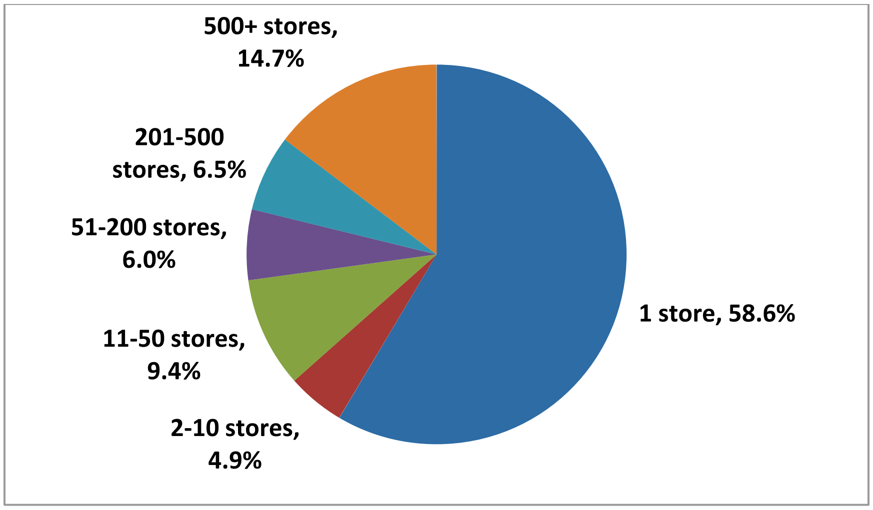


Figure 1. Breakout of station ownership

Source: "2013 Retail Fuels Report." NACS, 2013.

While oil companies no longer own many stations, nearly 50% of convenience stores are branded by either an oil company (31%) or refinery/distributor (19%) (NACS 2013).[6] The other 50% of convenience stores sell unbranded fuel but are familiar to customers due to store branding—examples include 7-11 and Wawa. The motivation for oil companies and refiners to establish contracts with convenience stores is to ensure a market for their products. The motivation for station owners to establish a contract with a brand is for instant recognition by consumers. A contract is typically 10 years; terms include a guaranteed fuel supply and sales volume requirements. The brand also provides advertising, methods to attract customers, logos, signage, and standards for customer service and cleanliness. Under these contracts, the brand typically prices wholesale products against primary fuel indexes with a few-cent premium to cover brand marketing support and proprietary additives.

Another significant seller of transportation fuels is hypermarkets—either large grocery store chains or big merchandise stores. There are approximately 4,900 hypermarkets selling fuels (NACS 2013). Kroger and Walmart account for over 40% of the total; Sam's Club, Safeway, and Costco are the other leaders. These are high-volume sites with average sales volumes of 275,000 gallons/month—nearly double what the average convenience store sells.

Station owners with one to two convenience stores typically own them for between 5 and 10 years while larger ownership groups may own stations for decades. Larger ownership groups also analyze the performance of each location annually to determine which stores to keep and which to sell. Also, ownership groups differ in their approach to expanding with some like Kwik Trip building new stores while others such as Casey's buy existing locations and remodel the inside of the convenience store. Average costs for a new station are approximately $3.3 million with over $430,000 spent on equipment (Table 1). The Petroleum Equipment Institute (PEI) stated that few new stations are opting for E25- and/or E85-compatible equipment.

[6] An oil company is an oil producer while a refiner converts crude oil into products like gasoline; and a distributor delivers products from a refiner to terminals and stations.

Table 1. Costs for a New Station

Item	Cost
Land	$922,980
Building	$1,042,563
Food Service Equipment	$197,801
Motor Fuel Equipment	$435,993
Merchandise Equipment	$187,517
Car Wash	$323,918
Technology	$47,689
Beginning Motor Fuel Inventory	$64,967
Beginning Merchandise Inventory	$76,639
Total	$3,300,067

Source: NACS communication from John Eichberger.

It is important to note that for a new fuel to be commonly available, it does not have to be sold in every station. Estimates are that if RSP were available at 10%–20% of the retail fueling stations, it would be viewed as widely available (Greene 1998, Greene et al. 2008, Melaina et al. 2013, Nicholas et al. 2004).

1.3.2 Petroleum Infrastructure

Infrastructure for moving petroleum products is listed in Table 2. Ethanol is largely distributed by rail cars to the terminal and in tanker trucks from blending terminals to the destination. A limited amount of ethanol (E98) has been transported in a Kinder Morgan pipeline a short distance in Florida without incident. It is rare for ethanol to be transported in pipelines due to its affinity for water.

Table 2. Petroleum Distribution Infrastructure

Petroleum Distribution Method	Number
Refineries	144
Pipelines	200,000 miles
Terminals	1,400
Barges	3,300
Rail cars	200,000
Tanker trucks	100,000
Jones Act vessels[a]	38

[a] U.S. flag ships moving products between U.S. ports

Source: NACS. (2013). "2013 Annual Fuels Report."

1.4 Equipment at Station

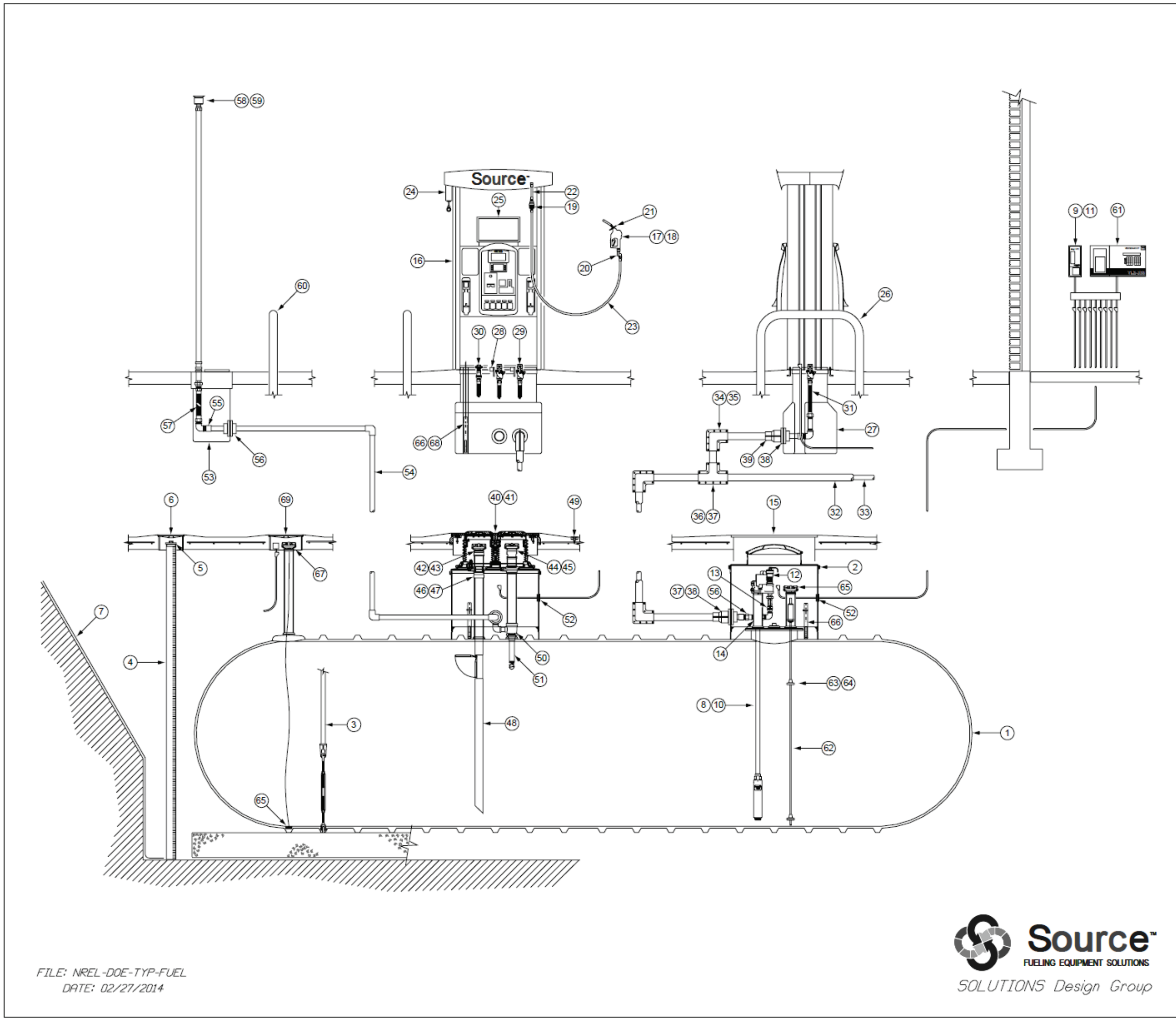
A fueling system at a service station consists of many interconnected pieces of equipment necessary to deliver fuel to vehicles. Major categories of equipment include tanks, tank vents, leak detection, vapor recovery devices, vapor processing units, pumps, fuel/vapor pipe, shear/impact fire valves, dispensers, hoses, breakaway, and nozzles. Figure 2 shows a diagram and list of station equipment. Costs for new equipment vary, but a new UST system and pipes at a new or existing station cost $75,000 to $95,000 (including installation); a new dispenser costs $15,000 or more depending on options; and hanging hardware costs a few hundred dollars. Costs are marginally more expensive for E25 dispensers and significantly higher for E85 dispensers and hanging hardware. The cost difference is less for E25 because it only requires upgrades to elastomers while E85 needs expensive specialized metals to combat corrosion. It is possible that the tank and piping are compatible, but some associated UST equipment may need to be replaced. A list of ethanol-compatible associated UST equipment is available in Appendix A.

There is no regulation that requires station owners to keep records of their equipment, and it is even more challenging as stations are sold regularly and equipment lists, if they exist, are not always transferred to the new owner. One potential source of tank information is the Steel Tank Institute, who maintains a list of tanks if owners send in the warranty card. NACS, the trade group representing retail stations, supports legislation to require equipment records for each station. Large retail service station chains are more likely to have equipment records than single-owner stations. Some equipment is above ground and can easily be identified while other equipment is difficult to access and fuel wetted, so while the manufacturer may be identifiable, the model or part number may not be. This creates an issue for determining compatibility because manufacturers state that certain product/model numbers can be used with high-level ethanol blends while others cannot.

NREL interviewed a well-known station inspector to determine the ability to inventory equipment at an existing station. The inspector stated that newer stations (5–6 years old) may have installation records and it would be possible to develop a list of equipment in 2–3 hours. Stations that have transferred ownership are less likely to have installation records. Newer stations without installation records would require 1–2 days to inventory equipment. For stations 10 to 15 years old or older, it may not even be possible to do an inventory. A skilled inspector would be able to identify the manufacturer of a piece of equipment, but not the model name or number of long-wetted fuel parts as they wear away over time. Correct identification of the tank manufacturer and year is of significant importance. This information is affixed on a plate on the outside of the tank. The inspector said it would require excavating or digging under the ground to identify the tank type as the identifying information is not in the areas where the tank is accessed. Some, but not all, states require record keeping of tank types, but these databases are often incomplete. The Steel Tank Institute suggests some methods to determine tank type (steel or fiberglass), manufacturer, and approximate date range of manufacturer (see Appendix B for details).

UST equipment may last 30 years or more while dispensers are typically replaced or refurbished after 15 years and hanging hardware after 3 years. The average number of tanks at a station is 3.3, with some stations having many more (especially truck stops) than the average. It is typical to store gasoline blends in two tanks (regular and premium with mid-grade made from blending the two) and diesel in a third tank (Johnson et al. 2007). Estimates vary widely, but between 30% and 60% of stations have a mid-grade tank that may or may not be in use. If a tank has not been used in a long time, it would be necessary to assess the viability of the tank and its ability to store a mid-level ethanol blend.[7] It is not unusual for dispensers to be used well beyond their expected life of 15 years, and sometimes just the shell of the dispenser is replaced to give an upgraded look for $3,000–$4,000 versus the costs of $15,000 or more for a new dispenser.

[7] EPA Office of Underground Storage Tanks (OUST), Title 40 Part 280, Subpart G 280.70) is a federal code with regulations for temporarily closed tanks; this regulation leads some service stations to remove tanks if they are unable to fulfill the requirements. Some state laws have regulations for unused tanks that are stricter.



