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DETECTING LEAKS

Successful Methods Step-by-Step

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Office of Underground Storage Tanks
U.S. Environmental Protection Agency
Washington, D.C. 20460

PREFACE

This handbook provides basic information on release detection that you—as state and local regulators—will find useful in developing and implementing the release detection portion of your program for regulating underground storage tank systems (USTs).

This information is meant to foster your understanding and use of the release detection methods appropriate for your individual UST programs. The handbook contains information on the methods of UST release detection that were the most widely used at the time of publication; inventory control, manual tank gauging, tank tightness testing, automatic tank gauging, vapor monitoring, ground-water monitoring, secondary containment with interstitial monitoring, and piping release detection methods.

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Disclaimer

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use. Other alternatives may exist or may be developed.

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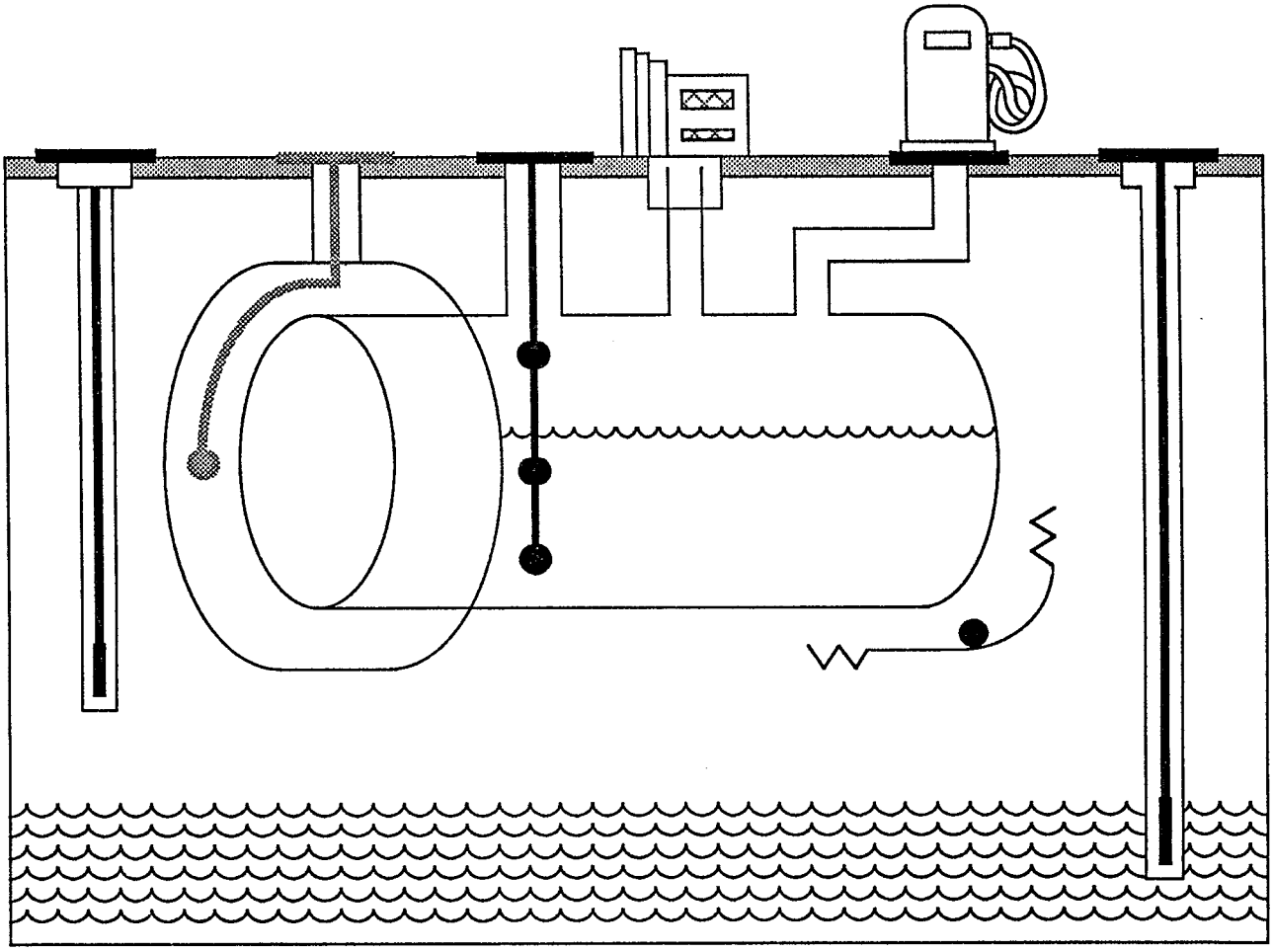
Chapter I
Introduction



INTRODUCTION I

PURPOSE OF THE HANDBOOK

This handbook provides basic information on release detection that you— as state and local regulators—will find useful in developing and implementing the release detection portion of your program that regulates underground storage tank systems (USTs).

Even though tens of thousands of UST systems have had leaks or are currently leaking, most existing UST systems are not currently being monitored for releases. As a result, Federal regulations now require all UST systems containing petroleum or certain hazardous chemicals to have effective release detection.

Although some states and local governments have had active UST programs for several years, most regulators are just beginning to acquire the knowledge necessary to develop and implement UST management programs. This handbook supplies information useful in acquiring that knowledge.

Because the Federal release detection requirements will be implemented through your state and local regulatory agencies, you need information during the development of your UST program to answer the following questions:

- What release detection methods are allowed?
- How do these methods basically work?
- What potential problems does each method have?
- What solutions to these problems are available?
- How can you make sure UST owners and operators are aware of these potential problems and respond to them?
- How can you make sure that the providers of release detection follow proper protocols and practices?

You will find enough basic information in this handbook to answer these kinds of questions as you develop and implement effective release detection programs.

The handbook is not intended, however, to be a technical "how to" manual for the release detection methods. It should not be used to become familiar with the intricacies of different brands of test equipment.

CONTENTS OF THE HANDBOOK

The handbook provides information about the following methods of release detection for tanks allowed in the final rule (53 FR 37196-37212):

- Inventory Control
- Manual Tank Gauging
- Tank Tightness Testing
- Automatic Tank Gauging
- Vapor Monitoring
- Ground-water Monitoring
- Secondary Containment with Interstitial Monitoring

The handbook also contains information on the release detection methods allowed in the final rule for underground piping.

The specific release detection methods allowed in the Federal rule have been demonstrated to successfully detect petroleum releases from UST systems and are currently allowed under several established state and local programs.

The chapters that follow describe the release detection methods allowed under the Federal regulation. Each chapter focuses on a series of topics presented in the same general order:

- Summary of the chapter
- Brief description of the release detection method
- Potential problems associated with the method
- Solutions to the problems
- Ways to oversee or enforce that proper release detection takes place
- Technical references

The information in this handbook was initially gathered by EPA to support development of the final federal regulations. It was gathered, in part, from numerous visits to state and local programs and from experienced vendors of the various methods. Additional important technical information came from an extensive release detection research and development program conducted by EPA laboratories in Edison, New Jersey, and Las Vegas, Nevada, from 1985 through 1988.

USE OF THE HANDBOOK

On the next page, you will find a generalized flow chart (Figure 1) of the process used by state implementing agencies to develop UST release detection programs. This chart is based on information from several states that have already developed UST programs. Agencies typically begin by writing regulations on leak detection. The crucial decisions in this area are what methods to allow and what design and performance standards are necessary to ensure that the methods are effective. Once the regulations are in place, the states face the issue of how to implement their requirements. States have developed a variety of oversight mechanisms to ensure that testers or installers follow the design and performance standards.

The following sections provide expanded discussions of how you can use the handbook in developing a leak detection program as outlined in Figure 1.

