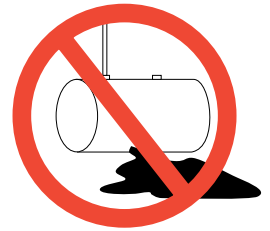


L.U.S.T.LINE



A Report On Federal & State Programs To Control Leaking Underground Storage Tanks

So What about Those E10 and E85 Fuels?

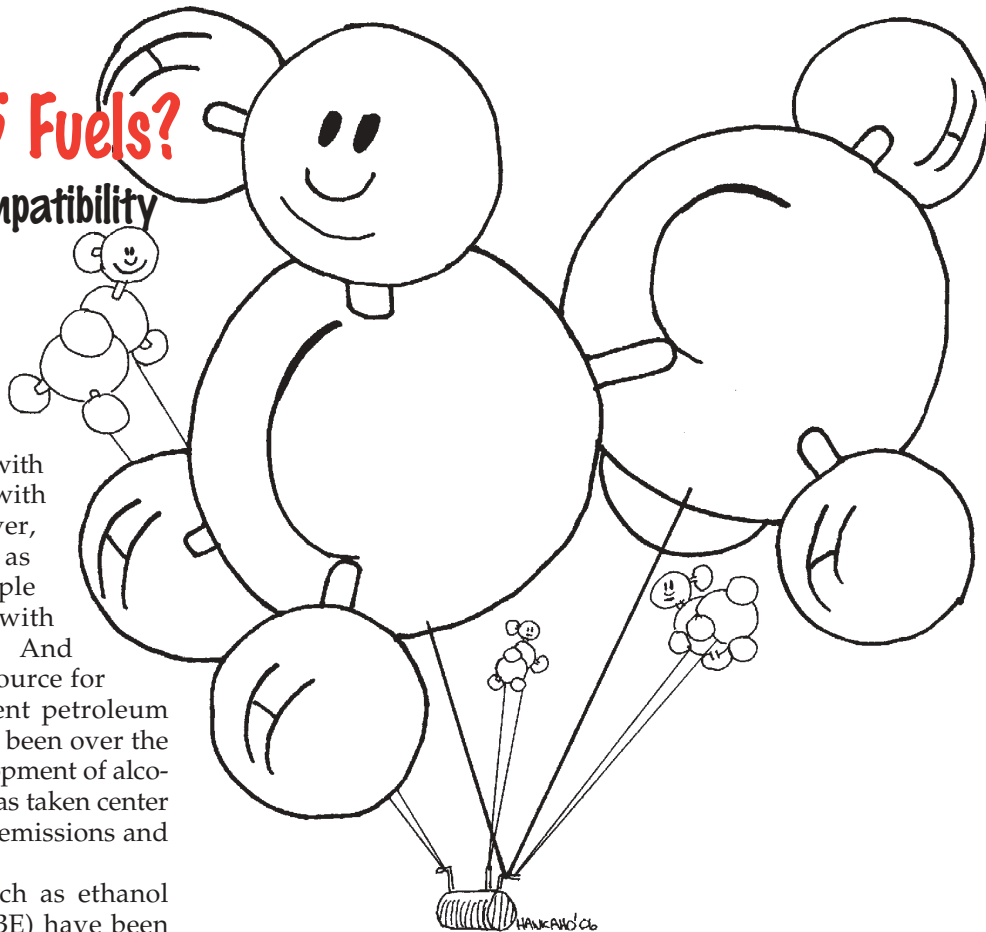
A Discussion on Materials Compatibility

by Edward W. English II

For some, the use of ethanol as a fuel blend seems like a new and intriguing concept. For as long as I can remember I have been filling my cars with gasoline refined from crude oil, and not with the fermentation product of corn. However, the use of ethanol as a fuel blend is not as new an idea as some would think. People have been experimenting successfully with ethanol fuel since the 18th century. And although ethanol was the primary fuel source for Henry Ford and was used to supplement petroleum feedstocks during World War II, it's only been over the last 25 to 30 years that research and development of alcohol fuels, such as methanol and ethanol, has taken center stage as a way to reduce vehicle tailpipe emissions and our reliance on foreign oil (1).

Since the late 1970s, oxygenates such as ethanol (EtOH) and methyl *tert*-butyl ether (MtBE) have been added to gasoline to improve vehicle emissions. Ethanol is not only an effective oxygenate, it has the added advantage of improving fuel octane. The use of 10 percent ethanol (E10) can increase the octane of base gasolines two to three points (1). This also made ethanol a good replacement to the lethal additive tetra ethyl lead (TEL) (2,3). E10 gasoline is currently used in about 30 percent of the gasoline consumed in the United States. However, due to the accelerated phaseout of MtBE, ethanol will soon be used to a much greater extent in gasoline.

For the past several decades, a variety of automotive manufacturers have been designing and manufacturing vehicles to run on fuels made of 85 percent ethanol and 15 percent gasoline (E85). Although ethanol fuel is approximately 25 percent lower in heat energy than con-



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ventional gasoline, for some the energy tradeoff at the E85 level is worth improved vehicle emissions and reduced consumption of foreign crude oil (1,4,5).

Since the early 1990s, there has been an accumulation of information documenting the compatibility of alcohols, such as methanol and ethanol, and ethers, such as MtBE, on the materials found in automobile fuel systems and petroleum storage equipment. However, there is a resounding lack of clearly defined industry standards that effectively and objectively evaluate the effects of E10 and E85 fuels on the variety of materials commonly found in the equipment used to store, distribute, and dispense ethanol-blended (E-blend) fuels (6,7,8).

The goal of this article is to shed some light on the history of ethanol as a fuel and to provide a glimpse into the chemical and physical properties of ethanol that are the basis for material-compatibility concerns.



L.U.S.T.Line

Ellen Frye, *Editor*
Ricki Pappo, *Layout*

Marcel Moreau, *Technical Adviser*

Patricia Ellis, Ph.D., *Technical Adviser*

Ronald Poltak, *NEIWPCC Executive Director*

Lynn DePont, *EPA Project Officer*

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NEIWPCC
116 John Street
Lowell, MA 01852-1124
Telephone: (978) 323-7929
Fax: (978) 323-7919
lustline@neiwpcc.org



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The History of Alcohol... as a Fuel Source

To appreciate ethanol fuel, it might be helpful to briefly review the history of alcohol and its evolution as a fuel source for today's modern internal combustion engine. The earliest mention of alcohol as a fuel was in 1798, when Colonel John Stevens proposed a simple internal combustion engine that was to be fueled by ethanol. Although the issue was not directly addressed, this may have been an attempt to improve upon the steam engine that was used to propel ships and trains. However, due to its design and the current technology issues, the engine had limited use and capacity.

In 1826, the prolific and somewhat eccentric inventor Samuel Morey proposed a prototype for an internal combustion engine that was to be powered by ethanol vapor. This was an extension of a previous invention that used a vapor containing a mixture of water and turpentine to fuel street lanterns. Unfortunately, Mr. Morey was unable to generate the necessary financial support to see his invention become reality.

When we fast-forward to 1877, we meet Nicholas Otto, who entered the scene with a prototype modern internal combustion engine designed to run on a purer form of ethanol. Just a few years later, in 1880, Henry Ford introduced the Quadracycle, which was powered by ethanol. By 1908, Ford began production of the Model T, which was designed to operate on gasoline or ethanol. Ford's vision was to "build a vehicle affordable to the working family and powered by a fuel that would boost the rural farm economy" (2).

Standard Oil mogul John D. Rockefeller and Henry Ford developed an alliance to sell gasoline and ethanol fuels to power the burgeoning automobile industry. In fact, the 1920s, ethanol fuel sales made up approximately 25 percent of Standard Oil sales. However good or bad, the relationship between Ford and Rockefeller did not last, and in 1935 Henry Ford joined with Atchison Argol in Kansas to produce a gasohol. The plant produced 18 million gallons of ethanol fuel per year, which was sold to over 2,000 distributors.

Prior to World War II, Europe had over 4 million cars powered by ethanol, and Chrysler was shipping ethanol-powered cars to New Zealand. During World War II, over 600 million gallons of alcohol fuels were produced to supplement petroleum feedstocks. It was not until the end of World War II that petroleum fuels flooded the market, making them inexpensive compared with the alcohol fuels. It was not until after the oil embargo of the 1970s that E-blend fuels were "back on the drawing board" as a fuel supplement and possible replacement for petroleum-based fuels (4).

Gasoline versus Ethanol

To better understand the effects of ethanol on materials used in underground fuel storage facilities, it might be helpful to compare it to something we know a little about—gasoline, a liquid mixture of many different chemical compounds called hydrocarbons. These compounds come in a variety of shapes and sizes and are made almost exclusively of carbon and hydrogen atoms in various ratios and structures—long or short, branched or nonbranched, circular or straight, saturated or unsaturated.

Gasoline is considered to be fairly noncorrosive. It is nonpolar and electrically nonconductive, and does not absorb or permeate through metals. To date, in laboratory and field observations, gasoline has not been noted to permeate or swell fiberglass-reinforced polymeric tanks, rigid piping, or sumps made from thermoset resins and fiberglass. Regrettably, there have been a number of examples in which gasoline has been observed in the swelling, permeation, and degradation of thermoplastics such as flex piping and elastomeric materials, for example, in gaskets and seals (9,10).

Gasoline is composed of a variety of nonpolar aliphatic, olefinic, and aromatic compounds; that is, they do not exhibit any electrostatic interaction between individual molecules in the fuel. This is important because electrostatic interactions between individual molecules can significantly influence the chemical potential or activity of a solution and play an important role in the equilibrium absorption of chemicals by a given

material (8). Therefore, in this type of solution the activity or chemical potential of each component will be equivalent to its concentration or mole fraction in solution. This is best illustrated in Figure 1, where we can observe the activity of MtBE in an ASTM C test fuel that is composed of roughly equal proportions of toluene and isooctane.

MtBE is an ether, and as such, possesses an oxygen molecule. However, the surrounding atoms of carbon and hydrogen diminish the electrostatic nature of the oxygen atom, making it essentially nonpolar. This allows MtBE to commingle with the ASTM C fuel without significantly altering the activity of the solution. Therefore, individual activities of the MtBE, toluene, and isooctane are proportional to their respective concentrations or mole fractions.

It is the unique physical and chemical characteristics of gasoline

atom carries a partially negative charge, while the hydrogen atom carries a partially positive charge. The electrostatic charges carried by these two atoms give the hydroxyl group an overall "polar" characteristic, analogous to the poles on a magnet. There are a number of natural and manmade compounds that possess this type of functional group—water can be thought of as a hydrogen atom attached to a hydroxyl group (H-OH).

The unique aspect of the hydroxyl functional group is that it gives the ethanol molecule the ability to "hydrogen bond" with other chemicals that possess the complementary functional group—like water and ethanol. Although weaker than ionic bonding, hydrogen bonding is still a much stronger electrostatic force than the negligible forces that exist between the nonpolar compounds found in gasoline. For example,

hydrogen bonding is what gives water its surface tension and high boiling point. It has also been shown that hydrogen bonding is what allows alcohols such as neat methanol to self-associate, forming a tetracyclic and nonpolar compound (8).

When dilute or low concentrations of polar ethanol molecules are mixed with nonpolar gasoline, the ethanol molecules behave much differently and influence the activity of the other constituents, as demonstrated in Figure 2. Due to the electrostatic nature of the hydroxyl group, ethanol molecules preferentially hydrogen bond with each other rather than uniformly mix with the gasoline.

Since chemical potential or activity is directly proportional to temperature, the activity of dilute ethanol and other fuel constituents is disproportionately greater than their respective concentrations. The electrostatic interactions between molecules can significantly influence the chemical potential or activity of a solution, which plays an important role in the equilibrium absorption and permeation of chemicals by a nonmetallic material (8).

Potential E-blend Fuel Issues

So now that we have a better understanding of some of the physical and chemical differences between gasoline and ethanol, how can we apply what we've learned to better understand potential issues that could arise from E10 and E85 fuel systems? Generally, one or more of the following

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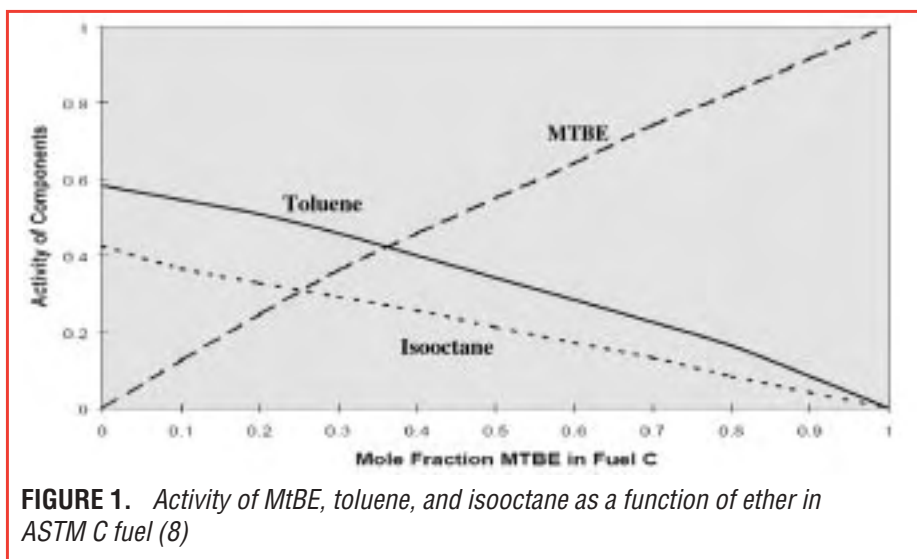


FIGURE 1. Activity of MtBE, toluene, and isooctane as a function of ether in ASTM C fuel (8)

that have permitted petroleum manufacturers to implement design strategies to make metallic and nonmetallic petroleum equipment compatible with gasoline and resistant to degradation during storage, transportation, and dispensing.

Comparatively, ethanol has a few characteristics that make it similar to gasoline. The ethanol molecule is composed of two carbon atoms linked together to form a short linear molecule that possesses six bonding locations, which are occupied by five hydrogen atoms and one unique functional group made up of a single oxygen and hydrogen atom called a hydroxyl group (OH). The oxygen

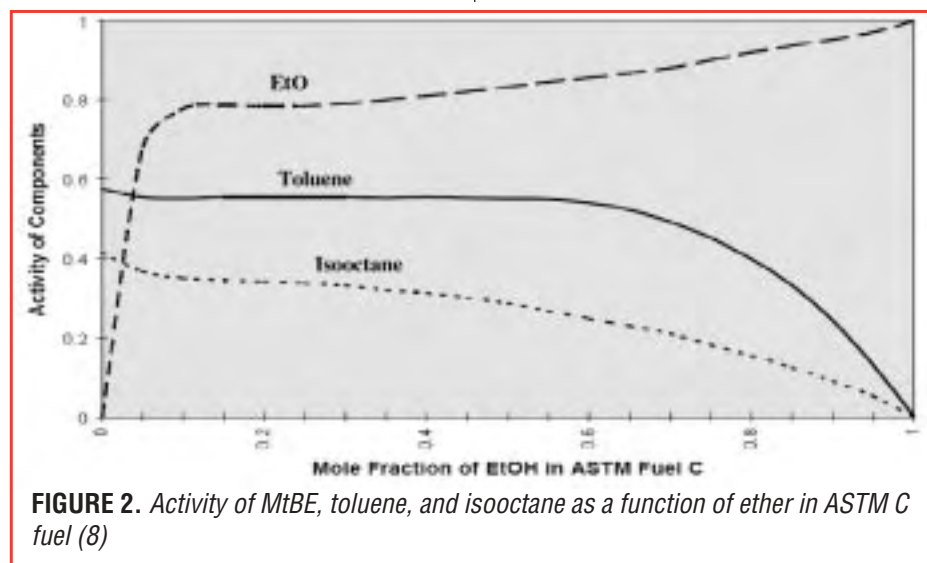


FIGURE 2. Activity of MtBE, toluene, and isooctane as a function of ether in ASTM C fuel (8)

■ E10 and E85 from page 3

issues could result when storing, distributing, or dispensing E10 and E85 fuels—phase separation, solvency, metal corrosion, and permeation of nonmetals.

■ Phase Separation

Ethanol will mix with gasoline, but it does so reluctantly. Although gasoline is nonpolar, it can only hold up to 0.2 percent dissolved water before the water “drops” out of solution to the bottom of the storage vessel as free water. Conversely, hydrogen bonding allows E10 fuel to hold much more dissolved water than gasoline—approximately 0.5 percent. This is because the energy needed for ethanol and water to hydrogen bond is much lower than the higher energy required to keep ethanol evenly distributed with gasoline. Because of this, ethanol and water will continue to preferentially bond until the ethanol and water drop out of solution, a process known as “phase separation.”

When an E10 fuel undergoes phase separation, a separate layer of water with a high percentage of ethanol settles to the bottom of the fuel system. The remainder of the fuel in the upper layer is gasoline containing a small percentage of ethanol. An E10 fuel system near its saturation limit may experience phase separation if there is a sudden drop in temperature.

Unfortunately, vehicles are not designed to run on a mixture of ethanol and water, so if phase-separated ethanol and water is pumped into a vehicle’s fuel tank, the vehicle will become stranded at the pump or eventually stall after fueling.

Phase separation of E85 fuels may also occur, but not as often. Approximately 4 percent water is needed for phase separation to occur. This is a significant amount of water for a fuel system and typically would not happen. However, more important is what a water concentration of 4 percent can do in an E85 system—namely facilitate galvanic corrosion.

■ Solvency

As we know, alcohol has the ability to dissolve organic material. Although E10 and E85 fuels have differing concentrations of ethanol, each has the ability to dissolve the petro-

leum-based sediment, particulates, and lacquers found in fuel tanks previously dispensing gasoline or diesel fuel. In this case, E85 would have a greater solvent capability than to E10. It is very important that used fuel tanks designated for E10 and E85 conversion are thoroughly cleaned and inspected by a reputable and bonded company in order to identify potential corrosion issues that could result in tank leaks.

It is also important that appropriate in-line filters are installed. These filters provide the last line of defense, protecting automobiles from receiving contaminated fuel that could seriously affect their drivability.

When selecting an in-line filter, two very important issues should be taken into consideration—particle size and efficiency. Particle size alone does not guarantee performance. When selecting a filter, it is just as important to consider its efficiency rating. The greater the efficiency rating, the better the filter will perform at its stated particle size.

■ Metal Corrosion

Metals typically found in UST-dispensing systems include aluminum alloys, brass, copper, steel, and zinc. As mentioned above, gasoline is electrically nonconductive and generally will not corrode these metals. Corrosion mechanisms found in gasoline fuel systems typically involve general corrosion and pitting corrosion, which usually take place at the bottom of the fuel-storage tank where the water layer exists.