FUEL SPEC EQUIP

ITEM	DESCRIPTION
1	DW FIBERGLASS UNDERGROUND TANK
2	42" SW 8 SIDED FG SUMP w/ WT COVER
3	TANK STRAPS, TURNBUCKLES, DEADMEN
4	4" x 16' WELL SCREEN
5	4" MONITORING WELL CAP
6	12" MONITORING MANHOLE
7	12.5' x 300' ROLL FILTER FABRIC
8	2 HP VAR. SPEED SUBMERSIBLE
9	MAG VAR. FREQUENCY CONTROLER
10	1.5 HP SUBMERSIBLE (4 disp or less / diesel)
11	SINGLE-PHASE CONTROL BOX
12	MECHANICAL LINE LEAK DETECTOR
13	2" FULL PORT BRASS BALL VALVE
14	4" x (CUT) STP RISER
15	40" COMPOSITE MANHOLE
16	ENCORE 700 S 3+0 DISPENSER
17	BLACK UNLEADED NOZZLE
18	GREEN DIESEL NOZZLE
19	RECONNECTABLE BREAKAWAY
20	3/4" TWO PLANE SWIVEL
21	SPLASHGUARD
22	3/4" x 8" WHIP HOSE (gasoline only)
23	3/4" x 8' HOSE (2 required for diesel)
24	DIESEL HOSE RETRACTOR
25	12" X 20" PUMP TOPPER
26	48" x 72" STEEL U-BUMPER
27	GILBARCO ENCORE FG DISPENSER SUMP
28	STABILIZER BAR KIT
29	1.5" 10+SERIES DP FEMALE SHEAR VALVE
30	VAPOR SHEAR VALVE (stage II only)
31	1.5" x 2" x 18" FLEX CONNECTOR, MS x F
32	3" SEC. CONTAINMENT FG PRODUCT PIPE
33	2" PRIMARY FG PRODUCT PIPE
34	3" SEC. CONTAINMENT 90 ELBOW
35	2" PRIMARY 90 ELBOW
36	3" SEC. CONTAINMENT TEE
37	2" PRIMARY TEE
38	3" BONDED ENTRY FITTING
39	4" X 3" CONCENTRIC REDUCER
40	40" WATERTIGHT MULTI-PORT FILL / VAPOR
41	FUEL GRADE ID TAG
42	4" SWIVEL FILL ADAPTER
43	4" FILL CAP
44	4" SWIVEL VAPOR ADAPTER
45	4" VAPOR CAP
46	FACE SEAL ADAPTER
47	JACK SCREW KIT
48	EVR OVERFILL VALVE
49	FUEL GRADE ID MARKER
50	EXTRACTOR TEE 4" x 4" x 2"
51	BALL FLOAT VENT VALVE
52	FIBERGLASS CONDUIT ENTRY 3/4"
53	VENT TRANSITION SUMP
54	2" SW FIBERGLASS PIPE (vents)
55	2" BELL x MALE FIBERGLASS ADAPTER
56	2" SINGLEWALL SUMP PENETRATION
57	2" x 2" x 18" FLEX CONNECTOR, MS x F
58	2" PV VENT
59	2" UPWARD VENT
60	60" x 72" STEEL U-BUMPER
61	TLS-350R VEEDER ROOT CONSOLE
62	MAG-PLUS PROBE
63	4" PHASE II FLOAT KIT, GAS
64	4" FLOAT KIT, DIESEL
65	INTERSTITIAL SENSOR
66	SUMP SENSOR
67	4" PROBE CAP ADAPTER
68	2" FIBERGLASS TUBE FOR SENSOR
69	18" WATEWRTIGHT MANHOLE
70	

Figure 2. Diagram and list of station equipment

2 Regulations and Codes

RSP will be subject to the same regulations and codes as other transportation fuels. There is a patchwork of federal regulations and codes that covers some, but not all equipment. Likewise, Underwriters Laboratories (UL) is the only U.S.-based third-party laboratory that offers testing and listing for refueling equipment. Regulators are very comfortable with UL-listed equipment; however, listing is not offered for every piece of refueling equipment at a station. Further, many states have additional regulations and standards for station inspectors that vary widely. There is no one entity that regulates an entire station.

2.1 EPA Office of Underground Storage Tanks

EPA's Office of Underground Storage Tanks (OUST) regulates tanks that store transportation fuels under Subtitle I of the Solid Waste Disposal Act (Title 40 Code of Federal Regulations Parts 280–282 and Part 302), which are currently under revision with a final rule expected by the end of 2014. States administer the UST program, and compatibility is the responsibility of the tank owner. The federal code states that a tank system must be compatible with the fuel stored.

The following are critical components for demonstrating compliance with federal code: tank (including tank lining); piping; line leak detector; flexible connectors; drop tube; spill/overflow equipment; submersible turbine pumps (STPs); sealants (pipe dope, thread sealant, fittings, gaskets, O-rings, bushings, couplings, boots); containment sumps; release detection floats/sensors/probes; fill and riser caps; and shear valves. Figure 2 shows a diagram of these components. Appendix A and Appendix C list compatible equipment and tanks, respectively.

In 2011, OUST released the "Compatibility of UST Systems with Biofuels Blends" guidance document, which provides an alternative path for demonstrating compliance with the compatibility requirements in federal code when storing biofuels above E10 or B20 (20% biodiesel; 80% petroleum diesel) (EPA 2011). EPA OUST believes that while most biofuels blends are compatible with tanks and pipes, there could be issues with associated UST equipment.[8] Tanks and associated equipment are in use for decades, and the guidance allows manufacturers to state compatibility with specific biofuel blends.

2.2 Underwriters Laboratories

UL is a third-party, independent safety laboratory and is the only U.S. laboratory offering testing standards and laboratory services for fueling infrastructure equipment. Testing subjects and standards are released when consensus is reached by stakeholders. There are many UL standards that apply to fueling infrastructure equipment. Some are nested standards that apply to a component used in a finished piece of equipment, such as meters or elastomers. Some standards expose equipment to test fluids while others do not or only test electronics safety. Primary UL standards for fueling infrastructure equipment are shown in Table 3.

[8] Communicated by EPA OUST staff during a December 2013 call with NREL and ORNL staff.

Table 3. Key UL Testing Standards for Refueling Equipment

UL Testing Standard	Equipment Covered	Listing for Ethanol Blends
UL 58	Underground steel tanks	Does not list for specific fuels
UL 1316	Underground fiberglass tanks	E85 (non-aggressive test fluids)
UL 971	Pipes	E100 (non-aggressive test fluids)
UL 2447	*Sumps:* tank, dispenser, transition, fill/vent *Sump fittings*: penetration, termination, internal, test and monitoring *Sump accessories*: cover, frame, brackets, chase pipe	E85 (non-aggressive test fluids for current listings). The new Standard 2447 requires testing with aggressive E25, E85, B25, and Reference Fuel F and requires manufacturers to resubmit and recertify by July 2015
UL 87	Dispenser, hose, nozzle, breakaway, swivel, valves, pumps, meters, and flow limiter, mechanical line leak detector, and strainers	E10 (standard is expected to sunset in the future and be replaced with UL 87A)
UL 87A	Same as UL 87	E25 and/or E85 (tests with aggressive test fluids)

Source: UL

UL Standard 87 has long been available for listing ethanol blends up to E10, and most equipment listed under this standard was not exposed to test fluids. In late October 2007, UL introduced testing Subject 87A—a new listing standard that covered blends between E10 and E85. UL Subject 87A requires the use of Reference Fuel C as a surrogate for gasoline (50:50 mix of isooctane and toluene) and an aggressive test fluid based on the formula SAE J-1681 (from the automotive industry) with 15 weeks of conditioning at 60°C. The elevated temperature is intended to simulate aging and is adopted from vehicle fuel system testing protocols. The conditioning phase is followed by performance testing specific to each type of equipment. In 2009, UL amended 87A to allow a separate test fluid of E25 to address an anticipated increased ethanol use in the mid-level range.

To determine the impacts of E15, NREL contracted with UL to test the best-selling new and used equipment under UL 87A with an E17 aggressive test fluid (Boyce et al. 2010). The results were mixed, with 30 of 54 pieces of equipment (56%) passing the test. Of particular concern was the failure of all six dispensers because they typically last 15 years or more. There were some positive results, with hoses, shear valves, and a submersible turbine pump (STP) performing well in UL testing. The conclusion was that existing equipment could not obtain a retroactive listing for E15.

A parallel activity was performed by ORNL to examine the compatibility of individual infrastructure materials with a range of test fuels representing ethanol-blended gasoline under controlled environmental conditions. The materials included 12 metal specimens, 19 elastomers, 23 plastics, and 2 pipe thread sealants. The majority of these materials were known infrastructure materials. The test fuels were formulated according to the protocols outlined in SAE J1681

"Gasoline, Alcohol, and Diesel Fuel Surrogates for Materials Testing."[9] The test fuel formulations were aggressive formulations of neat gasoline (Reference Fuel C), E10, E15, E25, E50, and E85. Due to time and resource constraints, the plastic materials were only evaluated in the test fuels presenting neat gasoline, E25, E50, and E85. The results showed negligible corrosion on the metals. It is important to note, however, that there were no separate water phases separating out during any of the exposure runs. The most notable impact of ethanol on the polymer materials was volume expansion. For the elastomers, peak swelling occurred for ethanol concentrations between 10% and 15%, which corresponds to the predicted solubility behavior for these materials. Higher ethanol concentrations actually reduced the volume swell (even below that observed for neat gasoline). The volume increase ranged from approximately 15% (for fluoroelastomers) to around 30% and 40% for acrylonitrile butadiene rubber (NBR) and neoprene, and over 100% for silicone. High-volume swell is expected for elastomers, and it does not necessarily affect their ability to form a leak-tight seal. However, the dissolution and extraction of compounded additives, such as plasticizers, does affect the physical properties and can reduce the durability of a seal material. The NBRs and neoprene materials evaluated by ORNL were susceptible to plasticizer extraction, but this effect was primarily caused by the gasoline component, not added ethanol. Of the elastomers studied, polyurethane was the only one that was subject to degradation caused by the ethanol. Therefore, polyurethane is not recommended for use as a seal for fuels containing ethanol.

In contrast to the elastomer materials, the plastics exhibited a variety of responses. These materials, as a general rule, did not swell as much as the elastomers. Those plastics used as barrier materials in flexible piping systems showed good compatibility (low swelling) with gasoline containing ethanol, which is important because they are in direct contact with the fuel. The resins used in fiberglass-reinforced plastic (FRP) tanks and piping are also in direct contact with the fuel. Without the fiberglass reinforcement, these resins may swell over 20%, but otherwise very low swelling was noted for specimens taken directly from FRP USTs. The other plastic materials in the ORNL study (nylon, polyethylene, acetals, etc.) exhibited volume expansions ranging from 5% to 15%; these materials are used predominantly in the outer walls of flexible piping, and therefore are not in contact with fuel.

The introduction of ULSD and expansion of ethanol in the gasoline resulted in manufacturers utilizing more fluoro-based elastomer materials in sealing applications. While more expensive, they are known to perform well with a variety of fuels. This is a promising development for new equipment; however, legacy equipment likely incorporates some materials that are unsuitable for use with ethanol-blended fuels.

2.3 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 and address the changing fuels landscape.

OSHA regulation 1910.106 (g)(3)(iv)(b)(1) requires dispensers, breakaways, and nozzles to be listed by a third party for specific fuels. Until 2010, UL-listed equipment for blends above E10 was not available. This means E85 stations in use prior to 2010 were out of compliance with

[9] http://www.sae.org/works/documentHome.do?docID=J1681&inputPage=wIpSdOcDeTaIlS&comtID=TEVFSS

this regulation. This regulation is a primary reason why large gas station chains and hypermarkets will not sell blends above E10.

OSHA 1910.106(b)(1)(i)(c) and (c)(2)(ii) require tanks, piping, valves, and fittings other than steel to use sound engineering design for materials used—there is no listing requirement. OSHA 1910.106(b)(1)(iii)(a) covers steel tanks and requires sound engineering and applicable UL listings.

2.4 Authorities Having Jurisdiction

Authorities having jurisdiction (AHJs) refers to regulating organizations, offices, or individuals responsible for overseeing codes and standards and approving the use of equipment. AHJs are responsible for enforcing codes to ensure public health and safety at fueling stations. Examples of AHJs include local fire marshals, state energy and environment offices, air and water boards, and similar organizations or offices. Jurisdictions and approval agencies vary in their roles and responsibilities. Public safety is the primary concern, and an AHJ may refer to local, state, federal, or third parties responsible for ensuring proper fueling infrastructure and adherence to regulations. As an example, fire departments need to know what types of fuels are stored at a service station in an event of a fire.

Each authority adopts codes and standards for its jurisdiction. These codes may be set and enforced on a state, regional, or local level. 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, provide standard codes for retail stations that are accepted or modified to meet local requirements.

For questions about waivers or variances, the state energy office should be contacted.

2.5 Other Code and Regulations Organizations

2.5.1 American Petroleum Institute

The American Petroleum Institute is a trade association representing the oil industry. The American Petroleum Institute develops specifications, standards, and recommended practices for petroleum equipment with particular emphasis on underground storage systems at service stations. It is common for American Petroleum Institute standards to be incorporated into state and federal regulations. www.api.org

2.5.2 California Air Resources Board

The California Air Resources Board is a division of the California Environmental Protection Agency tasked with reducing air pollutants. The California Air Resources Board develops test procedures for vapor recovery equipment and requires specialized vapor recovery equipment. Improvements in vehicle on-board vapor recovery systems may negate the need for vapor recovery equipment in the near future. www.arb.ca.gov

2.5.3 Fiberglass Tank and Pipe Institute

The Fiberglass Tank and Pipe Institute develops recommended practices and test protocols for fiberglass systems. www.fiberglasstankandpipe.com

2.5.4 NACE International

NACE International, previously known as the National Association of Corrosion Engineers, is focused on studying and preventing corrosion. NACE develops recommended practices and test methods for controlling corrosion. www.nace.org

2.5.5 National Conference on Weights and Measures

States regulate weights and measures using National Conference on Weights and Measures standards. This applies to service station dispenser meters, which measure the flow of product and determine taxation of fuels. www.ncwm.net

2.5.6 National Leak Prevention Association

The National Leak Prevention Association develops standards for entering, cleaning, inspecting, repairing, and lining liquid storage vessels. www.nlpa-online.org

2.5.7 Petroleum Equipment Institute

PEI is a trade organization representing fuel-dispensing equipment manufacturers, equipment distributors, and service technicians. PEI develops recommended practices for below- and above-ground equipment at service stations. www.pei.org

2.5.8 Steel Tank Institute

The Steel Tank Institute is a trade organization for steel tank fabricators. The Steel Tank Institute develops specifications for corrosion protection, standards for fire resistance, installation instructions, and a range of recommended practices for the use of steel tanks. www.steeltank.com

3 Above-Ground Equipment

Over the past few years, UL-listed equipment for ethanol blends above E10 has become increasingly available. E25 equipment uses upgraded materials compared to conventional equipment, particularly high performance elastomer materials. Many manufacturers now use fluoro-based elastomer materials because they perform well with several transportation fuels. E25 dispensers require an upgraded meter, valve, and elastomer package whereas E85 requires the use of both upgraded elastomer materials, meters, valves, and specialized metal (usually nickel-plated) for corrosion resistance. The premium for E25 equipment is minimal compared with conventional equipment while E85 equipment is significantly more expensive due to metal costs. UL-listed equipment is presented in Table 4, Table 5, and Appendix D, and approximate prices for conventional, E25, and E85 equipment are provided in Table 6. Figure 3 shows above-ground equipment.