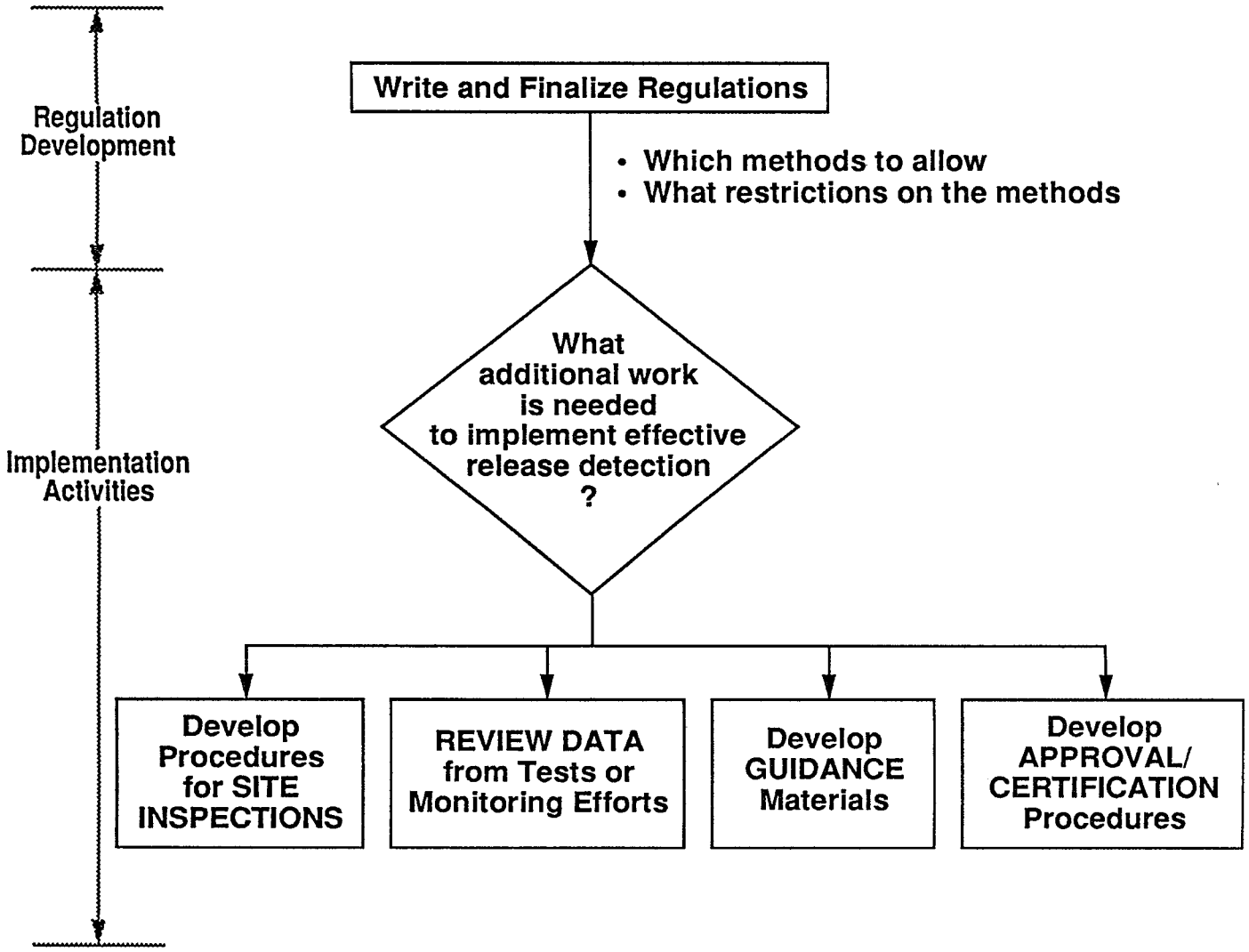


Figure 1. Development of a state or local leak detection program

Which Release Detection Methods Should You Allow?

In writing the federal regulation, the U.S. Environmental Protection Agency reviewed existing release detection methods and state UST programs and selected the methods that were demonstrated to be effective. States have the option of being more restrictive when deciding which methods to allow within their jurisdiction. EPA believes that, with appropriate restrictions and oversight, most, if not all, release detection methods discussed in this handbook can be successful for any given set of site conditions. Therefore, there should seldom be a reason to exclude a type of release detection from a state program. Many of the problems that are rumored about a method, such as background contamination interfering with vapor monitoring, can often be avoided or overcome. The chapters on the specific release detection methods provide detailed discussions of solutions to potential problems for both contractors and state officials.

None of the methods (including secondary containment with interstitial monitoring) is fail-safe and assures detection of all leaks. EPA research and state and local experiences in the field have shown, however, that each of these methods has proven to be effective in detecting UST releases when used properly and within the inherent design limitations of the method. EPA has developed this handbook in the belief that a better understanding of potential key limitations of each method will convince you that each one can have an important role in your UST program for detecting releases.

Although the handbook discusses the potential limitations or problems with each method, it does not provide information on how frequently these problems actually occur today in the field. In fact, many of the reservations identified in the handbook concerning a method's proper use are already well known and carefully controlled for by experienced providers of release detection. Thus, many of the problems identified in the handbook may not need special state or local consideration or oversight to ensure that a particular method is being effectively applied.

For example, numerous tightness testers have recently adjusted their protocols and training materials to incorporate the lessons learned from EPA's tank testing research completed at the Edison, New Jersey, laboratory in 1988. Accordingly, many of the concerns raised in the tank tightness testing and automatic tank gauging chapters of the handbook are now well known in the release detection service industry

and have been used recently to increase the quality of the testing services and equipment being provided nationwide.

In spite of the basic technical soundness of the different methods, however, new entrants or otherwise inexperienced members of the rapidly developing release detection service industry may need some state and local oversight and guidance to assure their methods are properly applied. Likewise, typical UST owners and operators may need some help in selecting and using the right release detection method for their sites. This handbook will help you develop regulatory programs that assure release detection is used effectively at all UST systems.

Table 1 on pages 8 and 9 presents a summary of the important factors that affect the success of each release detection method. Included in the table are summaries of the important design or operational elements that each method should include to account for specific site conditions. These elements are explained more completely in the chapters on each release detection method. As can be seen in the table, there are very few site conditions that completely eliminate from consideration any of the approaches to release detection. Most methods will work at a site given the selection of appropriate equipment and proper installation and operation. Different site conditions favor different methods. For example, ground-water monitoring is more effective in areas with shallow ground water and with a product that floats. Methods that are external to the tank itself, such as vapor monitoring or ground-water monitoring, are more effective for large tanks. Methods that are internal to the tank or its containment (interstitial monitoring, tank tightness testing, automatic tank gauging, manual tank gauging, and inventory) are more effective for highly contaminated sites. Tank owners and operators will be best able to meet the regulations considering their specific site conditions if all choices are left open to them. The availability of a wide selection of release detection methods allows the owner or operator to get an effective leak detection system for the lowest cost.

The information listed in the table is applicable to both tank and piping release detection. However, while manual tank gauging and inventory control will effectively detect leaks from tanks, the sensitivity of these methods is very low when applied to piping. Even the procedures outlined in the table will not improve the performance of these methods sufficiently to make them acceptable stand-alone release detection methods for piping. The sensitivity of automatic tank gauging to piping releases is still unproven.

What Restrictions Should You Place on the Methods?

As illustrated in Table 1, most methods will work in most situations as long as proper procedures are followed. In developing their UST programs, implementing agencies may elect to place restrictions on allowable release detection methods to ensure maximum effectiveness. Each chapter contains a table titled "Indicators and Solutions for Problems" that summarizes the information presented in the chapter, and the column titled "Solutions" summarizes the actions that are necessary to ensure effective release detection with that method. This is the information that should be evaluated when an implementing agency is considering regulatory limitations on the use of a method. For example, the chapters on ground-water and vapor monitoring include monitoring well network design requirements from several existing state UST programs that have been confirmed as effective through a combination of field experience and EPA research.

What Agency Oversight Mechanism Should You Use?

Once leak detection regulations have been adopted, there are four basic approaches that an implementing agency can use to oversee the work of release detection testers and installers to ensure that appropriate methods have been chosen and that the correct procedures are followed by testers and installers (see Figure 1). The "Indicators and Solutions for Problems" table in each chapter contains a column titled "Agency Oversight Options" that lists possible applications of these approaches to the specific release detection method; the oversight options are discussed in more detail in the text of the chapters. The following discussions present general descriptions of the approaches and their advantages and disadvantages.

Site inspections

Some local agencies have found that having their staff present during release detection tests effectively ensures that tests are conducted properly. Before such an approach can be implemented, agency personnel have to be trained in proper procedures and develop either a checklist of important features to be examined at each site or an inspection procedures manual.

