Survey of Current UST Management and Operation Practices

A Publication of:

The California MTBE Research Partnership

Edited by:

Gina Melin, National Water Research Institute

December 1999

Published by the
Center for Groundwater Restoration and Protection
National Water Research Institute

NWRI-99-04

10500 Ellis Avenue ✦ P.O. Box 20865
Fountain Valley, California 92728-0865
(741) 378-3278 ✦ Fax: (714) 378-3375
www.NWRI-USA.org

Limitations

This document was prepared by Alpine Environmental, Inc (Alpine) and is intended for use by members of the California MTBE Research Partnership (Partnership) pursuant to the Partnership Agreement. Neither Alpine nor the Partnership warrants, guarantees, or attests to the accuracy or completeness of the data, interpretations, practices, conclusions, suggestions, or recommendations contained herein. Use of this document, or reliance on any information contained herein, by any party or entity other than members of the Partnership, is at the sole risk of such parties or entities.

Acknowledgements

This report was prepared by James M. Davidson and Daniel N. Creek, P.E. of Alpine Environmental, Inc. (Fort Collins, Colorado, USA). The authors would like to thank the California MTBE Research Partnership and the National Water Research Institute (NWRI) for sponsoring this work. Many members of the Partnership's Research Advisory Committee provided valuable support and review of this work, for which the authors are grateful. Thanks also go to the many engineers, scientists, and manufacturer representatives who shared their documents, data, and time to improve this report. In June 1999, 21 UST experts attended a Partnership-sponsored workshop in Fountain Valley, California, and generously shared their extensive experience, insight, and ideas.

Table of Contents

Appendices

List of Tables

List of Acronyms

ACWA:	Association of California Water Agencies
ANSI:	American National Standards Institute
API:	American Petroleum Institute
ASTM:	American Society for Testing and Materials
ATG:	automatic tank gauge
BTEX:	benzene, tuolene, ethylbenzene, and xylenes (*o-, m-, p*-xylene)
CARB:	California Air Resources Board
CPPI:	Canadian Petroleum Products Institute
DOT:	Department of Transportation
FM:	Factory Mutual
GSA:	General Service Administration
IFCI:	International Fire Code Institute
LG:	Local Guidance
LIA:	Local Implementing Agencies
MTBE:	Methyl Tertiary Butyl Ether
NACE:	National Association of Corrosion Engineers
NFPA:	National Fire Prevention Association
NLPA:	National Leak Prevention Association
NWRI:	National Water Research Institute
O&M:	Operation and Maintenance
OFA:	Oxygenated Fuels Association
PEI:	Petroleum Equipment Institute
QA/QC:	Quality Assurance/Quality Control
RWQCB:	Regional Water Quality Control Board
STI:	Steel Tank Institute
SWRCB:	State Water Resource Control Board
UL:	Underwriters Laboratories
ULC:	Underwriters Laboratories of Canada
USEPA:	United States Environmental Protection Agency
USGS:	United States Geological Survey
UST:	underground storage tank
WSPA:	Western States Petroleum Association
Y2K:	Year 2000

Introduction

This report was supported by the California MTBE Research Partnership, which consists of representatives from the Association of California Water Agencies (ACWA), the Western States Petroleum Association (WSPA), and the Oxygenated Fuels Association (OFA). The California MTBE Research Partnership, which is managed by the National Water Research Institute (Fountain Valley, CA), was formed in 1997 to evaluate a variety of environmental topics related to the gasoline additive Methyl Tertiary Butyl Ether (MTBE).

This report presents a compilation and analysis of the current literature regarding management and operation practices for underground storage tank (UST) systems. The primary objectives of this project are to:

- Survey and compile the current literature regarding UST management and operation practices.
- Summarize from the literature the most promising suggestions for improved UST management and operation practices.
- Identify topics for further research that could refine and improve UST management and operation practices to further reduce/eliminate gasoline and MTBE releases from USTs.

The suggestions and research topics identified herein are based on currently available literature and on the results of an interactive workshop of 21 UST experts that was held in June 1999. The experts who attended the workshop included representatives from the petroleum industry, UST system manufacturers, environmental consultants, and the regulatory community.

Overview of Report Contents

The contents of this report include the following technical information relevant to UST system management and operation practices.

Section 2.0 Regulations, Codes, Specifications, and Practice Guidelines for Managing and Operating USTs

This section summarizes the primary information sources available regarding the management and operation of USTs. In addition to federal and California state regulations, there is an extremely wide variety of technical codes, standards, equipment specifications, material specifications, and guidelines that pertain to the installation, operation, and maintenance of UST systems. The U.S. Environmental Protection Agency (USEPA) alone has published over 150 documents that relate to various aspects of owning, operating, financing, investigating, remediating, and regulating underground storage tanks. Section 2.0 presents a brief discussion and reference information for this wide variety of UST-related literature.

Section 2.0 is supported by Appendix A, which lists approximately 100 references that provide detailed information on UST management and operation practices. These references provide a vast repository of detailed information on the equipment and procedures involved with the design, installation, operation, maintenance, and closure of USTs. Understanding and following these codes, standards, specifications, and guidelines is an excellent basis for a good UST operation and maintenance program.

Section 3.0 Managing and Operating Underground Storage Tank Systems

The equipment and practices documented in the extensive UST regulations, codes, specifications, and guidelines have certainly helped reduce and eliminate some gasoline releases from USTs, especially the larger releases. However, the complexity of the UST equipment — combined with equipment failures and the ever-present potential for human error — means that some spills, releases, and leaks from USTs will inevitably occur.

There are several types of incidents that can result in gasoline and/or MTBE being released from UST systems, including:

- Failure of the gasoline storage, piping, pumping, or delivery system
- Spillage during fuel delivery
- Spillage during fuel dispensing
- Possibly, vapor-phase losses

A variety of leak prevention and detection equipment has been developed over the years to eliminate/reduce the potential for these spills. There is some statistical evidence to support the beneficial aspects of these leak detection and prevention systems, though the data are limited. Improvements to UST equipment and practices have been continual over the last few decades. New and more sophisticated systems have been developed as innovation allowed and as the need for new systems dictated. Significant strides have been made as each successive generation of leak prevention and detection equipment was implemented. It seems to be industry consensus that it is now the small, slow, or subtle gasoline losses from USTs that remain the primary challenge. Preventing these small/subtle spill sources becomes even more important when MTBE (or any other generally recalcitrant compound) is present in the gasoline.

In trying to prevent and detect small/subtle spills, good management and operation practices are critical. Therefore, it is worthwhile to compile and analyze the UST management and operation practices currently in use. By doing so, poor practices are more readily avoided and, with time, improved practices are developed and implemented. To compile the current UST management and operation practices, dozens of government and industry documents were reviewed. Additional information was extracted from six example UST management and operation practices documents (see Appendix B).

Based on review of all these documents, two tables were compiled of the many components and activities that are required during UST design and installation. These two tables (Tables 1 and 2 in the report) list 16 general activities to be addressed during UST design and installation. When these categories are broken down into detail, there are more than 140 different factors to consider when installing a UST. These factors, in turn, relate to more than 110 potential problems that can arise during design and installation.

Additionally, two tables were made of the components and activities needed during UST operation and maintenance. These two tables (Tables 3 and 4 in the report) list 13 general categories of activities that occur continuously throughout the active operational and maintenance life of a UST facility. When these 13 general activities are broken down into detail, there are more than 120 different activities/factors that occur during UST operation and maintenance. When the 13 general activities are analyzed, more than 120 potential problems can be listed.

There are many different service station personnel involved in operating and maintaining a service station, and their different training, duration of employment, and level of commitment can lead to these UST practices being conducted in different ways, with varying degrees of accuracy. This greatly complicates UST operation and management and can confound even the best attempts to optimally operate and maintain USTs.

There are several UST performance studies that have been completed recently or are currently ongoing, including studies by the California State Water Resources Control Board, Couch and Young, the Santa Clara Valley Water District, and the USEPA.

In light of MTBE's physicochemical characteristics, there are certain aspects of UST releases that may be of even more concern if MTBE is present in the gasoline. These include the following: small/subtle gasoline leaks; losses from vapor systems; and, UST component incompatibility with MTBE. Although more research is needed, each of these factors may result in gasoline and/or MTBE releases that can impact the environment.

Section 4.0 Suggestions for Improved UST Management and Operation Practices

Section 4.0 presents a summary of suggestions for improved UST management and operation practices. These suggestions were isolated primarily from the current UST literature, while some previously undocumented suggestions for improved UST practices were identified during a 1-day workshop of UST experts (see Appendix C).

Many of the suggestions were found in more than one document. In order to compile a succinct list for the reader, Alpine has combined the similar suggestions into singular statements. These suggestions are meant to focus attention on potential improvements in UST management practices and to isolate the primary topics for possible research that might lead to further identifying, reducing, and eliminating gasoline and MTBE releases from USTs (see Section 5.0). The suggestions for improved UST management and operation practices can be organized into nine primary areas:

- Equipment Design
- Service Station Site Design
- UST System Installation
- Leak Detection Systems
- Customer Education
- UST System Inspection and Maintenance
- Owner/Operator Certification and Training
- Tanker Driver Certification and Training
- Regulatory Enforcement

Table 5 (page 49 of this report) presents a summary of the suggestions for improved UST practices for each of the categories listed above. As shown on Table 5, there are 54 suggestions regarding improvement of UST management and operation practices. It is important to note that some UST owners and operators have already incorporated many of the ideas presented in Table 5.

Improvements to UST designs and management practices are iterative. They have been significantly advanced with time as the required upgrades have been implemented and as UST systems knowledge has increased. Therefore, it is expected that this list of suggestions for improved UST practices will likely change as UST knowledge and technology develop further.

This report does not advocate implementation of all of the suggestions listed on Table 5. The suggestions are not all of "equal value" in reducing/eliminating gasoline and MTBE losses. In fact, not all of these suggestions are ready for immediate implementation. While some of these suggestions can be quickly implemented, others require further development or analysis (e.g., cost-benefit analysis). A few of the suggestions require additional research before deciding whether or not any change should be implemented. On Table 5, each of the suggestions is characterized with respect to the level of additional knowledge that is currently needed prior to implementation. The categories are as follows:

Some: These items require some refinement or additional development.

Moderate: These items require further development, analysis, or cost-benefit analysis to determine the most appropriate and beneficial implementation.

Extensive: These items require extensive research to evaluate feasibility and the potential benefits before they can be definitively recommended.

Prioritizing and researching these suggestions for possible improvement to UST management and operations are tasks appropriate for a multi-party team comprised of various stakeholders, including UST experts from government and industry.

Section 5.0 Primary Topics for Further Research

This section presents the primary topics for further research and work that may allow further refinements and improvements to be made to UST management and operation practices. The primary topics are:

- Training and Education for UST Personnel
- Third-Party Oversight and Inspection
- UST System Design
- Vapor Losses, Permeability, and Compatibility

Section 6.0 contains a list of references used to create this report. In addition, this report includes the following three appendices:

Appendix A - References for UST Management Practices, Specifications, Codes, Standards, and Guidelines

Appendix B - Summaries of Six Current UST Management and Operation Practice Documents

Appendix C - UST Workshop Notes

1.0 Introduction

1.1 Project Background

In 1997, the California MTBE Research Partnership (Partnership) was formed to research a variety of environmental topics related to the gasoline additive Methyl Tertiary Butyl Ether (MTBE). The Partnership consists of representatives from the Association of California Water Agencies (ACWA), the Western States Petroleum Association (WSPA), and the Oxygenated Fuels Association (OFA), and is managed by the National Water Research Institute (NWRI). The Partnership determined that it was crucial to investigate the causes of gasoline and MTBE releases from underground storage tanks (USTs) and to advance the knowledge regarding how to minimize and eliminate those releases. As a result, an initial research project was developed and entitled "Survey of Current UST Management and Operation Practices." This report, which contains the findings of that initial project, presents a compilation and analysis of the current literature regarding management and operation practices for USTs.

1.2 Objectives

The objectives of this project are to:

- Survey and compile the current literature regarding UST management and operation practices.
- Summarize from the literature the most promising suggestions for improved UST management and operation practices.
- Identify topics for further research that could improve UST management and operation practices to further reduce/eliminate gasoline and MTBE releases from USTs.

1.3 What this Document is

This report presents a compilation and analysis of the current literature regarding the potential causes of UST leaks and the literature that describes current management and operation practices used to minimize gasoline and MTBE losses from USTs. By surveying this extensive literature, this report provides the reader with a single reference that describes current UST management and operation practices (Chapters 2 and 3). Additionally, this report presents numerous suggestions for improving UST practices (Chapter 4) and identifies some topics for possible additional research (Chapter 5).

The discussions in this report are focused on retail gasoline outlets, but most of the findings are also applicable to non-retail facilities (e.g., private or government-owned USTs). In presenting the various UST components and the current management and operational practices reported in the literature, this report makes the reader aware of many (but not all) of the major and minor issues that need to be addressed during UST management and operations. For each of the issues raised, documents are referenced that can be used as a basis for developing some recommended procedures. In other words, this report, and the references discussed here, provides readers with a good starting point for defining their own site-specific UST management and operation practices.

1.4 Methodology

An extensive literature search was conducted, primarily focused on publicly available documents that reviewed UST components, UST leak causes, or management and operation practices. Then, approximately 20 UST experts were contacted to solicit additional references and ideas. Once all this information was compiled, a 1-day workshop of UST experts was sponsored by the Partnership and held at NWRI headquarters in Fountain Valley, CA. Twenty-one UST experts attended this workshop to discuss the findings and develop new suggestions for improved UST practices. Finally, this report was written to compile and synthesize the available information regarding current management and operational practices for USTs.

1.5 Report Organization

Section 2 of this report reviews federal and California UST regulations, summarizes the available UST codes and specifications available, and discusses some common causes of UST leaks/spills. Section 3 contains a series of tables compiled by Alpine Environmental that list the major components of UST systems as well as many of the potential problems that can occur due to poor UST management and operational practices. Section 4 compiles numerous suggestions extracted from the literature and the 1-day workshop regarding possible improvements to UST management and operational practices. In Section 5, the report presents the primary topics for further research that may have the potential to further reduce gasoline and MTBE losses from UST systems.

2.0 Regulations, Codes, Specifications, and Practice Guidelines for Managing and Operating USTS

2.1 Federal UST Regulations

On September 23, 1988, the Federal Register published the Final Rules regarding the technical requirements for USTs (Subtitle I of the Resource Conservation and Recovery Act passed by Congress in 1976 [USEPA, 1986a]). These regulations, entitled "Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks," became effective December 22, 1988 (Code of Federal Regulations, 1988). The regulations established performance standards for USTs and required leak detection, leak prevention, and corrective actions for leaks or spills (Code of Federal Regulations, 1988). Requirements for reporting such leaks to appropriate agencies were also contained in the regulations.

Under these federal regulations, a UST is defined as "any one or combination of tanks (including underground piping) that is used to contain an accumulation of regulated substances, and the volume of which (including the volume of underground pipes connecting thereto) is 10 percent or more beneath the surface of the ground" (Code of Federal Regulations, 1988). A variety of tanks are excluded from this definition, including septic tanks, farm or residential tanks of 1,100 gallons or less, USTs of less than 110 gallon capacity, and heating oil tanks that contain fuel for use on the premises.