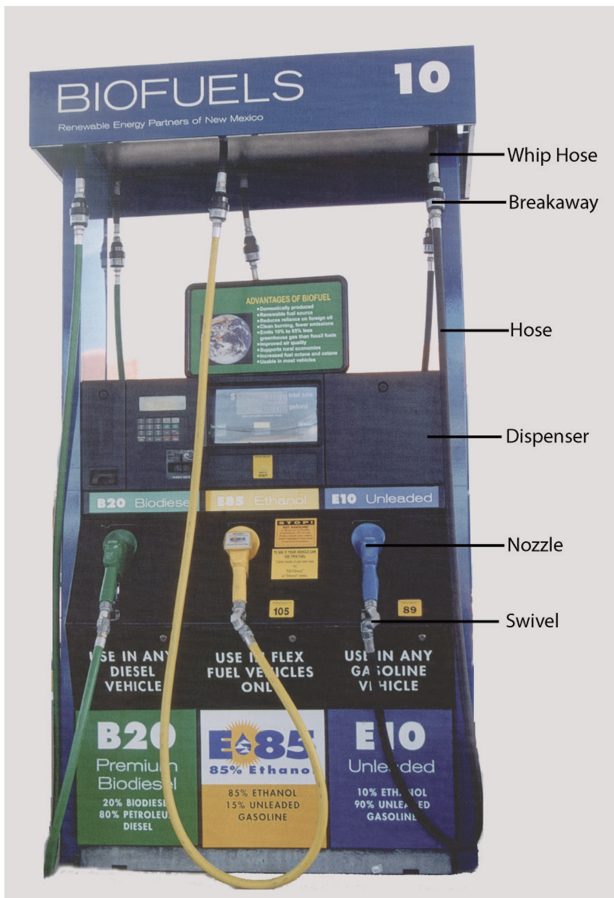


Figure 3. Above-ground equipment

(NREL 13531)

There are two options for offering up to E25 in a dispenser: purchase a new dispenser with a UL-listed E25 option or retrofit an existing dispenser with a UL-listed kit. The retrofit kits are intended to allow the use of E15 in existing dispensers, but were listed for E25 because E15 is not a UL test fluid. Gilbarco offers a UL-listed E25 option for any new dispenser with factory-installed costs of $650 per inlet. A dispenser may have one, two, or three inlets—this is how regular, midgrade, and premium are sold out of one dispenser. Alternatively, Gilbarco offers a retrofit kit for existing dispensers at a cost of $1,950 per inlet (labor costs are not included). The retrofit kit includes a compatible meter, valves, elastomers, and galvanized inlet tubes made of (older dispensers may have incompatible copper-based inlet tubes). Wayne reports that it will have a UL-listed retrofit kit for E25 by the end of 2015 (pricing is not available).[10] An E25 option is available on all Ovation models and will be available in early 2015 for Helix models with a price premium of $400–$700 over conventional equipment costs. At this time, any RSP fuel over E25 would require the use of an E85 dispenser (models available in Table 4). The premium for an E85 dispenser over a conventional one varies depending on options, but a comparison of bestselling dispensers and options suggests a premium of $6,500.

Table 4. UL E85-Listed Dispensers

Manufacturer	Model
Wayne	G520
Wayne	G610
Wayne	G620
Wayne	Ovation E
Gilbarco	Encore 300
Gilbarco	Encore 500
Gilbarco	Encore 550
Gilbarco	Encore 700
Gilbarco	Encore NJ2
Gilbarco	Encore NJ4
Gilbarco	Encore NL3
Gasboy	Atlas E85

Source: "Handbook for Handling, Storing, and Dispensing E85 and Other Ethanol-Gasoline Blends." DOE Clean Cities Program. September 2013.

Hanging hardware includes hoses, nozzles, breakaways, and swivels. OPW upgraded elastomer materials in many of its products and obtained E25 listing for a conventional swivel and breakaway, for which there is no price premium. UL-listed E85 hoses and nozzles are available for blends above E10; E25 versions are not available. Table 5 provides E25 and E85 hanging hardware models.

Shear valves are an important piece of safety equipment that operate by cutting off the flow of fuel from a UST into a dispenser and preventing a release or fire if a car or something else dislodges a dispenser. A few parties interviewed by NREL brought up the subject of shear valves not working properly because they were corroded or were never set up correctly. Some, but not all, states require manually tripping the arm of the spring-loaded poppet in the shear valve to see if a dispenser still distributes fuel. If the nozzle releases fuel, then it is clear the shear valve is

[10] Retrofit kits will be available for Ovation models 2003–2014 and Vista4 2009–2014; Vista3 is to be determined.

broken. A solution to this issue is to mandate states to test shear valves as part of a station inspection.

Table 5. UL E25- and E85-Listed Hanging Hardware and Shear Valves

Equipment	Manufacturer	Model	
		E85[a]	E25
Breakaway	OPW	66V-0492	66V-0300
Hose	Veyance	Flexsteel Futura Ethan-all	
Nozzle	OPW	21GE and 21GE-A	
Swivel	OPW	241TPS-0492	241TPS-0241, 241TPS-1000, 241TPW-0492
Shear valve	OPW	10P-0152E85 and 10P-4152E85	

[a]All E85 equipment is also UL listed for E25

Source: "Handbook for Handling, Storing, and Dispensing E85 and Other Ethanol-Gasoline Blends." DOE Clean Cities Program. September 2013.

Table 6. Dispenser and Hanging Hardware Costs for Conventional and Ethanol-Blended Fuels

Equipment	Conventional	E25	E85
Nozzle	\$50	not available	\$155
Breakaway	\$35	\$35	\$100
Swivel	\$30	\$30	\$56
Hose	\$90	not available	Starting at \$357
Whip hose	\$32	not available	Starting at \$138
Dispenser	\$15,000–\$17,000[a]	\$400–\$700[b] more or \$660[c] factory per inlet or retrofit kit \$1,950 per inlet	\$5,000–\$8,000[d] more
Shear valve	\$95	not available	\$120

[a] Dispensers can range from \$10,000 to \$25,000 or more depending on features and number of products dispensed.
[b] Estimate of premium over conventional equipment (Wayne).
[c] Actual costs for equipment at factory for a new dispenser or for a retrofit kit for an existing dispenser.
[d] Premium depends on options such as how many fuels it dispenses.

Source: Costs for conventional and E85 equipment were largely found from distributors. Dispenser pricing was provided by The SourceNA and dispenser manufacturers.

PEI conducted a survey of station ownership groups for the U.S. Department of Agriculture on equipment costs to store and dispense E15 at existing stations (Table 9) (PEI 2013). The ownership groups were asked to estimate costs for equipment and installation to accommodate E15 under five scenarios. While they were asked to accommodate E15, the equipment available is listed for E25.

- Scenario 1: All equipment is compatible; just signage and labeling need to be updated.
    - Scenario 1a: Tank is not compatible and entire UST system must be replaced; assumes no contamination of old tank.
- Scenario 2: Dispenser is upgraded with a UL-listed retrofit kit and hanging hardware is upgraded.
    - Scenario 2a: Dispenser is upgraded with retrofit kit, but hanging hardware is not upgraded (because AHJ approves).
    - Scenario 2b: UST system is replaced, dispenser is upgraded with retrofit kit, and hanging hardware is upgraded.
- Scenario 3: Dispensers are replaced with UL-listed E25 dispensers.
    - Scenario 3a: Dispensers are replaced with UL-listed E25 dispenser, and one UST system is replaced.
- Scenario 4: One standalone UL-listed E25 dispenser is installed on an existing island.
    - Scenario 4a: Replace a UST system and install one standalone UL-listed E25 dispenser.
- Scenario 5: Building a new station: estimate cost premium to offer E15. Assume one UST would store E85 and use associated UL-listed equipment. The other tank would store E10, and a UL-listed E85 blender pump would dispense E15.

Table 7. PEI Survey Scenario Costs to Accommodate E15

Scenario	Number of Dispensers	Average Cost ($)	Median Cost ($)
1		$1,167	$1,000
1a		$112,968	$115,000
2	2	$8,385	$7,600
2a	2	$6,961	$6,452
2b	2	$121,222	$126,170
3	2	$40,874	$36,200
3a	2	$156,667	$166,000
4	1	$31,775	$30,000
4a	1	$144,496	$140,199
5	2	$21,803	$24,000

Source: PEI. (2013). "Scenarios to Determine Approximate Cost for E15 Station Readiness." Prepared by Petroleum Equipment Institute for the United States Department of Agriculture.

4 Below-Ground Equipment

Below-grade equipment refers to underground tanks, pipes, and associated equipment that are below the ground. It also refers to equipment that is both below and above grade such as the STP that delivers fuel from a tank to a dispenser. While many tanks are compatible, when switching a tank to a different fuel the tank should be cleaned. PEI stated that an average cost to clean a tank is $1,500. If the tank is incompatible or no tank is available to store a new fuel, the costs for an installed UST system are $75,000 or $95,000 for a new or existing station, respectively.

4.1 Tanks and Pipes

4.1.1 Compatibility of Tanks

There are approximately 600,000 UST systems in the United States. Most tanks come with a 30-year warranty, a long time period compared with manufacturer warranties for other products. UST systems are often in the ground longer than 30 years. EPA OUST stated that it does not anticipate many issues with tanks and pipes, but there could be issues using existing associated UST equipment with a mid-level ethanol blend.

All existing steel tank companies have issued signed letters stating compatibility with up to E100 per EPA OUST biofuels guidance. Tanks are listed under UL 58, which does not expose tanks to test fluids; however, the Steel Tank Institute stated that independent tests have determined that steel tanks are compatible with all ethanol blends. Appendix C lists ethanol compatibility of tanks, by manufacturer.

Xerxes and Containment Solutions manufacture fiberglass tanks. Fiberglass tanks are listed under UL 1316, which offers non-aggressive E85 as a test fluid option, and both existing tank manufacturers have listings for E85. There are tanks in service by manufacturers that either no longer manufacture tanks or are no longer in business (Owens Corning, Total Containment). Containment Solutions' EPA OUST biofuels guidance compatibility letter states that all tanks are compatible with ethanol blends up to E100. Letters from Xerxes and Owens Corning state that compatibility is more complicated and depends on the tank type and the year the tank was manufactured. (See Appendix C to determine compatibility.)

If a station owner knows the manufacturer and year of its tank(s), then it can verify whether ethanol blends can be stored in them. The majority of tanks in the United States are believed to be compatible. The issue will be with older tanks or those made by manufacturers no longer in business. Checklists of requirements for storing E15 or E85 are available in *Clean Cities Ethanol Handbook* (Clean Cities 2013).

4.1.2 Compatibility of Pipes

Over 99% of installed pipes are either fiberglass or flexible plastic. Metal pipes are extremely uncommon due to corrosion risk. Flexible pipes did not begin to be used until the late 1980s or early 1990s, when EPA OUST recommended development of joint-less pipes. It is estimated that the installed base of piping is evenly split between fiberglass and flexible pipes with the latter being installed more often in recent years. Piping is listed under UL Standard 971, which includes several test fluids, including E50 and E100. All existing pipe manufacturers supplying U.S. stations have listings for E100. Table 8 shows manufacturers and ethanol-compatible models along with the year they obtained UL Standard 971 listings for E100. NOV Fiberglass produces fiberglass pipes, Brugg manufactures stainless steel pipes (more common in Europe or in U.S. marine applications), while the remaining manufacturers use plastic to produce piping products. Omega Flex and Franklin Fueling require the use of stainless steel fittings for use with ethanol blends above E10. If installation requirements are met, fiberglass pipes (e.g., from NOV Fiberglass) have a warranty of 30 years, and flexible pipes typically have a warranty of 10 years.

Table 8. Pipe Companies with Listing for E100

Company	Model(s)	Compatibility	UL 971 E100 Listing
Advantage Earth Products	1.5", 2", 3", 4"	E0-E100	2009
Brugg Pipesystems	FLEXWELL-HL, SECON-X, NIROFLEX, LPG	E0-E100	2007
Franklin Fueling	XP, UPP	E0-E100	2005, 2006
KPS Petrol Pipe Systems	Single and double wall	E0-E100	2005
NOV Fiberglass	Red Thread IIA	E0-E100	1990
NUPI	Smartflex	E0-E100	Has listing; date unknown
Omega Flex	DoubleTrac	E0-E100	2008
OPW	Pisces (discontinued) FlexWorks	E0-E100	2000 2007

Source: UL Online Certification Directory. NREL contacted manufacturers directly to obtain year of E100 listing.

It is likely that there are many installations of pipes from companies no longer in business; therefore, their compatibility with ethanol blends is unknown. As with other equipment, station owners will need to know what piping they have to determine whether it is compatible with the specific fuel dispensed.

4.2 Other UST Equipment

4.2.1 Compatible Equipment

While EPA OUST does not anticipate compatibility issues with tanks or pipes, it and other experts have expressed concern about other associated UST equipment. Some of this equipment is listed by UL, other equipment may have standards from another organization such as the American Petroleum Institute or PEI, and some pieces may not be subjected to any standard. These pieces of equipment include: sumps and accessories, manholes, flexible connectors, fill caps and adaptors, entry fittings, overfill prevention, leak detection, sensors, drop tubes, vents, and similar. Several manufacturers have issued letters for specific products and model numbers stating compatibility with either up to E85 or E100 per OUST's biofuels guidance. A list of these products and models is available in Appendix A. If all associated UST equipment had to be replaced (other than the pipes or tank), it would likely cost more than $10,000 per station.