Table 1. Effect of Site Conditions on Success of Release Detection Methods for Tanks and Piping

Site Conditions	Manual Tank Gauging and Inventory	Automatic Tank Gauging	Tank Tightness Testing	Secondary Containment with Interstitial Monitoring	Ground-Water Monitoring	Vapor Monitoring
Ground water	Shallow ground water may interfere under some conditions. Use water-finding paste to detect water in tank.	Shallow ground water may interfere under some conditions. Use sensor to detect water level in tank.	Shallow ground water may mask a leak. Can be used in high ground water if ground-water level is measured and product level in tank is raised to overcome ground-water pressure. Do not test when ground water is fluctuating.	Shallow ground water may interfere with sensors. Use fully double-walled USTs, excavation liners, or jacketed tanks or methods that are not affected by water.	Deep ground-water delays detection. Do not use for sites where (a) ground-water depth is > 20 ft or < 3 ft or (b) ground-water fluctuation exceeds well screen interval for more than 30 consecutive days. Place some wells downgradient to UST, if grade can be determined.	Shallow ground water may interfere with sensor. Do not use in saturated sites.
Product type	N/A	Effective for products with viscosity and thermal properties similar to gasoline and diesel fuel.	Effective for products with viscosity and thermal properties similar to gasoline and diesel fuel.	Depends on sensor construction.	Product must float on ground water to be detected (most petroleum products do).	Lower volatility products delay and may prevent detection. Effective for gasoline. Response to other products should be verified. For less volatile products, add tracer compound, use aspirated sensors and more and larger diameter monitoring wells, or set lower alarm levels.
Tank size	Less effective for large tanks. Manual tank gauging limited to less than 550 gallons when used alone or less than 2,000 gallons when combined with tightness testing.	Less effective for large tanks. Generally applicable to tanks ≤ 12,000 gallons. Applicability to larger tanks depends on method and must be demonstrated.	Less effective for large tanks. Generally applicable to tanks ≤ 12,000 gallons. Applicability to larger tanks depends on method and must be demonstrated.	N/A	N/A	N/A

Backfill permeability	N/A	N/A	N/A	With excavation liners, backfill must be permeable to allow release to be detected Use sand or pea gravel as backfill.	Use sand or pea gravel.	Use sand or pea gravel.
Existing site contamination	N/A	N/A	N/A	Use monitoring method that can distinguish leak from existing contamination or use full double-walled tank or completely sealed excavation liner or tank jacket.	Floating product from prior releases may cause false alarm. Do site assessment in areas of suspected background contamination, and use other methods if contamination would cause false alarm.	Do not use at site with high (background concentration $\leq$ 15,000 gallons ppm for gasoline) unless a manufacturer can show how their device works at high background levels. Tracer compound may also be used.
Temperature	Temperature difference between newly delivered product and product in tank limits accuracy. May use simple temperature measurement to partially compensate.	Measure product temperature for at least three levels in tank. Use longer waiting times before testing as temperature difference between newly delivered product and product in tank increases.	Requires frequent measurement of product temperature for at least three levels in tank; or that the product mixed. The greater the temperature difference between added product and tank, the longer the wait before testing. A few methods are independent of temperature.	Freezing of interstitial fluid in hydrostatic systems will prevent detection while high temperatures may cause false alarms because of loss of fluid through evaporation. Add antifreeze in cold weather and add more fluid in hot weather.	N/A	Low temperatures reduce sensitivity. Install sensors below frost line. Use more and larger wells or aspirated systems to compensate for reduced volatility of product.
Subsurface conduits	N/A	N/A	N/A	Subsurface conduits should not be in backfill. May cause leak to migrate so that it will not be detected.	Subsurface conduits should not be in backfill. May cause leak to migrate so that it will not be detected.	Subsurface conduits should not be in backfill. May cause leak to migrate so that it will not be detected.

*N/A = No significant impact on test method.

There are several advantages to having a knowledgeable regulator observe the installation and/or operation of the test equipment. Observation may cause the testers to be more conscientious about following procedures. If deviations from proper procedure occur, the inspector can catch them immediately and require a correction or retest. An observer may be able to provide suggestions when problems arise. A third-party observer may provide additional credibility to the test results, in essence "certifying" that the test results are valid. Finally, if a release is detected, the regulator is on-site and can begin investigation immediately. Site inspections, however, are expensive and labor intensive and may create considerable scheduling difficulties when a limited number of people are available to conduct the site visits. The following discussion on data reviews indicates a possible approach that requires less resources.

Data review

It is possible to require that release detection installers, testers, and tank owners keep detailed records of site conditions, events, time, results, etc., during a test and submit these records to the implementing agency. Regulators can then review all of the reports, which would be somewhat time-consuming and expensive, or a certain percentage of the reports, possibly on a random basis. All aspects of the tests may be reviewed or, to save time, only those aspects that have been determined to be most crucial for that method in that locale. The most important things to check for in the installation, operation, and interpretation of each method are listed in the method-specific chapters. For example, jurisdictions with a lot of clay deposits in the area may want to check the boring logs for ground-water or vapor monitoring wells to verify that product could get to the well if a leak occurred. For test methods that require calculation, a manual or computerized check of the calculations may be performed.

A program to review test data costs less in time and money than a site inspection program and has some of the same benefits, although to a lesser degree. The obviously bad tests will be identified with less effort than an inspection program would take. Discovery of questionable results in a data review may be used to target scarce inspection resources. There are two main drawbacks to such an approach. First, test reports may accumulate unread while regulators work on problems of more urgency. Second,

correcting a problem "after the fact" is more difficult than correcting it on-site as soon as it happens, both in terms of the regulator finding the time to do it and in enforcing additional action by the owner/operator or tester after the tester has left the site. A program to mail back deficient reports, inspect sites with deficient reports, enforce retesting, etc., may be as expensive as doing the site inspections initially.

Guidance or training

Release detection equipment installers and testers may conduct tests improperly out of ignorance of the proper procedures. Several implementing agencies have issued guidance to owners and testers that identifies the worst procedural violations and helps to ensure that release detection is effective. Guidance for testers and installers may be in the form of booklets, videos, or training seminars. Another approach to guidance would be to provide a checklist of important procedures for each release detection method to owner/operators for use during a test, so that they can knowledgeably observe installation and testing at their sites.

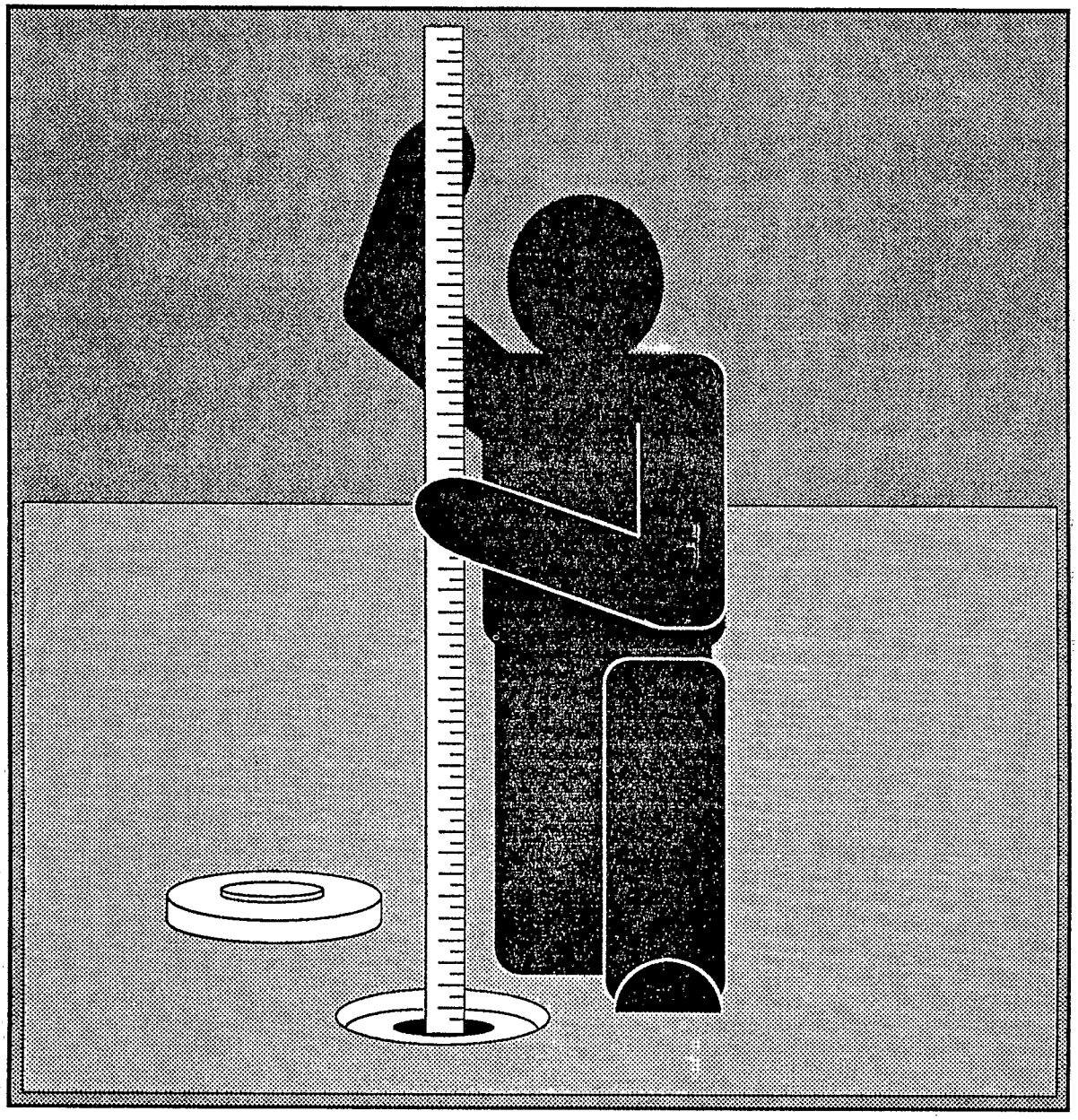
This approach attempts to correct the problems before they occur and can reach a fairly wide audience at relatively small expense. By educating one tester or testing company, procedures at many future tests have been improved. However, review of the guidance material and adherence to its recommended procedures is voluntary.

