Growth Energy Comments on EPA's Proposed E15 Fuel Dispenser Labeling and Compatibility with Underground Storage Tanks Regulations

Docket # EPA–HQ–OAR–2020–0448

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Introduction

Growth Energy respectfully submits these comments on the Environmental Protection Agency's (EPA's) proposed rulemaking entitled "E15 Fuel Dispenser Labeling and Compatibility with Underground Storage Tanks" ("E15 Proposal").[1] Growth Energy is the leading association of ethanol producers in the country, with 85 producer members, producing more than 6 billion gallons of ethanol, and 91 associate members who serve the nation's need for renewable fuel. Growth Energy strongly supports EPA's proposal to remove labeling and infrastructure barriers to E15. E15 is the lowest carbon-intensity gasoline product on the market; if the United States transitioned from E10 to E15 in the nation for 2001 and later model year vehicles, GHG emissions would be lower by 17.62 million tons per year, which is the equivalent of removing approximately 3.85 million vehicles from the road.[2] Moreover, more than 98% of registered vehicles on the road can use E15.[3]

Growth Energy supports modification of the E15 label requirement to increase clarity and ensure it adequately advises consumers of appropriate uses of the fuel, while not unnecessarily dissuading the vast majority of consumers whose vehicles can refuel with E15. Growth Energy also responds below to EPA's request for public comment on preemption considerations related to potential removal or revision of the label. In short, either modification of EPA's E15 label or removal of the E15 label requirement entirely would expressly preempt and conflict-preempt any state or local government E15 label requirement.

In addition, Growth Energy strongly supports EPA's proposal to modify the underground storage tank (UST) compatibility requirements applicable to E15 and other fuel blends. There is ample support that a wide variety of fuel storage equipment, including USTs and related piping, may store E15 if it is suitable for use with E10. Removing unnecessary impediments to retailers' use of such existing equipment is imperative to providing E15 equal footing in the fuels marketplace. We address these issues in detail below.

I. E15 Labeling Requirements

a. Modification of the EPA E15 Label is necessary and appropriate.

E15 has been legal for sale for over a decade, during which time consumers have engaged in millions of transactions to purchase the fuel and have driven more than twenty billion miles on it.[4] Today, sixteen of the largest retail chains in the nation offer E15 across 30 states.[5] The current EPA fuel label, however, persists as a barrier to consumers' purchase of E15 as it is

[1] Proposed Rule, *E15 Fuel Dispenser Labeling and Compatibility with Underground Storage Tanks*, 86 Fed. Reg. 5,094 (Jan. 19, 2021) ("E15 Proposal").
[2] Air Improvement Resources, Inc., *GHG Benefits of [E15] Use in the United States* (Nov. 30, 2020).
[3] Air Improvement Resources, Inc., *Analysis of Ethanol-Compatible Fleet for Calendar Year 2021* (Nov. 9, 2020).
[4] Growth Energy, "American Drivers Reach 20 Billion Miles on E15," https://growthenergy.org/2021/03/09/growth-energy-american-drivers-reach-20-billion-miles-on-e15/.
[5] Growth Energy, "Progress Report: E15 Rapidly Moving Into the Marketplace" (updated Mar. 16, 2021) https://growthenergy.org/wp-content/uploads/2021/03/e15-stationcount-2361-2021-03-16.pdf.

confusing and undermines consumer confidence in the fuel. Specifically, in a recent survey conducted by Quadrant Strategies, consumers responded that the current EPA label acts as a deterrent to purchasing E15, with almost half of respondents indicating the label makes them uncomfortable and unlikely to use the fuel.[6] Moreover, the label raises concerns about engine performance, with almost 40% of respondents indicating it leads them to believe E15 is bad for their vehicles' engine.[7] The wordiness of the current label is difficult for consumers to digest and leads to confusion about the fuel and whether it is allowed for use in the vast majority of vehicles on the road, for which it is legal.[8] In addition, with respect to the coloring of the label, almost half of respondents indicated that the orange/black coloring dissuades them from use of the fuel; whereas, a blue/white color scheme does not elicit such strong adverse reactions.[9] These unintended consequences of the current label's format, coloring, and content necessitate revision in order to correct perceptions and remove unnecessary barriers to consumer acceptance of the fuel.

Growth Energy requests that EPA consider replacing the current EPA label with this simplified, more clear label that succinctly informs consumers of the vehicles that may use the fuel:

Survey data strongly supports that this proposed label accurately informs consumers of acceptable uses of the fuel, while leading to substantially fewer misperceptions regarding engine performance.[10] The coloring and content of the label are informational, rather than unnecessarily alarmist. In other words, it conveys the salient information about E15's characteristics and legal uses without unduly raising the specter of engine damage or causing consumers' skepticism of the fuel. In addition, this proposed label adheres to FTC's recommendation that the E15 label "be as concise as possible since consumers are much less apt to read detailed labels, particularly

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[6] Quadrant Strategies, Memorandum re: "E15 Labeling Study" at 2 (Apr. 16, 2021) (Attachment 1) (hereinafter "Quadrant Survey").
[7] *Id.*
[8] *See id.* at 5.
[9] *Id.* at 6.
[10] *Id.* at 2.

in the context of routine activities like buying gas."[11] Moreover, its color scheme and content correct potential confusion with the FTC labels required for higher-level ethanol blends that may *only* be used in flex-fuel vehicles (FFVs), rather than the vast majority of light duty vehicles on the road today that may refuel with E15. Specifically, the FTC labeling scheme for higher-level ethanol blends that may only be used in FFVs is orange and black.[12] It is confusing for the E15 label, for a fuel that can be used in the vast majority of registered vehicles, to have the same color scheme.

This proposed label is similar to the alternative EPA proposes, but it removes superfluous language to clearly and succinctly inform consumers of acceptable uses consistent with FTC guidance on brevity. However, to the extent EPA does not adopt the proposed label, Growth Energy supports revision of the label as outlined in the E15 Proposal to: (1) modify the color scheme to blue and white, which survey evidence shows will prevent dissuading consumers from using the fuel; and (2) simplify and clarify the language.[13]

The recommended label changes outlined above are appropriate measures under EPA's Clean Air Act Section 211(c)(1) authority. Specifically, the proposed label would accomplish the same ends as set forth in EPA's original Misfueling Mitigation Rule (MMR), namely, that retailers selling E15 inform consumers of the legal and prohibited uses of E15 and prevent misfueling as is appropriate under Section 211(c)(1).[14] A decade ago, EPA acknowledged the MMR commenters' concerns that the label may "discourag[e] or chill[] appropriate use of E15 in MY2001 and new light-duty motor vehicles."[15] Survey evidence is clear that this is an unintended consequence of the current EPA label that requires correction.[16] In light of this new information, EPA is justified in revising the label to better inform consumers while requiring a label that prevents misfueling consistent with the original MMR and the agencies' authority under the Clean Air Act.[17]

b. STATE AND LOCAL LABELING OF E15 IS PREEMPTED.

Below we address EPA's request for comment on E15 labeling preemption considerations. As an initial matter, as EPA acknowledged in the E15 Proposal, both EPA and

[11] 76 Fed. Reg. 44,406, 44,414 (Jul. 25, 2011).
[12] *See* 16 C.F.R. §§ 306.10, 306.12. Unfortunately, the FTC requires that an E15 label state the fuel is for "use only in Flex-Fuel Vehicles," when E15's use is not restricted to such vehicles pursuant to the partial waiver decisions and EPA regulations.
[13] Specifically, Growth Energy would support, in the alternative, the label in Figure 2 in the docket memorandum, "Potential Label Changes," (Oct. 27, 2020), Doc. ID EPA-HQ-OAR-2020-0448-0002.
[14] 76 Fed. Reg. at 44,418; 42 U.S.C. § 7545(c)(1) (providing EPA authority to regulate fuel or fuel additives which contribute to air or water pollution that may reasonably be anticipated to endanger public health or welfare, as well as fuel or fuel additives that will impair to a significant degree the performance of any emission control device or system which is in general use).
[15] 76 Fed. Reg. at 44,413.
[16] *See generally* Quadrant Survey.
[17] *Nat'l Cable & Telecomms. Ass'n v. Brand X Internet Servs.*, 545 U.S. 967, 981 (2005) (internal citation omitted) (noting that it is entirely appropriate for an agency to continually evaluate the wisdom of its policies, especially "in response to changed factual circumstances").

FTC regulate labeling requirements for E15. Specifically, the FTC regulations found at 16 C.F.R. § 306.10 (Automotive Fuel Rating Posting) require fuel dispenser labels for gasoline-ethanol fuel blends containing greater than 10 percent ethanol. EPA has also adopted an E15 label under Clean Air Act (CAA) section 211(c)(1) that can be used in lieu of the FTC's label.[18] Thus, as EPA noted in its proposal, if it removes its own E15 label, the FTC label requirement would still apply.[19] Regardless of which label requirement is applicable, both the CAA and FTC regulations contain express preemption provisions that prohibit states or local governments from adopting or enforcing their own E15 label requirements. Specifically:

<u>CAA Preemption</u>. CAA section 211(c)(4)(A) provides that states and local governments cannot "prescribe or attempt to enforce, for purposes of motor vehicle emission control, any control or prohibition respecting any characteristic or component to a fuel or fuel additive in a motor vehicle engine," unless identical to the federal control or prohibition. As EPA noted in its proposal, section 211(c)(4)(A) preemption would apply to state controls and prohibitions respecting labeling of E15 fuel dispensers.[20]

<u>FTC Preemption</u>. 16 C.F.R. § 306.4 similarly provides that "[t]o the extent that any provision of this title applies to any act or omission, no State or any political subdivision thereof may adopt or continue in effect, [except as provided by limited exceptions], any provision of law or regulation with respect to such act or omission, unless such provision of such law or regulation is the same as the applicable provision of this title." Because the FTC has acted to regulate E15 with respect to labeling, preemption would apply to any state adoption or enforcement of an E15 label that differs from FTC's, even in the absence of an EPA label.

A. <u>State E15 Label Requirements Would Be Expressly Preempted by Either Modification of the EPA Label or Removal of the E15 Label</u>

If EPA modifies the E15 label (or retains the current label), any state that adopts a label requirement not *identical* to the EPA requirement for the purposes of motor vehicle emission control would be expressly preempted by Section 211(c)(4)(A). As EPA stated in the MMR and reiterated in the E15 Proposal, the E15 label is for purposes of vehicle emission control, and the label requirement is promulgated pursuant to Section 211(c)(1).[21] In addition, the FTC preemption provision prohibits states from adopting any regulation with respect to E15 labeling, regardless of purpose.[22] Thus, states and local governments are expressly preempted from prescribing and enforcing their own E15 label requirements under both the Clean Air Act and FTC regulations.[23]

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[18] *See* 76 Fed. Reg. 44,406; E15 Proposal at 5,096.
[19] 86 Fed. Reg. at 5,096 ("[I]f we were to remove our label requirement…absent additional action from FTC, retailers would be required to use FTC's label for ethanol blends containing between 10 and 15 percent ethanol.").
[20] *Id*. at 5,099.
[21] 76 Fed. Reg. at 44,411; 86 Fed. Reg. at 5,097.
[22] *See* 16 C.F.R. § 306.4.
[23] *See id*.; CAA § 211(c)(4)(A).

If EPA removes its label requirement (which Growth Energy does not support at this juncture), the FTC label would still apply.[24] Therefore, any state that sought to adopt a label requirement not identical to the FTC requirement would be expressly preempted by 16 C.F.R. § 306.4.

B. State E15 Label Requirements Would Be Conflict Preempted by Either Modification of the EPA Label Or Removal of the E15 Label

Even if express preemption did not apply (which it does), states would also be unable to adopt or enforce their own E15 labeling requirement pursuant to the doctrine of conflict preemption. Specifically, if EPA revises the label, a state control or prohibition on fuels or fuel additives that is not identical to EPA's modified E15 label would be impliedly preempted because it would "conflict" with the federal standard, preventing compliance with EPA's and FTC's E15 label requirements and/or serving as an obstacle to the accomplishment of EPA and FTC's objectives with respect to E15 regulation. Namely, a non-identical state label would serve as an obstacle to EPA's objectives of clearly conveying which vehicles and engines can lawfully use E15, reducing consumer confusion, and selecting a color and format most suited for the label's purpose. Any inconsistency with regard to the label requirement would jeopardize EPA's stated goal of "improving clarity regarding which vehicles can use E15 while protecting vehicles and engines for which E15 use in appropriate."[25]

Similarly, if EPA removes its label requirement, conflict preemption would apply to any state attempting to adopt an alternative E15 label because this would conflict with the federal standard, preventing compliance with the FTC label requirement. In addition to preventing compliance with the FTC label, a state label requirement would create an obstacle to the accomplishment of the FTC's goals in establishing a label requirement for E15. These goals include providing "information to consumers about ethanol concentrations and suitability for their cars and engines," "preventing consumer confusion," creating "greater flexibility for businesses to comply with the ethanol labeling requirements," and avoiding "unnecessary burden on industry."[26] Any state E15 label requirement not identical to the federal standard would create consumer confusion, burden industry which would have to comply with multiple different standards, and could dissuade consumers from using E15 altogether.

Consequently, whether EPA revises the label, retains, or removes it, states are preempted from requiring non-identical E15 labels, both expressly and impliedly. Therefore, EPA should confirm in its final rule that, regardless of the option it ultimately chooses, states and local government would continue to be unable to adopt or enforce their own E15 label requirements.

[24] *Id*. at 5,096, 5,098.
[25] *Id*. at 5,098.
[26] 81 Fed. Reg. 2,054, 2,055 (Jan. 14, 2016).

II. EPA Should Revise the 2015 UST Regulation to Be Less Burdensome for UST Owners and Operators to Demonstrate Compatibility.

Growth Energy strongly agrees with EPA that it is important for USTs to be constructed, maintained, and operated in a manner so that petroleum and other regulated substances are stored safely. Growth Energy also agrees that, due to the continued growth in biofuels in the United States, the 2015 UST regulation[27]—requiring owners and operators to provide additional notification, demonstration and recordkeeping when storing fuel blends, such as those with more than 10% ethanol or more than 20% biodiesel—should be revised to grant certain allowances for compatibility demonstration and make it less burdensome for UST owners and operators to meet the current requirements. By revising the 2015 UST regulation, EPA can ensure that the future national UST infrastructure is compatible with a broad range of biofuels while encouraging growth in the nation's renewable fuel production.

As an initial matter, the scientific literature strongly supports that UST systems compatible with E10 are also compatible with E15.[28] As a National Renewable Energy Laboratory (NREL) infrastructure report ("NREL Report") found, there have been *no* known incidents of E10 causing releases from UST systems, or even any association between E10 and any specific UST release.[29] E10 now constitutes 98% of gasoline sold in the United States, which means the vast majority of retailers have underground equipment that is already E15-compatible.

The agency states in the proposal that the following equipment is E15-compatible and warrants no further compatibility demonstration requirements:

- all steel tanks (single- and double-walled);
- all fiberglass tanks manufactured after July 2005;
- all flexible reinforced plastic piping.[30]

The existing scientific literature clearly indicates the compatibility of this equipment. In addition, according to manufacturers, *all* double-walled fiberglass tanks have always been E10 compatible, and single-walled fiberglass tanks have been E10 compatible since February 1981.[31]

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[27] 80 Fed. Reg. 41,566 (July 15, 2015).

[28] National Renewable Energy Laboratory, *E15 and Infrastructure*, DOE (May 2015) (hereinafter "NREL Report") (Attachment 2); Oak Ridge National Laboratory, *Analysis of Underground Storage Tank System Materials to Increased Leak Potential Associated with E15 Fuel*, ORNL/TM-2012/182 (Jul. 2012) (hereinafter "ORNL Report") (Attachment 3).

[29] *Id*. at 11.

[30] The Fiberglass Tank & Pipe Institute stated that "[u]nderground fiberglass piping and fittings installed in service stations have been compatible with up to 100%-percent ethanol for over 40 years." *See* http://www.fiberglasstankandpipe.com/wp-content/uploads/2018/11/Ethanol-Compatibility-with-Fiberglass-11102016-retired.pdf.

[31] US DRIVE Fuels Working Group, *Potential Impacts of Increased Ethanol Blend-Level in Gasoline on Distribution and Retail Infrastructure*, Figure 2-6 (Feb. 2019), https://www.energy.gov/sites/prod/files/2019/02/f59/USDRIVE_FWG_PotentialImpactsIncreasedEthanolBlend-Level.pdf.

Because the literature strongly supports that E10-compatible tanks can be safely used with fuel with 5% higher ethanol content,[32] EPA is warranted in excluding from additional compatibility demonstrations all double-walled fiberglass tanks and all single-walled fiberglass tanks manufactured after 1981. Moreover, the NREL Report comprehensively identifies in appendices the USTs, piping, and related equipment that are E15-compatible. This report supports and supplements the equipment that EPA may exclude from the compatibility demonstration requirements under 40 C.F.R. § 280.32. For example, the report supports that most flexible plastic piping is E-15 compatible.

In addition, based on robust compatibility analyses conducted by Oak Ridge National Laboratory, from a materials perspective, all metal and flexiglass UST system piping and the vast majority of flexible plastic piping is E15-compatible.[33] Particularly with respect to flexible plastic piping, Oak Ridge's analysis indicates a small minority of flexible plastic pipes with a nylon permeation barrier may not be compatible with E10, but that equipment would have long-since been replaced in the transition to E10, especially as this equipment is only warrantied for approximately 10 years.[34] Notably, the remainder of flexible plastic piping with polyvinylidene fluoride (PVFD) and polyethylene terephthalate (PET) permeation barriers, the two most common types, is compatible with intermediate ethanol blends.[35] This data supports exclusion of these piping materials from further compatibility demonstration. For other auxiliary equipment in a UST system, including containment sumps, pumping equipment, release detection equipment, spill prevention equipment, overfill prevention equipment, seals, pipe couplings, and sealants, the ORNL analysis supports that equipment suitable for use with E10 poses no E15-compatibility issues.[36] For example, ORNL found that pipe couplings using flexible plastic piping are generally comprised of a band of stainless steel compression-fitted around the pipe (which show no corrosion issues up to E25 blends). With regards to sealants, ORNL found that fluorocarbons are often used and perform well with intermediate ethanol blends including E15. In addition, pipe dope that is E10-compatible (most commonly Gasoila E-Seal) is appropriate for use with immediate blends, up to E25.[37]

In sum, ORNL stated: "The indication is that UST systems were affected by switching from E0 to E10. However, since E10 and E15 produce similar results, compatibility is not expected to be altered noticeably when moving from E10 to E15."[38] These technical judgments regarding the suitability of E10-compatible UST equipment for E15 support that EPA need only identify the small subset of in-use equipment that is not E10 compatible, and require a demonstration of compatibility for that subset of equipment. As an additional measure, Growth Energy recommends that EPA modify the existing compatibility regulations to allow a retailer

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[32] Oak Ridge National Laboratory, "Analysis of Underground Storage Tank System Materials to Increased Leak Potential Associated with E15 Fuel." ORNL/TM-2012/182 (Jul. 2012).
[33] ORNL Report at 24.
[34] *Id.*
[35] *Id.*
[36] *See e.g., id.* at 20.
[37] *Id.* at 21.
[38] ORNL Report at xviii.

that wishes to transition E10 retail equipment to E15 to forgo demonstration requirements if the regulated party is subject to semi-annual third-party UST inspections paid for by the party, with reporting of inspection results to the regulating agency. This alternative will remove unnecessary barriers to retailers' transition to E15, while ensuring protectiveness to the environment and no increased burden on regulating entities, which are already resource constrained in UST inspections. To the greatest extent possible, EPA should work with other relevant federal and state agencies to further clarify that all retail infrastructure above and below ground, including dispensers in use for E10, should be deemed compatible for use with E15.

Three final points: First, Growth Energy supports EPA's proposal to allow the use of secondary containment with interstitial monitoring in lieu of being able to demonstrate compatibility of all UST system equipment and components required by the 2015 UST regulation. As noted above, all double-walled tanks (i.e., secondary containment) are E15-compatible, and as EPA indicates, secondary containment with monitoring is adequately protective of the environment in ensuring any leaks are promptly addressed before substances reach the environment.[39] Second, Growth Energy also supports the agency's proposal to require newly-installed UST systems to be compatible with up to 100% ethanol. All tanks and piping manufactured today meets this requirement, and these components are the most expensive components of the UST system.[40] For other ancillary components, the costs of ensuring E100 equipment are minimal, particularly given the overall cost of installing a new UST system or replacing an existing system. In short, this measure will ensure flexibility in the fuel distribution system at minimal additional cost to retail stations. Third, EPA should reconsider its requirement that a retailer selling E15 on a shared hose with E10 must have a dedicated E10 (or E0) position on the premises. For retailers with few dispensers, this unnecessarily limits the availability of E15 despite the prevalence of E15 compatible vehicles.

[39] 86 Fed. Reg. at 5,099-5,100.
[40] NREL Report.

Attachment 1

TO: Interested parties
FROM: Quadrant Strategies
DATE: April 13, 2021
RE: E15 Labeling Study

Methodology: Between April 4, 2021 and April 9, 2021, Quadrant Strategies conducted an online quantitative survey of a random sample of 1,000 US consumers, reflective of the overall 18+ population in gender, age, education, race, ethnicity, area, and region. Of those US consumers, we looked at the data for drivers with E15 Eligible Vehicles[1] (n=841). The margin of error for US consumers was +/- 3.1 percentage points and the margin of error for drivers with E15 Eligible Vehicles was +/- 3.39 percentage points.

Objective: Determine the impact of the current EPA E15 Label, as well as alternative labels, on the perception of, and likelihood to use, E15.

[1] *Drivers with E15 Eligible Vehicles are defined as drivers who responded that their primary vehicle is a passenger vehicle produced in 2001 or later or is a flex fuel vehicle. Must have a current Driver's license and drive very frequently, somewhat frequently, or rarely. The vast majority of respondents had vehicles for which E15 is legal. Quadrant Strategies omits from these results the small, statistically insignificant number of responses from individuals with vehicles for which E15 is not allowed.*

Executive Summary:

The current EPA E15 label fosters misconceptions about E15 and likely deters its usage. Among drivers with E15 Eligible Vehicles, the current EPA E15 label raises concerns about the fuel's impact on vehicle engine condition and performance. The proposed Growth Energy E15 label is less likely to raise concerns while still providing similar guidance about E15 as the current EPA label.

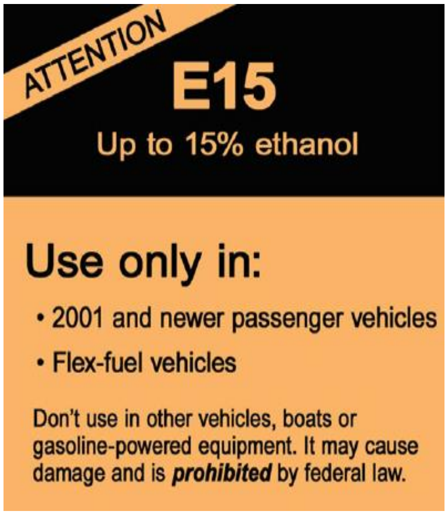
We found that the current EPA label:

- **Deters drivers with E15 Eligible Vehicles from using E15.** The label makes nearly half uncomfortable with E15 and unlikely to use it.
- **Raises concerns around engine performance**. After viewing the label, nearly 4 in 10 drivers with E15 Eligible Vehicles think that E15 is bad for engine performance and bad for the condition of their engine.

Meanwhile, the proposed Growth Energy label:

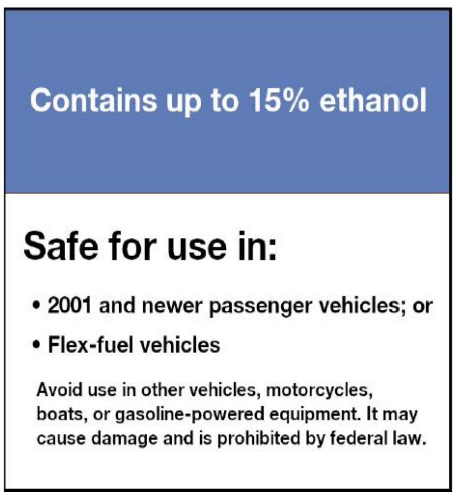
- **More effectively informs consumers about E15. The vast majority** of drivers with E15 Eligible Vehicles (84%) correctly interpret that they can use E15 - compared to 75% after seeing the current EPA label.
- **Generates far fewer misconceptions about E15.** Drivers of E15 Eligible Vehicles are much less likely to say the proposed label makes them uncomfortable with E15 (a 20-point difference compared to the current label). Similarly, they are much less likely to say E15 is bad for the condition of their engine based on the proposed label (an 18-point difference).

E15 Labels Tested:



Current EPA Label

Proposed Growth Energy Label

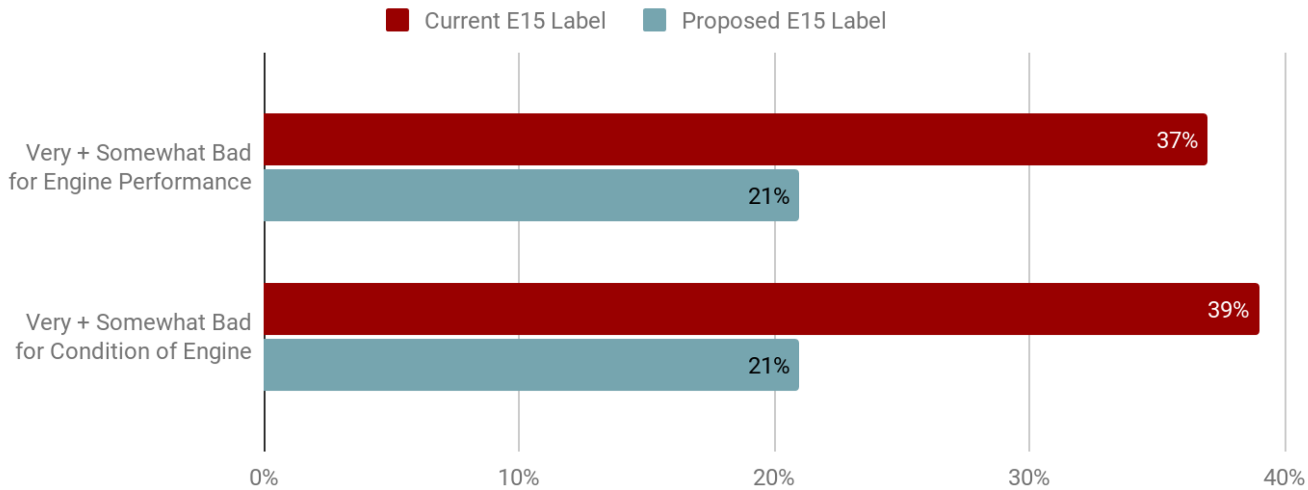


Proposed EPA Label #1

Proposed EPA Label #2

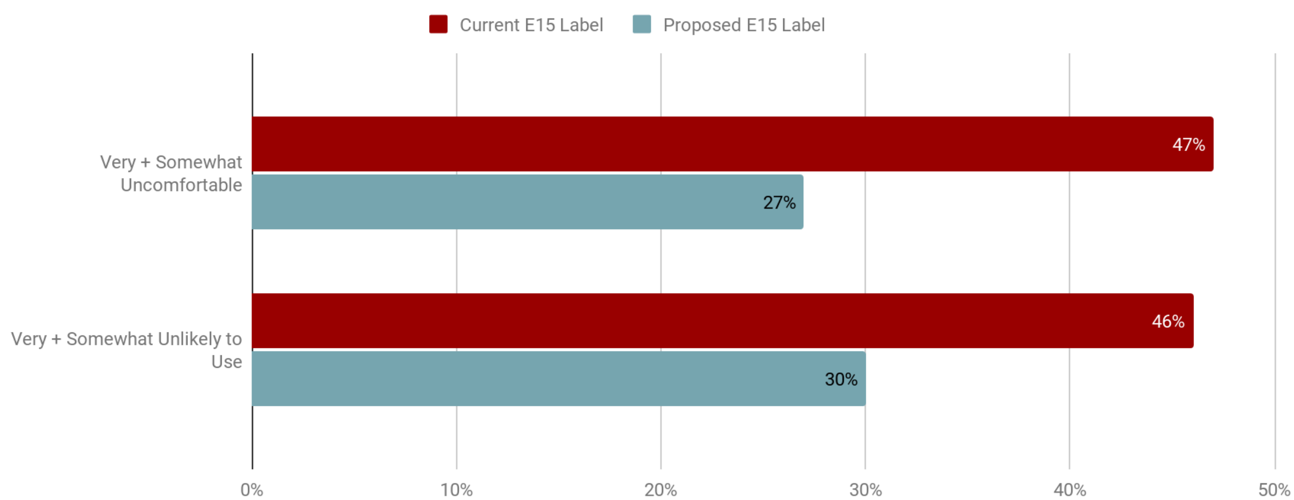
Key Data:

- **The current EPA label is much more likely to raise concerns about the fuel's impact on vehicle engines than the Growth Energy proposed label.**



Does this label make you feel like this fuel is good or bad for each of the following?
Showing drivers with E15 Eligible Vehicles (n=841)

- **And it makes drivers less comfortable with and less likely to use E15.**



Top*: Based on what you see, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.*
Bottom*: Based on what you see, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.*
Showing drivers with E15 Eligible Vehicles (n=841)

- **The proposed Growth Energy label provides more accurate E15 guidance than the current EPA label.**

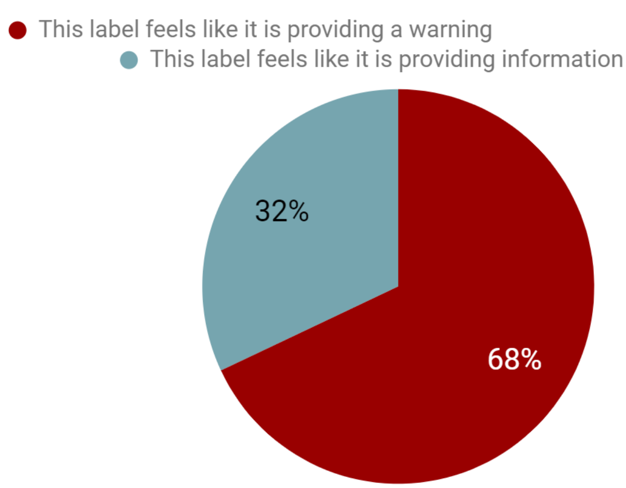
With E15 Eligible Vehicles: **84% correctly interpreted** that they can use E15

With E15 Eligible Vehicles: **75% correctly interpreted** that they can use E15

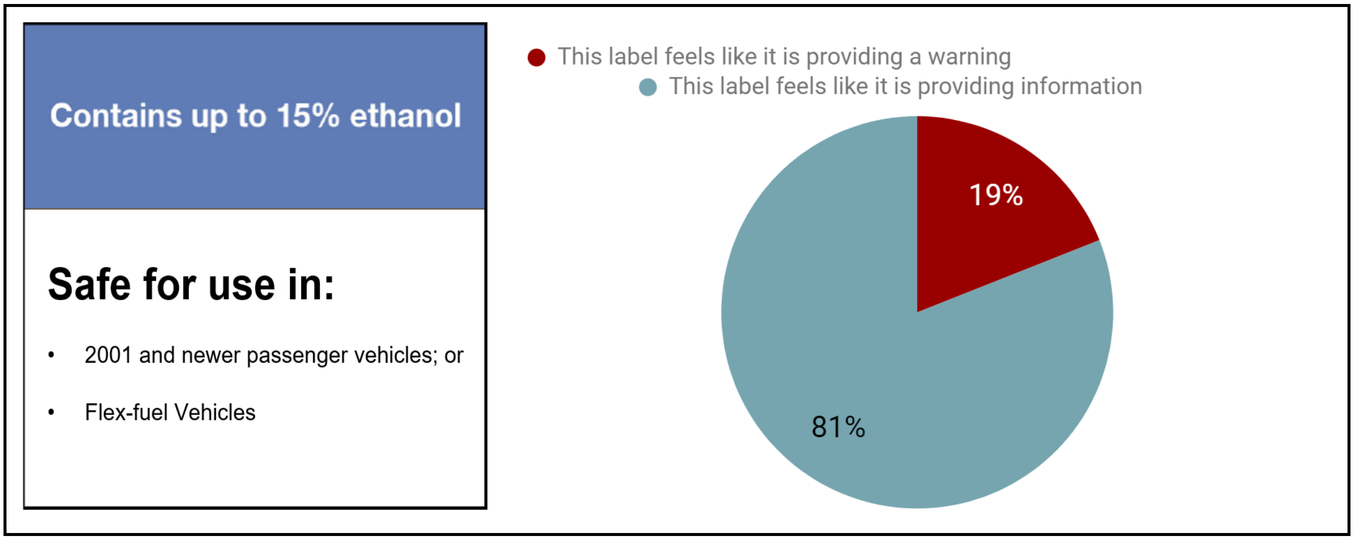
Based on what you see, can you put this type of fuel in your car?
Showing drivers with E15 Eligible Vehicles (n=841)

- E15 Eligible drivers overwhelmingly perceive the **current label more as a warning**.
- In contrast, they overwhelmingly perceive the **proposed Growth Energy label more as providing information**.