Several major manufacturers of associated UST equipment such as Franklin Fueling and OPW have not issued letters stating compatibility but either have E85 listing under UL 2447 or approve the use of E85 with particular model numbers (Appendix A). As explained in Section 1.4, it may not be possible to identify the model number of equipment submersed in fuel for years to determine whether it is compatible with ethanol blends or not.

UL 2447 listing applies to some, but not all of this equipment. E85 has been an option for listing for several years. All equipment listed under UL 2447 will be E85 compatible by July 2015 because the updated testing standard requires manufacturers to demonstrate compatibility with E25, E85, B20, and ULSD.

4.2.2 Leak Detection Equipment

Leak detection (also referred to as release detection) equipment is required by federal regulations developed by EPA OUST.[11] Several industry groups identified leak detection as a potential equipment issue with blends above E10. All federally regulated underground storage tank systems (tanks and piping) storing motor fuel must have leak detection equipment to identify any potential releases so the spread of contamination can be stopped before significant environmental impact occurs. Regulations allow for several types of leak detection methods. It is expected that some are functional with ethanol blends while others may require testing to determine functionality. Research by Battelle for EPA OUST finds that several leak detection methods may have issues related to functionality with either low or high level ethanol blends.[12]

Leak detection testing protocols were established in the early 1990s prior to widespread use of ethanol and other alternative fuels. Leak detection equipment was designed to operate with petroleum products, and some of the methods rely on density, conductivity, and refractive index differences between different petroleum products. The presence of ethanol blends may impact the performance of the equipment. States determine acceptability of leak detection equipment individually. For example, California has a list of leak detection equipment allowable for use with E85.[13]

In 2011, Battelle conducted a test of ethanol-blended fuels and an automatic tank gauging system to determine water detection functionality (Carvitti et al. 2010). E0 was used as a baseline, and E15 and E85 were tested. Fuel was tested at two tank levels—25% and 65% full. Two methods of water ingress were used: a continuous stream of water into a tank, and a quick water dump followed by a fuel dump. An automatic tank gauging system has a float that performs two functions: product level monitoring that leads directly to leak detection; and water detection. The water detection function detected the water stream with E0 and E15 but was not conclusive for E85.

Tanks must be monitored monthly in accordance with one or more of the following methods (EPA 2014)[14]:

1. *Secondary containment and interstitial monitoring*—there is a barrier between the tank and the environment, which is either the outer wall of a double wall tank, a liner, or vault. This space is then monitored with either a dip stick or by a permanently installed liquid or vapor sensor. Approximately 25%–30% of USTs use this method.

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[11] Details on leak detection requirements are available in Title 40 Code of Federal Regulations Part 280 Subpart D. http://www.epa.gov/region4/usttoolkit/pdfs/regulatorycompliance/40cfr280.pdf

[12] Please contact EPA OUST for a copy of the report, expected in 2015.

[13] http://www.waterboards.ca.gov/water_issues/programs/ust/leak_prevention/lg113/misc/e85veeder.shtml

[14] Estimate of percent of use was provided in an email from EPA OUST staff on March 4, 2014.

2. *Automatic tank gauging*—a monitor is installed in the tank that continuously measures fuel level and temperature. This method cannot be used on piping. Automatic tank gauges must be properly calibrated for ethanol fuels, and it must be verified that floats used in magnetostrictive probes are compatible with ethanol. Due to electrical conductivity in ethanol, capacitance probes sensors are not recommended. Approximately 30%–40% of USTs use this method.
3. *Vapor monitoring*—requires monitoring wells and monitors to detect vapor in soil near tanks and pipes. Approximately 5% of USTs use this method.
4. *Groundwater monitoring*—for sites where groundwater is within 20 feet of the surface. Monitoring wells and monitors are set up to detect the presence of liquid product floating in groundwater. This method is unlikely to work with ethanol due to its miscibility with water. Approximately 5% of USTs use this method.
5. *Statistical inventory reconciliation*—a computer system and vendor carefully monitor inventory, fuel deliveries, and dispensing data to determine whether there is a leak. Approximately 10%–15% of USTs use this method.

Manual tank gauging is a method available to tanks storing less than 2,000 gallons. Tanks 1,000 gallons or smaller can use this method alone. Tanks from 1,001 to 2,000 gallons can use manual tank gauging only when combined with periodic tank tightness testing for the first 10 years of operation, after which one of the above methods must be used. Another option for tanks with more than 2,000 gallons of storage for the first 10 years after installation is daily measurements of fuel levels in tanks and a tank tightness test performed by a vendor every 5 years.

Pressurized piping leak detection must use either an automatic shutoff device or a flow restrictor or a continuous alarm system AND any one of the five methods listed above (except #2) or annual line testing. Suction piping can use one of the five methods listed above (except #2) or line testing every three years. No leak detection is required if the following three criteria are met: below-ground piping is sloped towards the tank, each suction line is equipped with a check valve directly below the suction pump, and the system operates below atmospheric pressure.

EPA OUST funded research on the functionality of leak detection equipment in biofuels that evaluated the likelihood of methods and instruments to work with blends of up to E15 or E85 (E51–E83). A report on the research is pending and publication is expected in 2015 after undergoing external review.

5 Material Compatibility Issues

RSP blends will contain higher concentrations of ethanol than either E10 or E15. The impact of the E15 has been evaluated in several laboratory studies for elastomeric and metallic materials used in current infrastructure systems. The response of infrastructure plastics with RSP is being assessed using a combination of solubility analysis and empirical research. Field observations have shown several compatibility concerns with some polymer and metal components. These include swollen and buckled plastic piping and surface corrosion of metal components. The two primary areas of material compatibility concerns related to infrastructure are metal corrosion and polymer degradation. The mechanisms driving each are very different. Metal corrosion is a direct electrochemical reaction (usually oxidation) of the metal surface with an oxidant (usually an acid). Polymer degradation is dominated by the solubility of the polymer with a solvent. Solubility occurs as bulk rather than surface phenomena and is characterized by the thermodynamic similarity between the polymer and the solvent.

5.1 Metal Corrosion: Mechanisms and Examples

Ethanol (whether anhydrous or in solution with water) is not known to directly cause significant corrosion in infrastructure metal components. In fact, the ORNL study tried to promote corrosion through galvanic coupling and by introducing occlusion sites on the specimens. The results showed that, although many of the specimens incurred surface discoloration associated with oxidation and contamination, no significant corrosion was observed on any of the specimens (even for fuels containing 85% ethanol). Based on these (and other studies), corrosion due to RSP on a metal surface is not likely to occur.

However, ethanol may contain some acids derived from the production process, and, as a result, corrosion inhibitors are added to fuel grade ethanol to buffer any residual acidity. Motivated by these potential corrosion concerns, POET, an operator of 27 U.S. ethanol plants, conducted a fuel quality survey between January and May 2011. It drew samples of E85, regular, mid-grade, and premium (it is assumed that all three of these fuels were E10) from 27 stations in the Midwest (samples of E30—30% ethanol, 70% gasoline for FFVs—were drawn from 18 stations). The fuel quality survey measured NACE Corrosion Ratings, which determine the ability of a fuel to prevent corrosion by water. Fuel samples must receive a passing rating of B+ or better to be transported through pipelines. Premium gasoline exhibited the most failures with three samples below the B+ threshold; premium also received the fewest number of A ratings. A large oil refiner suggested this may be due to insufficient removal of acids used in the production of premium. Both regular gasoline and E85 had one sample each receiving a B. Samples of mid-grade and E30 received all B++ or A ratings. The results are provided in Appendix E.

If ethanol exists separately from the gasoline phase, which can occur when excess water is present or through vapor condensation, then corrosion may occur via microbic conversion of ethanol into acetic acid. This microbial-induced corrosion can occur if *acetobacter* microbes are present and in contact with aqueous ethanol. These microbes feed on ethanol (dissolved in water) and produce acetic acid and carbon dioxide as byproducts. The two key requirements for *acetobacter* to thrive are water and ethanol. Acetic acid is corrosive to many metallic materials, including copper, carbon steel, and iron. In order for the microbes to propagate (and produce acetic acid), this aqueous phase must be separate from the gas fuel. (If the water-soluble ethanol remains dissolved in gasoline, then microbial growth cannot occur.) Ethanol and water will readily absorb each other such that a liquid ethanol will absorb water vapor and vice versa. Therefore, liquid water (condensed or otherwise) will absorb ethanol vapors to create ideal conditions for *acetobacter* growth; thus, corrosion of metal surfaces via acetic acid may occur. Likewise, condensed ethanol will absorb atmospheric water vapor to create the same conditions leading to corrosion.

Investigations of metal surface corrosion in the some UST systems containing E10 have detected both acetic acid and *acetobacter* microbes, which suggest that fuel-borne ethanol may be the cause of the observed corrosion. It is also believed (though unproven) that ethanol residue or contamination may be responsible for recently observed corrosion of UST systems housing ULSD. Corrosion has been observed in sumps, submersible turbine pumps (STPs), ball valve floats, and drop tubes sumps. STPs are used to draw fuel from a tank and deliver it to a dispenser, and, to date, no failures of STPs have occurred in spite of significant surface corrosion. These are areas to explore further in order to understand the impacts of ethanol blends on equipment and how a mid-level ethanol blend might impact equipment already sensitive to E10.

Aqueous phase formation, whether separated out from the fuel itself or by the introduction of water, is a necessary condition for metallic corrosion to occur under ambient conditions. (It is important to note that at temperatures exceeding 100°C, many metals will react with, and corrode in ethanol-blended gasoline.) The other condition that can potentially cause corrosion results from the diffusion and/or condensation of ethanol vapors with water. Gaseous ethanol may diffuse into condensed or standing water to provide an environment suitable to *acetobacter* to propagate and thrive. The propagation of *acetobacter* microbes will produce acetic acid, which is highly corrosive to metal components. The volatilization of ethanol from ethanol-blended gasoline depends on the vapor pressure, as shown in Figure 4. The vapor pressure of ethanol is lower for concentrations higher than 10%-20% ethanol. As a result, the susceptibility to volatilization is actually lessened for gasoline containing 25% or 30% ethanol (relative to E10); therefore, the risk to metallic corrosion via ethanol vapor condensation may actually be lowered, albeit slightly.

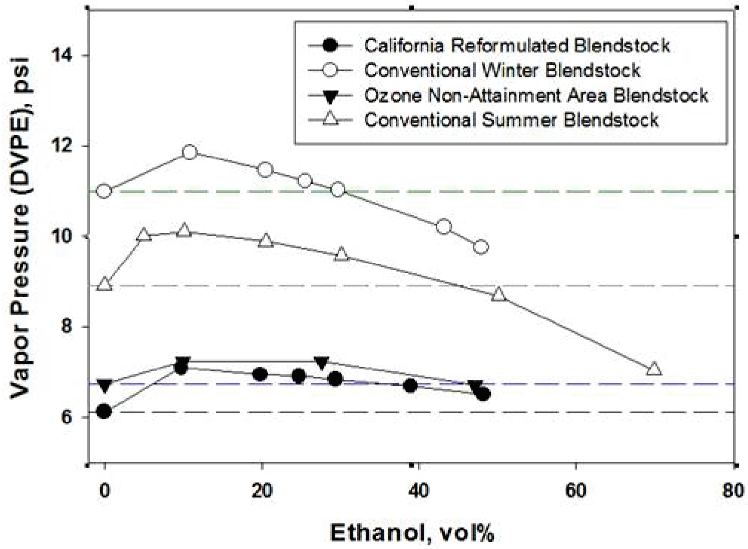

Figure 4. Vapor pressure of ethanol–gasoline blends

Sources: Andersen, V. F., Andersen, J. E., Wallington, T. J., Mueller, S. A., and Nielsen, O. J. (2010). *Energy Fuels,* 24, pp. 3647–3654; Chupka, G. Knock Resistance Properties. NREL. 2014.

Ethanol (either as a vapor only or when condensed with water) is believed to cause external surface corrosion of STPs, which draw fuel from a tank and deliver it to a dispenser. It is important to note that to date no failures of STPs have occurred in spite of significant surface corrosion. Another issue is corrosion in USTs storing ULSD. Additionally, a leading station inspector observed numerous corroded ball valve floats, which are designed to prevent overfilling while a fuel truck is unloading into a tank. This inspector has also seen corrosion on drop tubes that include overfill prevention. This is an area in which further understanding should be developed of the impacts of ethanol blends on equipment and how a mid-level ethanol blend might impact equipment already sensitive to E10 is needed.

Motivated by corrosion concerns, POET, an operator of 27 U.S. ethanol plants, conducted a fuel quality survey between January and May 2011. They drew samples of regular unleaded, super unleaded, premium, and E85 from 27 stations in the Midwest (samples of E30 were drawn from 18 stations). The fuel quality survey measured NACE Corrosion Ratings, which determine the ability of a fuel to prevent corrosion by water. Fuel samples must receive a passing rating of B+ or better to be transported through pipelines. Premium exhibited the most failures with three samples below the B+ threshold; premium also received the fewest number of A ratings. A large oil refiner suggested this may be due to insufficient removal of acids used in the production of premium (in the alkylation step used to create a high octane number blend component). Both unleaded and E85 had one sample each receiving a B. Samples of super and E30 received all B++ or A ratings. The results are provided in Appendix D.

