STATE WATER RESOURCES CONTROL BOARD'S ADVISORY PANEL ON THE LEAK HISTORY OF NEW AND UPGRADED UST SYSTEMS

OXYGENATE COMPATIBILITY AND PERMEABILITY REPORT
(UST Team 1 Report)

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I. EXECUTIVE SUMMARY

Team 1 addressed whether oxygenated fuels are incompatible with or able to permeate through materials used in underground storage tank (UST) systems. The fuel oxygenates of concern included two alcohols–methanol (MeOH) and ethanol (EtOH)–and four ethers–methyl tertiary butyl ether (MTBE), ethyl tertiary butyl ether (ETBE), tertiary amyl methyl ether (TAME), and diisopropyl (DIPE). Metallic and non-metallic materials used in the underground and aboveground components of a UST system–including not only the tank, piping, turbine sump, and fittings, but also the dispenser pan and hoses and vapor recovery equipment–were considered. Team 1 collected its information and data through an extensive literature review and a survey of the petroleum equipment industry.

Existing information indicates that MTBE and other ethers blended with gasoline are generally compatible with UST system components in liquid phase, and that releases should not occur due to the deterioration of system components from contact with the ether. However, some polymeric materials may be subject to swelling and softening when in contact with alcohols–either neat or blended with gasoline–or neat MTBE. Alcohols can pose compatibility problems for metals and non-metals, but industry recommendations have been made on appropriate materials for storing alcohol and alcohol-gasoline blends which should be followed and monitored. A single, comprehensive industry standard for compatibility testing of nonmetallic materials in UST systems does not exist, nor do the current standards ensure environmental protection. The federal and California UST regulations do not require UST equipment manufacturers to report third-party testing results for performance of tanks, piping, or other UST system components, as is required for leak detection equipment. Furthermore, results of third-party testing are generally treated as proprietary by the UST equipment industry.

The permeation rate of oxygenated gasoline is greater than nonoxygenated gasoline in common hose materials. In general, alcohol-blended fuels are more permeable than ether blends, with methanol being most aggressive. For both ethers and alcohols, greater permeability in gasoline blends is observed in elastomers (e.g., hoses, seals, gaskets, packing) than in thermoplastics (e.g., flexible piping, sumps, vapor recovery tubing). First, questions about permeation of oxygenated fuels through UST system equipment cannot be answered until a standard protocol is developed. The objective would be to directly measure the mass flow of ethers or alcohols, dissolved in gasoline, through materials of interest using techniques and instrumentation capable of quantifying individual chemical species. Second, using such a protocol, permeability data should be collected for non-metallic materials used in UST systems, especially composite materials used for rigid piping and tanks. Once these are accomplished, an estimate can be made for oxygenate permeation to air and soil from a UST system at a retail gas station. Any estimated volume of oxygenates due to permeation over time should be compared to the quantity of oxygenates released during small spills that frequently occur at retail gas stations and other dispensing facilities. An environmentally-based standard for permeability testing may need to be established, as the only permeation standard applicable to UST systems is intended to ensure safe operation of the equipment, not necessarily environmental protection.

II. BACKGROUND

A. <u>Problem Statement</u>

The task of Team 1 was to determine whether problems exist with oxygenated fuels being incompatible with or able to permeate through materials used in underground storage tank (UST) systems. The fuel oxygenates addressed in this inquiry included two alcohols–methanol (MeOH) and ethanol (EtOH)–and four ethers–methyl tertiary butyl ether (MTBE), ethyl tertiary butyl ether (ETBE), tertiary amyl methyl ether (TAME), and diisopropyl (DIPE). Although MTBE is the most widely used oxygenate in the United States, Team 1 included all commonly used oxygenates to broaden the inquiry on potential material compatibility and permeability issues.

1. Definitions

Chemical incompatibility refers to changes in the physical, chemical, or mechanical properties of a material resulting from thermal-chemical exposure, which subsequently alter the performance of a part in ways which induce or enhance new or existing failure mechanisms. For metals, chemical compatibility often implies corrosion resistance. While the term corrosion is not generally used to describe nonmetallic performance, a change in properties due to chemical exposure is often considered a form of corrosion. Important to note is that the same fuel that must be compatible with an UST system must also be compatible with an automotive fuel system. For gasoline, chemical compatibility also means that degradation products, of any, do not contaminate the fuel or impair automotive performance.