Conditions that lead to and exacerbate corrosion of metals in any hydrocarbon fuel system include water, ionic contaminants, pH, and microbial contamination (8). Water typically enters the fuel distribution and storage system either when newly refined warmer fuel cools in the distribution pipeline or when poor water-ballast-stripping techniques are used during offloading from tankers. Water enters an UST through a fuel delivery, poor tank seals, or condensation of water vapor in the vapor-recovery system (11).

Water entering ethanol fuel systems becomes a more serious issue. As discussed above, ethanol and water have a strong preference to hydrogen bond, even in the presence of gasoline. This preferential bonding

is the reason why the ethanol used to make E10 and E85 fuels is shipped by railcar or tanker truck, rather than pipeline, and blended at the terminal prior to final delivery to the UST facility.

As water or moisture enters ethanol fuel, it is drawn up into the bulk fuel along with ionic contaminants, which increases the conductivity of the solution. As the electrical conductivity increases, the fuel more easily facilitates galvanic corrosion between dissimilar metals—metals that are widely separated in the galvanic series, such as aluminum and steel (5,6,7).

Fortunately, in the quarter century that E10 fuels have been in the U.S. market, there have been very few reported incidents of significant corrosion of the metals typically found in fuel-dispensing systems. Metals recommended for E10 fuels are provided in Table 1 below.

TABLE 1
Metal Compatibility in E10
(5,14,15)

RECOMMENDED	NOT RECOMMENDED
<ul style="list-style-type: none"> • Aluminum • Black iron • Brass • Bronze • Carbon steel • Stainless steel 	<ul style="list-style-type: none"> • Galvanized zinc

On the other hand, E85 fuels are viewed much differently because there are other issues to consider. As discussed above, E85 fuel is capable of absorbing greater quantities of water and contaminants. As a result of the increased water content, E85 fuel becomes much more conductive, promoting galvanic corrosion more easily, which in turn has a very deleterious effect on active or anodic metals in a fuel system.

The effects of galvanic corrosion on soft or anodic metals were more readily apparent during the research and development of M85 fuels, which contained 85 percent methanol and 15 percent gasoline. Testing by the automotive industry in the late 1980s and early 1990s demonstrated that methanol in M85 fuels was observed to be very aggressive toward elastomers, polymers, and soft metals, extracting salts and com-

pounds from elastomers and polymers and aggressively dissolving soft metals, such as aluminum nozzles. The result was an M85 fuel that had a very high suspended solids content, creating a gel-like substance made of aluminum hydroxide, water, and methanol.

Although the difference between methanol and ethanol is one carbon, ethanol is not considered to be as aggressive as methanol, but many of the same degradation issues have been observed to occur over a longer period of time.

Thus, it is recommended that dissimilar metals not exist in systems that store, distribute, or dispense E85 fuels on a continuous basis. The metals recommended for E85 systems are provided in Table 2.

TABLE 2
Metal Compatibility in E85
(5,14,15)

RECOMMENDED	NOT RECOMMENDED
<ul style="list-style-type: none"> • Bronze • Black iron • Mild steel • Stainless steel • Unplated steel • Nickel-plated aluminum or brass • Aluminum alloy 	<ul style="list-style-type: none"> • Brass • Lead • Lead solder • Magnesium • Lead-tin alloy (tin-plated steel) • Zinc

■ **Permeation of Nonmetals**

Although the mechanism is not really understood, the presence of ethanol in fuel facilitates the permeation of hydrocarbons through certain elastomers and thermoplastics, and to a lesser degree, thermoset products (8,12,13). Permeation refers to the mass transport of a substance (or solvent) through a membrane that is driven by a chemical potential or activity gradient. Dilute ethanol in an E10 fuel possesses sufficient chemical potential or activity to become the chemical gradient that drives permeation through the material.

Of course, permeation is dependent on several factors, such as solvent-material interaction, the surface-area-to-thickness ratio of the nonmetal, and the degree of cross linking (e.g., elastic contraction) in a material (8).

For example, we know that ethanol and hydrocarbons do not

permeate through metals. To a lesser degree, the same could be said for thermoset products—fiberglass-reinforced polymeric materials (8). However, the same principles do not necessarily hold true for elastomers and thermoplastics—materials that have very little to no cross-linking. The lack of cross-linking can affect the rate of permeation.

The permeation of gasoline or ethanol through a nonmetal can result in a change in the physical, chemical, and mechanical properties of an elastomer or polymer. For example, permeation can result in excessive swelling. This in turn can cause an elastomer or polymer that performs an important dynamic function, such as a pump seal or pump impeller, to fail. In principle, the same can be said of elastomers and polymers that also perform static functions.

Elastomers and polymers also face an issue where excessive permeation and swelling can lead to plasticization. In some cases, chemicals such as antioxidants and heat stabilizers are added to nonmetals to confer certain performance properties. Since these additives are not chemically bound, excessive swelling in a material can eventually lead to the extraction of these plasticizers as the solvent passes through the material. This will lead to a measurable loss in strength and flexibility of the elastomer or polymer. A sampling of recommended elastomers and polymers is provided in Tables 3 to 6.

Okay, What Have We Learned?

We have learned that there are basically two types of ethanol fuels. Low-ethanol fuel blends like E10 that have been in use since the late 1970s, and high-ethanol fuel blends like E85 that have been in use since the 1990s. There are four major areas of concern for low- and high-ethanol fuel blends—phase separation, solvency, metal corrosion, and permeation of elastomers and polymers. Low-ethanol fuel blends have different material and handling recommendations compared with high-ethanol fuel blends.

Low-ethanol fuel blends are sensitive to water and temperature. High dissolved water content and/or a

TABLE 3
Elastomer Compatibility Issues
in E10 Fuels (5,14,15)

RECOMMENDED	NOT RECOMMENDED
<ul style="list-style-type: none"> • Acrylonitrile (hoses & gaskets) • Fluorocarbons • Fluorosilicone • Natural rubber • Polychloroprene (hoses & gaskets) • Polysulfide rubber 	<ul style="list-style-type: none"> • Acrylonitrile (seals) • Polychloroprene (seals) • Urethane rubber • Zinc

TABLE 4
Elastomer Compatibility Issues
in E85 Fuels (5,14,15)

RECOMMENDED	NOT RECOMMENDED
<ul style="list-style-type: none"> • Acrylonitrile, • Nitrile rubbers • Polychloroprene • Polytetrafluoroethylene • Fluorocarbon 	<ul style="list-style-type: none"> • Natural rubber • Cork gasket material • Leather

TABLE 5
Polymer Compatibility for
E10 Fuels (5,14,15)

RECOMMENDED	NOT RECOMMENDED
<ul style="list-style-type: none"> • Acetyl • Polyamides • Polypropylene • Polytetrafluoroethylene • Fiberglass-reinforced plastic 	<ul style="list-style-type: none"> • Polyurethane • Alcohol-based pipe dope

TABLE 6
Polymer Compatibility
for E85 Fuels (5,14,15)

RECOMMENDED	NOT RECOMMENDED
<ul style="list-style-type: none"> • Polyamide • Polyethylene • Polypropylene 	<ul style="list-style-type: none"> • Alcohol-based pipe dope • Methyl-methacrylate • Polyamide • Polyester bonded fiberglass laminates • Polyurethane • Polyvinyl chloride

sudden drop in temperature can result in phase separation of ethanol and water in the fuel tank. Phase-separated fuels that enter vehicle fuel systems can result in operational problems.

■ *continued on page 6*

■ E10 and E85 from page 5

Low E-blends can contain up to 10 percent ethanol. If a fuel system that previously dispensed gasoline or diesel fuel has not been properly cleaned prior to conversion, the ethanol will clean or dissolve a variety of materials found on the walls of USTs, piping, dispenser piping, hoses, and nozzles. The suspended or dissolved material can enter the bulk-fuel stream and could create drive-ability problems for vehicles.

Most of the available literature indicates that UST systems should fare well with low E-blend fuels and not experience metal corrosion. However, this may not be the case for certain elastomers and polymers. Current data suggest that low E-blend fuels have a higher activity or gradient than E85 fuels and therefore a greater potential for permeation, swelling, and possible performance degradation of the elastomer or polymer.

E85 presents other operational and compatibility considerations. Early work with E85 and M85 test fuels demonstrated that methanol was a more aggressive alcohol than ethanol and the source of many material compatibility issues. As a result, research and development shifted away from M85 and refocused on E85. This is not to suggest that E85 is immune from material compatibility issues but rather to suggest that certain material compatibility issues may take place over a longer period of time.

Because E85 can absorb a greater volume of water and ionic contaminants, E85 becomes a good electrical conductor. Metals that are in constant contact with E85 fuel should be of the same or similar material and more stable on the galvanic series. If soft or anodic metals such as aluminum or brass must be used, then they should be nickel plated if they are to be in continuous contact with E85 fuels. It is also possible that certain technologies that rely on the conductive or capacitance properties of gasoline may experience degradation in performance accuracy and precision due to the change in electrical properties of the E85 fuel.

E-85 fuels have a high solvent capability. Any retail station owner

considering converting a used UST over for E85 use *must* have the UST and associated piping thoroughly cleaned, dewatered, and carefully inspected by a bonded and insured company. Data and industry experi-

“There are four major areas of concern for low- and high-ethanol fuel blends—phase separation, solvency, metal corrosion, and permeation of elastomers and polymers. Low-ethanol fuel blends have different material and handling recommendations compared with high-ethanol fuel blends.”

ence suggest that E85 will dissolve material from the walls of the tank, piping, and dispenser.

Because E85 has greater solvency and increases the conductivity of the liquid, dissimilar metal piping, synthetic materials, nonmetallic materials, and nozzles made of soft metals could dissolve, degrade, and corrode, creating further problems for UST facility owners and their clients. It is strongly recommended that the owner convert equipment over to “approved E85 equipment.”

Degradation of nonmetallic materials, such as elastomers, polymers, and natural materials can occur when in constant contact with E85 fuel. Data also indicate the maximum swell of some polymers occurs at approximately 15 percent ethanol and diminishes as the ethanol concentration approaches 85 percent. Permeation of a nonmetal can cause swelling, plasticization, degradation, and loss of dynamic and static functions. ■

Edward W. English II is Vice President and Technical Director for Fuel Quality Services, Inc. He can be reached by phone at (770) 967-9790 or by email at english@fqsinc.com.

Ethanol Fuel Resources

Web Links:

- Alternative Fuels Data Center:
<http://www.eere.energy.gov/afdc/altfuel/altfuels.html>
- National Ethanol Vehicle Coalition :
<http://www.e85fuel.com/index.php>
- Renewable Fuels Association (RFA)
<http://www.ethanolrfa.org/>

Suggested Reading:

- New England Interstate Water Pollution Control Commission, Vol 3, Chapter 5, July 2001, *Health, Environment, and Economic Impacts of Adding Ethanol to Gasoline in the Northeast States.*
- SAE Technical Paper Service, 2005-01-3708, *Effects of Alcohol in Fuel-Line Material of Gasohol Vehicles.*
- Matthew F. Mynetti, February 2003, technical white paper, *A Comparison of Fuel and Oil Resistant Properties of Polymers.*

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15. United States of American Department of Energy, April 2002, *Handbook for Handling Storing and Dispensing E85.*

Is Your UST System Ethanol Compatible?

A Regulator's Perspective

by Jeff Kuhn

Legislation in Montana and across the United States banning the oxygenate compound MtBE has greatly increased the use of ethanol, another oxygenate slated to be the frontrunner to take the place of MtBE. Currently, twenty-six states and Washoe County, Nevada, have MtBE bans in place or enacted; six states considered bans in 2005. Oxygenates are a necessary part of gasoline formulation and create the octane ratings for various grades of fuel used in internal combustion engines.

Meanwhile, the fuel efficiency benefits and rising popularity of hybrid and flexible-fuel vehicles are also generating a great deal of interest in the use of ethanol, considered a more environmentally friendly and nationally acceptable alternative that may help loosen U.S. reliance on Middle East oil. According to the National Ethanol Coalition (<http://www.ethanol.org/production.html>) there are currently 94 ethanol production facilities in the U.S. and 31 more under construction.

Most folks in Montana seem to view the move toward ethanol as a step in the right direction—less dependence on foreign crude, and a potential boon to Montana's agricultural community that might provide the feedstock for future ethanol plants in the state. And given the average driving distances here, (it's not unusual to drive 4 hours in one direction and still be well within the state), most Montanans are painfully aware of rising fuel costs.

However, despite the benefits of ethanol, there are potential UST-system compatibility issues that need to be considered by owners and operators. A number of state websites provide information resources and fact sheets to assist UST owners and operators converting to gasoline-ethanol blends (E-blends), particularly E10. During my review of information gleaned from internet sources (e.g., industry literature, state websites, and published research), I noticed a recurring theme summed up by the

following statement from the Iowa Department of Natural Resources: "Without converting to compatible equipment, your UST system could degrade, and a product release could occur. Ultimately, the equipment and components must be compatible with the percentage volume of ethanol-blend you intend to use."

Many of these websites go so far as to strongly recommend or require that equipment used to dispense E-blends be certified by the manufacturer or that the owner/operator sign a "statement of compatibility," verifying that the equipment is compatible with E-blends. State and federal rules require that all components and equipment used for storing and dispensing motor fuels be compatible with the product stored. Owners and operators of UST systems in states using E-blends need to be aware of potential compatibility problems and plan to replace equipment reported to be prone to deterioration from E-blends.

Susceptible Components

So what materials are potentially at risk or prone to deterioration from contact with ethanol? Soft metals, including brass, aluminum, and zinc, commonly found in fuel-storage dispensing systems are not compatible with ethanol, especially at the higher concentrations found in E-85 motor fuel (Wisconsin DNR). Some non-metallic materials, such as natural rubber, polyurethane, adhesives (used in older fiberglass piping), certain elastomers, polymers used in flex piping, bushings, gaskets, meters, filters, and materials made of cork, are prone to deterioration from ethanol blends over 10 percent by volume (Office of the Illinois State Fire Marshal). Copper and plastic in air-eliminator floats may also not be compatible with ethanol.

For detailed information regarding specific storage and dispensing equipment for E-blends, see the New England Interstate Water Pollution Control Commission's (NEIWPC, 2001) *Health, Environmental, and Eco-*

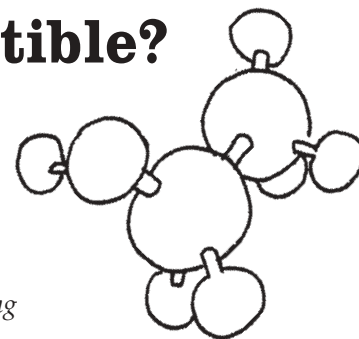
nomics
Impacts
of Adding
Ethanol

to Gasoline in the Northeast States, July 2001, pp. 70-71 at http://www.neiwpc.org/PDF_Docs/ethvol3.pdf. Also, a list of E-85 compatible equipment can be found at <http://www.e85fuel.com/information/manufacturers.htm>. This document provides a detailed and well-researched chapter on the storage and handling of E-blended fuels, with discussion regarding compatibility with specific UST-system components.

The California State Water Resources Control Board (SWRCB) strongly recommends that UST owners and operators request a written compatibility statement from respective equipment manufacturers before storing E-blends on site. Their website (http://www.swrcb.ca.gov/cwphome/ust/leak_prevention/ethanol/ethanol.htm) provides a reference list of equipment manufacturers to contact for more information. SWRCB also lists potential compatibility problems with the following UST-system components:

- Single-walled fiberglass tanks installed prior to 1/1/1984
- Single-walled fiberglass and flexible piping installed prior to 1/1/1984
- Lining material used to line old single-walled tanks for repairs or upgrade
- Adhesives, glues, sealants, and gaskets used around the piping and other parts of the UST system (more of a concern for older systems, but may be an issue for new installations if the contractor failed to use proper material)
- Pump heads and other auxiliary equipment, including certain metals (e.g., aluminum, brasses/bronzes) that come in contact with the product
- Older models of some leak-detection equipment that may not

■ *continued on page 8*



■ Ethanol Compatible? *from page 9*

operate properly or with parts that may wear out with exposure to E-blend fuels.

The SWRCB advises that if any of these components are present at a site, the owner/operator should contact the equipment manufacturer and installer to determine whether they are compatible with E-blends.

Affinity for Water

Ethanol, also known as ethyl alcohol, has a strong affinity for water (David Korotney, EPA, undated memo). This propensity to absorb water makes it even more important that water accumulation is carefully monitored and that water is routinely removed from tank bottoms. Absorbed water in fuel reduces motor fuel BTU and octane rating and can lead to phase separation—allowing the alcohol to drop out of the gasoline and form a layer of gasoline on top and a layer of ethanol on the bottom. This phase-separated alcohol/water bottom encourages the growth of aerobic bacteria, which can be detrimental to petroleum fuels and certain fuel-handling components. Phase separation can also be a problem for vehicle-fuel and ignition-system components when fuel contaminated with water is distributed.

Degradation and Accelerated Corrosion

Steel UST systems may be adversely impacted by ethanol due to accelerated corrosion caused by scouring or loosening of deposits in tanks and distribution lines. If a corrosion cell already exists, ethanol can increase the effect of scoured exposed steel surfaces and eventually cause a perforation of the steel. As mentioned, ethanol can corrode soft metals such as zinc, brass, copper, lead, and aluminum. These dissolved metals in the fuel can, in turn, contaminate a motor vehicle's fuel system.

Conductivity and ATG Probes

Capacitance probes may not work in E-blend fuels due to the higher conductivity of ethanol. Owner/operators should verify that magnetostrictive probes are alcohol compatible and that the automatic tank gauge (ATG) system is properly calibrated for E-blends.

Tank Linings

Older tank linings seem to pose a specific concern for the storage of E-blends because of the incompatibility of ethanol with epoxy-based tank linings. "Older epoxy linings used to line steel USTs, both inside and out, have been found to soften when exposed to E-blend (10 percent ethanol by volume)" (NEIWPC 2001, page 64. Source: Downstream Alternatives, Inc., 2000; Archer Daniels Midland Co., 2000). The American Petroleum Institute (API, 1985) also found that general purpose tank linings softened when exposed to ethanol vapors. Newer formulations of UST lining material may be compatible with ethanol.

Converting Existing Storage and Dispensing for E-Blends

The following state websites provide specific recommendations for owners and operators who are converting existing fuel storage systems for E-blends.

■ Iowa

The Iowa Department of Natural Resources (DNR) has an online checklist (<http://www.iowadnr.com/lan/ust/technicalresources/ethanol.html>) for upgrading UST systems for compatibility with ethanol blends greater than 10 percent ethanol by volume. Dispensers must bear the UL mark or be certified as compatible with the product stored and dispensed.