5.1.1 Submersible Turbine Pump Corrosion

Corrosion issues occasionally occur in fueling systems with both diesel and gasoline. The State of Tennessee and OUST have investigated and presented on premature STP corrosion. The observed corrosion is believed to be due to temperature differentials between sumps and UST systems in summer months (or warm and humid climates) that may enable vapors to enter STP sumps. Sumps are containers designed to contain spills from STPs. Sumps are not ventilated and are designed to be air- and water-tight; however, both air and water are known to enter sumps. Vapors may contain ethanol capable of dissolving in water condensed on metallic portions of STPs or in standing sump water. *Acetobacter* converts ethanol and oxygen into acetic acid leading to corrosion on exposed metal surfaces of STPs. The actual mechanism of corrosion is unclear, but is believed to be associated with acetic acid produced by *acetobacter* microbes. The two key requirements for *acetobacter* to thrive are water and ethanol. Ethanol and water will readily absorb each other such that a liquid ethanol will absorb water vapor and vice versa. Therefore, liquid water will absorb ethanol vapors to create ideal conditions for *acetobacter* growth; thus, corrosion of metal surfaces via acetic acid may occur. Likewise, condensed ethanol will absorb atmospheric water vapor to create the same conditions leading to corrosion.

EPA's Kerr Center requested and received 8 water and 70 vapor samples from STP sumps, which were analyzed for ethanol, acetic acid, benzene, and total benzene, toluene, ethylbenzene, and xylenes (Barbery 2011). A concentration of ethanol in vapors of at least 10,000 mg/L generally correlated to corrosion on the STP. This was found in 13 of 70 vapor samples (60% of samples with the higher ethanol vapor level were premium). EPA compared the concentration of ethanol in vapors to the concentration of acetate. Results were not conclusive with incidents of higher ethanol concentration vapors also exhibiting higher concentrations of acetate as well as higher ethanol concentration vapors with low acetate concentration. EPA stated that more corrosion was observed with intermediate and high levels of acetate in the vapor samples.

The RFA engaged NREL to contact inspectors and manufacturers to determine the extent of the issue and any factual or statistical data. Typical and corroded STPs are shown in Figure 5. NREL interviewed both county- and state-level UST inspectors in nine states. Inspectors were asked if they observed visible STP corrosion and kept records regarding unusual odors, gasoline grades, the presence of standing water, and any other observation related to corrosion in sumps. The most common comment from inspectors was "the evidence is anecdotal." None of the inspectors contacted keeps statistics. Inspectors stated that it occurs but not often enough to investigate further. Inspectors in the Midwest reported they have witnessed corrosion over many years. No inspectors reported a leak or early replacement of an STP as a result of the corrosion.

Figure 5. Comparison of typical and corroded STP

(photos courtesy of EPA OUST)

The National Institute of Standards and Technology tested the rate of corrosion of STPs. They found that it would take many years for the corrosion to compromise the steel casing of the STP, which is likely why there have not been any reported failures (Sowards et al. 2013). Of considerable concern is the rate of corrosion on the copper lines in the STP sump that connect to the line leak detector. These have been observed to have blue corrosion and sometimes crumble and disconnect when inspected, which means the line leak detector is no longer functional. This is an area that requires further work. EPA OUST is looking into this issue.

Potential solutions for reduction corrosion of STPs include upgrading material to stainless steel, but manufacturers are not open to this as it would immensely increase the cost. Another idea is venting sumps, but they are not currently designed to do this. However, the State of Tennessee found that piping running through a 4-inch chase (secondary containment) to the STP likely provides ventilation, resulting in significantly reduced corrosion.

5.1.2 Ultra-Low Sulfur Diesel Tanks

Aggressive metal corrosion has been observed in underground fueling systems used to store and dispense ULSD. Originally, these observations (first noted in 2007) were considered incidental, but are now considered prevalent enough to be a serious concern. Battelle Memorial Institute has conducted field surveys of fiberglass ULSD storage systems, but the exact cause of the corroded components has not been identified (Battelle 2012). The presence of *acetobacter* (and acetic acid) was noted in all of the tanks having corroded metal components, and because *acetobacter* needs ethanol to propagate, ethanol contamination from E10 fuel is considered a possible scenario. Other possible factors such as reduced sulfur, unique additives, and the reduced water solubility of ULSD should be considered as well. The source of potential ethanol contamination is not known at this time, but the leading theory is that the contamination occurs in transport tankers through the shared ventilation system. Other potential sources of contamination are residue left over from UST systems previously storing E10 or the close proximity of E10 fueling systems to ULSD storage tanks. This risk can be mitigated by cleaning a tank when changing the fuel it will store. A follow-on study by EPA OUST is underway and will examine and take samples from both clean and corroded tanks.

5.2 Non-Metals

ORNL conducted an extensive investigation examining the compatibility of ethanol-blended gasoline fuels to individual infrastructure polymers and sealants which are used throughout refueling equipment, an example is an O-ring (Kass et al. 2012). Standard gasoline pipe thread sealant, traditionally used prior to the introduction of E10, was found to be incompatible with ethanol-blended gasoline; however, newer sealants, such as Gasoila E, are now available and are considered standard for modern infrastructure piping.

In the ORNL study, polymers were divided into two classes: elastomers and plastics. The test fuels were SAE-specified formulations used to represent gasoline blended with ethanol in controlled material compatibility studies. The test standard uses an aggressive formulation to account for the upper acceptable limit of aromatic content as well as water and trace acids (and other corrosive species). For the ORNL-led investigation, the ethanol content of the test fuels ranged from 0% to 85%. Individual coupons (samples of materials used in equipment) were prepared and exposed to test fuel liquid and vapor phases. It is important to recognize that all polymers, whether elastomer or plastic, will exhibit some degree of solubility to gasoline fuels, either as neat fuels (E0) or when blended with ethanol. If fuel can permeate into a polymer, it will permeate through a polymer, and some level of release is accepted. There are EPA-established guidelines on release rates, and the allowable rate depends on the chemical compound being released. The property most associated with polymer compatibility is volume change, especially volume swell under wetted conditions. Volume expansion directly correlates to polymer-solvent solubility and therefore is a measure of fuel permeability as well. Appendix F provides some UL-listed E85-compatible materials.

5.2.1 Elastomers

Elastomers are used as seals, gaskets, and hoses. In underground storage systems, they are used primarily, if not solely, as seals. During the ORNL intermediate blends compatibility studies, elastomer specimens were exposed in ethanol-blended gasoline test fuels containing 0, 10, 17, 50, and 85 vol% ethanol. The data collected from these studies include the change in volume and hardness following fuel exposure and the glass transition temperature after drying for the specimens. Elastomers investigated included fluorocarbons, fluorosilicone, NBRs, neoprene, polyurethane, silicone, and styrene butadiene rubber. Of these, the elastomers most frequently used in fuel storage infrastructure are the fluorocarbons, fluorosilicone, NBRs, and silicone rubber.

5.2.1.1 Fluoroelastomers (Fluorocarbon and Fluorosilicone)

This class of elastomers is known for its excellent durability and compatibility with many chemical solvents, including gasoline. The volume change results for five fluorocarbons (Viton A401C, Viton B601, Viton GF-600S, Dyneon FE5620, and Dyneon FE5840) and one fluorosilicone sample are shown in Figure 6. Although the values vary depending on the fluorocarbon type, they do exhibit the same general behavior. The volume swells for the fluorocarbons peak between 15% and 20% ethanol. The increase in swell from 10% to around 25% to 30% for most fluorocarbons is negligible or around 2% to 3%. For fluorosilicone, the extent of swelling actually decreases with increasing concentration after peaking at 10% ethanol. These results suggest that RSP levels of ethanol will be compatible with fluoroelastomer seals and components.

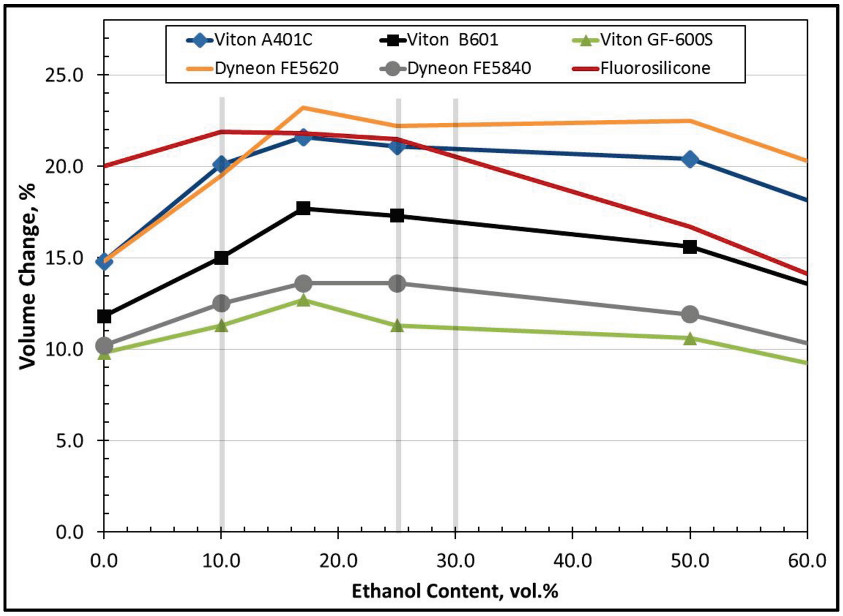

Figure 6. Volume expansion curves for selected fluoroelastomers

5.2.1.2 Acrylonitrile Butadiene Rubber (NBR)

These elastomers are actually co-polymers of two chemical monomers: acrylonitrile and butadiene. Acrylonitrile imparts flexibility, while butadiene contributes to strength and compatibility. The relative amounts of these two components determine the overall properties of these rubbers. In addition, they are also compounded with plasticizers and other chemicals to achieve a mix of properties to suit a particular application. NBRs are relatively inexpensive and, as a result, are ubiquitous as seals, gaskets, and hoses. For underground fuel storage systems, their use is limited to sealing applications; however, most above-ground dispenser hoses are NBRs. The volume expansion curves for six NBR types in gasoline-ethanol test fuel blends are shown in Figure 7.

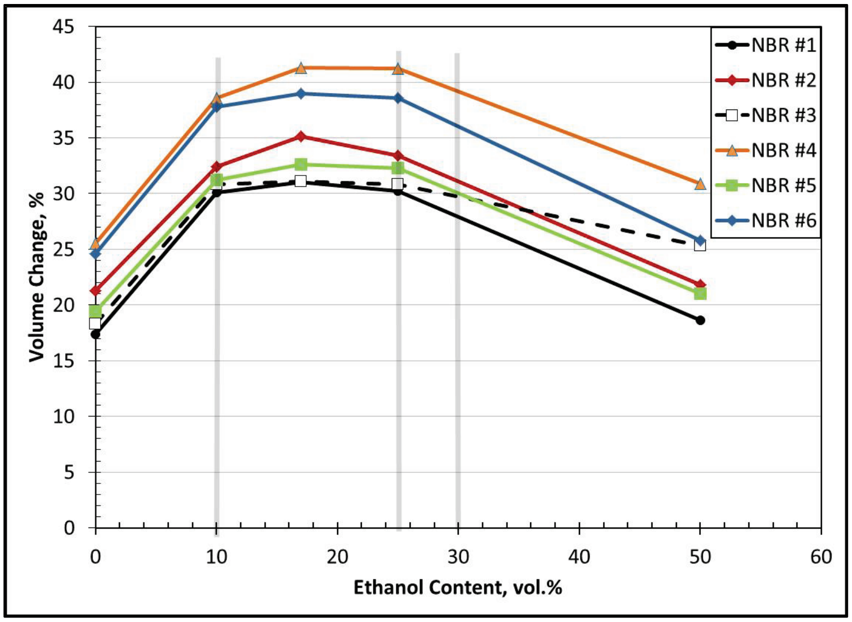

Figure 7. Volume expansion curves for six grades of NBR

For each NBR type, the largest increase in volume swell occurs for ethanol concentrations between 0% and 10%. As the ethanol content increases from 10% to 15%, the margin of additional volume expansion is small, and for most NBR grades is much less than 5%. For many NBR grades, the measured volume swells observed for 25% (or 30%) ethanol are essentially the same as that observed for 10%. In fact, in many cases the volume swell results at 30% are expected to be lower than those obtained at 10% ethanol. As a result, the compatibility of an RSP blend is expected to be similar to that of E10.

5.2.1.3 Silicone, Neoprene, and Polyurethane

The use of silicone, neoprene, and polyurethane is not as common as either fluoroelastomers or NBRs, but they may be present at some level. Typically, these elastomers are used as seals, but other possible applications include secondary wall containment, valves, and coatings. For each of these materials, the volume swell decreases with ethanol content for concentrations greater than 10% (see Figure 8). The implication is that these materials would be expected to have better compatibility with an RSP blend (25% or 30% ethanol) than with standard E10.