Permeation is mass transport, or flux, through a material that is driven by an activity gradient. Activity is a thermodynamic term which is related to the change in the chemical potential with chemical composition. Mass flux is proportional to the permeability coefficient of the solvent-material pair and also the surface area to thickness ratio of a membrane. Gasoline, oxygenated or not, does not absorb into or permeate through metals. The phenomenon of permeation is, thus, limited to certain nonmetals and will typically vary greatly depending upon the type of material in question.

2. Materials in UST Systems

Team 1 considered all the underground and aboveground components of a UST system, including not only the tank, piping, turbine sump, and fittings, but also the dispenser pan and hoses and vapor recovery equipment. Nonmetallic materials commonly found in a retail gasoline station may be classified into three categories: elastomers, thermoplastics, and thermosets. Elastomers are commonly used in flexible hose constructions, seals, gaskets, and packing. An elastomer may be defined as a material which can be stretched beyond its yield point and yet its strain is largely recoverable upon relaxing the applied stress. This strain recovery property is usually obtained by mild cross-linking (three mole percent or less) or vulcanization of a rubbery gum.

Thermoplastics are commonly used in flexible underground piping, sumps, and vapor recovery tubing. A thermoplastic is usually either a semi-crystalline or glassy amorphous material which, upon heating, will reversibly melt into a liquid that may be processed. Thermosets are commonly used in reinforced composites and are found as matrix materials for rigid underground piping and USTs. A thermoset is usually a glassy material which is cured into a highly cross-linked network. Once vitrified, a thermoset cannot be melted and reprocessed like thermoplastics.

The metallic materials commonly found in a retail gasoline station are steel, brass, aluminum, copper, and zinc. Other materials found in UST systems include ceramics, pipe dope, and organic coatings.

B. Approach to Data Gathering

Given that existing data on UST system material compatibility and permeability may be found in both published and unpublished documents, Team 1 undertook two separate research efforts to acquire as much of the available data as possible. First, a review of academic and industry literature was conducted. The sources dated from 1975 to 1997 and most were published documents, although some were unpublished. The review included published industry standards for testing UST equipment, as well as related industry standards (e.g., reference fuels to use in material testing). A technical assessment of the literature is presented in Appendix A. Second, a survey of UST equipment manufacturers was conducted to better understand the nature and extent of compatibility and permeability testing of tanks, piping, and other components of UST systems by third-party entities. The survey instrument developed by Team 1 is presented in Appendix B.

III. FINDINGS

A. Literature Review

1. Compatibility–Metals

The area of concern with metal in UST systems is general corrosion and pitting. The literature review focused on the occurrence of these phenomena caused by oxygenated fuels. The first part addresses ethers and the second part alcohols.

a. Ethers

Data: Very little information is available regarding corrosion of metals by ethers and, in particular, MTBE. Two studies on MTBE and one study on ETBE were identified and reviewed.

The first MTBE study looked at corrosion resistance of zinc, aluminum, and brass in neat MTBE and gasoline containing 20 percent MTBE by volume. The second MTBE study examined material damage to the fuel system of a fleet of flexible fuel vehicles using, over an extended period of time, gasoline containing 7 percent MTBE by volume. The ETBE study looked at corrosive effects to galvanized steel, cast iron, magnesium, brass, aluminum, 1018 carbon steel, and terneplate in experimental fuels blended with ETBE but not containing anti-corrosion additives normally used in finished gasoline.

Industry guidance on material usage: No information was identified on usage of ethers or ether-blended gasoline with metal materials.

b. Alcohols

Data: In contrast to the paucity of documented information on corrosion of metals by ethers, a significant amount of data has been published on corrosion by alcohols, the majority from research motivated by concerns about automotive fuel systems. Many general texts may be consulted regarding the phenomenon of metal corrosion by aggressive media.