Regulations allowing individual states to establish their own programs for enforcing these UST laws were also promulgated on September 23, 1988. As a result, most states now have primary enforcement responsibility for the UST laws. They also have the right to establish and enforce standards even stricter than those mandated by the federal laws. The owners/operators of a UST facility must comply with applicable state UST regulations or, in their absence, the federal UST regulations. An excellent summary of federal and state UST regulations is available (Thompson Publishing Group, 1998). Additionally, UST owners/operators must comply with any pertinent local UST regulations.

As of 1987, 1.8 million tanks had been registered with regulatory agencies and approximately 1.6 million of them contained petroleum products (Young et al., 1987). As of September 1998, the number of active USTs in the USA had dropped to 891,686 tanks, with 1,236,007 tanks having been reported as permanently closed. This 50 percent decline in the number of active tanks reflects how the phased-in tightening of the federal UST regulations between 1988 and 1998 caused many USTs to become "outdated" and permanently closed.

Initially, the USEPA estimated that as many as 25 percent of the 1.6 million registered USTs in the United States may have been leaking (USEPA, 1988), suggesting that petroleum from 400,000 UST leaks may have been impacting the subsurface. These initial estimates have been reasonably confirmed: as of September 1998, the USEPA reported that 371,000 confirmed releases of petroleum products from USTs had occurred. While cleanup has been completed at 203,000 of these releases, nearly 170,000 UST cleanups remain. In addition, a brief update from the USEPA reported that as many as an estimated 80,000 additional releases may occur from petroleum USTs between 1999 and 2005 (Ng, 1999), thus predicating that the problem of petroleum losses from USTs will continue. The methodology for making this estimate was not presented in the USEPA update.

The USEPA has published over 150 documents that relate to various aspects of owning, operating, financing, investigating, remediating, and regulating USTs. A comprehensive catalog is available (USEPA, 1998a) that includes brief descriptions of the all the USEPA UST publications (most in English, a few in Spanish), videos, and other materials available. Many can be downloaded from the USEPA Office of Underground Storage Tank home page (www.epa.gov/OUST/).

2.2 California UST Regulations

In California, USTs are regulated under Title 23, Division 3, Chapter 16 of the California Code of Regulations. These 78 pages of regulations can be downloaded from the World Wide Web (www.swrcb.ca.gov/~cwphome/ust/caustreg.htm). With select differences, California's UST regulations essentially mimic the federal regulations. One key difference is that, in California, the UST program is currently administered and enforced by Local Implementing Agencies (LIAs). Currently, there are 107 LIAs. Each LIA operates under the oversight of the State Water Resource Control Board (SWRCB) and the nine Regional Water Quality Control Boards (RWQCBs).

In consideration of the wide variety of UST equipment in use, federal and California regulations allow UST owners/operators to comply through a number of different procedure and equipment combinations. To aid the California UST community in understanding these complex options, the SWRCB has produced a series of eleven tables outlining the various compliance options available to UST owners/operators (www.swrcb.ca.gov/%7Ecwphome/ust/ustguide.htm). These tables succinctly explain many of the requirements for UST construction, monitoring, record-keeping, and upgrading in California.

Regardless of these detailed regulations, there are some unanswered or unclear tank issues that require interpretation and professional judgement by the UST regulators. To disseminate such decisions, as well as to provide regulatory updates, the SWRCB periodically issues Local Guidance letters, or LG letters (www.swrcb.ca.gov/%7Ewcphome/ust/avail.htm). As of May 1999, some 62 LG Letters were considered active and can provide a UST owner/operator with additional guidance regarding how to comply with UST regulations as well as provide technical guidance on various operation and maintenance issues.

As of December 17, 1998, the SWRCB reported that there were 61,029 active USTs in California. Of those, 55,162 USTs contained petroleum products. By early 1999, an estimated 90 percent of California's regulated tanks had been replaced, upgraded, or properly closed (Frye, 1999). As such, the actual number of active USTs in California is now likely smaller in response to the December 1998 regulatory deadlines.

2.3 Codes, Specifications, and Practice Guidelines

To the casual observer, it may seem that, with all these specific regulations for USTs, there would not be the need for even more detailed technical guidance. With USTs, however, this is not the case. UST facilities are much more than just a few tanks and pipes. Typically, modern UST facilities have a variety of subsystems, such as:

- Fuel storage systems (tanks)
- Fuel delivery systems (product lines, pumps, valves, filters, dispensers, hoses, nozzles, etc.)
- Tank fillports (piping, couplings, fillport boxes, etc.)
- Line leak detection systems
- Automatic tank gauging systems
- Overfill protection systems
- Spill prevention equipment (spill boxes, dispenser pans, etc.)
- Interstitial monitoring systems (for tanks, product lines, or both)
- Vent lines
- Vapor recovery systems

Through the use of these sophisticated subsystems, most UST systems have some redundancy to reduce or eliminate leaks, and/or to detect those leaks when they happen.

Each of these subsystems — and many of the individual components in each of these subsystems — are complex electrical/mechanical devices. Most have precise requirements for installation, operation, and maintenance. As a result, there is a need for extensive technical guidance regarding the appropriate operation and management practices for each component of each subsystem and how they all interact.

This need has lead to the creation of a wide variety of technical codes, standards, equipment specifications, material specifications, and guidelines that pertain to the design, installation, operation and maintenance of UST systems. As stated in the Underground Storage Tank Guide by Thompson Publishing Group (1998), "...industry codes and standards are developed and written by national standard-setting organizations established by the affected industries," and "EPA specifically refers to some of the standards in its regulations." The national organizations that are responsible for most of these standards and references include:

- American National Standards Institute (ANSI)
- American Petroleum Institute (API)
- American Society for Testing and Materials (ASTM)
- Canadian Petroleum Products Institute (CPPI)
- Factory Mutual (FM)
- International Fire Code Institute (IFCI)
- National Association of Corrosion Engineers (NACE)
- National Fire Protection Association (NFPA)
- National Leak Prevention Association (NLPA)
- Petroleum Equipment Institute (PEI)
- Steel Tank Institute (STI)
- Underwriters Laboratories (UL)
- Underwriters Laboratories of Canada (ULC)

Appendix A presents a summary of UST management practices, codes, standards, specifications, and guidelines prepared by various industry organizations. Most of the reference list presented in Appendix A was derived from the Underground Storage Tank Guide (Thompson Publishing Group, 1998), which contains brief descriptions of many of the references listed in Appendix A. Other UST references were added to the list in Appendix A based on a review of documents prepared by API, STI, and NEPA. In total, the 13 national organizations listed above have produced nearly 100 codes, standards, specifications, and guidelines pertaining to UST management and operations.

These extensive references provide a vast repository of detailed information on the equipment and procedures involved with the design, installation, operation, maintenance, and closure of USTs. The references were developed by UST experts, including manufacturers, owners, installers, and service personnel who work with USTs. Therefore, the references combine detailed engineering knowledge with decades of UST field experience. Understanding and following these codes, standards, specifications, and guidelines is an excellent basis for a good UST operation and maintenance program.

3.0 Managing and Operating Underground Storage Tank Systems

3.1 Spills, Releases, and Leaks from USTs

The equipment and practices documented in the extensive UST regulations, codes, specifications, and guidelines have certainly helped reduce and eliminate some gasoline releases from USTs, especially the larger releases. However, the complexity of the UST equipment — combined with equipment failures and the ever-present potential for human error — means that some spills, releases, and leaks from USTs will inevitably occur. There are several types of incidents that can result in gasoline and/or MTBE being lost from UST systems. The sections below review the common causes of UST releases and the equipment designed to prevent and detect them.

3.1.1 Failure of Storage, Piping, Pumping, or Delivery Systems

If the liquid containment system fails to stay liquid tight, gasoline will be released. Such failures can occur in the storage tank, product piping, pumping system, or delivery system. Corrosion, cracking, poor connections, improper equipment, improper installation, etc. may cause the failure.

It is important to note that fuel loss from leaking UST systems can be exacerbated by pressurized delivery systems. In a pressurized system, a pump (submerged in the UST) pushes the fuel through the piping system and into the vehicle. If the system piping is not tight, leakage of fuel to the environment will be increased when the pumping system is in operation. The other primary type of delivery system uses suction to move product through the system piping. In a suction system, a pump placed above the ground pulls the fuel out of the UST through the piping system. In general, suction systems are considered favorable with respect to product leakage as suction systems are less likely to leak.

In order to prevent the loss of gasoline during storage, pumping, or delivery, a large number of spill-prevention and spill-detection devices and techniques have been developed over the last two decades (USEPA, 1987, 1994, 1995, 1997). Although no tank system would need all these devices, the regulations require various combinations of equipment; therefore, most USTs will have many of these items. Major spill-prevention and detection devices include:

- Cathodic protection for steel tanks and lines (various types - see USEPA, 1994)
- External coatings and internal linings for tanks and lines
- Non-corrodible materials (ex: fiberglass reinforced plastic)
- Double-walled tanks
- Double-walled product lines

- Interstitial monitoring devices for double-walled tanks and/or double-walled lines
- Line leak detectors (USEPA, 1997)
- Automatic tank gauges (USEPA, 1997, 1998b)
- Vapor sensors (USEPA, 1997)
- Liquid product sensors
- Tightness testing of tanks
- Tightness testing of lines
- Manual tank gauging (USEPA, 1993, 1997)
- Statistical inventory reconciliation (USEPA, 1995)
- Dispenser pans

The current federal UST regulations (40 CFR, Part 280) set forth the required measurement sensitivities for the various types of leak detection devices and methods, including inventory control, automatic tank gauge systems (ATGs), line leak detectors, and line/tank tightness testing. The currently defined sensitivities are as follows:

- *Inventory control* - must be able to detect a release of at least 1.0 percent of flow-through plus 130 gallons on a monthly basis.
- *ATGs* - must be able to detect a leak of 0.2 gallons per hour from any portion of the tank that regularly contains product.
- *Automatic line leak detectors* - must be able to detect a leak of at least as small as 3 gallons per hour at a line pressure of 10 pounds per square inch within 1 hour.
- *Line tightness testing* - must be able to detect a 0.1 gallon per hour leak rate at one and one-half times the operating pressure.
- *Tank tightness testing* - must be capable of detecting a 0.1 gallon per hour leak rate from any portion of the tank that routinely contains product with a probability of detection of at least 0.95 and a probability of false alarm of no more than 0.05.

The measurement sensitivities listed above are the minimum standards set forth in the federal regulations. These regulations also list other requirements (e.g., testing frequencies) that are applicable to the specific methods and devices. It is important to note that individual states may have additional requirements and/or variances to the Federal regulations.

3.1.2 Spillage During Fuel Delivery

The USEPA has reported that spills often occur during fuel deliveries and that most of these spills are caused by human error (USEPA, 1994). It has also been reported that “overfills usually release much larger volumes than spills” (Alaska DEC, 1999). In addition to regulations that address proper filling procedures, a variety of spill prevention devices have been designed and implemented (USEPA, 1994, 1997) to prevent spillage during fuel delivery, including:

- Spill catchment basins (also called spill containment buckets, or spill boxes)
- Spill response supplies (i.e., spill kits of absorbent materials, etc.)
- Overfill protection - by regulation, USTs must now have this. There are three types:

1. *Automatic shutoff devices* – slow/stop fuel flow from the delivery truck as the UST approaches full capacity
2. *Overfill alarms* – sound an alarm to warn delivery truck driver when the UST approaches full capacity
3. *Ball float valve* – a floating ball contained in a cage, designed to create enough back pressure to restrict product flow into the tank before the tank is completely full

3.1.3 Spillage During Fuel Dispensing

Fuel spillage can also occur when a customer or service station employee is dispensing fuel into the vehicle due to:

- Drive-offs (i.e., customer drives off with hose nozzle still in the car's gas fillport)
- Vehicle accidents (spillage reduced by impact valves in dispensers and break-away hoses)
- Drippage from nozzle
- Over-filling vehicle, causing spillage (common when "topping-off tank")

Most of these dispensing spills are small, subtle, and due to human error. They are hard to detect and hard to prevent. Therefore, they are hard to control with technology or equipment.

Dispensing spills can be exacerbated by improper spill response. For example, hosing down the concrete after a spill may make the spill area look better, but can cause the spilled gasoline to be transported onto more permeable grass/soil areas (where it can infiltrate to ground water) or into storm drains (where it can be transported to surface-water bodies).

3.1.4 Possible Vapor-Phase Losses

There is some speculation that the UST systems may be releasing small amounts of vapor-phase gasoline and/or vapor-phase MTBE into the subsurface. These vapor losses may be "passive" or "breathing" losses, wherein small amounts of vapors are constantly being released from UST system components, such as fillports, tank headspace, vent lines, or vapor recovery lines. There may also be "active" vapor losses, which occur during the short periods when a positive pressure is applied to the UST system, such as during product delivery or certain types of tank/line tightness testing. These vapor losses may be especially important MTBE sources as the vapor in a UST system is probably more enriched with MTBE than the liquid-phase gasoline (due to MTBE's relatively high vapor pressure). While this topic may be quite important, it is still speculative and more research is required.

3.2 Benefits and Limits of Leak Prevention and Detection Equipment

The authors of this report, as well as many other UST researchers, have noted a distinct decline in major gasoline losses at UST sites over the last 12 years. This significant improvement is attributed to the success of the many sophisticated UST leak-prevention and detection subsystems described above, as well as the codes, standards, specifications, and guidelines listed in Appendix A. Empirically, these improvements have apparently produced a decrease in the frequency of major spill incidents and, perhaps, also a decrease in the average volume lost per incident.

There is some statistical evidence to support the beneficial aspects of these leak detection and prevention systems. Couch and Young (1998) report that the average annual leak rate for USTs in California was about 2.6 percent from 1992 through 1997. In contrast, upgraded UST systems (i.e., those that already met the 1998 upgrade standards) were estimated to have an average annual leak rate of about 0.07 percent. While the authors noted that this rate is expected to increase somewhat over time (as the new/upgraded tank systems age and incidents occur), it certainly demonstrates the beneficial impact of improved UST leak prevention and detection systems. The improvements to UST equipment and practices have been continual over the last few decades. New and more sophisticated systems have been developed as innovation has allowed and as the need for new systems has dictated. Significant strides have been made as each successive generation of leak prevention and detection equipment has been implemented. More incremental improvements can be expected in the years ahead.

Realistically, no equipment or set of procedures will be able to eliminate all UST leaks. This is true for three simple reasons:

1. UST systems require equipment (which ages/fails)
2. UST systems involve humans (who make errors)
3. Accidents inevitably occur

As a result, even after carefully following the UST regulations and the various industry procedures (Appendix A), modern UST systems may still release gasoline under some circumstances. This is evidenced by the fact that some new UST release incidents are still occurring, even to systems that apparently meet the 1998 standards (Couch & Young, 1998).

It seems to be industry consensus that it is now small, slow, or subtle gasoline losses from USTs that are the primary challenge. In trying to prevent and detect such subtle spill sources, the role of good management and operation practices is critical. Indeed, as concluded in the SWRCB Advisory Panel report (SWRCB, 1999a), "...releases found at UST sites meeting the 1998 standards generally appeared to be the result of improper installation, operation, or maintenance."