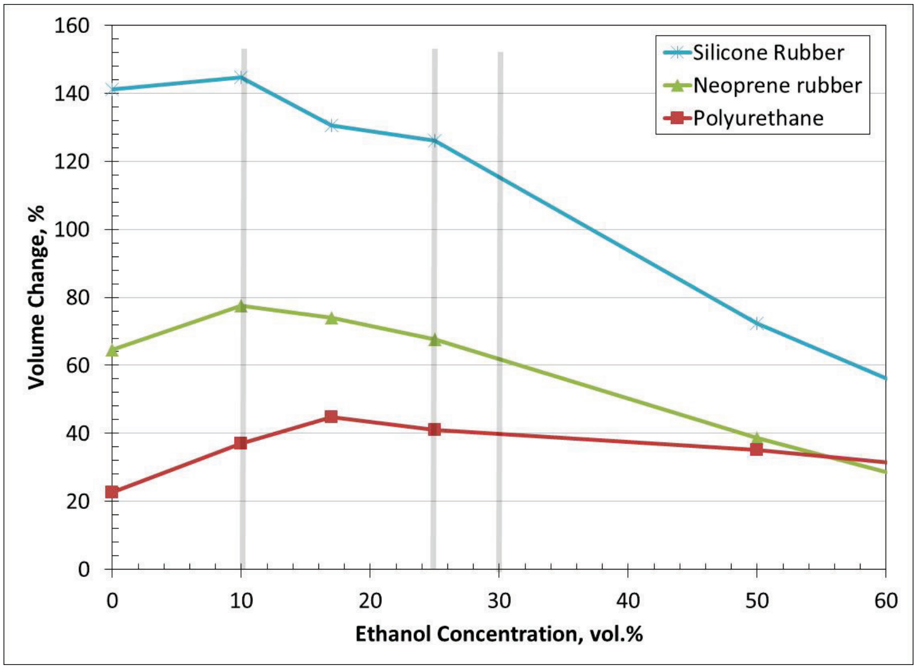

Figure 8. Volume expansion curves for silicone, neoprene, and polyurethane

5.2.2 Plastic Materials

Unlike elastomer materials, which are limited to sealing applications in underground storage systems, plastic materials have a wider range of use. They are predominantly used in flexible piping and as the matrix material in fiber-reinforced tanks and rigid FRP piping, but they are also used infrequently as bearings in some valve applications. For structural applications, if the component (such as piping) is held fixed on both ends, then the increase in the volume will impart mechanical stresses within the pipe walls, which can result in buckling if the expansion is excessive. These induced stresses can also be expected to reduce the useful life of the stressed component as well. Therefore, the high swelling values associated with most elastomers (up to and exceeding 50% in many applications) are not desirable for structural-type applications.

In contrast to the elastomer and metallic materials that were investigated in the ORNL ethanol blend compatibility experiments, plastic materials were not evaluated in test fuels representing gasoline containing 10% and 17% ethanol. For the majority of these materials, the volume swell increased from 0% to 25% ethanol, but the lack of data within this range of concentration means that the rate of increase (and location of peak swell for some materials) cannot be determined. Nevertheless, these data are considered useful because they provide conservative estimates of the volume swell at 10% and 15%, if linear swell is assumed. For the purposes of this discussion, plastic materials are placed in the following categories: barrier materials, nylon and high-density polyethylene (HDPE), and other common plastics and fiberglass resins.

5.2.2.1 Barrier Materials

These are plastics that are exposed directly to the fuel in flexible piping. As such, these materials are noted for their resistance to fuel permeation. In all flexible piping systems, there is an inner barrier layer composed of plastics whose purpose is to resist permeation. Four of the most commonly used materials are polyphenylene sulfide, polyvinylidenedifluoride (PVDF), polytetrafluoroethylene, and polyester terephthalate (PET), although sometimes nylon may also be used. Polytetrafluoroethylene, or Teflon, is also used ubiquitously as a seal material. Of these four materials, PET has the lowest cost and therefore is the most widely used. The volume change results for these four materials when exposed to test fuels based on the SAE J1681 protocol for test fluids are shown in Figure 9. Except for PVDF (Kynar), the three barrier materials show little volume change when moving from neat gasoline to fuel containing 50 vol% ethanol. These materials are not expected to exhibit solubility or swell differences when exposed to RSP blends. PVDF provides more of a challenge to assess. The volume swell increased from around 1.6% with no ethanol to just over 5% with 25% ethanol. For a plastic structural material, this increase in swell may be enough to stress the overall pipe structure and possibly result in delamination from the other pipe layers. However, we do not know the concentration at which maximum swelling occurs. As a result, there is not enough information to assess the relative compatibility of PVDF at E10 to an RSP blend.

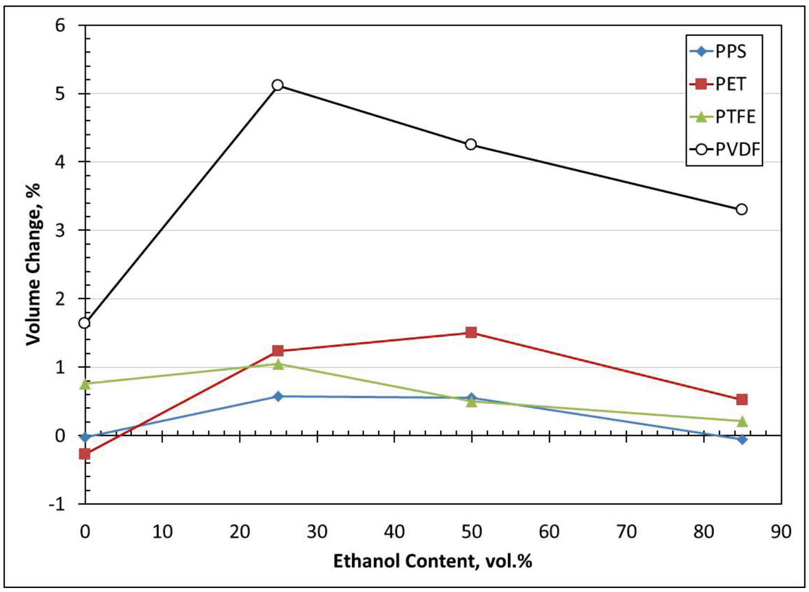

Figure 9. Volume expansion curves for permeation barrier plastics

5.2.2.2 Nylons and HDPE

The volume swell results for four different types of nylon are shown in Figure 10 along with the results for HDPE. The volume swell behaviors for the different nylons are essentially similar for ethanol concentrations higher than 25 vol%. In fact, for ethanol concentrations between 25% and 85%, the volume swell does not change significantly. However, the volume swells for the four nylons do show significant increases between 0% and 25% similar to that noted for PVDF and, as with PVDF, the relative compatibility differences between 10% and 25% blended ethanol cannot be assessed. The results do indicate that little to no differences with exposure to either 25% or 30% ethanol blends.

Nylons are normally used in the outer wall layers of flexible piping and therefore are not in direct contact with the fuel. As an outer wall material, the compatibility of nylon with an RSP blend is not as critical an issue as with a permeation barrier. If, in fact, nylon is used as a permeation barrier, then the piping may be susceptible to permeation and volume expansion.

Nylon 11 showed the highest level of swell and would therefore be less compatible than the other types listed.

The volume swell results for HDPE show that the extent of volume swell decreases linearly when the ethanol concentration is increased from 0% to 85%. Because the volume expansion decreases with increasing ethanol content, HDPE is expected to have good compatibility with RSP blends.

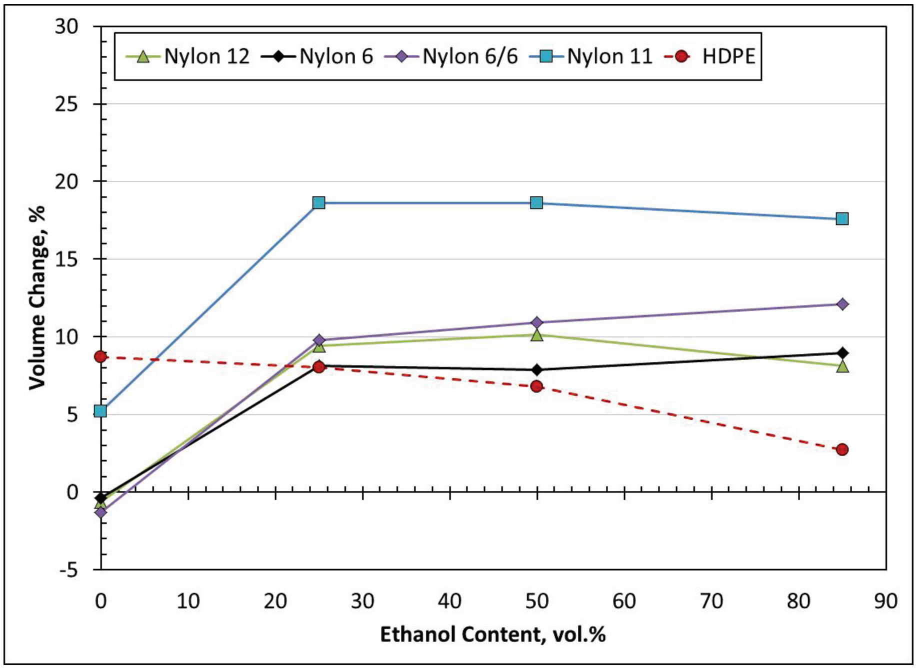

Figure 10. Volume expansion curves for nylons and HDPE

5.2.2.3 Other Common Plastics

Other common plastics include acetals, polybutylene terephthalate, polypropylene, and PET copolymer (PETG). The volume swell results for these materials are shown in Figure 10. Of these materials, acetals such as polyoxymethylene and its copolymers have been identified for use in ball float vent valves. Both polyoxymethylene and the accompanying copolymer have identical compatibilities to the test fuels evaluated in the ORNL compatibility studies. The volume increase when moving from 0% to 25% ethanol is relatively low, and acetal is expected to be compatible with RSP. The results for polybutylene terephthalate were similar to the acetals; therefore, components containing polybutylene terephthalate should be compatible with RSP.

The volume swell for polypropylene is highest for neat gasoline (E0). The extent of volume swell decreases significantly with increasing ethanol content and its compatibility to gasoline containing 25 vol% or 35 vol% would be better than with E10. PETG has not been identified for use in infrastructure components. As shown in the Figure 11, the volume increases from 16% to 24% when moving from 0% to 25% ethanol. This increase is large, but because the swell associated with E10 is not known, it is impossible to say whether this material exhibits compatibility differences between 10% and 25% (or 30%) ethanol. Because PETG has not been identified as an infrastructure material, it is not likely to be of much concern.

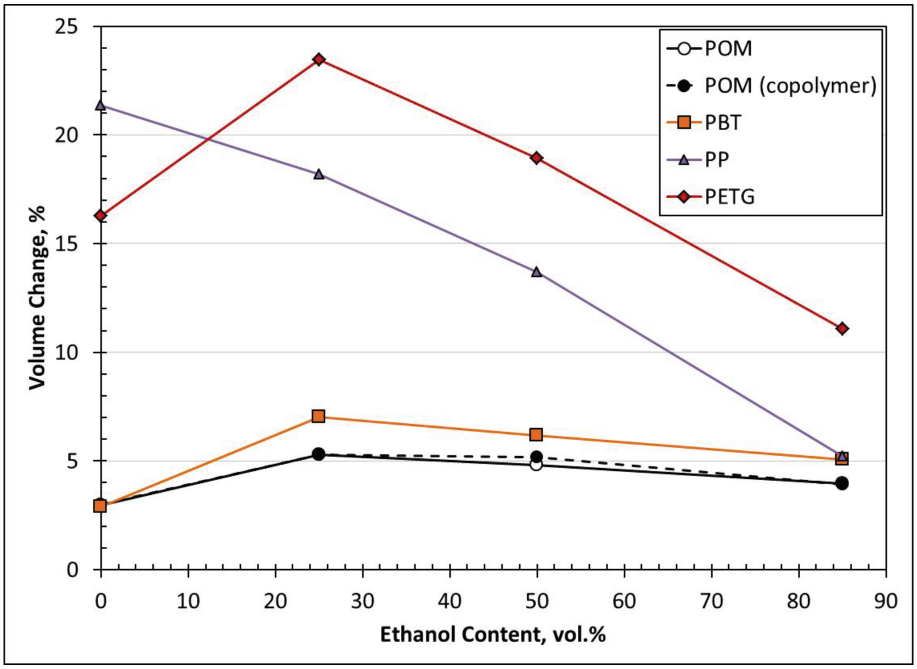

Figure 11. Volume expansion curves for other common plastics

5.2.2.4 Thermosetting resins

Thermosetting resins are used as the matrix material for FRPs. They are used throughout the infrastructure either in fuel storage tanks or in FRP rigid piping. The ORNL ethanol compatibility studies were mostly limited to pure resin coupons (the results of which are shown in Figure 11), but some coupons were prepared from legacy FPR fuel tanks. The tank cut coupons were reinforced with fibers and were not observed to swell noticeably following exposure to the test fuels. This result contrasts with the high swell measurements obtained from the resin-only coupons seen in Figure 12. The low swelling values of the FRPs suggest that these materials should be compatible with RSP fuel blends. However, if the pure resins evaluated in the ORNL studies are used to join FRP piping sections, then leaking may occur at the joined interfaces.

In summary, the majority of plastic materials used in underground storage systems should be compatible with RSP, but there are some materials that need to be further considered and tested in fuels representing E10 and/or E30. These materials include nylons (when used as permeation barriers) and possibly PVDF as well.

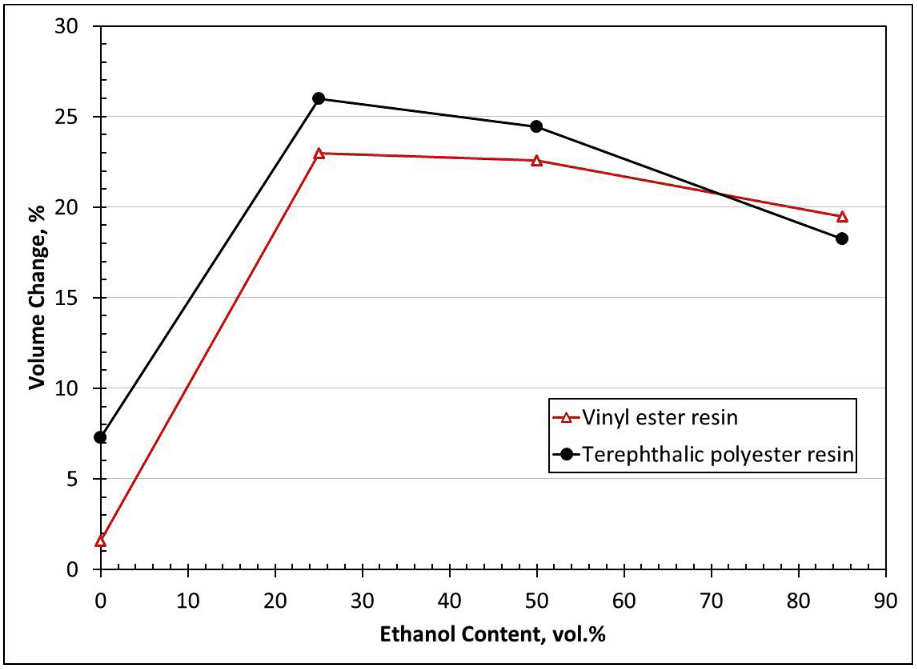

Figure 12. Volume expansion curves for two thermosetting resins

5.3 Comparison of E25 and E30+

The volume swell curves from the ORNL material compatibility studies discussed above show little to no difference in swelling can be expected for polymers exposed to either 25% or 30% ethanol. In most cases the volume swelling occurring at 30% ethanol is similar to or less than that observed for 25% ethanol.