Industry guidance on material usage: The American Petroleum Institute has published two documents which identify metals recommended and not recommended for use with ethanol, ethanol blends, and gasoline-methanol/cosolvent blends.

c. Industry Testing Standards

In addition to six ASTM standards reviewed (ASTM G1, G31-95, G46-94, G71-81, G119-93, and G133-95), numerous other industry standards have been established for evaluating metal corrosion and/or wear phenomena. In general, these standards call for the use of reference fuels and other test fuels that are same as those specified for standards addressing chemical resistance of non-metallic materials.

d. Conclusions

All three studies involving ethers indicate that no detrimental corrosive effects occur to the metals common to gasoline delivery and fueling systems. Given the data from these studies and the fact that finished gasoline normally contains anti-corrosion additives, gasoline is a rather benign chemical environment from a metals corrosion perspective. The addition of ethers to gasoline does not increase the aggressiveness of the fuel towards metals.

There are numerous material compatibility issues associated with gasohol, and they are well known in the fuel systems industry. Generally, methanol blends are more aggressive than ethanol blends. Metal corrosion problems include general and localized corrosion of active metals, galvanic corrosion, electrolytic corrosion, wear, and aqueous phase separation. Methanol blends with tertiary butyl alcohol are produced which mitigate some material concerns.

2. Compatibility–Non-metals

Elastomer material compatibility primarily concerns swelling, a critical performance factor which involves solvent absorption by the material at equilibrium and affects physical dimensions and mechanical properties of the material. For thermoplastics and thermosets, it is the retention of mechanical properties that is of concern.

a. Ethers

Data: Data on swelling was available from numerous sources for elastomers exposed to MTBE, ETBE, and TAME blends with gasoline in varying percentages by volume; and for thermoplastics and thermosets exposed to MTBE blends with gasoline in varying percentages by volume. By far the most data is reported for elastomer swelling in gasoline blended with varying percentages of MTBE between zero and 100 percent. The impetus for generating these data was to identify materials for automotive fuel systems which would meet the fugitive emission requirements of the Federal Clean Air Act. Data for thermosets, used in UST and rigid piping construction, and to a lesser extent thermoplastics, used in flexible piping and sumps, are predictably sparse since these materials are not used in automotive fuel systems.

Industry guidance on material usage: An API Publication, based on a petroleum industry survey, lists elastomers and polymers in pipeline/terminal components used for non-oxygenated fuels versus those used with oxygenated fuels in pipeline/terminal components; the survey did not distinguish between oxygenated fuels containing ethers versus alcohols.

b. Alcohols

Data: Data on swelling was available from numerous sources for elastomers exposed to methanol and ethanol blends with gasoline in varying percentages by volume; and for a thermoset composite exposed to methanol blended with gasoline at 85 percent by volume. As with metals, methanol blends are more aggressive towards non-metallic materials than are ethanol blends.

Industry guidance on material usage: The American Petroleum Institute has published two documents which identify elastomers and polymers recommended and not recommended for use with ethanol, ethanol blends, and gasoline-methanol/cosolvent blends. Guidance on the use of oxygenates with thermoplastics or thermosets was not identified.

c. Industry Testing Standards

Several industry testing standards suggest chemical resistance performance criteria for nonmetallic piping and tanks. ASTM C 581 is a general standard for chemical resistance of composite materials, specifically that of thermosetting resins used in glass-fiber-reinforced structures intended for liquid service. ASTM D 4021-92 and Underwriters Laboratories (UL) 1316 are standards of safety for glass-fiber-reinforced plastic USTs, and both involve immersion of coupons in test fluids followed by testing of mechanical properties. Both also specify chemical resistance performance criteria, but these criteria differ. The former standard requires at least 50 percent retention of initial material properties for coupons exposed to specified test media (i.e., fuels and other liquids), whereas the latter requires at least 50 percent property retention for coupons exposed to one group of test media and at least 30 percent property retention for coupons exposed to a second group of test media; the sets of ASTM and UL test media are not identical. Similar compatibility testing standards exist for plastic pipe under UL 971 and for pipe connectors, hoses, and seals (plastic and elastomeric) under UL 567. UL follows the same standard procedures for compatibility testing of gasoline hoses; polyethylene sumps with rubber fittings; and rigid, nonmetallic fitting and gasket materials in steel sumps.