If these small/subtle spill incidents are infrequent, it seems likely that the natural attenuation capacity of the subsurface may be able to prevent any significant contamination by reactive, degradable hydrocarbons such as benzene. Unfortunately, when a conservative, generally recalcitrant compound like MTBE is present in the gasoline, that compound may readily reach the water table; as a result, significant environmental impacts are more likely. Therefore, preventing these small/subtle spill sources becomes even more important when MTBE (or any other generally recalcitrant compound) is present in the gasoline. It should be noted that a joint project currently being performed by United States Geological Survey (USGS) and the American Petroleum Institute (API) is investigating the impacts of relatively small releases of MTBE-enriched gasoline to groundwater.

3.3 Management and Operation Practices

Finding and preventing small/subtle gasoline losses requires good UST management and operation practices. As such, it is worthwhile to compile and analyze the UST management and operation practices currently in use. By doing so, poor practices can be avoided and, with time, improved practices can be developed and implemented.

To compile the current UST management and operation practices, dozens of government and industry documents were reviewed (see Section 6 - References). Some of the best documents were those developed by API (1993, 1996a, 1996b, & 1997), USEPA (1993, 1994, 1995, 1997, 1998b, & 1998c), and the Minnesota Pollution Control Agency (1995), which described specific UST practices in detail. In addition, numerous back-issues of L.U.S.T.LINE (see Appendix A) provided valuable technical analysis of key UST field practices and potential problems. Additional information was extracted from the six example UST management and operation practices documents contained in Appendix B. From these documents, lists were compiled of the many components and activities that are required during UST design and installation. Lists were also made of the components and activities needed during UST operation and maintenance.

3.3.1 Current UST Design and Installation Practices

Table 1 presents 16 general activities to be addressed during UST Design and Installation, including everything from Pre-installation Site Analysis to Documentation. When these general activities are broken down into detail, there are more than 140 different factors to consider when installing a UST (Table 1). This allows greater opportunity for equipment failure or human error. In fact, when the 16 general activities for UST installation were analyzed, more than 110 potential problems could be listed (Table 2). It should be noted that this list of “Potential Problems During UST Design and Installation” (Table 2) is not necessarily complete.

If the reader is interested in developing good management practices for designing and installing USTs, then Table 1 could be used as a partial checklist of factors to consider. Conversely, Table 2 could be used as a partial list of potential problems to avoid.

3.3.2 Current UST Operation and Maintenance Practices

Table 3 presents 13 general activities that occur continuously throughout the active operational and maintenance life of a UST facility, including everything from Product Delivery to Record Keeping. When these 13 general categories are broken down into detail, there are more than 120 different activities/factors that consistently occur during UST operation and maintenance (Table 3). For a UST facility to be operated and maintained in a high quality manner, each of these activities must be continually conducted using the right equipment and proper procedures. This presents many opportunities for equipment failure or procedural errors. When the 13 general categories for UST Operation and Maintenance were analyzed (Table 3), more than 125 potential problems could be listed (Table 4).

Once again, this list of "Potential Problems During UST Operations and Maintenance" (Table 4) is not necessarily complete. In fact, the opportunity for problems to occur during operation and maintenance is compounded and magnified more than these tables can show as there are many different service station personnel involved in operating and maintaining a service station. Their different training, duration of employment, and level of commitment can lead to these activities being conducted in different ways, with varying degrees of accuracy. This greatly complicates UST operation and management and can confound even the best attempts to optimally operate and maintain USTs.

If the reader is interested in developing good management practices for operating and maintaining USTs, Table 3 could be used as a partial checklist of factors to consider. Conversely, Table 4 could be used as a partial list of potential problems to avoid.

3.4 Discussion of Potential Problems

By reviewing Tables 2 and 4, it is clear that there are numerous problems that can arise during UST design, installation, operation, and maintenance. The reader is cautioned that these tables are "pessimistic" because they attempt to list most potential problems. Many of the codes, specifications, and guidelines discussed in Section 2 were created specifically to avoid the problems listed in Tables 2 and 4.

Education is the foundation to improvement. Therefore, if a UST owner/operator is aware of the potential problems (Table 2 and 4) in advance, then operation and management practices can be developed to avoid the vast majority of problems. Those improved practices must then be consistently implemented in order to avoid the numerous potential problems. Section 4 identifies some of the UST operation and management practices identified in the current literature as being likely to provide the most benefits in preventing and minimizing gasoline releases. Some primary topics for possible further research are discussed in Section 5.

3.5 Recent and On-Going UST Performance Studies

There are several UST performance studies that have been completed recently or are currently ongoing. This subsection presents brief reviews of these studies.

The California State Water Resources Control Board (SWRCB) recently published a report entitled "Are Leak Detection Methods Effective In Finding Leaks in Underground Storage Tank Systems?" (SWRCB, 1998). The purpose of this study was to determine if leak-detection methods are finding leaks in USTs in California. All of the results and conclusions are based on data reported between October 1995 and May 1996. After studying 345 UST leak cases, it was reported that only four percent of the leaks were detected by leak detection systems. Instead, "…most leaks are discovered during tank closure/removal or other site activities." Other conclusions pertain to adequacy of monitoring protocol and documentation/interpretation of precision test results. Recommendations of the SWRCB report address regulatory enforcement, additional studies needed, and requirements for under-dispenser containment.

Couch and Young (1998) recently completed a study on USTs for the Senate Bill 521 report managed by the University of California. Results include the estimate that approximately 0.07 percent of the systems that meet the 1998 upgrade requirements are currently leaking (see study for analysis methods and assumptions). This rate is expected to rise slightly as the tank systems age and new leaks are discovered. Even so, this is a relatively low leak rate in contrast to the 2.6 percent of older systems that were found to be leaking in California from 1992 to 1997. Although limited in scope, this study clearly indicates that the many improved mechanics and practices that comprise a 1998-compliant UST system do measurably decrease the likelihood of UST system leakage. More time series studies are needed to confirm these initial findings.

The Santa Clara Valley Water District also recently funded a study related to performance of UST systems (Levine Fricke Recon, 1999). The primary purpose of this study was to determine the occurrence of MTBE at sites with operating USTs and identify if MTBE is being released undetected at facilities with 1998 upgrade-compliant UST systems. This study was performed by conducting a soil and groundwater investigation of 28 facilities within the Santa Clara Valley Water District that have operating 1998 upgrade-compliant UST systems. Results indicate that:

- "MTBE may be present in groundwater at approximately 50 percent of the UST facilities that meet the 1998 upgrade requirements within Santa Clara County."
- There appears to be "a statistically significant association between the occurrence of MTBE and the presence of an assisted vapor recovery system versus a balanced vapor recovery system."

- At most of the sites that detected MTBE, it is not clear whether MTBE-enriched gasoline left the UST system before the 1998 compliant upgrades were made, during the upgrade process, or after the systems were 1998 compliant.
- Of the four sites with no UST use before operation of a 1998-compliant system, one site had MTBE detected in the ground water at 25,000 µg/L.

The USEPA currently has several ongoing studies related to performance of USTs (see Appendix A). The first study, "UST System Performance Information Search," is a literature search on data pertaining to UST system performance. A preliminary draft contains a brief summary of the work performed and approximately 30 references, including web pages, state regulatory data, and formal UST publications. The preliminary draft also includes documentation of correspondence with UST experts from a variety of organizations (see Appendix A for contact information).

Another study currently being performed by USEPA involves a follow-up to the information search described above. The objective of this study is to make recommendations regarding what, if any, improvements in performance and management of USTs are needed. Results are expected to be available by late 1999 (see Appendix A for contact information).

The University of California at Davis is currently performing a USEPA-funded study entitled "Field Verification of UST System Leak Detection Performance." The objective of this study is to analyze the implementation of leak detection methods on USTs and to assess their effectiveness in detecting releases, particularly MTBE. The study, which involves collection of data from across the country, will attempt to correlate type of tank with leak rate or other type of failure (see Appendix A for contact information).

3.6 Special UST Release Considerations for MTBE

In light of MTBE's physicochemical characteristics, there are certain aspects of UST releases that may be of even more concern if MTBE is present in the gasoline. Some of these are discussed below.

3.6.1 Small/Subtle Gasoline Leaks

Small, subtle leaks or spills of gasoline may occur from the UST systems. These leaks may be low flow rate, continuous leaks, or small-volume discrete leaks. Some leak detection devices are designed to measure more substantial leaks (e.g., automatic line leak detectors can detect leaks as small as 3 gallons per hour at a line pressure of 10 pounds per square inch). Therefore, these devices may simply be unable to detect small leaks. For example, a California study was conducted on leak detection methods (SWRCB, 1998). After studying 345 UST leak cases, it was reported that only four percent of the leaks were detected by leak detection systems. This may be due to variety of causes (SWRCB, 1998), one of which may be that some systems are simply just not sensitive enough to detect the small (but important) gasoline losses.

Gasoline losses that are smaller or slower than the low-end thresholds of the various leak prevention and detection systems would likely not be detected by current systems. While undesirable, the impacts of such small gasoline losses may only cause minor to no environmental impact when adsorbing biodegrading compounds like benzene, toluene, ethylbenzene, and xylene (BTEX) are considered. However, such small/subtle leaks may cause significant environmental impact if the leaking gasoline contains a poorly retarded, slowly biodegrading compound like MTBE.

3.6.2 Losses From Vapor Systems

Due to MTBE's relatively high vapor pressure (approximately 11 times that of benzene), it is probable that vapors stored in a UST system will become enriched with MTBE. These MTBE-enriched vapors might escape from different portions of UST systems, including:

- UST headspaces
- Vapor recovery systems
- UST venting systems
- UST fillports

MTBE-enriched vapors can escape from these portions of the UST system if they are not designed to be vapor tight. As described in Section 3.1.4, these losses may be passive "breathing" losses and, therefore, may be ongoing. Alternately, the losses may be the more vigorous active vapor losses that occur only during the short intervals when a positive pressure is put on the UST during product delivery or during certain types of tightness testing. Although the database of sites is small, preliminary investigations of MTBE contamination in Santa Clara Valley, California, found a statistical correlation between MTBE-impacted groundwater and certain types of vapor-recovery equipment (Levine Fricke Recon, 1999).

Additionally, MTBE-enriched condensate might collect from the MTBE-enriched vapors. This condensate could collect within the vapor-recovery system or vent system. If these vapor systems are not liquid-tight, the MTBE-enriched condensate could escape into the environment. The extent and significance of these release mechanisms (if, in fact, they are occurring at all) is unknown at this time. Therefore, these possibilities should be considered as theoretical until further research and field studies are conducted. As mentioned earlier, a related project (i.e., vadose-zone modeling study) is currently being performed by the USGS and API. In addition, the California MTBE Research Partnership is currently considering several projects that are relevant to this issue.

3.6.3 UST Component Incompatibility with MTBE

In searching for reasons why MTBE might escape from UST systems, one must consider the possibility that MTBE may be incompatible with certain UST components. Various studies have been conducted on metals, fiberglass tanks, fiberglass piping, and on common elastomers and plastics. An initial literature review by Davidson (1998) concluded that "there are no obvious compatibility problems between USTs and MTBE used as a gasoline additive…however, the available information regarding permeability and vapor-phase compatibility are limited." Davidson recommended several topics for further research, including permeability and vapor-phase compatibility.

Couch and Young (1998) reached a similar conclusion that "no significant threat exists to UST systems from the concentrations of MTBE likely to be present in reformulated fuels." However, these authors also noted that "nonetheless, we believe there is a sufficient lack of objective, independent and quantitative research on materials compatibility with MTBE to warrant further investigation." An even more extensive study of the MTBE compatibility issue reached similar conclusions (SWRCB, 1999c). This study also conducted a limited survey of UST manufacturers regarding their compatibility data.

In conclusion, all three summary studies reached the same general conclusion that no known incompatibilities exist between MTBE as a gasoline additive and UST components. However, all three studies noted some sub-topics that require more research, testing, or objective analysis before all the MTBE/UST component compatibility concerns can be put to rest.

4.0 Suggestions for Improved UST Management and Operation Practices

This section presents a summary of suggestions for improved UST management and operation practices. These suggestions were extracted from the recent UST literature, including documents prepared by the California Stormwater Quality Task Force (1997), State Water Resource Control Board (1998, 1999a, 1999b, 1999c, & 1999d), and Western States Petroleum Association (1999). Technical data contained in numerous back-issues of L.U.S.T.LINE (see Appendix A), the examples in Appendix B, and other UST documents provided the basis for refining some suggestions. In addition, several previously undocumented suggestions for improved UST practices were identified during a 1-day workshop of UST experts (see Appendix C).

Many of the suggestions listed below were found in more than one document. In order to compile a succinct list for the reader, Alpine has combined the similar suggestions into singular statements. Additionally, because the sources of several suggestions wished to remain anonymous, specific suggestions are not referenced back to individual documents or people.

These suggestions are meant to focus attention on potential improvements in UST management practices and to isolate the primary topics for possible research that might lead to further identifying, reducing, and eliminating gasoline and MTBE releases from USTs (see Section 5.0). These suggestions are not meant to be inclusive of all UST management practices that will reduce releases to the environment. Instead, it is a list of many of the technical improvements suggested by UST experts in recent publications. It should be noted that some UST owners and operators have already incorporated many of these recommendations into their normal operations. In addition, some of the recommendations listed below have been addressed recently in federal or California documents.

Based on a review of the current UST practices literature and the UST workshop, the suggestions for improved UST management and operation practices can be organized into the following general categories:

- Equipment Design
- Service Station Site Design
- UST System Installation
- Leak Detection Systems
- Customer Education
- UST System Inspection and Maintenance
- Owner/Operator Certification and Training
- Tanker Driver Certification and Training
- Regulatory Enforcement

Each of these general categories is discussed in subsections 4.1 through 4.9; fifty-four different suggestions are described in these subsections. To aid the reader, these 54 suggestions for improved UST practices are also compiled in Table 5.

Improvements to UST designs and management practices are iterative. They have been significantly advanced with time as the required upgrades have been implemented and as UST systems knowledge has increased. Therefore, it is expected that this list of suggestions for improved UST practices will likely change as UST knowledge and technology develop further.

4.1 Equipment Design

Based on a compilation of the current literature on UST management and operation practices, it has been suggested that, with regards to Equipment Design, some possible improvements could include:

- Striker plates for all tanks to reduce potential for tank damage due to repeated hitting with gauging stick.
- Under dispenser containment sumps (or pans) to capture drips and small spills, in combination with sump monitoring devices to provide early warning of dispenser area leaks.
- Spill containment boxes at UST Stage I vapor recovery risers to minimize potential for release of overflow from the fill riser containment box.
- Dispenser hoses equipped with dry-breakaway connections to minimize product losses due to customer drive-offs.
- Fuel dispensing nozzles with “hold-open latches” (automatic shutoffs) except where prohibited by local fire departments.
- UST systems designed to minimize vapor losses to the subsurface including from the vapor return lines, the UST headspace, the vapor recovery systems, the tank vent lines, and the fillports. This may include modifications to materials (compatibility and/or permeability problems), condensate pots/sumps, and fittings/connectors (design changes)
- Post-installation tightness testing of overfill containment sumps. A protocol for this type of testing is needed.
- Design and implementation of overfill protection systems that cannot be easily disabled or do not malfunction due to inappropriate tank fill-up procedures. One suggestion is to install overfill protection devices on tanker trucks instead of USTs. This may reduce overfills due to tanker driver errors (overfill protection systems on USTs vary widely and are often not well marked as to which method/equipment type is used).
- Phase-out of float-ball valves as primary overfill-protection devices. Experience has shown that these devices are significantly less effective than other methods/equipment.