Because there are currently no E-blend-compatible dispensers available with a UL listing mark, Iowa allows incompatible dispensers a two-year phase-in for E-blend use. However, shear valves or emergency valves on existing and new UST systems must be compatible with E-blend fuel. UST systems installed after August 1, 2005, must use available compatible equipment at the dispenser if E-85 is stored and dispensed. The final phase-in for ethanol-compatible dispensing equipment in Iowa is July 1, 2007. Incompatible dispensers may not be used after that date.

During the phase-in, dispensers not certified by the manufacturer or UL marked as compatible for E-blends must be checked daily for leaks and equipment failure. Daily inspections must be completed for

non-compatible dispensers and visual observations recorded on a form provided by the DNR. Any incompatible component that leaks or does not operate as designed must be removed and replaced with E-blend-compatible components. The DNR must be notified immediately of any failed component.

■ Wisconsin

The Wisconsin Department of Commerce (WDC) has prepared an excellent brochure that summarizes steps that should be taken to prepare UST systems for conversion to E-blends: http://commerce.wi.gov/ERpdf/bst/ProgramLetters_PL/ER-BST-PL-PreparingForEthanolBrochure.pdf. The website notes that "the first-time transition to blends of up to 10 percent ethanol should not be assumed to be trouble free" and lists a series of assessments and procedures for owners and operators to follow.

One of the most notable statements on the site is that "no level of water is acceptable for ethanol-blended fuel due to the phase-separation problems." WDC tells owners and operators to make certain that "all fittings and connections at the top of the tank are tight (no vapors escape and no water enters) and that all sump and spill-containment covers prevent water from entering. Any water intrusion problems must be corrected."

The brochure cautions tank owners to "clean any tank used to store ethanol to remove all sludge from the bottom of the tank. Any sludge or particulate in the bottom of the tank will be suspended in the ethanol and cause problems with filters and fuel lines."

■ Illinois

The Office of the Illinois State Fire Marshal requires that owners and operators sign a *Statement of Compatibility* form, which can be found on their website, certifying that UST systems under their control that store E-85 are compatible with E-blends. Owners and operators must also submit a *Notification Form for Underground Storage Tanks* to the Office of the State Fire Marshal indicating the change of product that will be stored in the UST. The form must be signed by the UST-system owner. (The form may be downloaded from the OSFM website at www.state.)

il.us/osfm and then following prompts to “Division of Petroleum and Chemical Safety” and then to “Download Applications” and then choose “UST Notification Form.”)

The Future

Most people in the petroleum industry are keenly aware of the ongoing changes in fuel formulation, due in part to advances in technology in petroleum refining, chemical engineering, automobile manufacturing, and energy conservation. Some of these changes are also due to recognition of oxygenate impacts at LUST sites and the “boutique fuels” with geographic-specific fuel formulations to address the needs and requirements of different areas of the country.

As with all advances in technology, the benefits of the technology should outweigh its risks. The increased use of ethanol means the decreased use of MtBE and other similar compounds that, due to their unique chemistry, have the ability to travel farther and faster in groundwater and pose a greater threat to drinking water supplies.

However, even the best technological advances have a retooling cost—both at the refinery level and at marketing and retailing levels. Ethanol typically requires bulk transportation and on-site splash blending at fueling terminals to avoid its absorption of water in pipelines. Special handling practices and precautions must be taken.

Such considerations were a very significant part of discussion that led up to the phase-out of MtBE in California and the phase-in of ethanol in gasoline. (See *Health & Environmental Assessment of the Use of Ethanol as a Fuel Oxygenate*, California Air Resources Board, the State Water Resources Control Board, and the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment, 1999—<http://www-erd.llnl.gov/ethanol/eto-hdoc/index.html>.)

Another important question is whether state UST inspectors, during the transition to E-blends, will even look for potential compatibility problems by carefully inspecting specific components that are prone to degradation from ethanol. Perhaps this

will require additional training or a specific module in state training programs (classroom and web-driven) that focuses on key compatibility concerns identified by the petroleum-equipment industry and other information sources.

The advent of E-blend fuels in Montana and other states has been a longtime coming. The Montana Department of Environmental Quality views ethanol as a favorable alternative to MtBE and a step in the right direction toward environmental stewardship and energy sustainability. At this time, a limited number of Montana distributors provide E-85 or other E-blends for consumers.

However, as more UST owners and operators in Montana, and throughout the nation, consider storing and distributing E-blends, they need to plan accordingly and verify that their fuel storage systems are compatible with ethanol. Otherwise we will only succeed in creating another means for petroleum from fuel-storage systems to be released into the environment, thus carrying on the long legacy of groundwater contamination that many of us have spent our careers trying to rectify. ■

Jeff Kuhn is manager of the Montana DEQ Petroleum Release Section. He can be reached at jkuhn@mt.gov.

References

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- Office of the Illinois State Fire Marshal www.state.il.us/osfm
- Iowa Department of Natural Resources <http://www.iowa.dnr.com/lan/ust/technicalresources/ethanol.html>
- California EPA SWRCB's advisory to UST Owners and Operators Regarding Ethanol-Blended Fuel Compatibility http://www.swrcb.ca.gov/cwphome/ust/leak_prevention/ethanol/ethanol.htm
- California Environmental Protection Agency State Water Resources Control Board http://www.swrcb.ca.gov/cwphome/ust/leak_prevention/ethanol/ethanol.htm
- Wisconsin Department of Commerce: “Preparing For Ethanol Brochure” http://commerce.wi.gov/ERpdf/bst/ProgramLetters_PL/ER-BST-PL-PreparingForEthanolBrochure.pdf
- *Health & Environmental Assessment of the Use of Ethanol as a Fuel Oxygenate*, California Air Resources Board, the State Water Resources Control Board (SWRCB), and the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (CalEPA/OEHHA, 1999). <http://www.erd.llnl.gov/ethanol/eto-hdoc/index.html>
- Water Phase Separation in Oxygenated Gasoline by David Korotney, EPA, Chemical Engineer, Fuels Studies and Standards Branch <http://www.epa.gov/otaq/regs/fuels/rfg/waterphs.pdf>

Recommended Practices and Codes:

- American Petroleum Institute. (April 1985) *Storing and Handling Ethanol and Gasoline-Ethanol Blends at Distribution Terminals and Service Stations*. API Recommended Practice 1626.
- National Fire Protection Association (NFPA) 30, *Flammable and Combustible Liquids Code*, 2000 Edition; NFPA 30A *Code for Motor Fuel Dispensing Facilities and Repair Garages*.
- Renewable Fuels Association, *Fuel Ethanol: Industry Guidelines, Specifications and Procedures*, RFA Publication # 960501, Revised December 2003. <http://www.ethanolrfa.org/final960501.pdf>
- US Department of Energy, *National Renewable Energy Laboratory: Handbook for Handling, Storing, and Dispensing E85*, April 2002 <http://www.eere.energy.gov/biomass/pdfs/30849.pdf>



Good-bye Sammy and Thanks

Sammy Ng, U.S. EPA Office of Underground Storage Tanks (OUST) Deputy Office Director, says good-bye to state and federal UST/LUST program friends at the 18th Annual National Tanks Conference in March in Memphis, Tennessee. Sammy is retiring from EPA and says he plans to look for America... um...in an old VW van? He joined the OUST staff in 1985 as one of the original members of the UST/LUST program team and served as Acting OUST Director from 1999 to 2000. Have fun, Sammy. We'll miss you.

Photo courtesy of Kim Schweisberg

Wander LUST

by Patricia Ellis

A roving column by reporter Patricia Ellis, a hydrologist with the Delaware Department of Natural Resources and Environmental Control, Tank Management Branch. Pat served as a member of U.S. EPA's Blue Ribbon Panel on MtBE. She welcomes your comments and suggestions and can be reached at Patricia.Ellis@state.de.us.



Ethanol? Good. Yes? Um...

It started as an ordinary day, but rapidly degraded into an antacid kind of day. Why? Because ethanol was going to be replacing MtBE as a gasoline oxygenate a lot faster than any of us expected. Here's the story.

The Valero Energy Corporation recently purchased the Delaware City Refinery (and that's fine and dandy). Because the refinery is within the coastal zone and is subject to the requirements of the federal Coastal Zone Act, any new activities that take place within the facility must be permitted. So a request was circulated to various groups within the Department of Natural Resources and Environmental Control (DNREC) to provide comments about the refinery's request to change its gasoline oxygenate from MtBE to ethanol, which requires some piping changes and modifications to at least one large aboveground storage tank (AST), internally lining the AST, sealing roof joints, and installing a jet mixer.

The ethanol is to be shipped in to the terminal by barge or tanker, transferred to storage via an existing pipeline, and stored in an AST. Prior to storage, the ethanol will be blended with 2 percent gasoline as a denaturant. Additional modifications will be made to transfer the ethanol to the truck-loading lanes, where it will be blended with gasoline before leaving the terminal.

I was thrilled to hear this because, after all, Delaware has not yet managed to ban MtBE. Last year, our assembly passed a bill to ban MtBE, which was to become effective in 2008, but the bill is now "languishing" in a senate committee. The sen-

ate passed a bill to form a task force to study the issue of an MtBE ban. It was referred to a house committee, where it now sits. The bills were carried over into the current legislative session, but they may never get out of committee. Since the refinery in question supplies the majority of gasoline used in Delaware, we'd at least be getting rid of a large chunk of potential MtBE problems, whether or not a ban bill is passed.

Whoa, Nellie!

As vocal as I've been about the evils of MtBE over the past years, you'd think that I'd be thrilled to hear that our refinery wants to stop adding MtBE to our gasoline. But the kicker in the application was the statement: "As part of its clean fuels strategy for the Delaware City Refinery, Valero will no longer use MtBE as a gasoline-blending component effective May 1, 2006." Whoa...that's soon! That's lots sooner than the bill that proposed banning MtBE in 2008!

Most of the other states that are using 10 percent ethanol by volume (E10) in their gasoline seem reasonably happy. Either they've been using it for years because they're Corn Belt states, or they're using it because they banned MtBE and have had a few years to prepare. So far as I can tell there were no major problems with switching over. Clean out the tank ahead of the switch, change filters more frequently, at least for a

while, and be diligent about keeping water out of the tank. But wait.

Federal regulations say "owners and operators must use an UST system that is made of or lined with materials that are compatible with the substance stored in the UST system." Paul Miller of the U. S. EPA Office of Underground Storage Tanks says "to date, EPA has relied on UL testing to help in the compatibility determination."

Our regulations state that all equipment used as part of a tank system must be compatible with the substance stored, as do those of about ten other states that I checked with, where I know ethanol is in use. A quick scan of our database last summer showed me that we had 121 fiberglass tanks installed before January 1, 1984, only one of which is double-walled.

California advised their tank owners that pre-1984 tanks may not be ethanol compatible. We had 306 fiberglass tanks with gasoline installed after that date, 133 of which were single-walled. We haven't run queries yet on tank piping. What do we currently have in the ground for flexible piping and rigid fiberglass piping, and when were they installed? Are they certified as being E10 compatible? Dates for E10 compatibility for tanks and lines vary by years among different manufacturers.

Calls to some of the manufacturers concerning UL approval of some of the equipment have resulted in answers such as "Well, it isn't officially UL approved for use with E10, but it's probably okay to use it." "Probably okay" doesn't cut it for concurrence with the regulations.

How many of our roughly 350 gasoline stations can prove that all their equipment is approved for use with E10?

Where are the compatibility concerns? Our regulations state that "The material used in the construction and/or lining of the UST system must be compatible with the product stored." The New England Interstate Water Pollution Control Commission published a report in 2001 entitled *Health, Environmental, and Economic Impacts of Adding Ethanol to Gasoline in the Northeast States*. Volume 3, Chapter 5 deals with ethanol storage and handling, and provides an excellent summary of the parts of tank systems where there may be compatibility issues. Besides tanks and lines, there may be compatibility issues with leak-detection devices, dispensers, pumps, and almost every part of an UST system. I'll leave you to read that excellent summary at http://www.neiwpc.org/PDF_Docs/ethvol3.pdf.

The Heartburn Thickens

So, since a large percentage of the gasoline sold in Delaware comes from the Delaware City Refinery, we could all be driving with ethanol in the very near future. If a retailer buys gasoline from that refinery, he'll be getting E10. If he can't prove that all his equipment is approved for use with ethanol, he's in violation of our regulations. He might also be voiding the warranty on parts of his tank system.

Now supposing there is a release. Will his insurance company pay for investigation and remediation if the equipment warranties have been voided and he's potentially in violation of our regulations? I certainly doubt it! Are other states as concerned about compatibility issues? New York and Connecticut evidently recommended that owners clean their tanks thoroughly before switching, and check filters frequently. And what about proving compatibility? I checked around to find out where states are with regard to E10 and E85. Here's what I've learned so far.

■ California

In March 2000, California issued an advisory to tank owners/operators regarding E-blend fuel compatibility. At that time, some parts of the state were already using E10. The

advisory stated that if the UST system was not compatible with this fuel, there would be a higher risk of damage to the UST system and the environment. It urged "that you verify that your entire system is compatible with the ethanol-blend fuel before you store it in your UST system," and that compatibility information may be available from your equipment manufacturer. As far as I can tell, this advisory does not require that you prove or certify that your entire UST system is compatible. (http://www.swrcb.ca.gov/ust/leak_prevention/ethanol/ethanol.htm)

■ Illinois

Some states seem to be concerned with compatibility issues when you convert from E10 to E85. A memo from the Office of the Illinois State Fire Marshall states that "components and equipment used for storing/dispensing conventional fuels are time tested for compatibility and readily available through your petroleum supplier. High-percent ethanol, however, does not have the same compatibility characteristics of conventional fuels when it comes to storage and dispensing...In order to store and dispense high-percent ethanol, fiberglass and steel UST systems must be listed by Underwriters Laboratories, Inc. [UL] or certified by the manufacturer." Illinois says that if you store E85, you must certify that you have researched all of the various components of your tank system and certify that they are E85 compatible. (www.state.il.us/osfm/PetroChemSaf/Home.htm) I didn't find any information on their website about compatibility with E10 blends; this seems to be a nonissue for Illinois.

■ Iowa

Iowa is allowing existing facilities a two-year phase-in period to upgrade so they are compatible with E85. This allows retailers to begin selling E85, but it requires that dispensers and components not certified as compatible be upgraded within the two-year period. I guess that this gets you to replace any parts that may be starting to get squishy before they completely fail. (<http://www.iowadnr.com/land/ust/technicalresources/ethanol.html>) Again, I don't know whether E10 is a non-issue. Both Illinois and Iowa have been using E10 for years.

■ New Hampshire

Lynn Woodard, New Hampshire Department of Environmental Services (DES), realized that ethanol was coming to the nearest gas station much sooner than later and spent considerable time and effort researching what tank owners needed to know about an ethanol changeover. The DES has posted an ethanol fact sheet for tank owners, Qs&As, and a Power Point presentation on its website at <http://des.nh.gov/mtbetrans.html>.

Woodard says tank owner/operators of facilities changing over to ethanol need to be aware of the importance of getting rid of their existing water-finding paste. They need to ask their fuel supplier for a paste designed to detect water in an ethanol-blend gasoline. Further, they need to gauge the tank at its lowest end, allow at least one minute for the reaction to occur on the paste, and check the directions to determine what each resulting color means (i.e., is water present or has phase separation occurred?).

"We also encourage tank owner/operators to install alcohol-sorbing filters on the dispensers," says Woodard. "These water-sensitive filters absorb water present in the tank. When the filter's capacity is exceeded, it slows the flow of gasoline to a very low rate or stops it entirely. The filter then has to be removed and replaced."

Woodard emphasizes the importance of making sure the tank is cleaned of all water and all pathways for water intrusion are eliminated prior to receiving the initial drop of an ethanol-blend gasoline. "Failure to do so can result in economic disaster for the tank owner," says Woodard.

If sufficient water remains in the tank—0.2 to 0.5 percent by volume—phase separation can occur. Once this happens, approximately 40 to 60 percent of the ethanol will have migrated out of the gasoline to the water. The ethanol-water level will more than likely exceed the withdrawal level in the tank, resulting in disruption in the ability to pump product or in a worst-case scenario (if a water-sorbing filter is not in place) dispensing a water-ethanol solution to customer vehicles. Repair of the vehicles can be costly.

■ continued on page 12

■ WanderLUST from page 11

"The economic problems don't stop there," explains Woodard. "The octane of the remaining gasoline in the tank will have diminished substantially, and the gasoline won't be suitable for sales. Unless it can be shipped back to the refinery, it will have to be disposed of as a hazardous waste at a rate of two to three dollars per gallon. This could be the financial straw that breaks the tank owner's back."

■ Wisconsin

Sheldon Schall of the Wisconsin Department of Commerce (DOC) told me that they have stations selling E10, E20, and E85, and that they expected more problems than they've experienced. They did try to mandate ethanol-compatible dispensers, but the retrofit is \$7,000, and the ethanol and corn grower's lobby painted them as "ethanol unfriendly," so they had to back off. The decision to allow dispensers that were not UL-listed for E85 was based on common sense, experience, and professional judgment, and not the thought of being painted as "ethanol unfriendly."

Manufacturer Gilbarco told Schall that they use the same dispensers for ethanol in South America (Argentina and Brazil)—where cars may be fueled with anything up to 100 percent ethanol—that we use for gasoline in the United States. Also, Minnesota had been using higher-percentage ethanol for years with no particular problems.

Wisconsin has had problems when tank owners didn't clean tanks before switching to gas with ethanol. Schall described a fuel-system episode last spring in tanks that had not previously held E10. The operator ran a few tanks that were low on product, refilling each time with E10, but still had a problem with the ethanol loosening buildup on the tank wall. Within hours DOC had bad gas calls from owners of stalled cars.

Wisconsin guidance states that E10 is a normal component of today's automotive fuel, and it is accurate to refer to it as "gasoline." Any level above 10 percent ethanol cannot be labeled as gasoline. DOC requires that a form be submitted when there are plans for a new installation or plans to convert an existing system from conventional motor fuels to

blends greater than 10 percent ethanol. The form requires that the petroleum equipment contractor or a professional engineer verify that the system is E85 compatible either by UL listing or by the component manufacturer. No special certification is required if the tank system will be storing gasoline with 10 percent or less ethanol.

■ New York

Certain areas of New York State have been using E10 since MtBE was banned on January 1, 2004. Russ Braukseick of the New York Department of Environmental Conservation (DEC) says that "generally speaking, if the owner/operator prepared for the switch from gasoline with MtBE to E10 (by cleaning the tank of water and precipitated materials) there did not seem to be much of a problem.

"However," cautions Braukseick, "some operators of nonretail gasoline USTs (typically municipalities) did less to prepare for the introduction of E10 and had some issues with fuel quality. This has led to maintenance issues requiring filters to be changed more frequently. These problems seem to have been corrected over time.

"While DEC has not observed any compatibility issues with tank systems storing E10 to date," says Braukseick, "we are still concerned with long-term exposures of certain storage tank systems to ethanol. In particular, it has not been demonstrated that fiberglass tanks and piping manufactured in the early 1980s have long-term compatibility with ethanol. This has the potential for weakening the tanks or piping over time such that a failure is possible."