6 Conclusions

Retail fueling station equipment is commercially available to accommodate both an E25 and an E25+ fuel. Infrastructure costs to introduce E25 are not expected to be significant, but are much higher for any ethanol blend above E25. Both industry stakeholders and manufacturers are more supportive of an RSP at the E25 level with an octane number around 100. The challenges and barriers faced with RSP are not technical but economic, and are similar to those experienced in the deployment of E15 and E85. The higher level of ethanol in RSP does not make the fueling infrastructure issues any worse—the primary issue is demonstrating compliance with applicable legislation, codes, and standards. Retail station owners will need equipment records to demonstrate compatibility with tanks, pipes, and other associated underground equipment. Limited future research is needed to address corrosion issues experienced in the retail station environment, assess the functionality of leak detection methods with RSP, and complete additional materials compatibility studies with plastics.

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Appendix A. Other Ethanol-Compatible UST Equipment

Manufacturer	Product	Model	Ethanol Compatibility
Bravo Systems	Fiberglass Fittings	Series F, FF, FPE, FR, Retrofit-S, D-BLR-S, D-INR-S, FLX, 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
Bravo Systems	Under Dispenser Containment Sumps	B1XXX, 7XXX, B8XXX, B9XXX	E0-E100
Bravo Systems	Under Dispenser Containment Sumps	B7XXX, B8XXX, B9XXX	E0-E100
Morrison Bros	Expansion Relief Valve	076DI, 078DI	E0-E85
Morrison Bros	Frost Proof Drain Valve	128DIS	E0-E85
Morrison Bros	Double Outlet Vent	155	E0-E85
Morrison Bros	Double Tap Bushing	184	E0-E85
Morrison Bros	Anodized Farm Nozzle	200S	E0-E85
Morrison Bros	Emergency Vents	244	E0-E85
Morrison Bros	Swing Check Valves	246ADI, 246DRF	E0-E85
Morrison Bros	Internal Emergency Valves	272DI, 72HDI	E0-E85
Morrison Bros	Line Strainers with Teflon	285	E0-E85
Morrison Bros	Caps	305C	E0-E85
Morrison Bros	Tank Monitor Adaptor and Cap Kits	305XPA	E0-E85
Morrison Bros	Float Vent Valves	317	E0-E85
Morrison Bros	Vapor Recovery Adaptor with Viton	323	E0-E85
Morrison Bros	Vapor Recovery Caps	323C	E0-E85
Morrison Bros	External Emergency Valves	346DI, 346FDI, 346SS, 346FSS	E0-E85
Morrison Bros	Updraft Vents	354	E0-E85
Morrison Bros	Flame Arrester	351S	E0-E85
Morrison Bros	Anodized Drop Tubes	419A	E0-E85
Morrison Bros	Spill Containers	515/516/517/518	E0-E85
Morrison Bros	Anodized Diffusers	539TO, 539TC	E0-E85
Morrison Bros	Pressure Vacuum Vents	548	E0-E85
Morrison Bros	Extractors	560/561/562/563	E0-E85
Morrison Bros	Ball Valves	691BSS	E0-E85
Morrison Bros	Solenoid Valves (3" Must be all Teflon version)	710SS	E0-E85
Morrison Bros	Pressure Vacuum Vents	748, 749	E0-E85
Morrison Bros	Clock Gauges	818	E0-E85
Morrison Bros	Anti-Syphon Valve	912	E0-E85
Morrison Bros	Clock Gauge with Alarm	918	E0-E85
Morrison Bros	Overfill Alarm	918TCP	E0-E85
Morrison Bros	Combination Vent/Overfill Alarm	922	E0-E85
Morrison Bros	Dry Disconnect Adaptor	927	E0-E85
Morrison Bros	In-Line Check Valve	958	E0-E85
Morrison Bros	Overfill Prevention Valve	9095A-AV, 9095SS	E0-E85
National Environmental Fiberglass	Dispenser Sumps	All	E0-E100
National Environmental Fiberglass	Tank Collars	All	E0-E100
National Environmental Fiberglass	Tank Sumps & Collars	All	E0-E100
National Environmental Fiberglass	Transition Sumps	All	E0-E100
National Environmental Fiberglass	Single Wall Tank and Transition Sumps	All	E0-E100
National Environmental Fiberglass	Double Wall Tank and Transition Sumps	All	E0-E100
Vaporless Manufacturing, Inc.	Leak Detectors	99 LD-2000/2200/3000 (must use stainless steel tubbing and fittings)	E0-E100
Vaporless Manufacturing, Inc.	Overfill Prevention Valve	OFP-2/3 (must use stainless steel tubbing and fittings)	E0-E100
Western Fiberglass	CO-Flex Piping	All	E0-E100
Western Fiberglass	Cuff Fittings	All	E0-E100
Western Fiberglass	Sumps (tank, dispenser, transition, vapor/vent)	All	E0-E100
Western Fiberglass	Co-Flow Hydrostatic Monitoring Systems	All	E0-E100

Source: "Handbook for Handling, Storing, and Dispensing E85 and Other Ethanol-Gasoline Blends." DOE Clean Cities Program. September 2013. Last accessed March 5, 2014: http://www.afdc.energy.gov/uploads/publication/ethanol_handbook.pdf.
Prices provided by Jeff Dzierzanowski, Source North America Corporation.

Manufacturer	Product	Model	Ethanol Compatibility
Franklin Fueling	Ball float vent valves	308	E0-E85
Franklin Fueling	Fill cap	777-201-02	E0-E85
Franklin Fueling	Fill pipe adaptor	778-301-05	E0-E85
Franklin Fueling	Automatic shutoff valve	708-491-32, 708-492-32	E0-E85
Franklin Fueling	Drop tube	782-204-30-2, 782-204-32-2	E0-E85
Franklin Fueling	Probe cap and adaptor kit	90037-E	E0-E85
Franklin Fueling	Tank bottom protectors	TBP-3516-E	E0-E85
Franklin Fueling	Sw ivel and non-sw ivel pipe fitting	all stainless steel models	E0-E85
Franklin Fueling	End connections and fittings	all stainless steel models	E0-E85
Franklin Fueling	Hardw all hose	FLEX-ING FLEX-ON FR	E0-E85
Franklin Fueling	API bottom loading adaptor	880-500-04, 800-500-05	E0-E85
Franklin Fueling	Submersible turbine pumpe	all models	E0-E85
Franklin Fueling	Vapor recovery cap	304-301-03	E0-E85
Franklin Fueling	Coaxial vapor recovery adaptors/drop tubes	All models staring w ith 306 or 708	E0-E85
Franklin Fueling	Extractor vent valves	All models staring w ith 300	E0-E85
OPW	Shear valve	10 series, 10 Plus series (UL listed 10P-0152E85)	E0-E100
OPW	Vertical check valve	70	E0-E100
OPW			E0-E100
OPW	Extractor valve and test plug	233	E0-E100
OPW	Overfill Prevention Valve	61SOM series, 71SOM series	E0-E100
OPW	double w all piping	CXXA	E0-E100
OPW	Double Wall Pipe Couplings	DPC-2150/DPC-2200	E0-E100
OPW	Single w all pipe couplings	SPC-0150, SPC-0200, SPC-0300	E0-E100
OPW	Single Wall Coupling Male NPT	SPC-0075, SPC-0100	E0-E100
OPW	E-Coated Male Adaptors	SPC-0075, SPC-0100	E0-E100
OPW	E-Coated Sw ivel Tees	STF-1515, STF-2020, STF-2215, STF-2020	E0-E100
OPW	E-Coated Sw ivel Elbow s	STF-1515, STF-2020, STF-2215, STF-2020	E0-E100
OPW	Stainless Steel Sw ivel Bolt On Coupling	SBC-2150, SBC-2200	E0-E100
OPW	Spill Containers	1-2100 series / Multiports, 101BG-series, 101BG-series	E0-E100
OPW	Shear valve-vapor line	60V series	E0-E100
OPW	Fill sw ivel adaptor	61SALP-1020-EVR	E0-E100
OPW	Fill adaptor	633T-8076	E0-E100
OPW	Vapor sw ivel adaptor	Vapor Sw ivel Adaptor	E0-E100
OPW	Vapor adaptor	1611AVB-1625	E0-E100
OPW	Fill cap	634TT-7085-EVR, 634LPC-040	E0-E100
OPW	Vapor cap	1711T-7085-EVR, 1711LPC-0300	E0-E100
OPW	Monitoring probe cap	62M series	E0-E100
OPW	Stainless Flex Connectors	FCXX series	E0-E100
OPW	Ball valve float	53VML/30MV series	E0-E100
OPW	Pressure vacuum vent	523V series, 623V series	E0-E100
Veeder-Root	Electric line leak detection sensor	Position-Sensitive, Interstitial Sensor for Double-Wall Fiberglass Tanks - High Alcohol, Interstitial Sensors for Steel Tanks - High Alcohol, MicroSensor	E0-E85

Source: Franklin Fueling and OPW catalogs; Veeter Root website.

Appendix B. Methods to Identify UST

(double click below for full article)

Steel Tank Institute

Tank Talk, September 2012

Identifying Buried Fuel Storage Tanks

by Bert Schutza, Tanknology, with contributions from Danny Brevard, ACCENT

How to identify the construction of your buried fuel storage tank when original purchase documents are missing – a guidance tool offering some simple suggestions.

More than one method is often required to make conclusions specific to tank type:

1. Stick your tank to determine the tank diameter. Certain diameters of tanks between 6,000-gallon to 15,000-gallon capacity are indicative of steel tanks and some of the fiberglass reinforced plastic (FRP) tanks. 92" diameter tanks, for example, are almost always FRP, while 96" diameter tanks are normally steel.
    a. Tank Diameter Measurement: Measure from bottom of tank to top of riser and then subtract the length of the riser.

Finding a label is very helpful!

2. Knowing the date of installation is a great tool for figuring out what type of steel tank you might have. This chart gives you important dates in the history of steel tank technology development:

Date	Event	Tank Type
1969	Sti-P3 technology created	Cathodically Protected
1984	STI Dual Wall Tank Standard published	
1987	Original Association for Composite Tanks was formed	Composite
1990	First STI standard for ACT-100 developed	Composite
1992	STI adopted the Permatank technology	Jacketed
1996	ACT-100-U created	Coated

3. Is your tank single wall or double wall? Double wall tanks will have an interstitial monitoring opening, which is often a 2" fitting. Double wall steel tanks have an access port directly down to the bottom of the steel tank, usually at the end of the tank. Some steel tanks, most often jacketed tanks, have a 2" interstitial riser pipe down through the inside of the tank, with tanks constructed since 1998 with the pipe in the longitudinal center of the tank. FRP tanks will usually have an access riser that goes down the tank top, and then circles the annular space around the tank. Some double wall FRP tanks have a liquid reservoir at the tank top, and the interstice is full of brine solution.