- Integrity testing of secondary containment systems (including the development of associated protocol). In particular, there is no regulatory requirement for integrity testing of secondary containment system "except at the time of initial installation" (SWRCB, 1999a).
- Compatibility and permeability testing (particularly vapor-phase testing) of select UST system components for use with MTBE-enriched gasoline.

Not all of these potential improvements are of equal value or equal importance for minimizing fuel losses. More work is needed before these potential improvements are proven to be valuable. As concluded in the SWRCB Advisory Panel report (SWRCB, 1999a), "...additional research is needed to quantify the leak history for the post-1998 UST population before it can be determined what, if any, changes to the current design, construction, and monitoring standards are needed to assure the prevention and detection of oxygenates releases at UST facilities."

4.2 Service Station Site Design

Based on a compilation of the current literature on UST management and operation practices, it has been suggested that, with regards to Service Station Site Design, some possible improvements could include:

- Service station designs that minimize the potential for gasoline/MTBE to contaminate stormwater runoff. Surface water drainage patterns could be designed to minimize the flow of stormwater over refueling areas, product and vapor recovery spill containment boxes, and air/water supply areas. This can be done by grading and paving to prevent run-on of stormwater and/or by installation of a roof over the area in question.
- Design all catchments on-site to drain to oil-water separators.
- Highly visible signs posted at all fuel dispensers warning customers against "topping- off" vehicle fuel tanks.
- All signage at service stations (including the emergency shutoff switch sign and the labels for fill pipes, vent systems, aboveground system piping, and water drains) to be legible and clearly visible.
- Complete documentation kept on site at all times, including a spill response plan, contact information, site plan, operation and maintenance manuals, UST equipment manuals and specifications, operation and maintenance records, etc.
- Label drains within the facility boundary, by paint/stencil (or equivalent), to indicate whether they flow to an oil/water separator, directly to the sewer, or to a storm drain.

4.3 UST System Installation

A poorly conducted UST system installation can be one of the primary causes of fuel releases to the environment. As shown on Tables 1 and 2, there are numerous components and activities involved in UST installation that can be problematic. The potential for problems is greatly increased if unqualified or unlicensed workers conduct UST installation or maintenance work. However, the problems identified from the current literature indicate that human error is the primary challenge to overcome during UST system installation (as opposed to equipment problems). Based on a compilation of the current literature on UST management and operation practices, it has been suggested that, with regards to *UST System Installation*, some possible improvements could include:

- Training and certification requirements for all personnel involved in UST system installation activities (e.g., materials/equipment selection, tank placement, sensors placement, corrosion protection installation and testing, leak detection system installation and testing, etc.).
- Qualified third-party oversight for all aspects of UST-system installation.
- Complete QA/QC documentation that includes materials and equipment used, equipment performance certifications, personnel involved in the installation, and installation procedures followed.

4.4 Leak Detection Systems

As shown in Tables 2 and 4, numerous systems associated with USTs require periodic maintenance and testing, including leak detection systems. Leak detection systems can be placed on USTs, product piping, under dispenser containment sumps, etc. Testing these different systems requires varying approaches and methods based on the equipment being tested and the leak detection sensitivity required. There is a wide range of leak detection equipment available and a wide range of testing methods that can be used to evaluate the system tightness. Based on a compilation of the current literature on UST management and operation practices, it has been suggested that, with regards to *Leak Detection Systems*, some possible improvements could include:

- More careful selection of the appropriate system for a site. Site-specific design is a critical step in the application of leak detection protocol. Qualified third-party oversight and documentation are critical during this phase of the work.
- SWRCB (1998) states that "...the use of frequent monitoring methods over annual type monitoring are the preferred alternative because of their ability to detect leaks within a reasonable time frame." SWRCB (1998) also concludes that primary concerns with leak detection systems include ignoring or overruling failed monitoring results and incorrect reporting of monitoring results. To avoid these problems, it is necessary to ensure that: 1) leak detection testing methods are appropriate for the site conditions; and, 2) testing/monitoring results are interpreted and reported by qualified personnel.
- As concluded by SWRCB (1998), leak detection systems at many sites are not consistently monitored. Therefore, more emphasis should be placed on the importance of following manufacturer and industry protocols and their recommended schedules for maintenance.

- Appropriate QA/QC documentation and reporting during all phases of installation, maintenance, and testing of leak detection systems. This documentation should be kept on-site with copies forwarded to the appropriate regulatory agencies and to the off-site office of the owner/operator (if applicable). It has been suggested that regulatory agencies should be more involved in enforcement of this aspect of UST management. For example, SWRCB (1998) recommended "an aggressive enforcement of leak detection requirements."
- The adequacy and sensitivity of current leak detection systems and sensors may also need to be evaluated and improved. If current systems are found to be inadequate to detect and prevent small/subtle gasoline losses, then improved systems may need to be researched and developed, particularly if generally recalcitrant additives like MTBE are added to gasoline.

It should be noted that several LG letters are available on the World Wide Web (www.swrcb.ca.gov/%7Ecwphome/ust/avail.htm) that address specific aspects of leak detection systems for USTs. These include:

LG 43	Reporting of Failed Precision Tests
LG 105-10	Licensed Tank Testers and Tank Testing Companies
LG 108	How to Demonstrate that Underground Storage Tank Leak Detection Methods Meet Performance Standards
LG 113-12	List of Leak Detection Equipment and Methods for Underground Storage Tanks
LG 118	Underground Storage Tank Test Result Reporting

4.5 Customer Education

There currently is very little emphasis placed on public outreach with regards to leak prevention at service stations. In 1993, USEPA's Office of Air and Radiation produced a booklet, *Your Car (or Truck) and the Environment*, that addressed emissions during fueling. Some local programs have implemented attempts to educate the general public about their role and responsibility in the proper handling and use of gasoline. This has been done primarily through "don't top-off your tank" stickers or flyers. These often stress air-emission reductions but could be readily changed and expanded to also include other spill prevention benefits such as protection of water resources. Based on a compilation of the current literature on UST management and operation practices, it has been suggested that, with regards to *Customer Education*, some possible improvements could include:

- Training materials showing proper refueling techniques provided to full-service attendants and self-service customers. Possible ways to disseminate this information include: placing educational stickers or signs near/on all dispensers; inserting information in credit card customers' monthly bills; setting up point-of-sale flyers and materials; preparing public service announcements for radio and television; and, providing instructional videos for driver-education classes and traffic schools.

Areas that could be addressed in public outreach efforts include:

- Importance of not "topping-off tank" during fueling (provides air benefits and helps prevent subsurface contamination).
- Avoiding and reporting surface spillage.
- Using portable fuel containers and properly disposing unused gasoline to prevent spills in remote locations.
- Avoiding customer drive-offs.
- Improving signage at service stations.
- Overall importance of public activities with respect to spill prevention.

It should be noted that the SWRCB Advisory Panel report (SWRCB, 1999a) concludes that small spills that occur during dispensing may "cause some occurrences of MTBE in groundwater at petroleum facilities."

4.6 UST System Inspection and Maintenance

Since December 1998, all new and upgraded UST systems are required to have leak detection and protection from spills, overfills, and corrosion. However, due to the wide variety of acceptable equipment, the inspection and maintenance requirements for these systems can not be standardized (as of October 1998, over 250 leak detection systems had undergone third-party evaluations, per USEPA, 1998c). This leads to the potential for human error and, hence, accidental releases of gasoline to the environment. Based on a compilation of the current literature on UST management and operation practices, it has been suggested that, with regards to *UST System Inspection and Maintenance*, some possible improvements could include:

- Training and certification requirements for all personnel involved in UST system maintenance and testing (e.g., corrosion protection systems, leak detection systems, overfill protection systems, product dispensers, vapor recovery systems, etc.).
- Qualified third-party oversight for critical aspects of UST-system maintenance and testing.
- Complete QA/QC documentation and reporting during all phases of maintenance and testing of UST systems. This documentation should be kept on-site with copies forwarded to the appropriate regulatory agencies.
- Interpretation and reporting of maintenance testing results by qualified/certified personnel for critical UST components.
- Periodic inspection of fill riser spill containment boxes that are not secondarily contained for liquid leak tightness. Protocol is needed for inspecting and quantifying leakage from spill containment boxes.

- Development of well-defined protocols for maintenance, inspection, and testing of the various types of UST equipment. It should be noted that many of the equipment manufacturers have operations and maintenance manuals for their specific piece(s) of equipment. However, more care is needed to ensure that appropriate protocols are used.
- Increased awareness of proper handling and disposal techniques for used gasoline filters located inside dispensers and submerged turbine pump enclosures.
- More frequent testing of overfill protection systems on USTs to ensure they are functional and operate within design tolerances.
- Consistent and timely monitoring and maintenance of the corrosion protection systems.
- Dispensing nozzles should be periodically inspected to assure that the automatic shutoff works properly and that components and fittings are free of liquid product leaks. Nozzle shutoffs should be checked by observing "hands-off" fill-ups of vehicles at stations. Defective shutoffs and leaking components should be repaired or replaced.
- Joints and cracks in paving at vehicle refueling areas and around UST fills should be sealed/caulked to reduce potential for gasoline/water infiltration.
- Maintain and keep current a spill response plan, as required by other regulations.
- Complete spill cleanup supplies should be kept onsite and maintained regularly. Spent sorbent materials used to clean up spills should be segregated in closed containers and properly managed.
- Good housekeeping practices should be used to minimize possible contamination of stormwater runoff from stations.
- "Spot clean" leaks and drips routinely. Leaks are not cleaned up until the absorbent is picked up and disposed of properly.
- Cleaning and spill response methods that do not involve water or that collect the water used are recommended. Maintain fuel-dispensing areas using dry cleanup methods such as sweeping for removal of litter and debris, or use of rags and absorbents for leaks and spills. Avoid "washdowns" with water hoses or steam cleaners. Fueling areas should not be washed down unless the wash water is collected and disposed of properly.
- At stations equipped with groundwater monitoring wells, well-water samples should periodically be collected and tested for gasoline components, including MTBE.
- Inspect and clean (if necessary) storm drain inlets and catch basins within the facility boundary before the start of rainy seasons.
- Consider developing site-specific "Best Management Practices" for each UST system (*Note:* the U.S. Post Office is working toward this goal for its USTs). Keep document on-site at all times.

It should be noted that the SWRCB has produced model forms for UST monitoring procedures and response plans (see local guidance letter LG 133). LG 145 addresses requirements for contractors performing cathodic protection testing. In addition, the "Handbook for

Tank Owners, Manual and Statistical Inventory Reconciliation” is included with LG 52-1. This handbook includes forms for:

- Dispenser meter recording sheet
- Dipstick recording sheet
- Meter calibration check form
- Fuel delivery recording sheet
- Monthly inventory reconciliation worksheet
- Annual inventory reconciliation summary report
- Annual statistical inventory reconciliation summary report

4.7 Owner/Operator Certification and Training

There is no requirement, nor any authority, in federal law for certification of owners, operators, inspectors, or contractors. However, California does have a certification and licensing program for contractors involved with the installation, removal, and upgrade of USTs (see local guidance letters LG 48-5 and LG 119-1). Currently, training classes are available for the following: UST installation, UST upgrading - interior lining and corrosion protection; UST leak detection standards and systems; UST compliance inspections; and, UST removal — technical and regulatory aspects. In addition, there are numerous other federal, state, local, and private training classes available. However, the literature suggests that the current extent of training may be inadequate. Based on a compilation of the current literature on UST management and operation practices, it has been suggested that, with regards to Owner/Operator Certification and Training, some possible improvements could include:

- Provide specialized training and certification within the following areas:
    - Spill response and reporting
    - Site maintenance and cleanup
    - Inventory control
    - Overfill prevention
    - Operating and understanding leak prevention and alarm systems
    - Requirements for third-party oversight and QA/QC documentation
- Train all employees upon hiring and annually thereafter on proper methods for handling and disposing of waste. Make sure that all employees understand storm- water discharge prohibitions and wastewater discharge requirements. Use a training log or similar method to document training.
- Certify service station attendants (similar to Oregon)

California may have already implemented many of these suggestions. As presented in LG 48-5, a licensing and certification program has been implemented for contractors involved in installation, removal, and upgrading of underground storage tanks. In addition, a program for certification of UST installations is presented in LG 119-1.

It should be noted that the SWRCB report (SWRCB, 1999a) determined that "immediate improvements are warranted in areas such as owner/operator, contractor, and inspector training" and "operator compliance with leak detection and response requirements." That report also stated, "...training should emphasize operation of leak detection systems and response procedures to suspected releases."

4.8 Tanker Driver Certification and Training

Tanker driver training programs and materials have been available for years and have surely produced benefits. However, refinements and improvements can be made which could potentially reduce overfills and surface spillage even more. Based on a compilation of the current literature on UST management and operation practices, it has been suggested that, with regard to Tanker Driver Certification and Training, some possible improvements could include:

- More rigorous training programs for all tanker drivers, including sections on: importance of drivers' roles in avoiding and reducing spills; spill response and reporting; tank gauging; purpose and function of overfill protection devices and spill boxes; vapor recovery systems; and, health and safety.
- Consistent certification requirements for all tanker drivers (Note: Department of Transportation [DOT] requirements for this already exist).
- Third-party oversight during product delivery, particularly for newly trained drivers.
- Statistical study of pertinent driver errors that lead to fuel losses.

4.9 Regulatory Enforcement

The SWRCB Advisory Panel report (1999a) states that "immediate improvements are warranted in areas such as…regulatory agency inspection and enforcement procedures." The report also states that "there appears to be a lack of adequate enforcement against owners/operators who are not complying with leak detection requirements or who fail to follow-up on suspected releases." Similarly, during a 1-day workshop (see Appendix C), UST experts suggested several other improvements to the regulatory enforcement process, including:

- Consolidate regulations to reduce overlap and improve clarity (e.g., clearly define "reportable quantity").
- Expand training for regulatory inspectors and ensure the uniformity of that training.

- Increase administrative and legal support for enforcement activities.
- Provide sufficient funding and human resources for these regulatory improvements, particularly at the local level.

4.10 Summary

In the previous subsections, 53 suggestions for possible improvements to UST management and operation practices were summarized based on a review of the current literature and upon the workshop of UST experts. Some UST owner/operators and regulatory bodies are already implementing many of these practices; they are to be commended for their progress. However, more improvement is possible. A recent summary report by SWRCB (1999a) contained an extensive list of UST practice recommendation; these were summarized from three companion documents (SWRCB, 1999b, 1999c, & 1999d).

This report does not advocate implementation of all of the suggestions listed here. The suggestions are not all of “equal value” in reducing/eliminating gasoline and MTBE losses. In fact, not all of these suggestions are ready for immediate implementation (Table 5). While some of these suggestions can be quickly implemented, others require further development or analysis (e.g., cost-benefit analysis). Several suggestions require additional research before deciding whether or not any change should be implemented. Prioritizing and researching these suggestions for possible improvement to UST management and operations are tasks appropriate for a multi-party team comprised of various stakeholders, including UST experts from government and industry.

5.0 Primary Topics for Further Research

This section presents the primary topics for further research that might lead to better identification, reduction, or elimination of gasoline and MTBE losses from operating UST systems. These research topics were identified in Section 4.0 (see Table 5) and are further discussed here to more fully describe what critical information is still unknown. This section also presents how new information may allow further refinements and improvements to be made to UST management and operation practices.