For any hardware designed for use in retail gas stations which has undergone third-party testing, there is no evidence to suggest that the hardware would not meet these performance standards in applied use. While the standards mentioned above specify test fuels which include methanol and ethanol blends, none specifically requires that the test fuels contain MTBE or other ethers (in ASTM D 4021-92 a note is made that the purpose of chemical testing is to determine the applicability of tank materials to specific uses, and that the set of test media should include all liquid products to be contained in the tank). However, these standards should allow for equipment to be tested with any fuel blend if the manufacturer makes such a request.

d. Conclusions

No documented material incompatibility issues exist for retail gas stations dispensing reformulated fuels containing ethers up to 15 percent by volume. In concentrations greater than about 20 percent by volume, MTBE and TAME cause swelling of some fluoroelastomers which may be excessive for some applications, specifically dynamic sealing, e.g., in check valves, valve stems, and rotating shafts. Swelling of fluoroelastomers in neat ETBE is substantially lower than in other ethers.

Regarding alcohols, problems posed to polymeric materials include swelling and softening due to absorption of alcohol and extraction of plasticizers and antioxidants. Generally, compatible material alternatives are available, but the extent to which they are utilized in the construction of components for UST system components could not be determined.

A single, comprehensive industry standard for compatibility testing of nonmetallic materials in UST systems does not exist. Neither the federal nor the California UST regulations require UST equipment manufacturers to report third-party testing results for tanks, piping, or other UST system components, as is required for leak detection equipment. Furthermore, results of third-party testing are generally treated as proprietary by the UST equipment industry.

3. Permeability–Non-metals

Any solvent which can absorb into a material will also permeate through it. The phenomenon is therefore limited to polymeric materials. Generally, the presence of oxygenates accelerates permeation of hydrocarbon fuels in elastomers and thermoplastics. The argument has been made that, given the larger molecular size of MTBE compared to methanol, any material which is compatible with methanol will not allow permeation of MTBE. While this idea has become popular wisdom, it is not a rigorous theory, nor should it be a substitute for direct measurement.

The literature review focused on identifying the available data on permeation rates of oxygenated fuels and their separate alcohol or ether constituents. Data for composites (used for rigid piping and USTs), and to a lesser extent thermoplastics (used for flexible piping, sumps, and vapor recovery tubing) are noticeably sparse. This lack of data is explained by the fact that most data on materials permeability (and compatibility) have been reported by the automotive industry for vehicular fuel systems, which do not contain composite materials.

a. Ethers

Data: Permeability data for MTBE-blended gasoline as well for other ether blends are sparse compared to data for alcohol blends. Data on permeability was available from numerous sources for elastomers exposed to MTBE blends with gasoline in varying percentages by volume. Some data for elastomers and thermoplastics used in hoses and flexible piping were identified. No data for fiberglass composites used in construction of tanks and piping were found. However, there is no theoretical reason to expect strong selective absorption of MTBE by isophthalic polyesters. MTBE may be more permeable than TAME. The solubility characteristic of ETBE indicates that it may be substantially less permeable in fluorocarbon elastomers than either MTBE or TAME.

From available data on total mass flow rate due to permeation, an attempt was made in the technical assessment of the literature review (see Appendix A) to estimate the component contribution of MTBE permeation directly to the soil column through buried thermoplastic flexible piping. Assuming 500 square feet of surface area of underground piping, with secondary containment, in a typical gasoline station, the fugitive emission of MTBE is expected to be approximately 8 g/day.

A similar estimate was made for the permeation of MTBE directly to the air through elastomeric dispenser hoses. The estimate required many assumptions. Depending on the total surface area of hoses and other considerations, calculations suggest that up to 10 g/day total MTBE emission may occur from permeation through nitrile rubber (NBR)-based hoses at a typical gasoline station. (The automotive fuel system industry changed to viton-lined NBR hoses to reduce fugitive emissions of total hydrocarbons to meet the requirements of the Clean Air Act of 2 g/day/vehicle. However, viton selectively absorbs and permeates MTBE, relative to the aromatic and aliphatic hydrocarbons, even though MTBE is a minor constituent in gasoline.)