Current Label

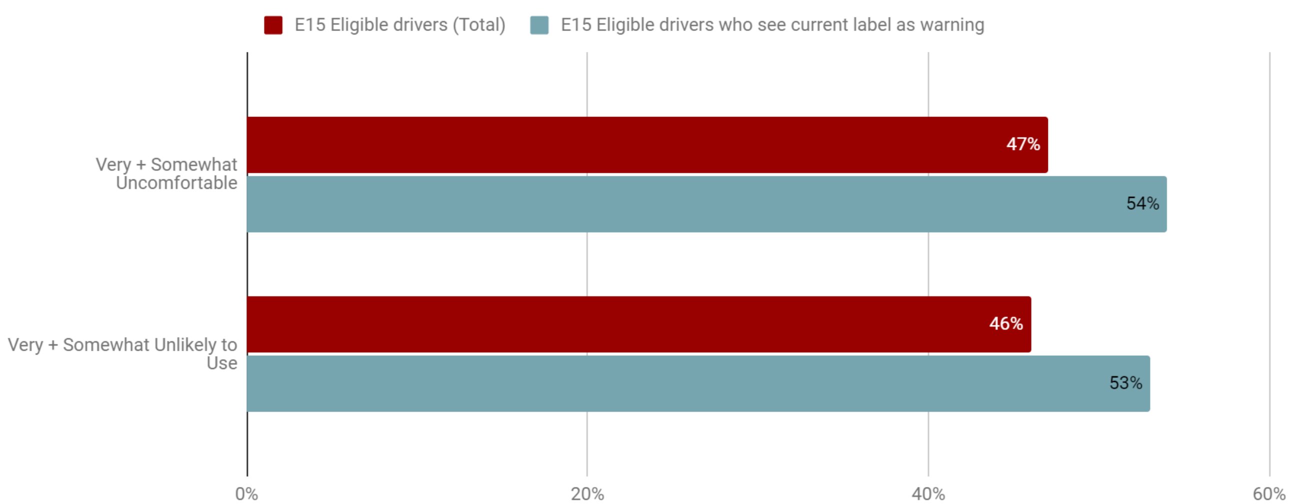


Proposed Growth Energy Label



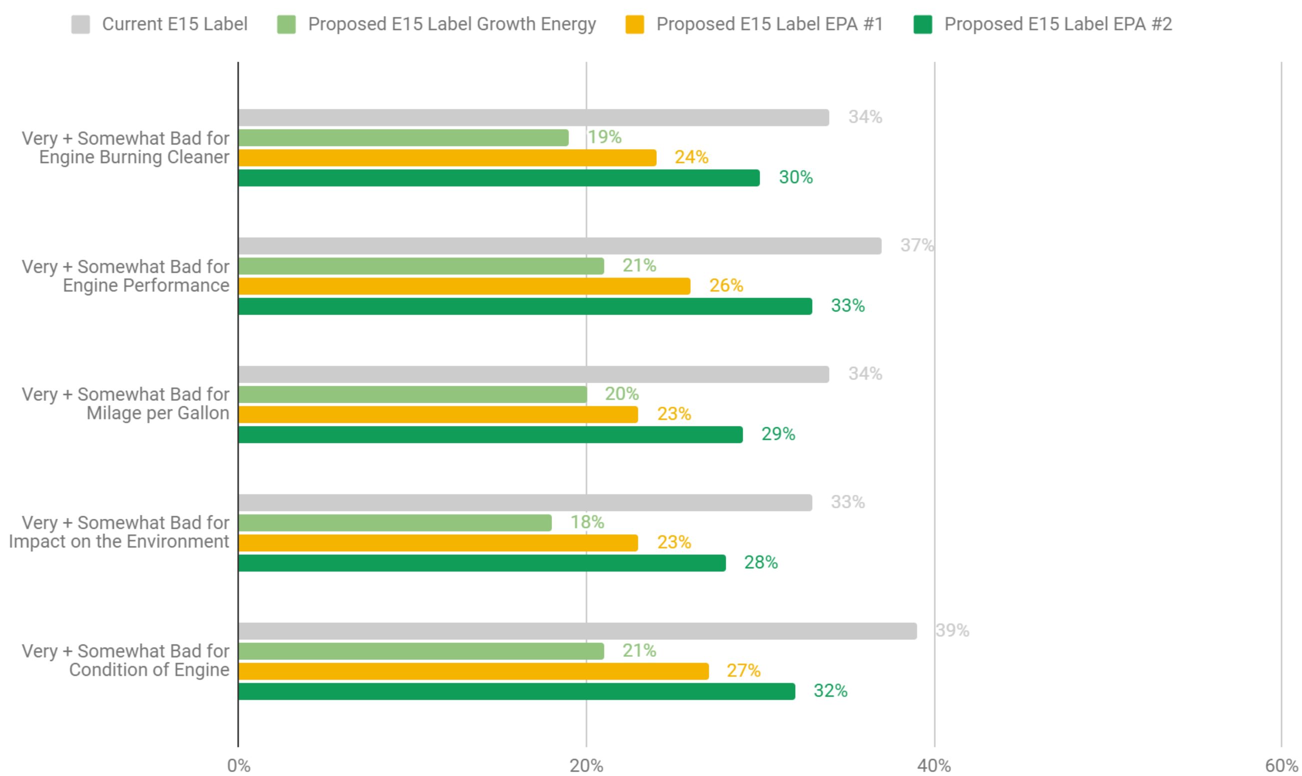
Which of the following most aligns with how you feel about the label?
Showing drivers with E15 Eligible Vehicles (n=841)

- **And E15 Eligible drivers who perceive the current label as a warning are both more uncomfortable and more unlikely to use E15.**

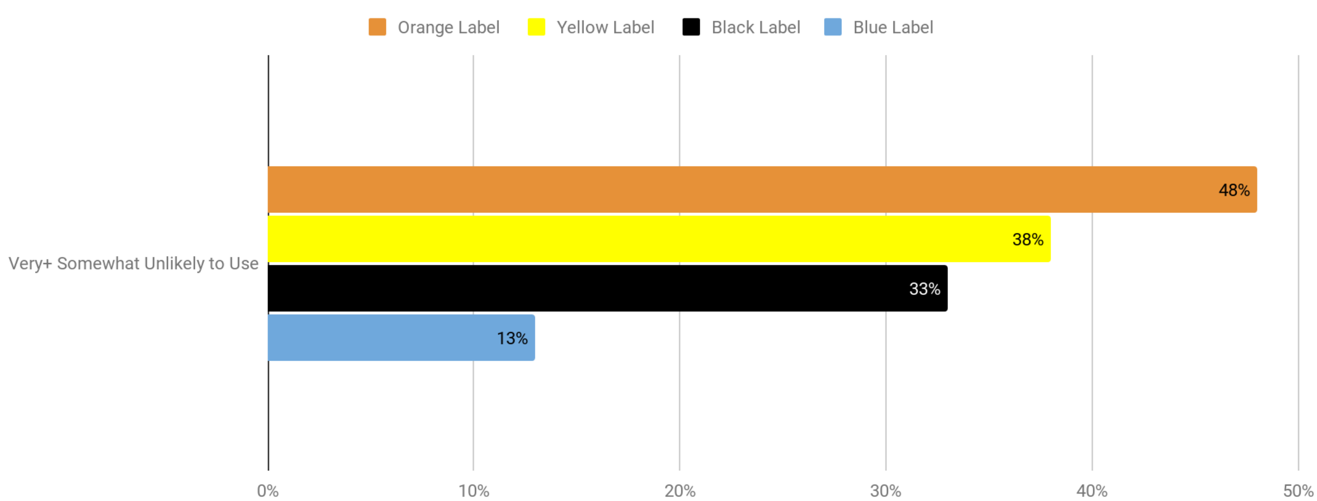


Top: Based on what you see, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.
Bottom: Based on what you see, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did
Showing drivers with E15 Eligible Vehicles (n=841)
Showing drivers with E15 Eligible Vehicles who see current label as a warning (n=575)

- **Among the four E15 labels tested, the proposed Growth Energy is the least likely to generate misconceptions about E15.**



- **Label color has an impact on likelihood to use. Orange and black make drivers much less likely to use a fuel than blue.**



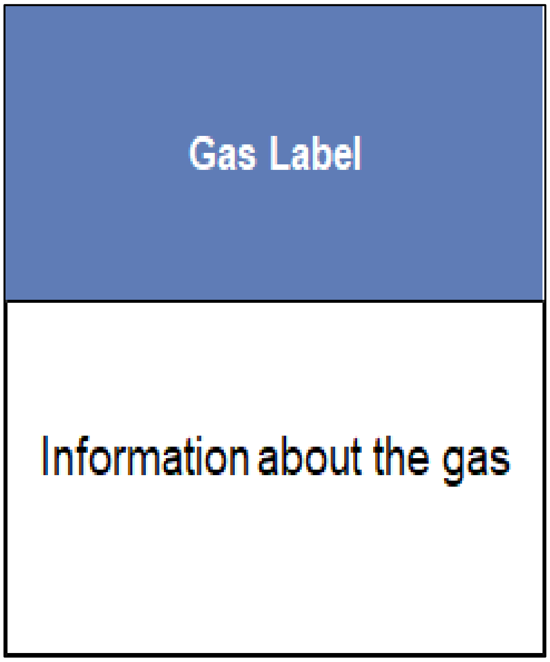
Based on the color alone, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.
Showing Drivers with E15 Eligible Vehicles (n=841)

Current EPA Label

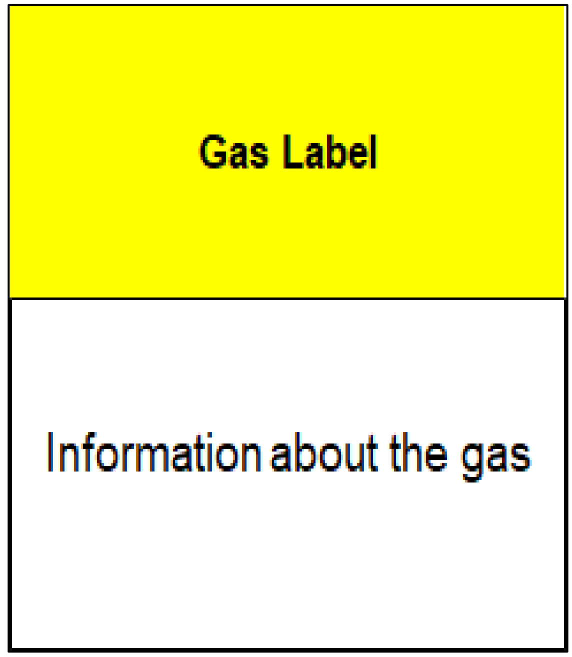
Proposed Growth Energy Label

Proposed EPA Label #1

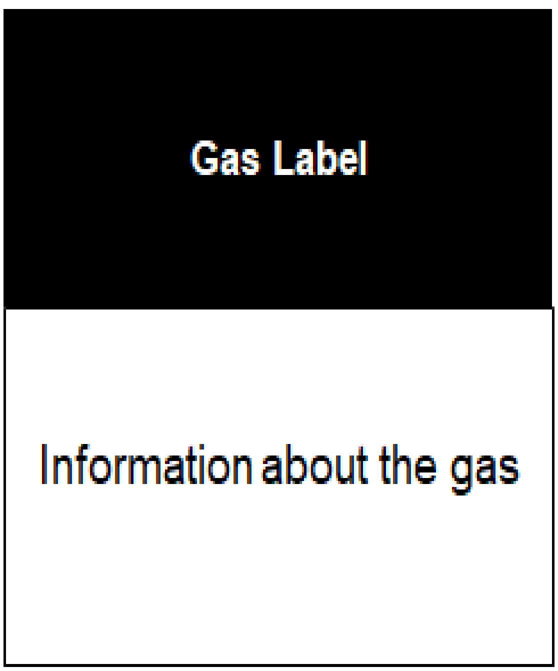
Proposed EPA Label #2



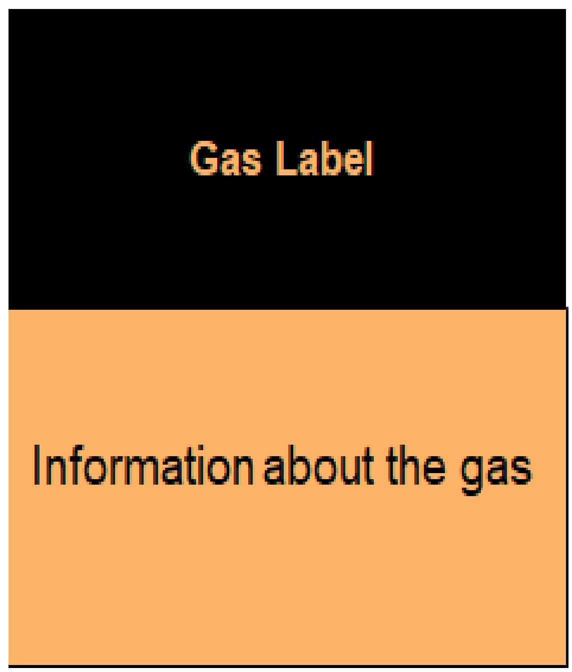
Blue Blank Label



Yellow Blank Label



Black and White Blank Label



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APPENDIX II: FULL DATASET

Between April 4, 2021 and April 9, 2021, Quadrant Strategies conducted an online quantitative survey of a random sample of 1,000 US consumers, reflective of the overall 18+ population in gender, age, education, race, ethnicity, area and region. Of those US consumers, we looked at the data for drivers with E15 Eligible Vehicles[2] (n=841). The margin of error for US consumers was +/- 3.1 percentage points and the margin of error for drivers with E15 Eligible Vehicles was +/- 3.39 percentage points. Full survey results are below.

Do you currently describe yourself as a man, a woman, or in some other way? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
A man	47%	48%
A woman	53%	52%
In some other way	0%	0%

Please enter your age: (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Under 18	0%	0%
18-24	15%	14%
25-34	16%	16%
35-49	31%	31%
50-64	28%	29%
65+	10%	11%

[2] *Drivers with E15 Eligible Vehicles are defined as drivers who responded that their primary vehicle is a passenger vehicle produced in 2001 or later or is a flex fuel vehicle. Must have a current Driver's license and drive very frequently, somewhat frequently, or rarely.*

Which state do you live in? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Alabama	2%	2%
Alaska	0%	0%
Arizona	2%	2%
Arkansas	0%	0%
California	11%	11%
Colorado	1%	1%
Connecticut	2%	2%
Delaware	0%	0%
District of Columbia	0%	0%
Florida	6%	6%
Georgia	3%	4%
Hawaii	0%	0%
Idaho	0%	0%
Illinois	4%	5%
Indiana	2%	2%
Iowa	1%	1%
Kansas	1%	1%

Kentucky	1%	1%
Louisiana	1%	1%
Maine	1%	1%
Maryland	2%	2%
Massachusetts	3%	3%
Michigan	4%	4%
Minnesota	2%	2%
Mississippi	1%	1%
Missouri	1%	1%
Montana	0%	0%
Nebraska	0%	0%
Nevada	1%	1%
New Hampshire	1%	1%
New Jersey	4%	4%
New Mexico	1%	1%
New York	7%	6%
North Carolina	3%	3%
North Dakota	0%	0%

Ohio	3%	4%
Oklahoma	2%	2%
Oregon	0%	0%
Pennsylvania	4%	4%
Rhode Island	0%	0%
South Carolina	2%	2%
South Dakota	0%	0%
Tennessee	3%	3%
Texas	7%	7%
Utah	1%	1%
Vermont	0%	0%
Virginia	2%	3%
Washington	3%	2%
West Virginia	0%	0%
Wisconsin	1%	1%
Wyoming	0%	0%
Other	0%	0%

In the past 3 years, have you or anyone in your household worked for any of the following industries? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Advertising	0%	0%
Banking	3%	3%
Finance or accounting	4%	4%
Government	6%	7%
Transportation	3%	3%
Agriculture or farming	1%	1%
Healthcare or pharmaceutical	11%	12%
Journalism, media or the press	0%	0%
Computer manufacturer and design	1%	1%
Market research	0%	0%
Tourism or hospitality	2%	2%
Energy or electricity	2%	1%
Public relations	0%	0%
None of the above	73%	71%

What is the highest level of education that you have attained? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Grade school	0%	0%
Some high school	1%	1%
High school graduate	21%	19%
Some college	26%	25%
College graduate	29%	30%
Graduate school / Advanced degree	20%	21%
Technical school	3%	3%
Prefer not to answer	0%	0%

Which of the following best describes your current employment status? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Employed full-time	47%	51%
Employed part-time	12%	12%
Stay-at-home-parent / homemaker	7%	6%
Unemployed	12%	9%
Full time student	7%	5%

Retired	15%	16%
Prefer not to answer	0%	0%

For statistical purposes only, please select the following category below that represents your total personal annual income? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Less than $25,000	23%	18%
$25,000 to $49,999	23%	22%
$50,000 to $74,999	19%	20%
$75,000 to $99,999	11%	13%
$100,000 to $124,999	8%	9%
$125,000 to $149,999	6%	7%
$150,000 to $199,999	6%	7%
$200,000 to $249,999	2%	2%
$250,000 or more	2%	2%
Prefer not to answer	0%	0%

Are you of Hispanic, Latino, or Spanish origin, such as Mexican, Puerto Rican, or Cuban? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)

Yes	13%	13%
No	87%	87%

What is your race or origin? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
White	71%	75%
Black or African-American	15%	13%
Asian or Asian-American	9%	8%
American Indian or Alaska Native	3%	2%
Native Hawaiian or other Pacific Islander	1%	1%
Some other race or origin	6%	6%

Do you live in a city, just outside a city or suburb, or a less developed or rural area, not near a city? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
City	34%	33%
Just outside a city or suburb	47%	49%
More rural, less developed area	18%	18%
Prefer not to answer	0%	0%

How would you describe your political party affiliation? (Showing % Selected)	Total (n=1000)	E15 Eligible (n=841)
Strong Republican	14%	14%
Lean Republican	15%	16%
Independent	28%	27%
Lean Democrat	18%	18%
Strong Democrat	25%	24%
Prefer not to answer	0%	0%

How many cars does your household own or lease? (Showing % Selected)	Total (n=1000)	E15 Eligible (n=841)
0	8%	0%
1	43%	47%
2	33%	36%
3	11%	12%
4 or more	5%	5%
Prefer not to answer	0%	0%

Do you have a driver's license? (Showing % Selected)	Total (n=1000)	E15 Eligible (n=841)

Yes	92%	100%
No	8%	0%
Prefer not to answer	0%	0%

How often do you drive? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very frequently	52%	60%
Somewhat frequently	30%	33%
Rarely	10%	7%
Never	8%	0%
Prefer not to answer	0%	0%

My primary vehicle (select all that apply)... (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Uses unleaded gasoline	92%	93%
Uses diesel	7%	7%
Is electric	3%	3%
Other:	2%	1%

How familiar, if at all, are you with the following fuel sources? (Showing % Selected)

Total (n=1000)	Regular or unleaded	Mid Grade	Premium	E15	E85
Very familiar	78%	36%	44%	7%	13%
Somewhat familiar	18%	38%	36%	15%	17%
Not very familiar	2%	15%	13%	21%	18%
Not at all familiar	2%	11%	7%	58%	52%
E15 Eligible (n=841)	**Regular or unleaded**	**Mid Grade**	**Premium**	**E15**	**E85**
Very familiar	79%	37%	44%	7%	13%
Somewhat familiar	17%	38%	37%	15%	18%
Not very familiar	2%	14%	12%	21%	18%
Not at all familiar	2%	11%	7%	57%	51%

How likely are you to use each of the following types of fuel for your car? If you aren't familiar enough with a particular source to have an opinion, please answer "don't know."
(Showing % Selected)

Total (n=1000)	Regular or unleaded	Mid Grade	Premium	E15	E85
Very likely	81%	20%	25%	5%	8%
Somewhat likely	10%	29%	20%	9%	8%
Somewhat unlikely	4%	17%	18%	7%	8%
Very unlikely	3%	24%	30%	35%	34%

Don’t know	2%	10%	7%	44%	42%

E15 Eligible (n=841)	**Regular or unleaded**	**Mid Grade**	**Premium**	**E15**	**E85**
Very likely	81%	20%	25%	5%	9%
Somewhat likely	10%	30%	19%	10%	9%
Somewhat unlikely	4%	17%	18%	7%	7%
Very unlikely	3%	24%	31%	35%	35%
Don’t know	2%	9%	7%	43%	41%

CURRENT EPA LABEL **Which of the following most aligns with how you feel about the label?** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
This label feels like it is providing a warning	68%	68%
This label feels like it is providing information	32%	32%

CURRENT EPA LABEL **Based on what you see, can you put this type of fuel in your car?** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Yes	72%	75%
No	28%	25%

CURRENT EPA LABEL **Based on what you see, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	19%	21%
Somewhat comfortable	32%	32%
Somewhat uncomfortable	28%	28%
Very uncomfortable	20%	19%

CURRENT EPA LABEL **Based on what you see, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very likely	20%	22%
Somewhat likely	32%	32%
Somewhat unlikely	26%	26%
Very unlikely	23%	21%

CURRENT EPA LABEL **Does this label make you feel like this fuel is good or bad for each of the following?** (Showing % Selected)					
Total (n=1000)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	17%	18%	17%	20%	17%
Somewhat good	47%	43%	48%	45%	43%
Somewhat bad	26%	29%	26%	25%	29%
Very bad	10%	10%	9%	10%	11%
E15 Eligible **(n=841)**	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	18%	19%	17%	22%	17%
Somewhat good	47%	44%	49%	45%	43%
Somewhat bad	25%	28%	26%	24%	29%
Very bad	9%	9%	8%	9%	10%

CURRENT EPA LABEL **Based on what you see, please select all of the following vehicles this fuel may be used in.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
2001 Sedan	78%	79%
2009 flex fuel SUV	81%	82%

2008 pick-up truck	66%	66%
1999 SUV	3%	4%
All of these	4%	3%
None of these	4%	3%

PROPOSED EPA LABEL #1 Which of the following most aligns with how you feel about the label? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
This label feels like it is providing a warning	34%	33%
This label feels like it is providing information	66%	67%

PROPOSED EPA LABEL #1 Based on what you see, can you put this type of fuel in your car? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Yes	77%	81%
No	23%	19%

PROPOSED EPA LABEL #1 **Based on what you see, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	26%	27%
Somewhat comfortable	41%	41%
Somewhat uncomfortable	19%	19%
Very uncomfortable	14%	13%

PROPOSED EPA LABEL #1 **Based on what you see, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very likely	26%	27%
Somewhat likely	39%	39%
Somewhat unlikely	20%	20%
Very unlikely	15%	13%

PROPOSED EPA #1 Does this label make you feel like this fuel is good or bad for each of the following? (Showing % Selected)					
Total (n=1000)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	21%	21%	19%	25%	19%
Somewhat good	54%	52%	56%	50%	52%
Somewhat bad	20%	21%	20%	18%	22%
Very bad	6%	6%	5%	7%	6%
E15 Eligible (n=841)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	21%	21%	20%	27%	21%
Somewhat good	55%	53%	57%	50%	52%
Somewhat bad	19%	21%	19%	17%	22%
Very bad	5%	5%	5%	5%	5%

PROPOSED EPA LABEL #1 **Based on what you see, please select all of the following vehicles this fuel may be used in.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
2001 Sedan	78%	79%
2009 flex fuel SUV	83%	84%

2008 pick-up truck	67%	67%
1999 SUV	3%	3%
All of these	5%	5%
None of these	3%	3%

PROPOSED EPA LABEL #2 **Which of the following most aligns with how you feel about the label?** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
This label feels like it is providing a warning	52%	52%
This label feels like it is providing information	48%	48%

PROPOSED EPA LABEL #2 **Based on what you see, can you put this type of fuel in your car?** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Yes	74%	78%
No	26%	22%

PROPOSED EPA LABEL #2 **Based on what you see, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)

Very comfortable	22%	24%
Somewhat comfortable	39%	40%
Somewhat uncomfortable	24%	24%
Very uncomfortable	15%	13%

PROPOSED EPA LABEL #2 **Based on what you see, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very likely	22%	23%
Somewhat likely	36%	37%
Somewhat unlikely	25%	24%
Very unlikely	17%	16%

Proposed EPA Label #2
Does this label make you feel like this fuel is good or bad for each of the following?
(Showing % Selected)

Total (n=1000)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	18%	18%	17%	21%	17%
Somewhat good	51%	48%	53%	49%	49%

Somewhat bad	25%	27%	23%	22%	26%
Very bad	7%	6%	6%	8%	8%

E15 Eligible (n=841)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	19%	18%	18%	23%	17%
Somewhat good	52%	49%	53%	49%	50%
Somewhat bad	24%	28%	23%	21%	26%
Very bad	6%	6%	6%	7%	6%

PROPOSED EPA LABEL #2 **Based on what you see, please select all of the following vehicles this fuel may be used in.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
2001 Sedan	80%	81%
2009 flex fuel SUV	82%	83%
2008 pick-up truck	67%	67%
1999 SUV	3%	3%
All of these	4%	4%
None of these	3%	3%

PROPOSED GROWTH ENERGY LABEL **Which of the following most aligns with how you feel about the label?** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
This label feels like it is providing a warning	20%	19%
This label feels like it is providing information	80%	81%

PROPOSED GROWTH ENERGY LABEL **Based on what you see, can you put this type of fuel in your car?** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Yes	81%	84%
No	19%	16%

PROPOSED GROWTH ENERGY LABEL **Based on what you see, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	31%	33%
Somewhat comfortable	39%	40%
Somewhat uncomfortable	18%	17%
Very uncomfortable	12%	10%

PROPOSED GROWTH ENERGY LABEL **Based on what you see, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very likely	28%	30%
Somewhat likely	40%	40%
Somewhat unlikely	19%	19%
Very unlikely	13%	11%

PROPOSED GROWTH ENERGY LABEL
Does this label make you feel like this fuel is good or bad for each of the following?
(Showing % Selected)

Total (n=1000)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	22%	23%	22%	27%	21%
Somewhat good	57%	55%	58%	53%	57%
Somewhat bad	17%	18%	16%	15%	17%
Very bad	4%	4%	4%	4%	4%
E15 Eligible (n=841)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**

Very good	22%	23%	22%	29%	22%
Somewhat good	58%	55%	58%	53%	57%
Somewhat bad	16%	18%	16%	15%	17%
Very bad	3%	4%	4%	4%	4%

PROPOSED GROWTH ENERGY LABEL **Based on what you see, please select all of the following vehicles this fuel may be used in.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
2001 Sedan	80%	80%
2009 flex fuel SUV	84%	85%
2008 pick-up truck	70%	70%
1999 SUV	3%	3%
All of these	5%	5%
None of these	3%	2%

Out of all of the labels you've seen, which one makes you the most comfortable about putting the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did. (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Current EPA Label	18%	17%

Proposed EPA Label #1	35%	36%
Proposed EPA Label #2	9%	9%
Proposed Growth Energy Label	38%	38%

Out of all of the labels you've seen, which one makes you the least comfortable about putting the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did. (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Current EPA Label	58%	59%
Proposed EPA Label #1	12%	12%
Proposed EPA Label #2	10%	10%
Proposed Growth Energy Label	19%	19%

Between these two labels, which one makes you the most comfortable about putting the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did. (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Current EPA Label	27%	28%
Proposed Growth Energy Label	73%	72%

BLACK AND WHITE BLANK LABEL **Based on the color alone, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	21%	22%
Somewhat comfortable	45%	45%
Somewhat uncomfortable	25%	24%
Very uncomfortable	9%	8%

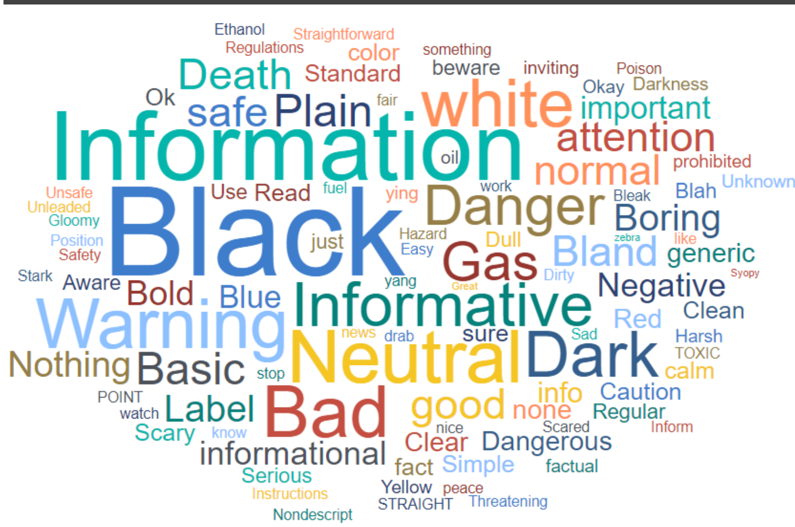
BLACK AND WHITE BLANK LABEL **Based on the color alone, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	22%	23%
Somewhat comfortable	44%	45%
Somewhat uncomfortable	25%	24%
Very uncomfortable	9%	9%

BLACK AND WHITE BLANK LABEL **Based on the color alone, do you feel like this fuel would be good or bad for each of the following?** (Showing % Selected)		

Total (n=1000)	Engine burning cleaner	Engine performance	Mileage per gallon	Impact on environment	Condition of engine
Very good	15%	17%	17%	16%	17%
Somewhat good	49%	48%	48%	45%	47%
Somewhat bad	30%	29%	28%	30%	30%
Very bad	7%	6%	6%	8%	7%

E15 Eligible (n=841)	Engine burning cleaner	Engine performance	Mileage per gallon	Impact on environment	Condition of engine
Very good	15%	17%	18%	16%	17%
Somewhat good	50%	49%	49%	46%	47%
Somewhat bad	29%	28%	28%	29%	29%
Very bad	6%	6%	6%	8%	6%

BLACK AND WHITE BLANK LABEL
What word do you associate with this color? (OPEN END)
(Showing Total)



ORANGE BLANK LABEL **Based on the color alone, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	15%	16%
Somewhat comfortable	34%	35%
Somewhat uncomfortable	37%	38%
Very uncomfortable	13%	12%

ORANGE BLANK LABEL **Based on the color alone, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very likely	16%	16%
Somewhat likely	35%	36%
Somewhat unlikely	36%	35%
Very unlikely	13%	13%

ORANGE BLANK LABEL
Based on the color alone, do you feel like this fuel would be good or bad for each of the following?
(Showing % Selected)

Total (n=1000)	Engine burning cleaner	Engine performance	Mileage per gallon	Impact on environment	Condition of engine
Very good	13%	14%	14%	14%	13%
Somewhat good	40%	39%	39%	37%	39%
Somewhat bad	39%	39%	38%	39%	39%
Very bad	9%	9%	9%	11%	9%
E15 Eligible (n=841)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	14%	14%	15%	15%	14%
Somewhat good	39%	39%	39%	37%	39%
Somewhat bad	39%	39%	38%	38%	39%
Very bad	8%	8%	8%	10%	8%

ORANGE BLANK LABEL
What word do you associate with this color? (OPEN END)
(Showing Total)

BLUE BLANK LABEL **Based on the color alone, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	38%	39%
Somewhat comfortable	48%	49%
Somewhat uncomfortable	9%	8%
Very uncomfortable	4%	4%

BLUE BLANK LABEL **Based on the color alone, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very likely	36%	38%
Somewhat likely	49%	49%
Somewhat unlikely	10%	9%
Very unlikely	5%	4%

BLUE BLANK LABEL
Based on the color alone, do you feel like this fuel would be good or bad for each of the following?
(Showing % Selected)

Total (n=1000)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	26%	26%	26%	29%	25%
Somewhat good	60%	60%	61%	55%	62%
Somewhat bad	11%	11%	10%	12%	11%
Very bad	2%	3%	3%	4%	2%

E15 Eligible (n=841)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	26%	26%	26%	29%	24%
Somewhat good	61%	61%	63%	57%	63%
Somewhat bad	10%	10%	9%	10%	10%
Very bad	2%	2%	2%	4%	2%

BLUE BLANK LABEL
What word do you associate with this color? (OPEN END)
(Showing Total)

YELLOW BLANK LABEL **Based on the color alone, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	19%	19%
Somewhat comfortable	42%	43%
Somewhat uncomfortable	32%	31%
Very uncomfortable	8%	7%

YELLOW BLANK LABEL **Based on the color alone, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very likely	19%	19%
Somewhat likely	41%	42%
Somewhat unlikely	32%	31%
Very unlikely	8%	7%

YELLOW BLANK LABEL
Based on the color alone, do you feel like this fuel would be good or bad for each of the following?
(Showing % Selected)

Total (n=1000)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	16%	16%	17%	16%	15%
Somewhat good	46%	47%	48%	45%	47%
Somewhat bad	32%	32%	31%	32%	32%
Very bad	6%	5%	5%	7%	5%
E15 Eligible (n=841)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**

Very good	16%	17%	18%	16%	16%
Somewhat good	47%	48%	48%	47%	48%
Somewhat bad	32%	31%	30%	31%	31%
Very bad	5%	4%	4%	6%	5%

YELLOW BLANK LABEL
What word do you associate with this color? (OPEN END)
(Showing Total)

What type of car do you drive most often? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Compact Car (e.g. Ford Focus)	12%	12%
Regular Sedan (e.g. Honda Accord)	31%	31%
Truck (e.g. Chevrolet Tahoe)	8%	8%

Minivan (e.g. Toyota Sienna)	5%	5%
SUV (e.g. Ford Explorer)	30%	32%
Luxury Sedan (e.g. Mercedes Benz S-Series)	8%	9%
Sports Car (e.g. Chevrolet Corvette)	3%	3%
Prefer not to answer	2%	1%

Is the vehicle you drive most often a flex fuel vehicle? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Yes	23%	24%
No	61%	60%
Unsure	16%	15%

Approximately, what year was your primary vehicle manufactured? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
2010-2022	66%	70%
2001-2009	29%	30%
1990-2000	4%	1%
Older than 1990	1%	0%

How often do you generally fill up your car(s) with gas? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Less than once per month	5%	4%
Once per month	14%	14%
Twice per month	27%	29%
Three times per month	13%	13%
Once per week	26%	27%
Twice per week	9%	8%
Three times per week	3%	3%
More than three times per week	1%	1%
Prefer not to answer	1%	0%

How far do you estimate you drive per day? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Less than 10 miles per day	30%	29%
Between 10 and 20 miles per day	32%	33%
Between 20 and 30 miles per day	18%	18%
Between 30 and 40 miles per day	8%	9%
Between 40 and 50 miles per day	5%	5%

More than 50 miles per day	6%	6%
Prefer not to answer	1%	1%

Do you own, lease, or rent your car(s)? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
I own my car(s)	89%	89%
I lease my car(s)	10%	10%
I rent my car(s)	2%	2%
Prefer not to answer	1%	1%

How much attention do you pay toward each of the following? (Showing % Selected)			
Total (n=1000)	**The gasoline you put in your car**	**How clean burning your car engine is**	**The performance of your car engine**
A lot	49%	28%	47%
Some	39%	39%	39%
Not a lot	10%	25%	10%
None	2%	8%	4%
E15 Eligible (n=841)	**The gasoline you put in your car**	**How clean burning your car engine is**	**The performance of your car engine**

A lot	48%	29%	48%
Some	40%	40%	39%
Not a lot	10%	24%	10%
None	2%	7%	4%

Which type of fuel do you most frequently put in your car? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Regular or unleaded	69%	68%
Mid Grade	6%	6%
Premium	16%	16%
E15	2%	3%
E85	2%	2%
Diesel	4%	4%
Other:	1%	1%

What is your current marital status? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Single/Never married	36%	31%
Married	48%	53%
Widowed	3%	3%

Divorced	11%	11%
Separated	2%	1%
Prefer not to answer	1%	1%

Do you have children? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Yes	52%	56%
No	47%	43%
Prefer not to answer	0%	0%

Attachment 2

E15 and Infrastructure

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Produced under direction of Renewable Fuels Association by the National Renewable Energy Laboratory (NREL) under Technical Services Agreement No. TSA 14-665 and Task No. WTJZ.1000.