5.1 Training and Education for UST Personnel

Some training courses are already available for UST personnel, such as tanker drivers, service station attendants, and UST inspectors. However, more training seems to be needed to ensure that spills caused by mechanical failure and human error are prevented, reported, and handled as best possible. The training should educate both frontline UST personnel and customers so that relevant human behaviors and procedures may be further improved.

Before increased training and education are implemented, several topics will require further analysis/research, including:

- Study current field behaviors to identify the most critical training for leak prevention (see *Note* below).
- Review the content, methodology, duration, certification, and documentation of existing UST training programs.
- Establish how to best improve and customize the training for the different UST personnel involved (e.g., tanker drivers, service station attendants, UST inspectors).
- Determine the best means to educate customers.
- Conduct cost/benefit analysis of the refined and expanded UST training.

Summary: Study current training sufficiency and, if necessary, develop refined and expanded training/education programs for improving the behavior of customers, service station personnel, owner/operators, and tanker drivers.

Note: Levine Fricke Recon (Emeryville, CA) is currently performing a project entitled “Leak Detection and Prevention Field Study” under a contract with NWRI and the California MTBE Research Partnership. The first phase of this project may include a field survey and interviews with UST personnel. A later phase of this project may include on-site observations of UST system operations practices. It is expected that results of this project will be useful in developing appropriate training programs.

5.2 Third-Party Oversight and Inspection

Many of the potential problems listed in Tables 2 and 4 could be avoided if there were more comprehensive third-party oversight and inspection. Improved oversight could be quite beneficial during UST installations and, to a lesser degree, during critical operation, maintenance, and testing activities. The need for oversight and inspection was mentioned several times in the workshop of UST experts (see Appendix C). Similarly, SWRCB (1999a) concluded that regulatory agencies should be more involved in oversight. SWRCB (1998) stated that most of the USTs in the database "had not been monitored at all or were not monitored consistently."

Summary: Perform cost-benefit analysis of having additional personnel on-site for third-party oversight and inspection during UST installations and during critical operation and maintenance activities.

5.3 UST System Design

Section 4 presents several suggestions with respect to UST-system design that will help prevent and detect gasoline/MTBE releases. Most of the suggestions given do not require further research (see Table 5). However, there are some issues that may need more research, including:

- Are current leak detection systems designed correctly?
- Are they being operated, maintained, and tested properly? Frequently enough?
- Are current leak detection systems sufficiently sensitive to find the small/subtle leaks that may cause environmental problems (particularly in light of using MTBE or other generally recalcitrant additives)?
- Are new leak detection systems or procedures needed?
- Are overfill protection devices (especially float-ball valves) operating as designed?

The answers to these research questions will allow equipment manufacturers, UST owners /operators, and UST installers/contractors to design and maintain UST systems better.

Summary: Conduct field and laboratory studies (as necessary) to determine if the leak detection and overfill protection portions of the UST systems can/should be designed, installed, maintained, and operated better.

Note: The Levine Fricke Recon project, "Leak Detection and Prevention Field Study," may include a screening-level investigation of a range of UST system components and the effectiveness of leak detection equipment at approximately 30 sites. It is expected that results of this project will be useful in addressing some of the UST system design issues discussed above.

Note: The USEPA has several on-going workgroups that are studying some of the UST design issues listed above (see Appendix C).

5.4 Vapor Losses, Permeability, and Compatibility

Because of the physicochemical properties of MTBE, concern has arisen that relatively small/subtle gasoline releases may cause significant MTBE contamination of groundwater. There is also concern that gasoline vapors and/or MTBE-enriched vapors may be escaping from UST systems, thereby impacting shallow groundwater (see Section 3.1.4 and 3.6). As a result, vapor losses, permeability, and compatibility of UST system components with vapor-phase gasoline and vapor-phase MTBE are topics that may require additional research. As concluded in the SWRCB Advisory Panel report (SWRCB, 1999a), "…there is insufficient information available to determine whether there are UST system material or permeability problems associated with vapor-phase MTBE."

Field and laboratory research could be performed to evaluate these possibilities, including determination of locations and magnitudes of vapor escape. The answers to these research questions will allow equipment manufacturers to redesign, if necessary, UST systems to be more vapor-tight and/or more vapor compatible.

Summary: Conduct field and laboratory (if necessary) studies to determine if current UST systems are having vapor loss, vapor permeability, or vapor compatibility problems with gasoline vapors and/or MTBE vapors.

Note: The Levine Fricke Recon project, "Leak Detection and Prevention Field Study," may include a screening-level investigation of a range of UST system components, including searching for vapor losses from the UST systems. The results may be useful in addressing some of the vapor issues discussed above.

Table 1
Factors to Consider for UST Design and Installation

Activity	Factor to Consider
Preinstallation site analysis	soil conditions (stability, corrosion potential, etc.) nearby subsurface structures (utilities, wells, etc.) ground-water level site drainage and topography corrosion protection requirements secondary containment requirements
Site design/layout	federal, state, and local requirements and permits stormwater drainage system shoring evaluation UST system location dispenser and fillport locations tanker truck entry/exit pathways customer entry/exit pathways nearby structures/utilities
Materials/equipment selection	federal, state, and local requirements and permits material selections material specifications handling requirements preinstallation inspection and testing installer qualifications inspection/oversight
Excavation	OSHA/safety considerations excavation dimensions variances based on soil type inspection/oversight requirements
Tank placement	tank bedding material tank bedding material placement/compaction tank placement anchorage/ballasting (for high ground water) secondary containment (tank sump) tank sump sensors fillport connections piping connections (fuel, vapor recovery, vent) drop tube for gauging tank level probe installation procedures installer qualifications inspection/oversight
Overfill protection	automatic shutoff devices flow restrictors/ball float valves overfill alarms testing requirements installer/inspector qualifications inspection/oversight

Table 1 *(continued)*
Factors to Consider for UST Design and Installation

Activity	Factor to Consider
Fillport spill containment	catchment basins/containment sumps drainage systems sump manway installer/inspector qualifications inspection/oversight
Vapor recovery systems	system design/layout Stage I systems Stage II systems fill buckets vent lines testing requirements installer/inspector qualifications inspection/oversight
Product dispensers	dispenser pans dispenser pan sensors under dispenser piping automatic shutoff system for nozzles vapor recovery systems impact valves dispenser protection posts product filter system signage for customers meter calibration testing requirements installer/inspector qualifications inspection/oversight
Pumping systems	suction pumping systems pressurized pumping systems remote pumping systems check valves pump turbine containment sumps sump manway sump sensors testing requirements installer/inspector qualifications inspection/oversight
Other equipment	waste disposal equipment signage and labeling emergency shutoff switch paving/foundations stormwater control structures driveway manholes station spill kit

Table 1 ***(continued)***

Factors to Consider for UST Design and Installation

Activity	**Factor to Consider**
Tankpit and trench backfilling	initial UST system tightness test initial secondary containment testing (e.g., soap test) soil placement/compaction contractor qualifications underground line considerations underground tank considerations grading and paving aboveground labeling post-backfill inspection of UST system final testing installer/inspector qualifications inspection/oversight
Documentation	As-builts facility plot plan equipment warranties permits O&M Plan final checklist and walkthrough report installer certification of installation

Table 2
Potential Problems During UST Design and Installation

Activity	Potential Problems
Preinstallation site analysis	analysis not performed or not performed correctly nearby underground structures/utilities/wells unknown high ground-water level problematic soil conditions
Site design/layout	problematic site layout poor site drainage tanker truck entry/exit problematic
Materials/equipment selection	materials/equipment don't meet specifications poor material selection (e.g., seals not compatible with gasoline/MTBE) materials/equipment damaged during transport materials/equipment damaged during unloading preinstallation inspections not performed unqualified installers inspector not qualified/not present oversight/inspection not performed/inadequate poor documentation
Excavation	OSHA safety guidance not followed excavation too small for clearance requirements
Tank placement	tank damaged during unloading/placement tank bedding materials don't meet specifications placement of tank bedding materials doesn't meet specifications ballasting/anchorage not performed properly oversight/inspection not performed/inadequate unqualified installers inspector not qualified/not present poor documentation
Corrosion protection	improper selection of cathodic protection method/devices improper installation of cathodic protection initial testing not performed exposed surfaces not insulated impressed-current system disabled inspection/oversight not performed/inadequate UST system not isolated from nearby electrical sources bimetallic corrosion problems underground wire not properly insulated unqualified installers inspector not qualified/not present poor documentation

Table 2 *(continued)*
Potential Problems During UST Design and Installation

Activity	Potential Problems
Leak detection and prevention systems	tank and line tightness testing not performed/performed incorrectly automatic tank gauging system not installed properly tankpit observation wells not installed properly unqualified installer/inspector secondary containment sumps not sealed/installed correctly alarms not in appropriate location (inaudible) vapor monitors, or other monitors, not installed properly poor selection of system for product types, site conditions, etc. improper initial calibration of sensors improperly installed electrical systems ground-water monitoring wells not installed properly poor selection of leak detection system for site conditions, etc. system not sensitive enough to detect small/subtle leaks integrity of fiber trenches line leak detectors not installed properly alarm panel not installed correctly striker plates not installed correctly unqualified installers inspector not qualified/not present
Piping	poor layout/design piping materials do not meet specifications pipe fittings not secured properly improper fiberglass/steel connections improper unions or swing joints trenches incorrect depth/slope flexible connectors not secured properly backfill materials selected or placed/compacted improperly initial tightness testing not performed aboveground piping not labeled unqualified installers inspector not qualified/not present
Overfill protection	overfill protection devices not installed properly poor selection of overfill protection system flow restrictors/ball float valves not installed properly overfill alarms not installed properly unqualified installers inspector not qualified/not present
Fillport spill containment	catchment basin not installed/sealed properly poor selection of containment/drainage system unqualified installers inspector not qualified/not present

Table 2 *(continued)*
Potential Problems During UST Design and Installation

Activity	Potential Problems
Vapor recovery systems	poor system design/layout equipment does not meet specifications Stage I equipment not installed properly Stage II systems not installed properly systems not vapor/liquid tight unqualified installers inspector not qualified/not present
Product dispensers	poor system design equipment does not meet specifications under dispenser containment not installed/not required/ not installed properly under dispenser monitoring not installed/not required/ not installed properly under dispenser piping not installed/secured properly meters not calibrated properly automatic shutoff valves not tested impact valve not installed properly filter not installed/secured properly unqualified installers inspector not qualified/not present
Pumping systems	pumping systems not installed/not secured properly poor selection of pumping system for site conditions pump turbine containment sumps not installed/secured properly inadequate cleaning of piping adjacent to check valve before startup unqualified installers inspector not qualified/not present
Other equipment	tank fittings not secured inadequate signage stormwater control structures not installed improper identification of driveway manholes or UST fillports
Tankpit and trench backfilling	secondary containment tightness testing not performed/ performed incorrectly inspection/oversight not performed post-backfill inspection not performed final testing not performed
Documentation	inadequate documentation for: As-builts facility plot plan equipment warranties permits O&M Plan final checklist and walkthrough report installer certification of installation

Table 3
Factors to Consider for UST Operations and Maintenance

Activity	Factor to Consider
Product delivery	predelivery product level gauging water gauging fuel hose hookup overfill protection engaged spill box drainage vapor recovery system hookup driver responsibilities owner/operator responsibilities receipt of delivery documentation spill response
Product dispensers	customer education owner/operator staff training maintenance requirements visual inspections (dispenser pans, drippage, etc.) filter changeout (frequency, spent filter handling/disposal) testing/calibration of meters testing procedure for automatic shutoff systems testing schedule response to failed test tester qualifications
Pumping Systems	proper usage inspection and maintenance requirements inspection and cleanout of check valves inspector/maintenance personnel qualifications
Leak detection and prevention systems	inventory reconciliation/interpretation (daily; monthly) evidence of leakage periodic visual inspections of equipment tankpit monitoring automatic tank gauging (ATG) test tightness testing (tanks and lines) periodic sensor calibration under dispenser monitoring pump turbine sump monitoring inspection and maintenance of overfill sump interpretation of monitoring/test results alarm panel testing proper response to leak alarms communication/documentation system sensitivity
Vapor recovery systems	proper usage fill bucket inspection/drainage maintenance requirements inspection/testing criteria

Table 3 ***(continued)***
Factors to Consider for UST Operations and Maintenance

Activity	Factor to Consider
Spill response	spill response plan personnel training and responsibilities spill response equipment agency notification and communication documentation spill kit maintenance stopping the spill/leak/release reporting the release emergency response investigation of spill cause containment of released product spill response follow-up
Tank/line repairs	industry codes contractor qualifications equipment certification testing requirements tester qualifications documentation

Inventory control	federal, state, and local requirements
	manual tank gauging
	manual tank gauging before and after product delivery
	proper tank charts
	water gauging procedure
	accounting system requirements
	daily reconciliation
	record and reconciliation forms/instructions
	product losses:
	    sources
	    unavoidable losses
	    controllable losses
	procedures for reduction of controllable losses
	procedure for receipt of product
	response to inventory variance

Tank/line precision testing	testing requirements/frequency environmental conditions recorded/considered tester qualifications criteria for pass/fail response to failure of test documentation sensitivity
Corrosion protection systems	maintenance/monitoring requirements sacrificial anode replacement inspection/testing criteria tester qualifications

Table 3 *(continued)*
Factors to Consider for UST Operations and Maintenance

Activity	Factor to Consider
Stormwater control/cleanup	inspection/cleaning of storm drain inlets inspection/cleaning of catch basins spot cleaning of drips/spills disposal of cleanup materials
Training for station personnel and tanker truck drivers	alarm panel testing procedures for receipt of product product delivery/tank fillup inventory reconciliation station inspection response to alarms spill response site cleanup/waste disposal on-site record keeping daily procedures tank gauging dispenser inspection/calibration oversight of personnel communication/documentation
Record keeping	history of UST usage prior to current usage equipment maintenance schedules equipment certification and testing equipment operating manuals from manufacturers station operating permits records of maintenance, calibration, repairs suspected/confirmed releases corrective action taken ground-water monitoring vapor monitoring temporary closures corrosion protection system analysis of corrosion potential leak detection performance inventory variance repair/upgrade documentation change-in-service accidents/incidents/spills

Table 4
Potential Problems During UST Operations and Maintenance

Activity	Potential Problems
Product delivery	not gauging tanks before and after delivery fill hose not connected properly overfill due to failure to account for accurate ullage volume inaccurate gauging stick driver not present during entire filling process driver unaware of overfill protection type spill boxes not emptied properly Stage I vapor recovery systems not connected properly overfill alarm ignored or inaudible overfill protection system disabled/malfunctioning (e.g., leaking) improper draining of fill hose proper procedure for receipt of product not followed surface spill ignored by tanker driver improper spill response stress/damage to UST and/or piping due to heavy delivery truck no reporting of known spill
Product dispensers	customer drive-off causes release automatic dispenser shutoff not functioning properly spills caused by customer top-off improper cleanup of spills near dispensers improper handling/disposal of product filter too long between filter changeouts dispenser pans not liquid tight and/or not checked
Pumping systems	pumping systems not installed/secured properly poor selection of pumping system for site conditions pump turbine containment sumps not installed/secured properly inadequate cleaning of piping adjacent to check valve before startup unqualified installer/inspector
Leak detection and prevention systems	inventory variance not detected/reported leak detection systems not tested/calibrated regularly leak detection systems disabled/ignored leak alarm disabled/ignored/inaudible poor selection of leak testing method visual inspections not performed or performed poorly scheduled maintenance not performed testing performed too soon after product delivery leak detection system computer malfunction (e.g., Y2K) failure of automatic tank gauging (ATG) test misinterpreted line leak detector malfunction due to faulty check valve, etc. failure of tightness test ignored or misinterpreted (tanks and/or lines) evidence of leakage ignored (e.g., slow pumping dispenser) incorrect interpretation of monitoring/test results tanks not checked periodically for water under dispenser monitoring not performed pump turbine sump monitoring not performed significant vapor releases not detected maintenance/testing performed by unqualified personnel inadequate communication/documentation