Approval/certification of release detection methods and personnel

Licensing or certification of release detection equipment and/or operators is one potential means of ensuring valid test results. The regulatory agency would have to set up some mechanism for reviewing and approving equipment and/or personnel. There are several ways in which equipment might be approved. A board of knowledgeable regulators can review written evaluations of a method's performance or hear presentations made by manufacturers, during which any questions can be answered. A regulatory agency may accept the findings of an independent third-party evaluation. EPA is developing standard procedures for testing leak detection equipment that can be used by independent laboratories to evaluate the performance of commercial methods.

Approving leak detection equipment has two main advantages. First, it allows the agency to make clear and helpful recommendations to owners about what methods are acceptable. Second, it allows the agency to evaluate the claims made by manufacturers and ensure that owners and operators use effective equipment. The EPA test procedures should allow regulators to compare the performance of various methods that have each been tested the same way. Licensing of leak detection testers or installers is more difficult than approving equipment. There are many more contractors than manufacturers and the skills required are diverse. Possible methods for screening personnel for licensing include written examination, field observation, field test, apprenticeship, and training requirements (manufacturer certification). Any effective licensing/certification program also requires a follow-up program to identify equipment or personnel that is operating without a license. Also, some system of sanctions against violators is needed. Such follow-up programs also may be time-consuming and expensive. Studies of occupational licensing programs in many areas have shown little improvement in service quality after the program has been initiated, especially when an examination is the only requirement. Controlling testers and installers is important, however, because of the crucial role procedure plays in determining leak detection effectiveness. Each of the following chapters describes the available leak detection methods and important aspects of procedure in greater detail.

Chapter II
Inventory Control



INVENTORY CONTROL II

SUMMARY

To date, the practice of underground storage tank (UST) inventory control primarily has been limited to use as a business practice to keep track of product, and indirectly as a release detection method, for motor fuels stored at retail distribution facilities. Inventory control, also called inventory reconciliation is claimed to be the simplest and most economical leak detection method. The technique is effective for finding larger leaks (over 1 gal/h) if "recommended practices" are followed. Because inventory control has low sensitivity, EPA requires that it be combined with tank tightness testing. Recommended practices for inventory control can be found in the American Petroleum Institute's Publication API 1621, *Recommended Practice for Bulk Liquid Stock Control at Retail Outlets*. Parts of the following discussion are largely based on this publication.

The discussion presented in this chapter covers many of the possible problems that may occur during inventory control. This does not mean that all, or even most, of these problems will occur. Nor does it mean that all of the problems are of equal importance, in terms of frequency of occurrence or severity of impact on the effectiveness of inventory control. Some problems occur infrequently, while others have limited impact. This chapter presents a range of potential problems for educational purposes, not to imply that they will always occur.

BRIEF DESCRIPTION

Inventory control is basically an ongoing accounting system, similar to a check book. Its objective is to reconcile the inputs and outputs of a stored substance in a given UST with the volume remaining in the UST. Careful records of all product delivered, product dispensed, and daily tank inventories are recorded on a ledger-like form and reconciled on a monthly basis. The system "imbalance" at the end of a month, the difference between book inventory and measured inventory, is compared to a threshold value to help determine whether the imbalance signifies a leak.

Daily UST inventories are determined by using a gauge stick (similar to a yard stick). The stick is inserted vertically through the fill tube until the end of the stick touches the tank bottom. When the stick is removed, the level of the product corresponds with a number on the stick (similar to the way a car's oil level is indicated on its dipstick) which, by using a calibration chart, can be translated to a volume of product in the tank. A calibration chart often is furnished by the UST supplier. The chart shows the number of gallons represented by each inch on the gauge stick. Each chart is calculated for a specific brand of tank with particular dimensions and capacity, and the chart used must correspond to the tank being gauged.

Once the volume of product in the UST is determined, it is recorded on a ledger form as the UST's daily inventory. The amounts of product delivered to and withdrawn from the UST each day are also recorded. At least once each month, these data are compared to determine if the volume measured in the tank corresponds with sales and delivery records.

The process of obtaining inventory information and its reconciliation, can be divided into five steps: (1) tank gauging—the process of measuring the stored substance or the water in an UST; (2) calibration—the correlation of a gauge reading with the proper calibration chart to determine the volume of the product in the UST; (3) tank stock control—the determination of the amount of product that was added to and withdrawn from the UST; (4) recording and reconciliation—the use of an accounting form to record and reconcile the information gathered; and (5) interpretation—the determination of whether the result of a month of inventory records signifies an UST release. The relationships among these five stages are shown in Figure 2.

POTENTIAL PROBLEMS AND SOLUTIONS

A number of factors can affect the accuracy of inventory control as a release detection method. Often an apparent loss of inventory may occur even though the UST is sound; inventory records also may show an overall increase in product. The following sections discuss problems and solutions related to each of the five steps involved in implementing inventory control. The order of discussion is not intended to prioritize the importance of the problems, rather it is intended to follow the order in which they would occur according to

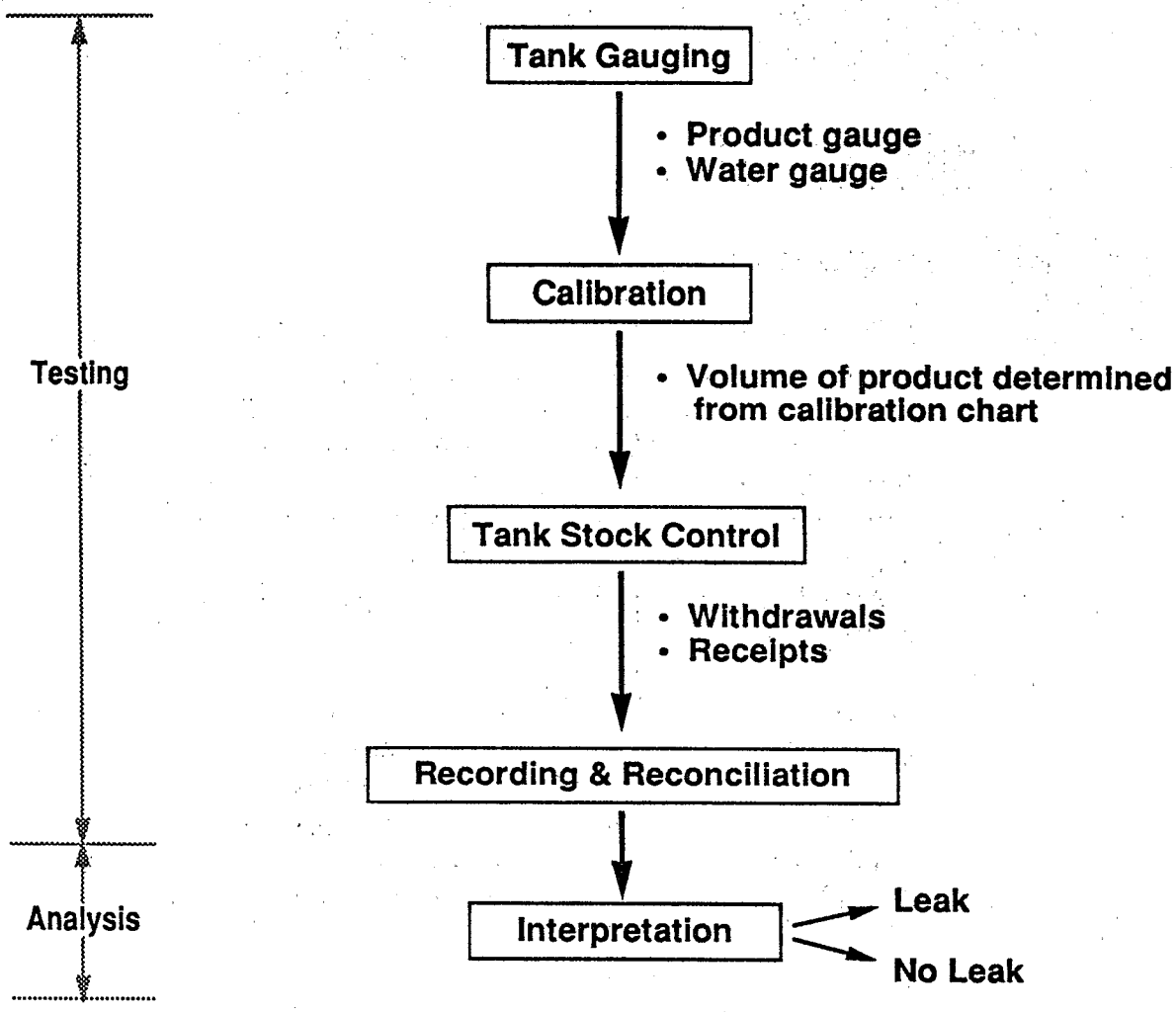


Figure 2. General procedure for inventory control

the flow chart in Figure 2. The discussion of problems and solutions is summarized in Table 2 on pages 18 and 19, in the order of the discussion, and the most serious concerns have been marked by an asterisk. Some agency oversight options are offered for problems, when applicable, but not all of them need be undertaken.