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Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

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Strategic Partnership Project Report
NREL/TP-5400-64156
May 2015

Contract No. DE-AC36-08GO28308

E15 and Infrastructure

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Prepared under Task No. WTJZ.1000

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List of Acronyms

AHJ	authority having jurisdiction
CARB	California Air Resources Board
CFR	Code of Federal Regulations
E0	pure gasoline
E10	10% denatured ethanol; 90% gasoline blendstock
E100	pure ethanol fuel
E15	15% denatured ethanol, 85% gasoline blendstock
E25	25% denatured ethanol, 75% gasoline blendstock
E85	marketing term for high-blend ethanol 51%–83%
EPA	U.S. Environmental Protection Agency
FDEQ	Florida Department of Environmental Quality
NACS	National Association of Convenience Store Owners
NREL	National Renewable Energy Laboratory
OSHA	Occupational Safety and Health Administration
OUST	Office of Underground Storage Tanks
PEI	Petroleum Equipment Institute
psi	pounds per square inch
RFA	Renewable Fuels Association
STI	Steel Tank Institute
STP	submersible turbine pump
UL	Underwriters Laboratories
ULSD	ultra-low sulfur diesel
UST	underground storage tank
vol%	percent by volume

Executive Summary

This paper addresses the compatibility of E15 (15% denatured ethanol, 85% gasoline blendstock) with equipment at refueling stations. Over the last decade, a tremendous amount of work by refueling equipment manufacturers, industry groups, and federal agencies has resulted in a long list of equipment that can be used with E15. This report addresses compatibility through a literature review, a summary of applicable codes and standards, review of equipment manufacturer products, and verification with manufacturers regarding which ethanol blends work with their products. Over time, the refueling equipment manufacturers have improved their sealing materials for compatibility with a wide range of fuels. Upgrading materials in equipment improves consumer safety and reduces the risk of releases to the environment.

It is often stated that tanks cannot be used to store E15, but this assumption is incorrect as the majority of installed tanks can store blends above E10. For many decades, underground storage tank (UST) manufacturers approved their tanks for blends up to E100, for example, all steel tanks and double-walled fiberglass tanks since the year 1990. Manufacturers of pipe thread sealants (pipe dope) used in UST systems have stated that their products have been compatible with ethanol blends up to E20 for many years. For those tanks with low ethanol blend certifications, the U.S. Environmental Protection Agency's (EPA's) Office of Underground Storage Tanks (OUST) issued *Guidance – Compatibility of UST Systems with Biofuels Blends* in 2011 to enable alternative compliance with federal code as UST systems are in use for decades. This guidance allowed tank manufacturers to issue letters stating the compatibility of their tanks with specific ethanol blends. All existing tank manufacturers have issued such letters, and the majority of installed tanks are compatible with E15. Additionally, all existing pipe manufacturers have Underwriters Laboratories (UL) listing for E100.

All fuel and vapor handling equipment at a station was reviewed to determine if it was certified by a third-party (such as UL) and if it was listed for specific ethanol blends. The aggregated list confirms there are UL testing standards available now for all gasoline–ethanol blends from 0% to 85% ethanol. Stations comprise approximately 60 pieces of equipment designed to move and control fuel and vapors. The function of most equipment is to prevent, detect, and contain releases. The equipment includes tanks; pipes; dispensers and associated hanging hardware (breakaway, hose, nozzle, and swivel); fill equipment; leak detection; overfill prevention; and vapor equipment. Some of this equipment is specifically covered by codes and standards while other equipment relies on sound design and manufacturing. Certain equipment types are typically UL listed—these include tanks, pipes, dispenser, hanging hardware, submersible turbine pumps, and shear valves. UL listing is not a requirement; some manufacturers simply prefer to have UL listings for their products. Manufacturers will select, which, if any, models they will list for ethanol blends above E10. A review was conducted with each manufacturer to determine compatibility with ethanol blends. There is an extensive list of E15 and E15+ compatible equipment available in the appendices.

A literature review going back 15 years was conducted to determine if there were any negative impacts during the multi-year deployment of E10 nationwide. No incidents of E10 causing releases (also referred to as leaks) from UST systems were identified. None of the reviewed literature noted any association between E10 and any specific UST release. The EPA OUST's Performance Measures' data on UST releases were reviewed, and as E10 was deployed

nationwide, the trend was fewer UST releases. Anecdotal input solicited from infrastructure industry experts said that they knew of no published reports of releases caused by E10.

There are future opportunities for retailers to remove or replace their current equipment not necessarily related to continuous changes in motor fuel composition. Credit card companies are requiring retail fueling stations to update their dispensers to accept new chip and PIN secure credit cards by October 2017, at which time fraud liability would switch to station owners if they have not updated their equipment. This presents an opportunity to increase E25 UL-listed equipment through a retrofit kit if electronics are being upgraded to accommodate the new credit cards, or if a station owner must purchase a new dispenser, it could pay a minimal amount more for an E25 dispenser. If a new dispenser is purchased, this may also present an opportunity to upgrade to an E85 dispenser, but at significant additional cost.

Table of Contents

List of Figures

List of Tables

1 Background

1.1 E15 Background

In 2011, the U.S. Environmental Protection Agency (EPA) approved E15 for use in conventional light-duty cars and trucks model year 2001 and newer.[1] As of the end of 2014, 65% of the registered gasoline vehicles are 2001 and newer.[2] EPA approved the Clean Air Act waiver based on significant testing and research (McCormick et al. 2013). EPA defines E15 as ethanol blends greater than 10 volume percent (vol%) and up to 15 vol% ethanol. E15 is not widely available largely due to misinformation and retailer concerns. The primary concerns retailers have expressed include additional federal and state regulations to sell E15, misfueling liability, and the inability to meet the EPA's vapor pressure requirement for E15 in the summer.

Regulations to sell E15: There are several federal government requirements for selling E15 that do not apply to other fuel sold at stations. Federal regulations for a station to sell E15 include: an EPA E15 label on each dispenser selling E15, implementation of a misfueling mitigation plan,[3] participation in a fuel quality survey (ensures dispenser is labeled and measures ethanol content and vapor pressure), product transfer documents for all deliveries of fuel for E15 use, and an approved dispenser/hose configuration.[4] All requirements for E15 are available in the Renewable Fuels Association's (RFA's) *E15 Retailer Handbook*.[5]

Exposure to liability: Some stations owners have expressed concerns about misfueling of E15 into older vehicles. It is not uncommon for a consumer to be unaware of the model year of their vehicle. Under the Clean Air Act, any entity in the transportation fuel supply chain, including refueling stations, could be fined by the EPA up to $37,500 per day for violations. The EPA has never fined a station this amount, and it has the authority under code to reduce the fine based on business size.

Vapor pressure: Blending of ethanol in to gasoline in the 10 to 15 vol% range typically causes the vapor pressure to increase by 1 pound per square inch (psi).[6] The EPA regulates gasoline vapor pressure from June 1 to September 15 to reduce evaporative fuel emissions. In 1992, E10 received a 1-psi waiver, commonly known as the 1-pound waiver, from these requirements for non-reformulated gasoline areas. For purposes of the 1-pound waiver, E10 blends are defined as containing 9 to 10 vol% ethanol. The E10 1-pound waiver code is included in the Code of Federal Regulations which states that the waiver is for E10 only and not any other ethanol blend.

[1] E15 Notices & Regulations. EPA. http://www.epa.gov/otaq/regs/fuels/additive/e15/e15-regs.htm
[2] Polk data 2014. Based on a total U.S. gasoline light-duty vehicle registration of 228 million of which 149 million are model year 2001 and newer.
[3] RFA developed *Renewable Fuels Association Model E15 Misfueling Mitigation Plan*, which was approved by EPA in March 2012 and is available free of cost to stations selling E15. http://www.epa.gov/otaq/regs/fuels/additive/e15/documents/rfa-model-e15-misfueling-mitigation-plan.pdf
[4] For hose configurations, please review the EPA-approved *Addendum: E15 Retail Advisory (updated 1/2013)*. Last accessed March 10, 2015: http://www.epa.gov/otaq/regs/fuels/additive/e15/documents/rfa-e15-retail-advisory-addendum.pdf
[5] *E15 Retailer Handbook*. RFA. Accessed March 10, 2015: http://ethanolrfa.3cdn.net/643f311e9180a7b1a8_wwm6iuulj.pdf
[6] Vapor pressure is a method to measure the volatility of gasoline. Formerly known as Reid vapor pressure or RVP, today it is technically dry vapor pressure equivalent (DVPE) and is measured using ASTM Method D5191.

E15 is not afforded the same 1-pound waiver and therefore cannot be sold in non-reformulated gasoline areas in summer months unless a lower vapor pressure hydrocarbon blendstock is used.[7]

1.2 Station Data

Overall, the total number of retail stations has declined over time, but approximately 1,600 new stations open annually (AFDC 2015, NACS 2014a). The following statistics from the National Association of Convenience Store Owners (NACS) *2015 Retail Fuels Report* show some of the challenges in reaching various types of station owner and their ability to afford equipment upgrades and installations (NACS 2015):

- There are approximately 153,000 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.
- Convenience stores sell 80% of transportation fuels. Hypermarkets (large grocery chains or merchandise stores) sell 14%. The remainder of fuel is sold at low-volume locations like marinas.
- 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.
- The average profit per convenience stores in 2013 was $55,000 with most profit coming from selling products in the store.

One of the challenges in introducing E15 is reaching all the single-station owners. As evidenced in Figure 1, after single-store owners, the next highest percentage of ownership—17%—is ownership groups with more than 500 stations.

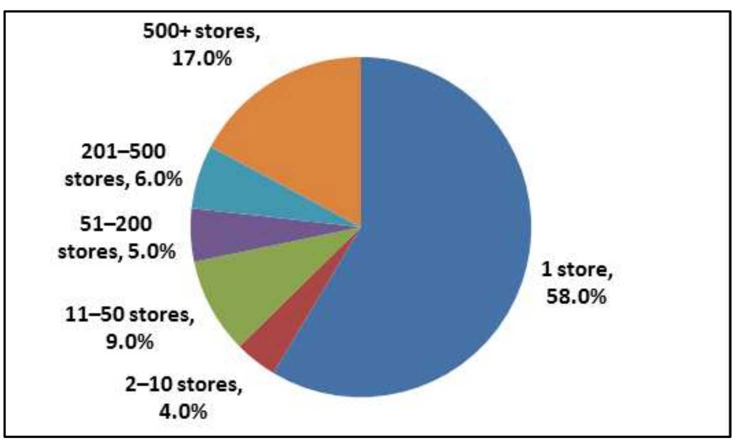

Figure 1. Breakout of station ownership

Source: *2015 Retail Fuels Report.* NACS, 2015

[7] CFR 42 Chapter 85 Subchapter II Part A 7545 Regulation of Fuels (h) (4)

Approximately 50% of convenience stores are branded by either an oil company (31%) or refinery/distributor (19%) (NACS 2014b). This ensures a market for oil and refinery company products and provides station owners with brand recognition. A contract typically lasts 10 years, and the terms will include sales volume requirements for fuels supplied, including regular and premium, and diesel if the station sells it. Due to sales volume requirements, there will be more challenges for branded stations to sell E15 than independent stations or convenience store chains.

2 Regulations, Codes, and Certifications

In addition to the EPA requirements summarized in Section 1.1, E15 is subject to other regulations and codes that apply to other transportation fuels. There is no one entity that regulates all equipment at a station. Often times, the local authority having jurisdiction (AHJ) approves a station to sell a new fuel. “AHJ” refers to regulating organizations, offices, or individuals responsible for overseeing codes and standards and ensuring safety. Examples of AHJs include local fire marshals, state energy and environment offices, air and water boards, and similar organizations or offices. The most significant federal agencies overseeing some equipment at stations include EPA’s Office of Underground Storage Tanks (OUST) and the Occupational Safety and Health Administration (OSHA). The Underwriters Laboratories (UL) role is significant in developing testing protocols and certifying refueling equipment for specific fuels.

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

2.1 EPA Office of Underground Storage Tanks

EPA’s OUST regulates tanks that store transportation fuels under Subtitle I of the Solid Waste Disposal Act states that a tank system must be compatible with the fuel stored. This code is currently under revision with a final rule expected in 2015. States administer the underground storage tank (UST) program, and compatibility is the responsibility of the tank owner.

The following critical components must be demonstrated as in 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.

Title 40 of the Code of Federal Regulations (CFR) Part 280–Technical Standards and Corrective Action for Owners and Operators of Underground Storage Tanks (UST), covers design, construction, and installation; operating requirements; release detection; release reporting; corrective action for releases; UST out-of-service and closures; financial responsibility (ability to cover the costs to clean up a release); and lender liability. It requires that tanks and piping be constructed, installed, and any portion that is underground and routinely contains product be protected from corrosion in accordance with a code of practice developed by a nationally recognized association or independent testing laboratory. It also requires that the UST be made of or lined with materials compatible with the regulated substance stored. There are requirements to have equipment installed to prevent releases, including the use of spill containment and overfill prevention equipment. There are also requirements to have equipment capable of detecting releases of regulated substances from the portions of the UST that routinely contain product. Since 1986, UST owners must submit documentation that a new tank has been installed along with certification of installation and keep maintenance records. UST owners must report all suspected and confirmed releases, generally within seven days.

40 CFR Part 281–Approval of State Underground Storage Tank Programs, and Part 282–Approved Underground Storage Tank Programs, explain the requirements to authorize states to administer UST federal code under Subtitle I of the Resource Conservation and Recovery Act. 40 CFR Part 302 Designation, Reportable Quantities, and Notification, defines hazardous subjects stored in USTs (includes gasoline, ethanol, and many other chemicals), releases, and penalties.

In 2011, OUST released the *Guidance – Compatibility of UST Systems with Biofuels Blends* 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). OUST believes that while most biofuel 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. This guidance is expected to be published in the CFR in 2015 after the Office of Management and Budget approves it. Incorporating this guidance into the CFR gives refueling station owners an added layer of security as it ensures their tank insurance is uncompromised, which is also an important factor in their ability to maintain a line of credit with their financial institution.

2.2 Underwriters Laboratories

UL is the primary third-party certification laboratory servicing the refueling equipment industry globally. UL develops testing standards by consensus and allows manufacturers time to comply.[9] These standards have been available for many decades in the marketplace. There are many standards covering individual products in the fueling system and many different approaches to evaluating safety. The more recent standards address higher levels of ethanol and the introduction of biodiesel. Some standards comprehensively evaluate structural integrity, material compatibility, operating performance, and electrical safety while others may limit evaluations to specific items. In the past, some standards that provided listings for specific fuels were limited to petroleum products, but were then revised to handle low levels of ethanol blends. Over time, many UL standards provided the option for equipment manufacturers to list their products for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85). While some UL standards allow manufacturers to select which fuel ratings to list for, there is trend towards revising standards to require equipment to be listed for all fuel types and blends that are commercially available. Testing is not conducted with commercial fuels. The trend is towards aggressive test fluids where gasoline is represented by Reference Fuel C (equal parts iso-octane and toluene) and it is mixed with ethanol, acid, and water. Table 1 summarizes the relevant refueling equipment UL standards. Information on applicable UL standards for each piece of refueling equipment at a station is described in Section 4. Table 1 confirms that there are UL testing standards available now for all gasoline–ethanol blends from 0% to 85% ethanol content.

[8] Communicated by EPA OUST staff during a December 2013 call with National Renewable Energy Laboratory and Oak Ridge National Laboratory staff.
[9] The terms "UL listed" and "UL certified" can be used interchangeably.

Table 1. 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	E100 (non-aggressive test fluids)
UL 971	Pipes and pipe fittings	E100 (non-aggressive test fluids)
UL 2447	*Sumps:* tank, dispenser, transition, fill/vent (spill buckets) *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 and E85. Manufacturers must recertify by June 2016.
UL 2583	*Part I Vapor Control Products:* emergency vents, pressure vacuum vents, fill and vapor adaptors, and monitor well caps *Part II Liquid Control Products:* overfill protection (or prevention) valves, ball float vent valve (or flow restriction device), drop tubes, extractor tee, jack screw kit, face seal adaptor (or threaded riser adaptor), fill cap and adaptors	Part I and Part II require testing with aggressive E25, E85, B25, and Reference Fuel F.
UL 87	Power-operated dispensing devices for petroleum products	E10 (non-aggressive test fluid)
UL 87A	Power-operated dispensing devices for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 25	Meters for flammable and combustible liquids and LP-gas	E10 (non-aggressive test fluid)
UL 25A	Meters for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 79	Power-operated pumps for petroleum dispensing products	E10 (non-aggressive test fluid)
UL 79A	Power-operated pumps for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 330	Hose and hose assemblies for dispensing flammable liquids	E10 (non-aggressive test fluid)
UL 330A	Outline for hose and hose assemblies for use with dispensing devices dispensing gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 331	Strainers for flammable fluids and anhydrous ammonia	E10 (non-aggressive test fluid)

UL Testing Standard	Equipment Covered	Listing for Ethanol Blends
UL 331A	Strainers for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 428	Electrically operated valves	E10 (non-aggressive test fluid)
UL 428A	Outline for electrically operated valves for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 567	Emergency breakaway fittings, swivel connectors and pipe-connection fittings for petroleum products and LP-gas	E10 (non-aggressive test fluid)
UL 567A	Emergency breakaway fittings, swivel connectors and pipe-connection fittings for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 842	Valves for flammable fluids	E10 (non-aggressive test fluid)
UL 842A	Valves for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 - E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 2586	Hose nozzle valves	E10 (non-aggressive test fluid)
UL 2586A	Hose nozzle valves for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)

Source: UL

2.2.1 UL Standards Summary

UL 1316, Glass-Fiber-Reinforced Plastic Underground Storage Tanks for Petroleum Products, Alcohols, and Alcohol-Gasoline Mixtures

This standard covers underground fiberglass tanks and allows manufacturers to select in which of three fuel ratings to have their product listed. Essentially it is an “a la carte” menu. Both existing fiberglass tank manufacturers have UL listing for E100.

The test fluids used to evaluate compatibility for the three fuel ratings are:

1. Petroleum products: includes but is not limited to: regular and premium gasoline, diesel fuel, fuel oil, Reference Fuel C, kerosene, and fuel oil #6 (option at elevated temperature)
2. Alcohol and petroleum blends: includes fuel #1 plus E10 and E30. (This allows listing for E10 but not E30 despite testing with it.)
3. Alcohol and petroleum blends: includes #1 and #2 test fluids plus E15, E50, E100, and methanol blends at the same volumes.

UL 58, Standard for Steel Underground Tanks for Flammable and Combustible Liquids

This standard covers underground steel tanks. It does not test or certify equipment for specific fuels but instead for flammable and combustible liquids. All existing U.S. steel tank manufacturers have UL listing under this standard.

UL 1746, External Corrosion Protection Systems for Steel Underground Storage Tanks

This standard provides certification for external corrosion protection systems applied to UL 58 steel tanks. There are four parts, and parts i (galvanic-type cathodic protection systems), ii (fiber-reinforced plastic composite systems), and iv (polyurethane-coated systems) do not test with specific fuels; listing is for flammable and combustible liquids. Part iii (polyurethane, polyurea, high density polyethylene, or fiber-reinforced plastic jacketed systems) provides ethanol listing only for jacket tanks with secondary containment because there is an interstitial space formed by the jacket. The test requires 30 days of exposure to test fluid and includes the same testing fluids as UL 1316.

UL 1856, Underground Fuel Tank Internal Retrofit Systems

This standard allows a station owner to retrofit the existing tank onsite in three ways, all of which require the tank's internal surface to be refurbished prior to applying nonmetallic coatings with new fuel ratings. In the past, this standard allowed manufacturers to select which class of fuels to list for, the same as UL 1316. However, UL 1856 has recently been revised to require compliance with all automotive fluids, including E25 and E85, by June 14, 2017.

UL 142, Aboveground Flammable Liquid Tanks

This standard covers aboveground tanks, which are not very common at commercial fueling stations. It does not test or certify equipment for specific fuels but instead for flammable and combustible liquids. UL Standards 2080 and 2085 also apply to aboveground tanks for fire protection, as they require use of a UL 142 core tank.

UL 971, Standard for Nonmetallic Underground Piping For Flammable Liquids, and UL 971A, Outline of Investigation for Metallic Underground Piping for Flammable Liquids

This standard covers flexible and rigid piping and pipe fittings for both fuel and vapor. This standard has similar fuel ratings and uses similar test fluids as UL 1316. All existing pipe manufacturers have UL listing for E100.

UL 2039, Outline of Investigation for Flexible Connector Piping for Fuels

This standard covers flexible connectors that typically connect underground piping to other equipment in sumps. In the past, this standard offered the same selection of test fluids as UL 1316. The standard was updated in December 2010 to require all automotive fluids, including E25 and E85.

UL 2447, Containment Sumps, Fittings and Accessories for Fuels

This standard covers containment sumps (dispenser, tank, transition, spill buckets) and all the fittings (termination, penetration, test/monitor, internal) and accessories (frames, brackets, chase, etc.). This standard previously and currently allows manufacturers to select test fluids from the same three classes as UL 1316. However, the standard has been updated, and manufacturers will need to demonstrate compliance with the standard and listing for all automotive fuels, including E25 and E85, by June 30 2016 (originally the date was June 30, 2015, but manufacturers asked for an extension). Some manufacturers list under this standard and others do not.

UL 2583, Outline for Investigation for Fuel Tank Accessories

This new standard covers equipment that may have been listed under other, older standards and also covers equipment that has never previously been listed by UL. Few manufacturers listed products under the old standards. This new standard requires manufacturers to list all automotive fuels, including E25 and E85. Part I was issued in June 2011 to cover all vapor control products—any functional device on tank top or directly fitting on or indirectly connected to a pipe to control vapors. Equipment covered includes emergency vents, pressure vacuum vents, fill and vapor adaptors, and monitor well caps. Part II was issued in June 2014 and covers liquid control products; specifically functional equipment designed to connect to tank top and to contain spills and prevent overfills. This covers overfill protection (or prevention) valves, ball float vent valves (or flow restriction devices), drop tubes (never previously listed by UL), extractor tees, jack screw kits, face seal adaptors (or threaded riser adaptors), fill caps, and adaptors.

UL 87, Power-Operated Dispensing Devices for Petroleum Products, and UL 87A, Standard for Power-Operated Dispensing Devices for Gasoline and Gasoline/Ethanol Blends with Nominal Ethanol Concentrations up to 85 Percent (E0 – E85)

UL 87 allows listing for up to E10 with minimal exposure to test fluids. In 2007, UL introduced UL 87A, Outline of Investigation for Power-Operated Dispensing Devices for Gasoline/Ethanol Blends with Ethanol Content Greater than 15 Percent to address E85. At the time, UL 87A covered additional testing for multiple pieces of related equipment. These standards work somewhat differently than those for tanks, pipes, and associated tank equipment. A manufacturer can select UL 87 for listing a product up to E10 or UL 87A to list a product for up to just E25 or opt to test and list it for E85 also. Since development of UL 87A in November 2012, equipment has been split out into different standards specific to each equipment type. (The designation "A" after a listing denotes the option to list a product for up to just E25 and/or E85).

- Breakaways, swivels, pipe connection fittings: 567/567A
- Dispensers: 87/87A
- Filters: 331/331A
- Hoses: 330/300A
- Meters: 25/25A
- Nozzles: 2586/2586A

- Shear valve (emergency shut-off valve): 842/842A
- Submersible turbine pump: 428/428A

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 to address new fuels in the marketplace.

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

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

2.4 State Regulations

2.4.1 California Air Resources Board

The California Air Resources Board (CARB) is the division of the California Environmental Protection Agency tasked with reducing air pollutants. CARB developed test procedures for vapor recovery equipment and requires specialized enhanced vapor recovery equipment. The following equipment must be approved under this program: adaptors, drop tubes, hoses, nozzles, overfill protection devices, pressure vacuum vents, spill containers, and vapor return piping (CARB 2015). The requirements are not for equipment use with specific fuels.

2.4.2 Florida Department of Environmental Quality

The Florida Department of Environmental Quality (FDEQ) approves station storage tank equipment through state regulations (FDEQ 2015). The regulations require State of Florida approval of tank system equipment prior to installation or use, except for the following equipment: dispensers, islands, nozzles, hoses; monitoring well equipment; manhole and fillbox covers; valves; cathodic protection stations; metallic bulk product piping; small-diameter piping not in contact with soil unless the piping extends over or into surface waters; and vent lines. All other equipment must be approved through a third-party laboratory demonstration that provides a technical evalution of the equipment, test results verifying equipment functions as designed, and a professional certification that the equipment meets Florida performance standards (FDEQ 2015). The performance standards are straightforward and are not fuel specific. The State of Florida has a long list of approved equipment (FDEQ 2015).

3 Literature Review

A literature review was performed to identify specific components or materials that have been associated with releases from USTs storing E10. The information is intended to be used to minimize the potential for future releases, particularly during the rollout of E15. The literature review was limited to releases identified during the years 2000 to the present. During the years covered by this literature review, the penetration of E10 into the U.S. gasoline pool went from minimal in many regions of the country to full saturation.

Scope of Review

The following sources were used:

- LUSTLine 2000 – present.
- *PEI Journal* 2009 – present (PEI Journal not available online before 2009).
- *TulsaLetter* (The *TulsaLetter* is the official e-newletter of PEI.) 2000 – present.
- Experts in refueling infrastructure were contacted, including EPA, Fiberglass Tank and Pipe Institute, PEI, STI, and oil industry representatives.
- EPA OUST release data website.
- Web search for literature and data on UST E10 releases.

Major Findings

- The number of reported UST releases has been steadily declining since 2000 from occurring in about 2% of all USTs in the United States to about 1% in 2014 (EPA 2015a).
- There is no evidence of different trends in the number of UST releases between states that were early adopters of E10 and states that only recently reached full saturation of E10.
- EPA has collected data on the source and cause of UST releases. Because of the high number of releases that were attributed to "unknown" or "other causes," the data cannot be considered conclusive, but roughly 10% of all releases were attributed to corrosion in a 2004 review and 7% in 2009 (EPA 2004, Eigmey 2011).
- Anecdotal input solicited from infrastructure industry experts said that they knew of no published reports of releases caused by E10.
- None of the reviewed literature listed any association between E10 and any specific UST release.

Figure 2 shows the number of USTs declining over time which is a result of the declining number of retail stations. There were approximately 571,000 registered USTs in the United States as of September 2014 (EPA 2015a).[10] OUST provides UST release data annually, and over the time that E10 spread across the country, the number of releases has tended to decline from 2% of registered tanks in 2000 to 1.2% of USTs experiencing a release in 2014. Figure 3

[10] A year is measured by the federal government's fiscal year from October 1 to September 30.

shows that as E10 was deployed over the last several years, the number of UST releases did not increase. Any problems associated with introducing a different fuel at an existing station usually happen soon after storing a different fuel. In interpreting these results, it should be noted that many releases are discovered and reported years after they first occurred when the tank is removed from service. Other releases are due to operator errors (such as overfilling or poor maintenance) and may be completely unrelated to the fuel stored.

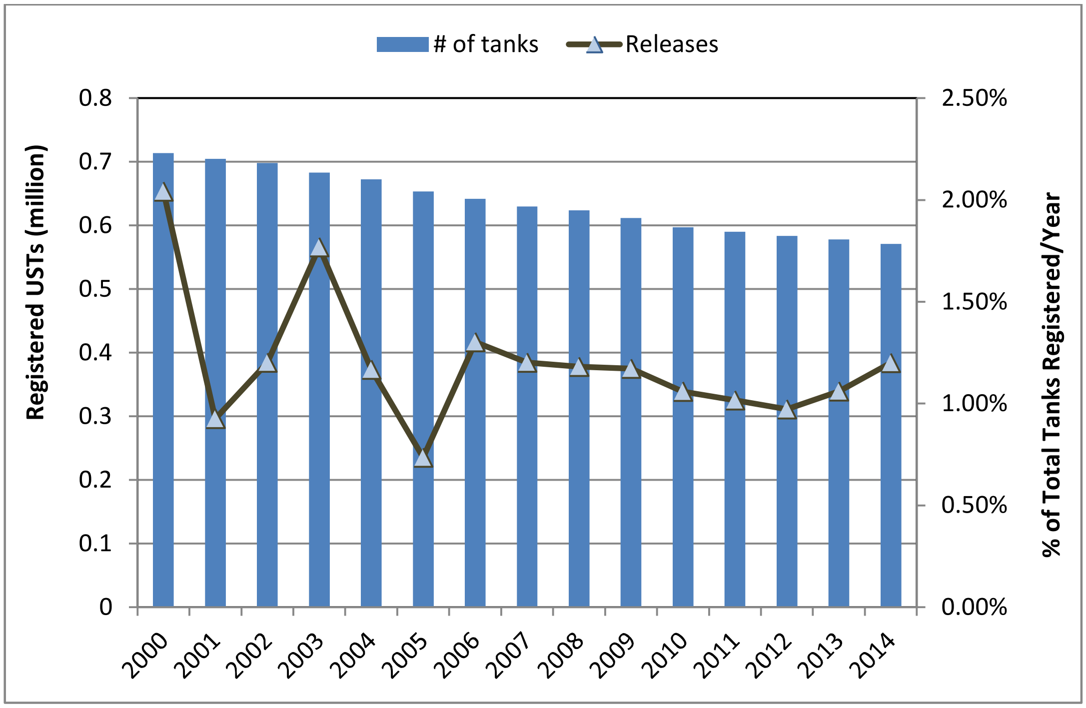

Figure 2. Registered USTs and releases

Source: UST Performance Measures. EPA OUST. Last accessed March 10, 2015: http://www.epa.gov/oust/cat/camarchv.htm

The Energy Policy Act of 2005 included a requirement for UST release reports to include a source and cause. A LUSTLine report analyzed 2009 data reports from 47 states reviewing 5,168 UST releases (Eighmey 2011). While the data point to some areas where leaks are common and uncommon, approximately one-third of leaks were listed as other or unknown. Some releases occur no matter what fuel is being delivered or stored. These releases include physical/ mechanical damage (14.9%), overfills (4.8%), spills (3.8%), and installation problems (1.0%). Transportation fuels can cause corrosion, and this study found corrosion caused 7.5% of releases. The topic of STP corrosion comes up as an issue, but a small scoping study performed for RFA found that STPs were not failing. This 2009 report shows the STP as the source of a release in just one of 5,168 incidents. The EPA reviewed 608 UST releases in 2004 and found causes of release were physical/mechanical (39.8%), other/unknown (27.0%), spill/overfill (26.6%), and installation (3.1%) (EPA 2004). Table 2 summarizes 2009 data for cause and source with detailed data available in Appendix A.

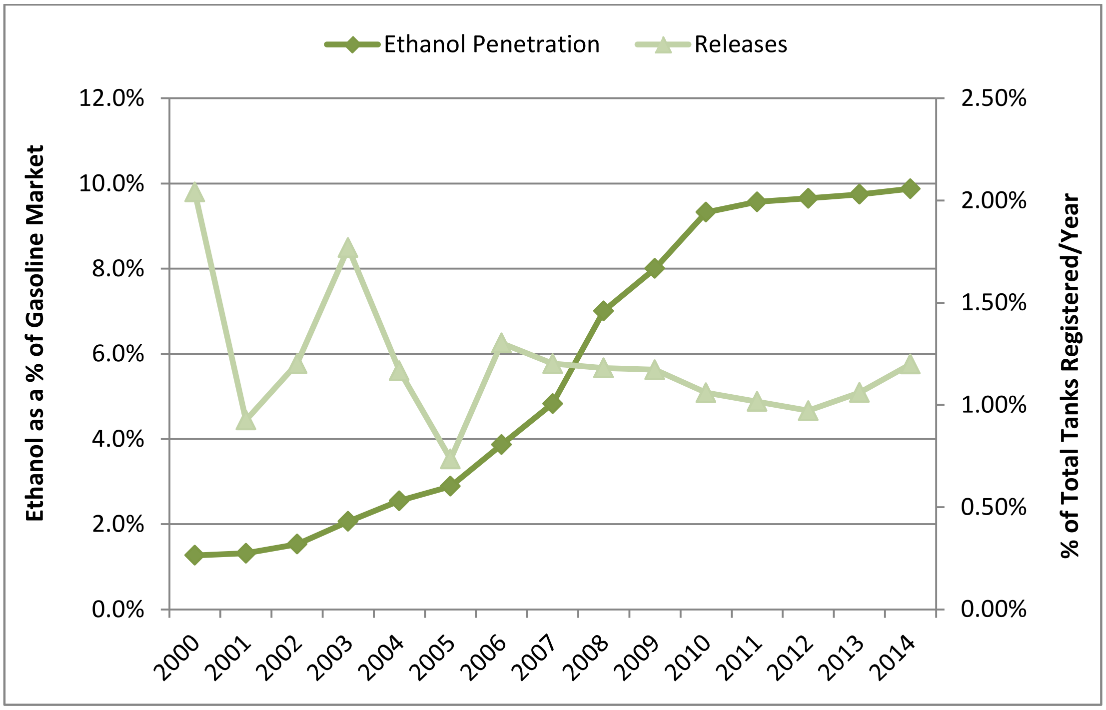

Figure 3. Ethanol penetration and UST releases

Source: Energy Information Agency U.S. Product Supplied of Finished Motor Gasoline: http://www.eia.gov/tools/faqs/faq.cfm?id=23&t=10 and Monthly Energy Review Table 10.3 Fuel Ethanol Overview: http://www.eia.gov/totalenergy/data/monthly/

Table 2. Sources and Causes of UST Releases

UST Releases	2009 Data (5,168 releases)	
Source	**#**	**%**
Tank	1,616	31.3%
Piping	720	13.9%
Dispenser	655	12.7%
STP	76	1.5%
Delivery Problem	342	6.6%
Other	564	10.9%
Unknown	1,195	23.1%
Physical/Mechanical Damage	770	14.9%
Spill or Overfill	441	8.5%
Corrosion	385	7.4%
Installation	54	1.0%
Other	466	9.0%
Unknown	3,051	59.0%

Source: Eighmey, C., March 2011, LUSTLine Bulletin #67. Accessed March 10, 2015: http://www.neiwpcc.org/lustline/lustline_pdf/lustline_67.pdf .

As of January 2003, FDEQ requires County Tanks Program inspectors to submit a leak autopsy form. A 2007 study reviewed Florida leak data and found the sources were spill buckets (48%), piping (14%), dispensers (12%), and tanks (10%) (Mott-Smith 2007). The causes were unknown (36%), overfill (25%), mechanical (16%), material (10%), and corrosion (7%). Spill buckets are designed to reduce leaks during fuel delivery. At the time of the report, Florida's E10 penetration was only 5%, so these results do not reflect E10 storage releases but do highlight the importance of maintenance and appropriate fill techniques.