Table 4 *(continued)*
Potential Problems During UST Operations and Maintenance

Activity	Potential Problems
Vapor recovery systems	improper usage (e.g., bypassed) leaking (i.e., not vapor tight) inadequate/improper maintenance unqualified maintenance personnel
Spill response	inadequate spill response plan, or not followed properly inadequate cleanup equipment available inadequate personnel training personnel responsibilities not understood reportable quantity is unclear in regulations poor communication between owner/operator and regulatory agency inadequate documentation of release release not contained ASAP release washed down with water release not reported improper emergency response
Tank/line repairs	repairs insufficient/inappropriate (not to code) inadequate maintenance/inspection unqualified or inadequately-trained repair personnel tightness testing after repairs not performed/not performed properly
Inventory control	federal, state, or local requirements not followed meter and tank readings not reconciled inaccurate gauging stick product level not stabilized in tank prior to gauging tanks not gauged before and after product delivery improper temperature compensation automatic tank gauging system not calibrated properly tank not level causing gauging inaccuracies theft water gauging not performed properly dispenser meters inaccurate/not tested adjustments for water level not made tank volume chart used incorrectly/wrong chart used math errors/transcription errors improper response to inventory variance inadequate documentation
Tank/line precision testing	required testing frequency/procedures not followed unqualified or inadequately trained testers misapplication of volumetric testing methods leakage rate below threshold detection level ATG system not calibrated properly tank volume too low/too high for testing criteria for pass/fail not followed or not known improper response to failure of test math errors/transcription errors inadequate documentation

Table 4 *(continued)*
Potential Problems During UST Operations and Maintenance

Activity	Potential Problems
Corrosion protection systems	maintenance procedures not followed sacrificial anode not replaced as necessary corrosion protection system disabled inspection/testing not performed anchoring system not protected loss of electrical isolation (various causes) unqualified or inadequately trained testing personnel unqualified or inadequately trained maintenance personnel inadequate documentation
Stormwater control/cleanup	inspection/cleaning of storm drains not performed inspection/cleaning of catch basins not performed spot cleaning of drips/spills not performed improper disposal of cleanup materials
Training for station personnel and tanker truck drivers	inadequate training of various procedures inadequate understanding of responsibilities poor oversight of personnel inadequate communication/documentation
Record keeping	poor record keeping for any of the following: historical UST usage prior to current usage schedules of calibration, maintenance, and repairs inventory reconciliation suspected/confirmed releases corrective action taken ground-water monitoring data vapor monitoring data temporary closures corrosion protection system data analysis of corrosion potential certification of equipment performance leak detection performance repair/upgrade documentation change-in-service documentation records for all manufacturers and installers

Table 5
Suggestions for Improved UST Practices

Category: Equipment Design	Additional Knowledge Needed for Implementation		
	Some[A]	Moderate[B]	Extensive[C]
Implement properly installed striker plates for all tanks.	x		
Implement under-dispenser containment sumps, in combination with sump monitoring devices.	x		
Implement spill containment boxes at Stage I vapor recovery risers.	x		
Implement dry breakaway connections for all dispenser hoses.	x		
Implement automatic shutoffs for all fuel dispensing nozzles.	x		
Research and development to further reduce vapor loss from all UST components.			x
Post-installation tightness testing of overfill containment sumps. Development of associated testing protocol.		x	
Design and implement more reliable overfill protection systems (e.g., not easily disabled, less likely to malfunction).			x
Phase-out float-ball valves as primary overfill protection devices.	x		
Implement integrity testing of secondary containment systems. Develop associated protocol.		x	
Conduct compatibility/permeability testing of select UST components for use with MTBE-enriched gasoline.		x	

Category: Service Station Site Design	Additional Knowledge Needed for Implementation		
	Some[A]	Moderate[B]	Extensive[C]
Design service stations are to minimize potential for contaminated stormwater runoff.	x		
Design all catchments on-site to drain to oil-water separators.	x		
Implement high visibility signs warning against "topping off" on all dispensers.	x		
Ensure that all signage at service stations is clearly visible, including signs for emergency shutoff switch and labels for fill pipes.	x		
Complete documentation kept on-site at all times, including spill response plan, emergency contact information, site plan, O&M records and manuals, etc.	x		
Label all drains within facility boundary to indicate drainage to oil/water separator, sanitary sewer, or storm drain.	x		

Table 5 *(continued)*
Suggestions for Improved UST Practices

Category: UST System Installation	Additional Knowledge Needed for Implementation		
	Some[A]	Moderate[B]	Extensive[C]
Expand the training and certification for all personnel involved in UST installation activities.		x	
Implement qualified third-party oversight for all aspects of UST system installation.		x	
Develop and implement requirements for comprehensive QA/QC documentation including materials and equipment used, equipment performance certifications, installation personnel, and installation procedures."		x	

Category: Leak Detection Systems	Additional Knowledge Needed for Implementation		
	Some[A]	Moderate[B]	Extensive[C]
Ensure that an appropriate system is carefully selected (e.g., third-party oversight, documentation).	x		
Ensure that testing/monitoring results are interpreted and reported by qualified personnel.	x		
Train UST personnel on the importance of following manufacturers' and industry maintenance protocols.	x		
Ensure that appropriate documentation and reporting are completed during all phases of installation, maintenance, and testing of leak detection systems.	x		
Determine if existing leak detection systems are adequate and if they are sufficiently sensitive to find small/subtle leaks (particularly if using generally recalcitrant compounds like MTBE).			x
Develop and implement improved environmental sensors (e.g., for ground water) for selectively identifying the presence of released petroleum.			x

Category: Customer Education	Additional Knowledge Needed for Implementation		
	Some[A]	Moderate[B]	Extensive[C]
Develop training program to educate public and full-service attendants on proper refueling techniques and related UST issues.		x	

Table 5 *(continued)*
Suggestions for Improved UST Practices

Category: UST System Inspection and Maintenance	Additional Knowledge Needed for Implementation: Some[A]	Moderate[B]	Extensive[C]
Expand training and certification programs for all personnel involved in UST system maintenance and testing.		x	
Implement qualified third-party oversight for all aspects of UST system maintenance and testing.		x	
Develop requirements for comprehensive QA/QC documentation and reporting during all phases of maintenance and testing of UST systems.		x	
Ensure that maintenance testing results are interpreted and reported by qualified/ certified personnel.	x		
Perform periodic inspections of fill riser spill containment boxes for liquid leak tightness. Develop protocol for inspection and quantification of leakage.		x	
Develop well-defined protocols for maintenance, inspection, and testing of the various types of UST equipment. Ensure that appropriate protocols for specific systems are used."		x	
Expand training for proper handling and disposal techniques for used gasoline filters.	x		
Increase required testing frequency for overfill protection systems.	x		
Expand the implementation consistent/timely monitoring and maintenance of corrosion protection systems.	x		
Expand the implementation of inspection and maintenance protocol for dispensing nozzles at all pumps.	x		
Ensure that joints and cracks in paving at UST sites are periodically sealed/caulked to reduce potential for infiltration.	x		
Ensure that a current spill response plan is maintained on-site at all times.	x		
Ensure that spill cleanup supplies are maintained regularly. Ensure that used sorbent materials are handled/disposed properly.	x		
Utilize good "housekeeping" practices to minimize contamination of stormwater runoff. Spot clean drips regularly with appropriate materials.	x		
Develop system-specific "best management practices"" document for each individual site, and keep it on-site at all times."		x	
Avoid use of cleanup and spill response methods that involve water to minimize additional waste disposal requirements. Ensure that any washdown water is collected and disposed of properly.	x		
Expand periodic collection and analysis of ground-water samples at sites with monitoring wells in-place.	x		
Expand periodic inspection and cleanout of storm drain inlets and catch basins within facility boundary.	x		

Table 5 *(continued)*
Suggestions for Improved UST Practices

Category: Owner/Operator Certification and Training	Additional Knowledge Needed for Implementation		
	Some[A]	Moderate[B]	Extensive[C]
Expand training program that addresses: importance of their role; spill response and reporting; site maintenance and cleanup; inventory control; overfill protection; operation of leak prevention and alarm systems; and, requirements for third-party oversig		x	
Ensure training for all UST personnel upon hiring and annually thereafter on proper handling and disposal of waste materials.	x		
Implement certification program for service station attendants (e.g., Oregon program).		x	

Category: Tanker Driver Certification and Training	Additional Knowledge Needed for Implementation		
	Some[A]	Moderate[B]	Extensive[C]
Expand the training programs for all tanker drivers, including sections on: importance of driver's role; spill response and reporting; tank gauging; overfill protection devices; spill boxes; vapor recovery systems; and, health and safety."		x	
Develop training certification requirements for all tanker drivers.		x	
Implement periodic third-party oversight during product delivery, particularly for newly-trained drivers.	x		

Category: Regulatory Enforcement	Additional Knowledge Needed for Implementation		
	Some[A]	Moderate[B]	Extensive[C]
Expand and improve regulatory agency inspection and enforcement procedures.		x	
Consolidate regulations to reduce overlap and improve clarity.			x
Expand and provide uniform training for regulatory agency inspectors.		x	

Notes:

A: These items require some refinement or additional development.

B: These items require further development, analysis, or cost-benefit analysis to determine the most appropriate and beneficial implementation.

C: These items require extensive research to evaluate feasibility and the potential benefits before they can be definitively recommended for implementation.

6.0 References

Alaska Department of Environmental Conservation, 1999. Underground Storage Tank Operation and Maintenance Manual for Owners and Operators, Alaska Department of Environmental Conservation, DRAFT-Version 1.5, May 28, 1999, www.state.ak.us/dec/dspar/stp/usto&m/o&m.htm, 37 pages.

American Petroleum Institute, 1993. Bulk Liquid Stock Control at Retail Outlets, API Recommended Practice 1621, Fifth Edition, May 1993, 26 pages.

American Petroleum Institute, 1996a. Installation of Underground Storage Systems, API Recommended Practice 1615, Fifth Edition, March 1996, 51 pages.

American Petroleum Institute, 1996b. Cathodic Protection of Underground Storage Tanks and Piping Systems, API Recommended Practice 1632, Third Edition, May 1996, 11 pages.

American Petroleum Institute, 1997. Interior Lining of Underground Storage Tanks, API Recommended Practice 1631, Fourth Edition, October 1997, 10 pages.

California Stormwater Quality Task Force, 1997. Best Management Practice Guide - Retail Gasoline Outlets, prepared by the Retail Gasoline Outlet Work Group, California Stormwater Quality Task Force, March 1997, 8 pages.

Code of Federal Regulation, 1988. Title 40, Parts 280-281.

Couch, Kevin and Thomas Young, 1998. Leaking Underground Storage Tanks (USTs) as Point Sources of MTBE to Groundwater and related MTBE-UST Compatibility Issues, UC SB 521 Report, Volume 4.2, 21 pages.

Davidson, James M., 1998. MTBE & Underground Storage Tank Systems - A Question of Compatibility, L.U.S.T.LINE, Bulletin 28, page 18-30.

Frye, Ellen, 1999. Now That the '98 Deadline Has Come and Gone...How's It Going? L.U.S.T.LINE, Bulletin 31, March 1999. New England Interstate Water Pollution Control Commission, Lowell, MA.

Levine Fricke Recon, 1999. Summary Report, Santa Clara Valley Water District, Groundwater Vulnerability Pilot Study, Investigation of MTBE Occurrence Associated with Operating UST Systems. Prepared for Santa Clara Valley Water District, Emeryville, CA. July, 1999.

Minnesota Pollution Control Agency, 1995. Field Reference Handbook for Inspectors: Underground Storage Tank Installations and Facility Inspections, Minnesota Pollution Control Agency, St. Paul, MN, January 1995, 126 pages.

Ng, Sammy, 1999. The View from the U.S. EPA: Program Direction for 1999 and Beyond. Underground Tank Technology Update, Vol. 13, No. 5, pg. 10-12.

State Water Resources Control Board, 1998. Are Leak Detection Methods Effective in Finding Leaks in Underground Storage Tank Systems? Published by State Water Resources Control Board, Sacramento, CA, January 1998, 13 pages plus tables and appendices.

State Water Resources Control Board, 1999a. Report of the State Water Resources Control Board's Advisory Panel on the Leak History of New and Upgraded UST Systems. Published by State Water Resources Control Board, Sacramento, CA, 8 pages.

State Water Resources Control Board, 1999b. 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). Published by State Water Resources Control Board, Sacramento, CA, 14 pages plus appendices.

State Water Resources Control Board, 1999bc. State Water Resources Control Board's Advisory Panel on the Leak History of New and Upgraded UST Systems, Upgraded UST Release Site Evaluation Case Studies (UST Team 2 Report). Published by State Water Resources Control Board, Sacramento, CA, 8 pages plus appendices.

State Water Resources Control Board, 1999d. State Water Resources Control Board's Advisory Panel on the Leak History of New and Upgraded UST Systems, Leak Source and Leak Detection Data Collection and Analysis (UST Team 3 Report). Published by State Water Resources Control Board, Sacramento, CA, 21 pages plus appendices.

Thompson Publishing Group, 1998. Underground Storage Tank Guide. Published by Thompson Publishing Group, Washington, D.C., Volumes I and II.

USEPA, 1986. RCRA Orientation Manual, EPA/530-SW-86-001, United States Environmental Protection Agency, Office of Solid Waste, 189 pages.

USEPA, 1987. Underground Storage Tank Corrective Action Technologies.

EPA/625/6-87-015, United States Environmental Protection Agency, January 1987.

USEPA, 1988. Musts for USTs - A Summary of the New Regulations for Underground Storage Tank Systems. USEPA, Office of Underground Storage Tanks, Washington, D.C., 50 pages.

USEPA, 1993. Doing Inventory Control Right. EPA 510-B-93-004, United States Environmental Protection Agency, November 1993, 17 pages.

USEPA, 1994. Don't Wait Until 1998 - Spill, Overfill, and Corrosion Protection for Underground Storage Tanks, EPA 510-B-94-002, United States Environmental Protection Agency, April1994, 16 pages.

USEPA, 1995. Introduction to Statistical Inventory Reconciliation for Underground Storage Tanks, EPA 510-B-95-009, United States Environmental Protection Agency, September 1995, 12 pages.

USEPA, 1997. Straight Talk on Tanks - Leak Detection Methods for Petroleum Underground Storage Tanks, EPA 510-B-97-007, United States Environmental Protection Agency, September 1997, 28 pages.

USEPA, 1998a. Catalog of EPA Materials on Underground Storage Tanks. EPA 510-B-098-001, United States Environmental Protection Agency, March 1998, 34 pages.