Rather than making theoretical estimates, it would be preferable to directly measure the mass flow of ethers, when dissolved in gasoline, through materials of interest using techniques and instrumentation capable of resolving the quantifying individual chemical species.

Industry guidance on material usage: None was identified pertaining to permeability or resistance to permeation of nonmetallic materials in contact with oxygenated fuels containing ethers.

b. Alcohols

Data: Data on permeability were available from numerous sources for elastomers and thermoplastics exposed to methanol and ethanol blends with gasoline in varying percentages by volume. A limited amount of data were available for permeability of hose constructions to fuels containing alcohols. No data for fiberglass composites used in construction of tanks and piping were found.

Industry guidance: None was identified pertaining to permeability or resistance to permeation of nonmetallic materials in contact with oxygenated fuels containing alcohols.

c. Industry Testing Standards

Permeability testing is required under UL 971 ("Nonmetallic underground piping for flammable liquids"). The test is performed by taking 18 inches of the smallest diameter pipe, weighing it empty, then filling it with the test liquid and sealing it. Samples are weighed every month for 180 days for primary pipe and twice a week for 30 days for secondary pipe. The rate of permeation is calculated monthly and compared to the maximum allowed weight loss for primary pipe of 0.013 oz/ft^2/day (4 g/m^2/day) and for secondary pipe of 0.079 oz/ft^2/day (24 g/m^2/day). There are 10 test liquids, including pure methanol and ethanol, 50 percent blends of each with gasoline, and 10 and 30 percent blends of ethanol with gasoline. No requirement for testing with MTBE blends or other ether blends is specified. UL does have standard procedures for permeability testing of polyethylene sumps. The test duration is at least 30 days and until the permeation rate reaches a constant level; the evaluation criterion is that the permeation shall not exceed 0.25 oz/ft^2/day. Three SAE standards were identified which address permeation requirements for non-metallic tubing and flexible hoses used in automotive fuel systems.

Although UL 567 and ASTM D 4021-92 contain various procedures to test compatibility of pipe connectors and glass-fiber-reinforced polyester USTs, respectively, testing for permeability is not addressed. Similarly, while UL 1316 and ASTM D 4021-92 address compatibility of glass-fiber-reinforced plastic/polyester USTs, they do not contain procedures for permeability testing. ASTM standards for permeation of plastics do exist, but are intended for the food packaging industry, and, as such, focus on oxygen and other gas components rather than hydrocarbons. However, these standards do stress the requirement to achieve steady state permeation.

In summary, standards and procedures do exist for measuring the total hydrocarbon permeability in hoses, sumps, flexible piping, and rigid piping but not for composite USTs. However, the standards do not allow the calculation of mass flow contributions from individual hydrocarbon species. The existing standards are not adequate for steady state measurement of individual oxygenated species, particularly alcohols that may be present in dilute quantities in gasoline. Directly related to this issue, it should be noted that no environmental standards exist at the federal level or in California that limit fugitive emissions for gasoline retail stations, as for automobiles (under the Clean Air Act, the maximum level of fugitive total hydrocarbon emissions per vehicle is 2 g/day, which is a significant decrease from the previous requirement of 24 g/day). Only UL 971, for safe operation of underground piping, suggests a permeability limit for the primary conductor and secondary containment piping.

d. Conclusions

The permeation rate of oxygenated gasoline is greater than nonoxygenated gasoline in common hose materials. In general, alcohol-blended fuels are more permeable than ether blends, with methanol being most aggressive. The permeation rate of ETBE is postulated to be considerably lower than other oxygenates. For both ethers and alcohols, greater permeability in gasoline blends is observed in elastomers (e.g., hoses, seals, gaskets, packing) than in thermoplastics (e.g., flexible piping, sumps, vapor recovery tubing). In general, fluorinated elastomers and thermoplastics offer better permeation resistance than nonfluorinated materials. No successful attempts to measure permeation of ethers or alcohols in pipe or tank composites have been reported. There are not enough data to estimate the total fugitive emission of hydrocarbons from retail gas stations. If the mass flow of ethers or alcohol by permeation through UST system materials is desired, then it must be measured directly.