Tank Gauging

Testing → Analysis

Assure the tank is gauged properly

If a tank is not gauged properly, the gauge reading will not correspond well to the actual volume of product in the UST. Accuracy will decrease if a gauge reading is inadvertently taken with the stick slanted or resting upon a protrusion (e.g., an internal support ridge) in the tank, or if the stick is "bounced" off the bottom of the tank. Accuracy is increased by careful, vertical insertion of the stick, by taking more than one gauge stick reading and wiping off the gauge stick between readings, then carefully noting and averaging the results.

According to API, to properly gauge a tank, the stick is placed into the tank through one of the openings in the tank until its tip touches the tank bottom. Some tanks have a separate opening, called a gauge hole, used for gauging the tank. The tank fill pipe opening can be used to insert the stick if there is no gauge hole. The stick should be inserted at the same point in the gauge hole each time a gauge is taken and should be held in a vertical position. After the stick is quickly withdrawn, the product "cut" (wet mark left by the product on the gauge stick) is read on the graduated scale to the nearest 1/8 inch. Once the stick is cleaned by wiping the "cut" with a cloth, the procedure is repeated. Both readings should be recorded. The average of the measurements should be used to calculate the product volume in the tank.

Some UST owners prefer that two, consecutive gauge readings be taken at both open and close each day or before each change in working shifts. However, an accurate inventory reconciliation can be obtained with only consecutive closing *or* opening gauges on a daily basis. That is, one or the other should be chosen and the tank gauged consistently at that time. Additionally, the tank meter should be read at the same time of day that the tank gauges are taken. Implementing agencies could provide some type of training to owners and operators teaching a preferred method.

Testing → Analysis

Avoid damaging the tank from careless gauging

Repeated gauging of a tank may wear a hole in the bottom of the UST. When the gauge stick strikes the bottom of the tank, rust can be chipped off of the surface and expose new metal, thus allowing for quicker corrosion and the development of a hole in the tank base. This can be protected against by careful gauging and by outfitting the tank with a striker plate. A striker plate is simply a layer of metal added to the tank to increase its strength in the area that comes into contact with the gauge stick. Unless the striker plate is of negligible thickness, whenever a striker plate is added to an UST, the end of the gauge stick must be modified by cutting off a length equal to the thickness of the striker plate so that true volume conversions can be obtained.

Testing → Analysis

Ensure accuracy of the product reading

If the gauge stick is used to gauge gasoline or other volatile products, the side adjacent to the graduated side should be grooved every 1/8 inch to keep the product from moving up the stick past the measured level (creepage). Additionally, product-finding pastes, applied over the stick in a light, even film, can significantly improve the accuracy of gauging. Pastes improve adherence of product to the gauge stick and prevent creepage. Product-finding pastes change color in the presence of product.

Testing → Analysis

Water in the tank must be identified

The presence of water in an UST results in an inaccurately high gauge reading. Water intrusion may indicate a leak, especially in high ground water situations. In addition, water may enhance corrosion.

To identify the presence and measure the amount of water, a water gauge must be taken at least once a month. A water-finding paste, which is unaffected by the stored product but changes color in water, is used to check for water at the bottom of USTs. Information on satisfactory pastes may be obtained from an equipment supplier.

A water gauge is taken in the same manner as a product gauge; however, the length of time the stick remains in the tank should be monitored carefully. The immersion time for a water "cut" is

Table 2. Indicators and Solutions for Problems Encountered During Inventory Control

Problem	Indicators	Tester Solutions	Agency Oversight Options
***Assure tank is gauged properly.**	Slanted stick. Dipstick not wiped. Large discrepancy between consecutive gauges.	Take consecutive gauge readings. Wipe dipstick between gauges.	Provide training.
Avoid damaging tank from careless gauging.	Loss of product.	Add a striker plate to tank base. Gauge tank carefully.	
Assure accuracy of product reading.	No clear product line on gauge stick.	Use notched gauge stick. Use product-finding paste. Withdraw pole quickly.	
Water in the tank must be identified.	Water in gas. Unexplained gain in product amount.	Take a water gauge using water-finding paste. Take water gauges after delivery.	Require monthly water gauge. Check UST for water during site visits. Track customer complaints of water in gas.
Need to keep track of the temperature when taking gauges.	Large temperature changes.	Record daily temperature next to gauge readings. Do not take meter readings shortly after a delivery.	
Account for product evaporated during delivery.	Unexplained product losses.	Use vapor control. Use pressure relief valves.	Check weights and measures seal at retail stations. Check calibration before further leak investigation.
Assure the calibration chart corresponds to UST.	Specifications on chart do not match tanks.	Ask tank manufacturer to provide a chart that corresponds with their tank.	

Need to use the calibration chart correctly.	Imbalance in inventory.	Use chart according to API recommendations.	Review inventory forms.
Assure the accuracy for the pump meter.	Unexplained losses or gains.	Calibrate pump meter. Read meters when gauges are taken.	Require pump meter calibration.
Need to unquantify withdrawals or additions to the UST.	Unexplained losses.	Quantify all losses as closely as possible.	
Assure the data are recorded completely and correctly.	Imbalance in inventory.	Ask supply company for recommended recording practiice.	Review inventory forms.
***Assure proper reconciliation of data.**	Imbalance in inventory.	Follow proper reconciliation process. Double-check calculations.	Review inventory forms.
Need to interpret data correctly.	Imbalance in inventory.	Follow recommended interpretation process.	Review inventory forms.

***Indicates the most significant problem.**

approximately 10 seconds for light products such as gasoline and kerosene and 20 to 30 seconds for heavier products.

The quantity of water in the tank is calculated using the same procedure described for product calculations using a tank calibration chart. If the test shows more than 1/2 inch of water, arrangements should be made for its immediate removal, the product supplier should be notified that their product may contain significant amounts of water, and further tests should be conducted to ensure that the tank is not leaking.

Testing → Analysis

Need to keep track of the temperature when taking gauges

Temperature increases or decreases can cause an expansion or contraction, respectively, of the product within an UST. Expansions and contractions cause level changes that may mask or imitate a level change due to a leak. The difference between the temperature of the stored product and that of the delivered product will have the largest effect on the volume of product in the UST. However, the outside daily ambient temperature will also affect the system. On a daily basis it is important to be aware of the apparent losses and gains of product that temperature changes may cause. Ambient temperature should be noted when recording gauge readings, for reference when interpreting results. Effects may also be minimized by gauging the tank each day at the same time and by not taking gauges immediately after product delivery.

Testing → Analysis

Account for product evaporated during delivery

The more volatile (tendency of a liquid to change to vapor) the stored product is, and the higher the temperature is, the greater effect evaporation will have on the system. Evaporation losses primarily occur during UST filling. For gasoline, these losses average about 0.0012 gallon lost per gallon of throughput. This effect can be minimized by using vapor control, such as vapor recovery during filling, or by placing pressure relief valves on the tanks to reduce the pressure within the UST during filling, which reduces the amount of product that volatilizes.

Calibration

Testing → Analysis

Ensure the calibration chart corresponds with the UST

Underground tanks are fabricated as production items. The tank manufacturer supplies charts intended to be used for all tanks of the same nominal dimensions and capacities. Charts cannot account for variations in the position of a tank in the ground. For example, a tank may be tilted in the ground due to poor installation, settling, frost heave, etc. A tilted tank will vary from the chart in proportion to the degree it is tilted, and calibration charts cannot account for such variations. If a tank is tilted and the tank is being gauged from the middle, there is no effect. The amount of product will be overestimated if the tank is gauged at the low end and underestimated if the tank is gauged at the high end. The amount of overestimated or underestimated product will, however, be consistent as long as gauging is always done at the same end. If the tank is tilted, it should be remembered as a source of error. It is possible to create a tank chart specific to a tank by adding small known volumes of product to an empty tank and measuring the product level and repeating these steps until the tank is full. This approach is very time consuming.

The calibration chart's specifications should correspond to the UST's brand, size in gallons, and dimensions. Manufacturers should provide a calibration chart for their particular tank. A sample calibration chart is shown in Figure 3.

Testing → Analysis

Need to use the calibration chart correctly

If the calibration chart is read improperly or the calculations are done incorrectly, the volume of product in the tank may be estimated inaccurately resulting in false alarms or missed detections.