USEPA, 1998b. Getting the Most of Your Automatic Tank Gauging System. EPA 510-F-98-011, United States Environmental Protection Agency, March 1998, 2 pages.

USEPA, 1998c. List of Leak Detection Evaluations for UST Systems. Fifth Edition, EPA 510-B-98-005, United States Environmental Protection Agency, October 1998, 350+ pages.

Western States Petroleum Association, 1999. Minimizing Product Losses - WORKING DRAFT, May 1999, Western States Petroleum Association, Sacramento, CA, 4 pages.

Young, Albert D. Jr., Michael A. Barbara, James P. Miller, Raymond W. Kane, and Warren Rogers, 1987. Underground Storage Tank Management: A Practical Guide, Second Edition, Government Institutes, Inc., Rockville, MD, 311 pages.

Appendix A: References for UST Management Practices, Specifications, Codes, Standards, and Guidelines

The following is a list of the national organizations that write most of the management practices, specifications, codes, standards, and guidelines that are pertinent to USTs. These organizations include:

- American National Standards Institute (ANSI)
- American Petroleum Institute (API)
- American Society for Testing and Materials (ASTM)
- Canadian Petroleum Products Institute (CPPI)
- Factory Mutual (FM)
- International Fire Code Institute (IFCI)
- National Association of Corrosion Engineers (NACE)
- National Fire Protection Association (NFPA)
- National Leak Prevention Association (NLPA)
- Petroleum Equipment Institute (PEI)
- Steel Tank Institute (STI)
- Underwriters Laboratories (UL)
- Underwriters Laboratories of Canada (ULC)
- Local agencies (e.g., Fire Department, Health Department, Local Implementing Agencies, Local Oversight Programs, etc.)

Included below is a list of documents relevant to UST operational practices that are published by these organizations. (Please note that the Underground Storage Tank Guide [Thompson Publishing Group, 1998] presents brief descriptions of many documents prepared by these organizations as well as presents many other aspects of UST management, operations, regulations, etc.). A list of relevant UST documents published elsewhere appears at the end of this appendix.

American National Standards Institute (ANSI)

ANSI/ASME B31.3, Process Piping

ANSI/ASME B31.4, Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols

American Petroleum Institute (API)

API Publ 1628, A Guide to the Assessment and Remediation of Underground Petroleum Releases

API Publ 1628B, Risk-Based Decision Making

API Publ 2217A, Guidelines for Work in Inert Confined Spaces in the Petroleum Industry

API Publ 2219, Safe Operating Guidelines for Vacuum Trucks in Petroleum Service

API Publ 4422, Cost Model for Selected Technologies for Removal of Gasoline Components from Ground Water

API RP 2200, Repairing Crude Oil, Liquefied Petroleum Gas, and Product Pipelines

API RP 1132, Effects of Oxygenated Fuels and Reformulated Diesel Fuels on Elastomers and Polymers in Pipeline/Terminal Components

API RP-1604, Closure of Used Underground Petroleum Storage Tanks

API RP-1615, Installation of Underground Petroleum Product Storage Systems

API RP-1621, Bulk Liquid Stock Control at Retail Outlets

API RP-1631, Interior Lining of Underground Storage Tanks

API RP-1632, Cathodic Protection of Underground Petroleum Storage Tanks and Piping Systems

API RP-1637, Using the API Color-Symbol System to Mark Equipment and Vehicles for Product Identification at Service Stations and Distribution Terminals

API RP-1650, Digest of Six API Recommended Practices on Underground Petroleum Storage Tank Management

API Spec 5L, Specification for Line Pipe

API Std 2015, Safe Entry and Cleaning of Petroleum Storage Tanks, Planning, and Managing Tank Entry from Decommissioning through Recommissioning

API Std 653, Tank Inspection, Repair, Alteration, and Reconstruction

American Society for Testing and Materials (ASTM)

ASTM D4021-86, Standard Specification for Glass-Fiber-Reinforced Polyester Underground Storage Petroleum Products

ASTM E1430-91, Standard Guide for Using Release Detection Devices with Underground Storage Tanks

ASTM E1526-93, Standard Practice for Evaluating the Performance of Release Detection Systems for Underground Storage Tank Systems

ASTM E1599-94, Standard Guide for Corrective Action for Petroleum Releases

ASTM E1739-95e1, Risk-Based Corrective Action Applied at Petroleum Release Sites

ASTM E1912-98, Standard Guide for Accelerated Site Characterization for Confined or Suspected Petroleum Release

ASTM G-158, Standard Guide for Three Methods of Assessing Buried Steel Tanks

ASTM PS104-98, Standard Provisional Guide for Risk-Based Corrective Action

ASTM PS85-96, Standard Provisional Guide foe Expedited Site Characterization of Hazardous Waste Contaminated Sites

ASTM STP 1161, Leak Detection for Underground Storage Tanks

ASTM Vol. 1.01, Steel Piping, Tubing and Fittings (Sec. 1, Vol. 1.01 of the Annual Book of ASTM Standards)

Canadian Petroleum Products Institute (CPPI)

CAN/ULC-S603, Underground Steel Tanks

CAN/ULC-S603.1, Standard for Galvanic Corrosion Protection Systems for Steel Underground Tanks for Flammable and Combustible Liquids

CAN/ULC-S633, Flexible Underground Hose Connectors for Flammable and Combustible Liquids

CAN4-S603-M85, Standard for Steel Underground Tanks for Flammable and Combustible Liquids

CAN4-S631, Standard for Isolating Bushings for Steel Underground Tanks Protected with Coatings and Galvanic Systems

CPPI Report No. 81-4B, Inventory Control as a Means of Identification of Underground Tank Leaks

CPPI Report No. 82-3, Underground Tank Systems Review of State-of-the-Art and Guidelines

Factory Mutual (FM)

FM AS 1920, Approval Standard for Flexible Pipe Couplings in Fire Protection Systems

National Association of Corrosion Engineers (NACE)

NACE RP-0169, Control of External Corrosion on Underground or Submerged Metallic Piping Systems

NACE RP-0184, Repair of Lining Systems

NACE RP-0190, External Protective Coatings for Joints, Fittings, and Valves on Metallic Underground or Submerged Pipelines and Piping Systems

NACE RP-0285, Recommended Practices for Corrosion Control of Underground Storage Tank Systems by Cathodic Protection

NACE RP-0286, The Electrical Isolation of Cathodically Protected Pipelines

NACE RP-0375, Wax Coating Systems for Underground Piping Systems

NACE RP-0572, Design, Installation, Operation, and Maintenance of Impressed Current Deep Groundbeds

National Fire Protection Association (NFPA)

NFPA 30, Flammable and Combustible Liquids Code

NFPA 30A, Automotive and Marine Service Station Code

NFPA 326, Standard Procedure for Safe Entry of Underground Storage Tanks

NFPA 327, Cleaning or Safeguarding Small Tanks and Containers without Entry

NFPA 328, Recommended Practice for Control of Flammable and Combustible Liquids and Gases in Manholes, Sewers, and Similar Underground Structures

NFPA 329, Recommended Practice for Handling Underground Releases of Flammable and Combustible Liquids

NFPA 70, National Electrical Code

National Leak Prevention Association (NLPA)

NLPA Std 631, Spill Prevention, Minimum 10-Year Life Extension of Existing Steel Underground Tanks by Lining Without the Addition of Cathodic Protection

Petroleum Equipment Institute (PEI)

PEI RP 100, Recommended Practices for the Installation of Underground Liquid Storage Systems

Steel Tank Institute (STI)

STI F841, Standard for Dual-Wall Underground Steel Storage Tanks

STI F894, ACT-100 Specifications for External Corrosion Protection of FRP Composite Steel Underground Storage Tanks

STI F922, Permatank Specification

STI F923, Permatank Installation Instructions

STI R821, Cathodically Protected Underground Storage Tank (sti-P3) Installation Instructions

STI R831, Optional Recommended Practice for Control of Localized Corrosion Within Underground Steel Petroleum Storage Tanks

STI R891, Recommended Practice for Hold Down Strap isolation

STI R892, Recommended Practice for Corrosion Protection of Underground Piping Networks Associated with Liquid Storage and Dispensing Systems

STI R913, FRP Composite Steel Underground Storage Tank Installation Instructions

STI R923, FRP Jacketed Steel Underground Storage Tank Installation Instructions

STI R971, Urethane Coated Steel Underground Storage Tank Installation Instructions

STI R972, Recommended Practice for the Installation of Supplemental Anodes for sti-P3 USTs

STI T871, STI Test Procedure to Qualify a Coating for Acceptance by sti-P3 Specifications

STI-P3, Specification and Manual for External Corrosion Protection of Underground Steel Storage Tanks

Underwriters Laboratories (UL)

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

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

UL 567, Pipe Connectors for Petroleum Products

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

UL 971, Nonmetallic Underground Piping for Flammable Liquids

UL 2245, Standard Below Grade Vaults for Flammable Liquid Storage Tanks

Underwriters Laboratories of Canada (ULC)

ULC Subject C107.7, Glass-Fiber Reinforced Plastic Pipe and Fittings for Flammable Liquids

ULC/ORD-58.9, Secondary Containment Liners for Underground and Aboveground Tanks

ULC/ORD-C58.10, Jacketed Steel Underground Tanks for Flammable and Combustible Liquids

ULC/ORD-C58.12, Leak Detection Devices (Volumetric Type) for Underground Flammable Liquid Storage Tanks

ULC/ORD-C58.14, Leak Detection Devices (Non-volumetric Type) for Underground Flammable Liquid Storage Tanks

ULC/ORD-C58.15, Overfill Protection Devices for Flammable Liquid Storage Tanks

ULC/ORD-C58.19, Spill Containment Devices for Underground Flammable Liquid Storage Tanks

ULC/ORD-C58.20, Special Corrosion Protection, Underground Tanks

ULC-S615, Standard for Underground Reinforced Plastic Tanks

ULC-S616, Liquid Protective Coating Materials as Required by ULC-S603.1 for Use in Connection with the Corrosion Protection of Underground Tanks

Other References

Field Reference Handbook for Inspectors: Underground Storage Tank Installations and Facility Inspections, January 1995
Author: Minnesota Pollution Control Agency

The California Underground Storage Tank Program and the Matter of Methyl Tertiary Butyl Ether, February, 1999
Produced for Lyondell Chemical Worldwide, Inc.
Author: White Environmental Associates

Installation Manual and Operating Guidelines for Single-Wall and Double-Wall Fiberglass Underground Storage Tanks, 1999
Author: Xerxes Corporation

L.U.S.T.LINE - A Report on Federal & State Programs to Control Leaking Underground Storage Tanks
Publisher: New England Interstate Water Pollution Control Commission
Boott Mills South, Lowell, MA 01852-1124
Bulletins Published from August 1985 to present
31 Bulletins published as of March 1999

Underground Storage Tank Installation
Author: G. Mattney Cole
Publisher: Lewis Publishing

Underground Storage Tank Management: A Practical Guide
Authors: Joyce Rizzo and Albert D. Young
Publisher: Government Institutes, Inc.

Technology of Underground Liquid Storage Tank Systems, 1997
Author: John Hartmann
Publisher: Wiley and Associates

Underground Storage Systems: Leak Detection and Monitoring, 1988
Authors: Todd G. Schwendeman and H. Kendall Wilcox
Publisher: Lewis Publishers

Uniform Fire Code

Local Fire Codes

Videos

USEPA, 1992. *Keeping it Clean: Making Safe and Spill-Free Motor Fuel Deliveries*
For ordering information call USEPA's RCRA/Superfund Hotline at 800-424-9346

DGI Communications, 1988. *Doing it Right - Proper Installation of Underground Storage Tank Systems, Part I: Tanks, Part II: Piping*. Bethesda, Maryland.

American Petroleum Institute, 1986. *Effective Management of Underground Petroleum Storage Systems.* Publication 804-1640.

Ongoing Work Groups

Project:	UST System Performance Information Search
Organization:	USEPA, Office of Underground Storage Tanks
Contact:	David Wiley
Phone:	703-603-7178
Email:	wiley.david@epa.gov

Project:	Analysis of UST System Environmental Performance
Organization:	USEPA, Office of Underground Storage Tanks
Contact:	David Wiley
Phone:	703-603-7178
Email:	wiley.david@epa.gov

Project:	Field Verification of UST System Leak Detection Performance	
Organization:	USEPA, Office of Underground Storage Tanks/ UC Davis	
Contact:	David Wiley	Dr. Tom Young
Phone:	703-603-7178	530-754-9399
Email:	wiley.david@epa.gov	tyoung@ucdavis.edu

Project:	UST System Operation & Maintenance
Organization:	USEPA, Office of Underground Storage Tanks
Contact:	Paul Miller
Phone:	703-603-7165
Email:	miller.paul@epa.gov

Appendix B: Summaries of Six Current UST Management and Operation Practice Documents

Title: Underground Storage Tank Operation and Maintenance Manual for Owners and Operators

Author: Alaska Department of Environmental Conservation, Storage Tank Program

Contact: Ben Thomas
bthomas@envircon.state.ak.us
Fax = 907-465-5218
http://www.state.ak.us/dec/dspar/stp/usto&m/o&m.htm

Date: May 28, 1999 - DRAFT Version 1.5

Summary:

This 37-page document is very recent, with only a DRAFT version available on the Internet. It is divided into 11 sections, including several that provide general advice on operation and maintenance practices - both those required by regulation and those recommended to improve UST management. The manual contains a number of very useful checklists for the field operator and has several tables for the owner/operator to complete regarding their particular equipment. In this way, each facility can semi-customize the manual for its facility. Written in simple language, it provides an excellent start for creating a site-specific UST management and operation document.

Title: Field Reference Handbook for Inspectors: Underground Storage Tank Installations and Facility Inspections

Author: Minnesota Pollution Control Agency
Hazardous Waste Division, Tanks and Spills Section

Contact: Joan Henry or Roger Fischer
Phone: 612-297-8679

Date: January 1995

Summary:

This 126-page document is an excellent technical reference written for field inspectors to carefully inspect the installation of USTs as well as the operation and management of active UST facilities. It contains very specific technical advice on certain UST installation practices in great detail. For example, the document:

- Defines which brands of tanks can be safely rolled off a delivery truck and which ones can not be rolled without sustaining damage.

- Lists which types of adhesives to use with certain fiberglass tanks, how to blend them, and how to apply them.

- Provides a table of appropriate burial depths for specific types of tanks and piping.

To a lesser degree, the facility inspection section of this handbook provides some specific technical information on the desirable and/or required practices for many of the common UST subsystems and components (ex: ATG systems, flex connectors, etc.).

The limitations of this document include:

- Consistent references to Minnesota regulations (it may not be directly applicable elsewhere).

- Not addressing many personnel activities or spill prevention practices.

The handbook contains a number of useful checklists and tables for field personnel. Written in concise language, it is an excellent technical reference regarding installation practices and a good supporting document for equipment operation practices.

Title: Best Management Practice Guide
Retail Gasoline Outlets

Author: Retail Gasoline Outlet Work Group
California Stormwater Quality Task Force

Contact: Robert Hale, Chairman

Date: March 1997

Summary:

This nine-page document focuses on management and operation practices specific to reducing impacts to stormwater that emanate from gasoline service stations. The stated purpose of this report is to "assist municipal agencies and retail gasoline outlets subject to storm water regulations in attaining compliance with such regulations." Representatives from industry, municipalities, and regulatory agencies participated in the Retail Gasoline Outlet Work Group that authored this report. The "best management practices" presented in this report covered three activities or areas: fuel dispensing areas; air/water supply areas; and, outdoor waste receptacles. Each of these activities or areas are addressed with respect to existing facilities and new or substantially remodeled facilities. The document presents specific recommendations on how to reduce impacts to stormwater, such as:

- "Fit fuel dispensing nozzles with 'hold open' latches (automatic shutoffs) except where prohibited by local fire departments."