The literature review was directed specifically at identifying ethanol sensitive equipment and included conversations with several leading infrastructure experts to determine if there was evidence and/or literature showing issues with E10 in USTs. Experts suggested that the long, slow introduction of E10 allowed time for refueling equipment manufacturers to adjust to it. None of the experts was aware of any reports and thought it would be unlikely to find any reports on E10 releases. There are examples of equipment failing such as Total Containment, Inc. flexible piping, but it was the opinion of experts that poorly made products would have failed with any fuel, and the failures of flexible piping occurred not long after their introduction and prior to the widespread use of E10. This is not to say that there were no issues during the deployment of E10, just that there were no known releases and no reports on this subject. An Oak Ridge National Laboratory study of E15 stated "UST stakeholders generally consider fueling infrastructure materials designed for use with E0 to be adequate for use with E10, and there are no known instances of major leaks or failures directly attributable to ethanol use. It is conceivable that many compatibility issues, including accelerated corrosion, do arise and are corrected onsite and, therefore do not lead to a release." (Kass et al. 2012).

Several experts cited EPA work on STP corrosion, and both EPA and Battelle work on ultra-low sulfur diesel (ULSD) corrosion. The National Renewable Energy Laboratory (NREL) previously reviewed the STP corrosion issue for RFA. STPs draw fuel from the UST and deliver it to pipes connected to an aboveground dispenser. The State of Tennessee and EPA OUST have investigated and presented on premature STP corrosion. The theory on the cause is that temperature differentials between sumps and UST systems in summer months (or in warm and humid climates) may enable vapors to enter the STP sumps. Vapors that may contain ethanol capable of dissolving in water may condense on metallic portions of an STP, which reacts with acetobacter and oxygen to form acetic acid, leading to corrosion. NREL spoke with numerous state UST offices and county-level experts and did not find any evidence that corrosion was leading to failures or early replacement of STPs. Accelerated corrosion of ULSD UST systems has been observed nationwide. These instances of corrosion started to be reported in 2007 when ULSD was first introduced. The cause of corrosion is currently under investigation, and an EPA OUST study on ULSD corrosion is expected in late 2015.

4 Equipment at Station

A service station consists of many interconnected pieces of refueling equipment necessary to deliver fuel to vehicles. There are approximately 60 pieces of equipment at a station designed to handle fuel and vapor. The equipment delivering fuel to a vehicle includes tanks, pipes, submersible turbine pump, dispenser, and hanging hardware. The remainder and majority of equipment are used to prevent, detect, and contain releases and there is equipment for fuel delivery. This category includes overfill protection, leak detection, shear valves, fill and vapor caps and adaptors, containment sumps and all associated fittings and accessories of these equipment types.

Figure 4 is a diagram of equipment at a station. Table 3 provides a list of the equipment shown in the diagram and includes the purpose of the equipment; common materials; if the equipment is listed by UL, and if it is UL listed, is it tested with fuel or not; if it was tested with fuel; and what the highest level of ethanol listing available under the standard is. Note that #1 in Figure 4 shows just the tank on the diagram, but the table includes information about steel, fiberglass, and aboveground storage tanks and their protections. This list is comprehensive, and not all stations will have equipment on this list. The table data were taken from the following sources: equipment list and diagram (Source North America); UL; equipment materials (manufacturer product websites and catalogs); and function (PEI Wiki and manufacturer product websites and catalogs).

All known manufacturer website product pages and catalogs were reviewed for every equipment type and model to determine if the products could be used with blends above E10. All known manufacturers were contacted to review compatibility lists. This resulted in an extensive list of equipment compatible with blends above E10. Appendix B provides an equipment list of UL-listed aboveground components for blends above E10. Appendix C provides a compatibility list of tanks. Appendix D is a list of compatible pipes. Appendix E provides information for other UST equipment with manufacturer, equipment type, model names/numbers, ethanol compatibility (%), if it is UL listed, and if it is listed for the ethanol fuel determined by the manufacturer. It is important to note that manufacturers typically keep product names over time but may change product model numbers. Also, manufacturers will introduce new product names, and there is a higher likelihood that these products will be compatible with E15.

Determination of compatibility of equipment with ethanol blends is determined by both regulations and manufacturer statements. Manufacturers have laboratories where they conduct fuels testing to determine if the materials they are using work with a range of fuels. Tanks are subject to EPA OUST regulations, and all existing tank manufacturers provided letters stating compatibility with ethanol blends (see Appendix A). Tanks, pipes, and most aboveground equipment are typically UL listed for specific fuels. This includes dispensers, breakaways, hoses, nozzles, swivels, shear valves, and STPs.

Some manufacturers of other UST equipment make an effort to obtain UL listing for all their products, some obtain it for certain products, and others do not obtain UL listing for their products. Many products are approved by the manufacturer for blends above E10 but are not UL listed for blends above E10. This is largely due to the recent availability of ethanol test fluids under UL testing standards, and over time it is expected that more equipment will be UL listed for blends above E10. In many instances, there is not a history of many manufacturers obtaining UL listing for certain product types such as fill equipment or containment sumps.

There is no regulation that requires station owners to keep records of their equipment, making determination of compatibility challenging for stations without equipment records. One potential source of tank information is the STI, which maintains a list of steel tanks if owners send in the warranty card. STI also provides a method to determine tank type and manufacturer (see Appendix F).

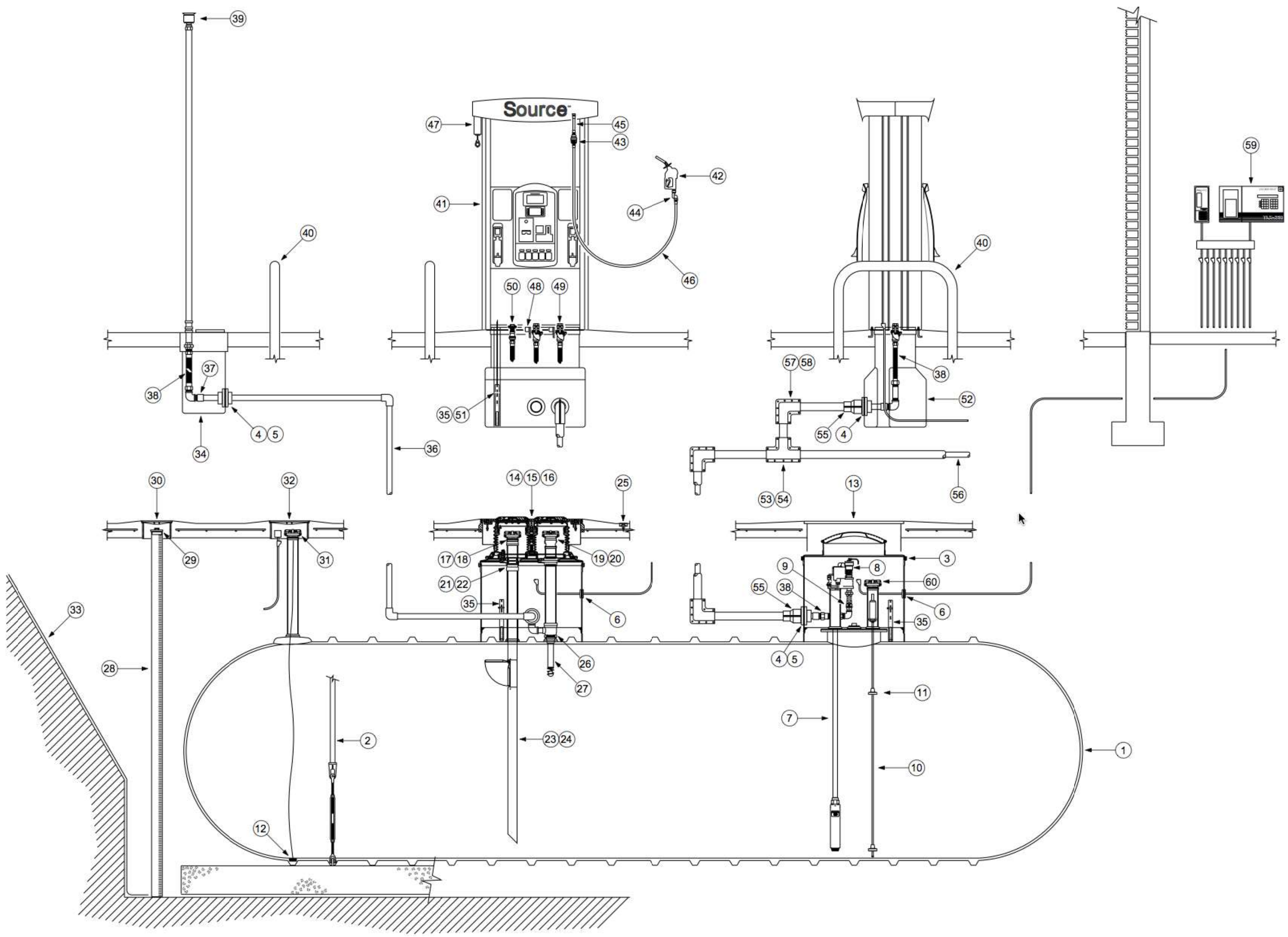

Figure 4. Station equipment diagram

Source: Diagram provided by Source North America, a fueling equipment distributor.

Source™ FUELING EQUIPMENT SOLUTIONS
SOLUTIONS Design Group

Table 2. Station Equipment List-Materials and Function

#	Equipment	UL	UL Std.	Test w/ fuel	Ethanol Test fluids	Materials	Function
1	Tank-steel	yes	58	no	none	steel	Stores fuel.
1	Tank-fiberglass	yes	1316	yes	E100	fiberglass	Stores fuel.
1	Tank-external corrosion protection Jacketed steel tank	yes	1746	yes[a]	E100[a]		Protects tank from corrosion.
1	Tank-lining and upgrades	yes	1856	yes	E100		General tank protection.
1	Tank-above ground	yes	142/142A	no	none	fiberglass or steel	Stores fuel.
1	Tank-above ground fire protection	yes	2080/2085	no	none		Protects tank from fire.
2	Tank straps	no				metal, fiberglass, and other	Outside of tank and usually made of concrete. Devices installed in storage tank excavations to prevent tanks from floating out of the ground in event of a high level of groundwater in the excavation or a high groundwater level after the installation is complete.
3	Sump and cover (tank)	yes	2447	yes	E85	polyethylene, fiberglass	Contains spills from a tank.
4	Sump entry fitting (boot)	yes	2447	yes	E85	fiberglass, bronze, stainless steel, nitrile rubber	These seals provide a studded flange connection to create a positive and secure seal where the rubber contacts the sump wall and also around the pipe or conduit.
5	Sump penetration fittings	yes	2447	yes	E85	fiberglass or flexible plastic	A fitting that provides a liquid and vapor-tight seal around both the piping or conduit and the wall of a containment sump.
6	Flexible entry boots (conduit entry)	yes	no	no	none	glass filled nylon, nitrile	Pipe where electric wires are inserted.
7	Submersible turbine pump	yes	428 428A	yes	E10 E25 and/or E85	cast aluminum, steel, flurocarbon	Delivers fuel from the tank to the dispenser.
8	Mechanical line leak detector	yes	1238	no	none	brass, stainless steel, copper, fluorocarbon	A device used to detect the presence of a leak in the piping. Usually connected to the STP.
9	Ball valve	yes	842 842A	yes	E10 E25 and/or E85	brass, plated steal, vinyl, fluorocarbon	A valve in a piping system that allows or stops flow of fuel.
10	Magnetostrictive probe	yes	1238	no	none	stainless steel, nitrile rubber	A form of measurement technology used in in-tank electronic monitoring systems.This is a leak detection method that relies on sound waves and a magnet.
11	Float kit	yes	1238	no	none	nitrile rubber, fluoropolymer	Works in conjunction with the magnetostrictive probe to determine inventory and identify leaks.
12	Interstitial sensor	yes	1238	no	none		An electronic device that can detect the presence of water, liquid product, product vapors or a loss of pressure or vacuum in the interstice of a tank, a tank top sump, fuel dispenser sump, or observation well.
13	Manhole-composite	yes	2447	yes	E85	fiberglass, steel, resin, nitrile	Manhole covering the STP sump.

a-only part III provides ethanol listing for jacket tanks with secondary containments; other methods covered in parts I, II, and IV list for flammable liquids rather than specific fuels

#	Equipment	UL	UL Std.	Test w/ fuel	Ethanol Test fluids	Materials	Function
14	Manhole-multi-port spill containment	no				fiberglass, steel, aluminum, iron, polyethelene, resin, nitrile	Provides spill containment for UST fill pipes and vapor recovery risers. They are installed on top of the tank sump.
15	Spill bucket	yes	2447	yes	E85	cast aluminum, cast iron, polyethylene, stainless steel, nitrile	Prevents spilled product from entering the soil near the fill and vapor return riser connections on underground storage tanks during normal tank filling operation, or if the tank overfilled.
16	Fuel grade ID tag	yes	969	no	none		Identifies fuel being stored.
17	Fill adaptor (top or side)	yes	2583	yes	E85	Bronze, nylon, stainless steel, nitrile rubber, fluorocarbon	A permanent fitting at the top of the fill pipe of an underground storage tank that allows for a delivery hose to be quickly connected to the fill pipe in a liquid tight manner.
18	Fill cap (top or side)	yes	2583	yes	E85	brass, epoxy coated aluminum	A cap that fits over the open end of a fill pipe.
19	Vapor adaptor	yes	2583	yes	E85	bronze, conductive nylon, stainless steel, nitrile	A special fitting in a Stage I vapor recovery system that is installed at the top of the vapor recovery riser in two-point and manifolded Stage I vapor recovery systems. The vapor recovery adaptor mates to the vapor recovery elbow attached by the fuel delivery driver prior to a delivery.
20	Vapor cap	yes	2583	yes	E85	aluminum, glass filled nylon, iron, copper, stainless steel, nitrile	A dust cover for the vapor recovery system.
21	Face seal adaptor (threaded riser adaptor)	yes	2583	yes	E85	aluminum	Connects fill pipe to swivel fill adaptor and Provides a flat, true sealing surface on threaded fill pipe where a gasket seal exists. is installed on the fill pipe riser below the spill container to provide a true sealing surface for the drop tube flange on the overfill prevention valves.
22	Jack screw kit	yes	2583	yes	E85	steel	The jack screw is designed to lock an overfill valve or a drop tube into an a spill container base below the outlet of the drain valve.
23	Overfill prevention valve	yes	2583	yes	E85	cast aluminum, nitrile rubber, fluoro based seals, acetal, stainless steel, acetal, closed cell foam	Prevents the overfill of underground storage tanks by providing a positive shut-off of product delivery.
24	Drop tube (often a part of #23)	yes	2583	yes	E85	stainless steel	Delivers fuel from fill cap to bottom of tank resultig in less vapors.
25	Fuel grade ID #	yes	969	no	none		Identifies fuel type.

#	Equipment	UL	UL Std.	Test w/ fuel	Ethanol Test fluids	Materials	Function
26	Extractor tee	yes	2583	yes	E85	cast iron, zinc	A fitting that allows access to ball valve be removed or repaired without the necessity of breaking concrete, digging down to the component, or cutting a hole in the tank.
28	Ball float vent valve (flow restriction device FRD)	yes	2583	yes	E85	Brass, chrome, fluoro based seals	During a product delivery, as the tank level rises, a counterweight stainless steel ball seats on the valve body and restricts flow of vapors back to the transport truck.
27	Monitoring well screen (pipe)	no	no	no	none	plastic, polypropylene (filter wrapping the pipe)	A slotted or screened tube or pipe, positioned vertically in an underground tank excavation, that permits an operator to check conditions in the excavation and, in particular, to determine whether there may be a leak in the tank system.
29	Well cap-monitoring	yes	2583	yes	E85	plastic, nitrile rubber	Provides access to well screen.
30	Manhole-monitoring	no				cast iron	Any tank opening, including those where delivery and vapor return hoses are connected.
31	Interstitial cap	yes	2583	yes	E85		Interstitial Caps are installed on tank riser pipes to help prevent vapors from escaping or water from entering the tank
32	Manhole	no				fiberglass, steel, resin, nitrile	Access to UST system.
33	Roll filter fabric	no				polypropylene, or polyester	A porous synthetic fabric, used in underground storage tank excavations, to provide a barrier between different types of soil, or between backfill and adjacent soil.
34	Transition sump-vent	yes	2447	yes	E85	polyethylene, fiberglass	A liquid tight container typically installed at a point where product piping from an aboveground storage tank transitions to underground piping. Other forms of transition sumps may accomodate piping from an UST tank to AST generators, or for piping that resides only below grade. The transition sump exists to contain any contaminants that may leak from any piping or their connectors and to isolate and protect metallic components or equipment from the elements.
35	Sump sensor	yes	1238	no	none		An electronic device that can detect the presence of water, liquid product, product vapors or a loss of pressure or vacuum in the interstice of a tank, a tank top sump, fuel dispenser sump, or observation well.
36	Pipe	yes	971	yes	E100	fiberglass or flexible plastic	Delivers fuel between different pieces of equipment in the refueling system.
37	Pipe adaptor	yes	971	yes	E100	aluminum, stainless steel, nitrile rubber or fluoro based elastomers	connect fuel delivery transport truck hoses or nozzles to the fill pipe of an aboveground storage tank
38	Flexible connector	yes	2039	yes	E85	stainless steel, fluoro based elastomers or nitrile rubber	Flexible Connectors can be used as a convenient means of connecting piping to pumps and dispensers and throughout the piping systems where connections and changes of direction are necessary.

#	Equipment	UL	UL Std.	Test w/ fuel	Ethanol Test fluids	Materials	Function
39	Vent	yes	2853	yes	E85	aluminum, brass	A pipe, usually 2 inches in diameter, that extends from a gasoline storage tank at a service station to a point 12 feet or more above grade level. The vent allows vapors that build up in the tank to escape and outside air to enter, thus keeping the tank at atmospheric pressure when liquids are added or removed.
40	Steel bumper	no				steel	Not fuel wetted. Designed to protect dispenser from vehicle impact.
41	Dispenser	yes	87 87A	yes	E10 E25 and/or E85	multiple parts/materials (metal, plastic, elastomers) in a dispenser-treated as a whole piece of equipment	The dispenser delivers fuel from the piping connected to the STP through the hanging hardware into a vehicle. It has numerous parts including meters, valves, seals, and electronics.
42	Nozzle	yes	2586 2586A	yes	E10 E25 and/or E85	aluminum, plastic, fluorocarbon	A device consisting of a spout, handle and operating lever, attached to the end of a hose and used for controlling the flow of a liquid motor fuel.
43	Breakaway	yes	567 567A	yes	E10 E25 and/or E85	steel, zinc, nylon, acetal, fluorocarbon	A device that disconnects dispenser from hanging hardware if a vehicle pulls away with the nozzle still in the vehicle gas tank.
44	Swivel	yes	567 567A	yes	E10 E25 and/or E85	aluminum, zinc, nitrile rubber	The swivel permits the nozzle to be rotated without rotating the hose at the same time.
45	Whip hose	yes	330 330A	yes	E10 E25 and/or E85	nitrile rubber	A short length of hose with threaded fittings at both ends that is usually installed adjacent to a breakaway valve. The whip hose ensures that forces exerted during a drive off are aligned with the axis of a breakaway valve.
46	Hose	yes	330 330A	yes	E10 E25 and/or E85	nitrile rubber	Delivers fuel to the nozzle.
47	Hose retractor	no				aluminum, polyester	A cable device, fixed to a gasoline station hose and dispenser, to pull the hose back to its storage position after it has been used. Usually used for longer hoses that allow refueling on either side of a vehicle.
48	Stablizer bar kit	yes	2447	yes	E85	steel	Provides support in a dispenser sump to attach the shear valve.
49	Shear valve	yes	842 842A	yes	E10 E25 and/or E85	cast iron, stainless steel, fluorocarbon	Cuts off the flow of fuel from the UST system in the event of vehicle impact, fire, or other catastrophe.
50	Shear valve-vapor (stage II only)	yes	842 842A	yes	E10 E25 and/or E85	cast iron, stainless steel, fluorocarbon	A fitting installed in the vapor piping at the base of a dispenser that is designed to “shear” or break off if the dispenser cabinet is dislodged from its base.

#	Equipment	UL	UL Std.	Test w/ fuel	Ethanol Test fluids	Materials	Function
51	Sensor tube	yes	1238	no	none		Contains the sump sensor.
52	Dispenser sump	yes	2447	yes	E85	fiberglass, flexible plastic	A container designed to contain leaks from dispensers
53	Pipe-secondary containment tee	yes	971	yes	E100	flexible plastic, fiberglass	A pipe fitting connector
54	Pipe-product tee	yes	971	yes	E100	flexible plastic, fiberglass	A pipe fitting connector
55	Concentric reducer	yes	2447	yes	E85		A seal that connects the sump entry/termination fitting to secondary containment pipe.
56	Pipe-product	yes	971	yes	E100	flexible plastic, fiberglass	Delivers fuel between tank and dispenser.
57	Pipe-secondary containment elbow	yes	971	yes	E100	flexible plastic, fiberglass	A pipe fitting that makes a right-angle turn
58	Pipe-product elbow	yes	971	yes	E100	flexible plastic, fiberglass	A pipe fitting that makes a right-angle turn
40	Steel bumper	no				steel	Protects equipment from vehicle impact.
59	Console	yes	1238	no	none		A control unit, containing switches, keys, or similar elements, used to control the operation of a dispenser or other device at a gasoline dispensing facility.
60	Probe cap adaptor	yes	2583	yes	E85	cast aluminum, nitrile rubber	Monitoring Probe Caps are installed on tank riser pipes to help prevent vapors from escaping or water from entering the tank. Monitoring Probe Caps include a wire grommet fitting to accommodate the electronic tank gauge probe.

4.1 Dispensers, Hanging Hardware, Shear Valves, and STPs

There are multiple dispenser options to sell E15: retrofit an existing dispenser with a UL-listed kit, purchase a UL-listed E25 dispenser (minimal cost over conventional E10 dispenser), or purchase a UL-listed E85 blender pump dispenser (higher cost but more options for fuel offerings). Both Gilbarco and Wayne provide UL-listed dispensers for blends above E10. Credit card companies are requiring retail fueling stations to update their dispensers to accept new chip and PIN secure credit cards by October 2017, at which time fraud liability would switch to station owners if they have not updated their equipment. This presents an opportunity to increase E25 UL-listed equipment through either a retrofit kit if electronics are being upgraded to accommodate the new credit cards, or if a station must purchase a new dispenser, they could pay a minimal amount more for an E25 dispenser.

Hanging hardware includes hoses, nozzles, breakaways, and swivels (Figure 5). OPW obtained E25 listing for a conventional swivel and breakaway, for which there is no price premium. Husky offers UL-listed E25 and E85 nozzles while OPW offers a UL-listed E85 nozzle. EMCO Wheaton, IRPCO, and Veyance have hoses warrantied for E15, and Veyance has a UL-listed E85 hose product. A best practice is to replace all hanging hardware with E15-compatible equipment.

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

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

Appendix B lists specific manufacturers and models for use with blends above E10.

Figure 5. Aboveground equipment

(NREL 13531)

4.2 Tanks, Pipes, and Other UST Equipment

4.2.1 Compatibility of Tanks

Most tanks are compatible with ethanol blends above E10. Appendix B lists tank manufacturers and their compatibility with ethanol blends. If a station owner does not have equipment lists, the information in Appendix F describes methods to determine tank type.

All existing steel tank companies manufacturing tanks to store transportation fuels 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. All STI members who fabricate regulated fuel USTs in the United States have UL 58 listings. STI conducted independent testing and determined that steel tanks are compatible with all ethanol blends.

Xerxes and Containment Solutions manufacture fiberglass tanks, and both have E100 listing for their products under UL 1316.[11] Per EPA OUST's biofuels guidance, Containment Solutions issued a letter stating that all tanks it has manufactured are compatible all ethanol blends. Xerxes and Owens Corning (which no longer manufactures tank) have stated that compatibility depends on tank type and the year manufactured. Appendix C includes specific information on fiberglass tank compatibility.

The following is from a Fiberglass Tank and Pipe Institute paper on ethanol compatibility (Curran 2015):

> *"By 1990, Institute member fiberglass tank manufacturers had modified their tanks constructions to handle gasoline with any level of ethanol or methanol up to 100% for all double-wall fiberglass tanks and in some cases single- wall fiberglass tanks. In 1992, Owens Corning, the manufacturer of the oldest UL Listed fiberglass tanks for petroleum service, advised certain major oil companies that some tanks were approaching 30 years in age and their 30-year warranties would expire. As a result, the affected companies conducted surveys of these older tanks, including tanks in E-10 ethanol service (e.g., in the Midwest) and confirmed that the tanks were performing satisfactorily for continued service. In summary, technical evaluations and historical experience demonstrated that there is no material or technical reason why properly installed pre-1988 piping and tanks in conventional gasoline or MTBE service should not perform equally as well when handling 10 percent ethanol blends."*

4.2.2 Compatibility of Pipes

Installed pipes are evenly split between fiberglass and flexible plastic pipes. Piping is listed under UL 971. E100 became an eligible test fluid in 1988, and all existing pipe companies have E100 listing (Appendix D). Fiberglass was the primary pipe type for decades. NOV is the only existing company providing fiberglass piping in this market, and its products received E100 listing in 1990. NOV provides a 30-year warranty.

Flexible pipes entered the marketplace in the 1990s after EPA OUST recommended development of jointless pipes. There were some issues with initial deployment and failures of Total Containment piping. Total Containment is no longer in business, and its piping is largely

[11] Decades-old fiberglass tanks may only be approved for use with E10; please refer to Appendix C.

believed to have been replaced. This occurred before E10 was widely available. Over time, more robust products were developed, and all existing flexible plastic pipe manufacturers have UL listing for E100. These manufacturers include Advantage Earth Products, Brugg Pipesystems,[12] Franklin Fueling, NUPI, Omega Flex, and OPW. Both Franklin Fueling and Omega Flex require the use of stainless steel pipe fittings for blends above E10. A typical warranty for flexible pipes is 10 years.

It is likely that there are stations using piping from companies no longer in business, and the compatibility with ethanol blends for these products is unknown.

4.2.3 Other UST Equipment

Other associated UST equipment includes sumps and accessories, manholes, flexible connectors, fill caps and adaptors, entry fittings, overfill prevention, leak detection, sensors, drop tubes, vents, and similar. Per EPA OUST's biofuels guidance, several manufacturers have issued letters for specific products and model numbers stating compatibility with various ethanol blends above E10. Some major manufacturers have not issued letters but have provided statements on their website product pages that the products are compatible with various ethanol blends, including E15, E85, and E100. Most manufacturers have their own laboratories where they test their products with fuels. Some smaller manufacturers likely rely on materials analysis to determine compatibility. Appendix D provides a list by manufacturer of compatible equipment.

While UL now has listing standards for most of this equipment, few products have UL listing for E10 and even fewer for blends above E10. This does not mean that the products are not compatible, just that manufacturers have yet to obtain listings.

Retailers should specifically investigate if their leak detection equipment is compatible with E15 (refer to Appendix E). Leak detection equipment is required by federal regulations developed by EPA OUST (EPA 2015b). All federally regulated UST systems (tanks and piping) storing motor fuel must have leak detection equipment to detect 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. The National Work Group on Leak Detection Evaluations has developed test protocols for various technologies with blends above E10 (NWGLDE 2011). It is expected that some will function with ethanol blends while others may require testing to determine functionality.

In 2011, Battelle conducted a test of ethanol-blended fuels and an automatic tank gauging system to determine water detection functionality (Carvitti and Gregg 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.

[12] Brugg Pipesystems manufacturers stainless steel pipes, which are rarely used at United States stations.

As a result of the E15 waiver request, the American Petroleum Institute funded a study to determine compatibility of some associated UST equipment, specifically tank vapor recovery equipment and overfill protection devices with E15 (Ken Wilcox Associates 2011). The testing protocol was to expose equipment to test fluids E10 (control) and aggressive E17 (test fluid formula from UL) for four weeks at 140°F followed by performance testing. The following equipment was tested: ball float vent valve, monitoring probe cap, overfill prevention valve, replacement drain valve kit (used to drain spill container after an overfill during delivery), swivel product adaptor, and swivel vapor adaptor. The report states that most of the equipment performed well during testing. All ball float vent valves, monitoring probe caps, and replacement drain valve kits passed. Two of three overfill prevention valves passed; the failing product was stuck in the OFF position during performance testing. Swivel product adaptor results were mixed, with one product failing on E10 and passing on aggressive E17 while the other product failed on both fuels. Swivel vapor adaptors did not perform well either with one failing on both test fluids and a second product failing on the E17 test fluid. The adaptor failures happened during performance testing due to leaks in sealing materials. Most manufacturers have upgraded sealing materials in the past few years after this test was performed to address the introduction of more ethanol and ULSD into the market.

The subject of older pipe dopes/sealants and their compatibility with ethanol fuels came up in the course of the original E15 infrastructure work performed by U.S. Department of Energy national laboratories. Pipe dope, also referred to as pipe thread sealant, is a sealing product used to make pipe thread joints leak proof and pressure tight. Refueling equipment with threaded ends is designed to achieve a tight fit during proper assembly but it is a regular practice to use pipe dope in some instances. Appendix G is a diagram of where pipe dope might be used in a refueling system. Jobbers who install, fix, and replace equipment at stations always have a jar of pipe dope available for use and the two main brands are RectorSeal and Gasoila. Gasoila's pipe thread sealants have used the same formula for decades and are compatible with ethanol blends up to 20%.[13] RectorSeal No.5 is their best selling product for use at refueling station and the manufacturer said it has long been compatible with ethanol blends including E15.[14]

[13] Gasoila pipe thread sealants are compatible with up to 20% ethanol. Blends above E20 need to use their Gasoila E-Seal product. http://www.gasoila.com/products/pipe-thread-sealants.html

[14] RectorSeal's Pipe Thread Sealant Chart shows No.5 as compatible with gasohol (10%), however, NREL spoke with their technical staff who said it is compatible with E15.

5 Conclusions

This study found that significant changes to safety testing standards have incorporated fuel blends with more than 10% volume ethanol. This has led to many refueling equipment products compatible with E15. A station owner can compare its equipment records against the compatibility list in the appendices of this report to determine if there is a need to update or upgrade any equipment to sell E15. The majority of tanks are compatible as existing pipe manufacturers have had listing for E100 for many years, UL-listed E25 dispensers and retrofit kits are available, as is hanging hardware (a combination of E25 and E85 UL-listed equipment). Many manufacturers' models, as well as other UST equipment including fill equipment, leak detection, overfill prevention, and containment, are compatible with E15.

A literature review was conducted to determine if there were any negative impacts during the multi-year deployment of E10 nationwide. No incidents of E10 causing releases were identified, and no infrastructure industry experts suggested that there were widespread issues with E10.