DEPTH	TANK CALIBRATION CHART							
Inches	550 Gal. 49 1/2"x5'5"	1000 Gal. 49 1/2"x10'	1000 Gal. 64"x6'	1500 Gal. 64"x9'	2000 Gal. 64"x12'	2500 Gal. 64"x15'	3000 Gal. 64"x18'	4000 Gal. 64"x24'
1	2	4	3	4	6	8	9	13
2	7	13	9	13	18	23	27	37
3	13	24	17	25	34	42	51	68
4	20	38	26	39	52	65	78	104
5	29	52	36	54	75	90	108	145
6	37	68	47	71	94	118	142	189
7	47	86	59	89	119	148	178	238
8	57	104	72	108	144	180	217	289
9	68	124	85	128	171	214	257	343
10	79	144	100	150	200	250	300	400
11	90	165	114	172	229	287	344	459
12	102	187	130	195	260	325	390	520
13	115	209	145	218	291	364	437	583
14	127	232	162	243	324	495	486	648
15	140	255	178	268	357	447	536	715
16	153	279	196	294	392	490	588	784
17	167	303	213	320	426	533	640	853
18	180	328	231	346	462	578	693	925
19	194	353	249	374	498	623	748	997
20	208	378	267	401	535	669	803	1070
21	222	403	286	429	572	715	858	1145
22	236	429	305	457	610	762	915	1220
23	250	454	324	486	648	810	972	1296
24	264	480	343	515	686	858	1030	1373
25	278	506	362	544	725	907	1088	1451
26	292	531	382	573	764	955	1147	1529
27	306	557	402	603	804	1005	1206	1608
28	320	583	421	632	843	1054	1265	1687
29	334	608	441	662	883	1103	1324	1766
30	348	633	461	692	922	1153	1384	1845
31	362	658	481	722	962	1203	1444	1925
32	375	683	501	752	1002	1253	1504	2005

33	389	707	521	781	1042	1303	1563	2085
34	402	732	541	811	1082	1353	1623	2164
35	415	755	561	841	1122	1402	1683	2244
36	428	778	580	871	1161	1452	1742	2323
37	440	801	600	901	1201	1501	1802	2402
38	452	823	620	930	1240	1550	1860	2481
39	464	844	639	959	1279	1599	1919	2559
40	476	865	659	988	1318	1648	1977	2637
41	486	885	678	1017	1356	1696	2035	2713
42	497	904	697	1046	1395	1743	2092	2890
43	507	922	716	1074	1432	1790	2149	2865
44	516	938	734	1102	1469	1837	2204	2939
45	524	954	753	1130	1506	1883	2260	3013
46	532	968	771	1157	1542	1928	2314	3085
47	539	980	789	1183	1578	1973	2367	3156
48	544	990	806	1210	1613	2016	2420	3226
49	548	997	823	1235	1647	2059	2471	3295
50	549	999	840	1260	1680	2101	2521	3361
51			856	1285	1713	2141	2570	3426
52			872	1308	1745	2181	2617	3490
53			887	1331	1775	2219	2663	3551
54			902	1353	1805	2256	2707	3610
55			916	1375	1833	2292	2750	3667
56			930	1395	1860	2325	2791	3721
57			943	1414	1886	2357	2829	3772
58			955	1432	1910	2388	2865	3820
59			966	1449	1932	2416	2899	3865
60			976	1464	1953	2441	2929	3906
61			985	1478	1971	2464	2957	3942
62			993	1490	1986	2483	2980	3973
63			999	1499	1998	2498	2998	3997
64			1002	1504	2005	2506	3008	4010

Figure 3. Sample Calibration Chart. Source: Buffalo Tank

The following procedure is excerpted from API publication 1621:

1. The chart should be read directly for all gauges which are to the exact inch or 1/16 inch above or below an exact inch mark.

2. For gauges of 1/8 inch (or more) over or under the exact inch the following procedure should be used:

a. The chart should be read for the exact inch on the scale above and below the actual gauge stick reading. For example, if the gauge stick reads 46 3/4 inches, the chart should be read at both 46 and 47 inches.

b. The smaller gallonage shown on the scale at these two readings should be subtracted from the larger, i.e., for a 1,000-gallon tank (diameter 64 inches; length 72 inches):

Chart reading at 47 inches = 789 gallons
Chart reading at 46 inches = 771 gallons
Subtracting = 18 gallons

c. This gallonage is then multiplied by the fraction of an inch shown on the original gauge, i.e.:

18 gallons times 3/4 = 13.5 gallons.

d. This gallonage (calculated in step c) is added to the gallonage shown on the chart for the lower whole inch reading, i.e.:

Gallons at 46 inches = 771 gallons
Gallons at 1/2 inch = 13.5 gallons
Total = 784.5 gallons

Therefore, a tank gauge of 46 3/4 inches, for the given UST, represents 784.5 gallons of product. Some companies offer computer programs that perform these calculations automatically.

If a water gauge has been taken, the quantity of water contained in the tank also is determined by using the above procedure. The total amount of water should be subtracted from the total amount of liquid in the tank (as determined in *step d*) to determine the net gallons of product contained.

Tank Stock Control

Testing → Analysis

Assure the accuracy of the pump meter

It is impossible to calibrate dispensing meters to be 100 percent accurate. Pump meter inaccuracy will cause a consistent, apparent loss or gain in inventory depending upon whether the meter is slow or fast. Once a meter has been calibrated, the system error can be limited during reconciliation. The pump meter must be maintained properly and calibrated frequently to keep it as accurate as possible and to determine the degree and direction of error the meter may be causing. All dispensing meters at retail outlets must be calibrated to weights and measure standards of the locality. A procedure for testing the accuracy of a dispensing meter is included in API publication 1621.

Testing → Analysis

Need to quantify all withdrawals or additions to the UST

Unaccounted for additions and withdrawals to the UST will cause an imbalance in inventory reconciliation. Withdrawal sources include all product withdrawn for personal use, any spills during delivery of product or at other times, and any thefts. For the sake of accuracy, withdrawals not shown by a meter should be quantified as carefully as is possible and included in the inventory records and reconciliation process.

All deliveries to the tank must be carefully recorded. A receipt showing the delivery amount should be kept for the inventory records. To check that the received product amount corresponds with the receipt amount, the delivery receipt should be reconciled with tank gauges taken immediately before and after delivery, noting any withdrawals that occurred during the delivery.

Recording and Reconciliation

Testing → Analysis

Ensure the data are recorded completely and correctly

Recording inventory data is the first step in the reconciliation process. The format for data entry varies greatly depending upon owner preference, number of USTs at a facility, and the inter-relation of these USTs. Because of the many different accounting systems that can be used to record and analyze the

inventory data, numerous different accounting forms are available. Many oil supply companies advise operators as to the proper accounting procedures to be used, including the use of suitable accounting forms and where they may be obtained. All inventory records should have a place to record daily receipts, daily withdrawals, and the volume of product associated with the closing inventory stick reading. A sample accounting form is shown in Figure 4.

Ensure proper reconciliation of inventory data

During inventory reconciliation it is easy to make mistakes that may improperly indicate that a tank is or is not sound. The basic formula for daily reconciliation of an UST's inventory is as follows:

Opening Inventory + Deliveries
- Sales - Unmetered Use - Closing Gauged Inventory
= Daily Overage or Shortage

Overage means that the gauged inventory is more than that which is accounted for by deliveries, sales, and other use. An overage is indicated by a final *positive* number. A shortage is indicated by a *negative* result, and suggests that the inventory remaining in the tank is less than that accounted for by deliveries, sales, and other use. This overage or shortage is recorded on a monthly reconciliation worksheet (see Figure 5 for an example). Inventory monitoring records from an UST that does not have a leak should have daily overages and shortages, that fluctuate randomly around zero. Large overages or shortages for one day, when no history of overages or shortages exists, should not be a cause for alarm unless similar results are obtained in future testing.

Sophisticated statistical analyses can be performed to reconcile the daily inventory records. These methods increase the sensitivity of inventory control and may identify tank conditions interfering with accuracy (e.g., tilted tanks). Owners/operators can purchase statistical reconciliation services from outside companies; such analyses typically cannot be performed by in-house personnel.

Sample Inventory Control Program DAILY Reconciliation Form

Location _____ Date: _____

Book Inventory			Regular Leaded	Regular Unleaded	Premium Unleaded	Diesel
1. Closing	1	+				
2.	2	+				
3.	3	+				
4.	4	+				
5.	5	+				
6.	6	+				
7.	7	+				
8.	8	+				
9.	9	+				
10.	10	+				
11. Total Meters		=				
12. Meters Out		+				
13. Meters In		−				
14. Dispenser Cal Test (gallons)		−				
15. Total Closing Meters		−				
16. Opening Meters		−				
17. Today's Sales		=				

Physical Inventory		Regular Leaded In. Gal.	Regular Unleaded In. Gal.	Premium Unleaded In. Gal.	Diesel In. Gal.
18. Tank 1 Product					
19. Tank 1 Water	−				
20. Tank 1 Net	=				
21. Tank 2 Product					
22. Tank 2 Water	−				
23. Tank 2 Net	=				
24. Physical Inventory					

Tank Reconciliation (gallons)		Regular Leaded	Regular Unleaded	Premium Unleaded	Diesel
25. Opening Physical Inventory					
26. Today's Sales	−				
27. Product Receipts	+				
28. Inventory Balance	=				
29. Physical Inventory	−				
30. Tank Over (if +)	=				
31. Tank Short (if −)	=				

Figure 4. Sample of daily reconciliation form

Sample Inventory Control Program MONTHLY Reconciliation Form

Location _____ Date _____

Daily Overage/Shortage Gallons

Line	Day	Regular Leaded	Regular Unleaded	Premium Unleaded	Diesel
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
	12				
	13				
	14				
	15				
	16				
	17				
	18				
	19				
	20				
	21				
	22				
	23				
	24				
	25				
	26				
	27				
	28				
	29				
	30				
	31				
1	Cum. Over. Total				
2	% Thru.				
3	Cum. Shrt.Total				
4	% Thru.				