- "Post signs at the fuel dispenser or fuel island warning vehicle owners/operators against 'topping-off' of vehicle fuel tanks."

- "Label drains within the facility boundary, by paint/stencil (or equivalent), to indicate whether they flow to an oil/water separator, directly to the sewer, or to a storm drain. Labels are not necessary for plumbing fixtures directly connected to the sanitary sewer."

The primary limitation of this document is that it focuses on reduction of impacts to stormwater only and, therefore, neglects numerous other critical categories of UST operations and management practices. For example, no specific equipment installation or maintenance practices are presented. However, the general recommendations made in this document allow it to be applicable to most gasoline service stations.

Title: Minimizing Product Losses – A Working Draft

Author: Western States Petroleum Association

Contact: Jeff Wilson
WSPA
818-543-5344

Date: May 1999 – WORKING DRAFT

Summary:

This WORKING DRAFT (four pages) identifies a range of practices that are intended to reduce the potential for gasoline releases from motor vehicle refueling at fueling facilities. As stated in the document, it "is not intended to be a prescriptive list of practices for all facilities." The suggested practices are broken down into three categories based on activities at service stations: station design and runoff control; operating practices; and, training. In total, 22 non-prioritized suggestions are presented, including:

- "Install under-dispenser containment at existing stations whenever work involves the replacement or removal of gasoline dispensers or concrete at the service island."

- "Caulk joints and cracks in paving at vehicle refueling areas and around UST fills to reduce the possibility of soil contamination of a spill occurs."

- "Establish specific procedures for training tank truck drivers to prevent and detect tank overfills during product loading."

No installation or maintenance practices that are specific to a particular equipment type are presented in this document. However, the suggestions made in this document are up-to-date and should be helpful for reducing leaks and spills at most UST sites.

Title: Service Station Monitoring Procedures
Underground Storage Tank Leak Response Plan

Author: Anonymous owner/operator of a California Service Station

Contact: Not applicable

Date: 1998

Summary:

This site-specific document presents very thorough coverage of the site-specific monitoring procedures for several subsystems of the particular UST system that existed at the site. Components of this document include the following:

- Tank information (volumes, product types)
- Persons responsible for monitoring
- Preventative maintenance schedule for monitors
- Records retention requirements
- Contact names and numbers
- Underground storage tank/line information (type, material, monitor type/manufacturer)
- Monitoring system profile (quantities and part numbers)
- Reporting requirements for alarms or failed inspection testing
- Training requirements for company personnel (for monitoring systems)
- Description of tank monitoring system and documentation
- Description of line monitoring system and automatic shutoff systems
- Description of dispenser containment and turbine containment
- Description of spill containment and waste oil containment
- Tank/line testing or certification results (documentation)
- Testing procedures and documentation for UST leak detection system
- Testing procedures and documentation for line leak detection system
- Testing procedures and documentation for waste oil tank leak detection system
- Daily procedure for vapor recovery system and spill boxes

The leak response portion of this document addresses the following topics:

- Emergency procedure to be used if alarm goes off
- Methods and type of equipment used for removing hazardous substances
- Location and availability of cleanup equipment
- Tank and line testing guidelines

The primary shortcoming of this document is that it fails to address reduction of human-based causes of gasoline spillage. In addition, no installation procedures are included. This document is primarily reference-oriented, listing equipment types, personnel, contact numbers, and other documents (e.g., manufacturer specifications) that should be used for operation and maintenance procedures.

Title: NEPA/GSA UST Fact Sheet

Author: General Services Administration

Contact: NEPA Call-in Program
202-208-6228
http://www.gsa.gov/pbs/pt/call-in/factshet/1098/10_98_12.htm

Date: October 1998 (apparently)

Summary:

This short document (six pages) "presents an overview of the requirements USTs must meet by December 22, 1998; discusses EPA and GSA policy; presents Best Management Practices (BMPs) for on-going UST management." It is essentially a brief summary of the federal UST regulations. It contains very few references regarding any particular operation and maintenance practices to follow; therefore, it is not really a BMP document or even a UST practices manual. It does reference some 1995 Technical Guides issued by GSA that provide more detailed tank-management information.

Appendix C: UST Workshop Notes

This appendix presents a summary of a 1-day UST Practices workshop that was held on June 17, 1999 at the offices of the National Water Research Institute (NWRI) in Fountain Valley, California. The 21 UST experts who attended the workshop represented the petroleum industry, UST system manufacturers, environmental consultants, and regulatory communities.

During the UST workshop, Alpine Environmental and a stenographer retained by NWRI documented the primary comments and ideas that were brought forth by the workshop attendees. Presented below is a compilation of notes taken by the stenographer and Alpine Environmental.

The following compilation is based primarily on the stenographer's notes submitted soon after the workshop. Because the stenographer was instructed to document only primary ideas and summary statements, these notes are generally in outline format. During the preparation of this appendix, the accuracy of the stenographer's notes were verified and/or edited by comparison with notes taken by Alpine Environmental.

In order to promote open discussion, none of the ideas or comments made at the workshop was attributed to specific attendees. The opinions and ideas expressed by individual workshop attendees have not been verified or validated in any way. For the sake of brevity, the text given below has been paraphrased from statements made at the workshop.

Note: The opinions and ideas presented below are solely provided by workshop attendees and are not necessarily the positions of NWRI, the California MTBE Research Partnership, or Alpine Environmental, Inc.

Notes from UST Workshop:

Round Robin 1: Identification of Suspected Problems

Note: These suspected problems have not been prioritized. The designation number is merely indicative of the sequence in which the suspected problems were identified by the workshop attendees.

1. Driver behavior.

2. Small/Insidious/Continuous Leaks.

3. Poor connections (still allowed) on older fiberglass tanks.

4. Owner behavior/attitude (reconciliation, poor records).

5. Repetition/overlap of regulations cause errors.

6. Lack of procedures/technologies to find small leaks.
7. Operational complexities of containment.
8. Under dispenser containment not required by federal regulations (California variability by time).
9. Lack of training/awareness of attendants.
10. Lack of clarity on rules and agency requirements.
11. No focus on big-ticket items.
12. We do not know if leak detection equipment and testing are adequate.
13. Standards not tight enough in light of recalcitrant compounds.
14. Current leak detection approach is inadequate.
15. Leak detection technology too gross (three orders of magnitude too high sensitivity).
16. Secondary containment design and management are inadequate.
17. Not enough consumer education/awareness.
18. We have not simplified design/install and operation and maintenance.
19. Vapor leaks.
20. Lack of enforcement of existing rules.
21. Inadequate secondary contaminant.
22. Inadequate training and associated requirements.
23. Regulations allow hybrid systems that leak.
24. Lack of oversight of UST personnel.

Explanations and Comments made during Round Robin 1:

- Fuel delivery is critical to perform properly - numerous ways for spillage to occur.
- We need to find contamination patterns for small leaks.
- Connections in old fiber-glass fittings - older single wall - use of improper materials for connections.
- Owner’s attitude and behavior - record keeping - reconciliation on a daily basis. What we want to see is the site that has a problem do proper record keeping. Problems can then be pin pointed immediately. The stations that are not record keeping are the ones with big spills underground.

- Inventory reconciliation - regulators/agencies are interpreting the data differently. Do not need new regulations - modify existing ones.
- Too many agencies and interpretations - cannot enforce.
- Repetition and overlap of regulations causes confusion and errors.
- Benefits of containment - owners have to deal with false alarms.
- Under dispenser containment not required in federal regulations.
- Lack of training/awareness - owners, operations, and station attendants are unaware of problems and/or do not report them. Lack of adequate response and poor vigilance prevalent.
- Vapor recovery systems not monitored.
- Lack of clarification of rules - confusion between agencies and agency requirements.
- Adequacy of leak detection devices is questionable. However, a lot of the systems do better than the leak detection rates required by the regulations.
- Deal with big-ticket items like: insure quality of installation; use good equipment; and, adequate enforcement leading to compliance. Make sure equipment is properly maintained. Tackle big known problems up front.
- Sophisticated detection systems not working because they are not turned on or are pulled out. Not finding leaks at right time - no adequate leak detection system, inadequate pressure testing. Existing procedures adequate?
- Better standards needed due to recalcitrant contaminants. There's no systematic testing protocol for compatibility. Permeability standards are safety-related, not tightness/leak related. Fiberglass Institute has done tests but not many and there's no standard method.
- Increase level of awareness and behavior of people throughout industry.
- Overall better approach to leak detection is needed. Examine approach.
- Fuel loss detection technology too gross. Systems not designed to measure small quantities.
- Better secondary containment and management (design and manage).
- Public education (consumer).
- Educate installers/designers.
- Upgrade design and qualifications of installation personnel.
- Vapor system leaks - sites with problems have high product alarms. Vapor tightness testing is required for vapor-assist systems (CARB requirement). Other vapor systems may not have testing requirements.

- Lack of enforcement on existing rules.
- Adequate training for contractors - qualifications of people installing needs to be looked at as well as training requirements.
- Training requirements in Calif. and Federal regulations need to be changed.
- Tank testing is scientific - people that do testing are not qualified especially on hybrid systems.
- Lack of oversight by inspectors of what is going on in field.

Round Robin 2: Suggestions for improved UST management and operations practices

Note: These suggestions have *not* been prioritized. The designation number is merely indicative of the sequence in which the suggestions were identified by the workshop attendees.

1. More regulatory authority over UST personnel.
2. Adequate and uniform training/education for regulators.
3. Provide a consolidated document for USTs and regulations.
4. Improved knowledge transfer to the field.
5. Improved/standardized protocol for annual certification of monitoring systems.
6. More thorough compilation and investigation of leak causes.
7. More vigorous enforcement.
8. Better design and management of secondary containment.
9. Better environmental sensors outside the UST system.
10. Better environmental sensors, specifically for groundwater.
11. Better design/more comprehensive containment.
12. Assuring adequate resources for enforcement.
13. Develop and fund service-station attendee certification program.
14. Better cleanup methods for recalcitrant compounds.
15. Ensuring technology upgrades/improvements are fully implemented.
16. Broaden responsibilities of service-station personnel.
17. Better forensic analysis of leak causes.

18. Continuously improve human factor.

19. More responsible and better-educated owners/operators.

20. Proactive and sensitive tank owners, or per regulations (if necessary).

21. More field forensic data.

Explanations and Comments made during Round Robin 2:

- More control over regulating people who work in industry; require that they have certifications. Limited by what is administratively enforced. More authority over them such as pull their license, take them off the job, etc. More regulatory control and authorization over installers, contractors and personnel.
- Regulators need to be more informed. For example, on the West Coast, some personnel who are overseeing tank installation do not know proper testing, installation, etc. Problems with knowledge level of inspectors and regulators.
- Consolidate and provide all requirements/documentation for operators of service stations, etc.
- Problem #18 needs to be more definitive. Standards do exist but how do you improve the knowledge base? We need requirements that will enforce the use of specs in the field and design requirements that we already have. How do you get them to installers?
- Better and more standardized protocol for monitoring systems. There's now a very wide array. Some problems include: sensors not being listed properly; wiring not done properly; and, no clear understanding of what a particular sensor can do.
- Systems recording feedback of various causes of leaks. Focus on investigative process of leak causes. More thorough investigation and compilation of information.
- Enforce more.
- Improvement in design construction operation.
- More emphasis on reporting when leak monitor goes off. We do not need new leak monitor systems, etc.
- We need better design and management.
- Change way of thinking regarding secondary containment and design. Change focus to monitoring of contaminants coming into the environment - put vapor sensors outside the secondary containment. Need better environmental sensors outside of tanks.
- Environmental monitoring systems - not vapor monitoring, but for shallow ground water. Need some kind of ground water detection device.
- Create fund through legislation.

- Protect resources/groundwater/drinking water.
- Better/more comprehensive design on overall leak detection system. Total system containment.
- More incentives or better way to ensure enforcement. Maintain adequate resources to make sure system works.
- Develop and fund service station attendant certification.
- Minimum frequency of inspections should be every six months. Ground water monitoring systems need to be regulated. This needs to be on oil company side - do engineering analysis of service station design/marketing. Design environmentally friendly system.
- Installation based on marketing system, *not* tank installation.
- Detect problems earlier — good ways to clean up what we have done.
- Secondary containment — areas that have concerns with MTBE. Something else we are missing — there's not a mechanism to deal with these problems. Needs to be a means to replace old technology with new technology — equipment can get aged — improve design -— it does not meet today's standards. Be able to deal with situation five years from now or we will be recycling the same problems. Bring in latest equipment to existing systems. Technology fully implementable.
- Broaden responsibilities of attendants. Watch carefully what is going on.
- Better forensic evaluation of leak cause(s).
- Slow down focus on new equipment/monitors/regulations, etc. and concentrate more on creating programs to make human factor more effective. Condense regulations and make more manageable.
- Make owners/operators aware of their responsibilities and educate. Owners will make sure operators are more educated. Operators often do not know how to manage USTs.
- Tank owners should take voluntary and more proactive role in technology changes.
- Need more field forensic data, prioritization, etc.
- Two studies done recently show good indication of enforcement and compliance.
- Bureau of Audits found sites audited that did not have permits and had disconnected leak detection systems.
- Vapor assist systems are required to be vapor tight. Bigger question is on balance systems. Vapor assist systems required to be tested on regular basis. Document compatibility of systems for end users. Only pre-1981-82 compatibility documentation is now available.

Open Discussion: Possible UST Topics for Research

- In 95-99 percent of cases, drivers are adequately trained but do not have personal level of responsibility. They currently sign documents stating they fully understand requirements. DOT requires training (minimum standards). Need bigger carrot/bigger stick. Fining them seems to improve behavior. Drivers need to understand they are "frontline" folks.
- Where is money going to come from?
- Clearly, we do not know enough about leaks. There are good stations and bad stations. Some leak, some do not.
- Industry does not have human behavior research results. Create model of desirable/good behaviors for education/training programs. Operators have "what's in it for me?" attitude. Identify positive behaviors and prioritize them.
- With respect to human behavior, get personnel training and tools to do it. Ultimately, we will need "reward and penalize" systems. Empower frontline personnel.
- Create consequences so that people will comply. Difficulty in proving that person(s) had training and knowledge.
- Pass knowledge on to consumer. More public education is needed regarding such things as "topping-off."
- Prioritize all these factors. Which behaviors are key?
- Air-quality concerns.
- Take responsibility by informing someone if you have spilled or see someone spill.
- Research into leak detection designs that are specific to petroleum and do not get set off by water. More important than this is that sensors are used properly.
- Compatibility and permeability of existing systems to all new fuel components. Need hard data - tank owner should have data. Tank owners should know if certain components are compatible with certain products. Effectiveness of leak detection and all other systems (i.e., tanks/float valves/fiberglass tanks, etc.) is dependent on compatibility.
- There are many unregulated tanks outside California. The potential impact of these tanks should be evaluated.
- Consumers generally do not care about USTs; they need education.