Questions about permeation of oxygenated fuels through UST system equipment cannot be answered until (1) a standard protocol is developed to directly measure the mass flow of ethers or alcohols, when dissolved in gasoline, through materials of interest using techniques and instrumentation capable of resolving the quantifying individual chemical species; and (2) permeability data are collected for the composite materials used for rigid piping and USTs. Once these are accomplished, a better estimate can be made for oxygenate permeation from a UST system at a retail gas station. Any estimated volume of oxygenates due to permeation over time should be compared to the quantity of oxygenates released during small spills that frequently occur at retail gas stations and other dispensing facilities. An environmentally-based standard for permeability testing may need to be established, as the only permeation standard applicable to UST systems (UL 971) is intended to ensure safe operation of the equipment, not necessarily environmental protection.

4. Compatibility and Permeability−Other Materials

a. Data

The literature review revealed a limited amount of information concerning ceramics, pipe dope, and organic coatings. Concerning ceramic materials, no information about compatibility or permeability issues was found pertaining to oxygenated fuel blends. Several sources in the literature state that freshly applied pipe dope is subject to washing out by gasoline containing alcohol. Some pipe dope is alcohol-based, and the solids may be redissolved if the pipe dope has not had ample time to dry. Washed-out pipe dope can lead to leaks in threaded connectors. Polytetrafluoroethylene (PTFE)-based tape may be utilized as an alternative thread sealant.

Organic coatings, applied to the inside or outside of steel USTs, are used to provide cathodic protection. In a laboratory evaluation, it was found that gasohol tends to extract an epoxy coating from a fuel storage tank. Several sources mentioned the superior performance of urethane-based coatings in automotive finishes for splash exposure to gasohol. Lastly, a series of successful immersion tests have been done involving steel coated with ethylene acrylic acid polymer in 100 percent methanol and gasoline-methanol blends, in which no evidence of laminate deterioration of adhesion loss on any sample was found.

b. Industry Guidance on Material Usage

No guidance was identified on usage of organic coatings with fuels.

c. Industry Testing Standards

Two industry standards exist which address organic coating used to line the interior of USTs–American Petroleum Institute Publication 1631 and National Leak Prevention Association Standard 631. The former standard outlines coating specifications, including immersion tests which should be conducted under certain temperature conditions and time periods using a set of eight test media. Physical property retention after immersion must be at least 30 percent for three of the test media (toluene, xylene, and distilled water) and at least 50 percent for the remaining four test media, which includes gasoline blended with 10 percent ethanol but not methanol or any ether blends. The standard does note that a warranty certifying chemical compatibility is to be provided to the UST owner by the manufacturer before liquids other than the seven test media may be stored. (A copy of the latter standard was not available in time for review.) UL has a standard procedure for testing organic coating in steel sumps, which involves immersion in 21 test media including methanol and ethanol blends, but not specifically ether blends.

d. Conclusions

There is no reason to suspect compatibility or permeability problems with ceramic components in UST systems. Problems with pipe dope washing out can be avoided by following proper installation procedures. Some organic coatings are more suitable for gasohol storage than others. The practice of UST coating manufacturers providing a warranty for use with specific liquids should be continued.

B. Industry Survey

1. Overview

Team 1 developed a one-page, two-sided survey form (see Appendix B) which asked questions related to materials testing. The purpose of the survey was to determine the extent of testing conducted to date for oxygenate compatibility with and permeation in UST system components. The survey was sent out to 257 companies at the end of April 1998. As of the end of September 1998, 25 responses had been turned in. Basic statistics on the extent and nature of survey responses are included at the end of this section.

The companies which received the survey were selected from the Petroleum Equipment Institute s (PEI) 1998 Petroleum Equipment Directory, and specifically the list of equipment manufacturers. The survey responses are not included with this report due to the confidential and proprietary nature of some of the information presented. The surveys were made available to and reviewed by the Team 1 members.

Many of the companies on the PEI list of equipment manufacturers either do not market their products in California or manufacture products which do not come into direct contact with gasoline (e.g., electronic components). This partially explains the low response rate. Another issue leading to low responses was manufacturers concern about confidentiality and proprietary information. A third possible issue is the lack of testing done by some of the smaller manufacturers. Some verbal comments given to Team members indicate that some manufacturers rely on their larger competitors to do the testing. The smaller companies then use the same raw materials based on the assumption that adequate testing has been performed by the larger companies. There are some systems in use which may have components that are no longer manufactured. The survey responses only covered products currently being manufactured.