Attention: The cumulative sum of monthly overages or shortages should not exceed 1.0% of the monthly throughput plus 130 gallons.

Figure 5. Sample of monthly reconciliation form. Source: API

Interpretation

Testing → Analysis

Need to interpret the reconciled data properly

Improper interpretation may result in an inaccurate indication of the UST's status. The federal regulation requires that an UST be reported to the local implementing agency as leaking when monthly reconciliation for two consecutive months indicates there is a cumulative monthly overage or shortage equal to 1.0 percent of total flow-through for the month plus 130 gallons. Using the form shown in Figure 5, the following explains the steps for determining this result:

Step 1. Enter the daily overage or shortage for each product, as determined during manual reconciliation, for each operating day of the month.

Step 2. When the daily overages and shortages from 31 operating days (or one continuous month) have been entered, add all overages and shortages and enter the value on line 1 or 3, as appropriate.

Step 3. Calculate the total flow-through for the month for each tank. (The total flow-through volume can be either the sum of the monthly pump readings or the total amount of product delivered in a month. Whichever method is chosen should be used consistently.)

Step 4. Calculate one percent of the total flow through and add 130 gallons to it to determine a comparison number, using the following formula:

(0.01 x flow - through) + 130 gallons = comparison number

Step 5. If the *cumulative* overage or shortage (determined in *step 2*) exceeds the comparison number (calculated in *step 4*), a leak in the UST system may be present. (It is likely that a mathematical error, pump miscalibration, unaccounted for delivery, or unaccounted for water is responsible for the discrepancy.) These results should be rechecked carefully, remembering that water may still be an indication of a leak. If the subsequent month's results again exceed the comparison number, the results

must be reported to the local implementing agency as a possible leak.

This process should be performed individually for each tank.

ENSURING EFFECTIVE MANUAL TANK GAUGING

Chapter 1 provides a general description of the types of oversight that can be used. The following sections discuss how these approaches may be applied specifically to inventory control.

Site Inspections

Site inspections to review the inventory records is a possible oversight mechanism. It would also be possible to observe the staff performing the actual measurements, to see if the tank gauging is performed correctly.

Data Review

Although all inventory control recording forms could be reviewed for proper recording and interpretation of gauging data, this would entail reviewing numerous forms. However, a smaller number of forms would need review if submission of forms was only required when a leak is suspected. Forms should be reviewed for accuracy in recording, in conversion of gauge measurements to volumes and to ascertain correct reconciliation.

Guidance and Training

Training could be provided to teach owner/operators proper tank gauging techniques and how to conduct proper inventory control. An alternative to training classes is guidance materials (e.g., a manual or a video tape). The API 1621 is an excellent resource for tank owners using inventory control.

Approval and Certification

Most errors in inventory control take place because the tank is gauged improperly. An implementing agency could provide training and

certification for all persons using inventory control. Training should cover the proper tank gauging technique, recording, reconciliation and interpretation of data.

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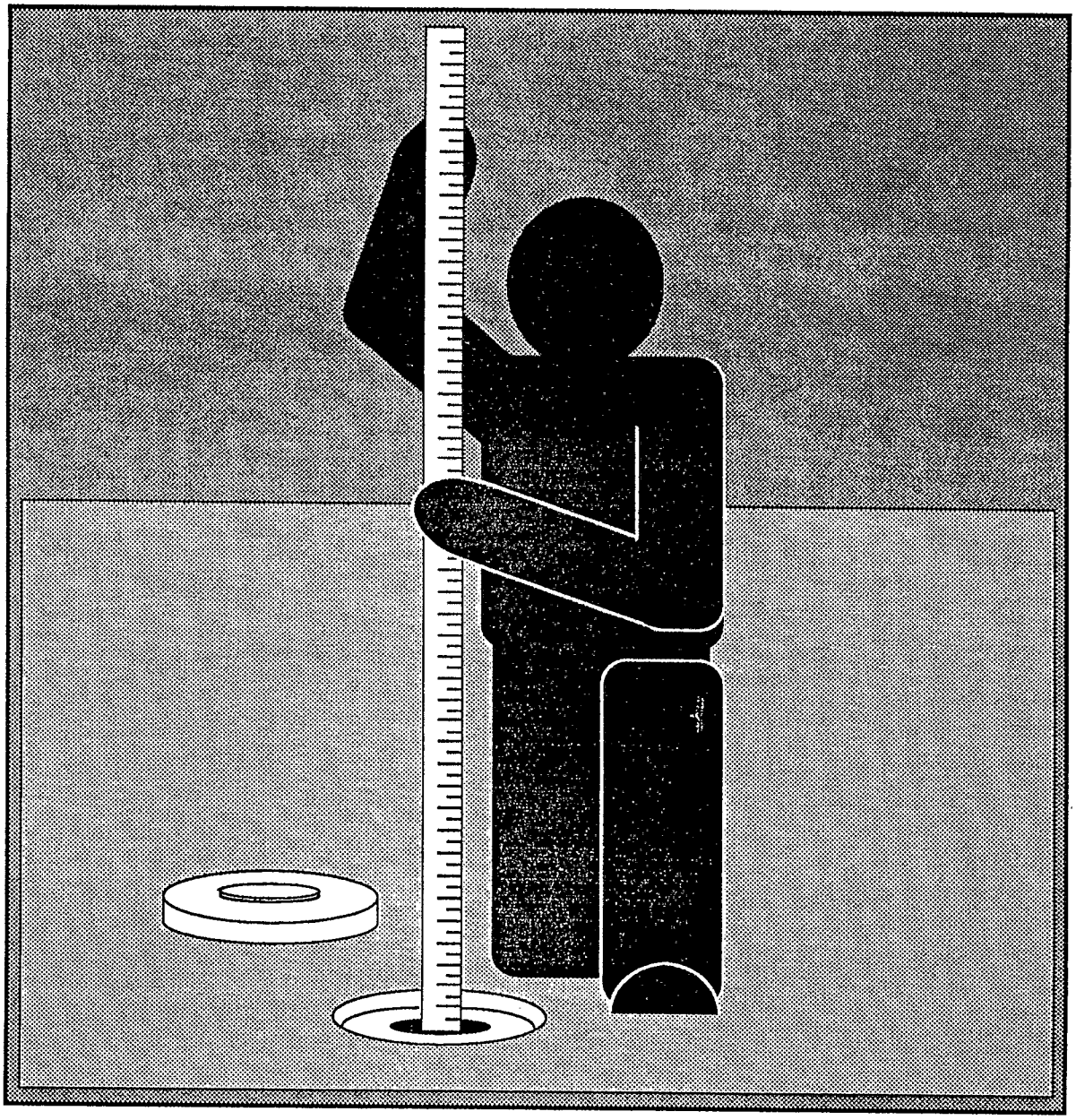
Chapter III
Manual Tank Gauging



MANUAL TANK GAUGING III

SUMMARY

Manual tank gauging, also called static tank testing, is an effective, easy, and inexpensive release detection method for small volume USTs. A study by EPA shows that manual tank gauging can detect leaks as small as 0.2 gal/h for tanks less than or equal to 550 gallons in capacity. The same study shows that for tanks of 551 to 2,000 gallons, manual tank gauging has about the same sensitivity as inventory control. These attributes make it a very appealing release detection method for smaller UST operators.

The discussion presented in this chapter covers many of the possible problems that may occur with manual tank gauging. This does not mean that all, or even most, of these problems will occur. Nor does it mean that all of the problems are of equal importance, in terms of frequency of occurrence or severity of impact to the effectiveness of manual tank gauging. Some problems occur infrequently, whereas others have limited impact. This chapter presents a range of potential problems for educational purposes, not to imply that they will always occur.

Manual tank gauging is a weekly, short-term static test in which the liquid level is measured in a quiescent tank at the beginning and end of a 36-hour time period. Any change in liquid level is used to calculate the change in volume, which is compared against established guidelines to determine whether any disagreement in the measurements is significant enough to indicate a leak in the UST system. Manual tank gauging is sometimes confused with inventory control. Although both methods involve "sticking the tank," manual tank gauging is a short-term static test, while, in contrast, inventory control is an ongoing record of all the activities at an operating UST for an entire month (for more information on inventory control, see Chapter 2 of this manual). Because the problems with inventory control and manual tank gauging are similar, Chapter 2 can used as a cross reference for this discussion.