One New York regulator recently visited a facility where the owner didn't clean his tanks when he began using E10 two years ago. Since then, he has had to change his filters at least weekly. He still has sludge in his tanks and it has cost him as much in filters as it would have cost to clean out the tanks. He is planning to take his tanks out of service to clean them out in the very near future.

What about Commingling MtBE and Ethanol?

Delaware gets gasoline from several refineries in the Philadelphia area, just across our northern border, and

from refineries in New Jersey, just across the river. Many gasoline stations receive all their gasoline from the same refinery, but some buy on the spot market, from whoever has the best price. The thing is, gasoline with MtBE and gasoline with ethanol should not be mixed. We haven't banned MtBE in Delaware, so it's perfectly legal to have it in gasoline sold in the state. But it shouldn't be hauled in the same tankers without cleaning, and it shouldn't be mixed in the same UST or in your car's gas tank, because commingling causes a vapor-pressure increase. How do we prevent this?

We probably had MtBE in our gasoline for 20 years before we knew about it, so we didn't require anyone to certify that the equipment that went into the ground was approved for use with gasoline containing MtBE. This time, we're going into it knowing that we're going to have a change in gasoline composition and that there may be compatibility issues. A strict reading of the regulations out there seems to mean that we shouldn't allow equipment to be used that isn't officially declared as compatible.

Okay, Check Your Equipment and Clean Your Tanks

Since I began working on this article, we've done an about-face, or a reevaluation of our position. Even if we're able to get firm dates for certification of E10 compatibility by manufacturers, much of the time we don't know exactly what is in the ground. For older sites, we don't have installation plans showing details about the equipment, and for newer sites, we may have names of manufacturers and installation dates, but not the manufactured date. Many gasoline stations have changed ownership frequently, and I know that the paperwork and warranties are not always provided to the new owner. If we stuck to a strict interpretation of our regulations, we'd probably have to shut down large numbers of stations in the state, and we'd all be walking or biking to work.

So, we've gone the path of many of the other states. Letters went out to the tank owners and operators suggesting that they check that their equipment is compatible with E10, and giving suggestions as to how to

prepare for delivery of E10. Press releases went out with similar information, resulting in articles in several Delaware newspapers.

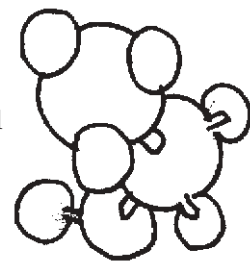
Some stations will be ready for ethanol. Many of the majors have arranged tank cleaning for company-owned stations; for those with delivery contracts, filters, water-finding paste, and information are being provided. On the other end of the spectrum are the suppliers that have provided no information whatsoever to their customer stations. At least one company has notified customers

that unless the operator can document that the tanks have been cleaned, no gasoline will be delivered. We're expecting at least a few of our operators to close up shop rather than bear the expense of the changeover.

Do We Need a 15th USTCA Work Group?

Following passage of the Energy Policy Act of 2005, U.S. EPA formed 14 different workgroups to deal with the issues related to changes made in the

Underground Storage Tank Compliance Act (USTCA). These changes were in Title XV, Part B of the Energy Bill. Part A of Title XV (by the way, Title XV is titled *Ethanol and Motor Fuels*) is the section that requires an increase in the volume of ethanol from 4.0 billion gallons in 2006 to 7.5 billion gallons in 2012, so it's probably coming soon to a station near you. ■



Field Notes

from Robert N. Renkes, Executive Vice President, Petroleum Equipment Institute

And Here Comes Ultra-Low Sulfur Diesel

With all the talk nowadays about getting underground storage tank systems ready to store ethanol and biodiesel, the implementation of new regulations to reduce the sulfur content in diesel seems to get lost in the shuffle. Yet in June 2006, the regulation that seemed so far away to many of us will be front and center. There is a new petroleum product in town, and its name is ultra-low sulfur diesel.

The new federal highway diesel-fuel sulfur rule (finalized in 2001), which requires a 97 percent reduction in the sulfur content of highway diesel fuel from its current level of 500 parts per million to 15 parts per million, provides that over the next four years, two distinct on-road diesel fuels will be available in the United States. One will be the traditional low-sulfur diesel (LSD) that has a maximum sulfur content of 500 parts per million (ppm). The other will be a new ultra-low sulfur diesel (ULSD) with a maximum sulfur content of 15 ppm.

Beginning June 1, 2006, 80 percent of the diesel produced by refiners must be ULSD, with the remaining 20 percent produced as LSD. The phase-in will continue until June 2010, when all on-road diesel fuel must be ULSD. Until that time, diesel marketers must make the choice to sell one of these products, or both.

For owners of diesel tanks, the first thing they must do is post new labels on their dispensers. The labeling of dispensers will help state UST regulators identify what product is being stored by the tank owner. By June 1, 2006, all retailers and wholesale purchasers/consumers of diesel fuel must post labels with the following language, depending on the product sold.

- **ULTRA-LOW SULFUR HIGHWAY DIESEL FUEL (15 ppm Sulfur Maximum)**
Required for use in all model year 2007 and later highway diesel vehicles and engines. Recommended for use in all diesel vehicles and engines.

- **LOW SULFUR HIGHWAY DIESEL FUEL (500 ppm Sulfur Maximum)**

Federal law *prohibits* use in model year 2007 and later highway vehicles and engines. Its use may damage these vehicles and engines.

From 2006 to 2010, both LSD and ULSD will be available in the marketplace for on-highway diesel use. Diesel engines manufactured in 2007 and later will run only on ULSD, so demand for ULSD will be relatively small in the early years of the program as the fleets start to turn over. However, there will be more ULSD-only engines on the road every year, and retailers will feel more pressure to offer ULSD to this growing market of truck drivers.

What does this mean to underground storage tank regulators? The answer lies with the choices made by the diesel marketers. If they choose to sell only LSD with a maximum sulfur content of 500 ppm, it will be business as usual, at least until 2010 when they must change to ULSD. If they decide to sell only ULSD with a maximum sulfur content of 15 ppm, there would be a change in service that regulators would want to know about. It will still be diesel, but with less sulfur.

The most significant change will result if retailers decide to expand their storage capacity to sell both LSD and ULSD until 2010. If they choose this option, they will either have to add tanks and/or convert existing gasoline or LSD diesel tanks to handle ULSD.

For most UST regulators, the introduction of ULSD will be no big whoop. Expect a few new tanks and some changes in service notifications during the second half of 2006. Anticipate more interest in ULSD later on as the price stabilizes and the new model diesel engines come out. And get ready for a lot of questions from owners of diesel storage tanks as they make the strategic decision about their diesel business.

For more information on the rule, go to www.epa.gov/otaq/diesel. ■

Using Direct-Push Tools to Map Hydrostratigraphy and Predict MtBE Plume Diving

by John T. Wilson, Randall R. Ross, and Steven Acree

MtBE plumes have been documented to dive beneath screened intervals of conventional monitoring-well networks at a number of LUST sites. This behavior makes these plumes difficult both to detect and remediate. Electrical conductivity logging and pneumatic slug testing performed in temporary push wells are two well-established technologies that are finding new applicability in characterizing sites with diving plumes. This article describes the use and evaluation of these techniques in finding a diving plume of MtBE in an aquifer that supplies water to the village of East Alton, Illinois. [Note: This article contains material previously published in *Ground Water Monitoring and Remediation*, Vol. 25, issue 3, pages 93–102.]

Now You See It, Now You Don't

In October 1999, MtBE was detected in water supply wells 6, 8, and 9 within the East Alton wellfield. (See Figure 1.) The staff of the Illinois EPA (ILEPA) identified the plausible sources of the MtBE contamination as releases of gasoline from two service stations located 400 and 500 meters northeast of the municipal water supply wells. However, results of the investigation revealed plume behavior that they could not easily explain. In the first 100-meter interval along the groundwater flowpath, the plume was readily delineated using shallow wells extending only a few meters into the water table. In the second 100-meter interval, however, MtBE was not detected in shallow groundwater but was detected at depths of between 6.5 and 12.5 meters below the water table.

Because there was minimal opportunity for recharge through the paving over the first 100-meter interval, burial of the MtBE plume by recharge could not explain the absence of MtBE in the shallow wells. ILEPA recognized that the MtBE plume may have moved below the conventional monitoring network. To find the diving plume, they assumed it would follow the flow of groundwater and that groundwater would flow through the more conductive material in the aquifer.

They used electrical conductivity logging, performed with push technology to characterize the hydrostratigraphy of the aquifer. This technique is affordable and produces data in real time. Southwest of the paved area, the water table was contained in a thick layer of silt and clay extending up to 7 meters into the

aquifer. Below the silt and clay there was a layer of sand and gravel. ILEPA collected water samples from the layer of sand and gravel and successfully located the diving plume.

Through a joint agreement between U.S. EPA Region 5 and the Office of Research and Development to provide technical assistance to state regulatory agencies in the region in identifying and predicting diving plume behavior at groundwater sites contaminated with MtBE, EPA's National Risk Management Research Laboratory (NRMRL, in Ada, OK) provided a team to conduct a more detailed characterization of the flowpath between the possible sources of MtBE and the impacted water-production wells. Our work at the site was designed to confirm and extend the site conceptual model developed by ILEPA and to evaluate their approach for site characterization to predict plume diving.

Potential Sources

A major highway (Illinois Route 3) extends across the catchments of the East Alton wellfield approximately 500 meters from the impacted wells. ILEPA identified two former gasoline service stations located immediately north and south of Route 3 as potential sources of the MtBE. (See Figure

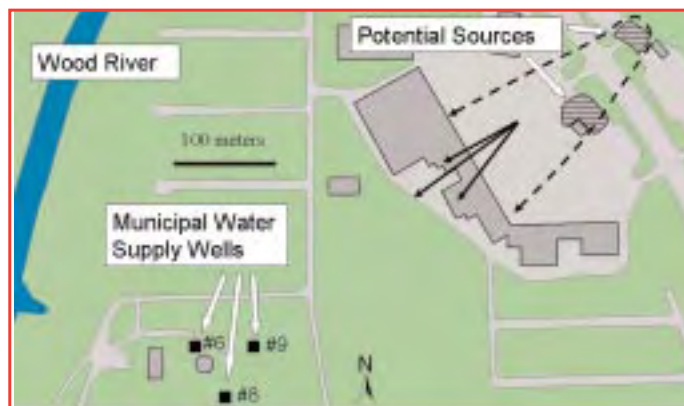


FIGURE 1. Relationship between possible sources of MtBE and water supply wells contaminated with MtBE. The dotted line encloses permanent monitoring wells with detectable concentrations of MtBE. The three solid arrows indicate the direction of ground water flow in separate rounds of sampling in 2001, 2002, and 2003. They extend from the most contaminated permanent well at the site.

1.) Monitoring wells at both sites were sampled in January 2000. The maximum MtBE concentration in wells to the north of Route 3 was 156 µg/L (although it increased to 1,800 µg/L in a subsequent round of sampling); in wells to the south, the maximum concentration was 2,200 µg/L.

The maximum concentrations of MtBE in East Alton water supply wells 6, 8, and 9 were 32, 61, and 560 µg/L, respectively. The concentration in water supply well 9 peaked in summer 2000 (Figure 2) and a year later the concentration was an order of magnitude lower. As part of cleanup activities at these two sites, nearly 30,000 tons of contaminated backfill and dirt were removed from the two sites and the holes refilled with clean material.

Hydrogeologic Characteristics of the Site

Data were available from a short-

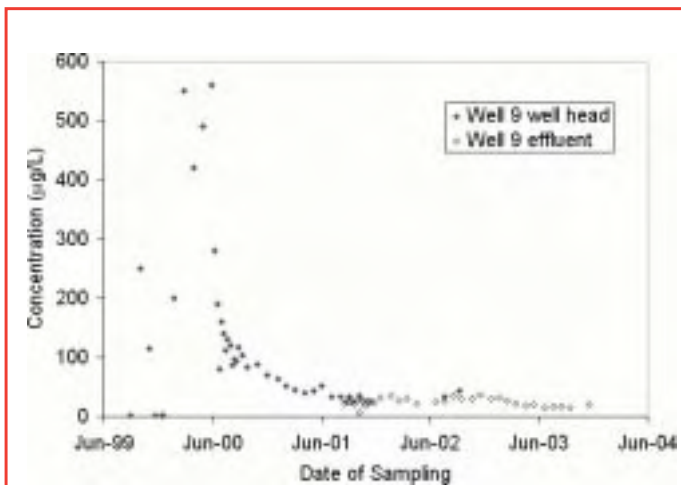


FIGURE 2. Concentration of MtBE in the most contaminated water supply well.

term pumping test (300 minutes at 6240 L/min) conducted on well 1, one of the pumping wells in the wellfield. Transmissivity was estimated based on analysis of drawdown curves from two observation wells using the Theis-type curve for a confined aquifer for the pumping data and the Theis-recovery method for the recovery data. These estimates of transmissivity varied from 2,320 to 2,590 m²/d. The transmissivity estimated from the specific capacity of the pumped well was 1,510 m²/d. The best estimate of the saturated thickness of the aquifer was 19.5 meters. The corresponding estimate of the hydraulic conductivity ranged from 77 to 134 meters per day.

In 1999, ILEPA simulated the municipal wellfield using MODFLOW. Their model assumed an average rate of recharge of 20 cm/year, an average porosity of 0.30, and an average hydraulic conductivity of 66 meters per day. The expected travel time of water from a point midway between the two possible source areas to water supply well 9 was five years. The concentration of MtBE reached a maximum concentration in the water supply wells in 2000. If the release of MtBE to the aquifer occurred in 1994, there is a good correspondence between the arrival time of MtBE in the monitoring record and the predictions of the model.

Groundwater Flow

The general direction of groundwater flow at the site is toward the southwest from the potential sources, then

under a shopping mall, and then under a grassy undeveloped area adjacent to the municipal water supply wellfield. The area to the north and east of the wellfield consists of single-family residential housing. To estimate the direction of groundwater flow from the possible source areas and the magnitude of the hydraulic gradient,

we used regression analysis to fit a plane to the elevation of the water table in permanent monitoring wells in the source areas. We fit the regression using the Optimal Well Locator (OWL) software (Srinivasan et al., 2004). Results are presented in Table 1.

Over the three rounds of sampling, the direction of groundwater flow varied by 23 degrees and the hydraulic gradient varied by 45 percent. The fit to the regression was particularly good for data collected on August 9, 2001, and September 19, 2002, although the fit was not as good for data collected on January 8, 2003.

In September 2002, the depth to water was determined in most of the permanent wells at the site. Figure 3 compares the projected groundwater contours from the regression to the actual water elevations on September 19, 2002. All the wells at the site fit the assumption that the water table was a plane. Presumably, the MtBE that first reached the water supply wells would have moved through the most conductive material in the aquifer.

As will be discussed later, the highest hydraulic conductivity determined at any depth interval in the aquifer was 51 meters per day. The three solid arrows in Figure 1 repre-

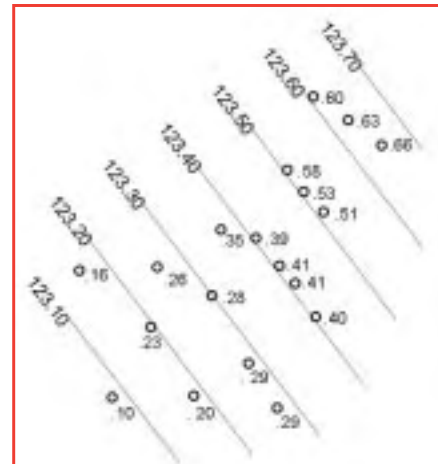


FIGURE 3. Correspondence between measured elevation (meters) of the water table in permanent wells on September 19, 2002, and the contours produced by regression to fit a plane. All the elevations fell between 123.0 and 123.7 m.

sent the direction of groundwater flow as estimated from the water elevation data collected in 2001, 2002, and 2003. The length of the arrows is the distance the groundwater would have moved in one year under the prevailing hydraulic gradient if the effective porosity of the aquifer was 0.30 and the hydraulic conductivity was 51 meters per day.

If these assumptions of porosity and hydraulic conductivity are valid, the MtBE plume near the possible source areas is moving toward the municipal wellfield at a velocity on the order of 86 to 133 meters per year. Thus, a plume from either of the two potential sources could reach the wellfield in three to six years.

Illinois EPA's Evidence for Plume Diving

ILEPA mapped the distribution of MtBE in the aquifer by sampling permanent wells installed northeast of the shopping center and by using

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TABLE 1 Hydraulic Gradient and Direction of Ground Water Flow Near the Source Areas of the MtBE Plume

Date of Measurement	Number of Wells Measured	Hydraulic Gradient (m/m)	Direction of Flow (degrees clockwise from north)	Correlation Coefficient r ²
August 9, 2001	13	0.00138	240.5	0.97
September 19, 2002	19	0.00214	233.2	0.98
January 8, 2003	7	0.00159	217.9	0.77

■ MtBE Plume Diving from page 15

push technology to sample groundwater southwest of the shopping center. (See Figure 4.) The permanent wells were installed through asphalt paving. They are screened to a depth ranging from 9.1 to 10.7 meters below land surface. The depth to water is about 8.5 meters below land surface. Water samples from temporary push wells were acquired in the paved area southwest of the shopping mall. They were acquired at depths of about 9, 15, and 21 meters below ground surface or 0.5, 6.5, and 12.5 meters below the water table.

The permanent wells are coded in Figure 4 according to the maximum concentration of MtBE in any of four rounds of sampling extending from January 2000 to September 2002. The plume of MtBE was easily detected by the shallow monitoring wells in the parking lot northeast of

MtBE greater than 1,000 $\mu\text{g/L}$. In contrast to the behavior of the plume northeast of the shopping center, MtBE was not detected in shallow groundwater southwest of the shopping center. (See Figure 4.)

Although MtBE was absent in the shallow groundwater, it was detected at two push-well locations at depths of 6.5 and 12.5 meters below the water table. The area above the plume of MtBE was paved or roofed. There is little possibility that burial of the plume by recharge could explain the diving plume.

To better understand the influence of hydrostratigraphy on the behavior of the plume of MtBE, ILEPA surveyed the aquifer using an electrical conductivity probe mounted on direct-push tools. (The electrical conductivity of sandy material that readily transmits groundwater is lower than the conductivity of silts and clays.) The electrical conductivity survey revealed that the water table in

the aquifer.

Building on the work of the ILEPA, our team from NRMRL conducted a more detailed characterization of the flowpath between the possible sources of MtBE and the impacted water production wells. We performed the characterization at locations A, B, C, D, and E in Figure 5. Our work at the site was designed to confirm and extend the site conceptual model developed by ILEPA and to evaluate their approach for site characterization to predict plume diving.