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Appendix A. EPA OUST Release Data

2009 release data from 47 states:

	Cause															
Source	Total		Spill		Overfill		Phys/Mech Damag		Corrosion		Install Problem		Other		Unknown	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Tank	1616	31.3%	37	19.0%	59	24.0%	179	23.3%	321	83.2%	9	16.7%	157	33.7%	854	28.0%
Piping	720	13.9%	9	4.6%	6	2.4%	190	24.7%	48	12.4%	25	46.3%	43	9.2%	399	13.1%
Dispenser	655	12.7%	38	19.5%	31	12.6%	160	20.8%	8	2.1%	9	16.7%	49	10.5%	360	11.8%
STP	76	1.5%	4	2.1%	2	0.8%	36	4.7%	1	0.3%	5	9.3%	9	1.9%	19	0.6%
Delivery Problem	342	6.6%	92	47.2%	121	49.2%	100	13.0%	0	0.0%	1	1.9%	14	3.0%	14	0.5%
Other	564	10.9%	14	7.2%	6	2.4%	97	12.6%	6	1.6%	4	7.4%	171	36.7%	266	8.7%
Unknown	1195	23.1%	1	0.5%	21	8.5%	8	1.0%	2	0.5%	1	1.9%	23	4.9%	1139	37.3%
Totals	5168		195		246		770		386		54		466		3051	

Source: Eighmey, C. LUSTLine Bulletin #67. March 2011

Appendix B. Aboveground Compatibility

Manufacturer	Product	Model	E%	UL listed	UL listed for this fuel?
Franklin Fueling	Shear valve	662 models (UL listing for #662502902)	E85	yes	yes
Franklin Fueling	Submersible turbine pump	FE Petro STPAG, IST	E85	yes	yes
Gilbarco	Dispenser, Retofit Kit	E25 option on any dispenser; E25 retrofit kit	E25	yes	yes
Gilbarco	Dispenser	Encore Flex Fuel	E85	yes	yes
EMCO Wheaton	Breakaway	A2119, A2219, A3019, A3219, A4119EVR	E15	yes	no
EMCO Wheaton	Breakaway	A4119-020E	E85	no	
EMCO Wheaton	Hose	all	E15	yes	no
EMCO Wheaton	Nozzle	A4005-002, A4005-004, A4015-002, A4015-004	E15	yes	no
EMCO Wheaton	Nozzle-balance vapor recov	A4005-002E, A4015-002E	E85	yes	no
EMCO Wheaton	Swivel	A0360 (not listed), A4110EVR (UL listing)	E15	yes	no
Husky	Nozzle	X E25, X E25, XSE25	E25	yes	yes
Husky	Nozzle	X E85, X E85 Cold Weather, XS E85, XS E85 Cold Weather	E85	yes	yes
IRPCO	Hose-dispenser	Steelflex Ultra Hardwall, Softwall (2 Braid, 4SP), Marina	E15	yes	no
OPW	Breakaway	66V-0300	E25	yes	yes
OPW	Breakaway	66V-0492	E85	yes	yes
OPW	Nozzle	21GE, 21GE-A	E85	yes	yes
OPW	Swivel	241TPS-0492	E85		
OPW	Swivel	241TPS-0241, 241TPS-1000, 241TPW-0492	E25	yes	yes
OPW	Shear valve	10P-0142E85, 10-P-4152E85	E85	yes	yes
Veeder-Root	Submersible turbine pump	Redjacket, Redjacket AG,	E100	yes	no
Veyance	Hose	Flexsteel Futura Ethan-all	E85	yes	yes
Veyance	Hose	Flexsteel Futura	E15	yes	no
Wayne	Dispenser	E25 option on any dispenser; E25 retrofit kit	E25	yes	yes
Wayne	Dispenser	Ovation E85, Helix E85	E85	yes	yes

For compatibility of older dispensers with E85, please refer to: DOE Clean Cities. *Handbook for Handling, Storing, and Dispensing E85 and Other Ethanol-Gasoline Blends*. September 2013. http://www.afdc.energy.gov/uploads/publication/ethanol_handbook.pdf

Appendix C. Tank Compatibility

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

Appendix D. Pipe Compatibility

Manufacturer	Product	Model	E%	UL listed	UL listed for this fuel?
Advantage Earth Products	Pipe	1.5", 2", 3", 4"	E100	yes	yes
Brugg Pipesystems	Pipe	FLEXWELL-HL, SECON-X, NIROFLEX, LPG	E100	yes	yes
Franklin Fueling	Pipe	XP, UPP	E100	yes	yes
Franklin Fueling	Pipe ducting	APT, UPP	E100	yes	yes
Franklin Fueling	Pipe fittings	XP stainless steel (ELB-XP-150, ELB-XP-175, ELB-XP-200, GSHP-150, GSHP-200, MS-XP-150-150SS, MS-XP-175-200SS, MS-XP-200-200SS, MS-100-100SS, MS-XP-150-150, MS-XP-SW-175-200, MS-XP-SW-200-200, QRS-XP-150-200, QRS-XP-175-200, QRS-XP-200-200, SSC-150, SSC-200, SSE90-150, SSE90-200, SSE90-150, SST-150, SST-200, SSU-150, SSSHP-150, TEE-XP-150, TEE-XP-175, TEE-XP-200) UPP stainless fittings	E85	yes	yes
NOV Fiberglass	Red Thread IIA	fiberglass	E100	yes	yes
NUPI	Smartflex	flexible plastic	E100	yes	yes
OMEGAFLEX	DoubleTrac	flexible plastic (must use stainless steel fittings)	E100	yes	yes
OPW	Pipe	FlexWorks, Pisces (discontinued)	E100	yes	yes
OPW	Pipe adaptors, couplers, fittings	FlexWorks	E100	yes	yes

Appendix E. Other UST Equipment Compatibility

Note: "UN" in the E% column indicates the manufacturer does not know if it is compatible with ethanol blends. ? = waiting on information from OEM

Manufacturer	Product	Model	E%	UL Listed	UL listed for this fuel	Other Approval
Clay and Bailey	AST anti-siphon valve	405	E10	no		
Clay and Bailey	AST manhole	API-650	E85	no		
Clay and Bailey	AST alarm	1400	E10	no		
Clay and Bailey	AST overfill prevention valve	1228	E85	yes	no	
Clay and Bailey	AST pressure vacuum vent	88	E10	no		
Clay and Bailey	AST spill containment	all	E85	no		
Clay and Bailey	AST emergency vent	354, 365, 366, 367, 368, 369, 370	E85	yes	no	
Clay and Bailey	Manhoes	all	E10	no		
Clay and Bailey	Ball valve	736	E10	no		
Clay and Bailey	Fill cap	94, 232, 233, 234, 235, 254	E85	no		
Clay and Bailey	Vent-upflow	395	E10	no		
Cimtek	Filter	300, 400, 450, 475	E15	yes	no	
Cimtek	Filter	800	E85	yes	no	
EMCO Wheaton	Nozzle-balance vapor recovery	A4005-002E, A4015-002E	E85	yes	no	CARB EVR
EMCO Wheaton	Nozzle-balance vapor recovery	A4005-002, A4005-004, A4015-002, A4015-004	E15	yes	no	CARB EVR
EMCO Wheaton	Breakaway	A4119-020E	E85	no		
EMCO Wheaton	Breakaway	A2119, A2219, A3019, A3219, A4119EVR	E15	yes	no	CARB EVR (A4119 only)
EMCO Wheaton	Swivel	A0360, A4110EVR	E15	yes (EVR only)	no	CARB EVR (A4110 only)
EMCO Wheaton	Hose	all	E15	yes	no	
EMCO Wheaton	Adaptors	A0030, A0030-142, A0076, A0076-142S A0089, A0096,	E15	no		CARB EVR (both A0030 and A0076)
EMCO Wheaton	Ball float	A0075E, A0078E	E85	no		CARB EVR (A0078)
EMCO Wheaton	Ball float	A0075, A0078	E15	no		CARB EVR (A0078)
EMCO Wheaton	Caps	A0097-005, A0097-004LP, A0097-010, A0099-002, A0099-004LP	E15	no		CARB EVR (A0097-005, A0099-02)
EMCO Wheaton	Drop tube	A0020-004E, A0020-005E, A0020-007E	E15	no		CARB EVR (A0020, A0088)
EMCO Wheaton	Drop tube	A0020-004, A0020-005, A0020-007, A0020-008, A0020-021, A0020-133, A0020-144, A0070, A0088	E15	no		CARB EVR (A0020, A0088)
EMCO Wheaton	Extractor fittings	A0079	E85	yes	no	CARB EVR
EMCO Wheaton	Overfill prevention valve	A1100-010E, A1100-056SE, A1100-055SERF, A1100-056SERF, A1100EVR-057E, A1100-067E, A1100-087E	E85	no		CARB EVR
EMCO Wheaton	Overfill prevention valve	A1100-010, A1100-011, A1100-054S, A1100-054SC, A1100-054SCN, A1100-055SRF, A1100-056SRF, A1100-053S, A1100-055S, A1100EVR-055, A1100-056S, A1100EVR-056, A1100-057S, A1100EVR-057, A1100-058S, A1100EVR-058, A1100-065S, A1100-066S, A1100-067S, A1100-085S, A1100-087S, A1100-087S	E15	no		CARB EVR (only models with EVR in model no.)
EMCO Wheaton	Ball valve	A0750	E15	no		
EMCO Wheaton	Check valve	A0066, A0732	E15	no		
EMCO Wheaton	Shear valve	A0060 with stainless steel body	E85	yes	no	
EMCO Wheaton	Shear valve	A0060 with cast iron body, A0063	E15	yes	no	
EMCO Wheaton	Vent	A0084, A0085, A4103, A0785	E15	yes (A4103 only)	no	
Husky	Pressure vacuum vents	4620, 4885, 5885, 8060	E85	yes	yes	

Manufacturer	Product	Model	E%	UL listed	UL listed for this fuel?	Other Approval
STP Equipment						
Franklin Fueling	Mechanical line leak detector	MLD+AG	E85	yes	?	
Franklin Fueling	Mechanical line leak detector	STP-MLD	E10	yes	yes	
Franklin Fueling	Shear valve (emergency shear	662 models	E85	yes (662502902)	yes	
Franklin Fueling	Shear valve-vapor	362 models	UN	no		
Franklin Fueling	Submersible pump controller	MagVFC IST,	E85	yes		
Franklin Fueling	Submersible turbine pump	STP	E10	yes	yes	
Franklin Fueling	Submersible turbine pump	FE Petro STPAG, IST	E85	yes	yes	
Fill Equipment						
Franklin Fueling	Ball float vent valve	308 models	E85	no		EVR CARB
Franklin Fueling	Drop tube	306 and 708 models, 782-204-30-2, 782-204-32-2, 782-202-12, 782-203-12, 782-204-10-2, 782-204-12-2, 782-204-15-2	E85	no		
Franklin Fueling	Extractor vent valve (tee)	300 series models	E85	no		
Franklin Fueling	Fill adaptor-side	776-300-01, 776-300-31	E85	no		
Franklin Fueling	Fill adaptor-swivel	SWF-100-SS, SWFV-PKGSS	E85	no		EVR CARB
Franklin Fueling	Fill adaptor-swivel	SWFV-PKG, 705-412-01, 705-412-02	E85	no		
Franklin Fueling	Fill adaptor-top	778-301-05	E85	no		EVR CARB
Franklin Fueling	Fill adaptor-top	776-300-01, 776-300-31, 778-301-01, 778-301-02, 778-301-06, 778-301-32, 778-301-01, 778-302-31, 778-303-02, 778-303-32, 780-200-01	E85	no		
Franklin Fueling	Fill cap-side	775 series	E85	no		
Franklin Fueling	Fill cap-top	777-201-02	E85	no		EVR CARB
Franklin Fueling	Fill cap-top	777-202-01, 777-202-02, 779-200-01, 774-202-03	E85	no		
Franklin Fueling	Vapor cap	304-301-03	E85	no		EVR CARB
Franklin Fueling	Vapor cap	304-200-01, 304-200-02, 304-301-01, 304-301-02	E10	no		EVR CARB (301-01 only)
Franklin Fueling	Vapor pipe adaptor	SWV-101-SS, SWFV-PKGSS	E85	no		EVR CARB
Franklin Fueling	Vapor pipe adaptor	SWV-101-B, SWFV-PKG, 705-413-01, 705-413-02	E10	no		
Franklin Fueling	Vapor recovery adaptor	306 and 708 models	E85	no		
Franklin Fueling	Overfill prevention valve	708-491-31, 708-491-32, 708-492-21, 708-492-22, 708-492-31, 708-492-32, 708-498-11	E85	yes	?	EVR CARB (ending in 11 or 12)
Franklin Fueling	Overfill prevention valve	708-491-01, 708-491-02, 708-491-11, 708-491-12, 708, 491-21, 708-492-01, 708-492-02, 708-498-11, 708-493-03, 708-493-04, 708-493-23, 708-493-24, 708-340-901, 708-494-02, 708-494-03, 708-494-04, 708-498-01, 708-498-02, 708-498-03	E10	yes	?	EVR CARB
Franklin Fueling	Probe cap and adaptor kit	90037-E	E85	no		EVR CARB
Franklin Fueling	Spill container (bucket)	702, 703, 705, 715	E10	yes (705 and 715 models only)		yes (705 and 715 models only)
Franklin Fueling	Spill container (bucket)	Phil-Tite series, Defender Series	E85	yes	?	EVR CARB
Franklin Fueling	Tank bottom protector	TBP-3516-E	E85	no		
Franklin Fueling	Tank bottom protector	785-200-02	E10	no		
Franklin Fueling	Vent valve (pressure/vacuum)	PV-ZERO models	E85	yes	?	EVR CARB

Manufacturer	Product	Model	E%	UL listed	UL listed for this fuel?	Other Approval
UST Equipment						
Franklin Fueling	API adaptor	880-500-04	E85	no		
Franklin Fueling	Automatic tank gauge	TSP	E10	yes	yes	
Franklin Fueling	Ball valve (for pipe)	FLEX-ING	E85	yes	no	CSA
Franklin Fueling	Check valve	622-300-01, 65, 515, 516, 615, 635, 650	E10	no		
Franklin Fueling	Dispensing cutoff system	DC400	E10	no		
Franklin Fueling	Flexible connectors	FLEX-ING	E10			
Franklin Fueling	Flexible connectors	FIREFLEX	E85	yes	no	
Franklin Fueling	Float kit	TSP-IGF4P	E15	no		
Franklin Fueling	Float kit	TSP-IGF4D3, TSP-IGF4D	E85	no		
Franklin Fueling	Foot valve	50-201, 320	E10	no		
Franklin Fueling	Interstitial sensor	TSP-HIS, TSP-DIS, TSP-EIS, TSP-HFS	E85	no		
Franklin Fueling	Level sensor	TSP-HLS	E85	no		
Franklin Fueling	Magnostrictive probe	Moorman	E85	no		
Franklin Fueling	Manhole	14U, 20UR, 780, 781, 789, 808, 810, 814, 987, Defender, SSQ, SR series	E10	no		
Franklin Fueling	Monitoring test well	772, 773, 808, 810	E10	no		
Franklin Fueling	Monitoring well cap	TSP-KW4	E10	no		
Franklin Fueling	Monitoring well sensor	TSP-MWS	E0	no		
Franklin Fueling	Probe installation kit	FFS	E10	no		
Franklin Fueling	Pipe fittings	GC-150, GC-200, GE90-150, GE90-200, GE90-215, GE90-252, GHB-200-150, GT-150, GT-200, GT-215, GT-252, GU-150, GU-200, GHB-200-150, GSHP-150, GSHP-200, XP brass (MS-XP-150-150, MS-XP-175-200, MS-XP-200-200	E10	yes	yes	
Franklin Fueling	Sumps	2400, 4542 (UL), 4736, APT, AST, LM, TS, UPP (UL) models	E85	yes	no	
Franklin Fueling	Sump accessories, fittings, boots	APT	E85	yes	no	
Above-ground Equipment						
Franklin Fueling	Nozzle	400, 600, 708, 709, 800, 900 series (all vapor recovery II)	E10	no		EVR CARB (400, 600, 900)
Franklin Fueling	Breakaway	697, 698, ACCUBREAK, SAFETY-SEVER	E10	yes	yes	
Franklin Fueling	Hoses	FLEX-ING	E10	no		
Franklin Fueling	Hoses	FLEX-ON	E15	yes	no	
Franklin Fueling	Swivel	465	E10	no		
Franklin Fueling	Swivel	FLEX-ING multi-plane	E10	no		
AST Equipment						
Franklin Fueling	Anti-siphon valve	636-300-11, 636-300-12	E85	no		
Franklin Fueling	Anti-siphon valve	605-300-01, 606-300-01, 616-300-01, 616-300-02, 616-300-03	E10	no		API/RP 2000
Franklin Fueling	AST emergency vent	803	E10	yes		
Franklin Fueling	AST fill cap	751, 770	E10	no		
Franklin Fueling	AST overfill prevention valve	709	E10	no		
Franklin Fueling	AST Pressure regulator valve	620, 621, 622, 644	E10	yes		API/RP 2000
Franklin Fueling	AST pressure vacuum vent	802	E10	no		
Franklin Fueling	AST spill container (bucket)	706	E10	no		
Franklin Fueling	AST tank vent	800	E10	no		

Company	Product	Model	E%	UL Listed	UL listed for this fuel	Other Approval
Morrison Bros	Adaptor-coaxial	605	UN	no		
Morrison Bros	Anodized Farm Nozzle	200S	E85	no		
Morrison Bros	Anti-Syphon Valve	912	E85	no		
Morrison Bros	AST adaptor	927	E85	no		EVR CARBa (some)
Morrison Bros	AST adaptor	926, 927B	UN	no		
Morrison Bros	AST clock gauge	818, 818C, 818F, 818MET, 818MEF, 918F, 918FT, 918MEF, 918MET, 918T, 1018GM, 8181	UN	no		EVR CARBa (some)
Morrison Bros	Ball Valves	691BSS	E85	no		
Morrison Bros	Cap relief	779	UN	no		
Morrison Bros	Caps	305C	E85	no		EVR CARBa (some)
Morrison Bros	Caps-monitoring well	305XP, 305XPU	UN	yes (XPU)		EVR CARBa (some)
Morrison Bros	Cap-test well	178XAT, 178XB, 178XA, 305XA, 678XA	UN	no		
Morrison Bros	Clock Gauge with Alarm	918	E85	no		
Morrison Bros	Clock Gauges	818	E85	no		
Morrison Bros	Combination Vent/Overfill Alarm	922	E85	no		
Morrison Bros	Diffuser	539TO, 539TC	E85	no		EVR CARBa (some)
Morrison Bros	Diffuser	539, 539EXT, 539TC, 539TO	UN	no		EVR CARBa (some)
Morrison Bros	Double Tap Bushing	184	E85	no		
Morrison Bros	Drop Tubes	419A	E85	no		
Morrison Bros	Drop tubes	275, 419, 419SOS	UN	no		EVR CARBa (some)
Morrison Bros	Emergency Vents	244	E85	yes	yes	EVR CARBa (some)
Morrison Bros	Expansion Relief Valve	076DI, 078DI	E85	no		
Morrison Bros	External Emergency Valves	346DI, 346FDI, 346SS, 346FSS	E85	no		
Morrison Bros	Extractor pipe cap	578, 578P	UN	no		
Morrison Bros	Extractors	560/561/562/563	E85	no		
Morrison Bros	Fill cap	178, 178DT, 179, 179CI, 179M, 179MCI, 180M, 305CU, 379, 405C	UN	no		EVR CARBa (some)
Morrison Bros	Fill cap and adaptor	307	UN	no		
Morrison Bros	Fill swivel adaptor	305SA	UN	no		
Morrison Bros	Flame Arrester	351S	E85	no		
Morrison Bros	Float Vent Valves	317	E85	no		
Morrison Bros	Frost Proof Drain Valve	128DIS	E85	no		
Morrison Bros	Indicator paste	490G, 490W, SAR-GEL	UN	no		
Morrison Bros	In-Line Check Valve	958	E85	no		
Morrison Bros	Internal Emergency Valves	272DI, 72HDI	E85	no		
Morrison Bros	Interstitial sensor	918TCPS, 924LS	UN	no		
Morrison Bros	Manholes	318, 318L, 318TM, 318VR, 318XA, 418, 418L, 418TM, 418XA, 418XAP, 418XAH, 418XAW, 418LC, 424, 519, 524, 524H	UN	no		

Company	Product	Model	E%	UL Listed	UL listed for this fuel	Other Approval
Morrison Bros	Mechanical gauge	1018GM	UN	no		
Morrison Bros	Overfill Alarm	918TCP	E85	no		
Morrison Bros	Overfill Prevention Valve	9095A-AV, 9095SS	E85	no		
Morrison Bros	Overfill Prevention Valve	9095AA, 9095GBT	E85	no		
Morrison Bros	Pressure Vacuum Vent	948A	E85	yes	yes	
Morrison Bros	Probe cap and adaptor	307P	UN	no		
Morrison Bros	Solenoid Valves (3" Must be all Teflon version)	710SS	E85	no		
Morrison Bros	Spill Containers	515/516/517/518	E85	no		EVR CARBa (516)
Morrison Bros	Strainer	285	E85	no		
Morrison Bros	Strainer	284B, 284S, 285AL, 285DI, 285FDI, 286, 286FDI, 286U	UN	no		
Morrison Bros	Swing Check Valves	246ADI, 246DRF	E85	no		
Morrison Bros	Tank gauge	618	UN	no		
Morrison Bros	Tank Monitor Adaptor and Cap (	305XPA	E85	no		
Morrison Bros	Vapor Recovery Adaptor	323	E85	no		EVR CARBa
Morrison Bros	Vapor Recovery Caps	323C	E85	no		
Morrison Bros	Vent-double outlet (small UST)	155	E85	no		
Morrison Bros	Vent-double outlet (small UST)	155S, 155FA	UN	no		
Morrison Bros	Vent-pressure vacuum	548, 748, 749	E85	no		
Morrison Bros	Vent-updraft	354	E85	no		
Morrison Bros	Vent-updraft	354T	UN	no		
Morrison Bros		571, 571P	UN	no		
National Environmental Fiberglass	Sumps-tank	All	E85	yes	no	EVR CARB
National Environmental Fiberglass	Sumps-transition	All	E85	yes	no	EVR CARB
National Environmental Fiberglass	Sumps-dispenser	All	E85	yes	no	EVR CARB

Company	Product	Model	E%	UL Listed	UL listed for this fuel	Other Approval
Above Ground Equipment						
OPW	Balance Adaptor	28CS	E25	no		
OPW	Breakaway	66V-0492	E85	yes	yes	
OPW	Breakaway	66V-030RF	E25	yes	yes	
OPW	Breakaway	66V-0300, 66RB-2000, 68EZR-7575, 66REC-1000, 66SB-7575, 66SB-1010, 66CAS-0300, 66ISU-5100, 66ISB-5100, MFVA, 66CLP-5100, 66CSU-5200	E10	yes	yes	
OPW	nozzle	21GE-0992	E85	yes	yes	
OPW	Nozzle	11AP-0100-E25, 11AP-0300-E25, 11AP-0400-E25, 11AP-0900-E25, 11BP-0100-E25, 11BP-0300-E25, 11BP-0400-E25, 11BP-0900-E25	E25	yes	yes	
OPW	Nozzle	11AP / 11BP Series	E10	yes	yes	
OPW	Swivel	241TPS-75RF	E25	yes	yes	
OPW	Swivel	36S series, 241TPS series, 20S series, 45 series	E10	yes	yes	
OPW	Swivel	241TPS-0492	E85	yes	yes	
OPW	Emergency shear valve	10 series	E100	yes	no	
OPW	Vapor shear valve	60VS	E100	yes	no	EVR CARBa
AST Equipment						
OPW	AST anti-siphon valve	199ASV	E85	yes	no	
OPW	AST ball valve	21BV SS	E85	yes	no	
OPW	AST check valve	175, 1175	E85	no	no	
OPW	Drop tube	61FT	E25	no	no	EVR CARBa
OPW	AST emergency shut off valve	178S	E85	no	no	
OPW	AST emergency vent	201, 202	E85	yes	no	
OPW	AST emergency vent	301	E86	yes	no	EVR CARBa
OPW	AST mechanical gauge	200TG	E85	yes	no	EVR CARBa
OPW	AST overfill prevention valve	61fSTOP A or M versions	E85	yes	no	EVR CARBa
OPW	AST overfill prevention valve	61ƒSTOP	E25	yes	no	
OPW	AST pressure vacuum vent	523V, 623V	E100	yes	no	
OPW	AST solenoid valve	821	E25	yes	no	
OPW	AST spill container	211-RMOT, 331, 332	E85	yes (ulc	no	EVR CARBa
OPW	AST swing check valve	all	E85	no	no	
OPW	AST tank alarm	444TA	E85	no (ETL	no	
OPW	AST vapor adaptor	1611AVB-1625	E85	no		
OPW	AST vapor cap	1711T-7085-EVR, 1711LPC-0300	E85	no		

Company	Product	Model	E%	UL Listed	UL listed for this fuel	Other Approval
UST Equipment						
		Caps and adaptors				
OPW	Fill adaptor-top	633T, 633TC	?	yes	no	
OPW	Fill-swivel adaptor	61SALP-MA, 61SALP-1020-EVR	E85	yes	no	CARB EVR
OPW	Vapor swivel adaptor	61VSA	?	yes	no	CARB EVRa
OPW	Fill-swivel adaptor (vapor)	61VSA-MA, 61VSA-1020-EVR	E85	yes	no	CARB EVR
OPW	Fill cap-side	62TT	?	yes	no	
OPW	Fill adaptor-side	61AS	?	yes	no	
OPW	Vapor adaptor	1611AV, 1611AVB	E100	yes	no	CARB EVR
OPW	Vapor Cap	1711T	E85	yes	no	CARB EVR
OPW	Monitoring well probe cap	62M, 116M	E100	yes	no	
OPW	Monitoring well probe cap	62M-MA	E85	yes	no	CARB EVR
OPW	Monitoring well cap kit	634TTM, 62PMC	?	yes	no	
OPW	Monitoring test well	61SPVC	?	no		
		Extractors, Manholes, Multi-ports				
OPW	Extractor fittings and plug	233, 233VP	E85	no		CARB EVR
OPW	Multi-port spill containment	411, 511, 521, Fiberlite,	E100	no		CARB EVR
OPW	Jack screw	71JSK	E85	no		
OPW	Jack screw	61JSK	?	no		
OPW	Face seal adaptor (threaded riser adaptor)	FSA-400	?	no		CARB EVR
OPW	Manhole	Conquistador, Fiberlite, 104AOW-1200, 104C,	?	no		
		Overfill Prevention				
OPW	Overfill prevention valve	61SOM-412C-EVR, 61SOCM-4000, 71SO, 71SO-T, 71SOM	E85	no		CARB EVR
OPW	Overfill prevention valve	61SOC-4001, 61SOC-4011, 61SOP-4002, 61SOP-4012	E10	no		
OPW	Float kit	61SOK-0001	E10	no		
OPW	Ball float vent valve	21BV, 53VML, 30MV	E85	no		
OPW	Drop tube	61T, 61TC, 61TCP	E10	no		
OPW	Drop tube	61TSS	E85	no		CARB EVR
OPW	Spill container (bucket)	1-2100, 1SC-2100, EDGE	E100	yes	no	CARB EVRa
OPW	Spill container (bucket)	1-2105, 1-2200, 101-BG2100	E100	yes	no	
OPW	Tank bottom protectors	6111, 61TP	E10	no		
		Check Valve, Flexible Connectors, Vents				
OPW	Flexible connectors	All	E100	yes	no	SA
OPW	Check valve	70, 70S	E85	yes	no	
OPW	Pressure vacuum vent	523V, 623V	E85	yes	no	
OPW	Pressure vacuum vent	23	?	yes		
OPW	Vent	514, 515	?	?		
		Sumps				
OPW	Dispenser sumps	FlexWorks	E85	yes	no	
OPW	Tank sumps	Fiberlite, FlexWorks	E85	yes	no	
OPW	Transition sumps	FlexWorks	E85	yes	no	
OPW	Sump accessories	FlexWorks	E85	yes	no	

Manufacturer	Product	Model	E%	UL Listed	UL listed for this fuel	Other Approval
Petroleum Containment	Sump-dispenser	CLE, DCL, EZ-PLUMB, MVR	?	no		
Petroleum Containment	Sump-tank	4200	E100	no		
Petroleum Containment	Sump-transition	all	?	no		
Pneumercator	Magnetostrictive probe	MP450S, MP451S, MP452S, MP461S, MP462S, MP463S, MP464S MP550S, MP551S, MP552S, MP561S, MP562S, MP563S, MP564S	E100	yes	no	
Pneumercator	Leak sensors	ES825-100F, ES825-100XF,ES825-100CF, ES825-200F, ES825-200XF ES825-300F, ES825-300XF,ES825-300CF, ES825-400F, ES825-400XF HS100D, HS100ND LS600LD, LS600S, LS610 RSU800-2, RSU801F, RSU810	E100	yes	no	
Pneumercator	Single/Multi-Point Level Sensors	LS600, LS600F4, LS600M, LS600W, LS600X	E100	yes	no	
Pneumercator	Mechanical Gauges	DR-1-10, P5, P14	E100	no	no	
S. Bravo Systems	Fiberglass Fittings	Series F, FF, FPE, FR, Retrofit-S, D-BLR-S, D-INR-S, FLX, FLX-INR, FPS, TBF	E100	yes	no	
S. Bravo Systems	Spill Buckets	B3XX	E100	yes	no	
S. Bravo Systems	Tank Sumps & Covers	B4XX	E100	yes	no	
S. Bravo Systems	Transition Sumps	B5XX, B6XX, B7XX, B8XX	E100	yes	no	
S. Bravo Systems	Under Dispenser Containment Sumps	B1XXX, 7XXX, B8XXX, B9XXX	E100	yes	no	
Vaporless Manufacturing	Leak detector	99LD-2000/2200/3000 without stainless steel tubing/fittings	E20	yes	no	
Vaporless Manufacturing	Leak detector	99LD-2000/2200/3000 with stainless steel tubing/fittings	E100	yes	no	
Vaporless Manufacturing	Overfill prevention valve	OPF-2/3 without stainless steeltubing/fittings	E20	yes	no	
Vaporless Manufacturing	Overfill prevention valve	OPF-2/3 with stainless steel tubing/fittings	E100	yes	no	

Manufacturer	Product	Model	E%	UL Listed	UL listed for this fuel	Other Approval
Veeder-Root	AST probe	Mag-FLEX	E15	yes	no	
Veeder-Root	Float kit	846400	E15	yes	no	
Veeder-Root	Magnostrictive probes	Mag Plus Probe for Alternative Fluids with Water Detection P/N 846391-1xx or -2xx, Inventory Only Mag Plus Probe for Alternative Fluids with Water Detection P/N 846391-3xx	E20	yes	no	
Veeder-Root	Magnostrictive probes	Mag Plus Probe for Alternative Fluids without Water Detection P/N 846391-4xx or -5xx, Mag Plus Probe for Alternative Fluids without Water Detection P/N 846391-6xx	E100	yes	no	
Veeder-Root	Magnostrictive probes	Mag-D Density Probe, MagPlus Leak Detection Probe, MagPlus Inventory Measuremeant Probe	E15	yes	no	
Veeder-Root	Mechanical line leak detect	Red Jacket FXV	E100	yes	no	
Veeder-Root	Phase separation float	Phase-2	E15	yes	no	
Veeder-Root	Sensor-dispenser and sump	Discriminating and Non Discriminating Dispenser Pans and Containent Sensors, Sump sensor (piping), Mag Sump Sensor, Stand-alone Dispenser Pan Sensor	E15	yes	no	
Veeder-Root	Sensor-dispenser and sump	Position Sensitive Interstitial Sensor	E85	yes	no	
Veeder-Root	Sensor-groundwater	Groundwater Sensor	E15	yes	no	
Veeder-Root	Sensor-tank	Discriminating Interstitial Sensor Double Wall Fiberglass, Interstitial Sensors for Fiberglass Tanks, Intersitial Sensors for Steel Tanks	E15	yes	no	
Veeder-Root	Sensor-tank	Discriminating Interstitial Sensor Double Wall Fiberglass, Interstitial Sensors for Fiberglass Tanks-High Alcohol, Interstitsial Sensors for Steel Tanks-High Alcohol, MicroSensor (steel tanks, fill riser)	E85	yes	no	
Veeder-Root	Sensor-vapor	Vapor Sensor	E15	yes	no	
Western Fiberglass	Co-Flex piping	all	E100	yes	no	
Western Fiberglass	Cuff fittings	all	E100	no		
Western Fiberglass	Sumps (tank, dispenser, transition, vapor, vent)	all	E100	yes	no	
Western Fiberglass	Co-flow hydrostatic Monitoring systems	all	E100	no		

Appendix F. Methods to Identify Underground Storage Tanks

http://www.steeltank.com/Portals/0/TTNewsletter/September2012/TankTalk_September2012.pdf

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:

Finding a label is very helpful!

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.
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

Liquid reservoir

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.

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Appendix G. Pipe Dope Diagram

This diagram shows areas at a refueling station where pipe dope/pipe thread sealant might be used.

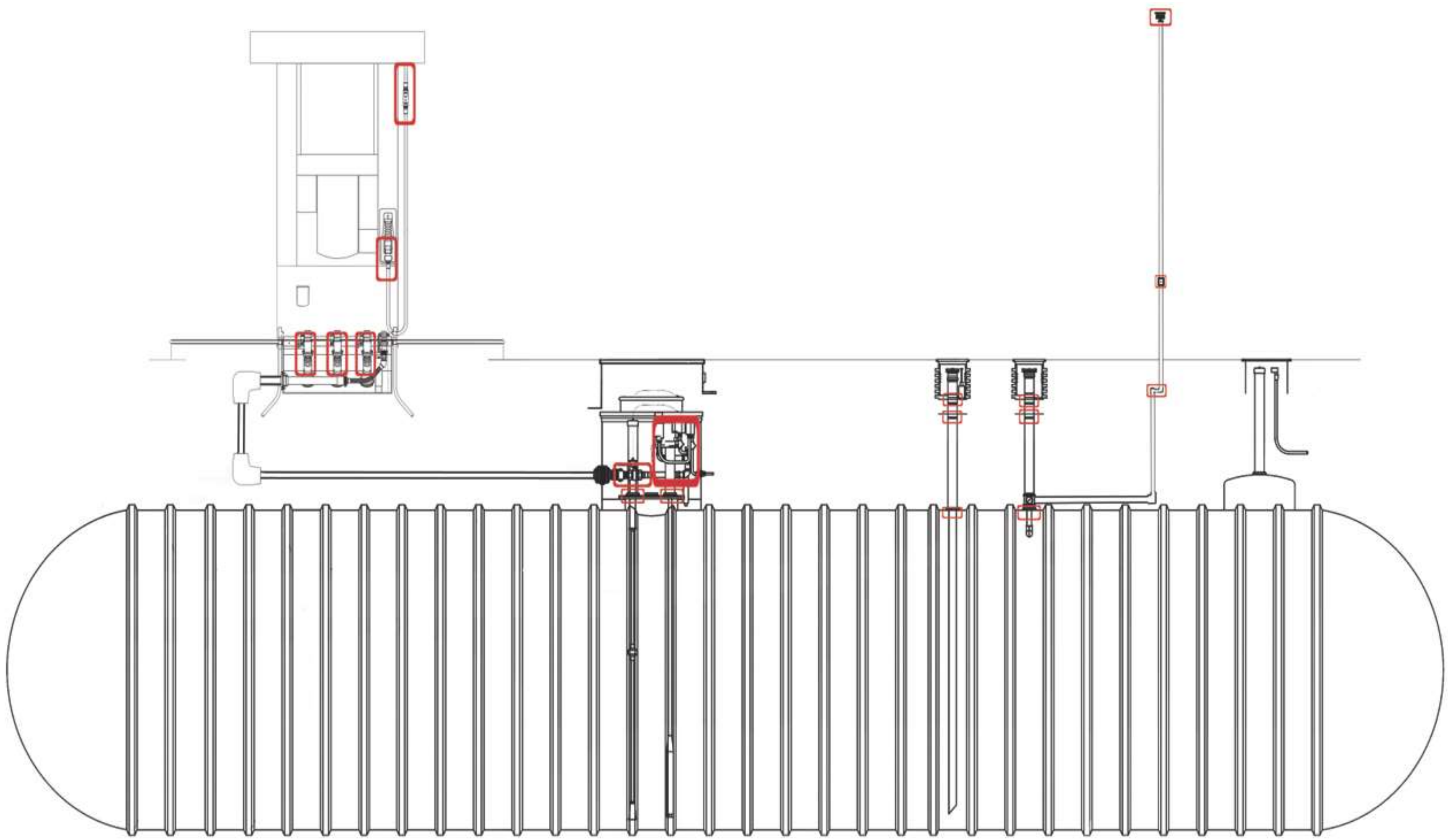

Diagram provided by Source North America, a fueling equipment distributor

Attachment 3

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ORNL/TM-2012/182

Analysis of Underground Storage Tank System Materials to Increased Leak Potential Associated with E15 Fuel

July 2012

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ANALYSIS OF UNDERGROUND STORAGE TANK SYSTEM MATERIALS TO INCREASED LEAK POTENTIAL ASSOCIATED WITH E15 FUEL

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CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

ASTM	American Society for Testing and Materials
DOE	Department of Energy
E10	Gasoline containing 10% ethanol by volume
E15	Gasoline containing 15% ethanol by volume
E50	Gasoline containing 50% ethanol by volume
E85	Gasoline containing 85% ethanol by volume
EISA	Energy Independence and Security Act
EPA	U. S. Environmental Protection Agency
F-HDPE	Fluorinated high density polyethylene
Fuel C	A gasoline representative test fuel composed of 50%vol. toluene and 50%vol. isooctane
FRP	Fiber-reinforced plastic
FFV	Flex-Fuel Vehicle
HDPE	High density polyethylene
HSP	Hansen Solubility Parameter
ISO	International Organization for Standardization
LG	Leaded gasoline
MIC	Microbial-induced corrosion
MTBE	Methyl tertiary butyl ether
NBR	Acrylonitrile (or nitrile) butadiene rubber
NREL	National Renewable Energy LaboratoryOBP DOE Office of Biomass Program
ORNL	Oak Ridge National Laboratory
PBT	polybutylene terephthalate
PEI	Petroleum Equipment Institute
PET	polyethylene terephthalate
PP	polypropylene
PTFE	polytetrafluoroethylene
PCV	polyvinyl chloride
PVDF	polyvinylidene fluoride
RFS	Renewable Fuel Standard
S	Siemens (unit of electrical conductivity)
SAE	Society of Automotive Engineers
SBR	Styrene butadiene rubber
UL	Underwriters Laboratories
UST	Underground Storage Tank
VS	Volume swell
VTP	DOE Vehicle Technologies Program

FOREWARD

It is not the purpose of this report to define the acceptable limits of material performance or to rate individual materials. Rather, the purpose of this study was to assess critical property changes (volume, hardness, mass, etc.) for representative classes of materials used in underground storage tank systems with exposure to E15.

ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

E.1 Background

The Energy Independence and Security Act (EISA) of 2007 was an omnibus energy policy law designed to move the United States toward greater energy security and independence.[1] A key provision of EISA modified the Renewable Fuel Standard (RFS) which requires the nation to increase the volume of renewable fuel blended into transportation fuels from 7.5 billion gallons by 2012 to 36 billion gallons by 2022. Ethanol is the most widely used renewable fuel, and increasing the ethanol content in gasoline to 15% offers a means of getting significantly closer to the 36 billion gallon goal. In March 2009, Growth Energy (a coalition of ethanol producers and supporters) requested a waiver from the United States Environmental Protection Agency (EPA) to allow the use of 15% ethanol in gasoline.[2] In response the US EPA granted two partial waivers that allow (but do not require) E15 in 2001 and newer light-duty vehicles. Prior to the waiver being granted, uncertainties arose as to whether the additional fuel ethanol (from 10% to 15%), would cause an increase in leaking of underground storage tank (UST) systems, which include not only the tank but also the piping and connecting hardware.

The USEPA Office of Underground Storage Tanks was interested in determining how many (of the nearly 600 thousand) federally regulated underground storage tank (UST) systems across the U.S. could have releases or other failures if the ethanol content in gasoline increases from 10 volume percent to 15 volume percent. To better assess the leak potential, the EPA commissioned a study at Oak Ridge National Laboratory to develop a means to determine the potential of changes in releases and other failures if E15 fuel is stored in UST systems. Part of this effort was to develop an approach to estimate likelihood of failures and approaches for mitigating consequences associated with these failures. Currently, the lack of availability of data is the most significant barrier that prevents EPA from being able to perform the analysis.

The initial approach was to develop and apply a probabilistic failure analysis tool based on expert elicitation to estimate how many more releases would occur if E15 replaced E10 in regulated UST systems. The key resources needed to establish this tool were opinions provided by industry and regulatory experts to quantify (most likely values and uncertainties) the critical variables that impact failure likelihood estimates. Unfortunately, over the course of the investigation, it was discovered that there was no information on the performance of existing UST systems with E15 and the state/industry experts were unable to speculate on E15's impact to UST systems. As a result, the project objective was redirected to address the added leak potential (or incompatibility) of UST system materials when switching from E10 to E15. The data used to make this assessment were obtained primarily from the ORNL intermediate blend compatibility study.[3] The ORNL study included metal and polymeric materials typically used in UST systems, and these materials were evaluated in aggressive test fuel formulations representing E0, E10, E15, and E25. Later studies investigated material compatibility to E50 and E85.

The elastomeric and metallic materials were exposed to Fuel C, CE10a, and CE17a test fuels, which are based on standard fluids described by the American Society for Testing and Materials (ASTM) and the Society of Automotive Engineers (SAE) for use in fuel-material compatibility studies. SAE Reference Fuel C (also known as Fuel C) is a 50:50 mix of isooctane and toluene, and was used as the base fuel in the ethanol-blended test fuels, where it is represented by the "C" nomenclature. The ethanol was made to an aggressive formulation per SAE J1681,[4] and is indicated by the letter "a". CE17a was chosen to represent E15 since fuel surveys have shown that the actual ethanol content in gasoline can vary by ±2%. Plastic materials were only evaluated in Fuel C and CE25a. Therefore it was necessary to assess E10 and E15 performance through an interpolation process using the known solubility parameters for these materials and their performance in Fuel C and CE25a.

E.2 Experimental Approach

The approach was to use the swell, mass change, and hardness data from the ORNL study to assess the risk of moving from E10 to E15. An extensive literature review was undertaken which was initially based on the EPA 22 state study[5] to accurately identify materials used in UST systems. The system components of interest included tanks, piping, sealants, and joined couplings. Piping was divided into three areas: metal, flexible plastic, and rigid fiberglass-reinforced plastic. Because most of the installed piping systems are plastic, these systems are discussed in greater detail. For the elastomeric and metallic materials, analysis was performed using results obtained from exposure to test fuels containing 10% and 17%. On the other hand, plastic materials were only exposed to Fuel C and CE25a. In order to estimate the level of swell (or solubility) for representative plastics in E10 and E15, an analysis was performed using the results obtained from the Fuel C and CE25a exposures and incorporating solubility theory. An estimate of the volume swell (at E10 and E15) was made by interpolating the results for Fuel C and CE25a.

E.3 Discussion and Analysis

Underground Storage Tanks and Piping Made of Steel

For metal-based tanks and piping, corrosion via oxidation of the metal can directly lead to the creation of a leak. Another potential concern with higher ethanol content is the initiation of a new phase of corrosion, such that previously passivated areas (rust plugs) are attacked and removed, thereby leading to potential leaks. All metal USTs are composed of mild-carbon steel and around 98% of metal piping is also mild-carbon steel.[5] The other metal of interest is aluminum since aluminum parts are used on submersible turbine pumps, connections and dispenser nozzle. The ORNL intermediate-blend study included both steel and aluminum; the study showed negligible corrosion of either steel or aluminum immersed in either CE10a or CE17a.[3] However, the test conditions may not accurately reflect actual field situations, whereby the metal structure may be under stress or exposed to fuel that has become separated into two phases, one of which is aqueous. Both of these conditions (stress and exposure to aqueous liquid) are considered to be more conducive to corrosion. The specimens evaluated in the ORNL intermediate-blends study were not placed under stress, so the stress corrosion cracking potential of steel to either E10 or E15 cannot be ascertained.

Phase separation (of water) is another scenario that needs to be addressed. The level of water that can be dissolved into E15 is roughly twice the amount that can be dissolved in E10. Therefore, under identical conditions of phase separation (such as temperature excursions causing evaporation and condensation) E15 has the potential to generate twice the volume of aqueous phase than E10, which could translate to a higher corrosion (and therefore leak) potential. The presence of an aqueous phase is also a precondition for supporting microbial-induced corrosion (MIC), and if E15 has a higher potential for water formation, then MIC may also result in increased corrosion. If precautions are undertaken to keep water out of tanks, and stress corrosion cracking is not a factor, then the corrosion potential is minimized and E15 offers no added risk to metal corrosion than E10.

Underground Storage Tanks and Piping Made of Fiberglass-reinforced Plastic (FRP)

The other material used in the construction of USTs is fiberglass-reinforced plastic (FRP). FRP construction consists of initially placing an approximately 0.5mm thick layer of resin on a mandrel followed by adding an additional ~6mm layer of resin reinforced with fiberglass. The inner bare resin surface serves as the barrier layer to prevent fuel permeation and the fiberglass-reinforcement provides strength and elasticity. Some legacy designs also may incorporate a separate plastic film that was glued to the inside surface to provide a fuel-resistant barrier layer. The ORNL intermediate-blend materials compatibility study[3] had evaluated four resin types representative of those used in legacy and modern FRP UST construction. One resin was used extensively prior to 1990 and therefore may not have been designed for E10 compatibility. Two of the test resins were introduced during the 1990s (post-1990), during which time E10 was beginning to be used in the marketplace. The fourth resin type was a new advanced resin developed for improved resistance to ethanol fuels. These four resins were made into test coupons (with no added fiberglass) and exposed to test fuels of Fuel C and CE25a.

Because E15 and E10 test fuels were not used in this evaluation, it was necessary to estimate resin performance in E10 and E15 using the swelling data obtained from the Fuel C and CE25a exposures. This estimation was performed by interpolating the measured swelling data using the differences in the known total Hansen Solubility Parameters (HSPs) for the resins and test fuels. (This procedure is described in detail in Section 2.1.1.) The solubility parameter is based on the free energy of mixing and is useful in predicting the mutual solubility (and therefore swell) between liquids and solid hydrocarbon materials. The pre-1990 resin was severely damaged from exposure to CE25a, along with one of the post-1990 resins. The remaining post-1990 resin and the advanced resin type both remained intact after exposure to CE25a, but they did swell to over 20% from their original volume with addition of ethanol. However, interpolation of these results using the Hansen Solubility Parameters suggests that the additional swell achieved from E10 to E15 will be around 1.5% (which is low). It is also important to keep in mind that the addition of fiberglass reinforcement to any of these resins will prevent significant swelling and debonding of the composite structure, since the fibers themselves do not swell.

The ORNL intermediate-blend materials compatibility study later included three legacy FRP UST specimens for evaluation, but they were only exposed to Fuel C, CE50a, and CE85a. One sample had a green coloration and contained a separate plastic barrier liner glued to the inner resin layer. The other two samples were amber in appearance, and of typical construction which consisted of an inner resin-only layer which was surrounded by a 6mm thick layer of fiberglass-reinforced resin. The resin used in the green UST survived Fuel C exposure but was severely degraded following exposure to CE50a and CE85a. In each case, the glue holding the plastic liner to the resin surface had dissolved, but, the plastic liner was unaffected. Unfortunately, the plastic composition of the liner was unknown, making it impossible to assess compatibility to E10 and E15. This particular UST design may be uncommon since, of the over two dozen samples provided to ORNL, it was the only one which had a separate inner liner and green resin. The other two USTs did not experience noticeable degradation or swell associated with exposure to the CE50a and CE85a test fuels. Because the difference in HSPs for resin and ethanol-blended gasoline increases with decreasing ethanol content, these epoxy resins should be more soluble in E50 and E85 than for intermediate E10 and E15 levels. Therefore, it is expected that USTs composed of amber resins will be compatible with gasoline containing 10 and 15 percent ethanol.

As of 2009, rigid FRP piping makes up around 58% of all installed piping systems.[5] The technology and materials used in the manufacture of FRP tanks also applies to underground FRP piping systems as well. Therefore the compatibility of FRP piping systems should be the same or similar to FRP underground storage tanks.

Flexible Plastic Piping

As of 2009, flexible plastic piping is estimated to make up around 13% of all installed piping systems,[5] but many new systems employ flexible plastic piping since these systems are easier to install. As a result, the percentage of flexible piping is expected to grow relative to other piping systems over the next 10 years. Typical compositional arrangement of most flexible piping includes an inner barrier liner with a layer of reinforcement (to provide strength) and an outer cover. Many of the outer layers are not compatible with ethanol and are only added to provide exterior protection and strength. The primary inner layer provides chemical resistance and a survey of flexible piping systems shows that the most common inner permeation barrier material is polyvinylidene difluoride (PVDF). Other plastics used as permeation barriers are nylons and polyethylene terephthalate (PET). PVDF, PET, and several grades of nylon were evaluated in the ORNL intermediate-blends study along with the other plastic materials that were exposed to Fuel C and CE25a. As with the UST resins, the performance (volume swell) with exposure to E10 and E15 was estimated using the measured volume swelling for exposure to Fuel C and CE25a and the known HSPs for these materials. The resulting analysis indicates that flexible piping permeation barrier materials will not have added significant swell (less than 1%) when moving from E10 to E15. Therefore, the increase in risk associated with leaking when switching from E10 to E15 will be low.

Elastomers, Sealants, Couplings and Fittings

Couplings and fittings used to connect piping, the submersible turbine pump, and valves represent one of the highest potential locations for leaking in UST systems. There are two potential locations/sources of leaks associated with fittings. One is where the coupling attaches to the piping and the other one is at the fitting-to-fitting seal interface. In many (but not all) cases fluorocarbons are used as interfacial seals between fittings. Fluorocarbons have been shown to be compatible with ethanol and it is unlikely that a properly installed fluorocarbon elastomer will leak when exposed to either E10 or E15. For metal and some rigid FRP piping systems, pipe thread sealants may be employed to seal fittings via threaded attachments. Some legacy pipe thread sealants were shown to be incompatible with gasoline containing 10% aggressive ethanol and would clearly not be acceptable for E15 use either. Newer engineered products (such as fluoroelastomers) have been developed for ethanol-blended gasoline and these sealants have been shown to be compatible with gasoline containing up to 25% aggressive ethanol.

For flexible piping systems a stainless steel coupling is normally compression fitted to the outer surface of the pipe so the leak potential is very low for properly installed couplings. In contrast fittings attached to rigid FRP systems typically utilize an adhesive to maintain a seal between the coupling and the outer pipe wall. Adhesives designed for fuel ethanol use are available. This material type was not included in the ORNL intermediate-blend study and its performance in either E10 or E15 was not ascertained. For rigid FRP pipe-to-pipe joining, fiberglass reinforced resin is also frequently applied to the joined ends in a butt-and-wrap arrangement. Since the wrapping is composed of fiberglass-reinforced resin similar to the piping itself, the leak potential with exposure to E15 for a properly installed joint should be low since the increase of swell associated with E15 (relative to E10) is estimated to be small (1.5%). It is important to note that the joined sections have lower structural integrity (mechanical strength) than the pipe as a whole, but should not leak as a primary result of the fuel exposure.

E.4 Conclusions

In general, the materials used in existing UST infrastructures would not be expected to exhibit compatibility concerns when moving from E10 to E15. The volume swell and hardness results of tested polymer materials were not significantly different when exposed to either CE10a or CE15a, although significant changes were observed when these fuels are compared to the E0 formulation. The indication is that UST systems were affected by switching from E0 to E10. However, since E10 and E15 produce similar results, compatibility is not expected to be altered noticeably when moving from E10 to E15. The metallic materials showed negligible corrosion as long as phase separation did not occur. If an aqueous phase is formed, then the possibility for aggressive corrosion exists. Therefore, the proper application of biocides and water monitoring is likely to be more critical at preventing corrosion for gasoline fuel containing ethanol.

1. INTRODUCTION

1.1 HISTORY AND BACKGROUND

In the United States oil dependence is driven primarily by the transportation sector. Transportation accounts for 69% of the total oil consumption in the United States, and the industry itself is around 90% oil dependent (and the remainder being natural gas, propane, electric and ethanol).[6] In 2008 the average daily oil consumption equivalent used the U.S. transportation sector was approximately 14 million barrels. This rate is projected to increase to around 16 million barrels per day by 2025.[7] Currently, the bulk of our oil usage is provided by other countries as foreign oil imports and makes up around 57% of the total oil usage.[8] This dependency impacts our nation's security, since our oil supply is determined partly by other countries, some of whom are not friendly to the United States. Foreign disruption has been shown to negatively impact the nation's economy and makes the U. S. more vulnerable during times of international crisis.

The Energy Independence and Security Act (EISA) of 2007 was enacted by Congress to move the nation toward increased energy independence by increasing the production of renewable fuels to meet its transportation energy needs. The law establishes a new renewable fuel standard (RFS) that requires the nation to use 36 billion gallons annually (2.3 million barrels per day) of renewable fuel in its vehicles by 2022. Ethanol is the most widely used renewable fuel in the United States, and its production has grown dramatically over the past decade. According to EISA and RFS, ethanol (produced from corn as well as cellulosic feedstocks) will make up the vast majority of the new renewable fuel requirements. However, ethanol use limited to E10 and E85 (in the case of flex fuel vehicles or FFVs) will not meet this target. Even if all of the E0 gasoline dispensers in the country were converted to E10, such sales would represent only about 15 billion gallons per year.[9] If 15% ethanol, rather than 10% were used, the potential would be up to 22 billion gallons. The vast majority of ethanol used in the United States is blended with gasoline to create E10, that is, gasoline with up to 10 % ethanol. The remaining ethanol is sold in the form of E85, a gasoline blend with as much as 85% ethanol that can only be used in FFVs. Although the U. S. Department of Energy (DOE) remains committed to expanding the E85 infrastructure, that market will not be able to absorb projected volumes of ethanol in the near term. Given this reality, DOE and others have begun assessing the viability of using intermediate ethanol blends as one way to transition to higher volumes of ethanol.

In October of 2010, the U. S. Environmental Protection Agency (EPA) granted a partial waiver to the Clean Air Act allowing the use of fuel that contains up to 15% ethanol for the model year 2007 and newer light-duty motor vehicles. This waiver represents the first of a number of actions that are needed to move toward the commercialization of E15 gasoline blends. On January 2011, this waiver was expanded to include model year 2001 light-duty vehicles, but specifically prohibited use in motorcycles and off-road vehicles and equipment.[2]

UST stakeholders generally consider fueling infrastructure materials designed for use with E0 to be adequate for use with E10, and there are no known instances of major leaks or failures directly attributable to ethanol use. It is conceivable that many compatibility issues, including accelerated corrosion, do arise and are corrected onsite and, therefore do not lead to a release. However, there is some concern that higher ethanol concentrations, such as E15 or E20, may be incompatible with current materials used in standard gasoline fueling hardware. In the summer of 2008, DOE recognized the need to assess the impact of intermediate blends of ethanol on the fueling infrastructure, specifically located at the fueling station. This includes the dispenser and hanging hardware, the underground storage tank, and associated piping.

The DOE program has been co-led and funded by the Office of the Biomass Program and Vehicle Technologies Program with technical expertise from the Oak Ridge National Laboratory (ORNL) and the National Renewable Energy Laboratory (NREL). The infrastructure material compatibility work has been supported through strong collaborations and testing at Underwriters Laboratories (UL). ORNL performed a compatibility study investigating the compatibility of fuel infrastructure materials to gasoline containing intermediate levels of ethanol. These results can be found in the ORNL report entitled *Intermediate Ethanol Blends Infrastructure Materials Compatibility Study: Elastomers, Metals and Sealants* (hereafter referred to as the ORNL intermediate blends material compatibility study).[3] These materials included elastomers, plastics, metals and sealants typically found in fuel dispenser infrastructure.

The test fuels evaluated in the ORNL study were SAE standard test fuel formulations used to assess material-fuel compatibility within a relatively short timeframe. Initially, these material studies included test fuels of Fuel C, CE10a, CE17a, and CE25a. The CE17a test fuel was selected to represent E15 since surveys have shown that the actual ethanol upper limit can be as high as 17%. Later, CE50a and CE85a test fuels were added to the investigation and these results are being compiled for a follow-on report to be published in 2012. Fuel C was used as the baseline reference and is a 50:50 blend of isooctane and toluene. This particular composition was used to represent premium-grade gasoline and was also used as the base fuel for the ethanol blends, where it is denoted by “C” in the fuel name. The level of ethanol is represented by the number following the letter E. Therefore a 10% blend of ethanol in Fuel C is written as CE10a, where “a” represents an aggressive formulation of the ethanol that contains water, NaCl, acetic and sulfuric acids per the SAE J1681 protocol.

1.2 ETHANOL COMPATIBILITY AND SOLUBILITY

Pure ethanol, by itself, is not generally considered corrosive toward most metallic materials; however, as a polar molecule, ethanol will be more susceptible to having compatibility issues with both metals and polymers due to (1) increased polarity relative to gasoline, (2) adsorption of water, and (3) a higher solubility potential relative to gasoline. The first two factors are relevant to metals and alloys, while the latter affects primarily polymers. The corrosion potential is directly related to the electrical conductivity of a solution. Kirk[10] measured the electrical conductivity for gasoline as a function of ethanol concentration and dissolved water level. A plot of the electrical conductivity as a function of ethanol concentration in gasoline is shown in Fig. 1. As shown in the figure, the electrical conductivity is low for ethanol-blended gasoline increases marginally with ethanol concentrations up to 20%. However, although the conductivity numbers are low, relatively speaking, E15 is 10 times more conductive than E10. As the ethanol concentration increases from 20% to 50%, the corresponding conductivity increases by almost two orders of magnitude. As a result, metal corrosion becomes a significant concern for gasoline blends containing 50% or more ethanol.

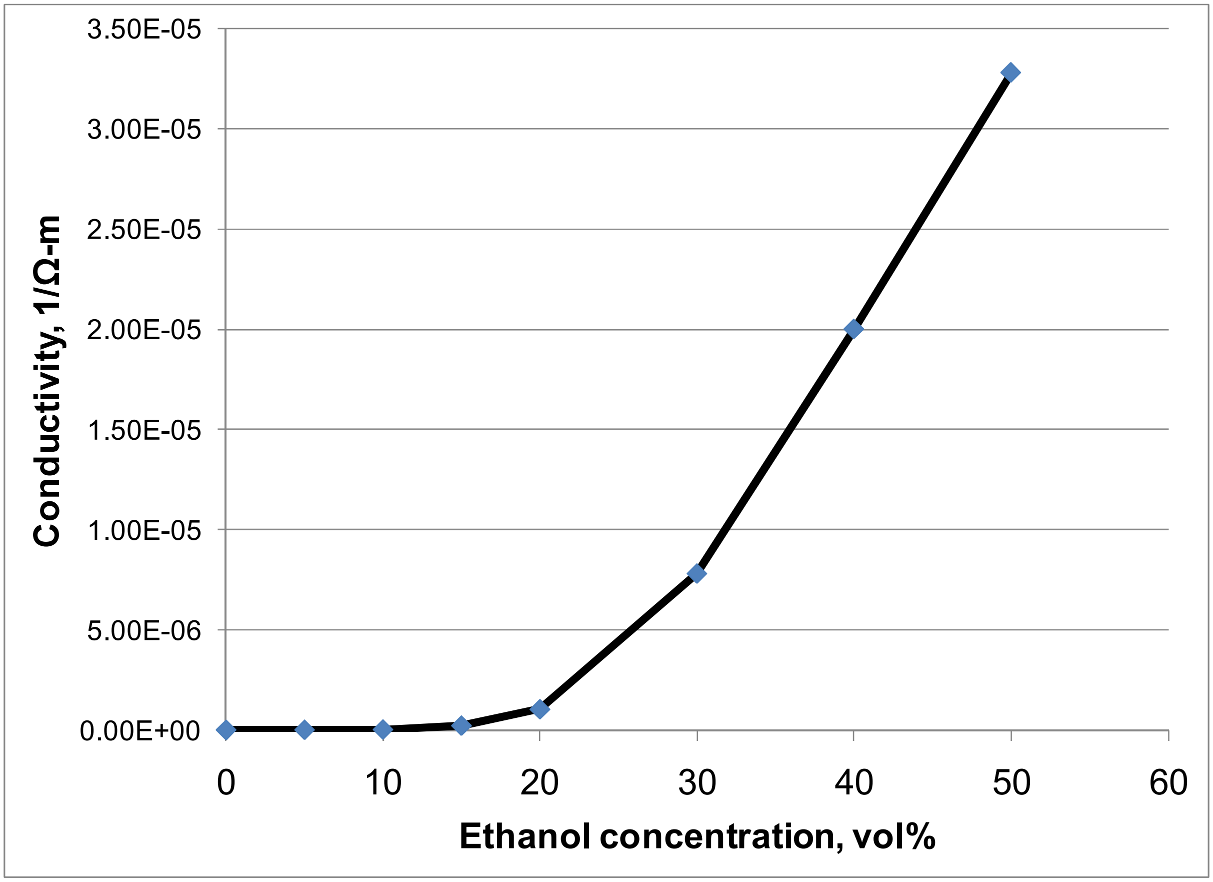

Fig. 1. Electrical conductivity of gasoline as a function of ethanol concentration. *Source:* D. W. Kirk, Fuel 62, 1512–1513 (December 1983).

The level of dissolved water also has a pronounced effect. The results in Fig. 2 show the effect of water concentration in addition to ethanol level. In this figure, the electrical conductivity (listed as S in Fig. 2 and 1/Ω in Fig. 1) is plotted for blends containing 5, 10, 15, 20, 30 and 40% ethanol by volume. As the level of ethanol increases, the conductivity curves for each blend increase as well, and for each set of curves the conductivity also increases with the level of dissolved water. In fact, the water solubility limit increases the conductivity by an order of magnitude when going from E10 to E15. In addition, water itself is a solvent for NaCl and acids, which can lead to even higher rates of corrosion.

Ethanol also affects the material-fluid mutual solubility associated with the fuel blend, which is an important parameter for gauging the compatibility of fuels with polymers. The influence of the solubility parameter is complex; however, solvents and solutes having similar solubility parameters will have a greater affinity for permeation and dissolution.[11] The solubility parameter, or more specifically, the difference in parameters between the solute (polymer) and solvent (fuel), is important in predicting and understanding the solubility of a system. As the solubility parameter values for the solute and solvent converge, the propensity for the two components to mix (or allow the solvent to permeate into the solute) becomes thermodynamically possible. For an elastomer or plastic, this effect will be an increase in swelling of the polymer.

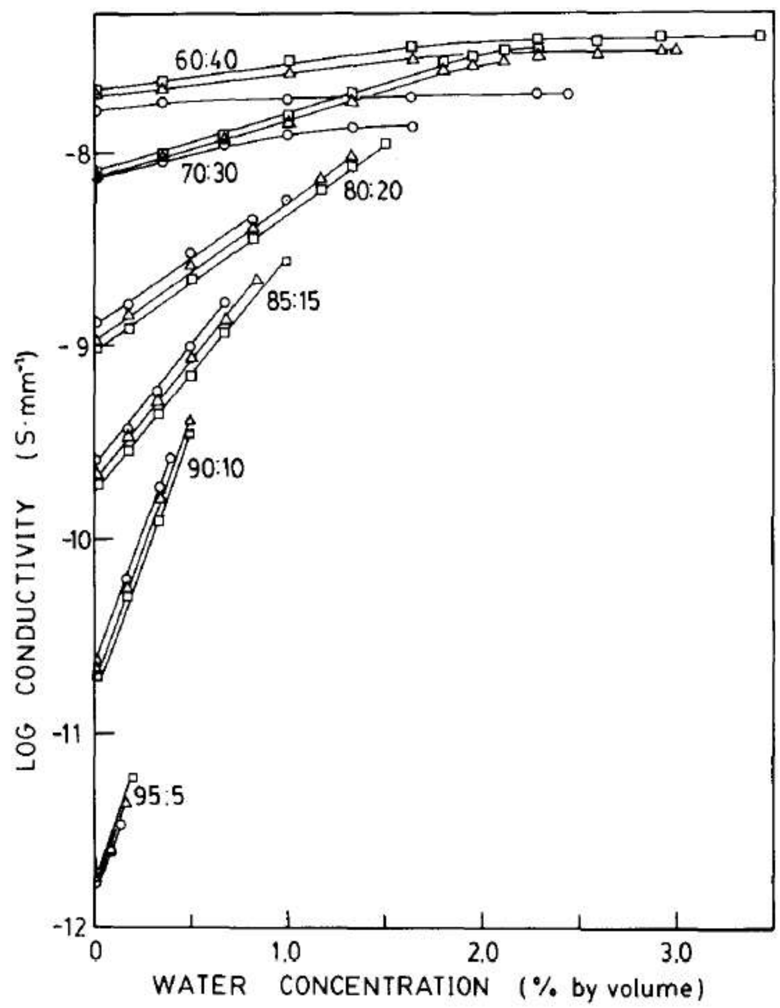

Fig. 2. Electrical conductivity of gasoline as a function of ethanol and water content. *Source:* D. W. Kirk, Fuel 62, 1512–1513 (December 1983).

A simplified representation of solubility as a function of ethanol concentration in gasoline is shown in Fig. 3. The wide shaded horizontal band in the chart represents the range of solubility parameters, expressed as total Hansen Solubility Parameter (HSP) for many dispenser polymers, especially elastomers. Epoxies, such as those used as the matrix materials for underground storage tanks, have a total HSP value around $24(MPa)^{1/2}$, which is noticeably higher than the HSP for polymers. The implication for UST resins is that the solubility of the epoxy in the fuel will be highest for gasoline containing around 80% ethanol.

As the ethanol concentration increases from zero to 15%, it effectively raises the solubility parameter and approaches the solubility parameter of most dispenser polymers. Therefore, the propensity for the fuel to permeate into and dissolve polymeric components is enhanced. It is important to note that, in reality, solubility is determined from multiple thermodynamic factors, and that the highest level of mutual solubility for a given polymer does not necessarily match precisely with the theoretically-derived parameters which have been simplified in Fig. 3. Standard gasoline fuel delivery systems contain elastomeric materials having excellent compatibility and stability with hydrocarbon fuels. However, the ethanol molecule is relatively small and highly polar due to the –OH group. In addition the tendency to introduce hydrogen bonding is high. These features enable ethanol's permeation into and interaction with the elastomer structure, which can result in swelling and softening of elastomers. Another negative feature associated with permeation is that soluble components, especially plasticizers added to impart flexibility and durability in the elastomer, may be leached out, thereby affecting the mechanical properties of the compounded elastomer component and degrading the ability of the component to perform its intended function.

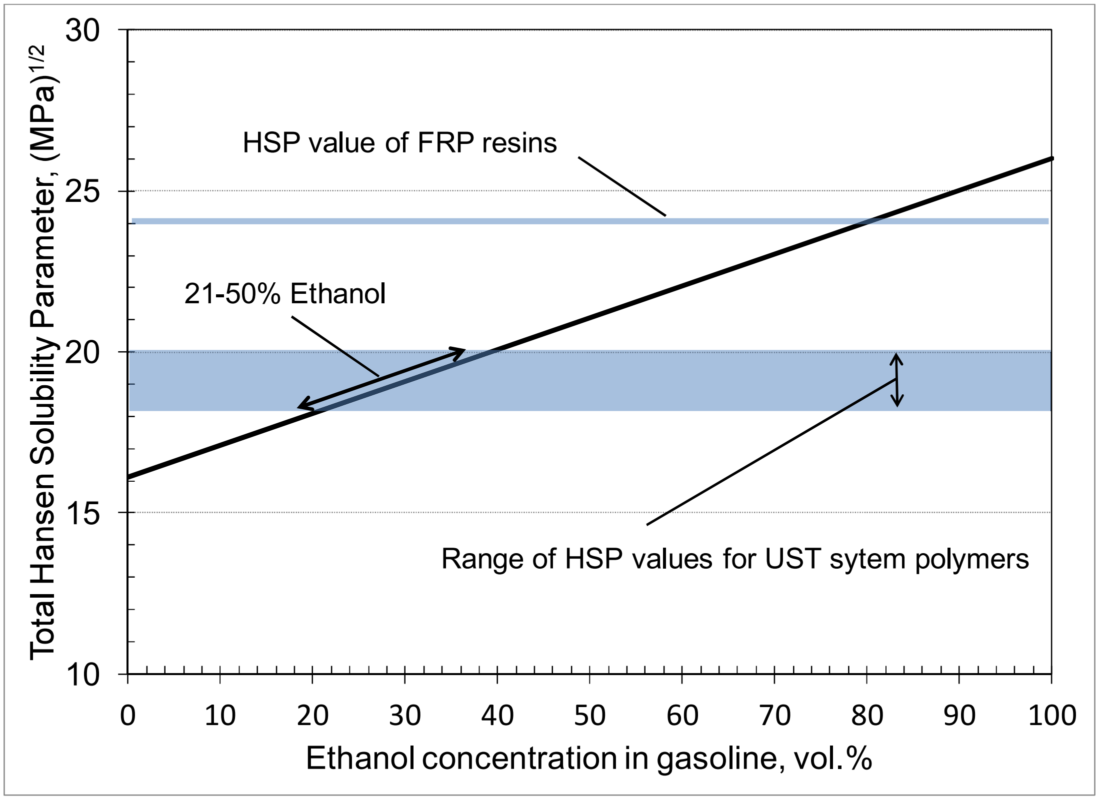

Fig. 3. Total Hansen Solubility Parameter as a function of ethanol concentration. The lower blue horizontal band represents the solubility range of many UST system elastomer and plastics. The upper blue band is representative of FRP resins.

Several studies have been undertaken to evaluate the compatibility of ethanol with engine materials, especially those used in fuel system components such as pumps, and much of this work has recently focused on the intermediate E15, E20, and E25 blends.[12–15] However, little work had been reported on the compatibility of these fuels to standard fuel dispenser materials, which subsequently became the focus of the ORNL-led materials compatibility study noted earlier.

1.3 FUELING DISPENSER MATERIALS AND ETHANOL COMPATIBILITY STUDY

As part of the ORNL intermediate-blend materials compatibility study, an extensive survey was performed to identify to the extent possible all materials used in the fueling dispenser infrastructure. A list of the materials identified and evaluated in the ORNL study is shown in Table 1, where those materials identified by the authors of this report for use in UST systems are highlighted. Most of the plastic materials are used as structural components in FRP tanks and in both FRP and flexible piping systems. The elastomeric materials most identified as seals and gaskets are Viton™ and Dyneon™ brand fluorocarbons, but NBR and rubberized cork may still be in use in legacy tank probes and overfill devices. Steel is used in tanks and piping and aluminum is also used in some applications, such as drop tubes.

It is important to note that while the researchers were able to discover and identify an extensive list of relevant materials over the course of this and other studies, it is possible, if not probable, that other materials used in legacy, and some new infrastructure systems, were not included in this investigation.

Table 1. List of materials evaluated in intermediate ethanol blends compatibility study. (Materials identified as being used in UST systems are highlighted.)

Metals/Alloys	Elastomers	Plastics	Sealants
304 stainless steel	**Viton™ fluorocarbon**	**High density polyethylene (HDPE)**	**PTFE-based sealants (two-types) with and without Teflon™ tape**
1020 carbon steel	**Dyneon™ fluorocarbon**	Fluorinated HDPE	
1100 aluminum	**Acrylonitrile butadiene rubber (NBR)**	Polypropylene (PP)	
Cartridge brass	Silicone rubber	Polyoxymethylene	
Phosphor bronze	Fluorosilicone rubber	**Nylon**	
Nickel 201	Neoprene rubber	**Polyvinylidene fluoride (PVDF)**	
Terne-plated steel	Styrene butadiene rubber (SBR)	**Polytetrafluoroethylene (PTFE)**	
Galvanized steel	Polyurethane	Polyphenylene sulfide (PPS)	
Cr-plated brass	**Rubberized cork**	**Polyethylene terephthalate (PET)**	
Cr-plated steel		Polybutylene terephthalate (PBT)	
Ni-plated		Polythiourea	
Ni-plated steel		**Isophthalic ester resin**	
		Terephthalic ester resin	
		Vinyl ester resin	
		Epoxy resin	

Of the all the test fuels investigated (Fuel C, CE10a, CE17a, CE25a, CE50a and CE85a), only the metal and elastomeric materials were subjected to each fuel type. The plastics were originally exposed to Fuel C and CE25a (and later to CE50a and CE85a) and the sealants were evaluated only in Fuel C, CE10a and CE25a. At a later point in this study, ORNL received sections of fiberglass USTs removed from use. Three UST sections were cut into test specimens and added to the final exposure runs of Fuel C, CE50a, and CE85a.