2. Summary of Responses

In addition to the response rate falling short of our expectations, only one quarter of the respondents (six companies) furnished some information regarding testing of their products with oxygenates. Of these, the tests of only three companies equipment included all oxygenates of concern to Team 1. Limited information regarding oxygenate compatibility is occasionally printed in manufacturers sales brochures, some of which were submitted with the survey responses and some which were collected by Team 1 separately. Although neither the Team 1 survey responses nor the sales materials provide analytical test results, except in the case of three respondents, they do offer some level of confidence that manufacturers are testing for material compatibility. A total of four respondents stated they warranty the equipment for storage of specific fuels. Only one specifically includes MTBE, and another mentions “oxygenate blends.” Three of the four specifically include alcohols and alcohol-gasoline blends.

The test results provided by respondents included tests on the most commonly used fuel system components. The materials of greatest concern are fiber-reinforced plastics (FRP or fiberglass), polyethylene, high density polyethylene (HDPE) and steel. Gasket materials such as viton, teflon, and rubber were not addressed by any of the survey responses, but they were well-covered in other papers discovered during the literature search.

Typically, material samples were tested with various formulations of gasoline and oxygenates. The compatibility tests generally included immersion of the product sample in the test liquids for varying lengths of time. The samples were then tested for elongation, strength, and swelling as a percentage of their original size and strength. The test results do not indicate any significant differences between samples tested with oxygenates versus those tested without oxygenates. Only one survey response contained information about permeability testing. The product tested was non-metallic piping under UL 971; the test result did not indicate any significant level of permeation as tested.

STATISTICS FROM THE SURVEY OF UST EQUIPMENT MANUFACTURERS			
ALL SURVEY RECIPIENTS		Number	Percent of All Recipients
Companies Who Were Sent the Survey (“Recipients”)		257	100
Companies Who Responded to the Survey (“Respondents”)		25	10
Recipients Marketing Equipment in CA (“CA Recipients”)		89	35
Breakdown:	Underground Storage Tanks	6	
	Underground Piping	8	
	Fuel System Components in Contact w/ Fuel	91	

	Components Not in Contact w/ Fuel	37	
CA RESPONDENTS		Number	
Breakdown:	Underground Storage Tanks	3	
	Underground Piping	3	
	Fuel System Components in Contact w/ Fuel	30	
	Components Not in Contact w/ Fuel	7	
ALL SURVEY RESPONDENTS		Number	Percent of All Respondents
Respondents Providing Compatibility Test Results		6	24
Respondents Providing Permeability Test Results		1	4
Respondents Specifying Warranties with Specific Fuels		4	16

IV. RECOMMENDATIONS

A. Collect Additional Data on Permeability of Oxygenated Hydrocarbons

1. Establish reliable and scientifically defensible techniques for determination of the individual contribution of the oxygenated hydrocarbon component to total permeability of gasoline blends in materials of construction commonly found in retail gasoline stations.

2. Directly measure the permeability of MTBE and other oxygenated hydrocarbons in these materials, including the comparative permeation rates of ETBE versus MTBE. From these data and geometrical considerations of UST systems, estimate the total fugitive emission rates to air and soil of oxygenated hydrocarbons via permeation through common retail gas station equipment.

B. Establish Environmental Standards for Compatibility and Permeability Testing

1. A standard or set of standards should be developed through a cooperative effort between government, the petroleum equipment industry, and nationally-recognized independent testing organizations to establish uniform criteria for material compatibility and permeability testing with conventional and oxygenated fuels which are environmentally protective, in addition to ensuring safe operation. For compatibility testing, the existing standards could be consolidated along with or in addition to establishing consistent criteria for swelling, physical property retention, and other compatibility measures. For permeability testing, new standard(s) and criteria for permeation need to be developed.

2. Results of material compatibility and permeability testing with conventional and oxygenated fuels should be made readily available to any interested party.

3. New fuel formulations should be tested for UST system compatibility before they are introduced for wide-scale use.

V. ATTACHMENTS