Evaluating the Hydrostratigraphy

Plume diving is controlled either by recharge to the aquifer, which "buries" the plume, or by the hydrostratigraphy of the aquifer. The approach to site characterization used by ILEPA is appropriate for sites where plume diving is con-

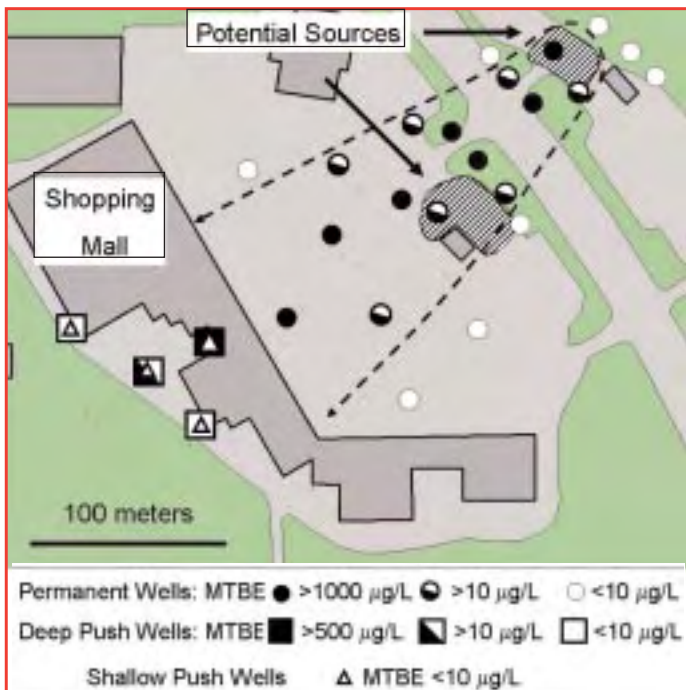


FIGURE 4. Distribution of MtBE in shallow ground water near the possible sources and in deeper ground water farther down-gradient of the sources.

the shopping mall. Although the screened intervals of the wells were very shallow, there is no indication of plume diving. The plume extended in the direction of groundwater flow that was predicted from water table elevations in the monitoring wells. The centerline of the plume contained wells with concentrations of

meters below land surface and 10.7 meters below the water table.

Apparently, groundwater moved beneath the layer of silt and clay as it flowed toward the municipal water supply wells, thus the MtBE plume "dived" below the elevation of the shallow groundwater samples as it followed the flow of groundwater in

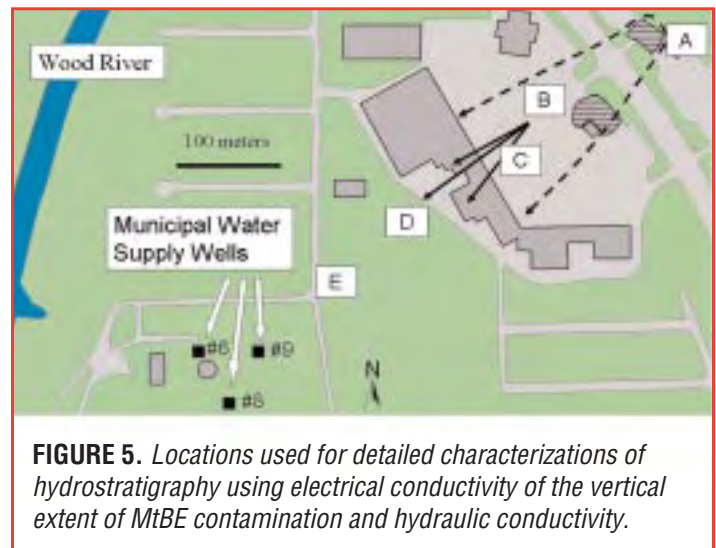


FIGURE 5. Locations used for detailed characterizations of hydrostratigraphy using electrical conductivity of the vertical extent of MtBE contamination and hydraulic conductivity.

the area southwest of the shopping center was contained within an interval dominated by silts and clays. The silt and clay interval extended about 18.3

controlled by hydrostratigraphy.

To better define the hydrostratigraphy of the aquifer, we repeated the electrical conductivity logging and extended it as far into the aquifer as the tools would allow. We defined the vertical distribution of hydraulic conductivity in the aquifer with a downhole-flowmeter survey in a well that was screened across most of the aquifer. We also evaluated the correspondence between hydrostratigraphy and hydraulic conductivity by comparing the electrical conductivity log to the vertical distribution of hydraulic conductivity determined with the flowmeter test.

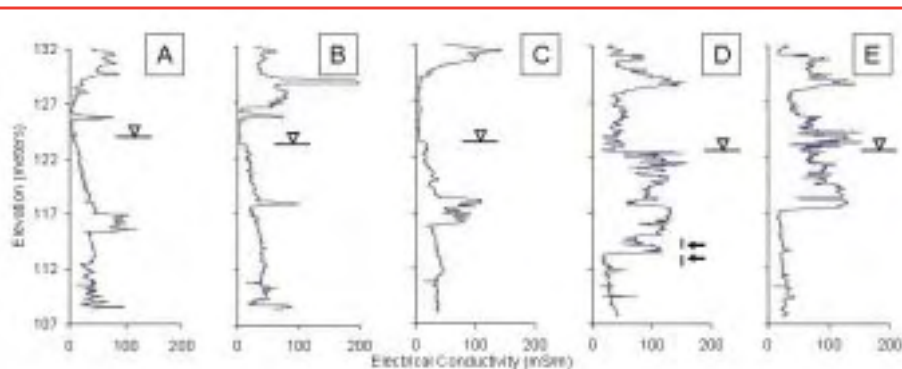


FIGURE 6. Distribution of electrical conductivity along the flowpath from the possible source areas of the MtBE plume to the water production wells.

In recent years, pneumatic-slug testing performed in temporary push wells has emerged as an affordable alternative to slug testing of permanent wells. To evaluate this approach, we obtained estimates of hydraulic conductivity from pneumatic-slug tests and compared them to the down-hole-flowmeter test. The vertical distribution of the MtBE plume was defined at high resolution by sampling water every 3.3 meters, extending from the water table to the point of refusal of the push sampling tool.

We evaluated the inferences made about the texture of aquifer material from electrical conductivity logs by acquiring core samples from a depth interval that had high concentrations of MtBE, high hydraulic conductivity, and low electrical conductivity; and a second interval of 3.3 meters above the first that had low concentrations of MtBE, low hydraulic conductivity, and high electrical conductivity.

Finally, we characterized the geochemistry of the MtBE plume to evaluate the prospects for natural biodegradation of MtBE along the flowpath. If conditions for natural biological degradation of MtBE in the aquifer were unfavorable, MtBE contamination would persist along the flowpath from the potential source areas to the municipal wells. (For more details on the materials and methods used in this evaluation see http://www.epa.gov/OUST/mtbe/Direct_push_tools_to_predict_MTBE_plume_diving.pdf)

Changes in Hydrostratigraphy along the Flowpath

The hydrostratigraphy was characterized using electrical conductivity

logging along an inferred flowpath, extending from the potential sources of MtBE contamination to the contaminated water supply wells. The sampling locations are depicted in Figure 5. Data from the electrical conductivity log are presented in Figure 6. In the experience of Butler et al. (1999) and Christy et al. (1994), an electrical conductivity of less than 20 millisiemens per meter (mS/m) is indicative of sand and gravel, while an electrical conductivity greater than 100 mS/m is indicative of clay and silt.

At locations A, B, and C, the MtBE plume was readily detected by conventional monitoring wells with shallow-well screens. As inferred from the low value for electrical conductivity, the water table at locations A, B, and C is contained within sandy material. In contrast, the MtBE plume was not detected in the shallow groundwater at locations D or E. At location D, the electrical conductivity

log indicates a layer of clay and silt extending from the water table an additional 9 meters into the aquifer. Similarly, at location E, the electrical conductivity log indicates a clay layer extending from the water table an additional 5.2 meters into the aquifer. Notice that at locations B, C, and D there is a two- to threefold increase in the electrical conductivity at the water table. The marked increase in electrical conductivity at location D at an elevation of 122 meters probably reflects the influence of the water table and does not indicate a change in the texture of the sediment.

To confirm the inferences made from the electrical conductivity logs, core samples were acquired from location D at elevations extending from 112.2 to 113.1 meters (in a zone of low electrical conductivity) and from 113.7 to 114.6 meters (in a zone of high electrical conductivity). The intervals are identified with arrows in panel D of Figure 6. The sediment recovered from the higher elevation with high electrical conductivity was plastic clay. (See Figure 7.) The sediment recovered from the lower elevation was coarse sand in a matrix of medium to fine sand.

Location D was the first location along the flowpath between the potential sources and the impacted water supply wells where the water table occurred in fine-textured material. The panel on the left side of Figure 8 compares the vertical distribution of electrical conductivity and hydraulic conductivity at Location D. There was an inverse correspondence

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113.7 meters amsl, location D



112.8 amsl, location D

FIGURE 7. Texture of materials recovered in two core samples from location D. Compare Figure 6 for the electrical conductivity of the depth interval sampled. Note that the sample from an absolute elevation of 113.7 m retained the imprint of the teeth of the core retriever.

■ MtBE Plume Diving from page 17

between electrical and hydraulic conductivity.

As determined from a pneumatic-slug test, the average hydraulic conductivity in the well used for the flowmeter test was 14.3 meters per day. In the first 9.1 meters of the aquifer, the hydraulic conductivity as revealed by the downhole-flowmeter test was low—0.4 meters per day or less. When the lithology transitioned from silt and clay to sand and gravel at an elevation of about 112.8 meters above mean sea level (amsl), the hydraulic conductivity increased dramatically. The hydraulic conductivity at an elevation of 111.3 meters was 51.2 meters per day, compared with 0.27 meters per day at an elevation of 114.3 meters. As revealed by the downhole-flowmeter test, 99 percent of the transmissivity in the interval between elevations of 120.4 and 106.7 meters amsl was associated with the sandy material that extended between 114.0 and 106.7 meters amsl.

The pneumatic-slug tests conducted in the temporary push wells also revealed the low hydraulic conductivity of the shallow silts and clays and the sharp increase in hydraulic conductivity in the interval between 114.3 and 111.3 meters amsl (panel on the right side of Figure 8). The hydraulic conductivity estimated from the pneumatic-slug test at an elevation of 111.3 meters was 12.5 meters per day, compared to 0.33 meters per day at an elevation of 114.3 meters.

The hydraulic conductivity as estimated by downhole-flowmeter testing was approximately two to three times higher than the hydraulic conductivity estimated by pneumatic-slug testing in temporary wells. (See Figure 8.) Water was not added to the rods of the temporary push-technology wells to equalize the pressure across the screens before the sheath was pulled away from the screen. As discussed by Butler et al. 2002, this can result in partial plugging of the screens. No attempt was made to develop the temporary push wells. Both of these practices may have contributed to the lower hydraulic conductivity determined in the temporary wells. In any case, the agreement between the estimate of

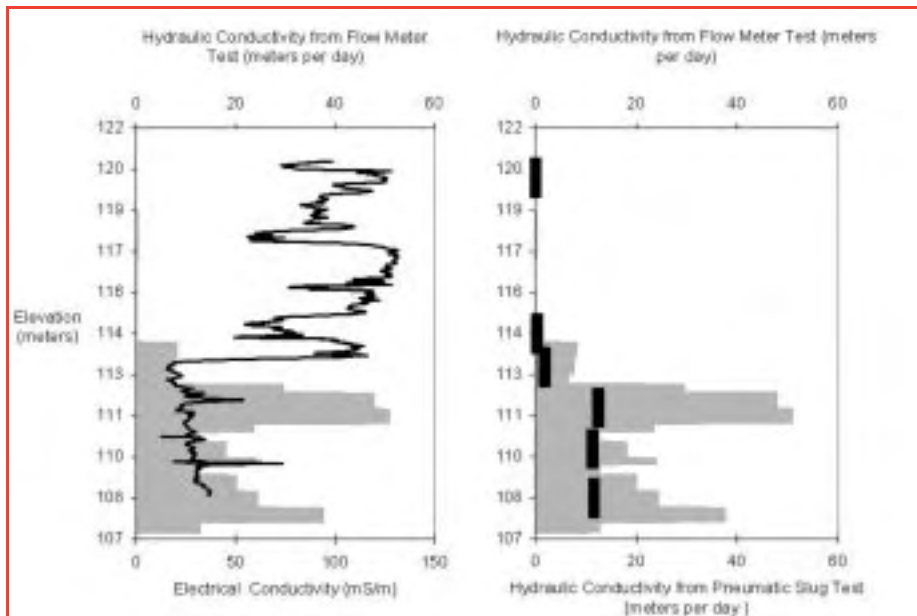


FIGURE 8. Inverse correspondence between electrical conductivity and hydraulic conductivity. The hydraulic conductivity distribution, measured with a downhole-flowmeter test, is depicted by the solid shape in both panels. The left panel compares the electrical hydraulic conductivity measured by a downhole flowmeter at location D in Figure 5. The right panel compares the hydraulic conductivity measured by a flowmeter test to the distribution of hydraulic conductivity measured by a pneumatic-slug test. The vertical extent of the dark lines in the right panel represents the screened interval of the temporary push well subjected to a pneumatic-slug test.

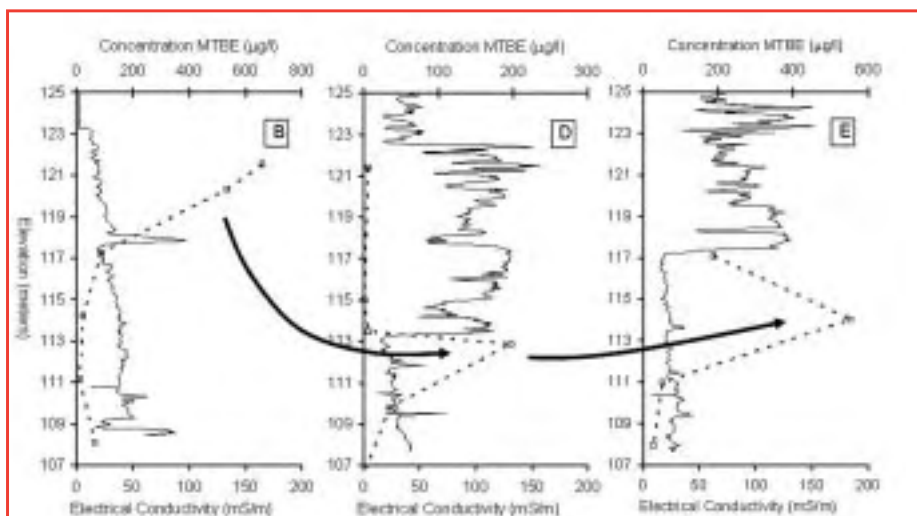


FIGURE 9. Association of higher concentrations of MtBE with sandy aquifer material (low electrical conductivity) along an inferred ground water flowpath from the potential sources of MtBE (location B), to a location where the plume dived below the water table (location D), to the vicinity of a municipal well (location E). Electrical conductivity logs are the solid lines; concentrations of MtBE are the dashed lines.

hydraulic conductivity from the slug tests and the flowmeter tests were acceptable.

MtBE Plume Diving Predicted from Hydrostratigraphy

Along the inferred flowpath between

the potential sources and the impacted water supply wells, the highest concentrations of MtBE were associated with sandy material with low electrical conductivity. (See Figure 9.) Near the potential sources, the highest concentrations of MtBE were found near the water table (location

B). In the location where the MtBE plume first dived below the water table, the highest concentrations of MtBE were found at the contact between the shallow clay unit and the underlying sand unit (location D). Further along the flowpath (location E), the highest concentration of MtBE was found more to the center of the sandy unit. Apparently, the plume of MtBE followed the hydrostratigraphic units with highest hydraulic conductivity.

Absence of MtBE Biodegradation

There is a general perception that MtBE does not biologically degrade in groundwater, even though MtBE has been shown to biologically degrade under aerobic and denitrifying conditions, iron-reducing conditions, sulfate-reducing conditions, and methanogenic conditions (Wilson 2003).

The rates of degradation under aerobic and denitrifying conditions are fast (Borden et al. 1997; Salanitro et al. 2000; Bradley et al. 2001a). The rates of degradation under iron-reducing conditions may be fast when readily available iron is supplied to iron-reducing bacteria (Finneran and Lovley 2001), but the rate under iron-reducing conditions in an aquifer appears to be slow (Landmeyer et al. 1998). Laboratory studies show that MtBE may degrade under sulfate-reducing conditions (Somsamak et al. 2001; Bradley et al. 2001b), but the field studies available to date indicate that MtBE degrades slowly in aquifers under sulfate-reducing conditions (Wilson 2003).

At two field sites, the rate of MtBE degradation to tertiary-butyl ether (TBA) was rapid under methanogenic conditions (Wilson et al. 2000; Kolhatkar et al. 2002). Many MtBE plumes are much longer than the associated plumes of BTEX, probably because the BTEX compounds were biologically degraded but MtBE failed to degrade or degraded very slowly (Amerson and Johnson 2002; Landmeyer et al. 1998). This pattern is most likely when the MtBE is contained in groundwater devoid of oxygen and nitrate, in water with low concentrations of methane (<0.5 mg/L), and in water with low concentrations of TBA compared with MtBE.

TABLE 2 Concentration of Contaminants and Geochemical Parameters at the Most Contaminated Depth Interval at Three Locations along the Flowpath. Samples Collected in August 2001 and November 2001

Parameter	B (near potential source)	D (downgradient)	E (farther downgradient)
MtBE (ug/L)	695	197	553
TBA (ug/L)	<10	<10	<10
Benzene (ug/L)	<0.5	<0.5	<0.5
BTEX (ug/L)	22	0.75	<0.5
Methane (mg/L)	0.06	0.17	0.31
Sulfate (mg/L)	232	46.2	46.5
Iron II (mg/L)	15	10	NA
Nitrate-N (mg/L)	<0.1	<0.1	NA
Oxygen	0.25	0.15	NA

Table 2 compares the concentrations of MtBE, TBA, and BTEX compounds near the potential source of contamination, at the first location where plume diving was noticed, and further along the flowpath near the water supply wells. Although MtBE persists along the flowpath, the BTEX compounds are depleted.

The groundwater was essentially devoid of oxygen and nitrate, contained little methane, and the concentration of TBA was below the detection limit, which was much lower than the concentrations of MtBE. Based on the geochemical environment, MtBE should degrade slowly or not at all in the groundwater at East Alton. Because it persists, there is an opportunity for the MtBE to move with the flow of groundwater to the water supply wellfield.