The test protocol consisted of immersing the specimen coupons in the test fuels and vapors for extended periods, 4 weeks for metals and elastomers and 16 weeks for plastics. During the exposure period the fuel temperature was maintained at 60°C in order to maintain consistency with the UL Subject 87A-E25 test standard used in by Underwriter Laboratories when assessing fuel compatibility.[16]

2. UNDERGROUND TANKS & PIPING SYSTEMS

Underground fuel storage tanks are composed either of steel or fiberglass reinforced plastic. Both of these materials, as well as flexible plastic, are also used in piping systems. A breakdown of the piping types using an analysis based on 22 state databases[5] is shown in Table 2. The overwhelming majority of installed piping (~71%) is either flexible or rigid fiberglass reinforced plastic. Of the remaining metal systems, approximately 18% of metal piping systems are steel. Copper makes around 2% of underground piping and approximately 8% is of unknown material construction.[19] The most common installed piping systems are rigid FRP and flexible plastic systems. Older piping systems were typically single-walled, but most newly installed systems are double-walled. FRP makes up approximately 58% of installed piping, while flexible plastic piping accounts for around 13% of all installed piping systems.[5]

Table 2. Breakdown of piping materials.[5,19]

Material Class	Approximate Percentage Used as of 2009
Steel	18
Rigid Fiberglass Reinforced Plastic (RFP)	58
Flexible Plastic Piping	13
Other (copper, PVC, etc.)	2
Unknown	8

A large percentage of leaks occur in the piping system between the tank and the dispenser.[17] These leaks typically occur at joints and connections where the stresses are highest. Contributors to stress include movement and forces exerted on piping from environmental factors which can be caused by changes in ground-water level and settling changes in the soil. Even a small change in the position of a UST will result in stress on the piping, especially at joints.[18] The level of stress will be higher for rigidly designed systems as opposed to flexible systems which can reduce stress through bending and relaxation. Outside of environmental contributions to stress, there are inherent changes caused by the piping materials' response to the fuel chemistry. As stated earlier, ethanol will raise the solubility parameter of the fuel so that the resulting potential for degradation of plastics is increased. Increased solubility will likely cause an increase in the volume of the plastic. This volume increase will place the component pipe under additional elongation and stress. Expansion of piping caused by solubility (even at low levels of approximately 2%) may be high enough to lead to failure based on life cycle studies of polymeric piping materials.[18]

2.1 METALLIC MATERIALS FOR TANKS, COMPONENTS, AND PIPING SYSTEMS

Steel is commonly used as a tank material for both legacy and newer systems, and steel piping is estimated to be used in approximately 18% of piping systems. The other metallic material that is exposed directly to E10 (and potentially E15) is aluminum which is used in submersible pumps. Both steel (carbon and stainless) and aluminum were included in the ORNL intermediate-blend materials compatibility study.

As shown in Fig. 1, the electrical conductivity for E10 and E15 is low in relationship to higher ethanol concentrations; however, when compared to each other, E15 is actually 10 times more conductive than E10. When water is added to levels approaching the solubility limit (as shown in Fig. 2), the conductivity is further increased. The test fuels used in the ORNL-intermediate blends study included relatively high levels of dissolved water (0.09% of the total ethanol volume) to account for this factor. In this study, steel and aluminum, along with the other metal coupons (tested either as single components or galvanic couples) showed negligible corrosion from exposure to the test fuels.[20] As a result, corrosion that does occur on metal tanks or piping systems is likely due to one of more of the following factors (none of which were included in the ORNL study):

1. Phase separation of water from the ethanol fuel blend
2. External water intrusion from rain, humidity, etc.
3. Contamination by other means such as road salt, dirt, etc.
4. Stress corrosion cracking

The potential for aqueous phase separation can be discussed relative to Fig. 2. As shown in Fig. 2, the level of water that can be dissolved into E15 is roughly twice the amount that can be dissolved in E10. The higher water content translates to a higher potential for corrosion.

2.2 POLYMER PIPING AND TANK SYSTEMS

As shown in Table 2, the majority of underground piping is constructed from plastic materials, which are categorized as two types, flexible piping and FRP piping. Although FRP systems are more established in the field, the majority of new piping systems installed today are flexible plastic systems because these systems are easier to install. As a result, the percentage of flexible piping is expected to grow relative to the other piping systems over the next 10 years. The piping arrangement can consist of either single- or double-walled systems. The majority of installed single-walled piping systems are legacy units, but new requirements are resulting in increased use of double-walled piping systems. Double-walled systems have an interstitial space between the walls that can be monitored for leaks.

2.2.1 Flexible Plastic Piping

Typical compositional arrangement of flexible piping includes an inner barrier liner within a layer of fiber reinforcement (to provide strength) and a cover to protect the inner layers from damage from handling and to prevent water intrusion. We surveyed the materials used in the construction of the outer wall for double wall plastic-based systems. In virtually every case, the outer wall is composed of inexpensive materials, known to be less chemically resistant to ethanol.

Multiple piping manufacturers and the materials used in their systems are listed in Table 3.[21-25] Some of the manufacturer and material information included in the table was taken from surveys dating to 1997, and therefore, may not reflect current construction.

Table 3. Flexible piping materials according to manufacturer.

Manufacturer	Permeation Barrier Material	Reinforcement	Primary Pipe Cover Material (Single-walled)	Secondary Containment Materials (double-walled)
Advanced Polymer Technology	Nylon 12	Nylon fiber wrap	Polyethylene	HDPE
Ameron	PVDF	Polyester braid polyethylene	Nylon	HDPE
Containment Technologies	Selar nylon (amorphous)	None	Polyethylene	HDPE
Environ	PVDF	Polyester braid	Nylon-coated polyethylene	Nylon coated polyethylene
Furon	PVDF	Polyester braid	Nylon II	
OPW	PVDF	Polyester braid	Nylon II	
PetroTechnik	Nylon	None	Polyethylene	Polyethylene
Total Containment	Carilon polyketone (product discontinued)	Polyester or Kevlar braid	Polyethylene	Polyethylene
Western Fiberglass	PVDF	Polyester braid	Nylon II	HDPE
XP-Piping	Nylon 12 and mylar (PET)	Nylon fiber	Mylar (PET) coated nylon 12	Nylon 12
Pisces	Kynar (PVDF)	Nylon fiber	Nylon	Nylon
Geoflex	Kynar (PVDF)		Nylon coated polyethylene	Nylon coated polyethylene

Of the flexible pipes reported in Table 3, the majority had inner barrier layers composed of PVDF. The three remaining designs incorporated nylon, either as nylon 12, Selar™ amorphous nylon, or a combination of nylon 12 and Mylar™ PET. For most systems the permeation barrier layer was externally reinforced with wound fibers composed of either nylon or polyester. This reinforcement, in turn, is usually coated with nylon or polyethylene. Likewise, the most common materials used for the outer wall are polyethylene and nylon.

One manufacturer used PET as the inner barrier layer. However, most materials are either nylon or PVDF. In reality the actual arrangement and location material arrangement for flexible piping is somewhat complex. A cutaway diagram showing the material arrangement for one commercially-available flexible pipe is shown in Fig. 4. In all flexible piping systems, there is an inner permeation barrier layer composed of a plastic material that has low solubility (i.e., high resistance) to petroleum fuels and alcohols.

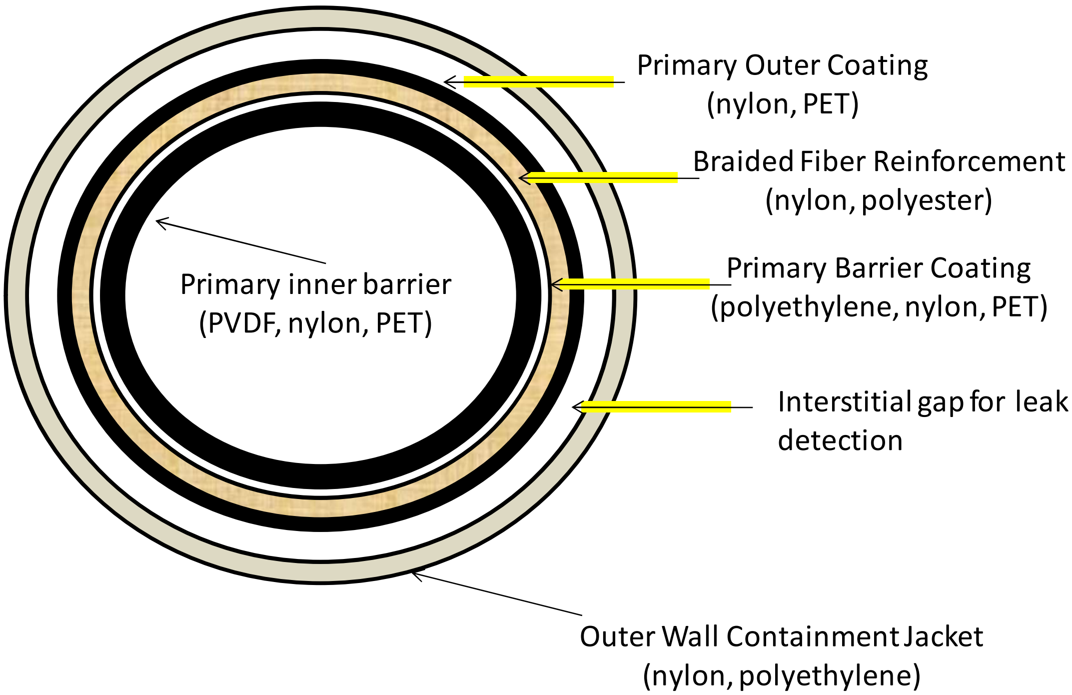

Fig. 4. Cross-section diagram of flexible piping showing an example of the layering position and arrangement of materials used in double-walled designs. A typical single-wall design is similar but would not include the outer wall containment jacket shown on the outside.

As stated earlier the two primary polymer types used in flexible fuel piping are nylon and polyvinylidene difluoride (PVDF). Other often used materials are polyketone and polyethylene terephthalate (PET). However, polyketone (Carilon™, Dupont) was discontinued and (to the best of our knowledge) the installed piping was removed and replaced. PET is more expensive than either nylon or PVDF, and as such, is not extensively used in piping applications. PVDF goes by the tradename, Kynar™ and is manufactured by Arkema, Inc. The other established material is the DuPont Selar™ nylon barrier material (which is amorphous grade of nylon).

Flex piping is easier to install and the flexible nature of the material allows the component to relax during swell. In contrast to fixed rigid piping systems, a flexible piping system can undergo small dimensional changes in volume and movement (relaxation), thereby reducing the stress load.

The ORNL intermediate blends compatibility study included samples of representative flexible pipe materials. These materials include PET, HDPE, nylon 6, nylon 6/6, nylon 11, and nylon 12. (Selar, which is an amorphous grade of nylon, was not evaluated.) These nylon grades are differentiated by the degree of molecular alignment (crystallinity), additives, and processing. In contrast to the other types, Nylon 11 is a unique specialty grade made from vegetable oil. Although Selar™ nylon was not specifically included among the test coupons, according to DuPont, its chemical resistance is comparable to other grades of synthetic nylon (nylon 6, 6/6, and 12).[26]

The ORNL materials compatibility study evaluated the response of selected plastic materials to Fuel C and CE25a only. Test fuels representing 10 and 15 percent aggressive ethanol were not exposed to plastics. Volume swell and hardness results are shown in Figs. 5 through 7 for common nylon grades, PET, PVDF, and HDPE exposed to Fuel C and CE25a.

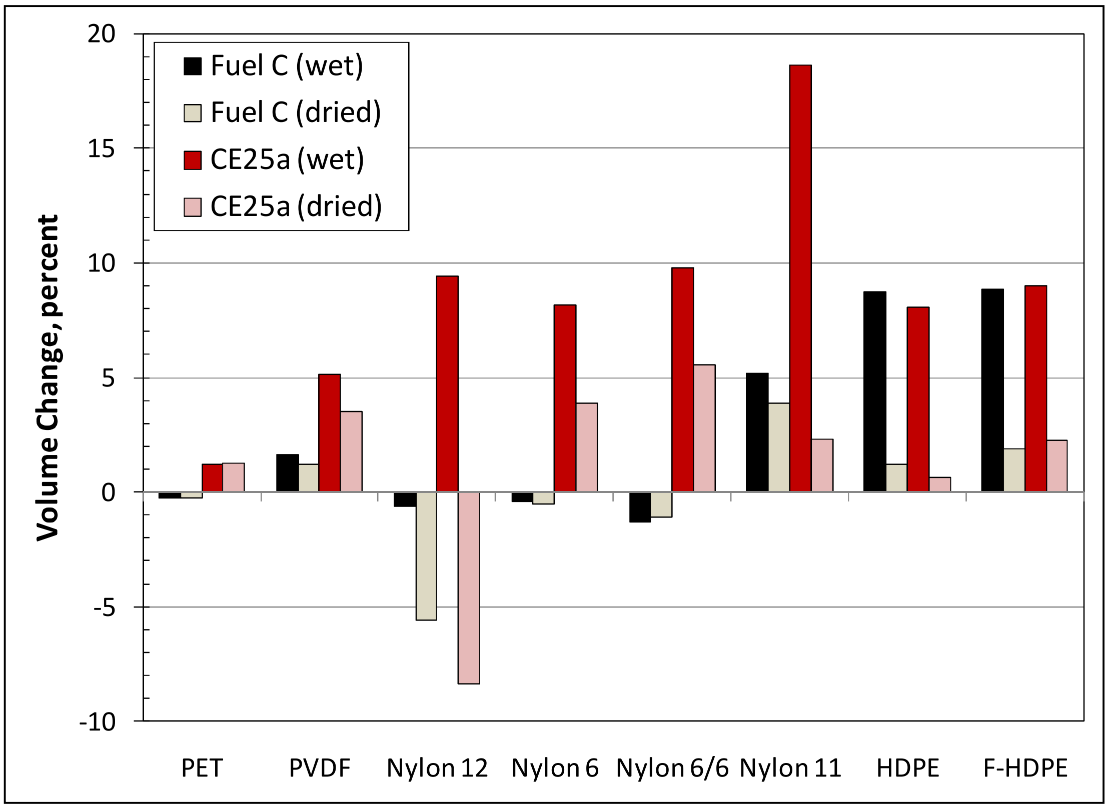

Fig. 5. Volume swell results for representative barrier materials used in underground piping.

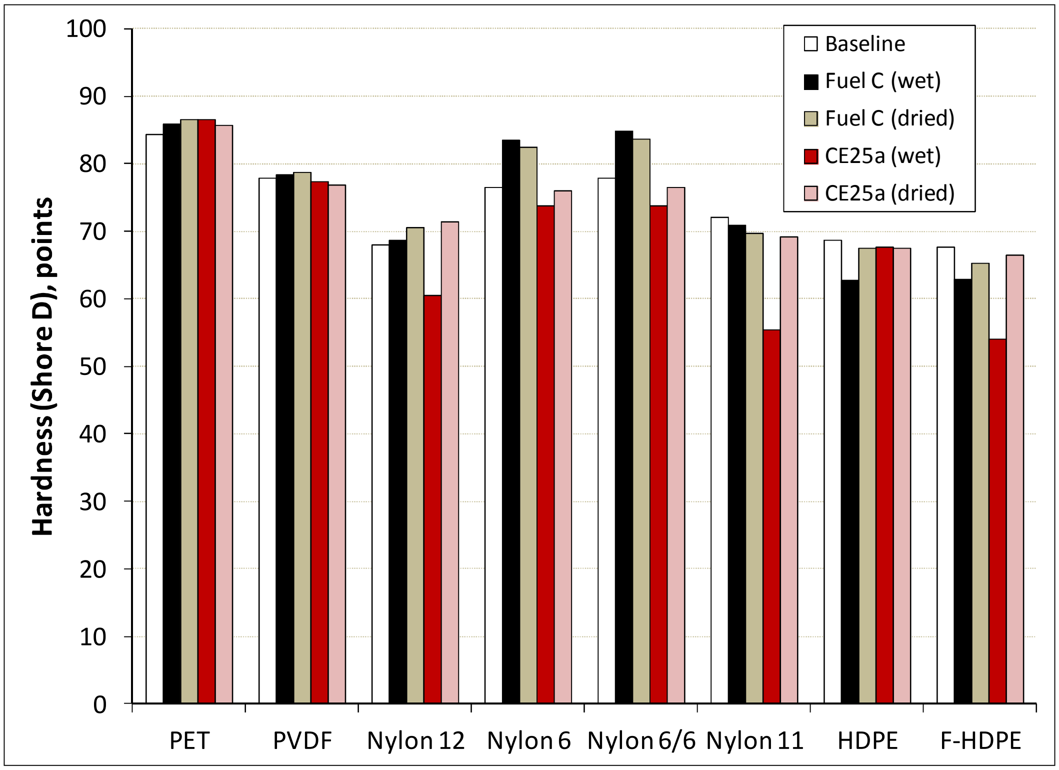

Fig. 6. Absolute hardness results for representative barrier materials used in flexible piping.

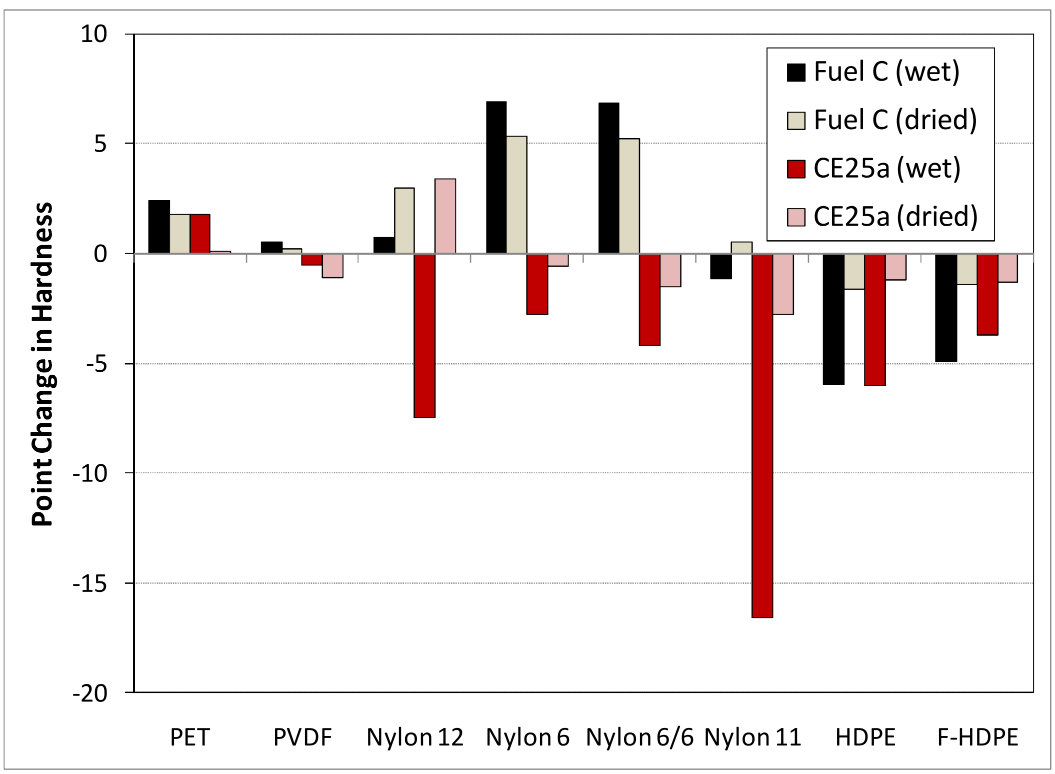

Fig. 7. Point change in hardness (from baseline) for representative barrier materials used in flexible piping.

As shown in Fig. 5, PET and PVDF experienced the lowest low volume swell (1.23% and 5.12%, respectively) following exposure to CE25a. In contrast, the nylon 6, nylon 6/6, and nylon 12, along with the HDPE samples swelled between 8 and 10 %. The highest level of volume swell occurred for nylon 11, and was around 18 %. Following dry out, these materials retained some fluid, as evidenced by the residual swell present in the dried samples. The one exception is nylon 12, which shrank from its original volume to over 5% from exposure to Fuel C and around 8% with CE25a. Such shrinkage is evidence that Fuel C and CE25a were able to dissolve and remove a significant portion of the solid material. The hardness results presented in Figs. 6 and 7 show that nylon 12 and nylon 11 both became softer with exposure to CE25. The decrease in hardness of nylon 12 was around 7 points, which is only marginally higher than the softening of the nylon 6, nylon 6/6 and the HDPE samples. However, nylon 11 dropped 17 points and this drop coupled with the high volume swell suggests that nylon 11 may not be acceptable for use in plastic piping, even for E0 formulations.

Although E10 and E15 test fuels were not evaluated, an estimation of the volume swell can be made using solubility parameters (obtained from the literature) and volume swell results in CE25a. Volume swell is a measurement of solubility. According to solubility theory, the difference between the solubility parameters is inversely related to the solubility between the solute (plastic) and solvent (test fuel). In other words, the closer match between the total Hansen Solubility Parameters of the solute and solvent, the more mutually soluble they are to each other. Using the known total HSP values for the plastic materials and E25, E15 and E10, and the measured volume swell in CE25a (as shown in Table 4), a calculated volume swell for each material in E15 and E10 can be made using the ratio of the differences in the total Hansen solubility parameters between the plastic and CE25a to the HSP difference between the plastic and CE15 and CE10. These calculated values are shown in Table 5.

The method for calculation of volume swell is as follows:

$$VS_{(EX)} = VS_{(E25)}\ (1-(\Delta HSP_{(EX)} - \Delta HSP_{(E25)}))/\ (\Delta HSP_{(EX)})$$

Where:

$VS_{(EX)}$ is the volume swell of the plastic sample after exposure to a fuel containing X percent of ethanol by volume.

$VS_{(E25)}$ is the volume swell of the plastic in CE25a

$\Delta HSP_{(EX)}$ is the difference between the total Hansen Solubility Parameter values for the plastic and the fuel containing X volume percent ethanol

$\Delta HSP_{(25)}$ is the difference between the total Hansen Solubility Parameter values for the plastic and the fuel containing 25 volume percent ethanol

Table 4. Volume swell results for representative barrier materials used in flexible underground piping

Plastic	Hansen Solubility Parameter ($MPa^{1/2}$)	Volume Swell in CE25a (%)
PVDF	23.17	5.12
Nylon 6	20.3	8.15
Nylon 12	22.2	9.40
PET	20.8	1.23
Fuel Type	**Hansen Solubility Parameter ($MPa^{1/2}$)**	
E25	18.58	
E15	17.59	
E10	17.09	

Table 5. Measured and calculated results for PVDF and Nylon 6

Barrier material	HSP ($MPa^{1/2}$)	Measured volume swell (CE25a)	Calc. Volume Swell for E15	Calc. Volume Swell for E10	Estimated vol. increase associated with increasing ethanol from E10 to E15
PVDF	23.17	5.12	4.1	3.6	0.5
Nylon 6	20.3	8.15	5.2	4.4	0.8
Nylon 12	22.2	9.4	7.4	6.7	0.7
PET	20.8	1.23	0.8	0.7	0.1

The results in Table 5 show that the expected increase in volume swell when going from E10 to E15 is less than 1 percent for the primary barrier liner materials used in flexible piping. The low additional volume swell is not likely to create much stress in the piping since these materials are able to relax due to the flexible nature of the piping. Based on these results, we do not anticipate any noticeable potential for release associated with going from E10 to E15. However, if the piping is rigidly constrained somehow, then stress buildup may occur to cause bucking (or cracking) of the piping. Most of the changes in swell (and hardness) will occur from moving from E0 to E10.

2.2.2 Fiber-reinforced Plastic Tanks & Piping

Fiber-reinforced plastic piping materials, design and construction are similar to those used in fiberglass tanks. The construction consists of first placing resin on a mandrel and later adding fiber reinforced resin to serve as the outer layer. A diagram showing layering and arrangement is depicted in Fig. 8.

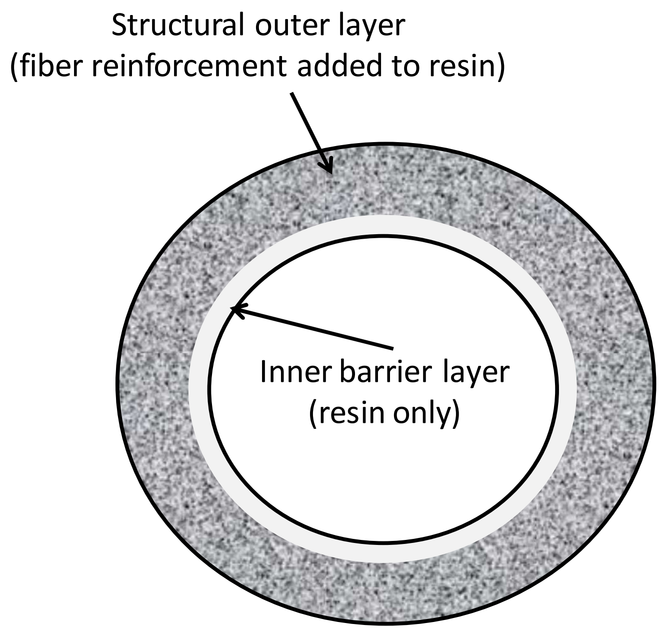

Fig. 8. Diagram of fiber-reinforced plastic piping.

As shown in Fig. 8, the inner barrier liner is approximately 0.5mm-thick resin layer surrounded by a much thicker (~6mm) layer of fiber-reinforced resin. For FRP systems used to contain petroleum fluids, the fiber reinforcing material is fiberglass.

ORNL tested several FRP resins to assess compatibility with CE25a. The resins that were evaluated included:

1. Isophthalic polyester resin (1 part isophthalic acid to 1 part polyester resin) known as Vipel F701- This resin type was used extensively in USTs prior to the 1990s.

2. Isophthalic polyester resin (2 parts isophthalic acid to 1 part polyester resin) known as Vipel F764- This resin type was used in USTs starting in the 1990s.

3. Terephthalic polyester resin (2 parts terephthalic acid to 1 part polyester resin) known as Vipel F774- This resin type was used extensively in 1990s.

4. Epoxy novolac vinyl ester resin known as Vipel F105-This is the most recently advanced corrosion resistant UST resin.

A survey of manufacturers shows that these resins are the most commonly used types for FRP UST construction.[27-30] It is important to note that for FRP tanks the construction does not consist of a multilayer structure similar to the arrangement used in flexible plastic piping. The inner barrier layer consists solely of the resin material, with fiberglass added to the thicker resin outer layer to provide strength and elasticity. The volume swell results are shown in Fig. 9 for these resins. (These specimens consisted of pure resin and did not contain fiber reinforcement.) Vipel F701 swelled to over 15 volume percent upon exposure to Fuel C. However, these samples fractured during dry-out making it impossible to ascertain accurate volume swell. For Vipels F764 and F774, the volume swell in Fuel C was around 9 percent and 7 percent, respectively. The most compatible grade was Vipel F085, which exhibited low volume swell (2%). When dried at 60^{o}C for 20 hours, the volume swell was lower than the wetted condition, but still significantly higher than the starting condition. The increase in dry-out volume compared to the initial condition indicates that significant levels of Fuel C are contained within the resin. This fact is further illustrated in Fig. 10 which shows the corresponding mass change of the specimens before and after dry-out.

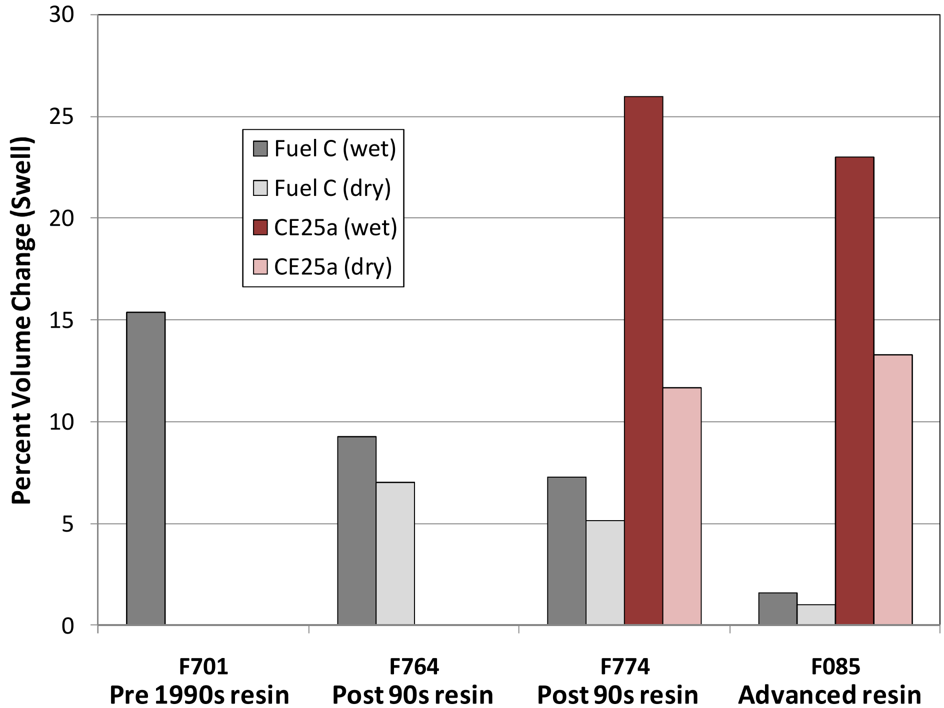

Fig. 9. Volume swell results for UST resins following exposure to Fuel C and CE25a.

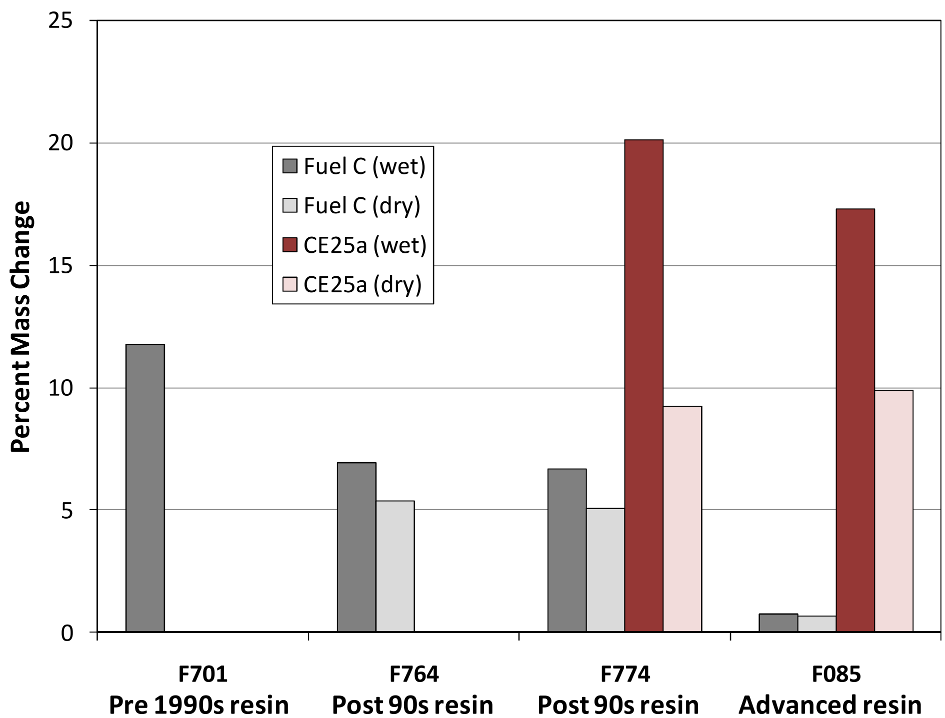

Fig. 10. Mass change for UST resins following exposure to Fuel C and CE25a.

Upon exposure to CE25a, Vipels F774 and F085 exhibited high degrees of swelling. F774 swelled to 26% while F085 swelled to around 23%. However, because the resins are reinforced with glass fibers, the actual swelling of the composite structure will be considerably lower. The inner barrier liner will be more susceptible to expansion, but the fiberglass reinforcement will prevent outward expansion of the resin barrier layer. However, inward expansion may occur and this effect may result in softening or cracking, or other forms of damage. It is important to note that the specimens which cracked in the test fuels (Vipel F701 and F764) were composed of pure resin, and these resins are not designed for use without fiberglass reinforcement. Fiberglass, by itself, is insoluble and is used in composite structures to provide modulus and strength. Fiberglass reinforcement would resist fuel permeation and elongation in the composite structure. As a result the level of swell in FRP systems would be expected to be much lower than for the pure resin. However, the inner barrier layer of an FRP tank (or FRP piping) is not reinforced and may experience degradation in the form of softening, spalling, or cracking.

The estimated volume swell for Vipel F774 and Vipel F085 in E10 and E15 was calculated using the Hansen Solubility Parameter-based method employed for estimating the volume swell for the flexible plastic materials. These results are shown in Table 6, and show that for the Vipel F774 and F085 resins, the difference in calculated volume swell associated with E10 and E15 is low (around 1.5% for both resin types). This means that in all likelihood there will be minimal effect when moving from E10 to E15. However, there is potential for a big difference when moving from E0 to E10.

Table 6. Measured and calculated results for UST resins Vipel F774 and Vipel F085

Resin material	HSP ($MPa^{1/2}$)	Measured volume swell (CE25a)	Calc. Volume Swell for E15	Calc. Volume Swell for E10a	Estimated vol. increase associated with increasing ethanol from E10 to E15
Vipel F774	24.1	25.99	22.0	20.5	1.5
Vipel F085	24.1	22.99	19.5	18.1	1.4

The change in hardness results for the UST resins are shown in Fig. 11. For each resin type, the hardness dropped slightly with exposure to Fuel C, but CE25a was shown to significantly lower hardness in the wetted condition. Vipel F701 and Vipel F764 exhibited greatest drop hardness (31 and 20 points, respectively) from the original condition. These values are considered high and since hardness is a measure of strength and elastic modulus, it is not surprising that these two specimens exhibited fracture following exposure to CE25a. Interestingly, Vipel F774 also experienced a relatively large decrease in hardness of around 15 points. The combination of reduced volume swell and lower change in hardness (relative to the F701 and F764 resins) were enough to prevent fracture of the F774 resin. The most advanced resin grade, Vipel F085 exhibited the least change in hardness of the resins tested.