Liquid reservoir

944 Donata Ct. Lake Zurich IL 60047 847-438-8265 info@steeltank.com

Appendix C. Compatible Tanks

Tank Manufactuer Compability with Ethanol Blends	
Manufacturer	**Compatibility Statement with Ethanol Blends**
FIBERGLASS[1]	
Containment Solutions	Tanks manufactured after January 1, 1995 are all compatible with ethanol blends up to 100% (E100) (UL Listed)
Owens Corning	
Single Wall Tanks	Tanks manufactured between 1965 and 1994 are approved to store up to 10% ethanol (E10)
Double Wall Tanks	Tanks manufactured between 1965 and July 1, 1990 are approved to store up to 10% ethanol (E10) .
	Tanks manufactured between July 2, 1990 and December 31, 1994 were warranted to store any ethanol blend.
Xerxes	
Single Wall Tanks	Tanks manufactured prior to 1981 are not compatible with ethanol blends
	Tanks manufactured from February 1981 through June 2005 are designed for the storage of ethanol fuel up to a 10% blend (E10)
	Tanks manufactured from July 2005 to date are designed for the storage of ethanol fuel blends up to 100% (E100) (UL Listed)
Double Wall Tanks	Tanks manufactured prior to April 1990 were designed for the storage of ethanol fuel up to a 10% blend (E10)
	Tanks manufactured from April 1990 to date are designed for the storage of ethanol fuel blends up to 100% (E100) (UL Listed)
STEEL[2]	
Acterra Group Inc.	Compatible with all blends up to 100% (E100)
Caribbean Tank Technologies Inc.	Compatible with all blends up to 100% (E100)
Eaton Sales & Service LLC	Compatible with all blends up to 100% (E100)
General Industries	Compatible with all blends up to 100% (E100)
Greer Steel, Inc.	Compatible with all blends up to 100% (E100)
Hall Tank Co.	Compatible with all blends up to 100% (E100)
Hamilton Tanks	Compatible with all blends up to 100% (E100)
Highland Tank	Compatible with all blends up to 100% (E100)
J.L. Houston Co.	Compatible with all blends up to 100% (E100)
Kennedy Tank and Manufacturing Co.	Compatible with all blends up to 100% (E100)
Lancaster Tanks and Steel Products	Compatible with all blends up to 100% (E100)
Lannon Tank Corporation	Compatible with all blends up to 100% (E100)
Mass Tank Sales Corp.	Compatible with all blends up to 100% (E100)
Metal Products Company	Compatible with all blends up to 100% (E100)
Mid-South Steel Products, Inc	Compatible with all blends up to 100% (E100)
Modern Welding Company	Compatible with all blends up to 100% (E100)
Newberry Tanks & Equipment, LLC	Compatible with all blends up to 100% (E100)
Plasteel[1]	Compatible with all blends up to 100% (E100)
Service Welding & Machine Company	Compatible with all blends up to 100% (E100)
Southern Tank & Manufacturing Co., Inc.	Compatible with all blends up to 100% (E100)
Stanwade Metal Products	Compatible with all blends up to 100% (E100)
Talleres Industriales Potosinos	Compatible with all blends up to 100% (E100)
Tanques Antillanos C. x A.	Compatible with all blends up to 100% (E100)
Watco Tanks, Inc.	Compatible with all blends up to 100% (E100)
We-Mac Manufacturing Company	Compatible with all blends up to 100% (E100)
Letters stating compability 1 PEI http://www.pei.org/PublicationsResources/ComplianceFunding/USTComponentCompatibilityLibrary/tabid/882/Default.aspx 2 STI http://www.steeltank.com/Publications/E85BioDieselandAlternativeFuels/ManufacturerStatementsofCompatibility/tabid/468/Default.aspx	

Source: "Handbook for Handling, Storing, and Dispensing E85 and Other Ethanol-Gasoline Blends." DOE Clean Cities Program. September 2013. Last accessed March 5, 2014: http://www.afdc.energy.gov/uploads/publication/ethanol_handbook.pdf.

Appendix D. UL E25- and E85-Listed Equipment

UL E25 & E85 Fuel Dispensing Certified Equipment List		
Manufacturer	Equipment	Model
Gilbarco	Dispenser	Encore Series 300, 500, 550, 700, may be suffixed S, Model N followed by A, followed by 0, 1, 2 or 3
Gilbarco	Dispenser	Encore Series 300, 500, 550, 700, may be suffixed S, Model N followed by B followed by 0, 1, 2, 3 or 4
Gilbarco	Dispenser	Encore Series 300, Model N followed by G, followed by 0 or 1
Gilbarco	Dispenser	Encore Series 300, 500, 550, 700, may be suffixed S, Model N followed by F followed by 0, 1, or 2
Gilbarco	Dispenser	Encore Series 500, 550, 700, may be suffixed S, Model N followed by G, followed by 0 or 1
Gilbarco	Dispenser	Encore Series 300, 500, 550, 700, may be suffixed S, Model N followed by J, followed by 0, 2 or 4
Gilbarco	Dispenser	Encore Series 300, may be suffixed S, Model N followed by L or N, followed by 0, 1, 2 or 3
Gilbarco	Dispenser	Encore Series 500, 550, 700, Model N followed by L or N, followed by 0, 1, 2 or 3
Gilbarco	Dispenser	Encore Series 300, may be suffixed S, Model N followed by P3, P4, or P5
Gilbarco	Dispenser	Encore Series 500, 550, 700, Model N followed by P3, P4, P5, P6, P8
Gilbarco	Dispenser (blender pump)	Encore 700 S NA0, NA1, NA2, NA3, NG0, NG1, NN1, NN2, NN3, NL0, NL1, NL2, NL3, NJ2, NJ4
Wayne	Dispenser	Model G610 with prefix E/, followed by 1, followed by D, with or without one or more of the following suffixes 7A, 7B, 8, J, K or Z, with or without one or more of the following suffixes J, W1, S, S1 or S2, for use with E85.
Wayne	Dispenser	Model G620 or G520, with prefix E, followed by 1, 2 or 3, followed by D, with or without one or more of the following suffixes 2, 5, 7A, 7B, 8, G, J, K, M or Z, with or without one or more of the following suffixes A, B, C, F, H, J, M1 or W1, for use with E85.
Wayne	Dispenser	Ovation Series, Model E, followed by B or R, followed by 1 or 2, followed by 1, 2 or 3, followed by 1, 2, 3, 4 or 5, followed by 1 or 2, followed by 1 or 2, followed by 0, followed by D, followed by 0, 1, 2 or 3, may be followed by one or more of the following option codes C, D, E, H, I, J, K, L, M, N, P, S, T, X, 6 or 7, for use with E85.
Wayne	Dispenser	Model E followed by 3/G2 or 3/G7, followed by 2, followed by 0, followed by 1, 2, 3, 7 or 8, followed by D, with or without one or more Suffixes 1, 2, 8, G, H, J, K, P1, R, S, S1, S2 or S3, followed by one or more Suffixes E, H, I, I2, J, K, L or X, for use with E85
Wayne	Dispenser (UL listing up to E25)	Helix Series, Models H, followed by N or W, followed by LM or LU, followed by 1, 2, 3 or 4, followed by 1, 2, 3, 4 or 5, followed by 1, 2, 3 or 4, followed by 1 or 2, followed by P and/or R, V.
Gasboy	Dispenser	Atlas E85 9872KX
OPW	Breakaway	OPW66V-0492 (UL listed E0-E85); 66V-0300 (UL listed E0-E25)
OPW	Swivel Connector	241TPS-0492 (UL listed E0-E85); 241TPS-0241 (UL listed E0-E25); 241TPW-1000 (UL listed E0-E25); 241TPW-0492 (UL listed E0-E25)
OPW	Nozzle	21GE
OPW	Nozzle	21GE-A
OPW	Shear Valves	10P-0152E85
OPW	Shear Valves	10P-4152E85
Veyane	Hose	Flexsteel Futura Ethan-ALL
Franklin Fueling	Submersible Turbine Pump	Basic Model designation STP with or without T, with AG, with or without F, with or without H, with or without K, with or without M, with or without R, with or without V, with or without W, followed by 33, 75, 150, 200, VS2 or VS4, may be followed by A or B or C, followed by -XXX (where XXX is numeric characters or VL1, VL2 or VL3 to indicate model length), and then followed by two characters (to indicate riser length). All models have been evaluated for use with gasoline-ethanol blends of 0% to 85% ethanol with gasoline
Franklin Fueling	Submersible Turbine Pump	Basic Model designation IST (with AG is implied) with or without T, with or without F, with or without K, with or without M, with or without R, with or without V, with or without W, with or without VS4 (without indicates VS2 is implied), followed by -XXX (where XXX is numeric character 1, 2, or 3 or VL1, VL2 or VL3 to indicate model length), and then followed by two characters (to indicate riser length). All models have been evaluated for use with gasoline-ethanol blends of 0% to 85% ethanol with gasoline
Red Jacket	Automatic Tank Gauge	Pro Max FJ PX-2, ProPlus PP2
Red Jacket	Submersible Turbine Pumps	STP AG07551 Fj2, AGP15021 RJ2, AGP200S1-3 RJ2
Veeder-Root	Automatic Tank Gauge	ATG/TLS TLS-300C, TLS-350 Plus, TLS-350R
Veeder-Root	Tank Probes	Mag Plus Stainless Steel Probe 846391-4xx to 6xx, Mag Plus Probe 847390-xxx
Veeder-Root	Sensors	794380-323, 794380-344, 794380-345, 794380-430

Source: "Handbook for Handling, Storing, and Dispensing E85 and Other Ethanol-Gasoline Blends." DOE Clean Cities Program. September 2013. Last accessed March 5, 2014: http://www.afdc.energy.gov/uploads/publication/ethanol_handbook.pdf.

Appendix E. POET NACE Corrosion Test Results

POET - Innospec Retail Fuel Corrosion Survey

Retail Site #	State	Sample Month, Year	As-is NACE Corrosion Rating: Unleaded Rating	Unleaded % Corr.	Super Unleaded Rating	Super Unleaded % Corr.	Premium Rating	Premium % Corr.	E30 Rating	E30 % Corr.	E85 Rating	E85 % Corr.
100	SD	January, 2011	A	0	A	0	A	0	A	0	A	0
101	MN	January, 2011	A	0	A	0	A	0	A	0	A	0
102	MO	January, 2011	A	0	A	0	A	0			A	0
103	IA	January, 2011	B	25	A	0	B	15	A	0	A	0
104	MI	January, 2011	A	0	A	0	A	0	A	0	A	0
105	IN	January, 2011	A	0	A	0	A	0	A	0	B++	<0.1
106	OH	January, 2011	A	0	A	0	A	0			A	0
107	MN	February, 2011	A	0	A	0	C	45			B	10
108	SD	February, 2011	A	0	A	0			A	0	A	0
109	IA	February, 2011	A	0	A	0	B++	<0.1	A	0	A	0
110	MO	February, 2011	B++	<0.1	A	0	A	0	A	0	A	0
111	IN	February, 2011	A	0	B++	<0.1	A	0			A	0
112	OH	February, 2011	A	0	A	0	A	0			A	0
113	MN	March, 2011	A	0	A	0	B++	<0.1	A	0	A	0
114	SD	March, 2011	A	0	B++	<0.1	A	0	B++	<0.1	A	0
115	IA	March, 2011	B+	<5	A	0	C	30	B++	<0.1	A	0
116	MN	March, 2011	B++	<0.1	A	0	A	0	B++	<0.1	A	0
117	IN	March, 2011	A	0	A	0	B++	<0.1			A	0
118	OH	March, 2011	A	0	A	0	A	0			B++	<0.1
119	SD	April, 2011	B++	<0.1	A	0	A	0	A	0	A	0
120	SD	April, 2011	B++	<0.1	A	0	B++	<0.1	A	0	A	0
121	IA	April, 2011	A	0	B++	<0.1	B++	<0.1			A	0
122	IA	April, 2011	A	0	B++	<0.1	A	0	A	0	A	0
123	IN	April, 2011	A	0	A	0	A	0			A	0
124	IA	May, 2011	A	0	A	0	B++	<0.1			A	0
125	SD	May, 2011	A	0	A	0	B+	<5	A	0	A	0
126	IA	May, 2011	B+	<5	A	0	A	0	A	0	A	0
127	SD	May, 2011	A	0	A	0	A	0	A	0	A	0

Color Key									
Rating	A	B++	B+	B		C			
% Corrosion	0	<0.1	<5	5	25	26	49		
				D		E			
				50	75	76	100		

Courtesy of POET

Appendix F. UL E85 Material Designation

UL E85 Material Designation (not a finished part)		
Manufacturer	Equipment	Model
RT/Dygert International	Gasket and Seal	N-7079 (Nitrile) for static and dynamic applications
RT/Dygert International	Gasket and Seal	F-7036 (Fluorocarbon) for static and dynamic applications
RT/Dygert International	Gasket and Seal	FLT-7003 (Fluorocarbon) for static and dynamic applications
RT/Dygert International	Gasket and Seal	FS-7002 (Fluorosilicone) for static applications
Fusion Inc	Gasket and Seal	V9701 (Viton A) for dynamic applications
Fusion Inc	Gasket and Seal	V9702 (Viton B) for static and dynamic applications
Fusion Inc	Gasket and Seal	V9703 (Viton GF) for static and dynamic applications
Fusion Inc	Gasket and Seal	V9704 (Viton GFLT) for static and dynamic applications
Fusion Inc	Gasket and Seal	F7010 (Fluorosilicone) for static and dynamic applications
GE Mao Rubber Industrial Co	Gasket and Seal	N7060AA (Nitrile Thermoset Rubber) for static and dynamic applications
GE Mao Rubber Industrial Co	Gasket and Seal	F7004BU02 (Fluorosilicone) for static and dynamic applications
International Seal Co	Gasket and Seal	V121 (Fluorocarbon) for static and dynamic applications
International Seal Co	Gasket and Seal	V123 (Fluorocarbon) for static and dynamic applications
Parco Inc.	Gasket and Seal	9131-75 (Fluorocarbon) for static and dynamic applications
Parco Inc.	Gasket and Seal	9124-65 (Fluorocarbon) for static and dynamic applications
Parco Inc.	Gasket and Seal	9167-60 (Fluorocarbon) for static and dynamic applications
Parco Inc.	Gasket and Seal	1932-75 (Fluorosilicone) for static applications only
Parker Hannifin	Gasket and Seal	V1163-75 (Fluorocarbon) for static and dynamic applications
Parker Hannifin – O-ring Div	Gasket and Seal	N0497-70 (Nitrile) for static and dynamic applications
Parker Hannifin – O-ring Div	Gasket and Seal	N1500-75 (Nitrile) for static and dynamic applications
Parker Hannifin – O-ring Div	Gasket and Seal	L1120-70 (Fluorosilicone) for static and dynamic applications
Parker Hannifin – O-ring Div	Gasket and Seal	V1263-75 (Fluorosilicone) for static and dynamic applications
Parker Hannifin – O-ring Div	Gasket and Seal	V1163-75 (Fluorocarbon) for static and dynamic applications
Parker Hannifin – O-ring Div	Gasket and Seal	V1436-75 (Silicone) for static and dynamic applications
Parker Hannifin – Seals Div	Gasket and Seal	VG273-75 (Fluorocarbon) for static and dynamic applications

Source: "Handbook for Handling, Storing, and Dispensing E85 and Other Ethanol-Gasoline Blends." DOE Clean Cities Program. September 2013. Last accessed March 5, 2014: http://www.afdc.energy.gov/uploads/publication/ethanol_handbook.pdf.