An Overall Thumbs Up

So, to sum it up, the MtBE plume stayed near the water table for the first 100 meters from the potential sources and then dived below conventional monitoring over the next 100 meters. At the location where the plume dived, the depth to water was 9.1 meters below land surface. The first 10 meters of material below the water table had an electrical conductivity near 100 mS/m, indicating silts and clays. An electrical conductivity near 25 mS/m, indicating sands or gravels, was encountered at a depth of 10.6 m below the water table, and the sands and gravel extended to a depth of at least 15.2 m below the water table.

Pneumatic-slug tests measured low hydraulic conductivity in the interval of silt and clay (0.34 and

0.012 m/d) and higher hydraulic conductivity in the interval with sands and gravels (12.5, 11.6, and 11.3 m/d). Groundwater with the highest concentration of MtBE was produced just below the contact between the silt and clay and the sands and gravel.

Two properties of the aquifer at East Alton are responsible for movement of the MtBE plume to below the water table, which gave the appearance that the plume dived into the aquifer. First, the geochemistry of the groundwater prevented rapid biodegradation of the MtBE and unacceptable concentrations of MtBE persisted along the flowpath. As a rule of thumb, long-term persistence of MtBE is possible in groundwater depleted of oxygen and nitrate but not accumulating significant concentrations of methane. Groundwater that meets this geochemical profile is vulnerable to plume diving caused by hydrostratigraphic influences. Characterization of the hydrostratigraphy and vertical distribution of hydraulic conductivity may be necessary to manage risk from MtBE contamination in these aquifers.

Second, the water table at the UST sites is in sandy material, but downgradient of the spill, the water table is in silts and clays. The natural flow of groundwater in the aquifer found its way into a deep layer of sand and gravels lying below the layer of silts and clays at the water table. The hydrostratigraphy of the aquifer controlled the vertical distribution of MtBE contamination. The plume of MtBE simply followed the natural flow of groundwater. This

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study validated the conceptual model of the diving MtBE plume that was developed by ILEPA.

In this case, electrical conductivity logs proved to be an effective tool for recognizing the vertical distribution of hydrostratigraphic features that control the movement of water in the aquifer. However, we have conducted electrical conductivity logs at other sites where the logs failed to recognize the controlling hydrostratigraphic features. At these other sites, cone penetration testing revealed the hydrostratigraphic features that controlled the flow of groundwater. In any case, it is worthwhile to recover and evaluate core samples to calibrate the log response at each site.

The downhole-flowmeter test was conducted as a research activity to provide a benchmark for the electrical conductivity log and the pneumatic-slug tests. Strictly speaking, flowmeter tests require a fully screened well across the aquifer of interest. However, such wells are expensive and are rarely available at UST-release sites.

The pneumatic-slug test offers a realistic alternative for mapping the vertical distribution of hydraulic conductivity, and identifying the optimum depth intervals for taking push samples or locating screens for permanent monitoring wells. Schulmeister et al. 2003, Butler 2002, and Butler et al. 2002 present a detailed description and evaluation of pneumatic-slug testing at sites in Kansas that is very similar to the aquifer at East Alton. Pneumatic-slug testing is well developed and can be considered a routine tool for site characterization.

These site-characterization tools are cost effective. During our investigation, a two-person crew set up the equipment for electrical conductivity logging, logged 80 feet of subsurface material, and then recovered and cleaned the tools in an average time period of two hours. A two-person crew installed and recovered the push tools for the pneumatic-slug tests, while a third person conducted the tests. One set of push tools was tested, while a second set was recovered, cleaned, and reinstalled at the next location.

On average, the three-person crew conducted a pneumatic-slug test every two hours. If time had been taken to develop the temporary push wells before they were slug tested, the three-person crew would have conducted a pneumatic-slug test every three to four hours. However, at this site, it was not necessary to develop the temporary push wells to discern the sharp contrast in hydraulic conductivity between the silts and clays at the water table and the sands and gravels that carried the plume of MtBE. ■

John T. Wilson, Ph.D., is a research microbiologist with the U.S. EPA Office of Research and Development. He is assigned to the Subsurface Remediation Branch in the Ground Water and Ecosystems Restoration Division of the National Risk Management Laboratory. Currently, Dr. Wilson is leading an evaluation of the natural biological processes that degrade MtBE and TBA in groundwater. He can be reached at wilson.johnt@epa.gov.

Randall R. Ross, Ph.D., is a hydrologist with the U.S. EPA Office of Research and Development. He is assigned to the Applied Research and Technical Support Branch in the Ground Water and Ecosystems Restoration Division of the National Risk Management Laboratory. He can be reached at ross.randall@epa.gov.

Steven D. Acree is a hydrologist with the U.S. EPA Office of Research and Development. He is assigned to the Applied Research and Technical Support Branch in the Ground Water and Ecosystems Restoration Division of the National Risk Management Laboratory. He can be reached at acree.steven@epa.gov.

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A Short Course on Plume Diving

To control the costs of monitoring, most LUST sites are characterized with conventional monitoring wells that are screened a few feet above and below the water table or by temporary push samples that are taken near the water table. Occasionally contamination is missed because of the plume movement beneath the screens of the monitoring wells, a situation termed “plume diving.” Weaver and Wilson (2000) discuss several environmental processes that may cause plume diving, illustrate the behavior with a case study on Long Island, New York, and offer recommendations to recognize and react to plume diving. The most widely recognized process that can produce plume diving is the burial of a plume by the recharge of clean water above it. U.S. EPA provides a calculator on its website that can be used to estimate plume diving caused by recharge (EPA On-line Tools for Site Assessment Calculation: Plume Diving):

www.epa.gov/athens/learn2model/part-two/onsite/diving.htm

Revised Operating and Maintaining UST Systems Manual Now Available

U.S. EPA’s revised *Operating And Maintaining UST Systems: Practical Help And Checklists* (EPA 510-B-05-002) is now printed and in stock at NSCEP in Cincinnati. Users can order printed copies by calling NSCEP toll free at (800) 490-9198. The publication is also available for downloading from the OUST website at <http://www.epa.gov/oust/pubs/index.htm>.

UST Program Meets All FY 2005 GPRA Goals

The LUST program had four national GPRA goals for FY 2005: (1) complete 14,500 cleanups, (2) complete 30 cleanups in Indian Country, (3) increase the significant operational compliance rate of UST facilities to 65 percent, and (4) decrease newly reported confirmed releases to fewer than 10,000.

In a memo dated December 15, OUST Director Cliff Rothenstein reported that the UST pro-

gram met all of these goals. EPA and state tank programs: (1) completed 14,583 cleanups in states and territories, (2) completed 53 cleanups in Indian Country, (3) achieved operational compliance at 66 percent of all UST facilities, and (4) reported 7,421 confirmed releases.

Since the beginning of the UST program, almost 74 percent of all reported releases (332,799) have been cleaned up, and the national UST cleanup backlog has been reduced to 119,240, which is an 8 percent drop from last year. The full end-of-year report is posted on OUST’s website at www.epa.gov/oust/.

Updated UST Program Directory Now Available:

The *Underground Storage Tank Program Directory*, which contains EPA and state UST program contact information, has been updated and is now available on the OUST website at <http://www.epa.gov/oust/pubs/reglist.htm>.

Congress Appropriates \$8 Million for UST Sites Impacted by Hurricanes Katrina and Rita

Congress has appropriated \$8 million in supplemental funding to address UST sites impacted by hurricanes Katrina and Rita. This funding will be used to conduct site assessments and, if necessary, clean up releases. As many as 800 UST facilities may have had hurricane-related damage that resulted in releases to the environment. This supplemental funding was part of a larger Katrina supplemental appropriations bill that was attached to the defense appropriations bill recently signed by President Bush.

Vapor Attenuation in the Subsurface from Petroleum Hydrocarbon Sources

An Update and Discussion on the Ramifications of the Vapor-Intrusion Risk Pathway

by Robin Davis

Petroleum-contaminated soil and groundwater caused by leaking underground storage tanks (LUSTs) can result in subsurface sources of vapor contamination. These vapors move slowly by diffusion through the subsurface and, if not attenuated, can intrude into overlying buildings, resulting in a complete vapor-intrusion pathway. Thankfully, there are very few reported cases of vapor intrusion, despite the thousands of LUST sites in this country. Even so, LUST project managers like me are saddled with the task of determining when and if the vapor-intrusion pathway is complete and justifying cleanup expenses since funds are limited. The purpose of this article is to show that natural biodegradation processes, accompanied by certain predictable characteristics, attenuate contaminant vapors and that project managers can determine when the pathway may be complete, based on those characteristics and contaminant concentrations.

I serve as a member of a U.S. EPA work group formed in early 2004 to study the behavior of subsurface petroleum hydrocarbons and the vapor-intrusion-to-indoor-air-exposure pathway. The decision to form the work group was sparked by U.S. EPA's draft guidance, Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (U.S. EPA, 2002).

This guide uses the Johnson-Ettinger model (J&E) (Johnson and Ettinger, 1991) to calculate groundwater-screening levels for the vapor-intrusion pathway that are expected to be protective of overlying receptors. The guide also presents conservative shallow and deep soil-gas concentrations that are expected to be equally protective (Table 2c, U.S. EPA, 2002). U.S. EPA wisely recognized that the J&E model often predicts that the vapor-intrusion pathway is complete, when it may not be, because the model does not account for biodegradation.

To explore this issue further, U.S. EPA's work group generated a repository of published literature on subsurface petroleum hydrocarbon vapor attenuation. As a member of the work group, I reviewed and compiled data from those publications, and published my initial findings in LUSTLine Bulletin 49, March 2005. Those findings were based on a relatively small set of vapor data but showed significant attenuation in a majority of the sample events.

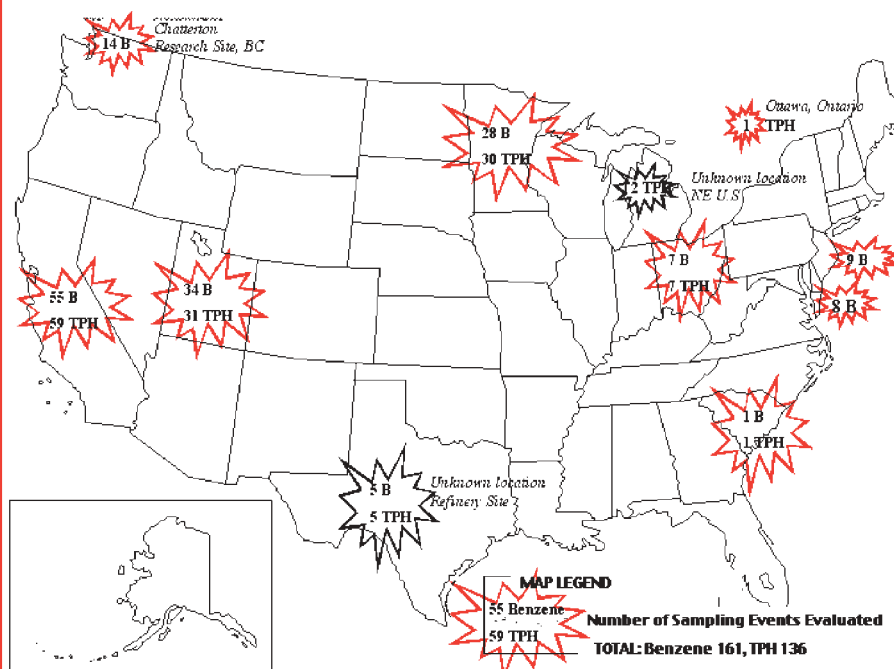
That data set indicated significant attenuation when accompanied by certain predictable signature characteristics of vapor biodegradation, specifically the presence of clean overlying soil and at least 5 percent oxygen in the vadose-zone soil gas. This paper presents the findings of a much larger data set, which continues to show that petroleum hydrocarbon vapors attenuate if there is clean, oxygenated soil overlying the contaminant source.

More Data Compilation

Since my last discourse on the subject of subsurface petroleum hydrocarbon vapor attenuation, I have amassed a larger data set, which currently includes 161 benzene events and 136 TPH events in which vapor samples were collected at multiple depths (Figure 1), including 28 events beneath buildings ("sub-slab"). Data for 59 benzene vapor events and 65 TPH vapor events were not useful for evaluating attenuation because they either took place in uncontaminated areas or they took place at depths or intervals of five or more feet and not within the zone of biodegradation. The data set for evaluating vapor attenuation was subsequently reduced to 102 benzene events (Figure 2) and 71 events for total petroleum hydrocarbons (TPH).

Subsurface attenuation factors (not the same as attenuation factors into buildings) were calculated by dividing the vapor concentration at

FIGURE 1. Locations of events where samples were collected at multiple depths.



the shallow depth by that at the deeper depth. The data set was categorized and evaluated according to the following site characteristics:

- Multi-depth and sub-slab vapor-phase benzene, TPH, oxygen, and carbon dioxide concentrations
- Depth to groundwater
- Depth to source*
- Source strength (NAPL, adsorbed and dissolved-phase benzene, TPH)*
- Presence of free product on groundwater
- Type of ground surface cover (paved, unpaved, buildings)
- Soil type
- Presence or absence of complete vapor attenuation*
- Sampling dates
- All media sampled correlated to date of collection

* Data categories added since Davis, 2005.

Attenuation factors at or below 0.1 are considered significant attenuation and those greater than 0.1 represent insignificant attenuation.

Attenuation Happenings

The findings of this study show significant attenuation of vapors in 98 percent of the benzene sample events and in 92 percent of the TPH sample events (Figure 3).

Figure 4 shows a representative example of significant attenuation from a multi-depth vapor sample point (Ririe, et al., 2002), where five feet of clean coarse-grained soil overlie a contaminant source and about 3 percent oxygen is present.

Biodegradation of the vapors is evidenced by oxygen depletion at depth accompanied by carbon dioxide enrichment, and a rebound of oxygen to near-atmospheric conditions above the contaminant source with concomitant reduced carbon dioxide production. The data indicate that only two feet of clean fine-grained overlying soil is necessary to attenuate petroleum vapors.

Soil types were divided into two groups according to permeability: coarse-grained ($>10^{-9}$ cm²) and fine-grained ($<10^{-9}$ cm²) (Freeze and Cherry, 1979). All of the benzene and TPH events in fine-grained soil exhibited significant attenuation. The

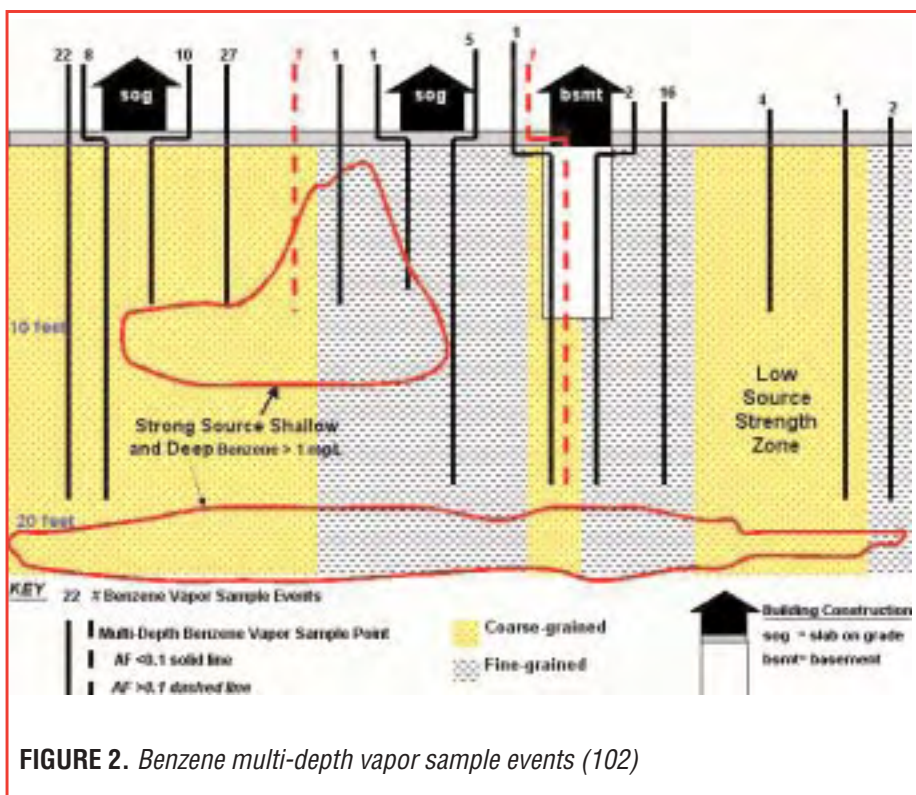


FIGURE 2. Benzene multi-depth vapor sample events (102)

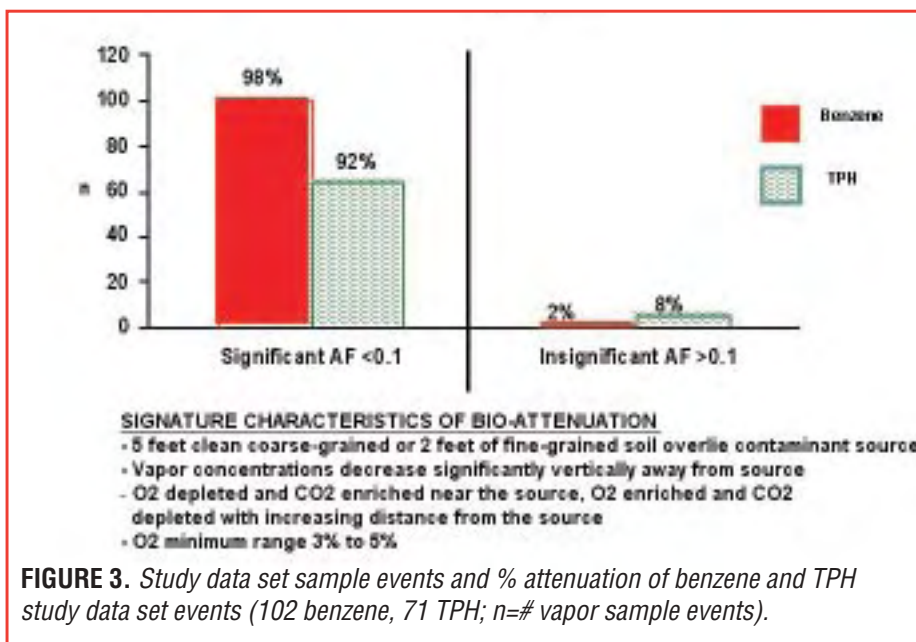


FIGURE 3. Study data set sample events and % attenuation of benzene and TPH study data set events (102 benzene, 71 TPH; n=# vapor sample events).

few events that exhibited little or no attenuation took place in coarse-grained soil.

Benzene events exhibiting significant attenuation occurred beneath buildings, pavement, and bare soil. Of the two events that did not exhibit attenuation, one was beneath a building basement (Roggemans, et al., 2001) and one beneath pavement with no clean soil overlying a shallow contaminant source (Roggemans, et al., 2001).