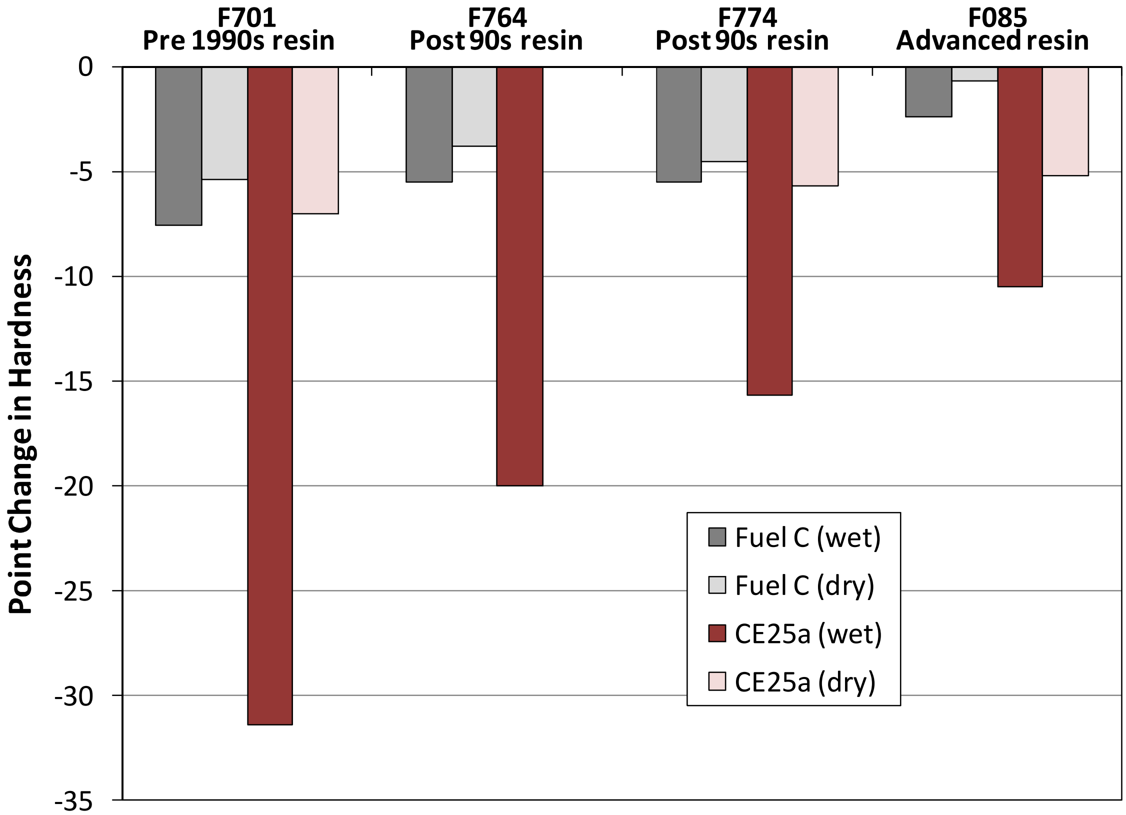

Fig. 11. Point change in hardness for the UST resin samples following exposure to Fuel C and CE25a.

Vipel F701 was used extensively in fiberglass reinforced USTs prior to 1990.[25] As such, it was designed primarily for gasoline use only and was not optimized for compatibility with ethanol-blended fuel. The volume swell and hardness decrease upon exposure to Fuel C would be considered acceptable for this resin type. F701 was replaced with more ethanol-resistant grades during the 1990s. Any legacy tanks composed of F701, or similar resin type, may be subject to ethanol degradation. Although the 30-year warrantee on tanks composed of F701 would have expired by now, many of these tanks are still in use. During the 1990s, many of the isophthalic resins were replaced by terephthalic-based and epoxy vinyl resins for improved performance.[28] The data provided by the materials compatibility testing shows that the terephthalic and vinyl resins are better suited for ethanol compatibility.

The ORNL intermediate-blend study also evaluated coupons taken from FRP underground storage tanks that had been removed from service. These tanks were cut into sections and sent to ORNL for evaluation. Photographs showing these specimens before and after exposure to the test fuels are shown in Figs. 12, 13, and 14. In each figure the baseline represents the unexposed sample.

Unfortunately the resin formulation of the UST sections was unknown, but the tanks were most likely pre-1990s vintage. Therefore, the resin formulations used in these tanks may not have been designed for use with ethanol-blended fuel. Over one dozen tanks were sectioned and sent to ORNL. All, except one, of these USTs were of amber coloration, similar to the pure resin coupons that were discussed previously, and nearly identical in appearance. There was one set of tank sections that was unique in that it was the only UST to have a corrugated plastic film adhered to the inner surface and was dark green in coloration. Test coupons were cut from three UST sections, which were labeled Batch 1, Batch 2, and Batch 3. Both

Batch 1 and Batch 2 were identical in appearance and of amber coloration, while Batch 3 was taken from the green section, which also contained the plastic film. Batch 3 was chosen since it represented an arrangement and coloration different from the rest.

Three coupons from each UST were evaluated in Fuel C, CE50a and CE85a test fuels. (The UST sections were not included in the earlier CE10a, CE17a, or CE25a test fluids, since this activity was started after these studies were completed.) These coupons were exposed in the test fluids for 16 weeks at 60°C along with other plastic specimens.

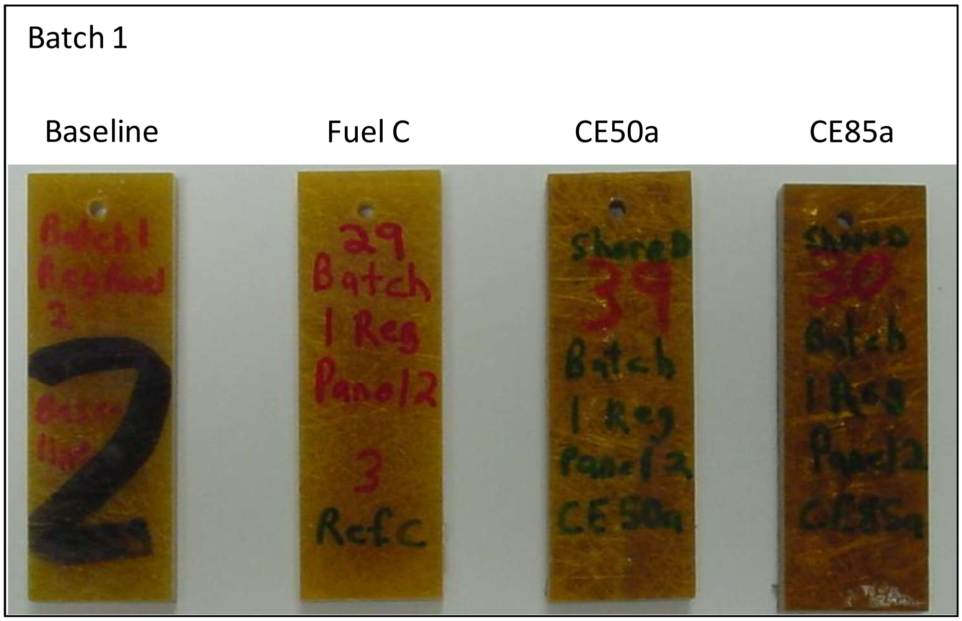

Fig. 12. Photograph showing the Batch 1 specimens before and after exposure to Fuel C, CE50a, and CE85a.

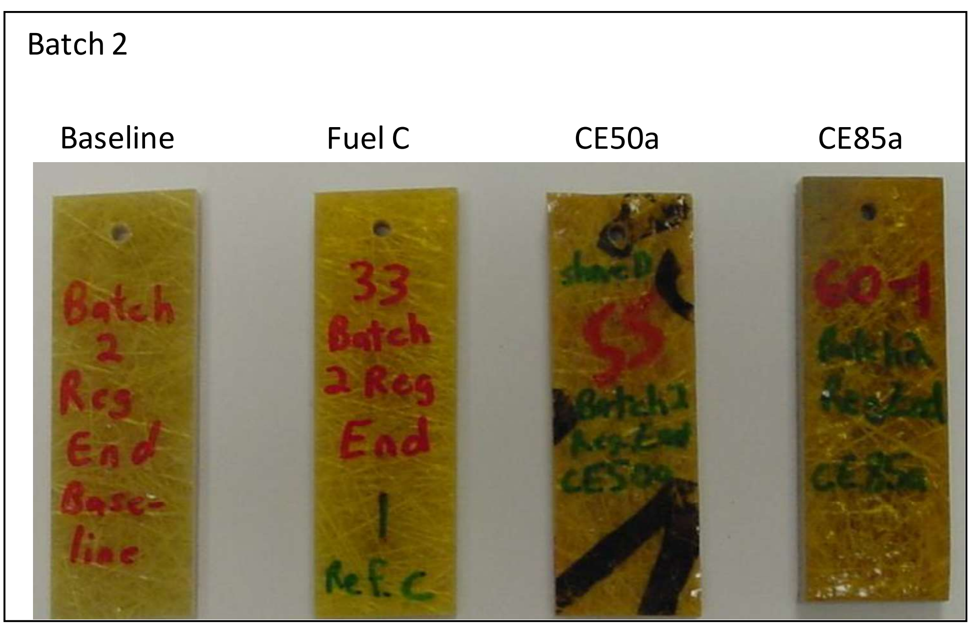

Fig. 13. Photograph showing the Batch 2 specimens before and after exposure to Fuel C, CE50a, and CE85a.

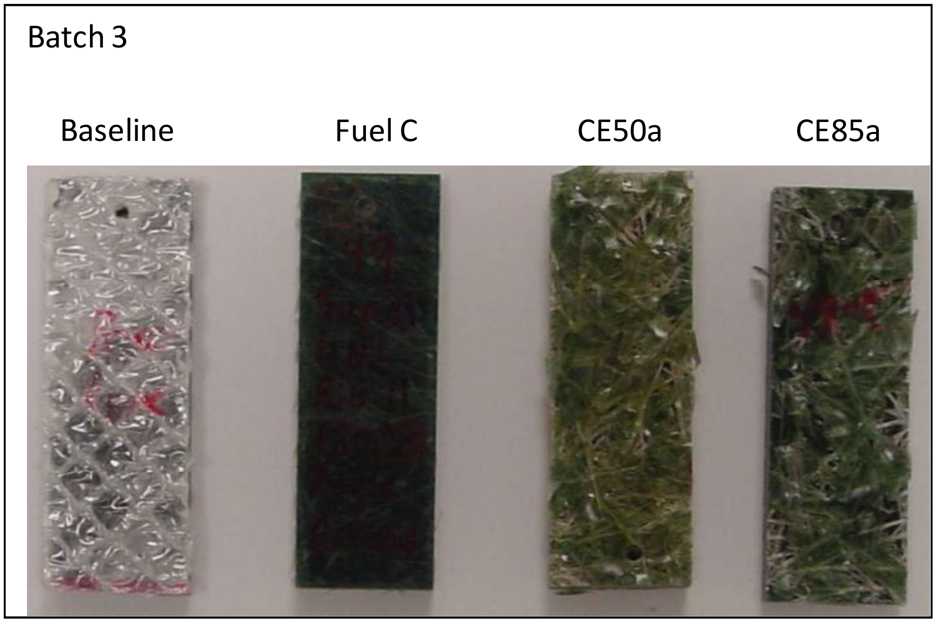

Fig. 14. Photograph showing the Batch 3 specimens before and after exposure to Fuel C, CE50a, and CE85a.

The photographs shown in Figs. 12 and 13 reveal that the amber resin specimens (Batch 1 and Batch 2) did not experience any observable degradation (outside of a slight change in color) from exposure to ethanol. However, the Batch 3 specimens (shown in Fig. 14) experienced massive degradation from the CE50a and CE85a test fuels. For this design, the corrugated liner was debonded by the Fuel C and the aggressive ethanol fuels. Interestingly, this liner survived exposure to the test fuels. However, the inner resin layer was removed and the resin surrounding the fiberglass reinforcement had dissolved to the extent that the fibers were completely exposed. It is important to note that, as depicted in Fig. 3, epoxy-based resins are likely to be more soluble in CE50a and CE85a fuels than for intermediate E10 and E15 levels. Therefore it is expected that the Batch 1 and Batch 2 USTs will be compatible to gasoline containing intermediate levels of ethanol. However, if the corrugated liner of the Batch 3 UST was damaged or breached, then it is likely that this UST has a high risk of leaking.

3. ELASTOMERS, SEALANTS, COUPLINGS AND FITTINGS

3.1 ELASTOMERS

Although elastomers are ubiquitous in fuel dispenser components, especially as hoses and seals, they are not used extensively as primary piping materials in either FRP or flexible piping systems. However, these elastomers could be used as gaskets and seals in the submersible tank pump head. A survey of piping and coupling manufacturers listed Viton fluorocarbon as the only o-ring material sold today for use in couplings and fittings for gasoline delivery systems.[31] Other elastomer types were not mentioned as coupling materials for current and new UST piping systems, although they may be prevalent in legacy systems. Of the elastomers evaluated in the ORNL intermediate-blend materials compatibility study, fluorocarbons were found to be the most compatible to ethanol. The other elastomers, in particular nitrile rubbers (NBRs), showed moderate but significant increases (10-12%) in swell and increased softening with exposure to aggressive ethanol as shown in Fig. 15. However, the additional increase associated with CE17a exposure (compared to CE10a) was small (5 to 8%).

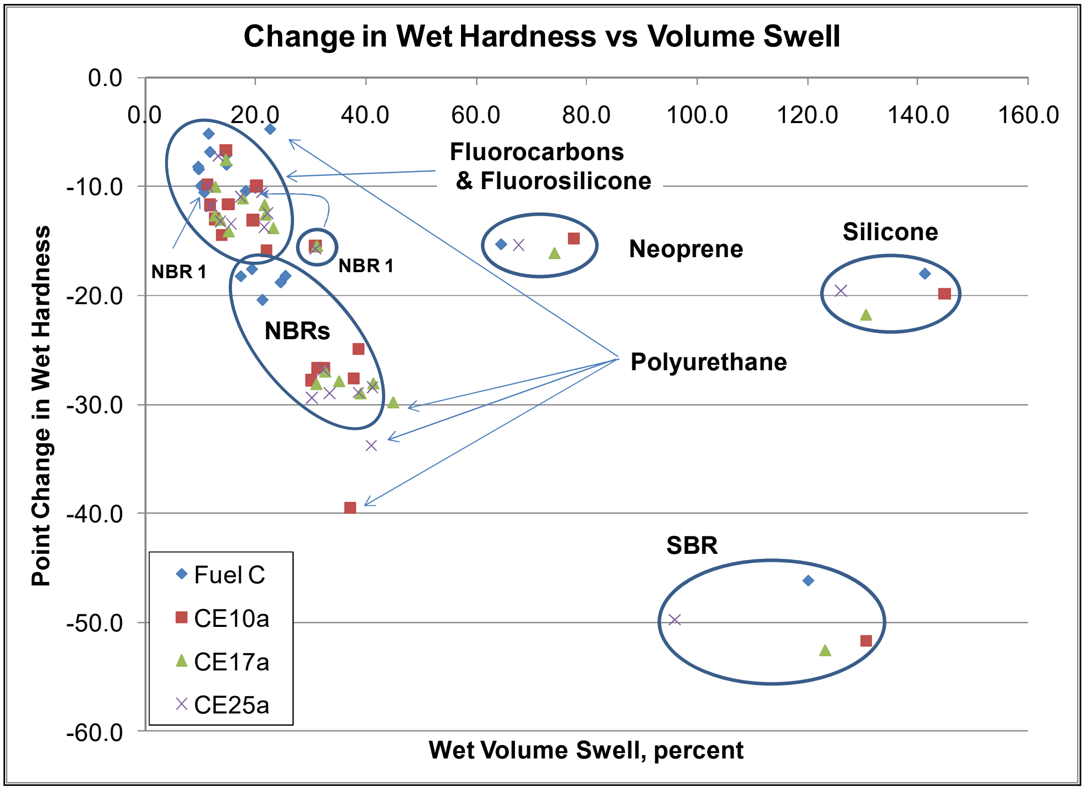

Fig. 15. Volume swell and point change in hardness for elastomers exposed to Fuel C, CE10a, CE17a and CE25a.

During dry-out, elastomers such as NBR and neoprene exhibit moderate shrinkage and embrittlement (see Fig. 16) which is attributed to extraction of the plasticizer components. However the level of shrinkage or mass reduction associated is constant and independent of ethanol content. As a result, the increase in leak potential among the elastomers when moving from E10 to E15 is expected to be low. However, these materials (especially NBR, neoprene, and SBR) will exhibit a high increase in swell when moving from E0 to E10 (or E15). Therefore, care must be taken when placing ethanol-blended gasoline into a system that had only contained gasoline.

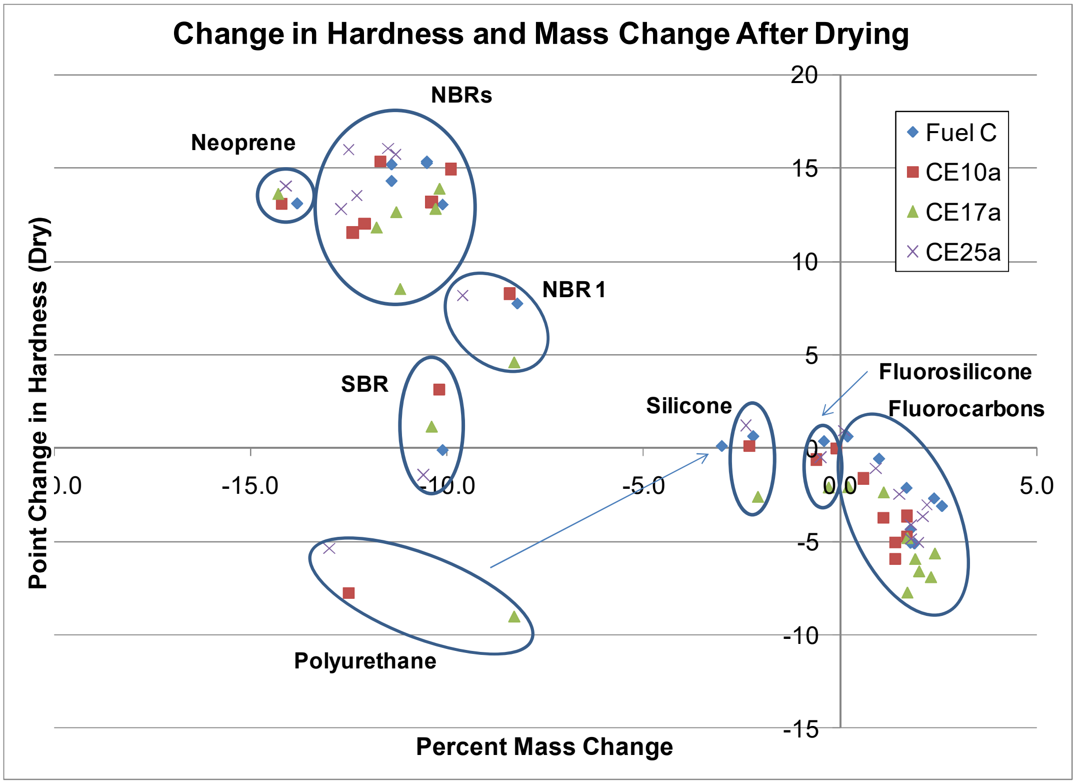

Fig. 16. Percent mass change and point change in hardness for elastomers exposed to Fuel C, CE10a, CE17a and CE25a following dry-out.

It is important to note that these elastomers are used solely as seals (i.e., o-rings, gaskets, etc.) and are not utilized as structural materials for UST systems. Additional swell for o-rings and gaskets in some cases does not degrade seals or diminish sealing potential, and may, to a small degree, improve the performance of the seal. These materials are not recommended for use as structural components of piping and UST systems, since even moderate levels of swell will create internal stresses which, even at low levels, can significantly reduce the lifecycle and durability of a component.

3.2 PIPE THREAD SEALANTS

Pipe thread sealants are used for metal piping and some FRP piping systems. Standard PTFE sealants (such as RectorSeal™) were originally developed for E0 use and were used extensively in legacy piping systems. These sealants have been shown to be incompatible for use with alcohols. In the ORNL intermediate-blend materials compatibility study, RectorSeal™ was shown to be incompatible with CE10a. This result strongly indicates that the pipe thread sealants used in the E0 legacy systems experienced leaking when exposed to E10. Ethanol compatible sealants such as GasOila ESeal™ were subsequently developed for ethanol-blended gasoline use and are now the industry standard. The ORNL study showed that the GasOila ESeal™ product is compatible with fuel containing up to 25 percent aggressive ethanol. It is very likely that the standard PTFE sealants used in the legacy systems were replaced with the ethanol-compatible products during the implementation of E10. There is no hard data to support this assessment, but based on the development and widespread use of the GasOila product, it appears to be the case. Except for polyurethane (which is used as a coating rather than as a seal), the elastomers and sealants evaluated in the ORNL intermediate-blend materials study showed no significant increase in swell and softening when moving from E10 to E15. Therefore, we do not foresee any added potential for releases when switching from E10 to E15.

3.3 COUPLINGS AND FITTINGS

One of the most susceptible locations of the underground storage tank systems are the couplings used to connect piping, fittings, and valves. There are two potential sources of leaks. One is where the coupling attaches to the piping and the other one is at the seal interface mating two couplings together. The interfacial seal issue was discussed under the elastomer section and is not considered to be a significant point of release if seals and gaskets are made of fluorocarbon materials and are properly installed.

Flexible plastic piping typically utilizes swage-type fittings to join piping and connect valves and flanges. A typical coupling assembly consists of a stainless steel insert with one or two o-rings, a stainless steel ferrule with one o-ring, and a swivel nut (or other means) to compress the ferrule against the outer pipe surface.[31] A simplified schematic is shown in Fig. 17. The compression of the plastic between the stainless steel insert and ferrule maintains a leak tight seal. In this configuration, the fuel is only exposed to the plastic piping, stainless steel coupling and the o-ring used to seal the coupling adjacent faces. Newer units were found to utilize fluorocarbon as the o-ring material, although legacy couplings may use other elastomers (such as NBR). These couplings usually require a special tool (from the piping supplier) to install properly. It is important to note that couples for FRP piping cannot be installed in this manner because the hard resin would fracture under high compression.

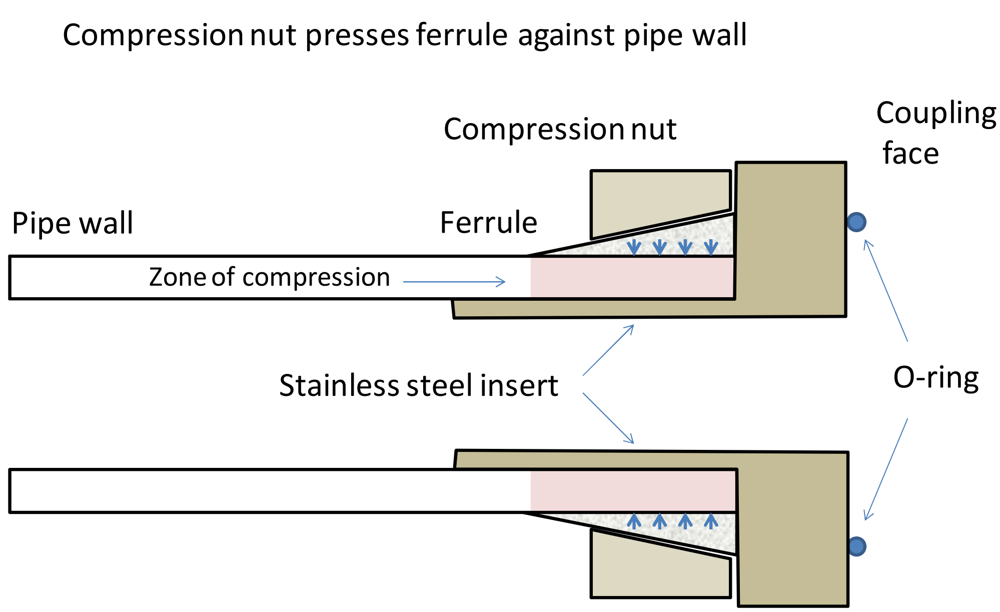

Fig. 17. Simplified schematic showing attachment of a coupling to flexible plastic piping.

The two most common methods for joining FRP piping and attaching couplings are adhesive bonding and butt and strap joints.[32] The butt and strap method is considered the most reliable means for joining FRP piping. Two pieces of pipe are butted together and layers of chopped fiberglass are wrapped around the pipe in a resin matrix similar to the pipe composition. A diagram depicting a butt and strap joint is shown in Fig. 18. If the butt and strap materials are similar or identical to the pipe materials, then compatibility performance is expected to be essentially the same and thus potential for further degradation due to E15 is minimal.

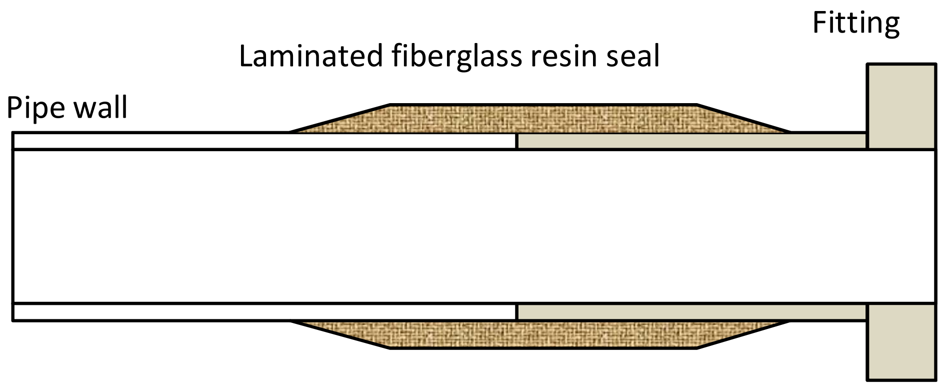

Fig. 18. Schematic diagram of the butt and strap joint.

The adhesive method involves adding an adhesive to glue a fitting or coupling to FRP. Because of its inherent weakness, this method is not used to join pipe sections, but is restricted to attaching fittings (such as flanges). Typically the outer surface of the pipe is sanded to allow better distribution of the sealant and to enable the adhesive to better grip the pipe surface and thereby form a strong mechanical bond. One application of this method is shown in Fig. 19. The adhesive maintains a seal between the fitting and the pipe end. At the fitting face, the adhesive will be exposed to fuel in the crevice region between the adjacent pipe ends. For some applications, the outer pipe walls are tapered at the ends to enable better fit between the pipe wall and fitting.

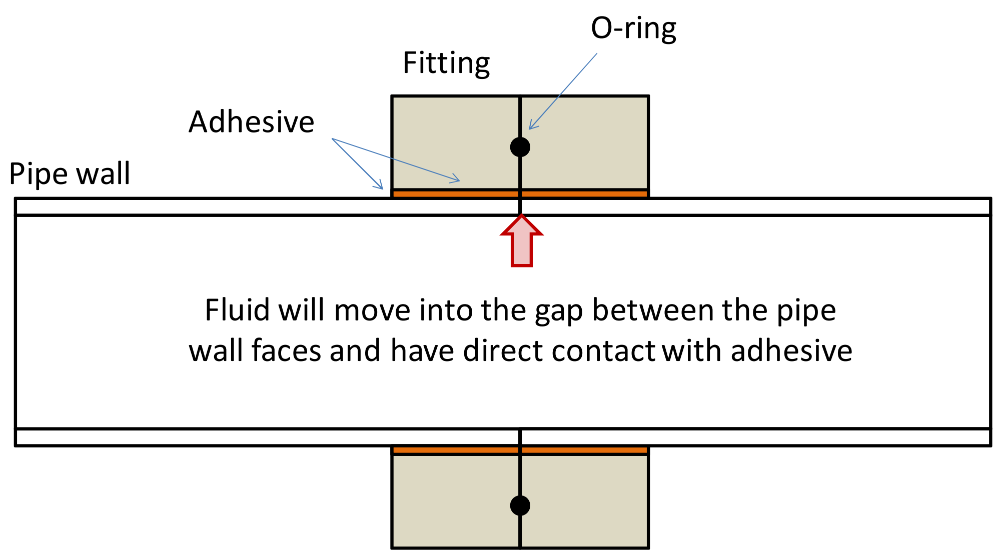

Fig. 19. Schematic showing a common arrangement of using adhesive on FRP piping.

The adhesives used for FRP systems contain a mix of inorganics (over 50%), such as clay, limestone, and silica and a mix of hydrocarbons.[33] The inorganic fraction imparts strength, rigidity and is resistant to attack from aggressive fuel components (including alcohols). The remaining hydrocarbons consist primarily of acrylic polymers, resins and distillate products. Information pertaining to adhesive resistance to ethanol was lacking and we were not able to ascertain ethanol compatibility.

4. CONCLUSIONS

The USEPA Office of Underground Storage Tanks commissioned a study at ORNL to evaluate whether an increased potential for leaking of USTs will occur when moving from E10 to E15 fuel. The original intention was to construct a probabilistic failure analysis tool to estimate the increase in releases, if any, if E15 replaced E10 in regulated UST systems. A key part of this process was to solicit opinions from a panel of industry and regulatory experts to identify critical variables that impact failure likelihood estimates. However, the lack of information on the performance of existing UST systems with E15 precluded the possibility that state/industry experts could speculate on E15's impact to UST systems. Therefore, the project objective was redirected to address the added leak potential (or incompatibility) of UST system materials when moving from E10 to E15. The data used to make this assessment were obtained primarily from the ORNL intermediate blend compatibility study. This study included metal and polymeric materials typically used in UST systems, and these materials were evaluated in aggressive test fuel formulations representing E0, E10, E15, E25, E50 and E85. Potential leak locations, such as pipe couplings were identified, and the elastomers and sealants used in couplings and joining were also studied.

4.1 CONCLUSION ON TANKS AND PIPING MATERIALS

Metallic materials included carbon and stainless steel and aluminum. A large number of USTs are composed of carbon steel, which is also used in approximately 18% of piping. Stainless steel is used in pipe couplings which are used to join piping sections and fittings. Aluminum, while not used as extensively as either carbon or stainless steels, is used in the construction of submersible pumps. However, failure of a submersible pump should not lead to leaking. The results from the ORNL intermediate-blends compatibility study showed that carbon and stainless steels, and aluminum will not undergo significant corrosion in either E10 or E15. However, it is important to note that the test conditions for these materials did not include stress or water-phase separation, both of which can contribute to increased corrosivity. In fact, if aqueous phase separation occurs, then the risk for corrosion will be higher for E15 since the maximum level of dissolved water is roughly twice that of E10.

Plastics are used extensively in underground piping systems. The two types of plastic piping, flexible and FRP, employ different types and grades of plastic materials. Flexible piping is primarily composed of various grades of nylon, PVDF, PET, polyester, and polyethylene. These materials were only tested in Fuel C and CE25a. As a result, the volume change, associated with CE10a and CE15a exposure, was estimated using the known swelling behavior at CE25a and Hansen Solubility Parameters for the plastics and test fuels. Nylon 11 exhibited the highest level of swelling (~18%) and would likely not be considered acceptable for use in USTs or flexible piping systems. Likewise, nylon 12 also may not be acceptable due to the significant loss of mass after drying. Other plastics, such as HDPE, F-HDPE, nylon 6 and nylon 6/6 exhibited relatively high swell (8-10%) and may not be suitable when switching from E0 to either E10 or E15. However, the calculated swell for nylon 6, nylon 6/6, PVDF, PET, and polyethylene indicated that the added increase in swell when moving from E10 to E15 was very low. This result suggests that the leak potential in E15 for flexible piping containing these materials will be low as well.

The performance of resins used in the construction of FRP tanks and piping is highly dependent on the type of resin. A pre-1990 legacy isophthalic polyester resin was visibly damaged with exposure to a test fuel containing 25% aggressive ethanol. Analysis of post-1990s resins (exposed to CE25a) were mixed; the resin composed of isophthalic polyester was damaged, while the resins composed of terephthalic polyester or vinyl ester were not. Interestingly, the two resins that were damaged from exposure to ethanol were both isophthalic polyesters. Based on these results, isophthalic polyester resins should be avoided in the construction of UST systems storing ethanol-blended fuels. The predicted level of volume swell associated with E10 and E15 was calculated for the terephthalic polyester and vinyl ester resins. The results suggest that the added volume swell associated with E15 (compared to E10) is extremely low and would not likely increase the potential for leaking with E15 fuel. ORNL was able to include three legacy UST samples in a later compatibility effort using CE50a and CE85a as test fuels. In one unique case, a legacy FRP UST that contained a separate plastic liner exhibited significant degradation of the resin material when exposed to high levels of ethanol. Although the liner was not visibly damaged, its performance with lower intermediate levels of ethanol-blended gasoline could not be ascertained. The other two UST sections were not damaged and would likely exhibit good compatibility with E10 or E15.

4.2 CONCLUSION ON ELASTOMERS, SEALANTS, COUPLINGS AND FITTINGS

A high leak potential also exists where piping sections are joined and fittings are attached. The structural material typically used in these applications is stainless steel and the sealing materials are either elastomers and/or pipe thread sealants. Modern joining units employ primarily fluorocarbons in o-ring and sealing applications; however some legacy systems may use NBRs and other elastomer types. The ORNL intermediate-blend ethanol compatibility study investigated the performance of fluorocarbons, fluorosilicone, NBRs, silicone rubber, styrene butadiene rubber, neoprene and polyurethane. These elastomers all showed significant swelling with exposure to ethanol. However, because elastomers are used solely as seals (i.e., o-rings, gaskets, etc.), swelling is not necessarily an indication of leak potential. Additional swell for o-rings and gaskets may improve the performance of the seal. Except for polyurethane (which is used as a coating rather than as a seal), the elastomers and sealants evaluated in the ORNL intermediate-blend materials study showed no significant increase in swell and softening when moving from E10 to E15. Therefore, for field applications and materials examined in this study, there should not be any corresponding potential for releases associated with increase the ethanol concentration in fuel gasoline from E10 to E15. The flanges used in coupling systems are composed of stainless steel and this material has been shown to have excellent compatibility with ethanol-blended fuels.

Pipe thread sealants are used for metal piping and some FRP piping systems. Standard PTFE sealants (such as RectorSeal™), used in E0 applications, were shown to be incompatible for use with E10. However, ethanol-compatible sealants (such as GasOila ESeal™) were compatible with fuel containing up to 25 percent aggressive ethanol. Although it is very likely that standard PTFE sealants used in legacy systems were replaced with the ethanol-compatible products during the implementation of E10, there may be systems still in use with the incompatible sealant material.

FRP piping joined using either a butt and strap configuration or an adhesive is used to secure a fitting on one end. The butt and strap consists of a FRP wrap that contains resin similar or identical to the FRP pipe resin, and therefore, should be compatible with ethanol-blended fuel. Adhesives consist of a mix of various organic and inorganic materials, and we could not assess their compatibility to ethanol since they were not included in the ORNL intermediate-ethanol blends compatibility study.

In general, several materials evaluated in this study were found to not perform well in fuel blends containing ethanol. These materials demonstrated incompatibility with E10 and should not be used for E15 (unless it can be demonstrated that a particular polymer grade is, in fact, compatible). Systems most susceptible to increased leakage will be those legacy USTs which are currently using E0 and will be switching directly to E15.

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