The event exhibiting insignificant attenuation may not be representative of attenuation beneath buildings because the depth at which vapor samples were collected is in dispute (Kremesec, 2004). All of the TPH events beneath a bare soil ground cover exhibited significant attenuation. TPH events that did not exhibit attenuation were overlain by pavement (Roggemans et al., 2001) and one building basement (Laubacher, et

■ continued on page 24

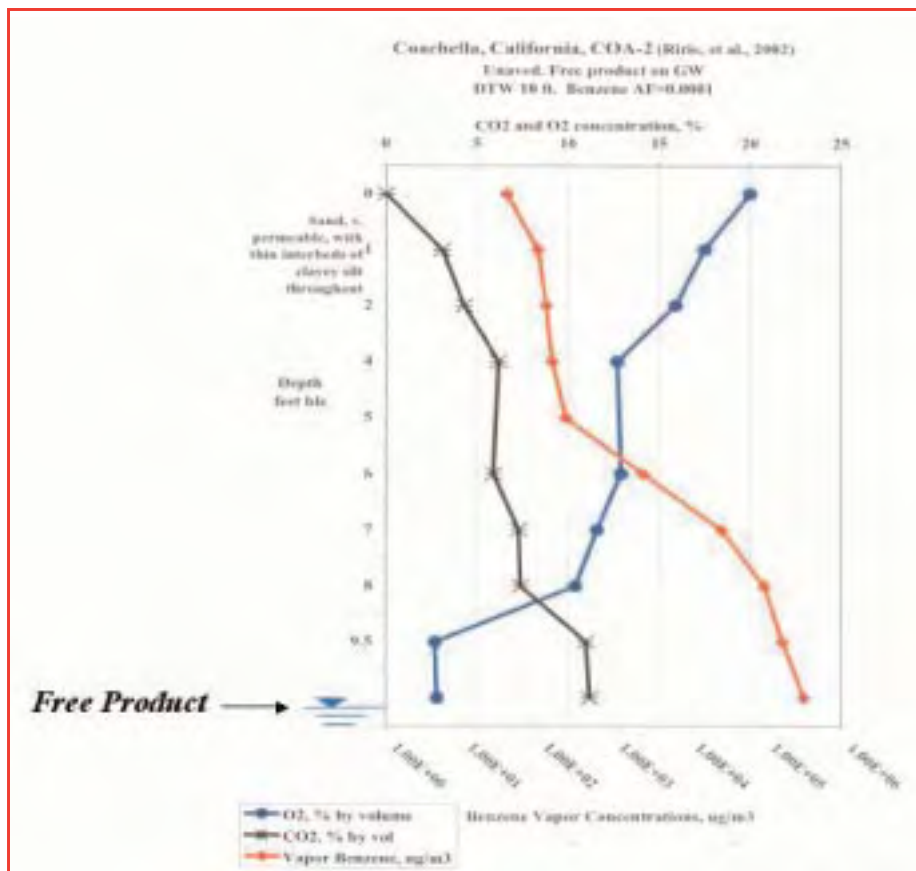


FIGURE 4. Typical signature of significant attenuation due to ~5 ft clean overlying coarse soil (depleting benzene, strong O₂ supply and CO₂ production).

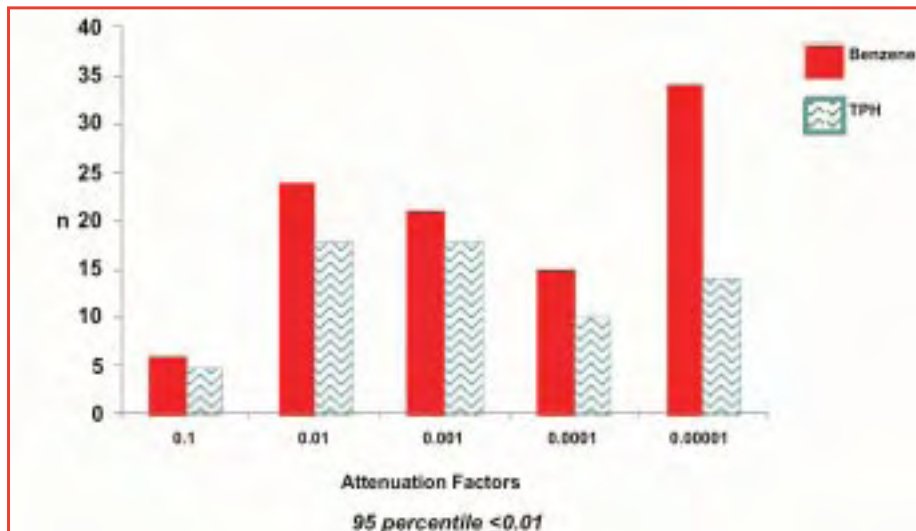


FIGURE 5. Magnitude of significant attenuation for benzene and TPH (n = # vapor sample events).

■ **Vapor Attenuation** from page 23

al., 1997). According to the reports for which sub-slab data were available, none of the buildings evaluated had vapor intrusion from the underlying petroleum source.

The above-referenced building events where significant attenuation was not observed were the only

events in this data set that exhibited strong depletion of oxygen, or an anoxic zone beneath the basement slabs of the buildings. All other events beneath buildings, where sub-slab soil gas oxygen was analyzed, and depth to contaminant sources ranged from about five to twenty feet below grade, exhibited near-atmos-

pheric sub-slab oxygen concentrations (Environ, 2005; Fischer, et al., 1996; Hers, 2000; Sanders and Hers, 2006; Secor, 2004). These findings, therefore, indicate that the area beneath most buildings is sufficiently oxygenated to biodegrade petroleum hydrocarbon vapors if there are at least five feet of overlying clean coarse-grained soil or two feet of fine-grained soil.

The magnitude of petroleum vapor attenuation is shown in Figure 5. The greatest number of events where benzene and TPH vapors attenuate have attenuation factors ranging from 0.01 to 0.00001. At the 95 percentile, the benzene attenuation factor is less than 0.01.

Concentration versus Distance

The larger data set includes vapor-sample events over a diverse range of site conditions and beneath buildings. The data indicate significant attenuation of benzene vapors (98 percent of the events) and TPH vapors (92 percent of the events). The data presented in this study strengthen the case that the vapor intrusion to the indoor air pathway is not likely complete for petroleum vapors if there are at least five feet of clean coarse-grained soil or two feet of fine-grained soil overlying the contaminant source.

Vapor samples should therefore be collected at depths and intervals less than five feet in order to determine if vapors are being degraded and to verify attenuation. If the pathway needs further evaluation, it is reasonable to permit vapor sampling within 10 feet of a building footprint to avoid intrusive activities like sub-slab sampling. This approach has also been suggested by Hartman (2005, 2006) and NJDEP (2005).

Finally, data presented in this paper show that a conservative sub-surface bio-attenuation factor of 0.01 can be applied to the dissolved- and vapor-phase concentrations for petroleum hydrocarbons. Hence, the allowable concentrations shown in Table 2c of the EPA 2002 guidance can be increased by a factor of 100 (Table 1). If vapor and groundwater concentrations exceed those levels, the vapor-intrusion pathway may require further evaluation.

TABLE 1 J&E-Predicted Residential Generic Screening Levels for Soil Gas and Groundwater (EPA, 2002, Table 2c Question 4) and Proposed Screening Level Concentrations Based on Observed Field Attenuation Factor of 100

Chemical	Target Indoor Air Concentration, 10-DG Risk Level and I.D. Hazard Index (ug/L)	Depth Below Cracks or Building Sibs (feet)	J&E Predicted Concentrations to Meet Target Indoor Air Concentrations				Proposed Screening Level Concentrations Attenuation Factor = 100 (0.01)			
			Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained	Coarse-Grained	Fine-Grained
			Soil Gas (ug/L)		Groundwater Concentration (ug/L)		Soil Gas (ug/L)		Groundwater Concentration (ug/L)	
Benzene	3.10E-01	5	3.10E+00	3.00E+02	3.31E+00	3.12E+01	3.10E+02	3.00E+04	3.31E+02	3.12E+03
		10	3.10E+01	5.00E+02	2.80E+00	3.23E+01	3.10E+03	5.00E+04	2.80E+02	3.23E+03
Total Petroleum Hydrocarbons (1,1,1-Toluene/Benzene average)	4.00E-01	5	6.00E+01	5.00E+03	2.50E+01	1.02E+03	6.00E+03	3.00E+05	2.50E+02	1.02E+05
		10	6.00E+02	9.00E+03	9.87E+01	1.05E+03	6.00E+04	9.00E+05	9.87E+02	1.05E+05

1. EPA, 2002, Table 2c. J&E predicted concentrations based on EPA's 10-DG risk level. Hazard Index calculated by dividing predicted concentrations by the appropriate MCL. Hazard Index calculated by dividing predicted concentrations by the appropriate MCL.

The conclusions from my data set are consistent with recent conclusions by Abreu and Johnson (2005), using 3-dimensional modeling. They have shown that a 10-fold reduction in the source strength from 200 mg/L-vapor to 20 mg/L-vapor leads to a 6 order of magnitude reduction in the attenuation factor. They also show that for the 20 mg/L-vapor scenario, vapors are reduced by a factor of 1,000 within a few feet of the source. Since the typical soil-gas concentrations in my data set are less than 2 mg/L-vapor for benzene and 20 mg/L-vapor for TPH, it is reasonable to expect that vapor intrusion from typical hydrocarbon sources is not likely to occur unless the source is within a couple of feet of the receptor.

Some states have accounted for bioattenuation by reducing EPA's proposed horizontal distance criteria of 100 feet to a building to a lesser distance (30 feet has been proposed by NJDEP, 2005; NHDES, 2005; UDEQ, 1997). In my opinion, these criteria are still too conservative and setting fixed distances may not be the best approach for determining when the vapor-intrusion pathway is complete and needs to be assessed.

My data set shows that vapors are biodegraded and completely attenuated beneath most of the buildings, even those that overlie very strong sources, when there is sufficient clean soil overlying sources. Because distance is critical in the

attenuation of petroleum sources, a better method of determining appropriate distances at which certain source concentrations may or may not constitute a vapor intrusion risk is to plot source concentration versus distance from the receptor. I am currently compiling my data set to generate such a plot, and I will report on it in a future issue of *LUSTLine*, so stay tuned. ■

Robin Davis is a project manager with the Utah Department of Environmental Quality, Leaking Underground Storage Tank program and member of EPA's petroleum hydrocarbon vapor intrusion workgroup. She specializes in fate and transport of petroleum hydrocarbons, and data acquisition, reduction and analysis, most recently for the vapor intrusion exposure pathway. Robin can be reached at (801) 536-4177, rvdavis@utah.gov

Disclaimer

Any opinion expressed herein is that of the author and does not represent opinions of the State of Utah, U.S. EPA, or authors cited.

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Tank -nically Speaking

by Marcel Moreau

Marcel Moreau is a nationally recognized petroleum storage specialist whose column, *Tank-nically Speaking*, is a regular feature of LUSTLine. As always, we welcome your comments and questions. If there are technical issues that you would like to have Marcel discuss, let him know at marcel.moreau@juno.com

Operator Training: Boon or Bust?

Among other things, the Energy Act of 2005 requires what many regulators have long considered a pipe dream – mandatory UST operator training. But sometimes a dream come true can turn into a living nightmare. Whether the operator training provisions of the Energy Act ultimately prove to be a boon or a bust will be determined largely by how these programs are designed. Without proper attention to the implementation aspects of training hundreds of thousands of people each year in the fairly esoteric world of UST operation, I fear many owners, operators, and regulators will come to rue the day the Energy Act became law.

Tuning the Tank Rules

The Energy Act of 2005 was signed some 21 years after President Reagan enacted Subtitle I of the Resource Conservation and Recovery Act that created the federal (and consequently most state) environmentally based underground tank regulatory programs. Since then, Congress has paid scant attention to underground tank regulations.

One could surmise that the return of this congressional focus on underground tanks portends some significant changes in the program. Interestingly enough, except for the secondary containment/insurance provisions for storage systems installed in proximity to water supplies, the new law does little to change the fundamental structure of the 1984 Subtitle I or the 1988 EPA tank regulations. The focus appears to be better implementation of the 1988 rules:

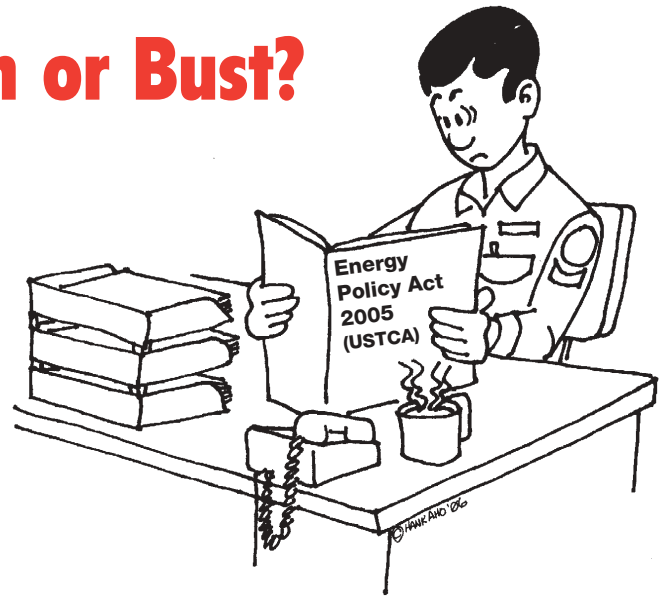
- The periodic inspection requirement is aimed at leveling the playing field by being sure everyone is in compliance.
- The delivery prohibition provisions are an attempt to facilitate enforcement of the existing 1998 upgrade requirements.
- The owner/operator training provisions make a requirement

out of what the initial rules had (mistakenly) taken for granted: that owner/operators would know how to operate their storage systems.

So just what are the benefits of training operators and what are the challenges to accomplishing this goal? Let me see...

The Dream

Well-trained UST operators could, in theory, provide substantial benefits to UST programs. Knowledgeable operators would understand how their UST systems worked, be able to identify problems, and know what to do when their systems weren't working. They would be able to conduct routine inspections for leaks (e.g., inside dispensers) and detect conditions that need attention (e.g., debris-filled spill buckets, leaking hoses and nozzles). They would know the regulatory requirements and have the required paperwork readily available and neatly organized for inspection. By responding appropriately and in a timely manner to alarm conditions, they would be able to detect releases sooner rather than later. The UST inspectors' job would be a cakewalk.



The Numerical Challenge

Achieving the benefits of a well-trained UST operator population will not be easy. First off, there is the sheer volume of people who would need to receive some form of training. Assuming roughly 250,000 facilities and two to three people per facility (a conservative estimate), we're talking about 500,000 to 750,000 people. And with convenience-store employee turnover at slightly over 100 percent per year, we're talking about providing roughly this same amount of training each year. This is not a trivial task. There are many questions to be answered:

- Who will provide this training? Regulators? Private-sector instructors? Employers?
- How will this training be delivered? Classrooms? Self-study workbooks? On the job? On the Web? On the fly?
- How will this training be documented (surely the requirement will be meaningless if there is no way to distinguish the trained from the untrained)? Certificates? ID cards? Employment records? Electronic databases?

All of these options are possible; indeed all of these options will likely be needed to meet the challenge of training this widely dispersed population with training needs that are variable, depending on the idiosyncratic characteristics of the storage systems they operate.

The Great “Who Is the Operator?” Challenge

The Energy Act specifies that there should be three levels of UST-operator competency, presumably based on the level of responsibility of different types of tank operator. There will be a strong temptation to make every UST operator scenario fit this statutory “mold.” But there are so many different possible distributions of responsibility that it would be a mistake to create a caste system of tank operators and try to force every situation to fit it.

There will be mom-and-pop retail operations or commercial-fleet fueling facilities (e.g., construction companies, car-rental agencies) where a single person is responsible for all facets of operating a specific storage system. In this situation, all categories of UST operator will be collapsed into a single person.

There will be other operations where the fuel ordering is handled remotely by a third party, the leak detection is handled by a remote monitoring service, and equipment maintenance is handled by yet another third-party provider, so that the on-site personnel are left primarily with the responsibility of knowing how to identify different levels of emergencies and whom to call to respond to them. In this situation, there may be many more than three categories of tank operator.

There are likely many thousands of different variations on the theme of “tank operator,” so how do you decide who the operator is and what he or she is responsible for?

The “What Should the Operator Know?” Challenge

I expect a roomful of regulators or tank owners could argue at great length about this topic, and I expect such arguments will occur with increasing frequency in the next few years. I submit that only information relevant to the facility for which the

operator is responsible should be taught.

There is no credible reason to try to teach an operator the ins and outs of groundwater monitoring when he is in charge of a facility with no such system. There is no reason anyone should know about leak detection for a suction-pumping system if she is responsible for a facility with pressurized piping (granted, it’s important know at a basic level how to tell which type of pumping system is present at a given facility). This approach, however, would require what amounts to individualized training for each UST operator, a daunting proposition when the number of people to be trained is considered.

“Without proper attention to the implementation aspects of training hundreds of thousands of people each year in the fairly esoteric world of UST operation, I fear many owners, operators, and regulators will come to rue the day the Energy Act became law.”

The alternative—teaching large classrooms of operators all aspects of the rule and all variations of the multitude of UST technologies in use today—will only produce bored and confused operators rather than knowledgeable ones. I would also submit that operators need to know much more about storage systems than what is contained in 40CFR280 or state-level regulations. The Energy Act presents a great opportunity for regulators and the regulated community to jointly define what an operator needs to know to ensure that facilities are both meeting regulatory requirements and being operated safely.

The Recordkeeping Challenge

If not carefully implemented, the operator-training requirement may simply become another record-keeping nightmare for tank owners and an enforcement quagmire for regulators. Tank owners will have to retain some type of documentation showing that each employee who falls in some category of “tank operator” has

received the appropriate training. Regulators will need to add to their inspection checklists verification that all current tank operators have been properly trained. And what reason is there to believe that compliance with the training provisions of the Energy Act will be any better than compliance with the leak detection or record-keeping provisions of the existing tank rules?

Knowing versus Caring

The theory behind the training provisions of the Energy Act appears to be that if operator ignorance is the problem, then operator training is the answer. I would suggest, however, that making tank operators knowledgeable (which I acknowledge is a noble goal) is very different than making them better tank operators.

I happen to be pretty ignorant about most matters relating to professional sports. You could possibly remedy my ignorance about sports with some special training, but that is not going to make me care any more about who plays in next year’s Super Bowl. In other words, it is not going to change my behavior.

Like the ol’ horse and the water trough, you can lead me there, but you can’t make me into a football fan any more than you can make a convenience-store manager into a tank operator by simply plopping the right information in front of us.

If training is going to have any effect on UST system operation besides multiplying several-fold the amount of paper records that are supposed to be maintained, tank operators will need to be held responsible for what they have been trained to do. But somehow I don’t think bringing enforcement actions against individual UST operators is going to be a very popular activity among regulators.

Consistency versus Chaos

By delegating the implementation of UST-operator training to states, the Energy Act has created what could become a major headache for the tank owner who owns tanks in multiple states. If each state creates state-specific operator-training requirements (e.g., different training content, different record-keeping requirements, dif-

■ continued on page 28

■ Tank-nically Speaking

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ferent amount of time before a new hire must be trained), it will create a patchwork of regulatory perplexity that will make compliance, even by willing tank owners, a Herculean task. Consistency of requirements among states would simplify the tank owner's life and ultimately that of the tank regulator who must enforce the requirements.

What's My Solution?

I believe the path to increasing UST-operator knowledge and motivation lies in creating a class of professional UST operators. This professional UST operator becomes the person with primary responsibility for the USTs in his or her care. This person also could assume responsibility for designating who among the on-site personnel should shoulder what responsibilities as well as provide the site-specific training required to carry out these responsibilities.

This approach is much like California's recently implemented designated UST-operator program. For a more complete description of this type of approach, see *LUSTline* #40, *Of Square Pegs and Round Tanks... What If Tank Operators Really Knew How to Operate Tanks?*

What's Your Solution?

Whether you are an UST regulator, UST owner, or UST operator, write and let me know at marcel.moreau@juno.com. ■

Marcel's Short List of What a Tank Operator Needs to Know

- How to respond to small spill incidents
- How to respond to substantial spill incidents
- How to respond to major spill incidents
- How to respond to accidents involving fueling equipment (e.g., drive-offs, collisions with dispensers)
- How to shut down or disable faulty equipment, ranging from individual nozzles, individual dispensers, individual products, or the entire fueling facility
- How to respond to customer reports of equipment malfunctions (e.g., nozzle not shutting off)
- How to respond to customer reports of slow product flow
- How to identify and respond to inappropriate customer fueling behavior (e.g., filling glass containers with gasoline, or filling plastic gas cans in the back of a pickup truck)
- How to respond to various fuel-related ATG alarms (e.g., overfill, fuel alarm, high product, low product)
- How to inspect hanging hardware for proper condition/operation
- How to look inside a dispenser for problems
- How to inspect spill-containment manholes
- How to keep inventory-control records
- How to tell how much fuel an underground tank can safely hold
- Type(s) of leak detection present (e.g., automatic tank gauge, secondary containment, line leak detector, etc.) at a facility and some basic information on how it functions and how a leak is indicated (e.g., alarm, slow flow)
- How to perform leak detection if it is not automatic (e.g., schedule a tightness test, sample groundwater wells)
- What leak detection records to keep, how to obtain/create them, where to store them, and how long to keep them
- How to calculate how much fuel to order
- Some basic information about how the storage system works (tank, piping, dispenser, pump)

Missouri Launches First-In-Nation Effort to Educate Fuel Tank Operators

Missouri has taken a bold step to help fuel storage system owners and operators understand and operate their equipment. Missouri's Petroleum Storage Tank Insurance Fund (PSTIF) insures 85 percent of the UST facilities in the state. "The key to preventing leaks or detecting them early is knowing how your equipment works. But it's very difficult for any company or local government that owns tank sites to train its employees in all of the many areas they are supposed to know," says Carol Eighmey, Executive Director of PSTIF.

"We are a state trust fund," says Eighmey, "so we have an obligation to the citizens of Missouri to do what we can to help prevent pollution. That means we need to keep fuel in the tanks and out of the ground as much as possible. It's a win-win situation for the tank owners, the trust fund, and the environment."

PSTIF set out to solve the problem of educating the people responsible for fuel-storage systems about how their systems work, how their leak-detection equipment functions, and how to respond when an alarm sounds. To get the maximum number of people involved, the PSTIF Board decided to purchase the Petroleum Equipment Institute's (PEI) on-line Learning Center courses in bulk and offer them for free to PSTIF participants.

"If we succeed in preventing only one gasoline leak, we will more than make up the cost of providing the courses," says Eighmey. Missouri is the first state to tackle the problem by offering free courses to people who work at facilities insured by the state's tank fund.

Anyone responsible for fuel tanks insured by PSTIF can take courses for free by logging on to www.pstif.org. To find out more about the PEI Learning Center go to www.pei.org/learn. ■

Update—ENERGY POLICY ACT

by Ellen Frye

Title XV, Subtitle B of the Energy Policy Act (EPA Act) of 2005 (entitled the Underground Storage Tank Compliance Act of 2005) contains amendments to Subtitle I of the Resource Conservation and Recovery Act—the original legislation that created the UST program. This new law significantly affects federal and state underground storage tank programs and requires major changes to them. Gas station owners and operators, as well as other non-marketers who own underground storage tanks, will be impacted by the changes U.S. EPA and states make in their tank programs as a result of the law.

Some of the provisions require implementation by August 2006; others will require implementation in subsequent years. To implement the new law, the U.S. EPA Office of Underground Storage Tanks (OUST) and states are working closely with tribes, other federal agencies, tank owners and operators, and other stakeholders to bring about the mandated changes affecting underground storage tank facilities. At this point, however, virtually everything associated with implementing and funding the provisions of the EPA Act is still being finalized. So, until we can report hard-and-fast decisions on the EPA Act, we will simply offer an ever-so-brief update.

Work Groups Addressing Grant Guidelines

Since Fall 2005, OUST has been working with the states through the Association of State and Territorial Solid Waste Management Officials (ASTSWMO) to implement the EPA Act. Fourteen work groups, composed of representatives from state and EPA regional and headquarters UST/LUST programs, as well as tribes for the tribal strategy, were organized to develop grant guidelines that will apply to any state receiving federal UST money from EPA.

The work groups cover the following specific issues associated with the EPA Act: Cost Recovery, Delivery Prohibition, Financial Responsibility and Installer Certification, Inspec-

tions, LUST Allocations, LUST Guidance, Operator Training, Public Records, Secondary Containment, State Fund Diversion, State Fund Soundness, Tribal Strategy and Report to Congress, Federal UST Compliance Report, State UST Compliance Report.

As draft guidelines are completed they will be posted on OUST's website for a 30-day public comment period. The first drafts will likely appear in May. Keep tabs on progress by visiting http://www.epa.gov/oust/fedlaws/nrg05_01.htm.

A New Twist on Funding

Among other things, the EPA Act expanded eligible uses of the Leaking Underground Storage Tank (LUST) Trust Fund, including meeting the requirements for preventing as well as cleaning up leaks. But now it looks as though FY 2007 LUST Trust Funds can only be used to perform traditional Subtitle I tank cleanup tasks, not to meet any of the new leak-prevention provisions in the EPA Act. The reason for this restriction is a clause inserted into a Transportation law enacted soon after the Energy Policy Act. This provision prevents further funding of the LUST Trust Fund if any of this money is spent on any uses not authorized in the original legislation (1986).

With the congressional FY 2007 appropriations cycle under way, U.S. EPA is asking for a little less than last year's \$73 million in LUST funds in its FY 2007 budget; this year's total request was for \$72,759 million. The agency is also seeking an additional \$26 million with the baseline \$11 million normally found in the UST STAG grants to cover non-cleanup UST functions—primarily those of enforcement and compliance.

EPA's FY 2007 budget request is looking primarily at the catch-up inspections required in the first two years after enactment of the EPA Act. This funding is also to be used to support work in initiating other new tasks mandated by the EPA Act for operator training, delivery prohibition, and secondary containment or expanded financial assurance. The

scope and universe of some of these new activities have not been established yet (e.g., the number of catch-up inspections that must be completed before August 2007).

OUST has other issues related to the new UST funding that will need to be sorted out over the next few months, including how EPA should distribute funds—by the same amount to all states, by a formula based on work to be accomplished, on the basis of need (e.g., number of catch-up inspections required), or some combination (e.g., expanded equal core amount plus some workload and current need formula).

All or Nothing?... Not Necessarily

EPA originally thought the language in the EPA Act meant that any state receiving funding under the new amendments to Subtitle I would be required to accomplish all of the new and existing mandates, and that a recognized failure to accomplish any of the mandates could result in the loss of all federal funding provided under the authority of Subtitle I (the "all-or-nothing" scenario). EPA has now concluded that a failure to meet a requirement in the law does not necessarily mean the agency must either terminate a funding arrangement or automatically withhold future funding to a state. Rather, if a state materially fails to meet a statutory obligation, EPA may use the discretion afforded it under the enforcement provisions of the existing grant regulations (40 CFR Section 31.43).

These enforcement provisions provide the agency with considerable flexibility. It's important to note that states receiving funding under Subtitle I are still required to meet the new mandates, but the ramification of missing a deadline is not necessarily the loss of all Subtitle I funding. EPA will be able to consider state-specific circumstances, including a state's progress and plan for meeting the requirements.

To see the full text of the new legislation, go to: http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_public_laws&docid=f:publ058.109.pdf (scroll to Title XV - Ethanol and Motor Fuels, Subtitle B - Underground Storage Tank Compliance, pages 500-513 of the pdf file) for the UST/LUST provisions. ■

TANKS ON TRIBAL LANDS

Nez Perce Pursue Cleanups, Inspections, and Nondegradation of All Aquatic Resources



Photo by Kevin Brackney

by Kevin Brackney

The Nez Perce Tribe has a Direct Implementation Tribal Cooperative Agreement with EPA Region 10 to conduct an UST compliance assistance program on the reservation. The 750,000-acre north Idaho reservation has 20 active UST facilities, the second highest number of any tribe in the Region.

The Nez Perce Tribe has two half-time UST inspectors who have completed or are currently enrolled in both a Region 10 and an Intertribal Council of Arizona UST inspector certification-training program. In addition to the UST program, the inspectors share duties with the CERCLA 128(a) State and Tribal Response Program to address RCRA/CERCLA issues other than USTs (e.g., aboveground storage tanks). The tribe's Water Resources Division hosts both of these inspection and capacity development programs.

The tribal inspectors are currently providing compliance assistance to UST owner-operators, while EPA is conducting federal enforcement activities. In addition, the tribe has developed a management strategy of having at least two people working to maintain program continuity in case something happens to one employee—after all, none of us is here permanently!

The tribe has successfully negotiated the cleanup of three abandoned and one inability-to-pay UST facilities on the reservation, utilizing the services of the Alaska-based, tribally owned national UST contractor, Bris-

tol Environmental & Engineering Services Corporation. A total of 13 tanks will be decommissioned during summer 2006. Any associated soil cleanup and remediation will utilize landfarming to biodegrade the contaminants. Groundwater contamination does not at present appear to be a serious issue at these facilities.

The Nez Perce Tribe agreed to pursue the compliance assistance program primarily to protect the water resources of the reservation. The Nez Perce are historically a fishing tribe, utilizing anadromous salmon and steelhead trout that annually returned from the Pacific Ocean to spawn in their natal streams in northern Idaho. The tribe is now playing a pivotal role in the restoration of these threatened and endangered fish runs, which have been decimated by downstream dams, spawning habitat degradation, overfishing, and changing environmental conditions in the ocean.

Much of the reservation overlies a federally designated sole-source aquifer in the Columbia River Basalt Group. Petroleum contamination of these bedrock aquifers would be difficult to remediate, and replacement of water wells would be expensive. The groundwater is hydrologically interconnected with surface water and readily moves back and forth based on local hydrogeologic conditions.

The Nez Perce are developing environmental codes to regulate USTs and other potential contaminant sources affecting soil, surface and groundwater, and air quality on the reservation. The tribe is proposing a nondegradation policy for

aquatic resources. This has implications for the UST Compliance Act of 2005, which requires additional measures to protect groundwater when USTs are located within 1,000 feet of a water supply.

However, the Nez Perce believe that all potable water resources should be protected—not just resources that are adjacent to a water well—using the nondegradation policy. Potable water is an increasingly valuable commodity, and many water-rich areas of the country are experiencing water shortages. One need only compare the price of bottled water to that of gasoline to know that potable water is a precious resource that should not be squandered.

The Nez Perce Tribe subscribes to the philosophy of responsibility for its actions to the seventh generation of children yet unborn. This is not meant to imply that the reservation should be wilderness; indeed, the Nez Perce rely on agriculture, timber, and gaming in addition to fishing, hunting, and gathering roots and berries to support the Tribe and its members. The tribe is located in a rural area and depends on petroleum to fuel its equipment and cars.

The tribe thanks EPA Region 10 for supporting its capacity development program to safely manage USTs on the reservation and for allowing members to play a direct role in protecting our shared natural resources. ■

Kevin Brackney, P.G., is the Nez Perce Tribe UST Program Manager. He can be reached at kevinb@nezperce.org.

Montana Offers Free Online Environmental Compliance Help for Tank Owners

The Montana Department of Environmental Quality (DEQ) Underground Storage Tank Unit has introduced a groundbreaking learning and compliance tool called TankHelper. This free Internet-based software program translates complex petroleum storage tank rules into simple, easy-to-understand instructions. The service asks owners and operators a series of questions about their facility and equipment online. It then provides the owners and operators with information that is specific to their tank systems.

After the owner completes the training, TankHelper can create a customized, printable management plan. The plan guides facility operators in the actions they will need to take to stay in compliance, based on their individual storage tank system.

TankHelper is the result of an alliance between government and the private sector. The system was funded with a grant from U.S. EPA, and cooperatively developed and supported by the DEQ UST Unit, Department of Administration's Information Technology Services Division, and Montana Interactive, LLC, a wholly owned subsidiary of eGovernment provider NIC (Nasdaq: EGOV). TankHelper is available at www.Tankhelper.mt.gov.

"In a few months we will have the opportunity to edit this program," says Bill Rule of the DEQ UST Unit. "We'd like to get some reviews from knowledgeable regulators to help us improve the application. Don't hesitate to jump in and use or work with any facility." The information is public and the database information is secure. You can also use a Montana Department of Transportation site with Facility # 07-04047. ■

For more information, contact Bill Rule at brule@mt.gov

U. S. Settles UST System Lawsuit Against New York City

The United States Attorney for the Southern District of New York and U. S. EPA Region 2 recently settled a civil lawsuit against the City of New York involving UST violations in connection with the City's UST systems. The settlement, filed in Manhattan federal court, requires the City to pay \$1.3 million in civil penalties and to bring standard tank systems into compliance with federal law (RCRA Subtitle I). The Consent Decree also requires the City to undertake an additional environmental project to improve the City's ability to identify releases from its USTs.

The United States charged in the lawsuit that, from at least 1997, the City has been violating federal UST requirements in connection with its UST systems. As alleged in the complaint, New York City owns at least 1,600 USTs in at least 400 locations throughout the metropolitan area, including all five boroughs.

The lawsuit charged that New York City has for many years committed numerous violations of the federal UST regulations issued, including failing to upgrade or close noncompliant UST systems; provide proper methods to detect releases of hazardous substances; and report, investigate, and confirm suspected releases of regulated substances.

As part of the settlement, the City is required to undertake a multi-year project to monitor releases and suspected releases from a central location for USTs owned and operated by the Police Department, Fire Department, and Department of Transportation. In addition, the Consent Decree requires the City to upgrade or close noncompliant USTs. ■



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Automatic Mechanical Line Leak Detectors (MLLD) – Part I

In this installment of FAQs from the National Work Group on Leak Detection Evaluations (NWGLDE), we discuss the operation of automatic mechanical line leak detectors (MLLDs) with regard to product type. The next part in this series will address the effects of piping type and installation location on MLLD operations. This article does NOT apply to electronic line leak detectors (ELLD). (Please note: The views expressed in this column represent those of the work group and not necessarily those of any implementing agency.)

Q. *Why do some MLLD manufacturers offer MLLDs that are certified for multiproduct (e.g., gasoline, diesel), and others for diesel only?*

A. When MLLDs were first introduced (circa 1960), they were not tested to evaluate their performance with different products. At the time, there was only one type of piping in widespread use: galvanized steel. Since 1991, MLLDs have been required to meet the performance standard specified in the U.S. EPA rule—to detect a leak of 3 gph at 10 psi with a minimum 95 percent probability of detection and a maximum 5 percent probability of false alarm. Because of this requirement, some manufacturers introduced MLLDs designed for use with diesel only to more reliably meet this performance criterion.

Q. *Can MLLDs be interchanged (e.g., diesel to gasoline or vice versa)?*

A. First, let's focus on the function of a MLLD. During the pumping phase, a MLLD detects line leaks by metering the flow into the line through a precisely sized orifice at a flow rate slightly less than the U.S. EPA standard of 3 gph. If this metered flow through the MLLD is greater than any downstream line leak present, the pressure in the line increases and the MLLD opens to full flow. If this metered flow is less than any downstream line leak present, the pressure in the line does not increase, and the MLLD restricts the flow to 3 gpm when a dispenser nozzle is opened. When the flow is restricted, the MLLD is said to have "tripped."

As long as the fuel being metered by the MLLD has the same physical properties as the fuel the MLLD was designed for, the MLLD will be able to properly detect leaks in accordance with the EPA standard. For example, MLLD units designed for use with diesel should be able to detect

leaks in tanks holding fuels with similar characteristics, such as kerosene or jet fuels, because they have similar viscosity signatures. However, if a MLLD unit designed for use with diesel fuel were placed in a gasoline product pipeline, the lower viscosity of the gasoline would cause the MLLD to meter the gasoline into the pipeline at a flow rate *above* the EPA standard, and a 3 gph leak would not be able to be detected.

MLLDs designed for use with gasoline will detect leaks within EPA standards for fuels with thicker viscosity signatures, such as diesel or kerosene, because the fuel will meter through the MLLDs at a flow rate *below* the 3 gph EPA standard. This means that MLLDs designed for use with gasoline and operating in diesel fuel, will be more sensitive to leaks.

For example, a MLLD designed for diesel and placed in a gasoline system might only be able to detect a 4 or 5 gph leak at 10 psi and would therefore not meet the regulatory requirements for flow rate. Conversely, a MLLD designed for gasoline and placed in a diesel system might be able to detect a leak of 1 or 2 gph at 10 psi, which does meet the regulatory requirements for flow rate, and, in theory at least, be able to detect even smaller leaks in diesel fuel than is required by the EPA standard. Since all MLLDs have the same diameter base and use the same thread, they can be installed for use with inappropriate fuel types.

Therefore, it is important to review the NWGLDE listings to determine what products a MLLD can handle to ensure that it is able to detect a leak within the EPA standard of 3 gph at 10 psi with a minimum 95 percent probability of detection and a maximum 5 percent probability of false alarm. As an inspector, the violation to watch out for would be a diesel MLLD installed on a gasoline storage system.

(To be continued)

About NWGLDE

NWGLDE is an independent work group comprising 10 members, including eight state and two U.S. EPA members. This column provides answers to frequently asked questions (FAQs) NWGLDE receives from regulators and people in the industry on leak detection. If you have questions for the group, please contact them at questions@nwglde.org.

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