The process of manual tank gauging involves the following steps: (1) tank gauging—the process of measuring the product level in an UST; (2) calibration—the correlation of a gauge reading with the proper calibration chart to determine the volume of the product in the UST; (3) recording—accurately recording gauging results; and (4) interpretation—the determination of whether the result of tank gauging signifies an UST release. The relationships among these four steps are shown in Figure 6.

POTENTIAL PROBLEMS AND SOLUTIONS

A number of factors can affect the accuracy of manual tank gauging as a release detection method. The following sections discuss problems and solutions related to each of the four steps involved in implementing manual tank gauging. The order of discussion is not intended to prioritize the importance of the problems, rather it is intended to follow the order in which they would occur according to the flow chart in Figure 6. The discussion of problems and solutions is summarized in Table 3, in the order of the discussion in the text, and the most serious concerns are marked with an asterisk. Some agency oversight options are offered for problems, when applicable, but not all of them need be undertaken.

Tank Gauging

Testing → Analysis

Ensure the tank is gauged properly

If a tank is not gauged properly, the gauge readings will not accurately reflect the amount of product in an UST. An inaccurate measurement will occur if the gauge is read incorrectly, or if the gauge is improperly taken with the stick slanted or resting upon an extension in the tank. To take a gauge properly, the stick is placed carefully into the tank through one of the tank openings until its tip touches the tank bottom. Some tanks have a separate opening, called a gauge hole, that should be used for this procedure; otherwise the fill pipe can be used. The stick should be inserted at the same point in the gauge hole each time a gauge is taken and should be held in a vertical position. The stick should not rest on a projection on the tank bottom (e.g., a reinforcement rib in the base of a fiberglass tank). After the gauge stick has been wiped off, the gauging procedure should be repeated and both readings should be recorded. The

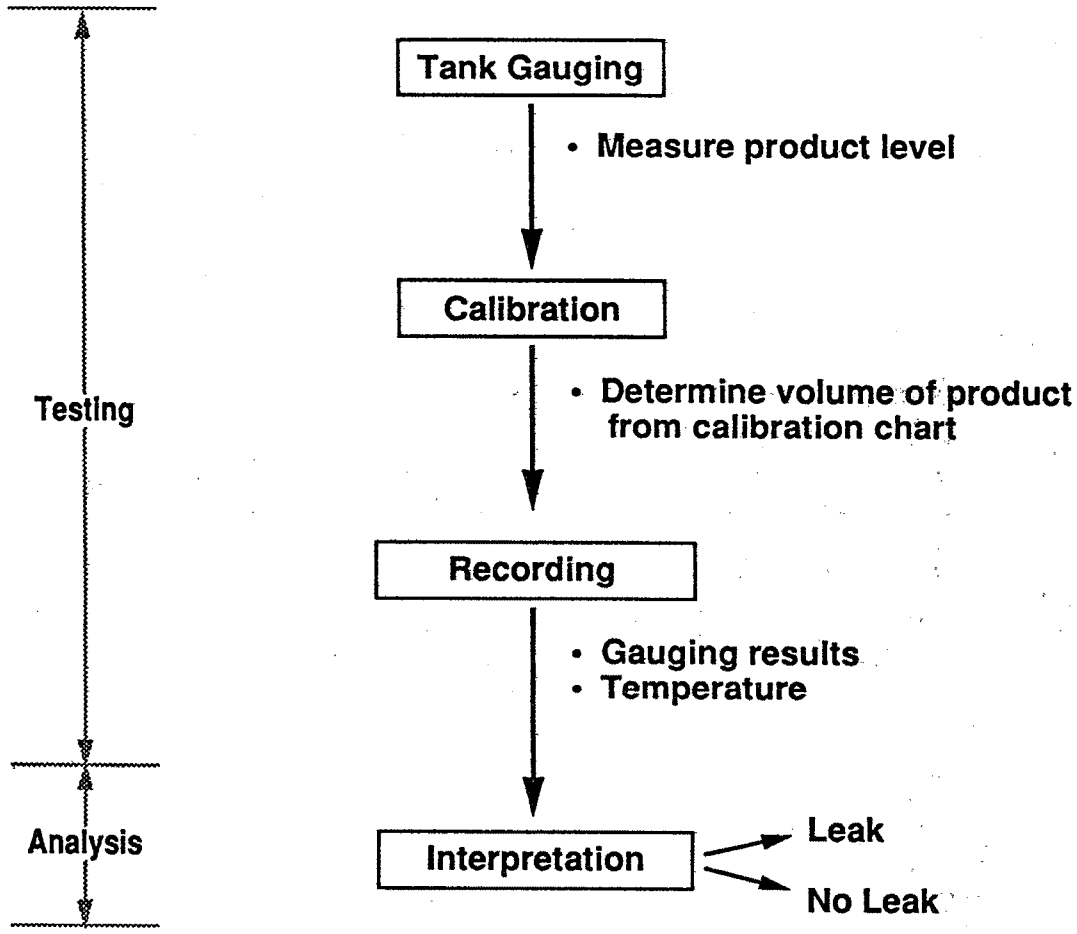


Figure 6. General procedure for manual tank gauging

Table 3. Indicators and Solutions for Problems Encountered During Manual Tank Gauging

Problem	Indicators	Tester Solutions	Agency Oversight Options
***Assure tank is gauged properly.**	Slanted stick. Gauge stick not wiped. Large discrepancy between consecutive gauges.	Take consecutive gauge readings. Wipe dipstick between gauges.	Provide training.
Avoid damaging tank from careless gauging.	Loss of product.	Add a striker plate to tank base. Gauge tank carefully.	
Assure accuracy of product reading.	No clear product line on gauge stick.	Use notched gauge stick. Use product-finding paste. Withdraw pole quickly.	
Assure sufficient testing period.	Time elapsed < 36 hours.	Wait 36 hours or more between beginning and ending gauge.	Set a mandatory waiting period Check beginning and ending times of test.
Identify water in the UST.	Gain in product amount.	Take a water gauge using water-finding paste.	Check during site visits for water in tank.
Need to keep track of temperature fluctuating during the test period.	Large temperature changes.	Take gauges at same time of day. Record daily temperature when gauging.	Require recording of temperature on gauging records.
Assure the calibration chart corresponds to UST.	Specifications on chart do not match tanks.	Ask tank manufacturers to provide a chart that corresponds with their tank.	
Need to use the calibration chart correctly.	Imbalance in results.	Use chart according to API recommendations.	Review gauging forms.
Record the data completely and correctly.	Imbalance in results.	Ask supply company for recommended recording practice.	Review gauging forms.
Need to interpret the data properly.	Imbalance in results.	Follow recommended interpretation process.	Review gauging forms.

***Indicates the most significant problem.**

average of the measurements should be used in conjunction with a calibration chart to calculate the product volume in the tank. After at least 36 hours, two more measurements should be taken.

Because two gauges must be taken consecutively at both the beginning and end of the time period, an error in stick placement will be apparent if the gauges differ by more than a few gallons. In this case, a third gauge should be taken to determine which of the first gauges is correct.

Testing → Analysis

Avoid damaging the tank from careless gauging

Repeated gauging of a tank may wear a hole through the bottom of the UST. When the gauge stick strikes the bottom of the tank, rust can be chipped off of the surface and expose new metal, thus allowing for quicker corrosion which may result in a hole. This can be protected against by careful gauging and by outfitting the tank with a striker plate. A striker plate is simply a layer of metal added to the tank to increase its strength in the area that comes into contact with the gauge stick. Unless the thickness of the striker plate is negligible, when a striker plate is added the end of the gauge stick must be modified by cutting off the exact length as the thickness of the striker plate so that true volume conversions can be obtained.

Testing → Analysis

Ensure accuracy of the product reading

If the stick is used for gauging gasoline or other volatile products, the edge of the stick adjacent to the graduated side should be grooved every 1/8 inch in order to keep the product from moving up the stick past the measured level (referred to as creepage). If desired, product-finding pastes can be used to improve the accuracy of gauging. These pastes improve adherence of the product to the gauge stick and prevent creepage that would distort the reading. Product-finding pastes change color in the presence of product, making it easy to identify the line left on the stick by the product. Information on satisfactory pastes may be obtained from an equipment supplier.

If product-finding paste is used, it should be applied in a light, even coat to the stick before insertion into the UST. After the stick is quickly withdrawn (to avoid creepage of the product), the product "cut" (the mark left by the product on the stick) is read on the graduated scale to the nearest 1/8 inch.

Testing → Analysis

Assure sufficient testing period

Manual tank gauging should take place weekly over at least a 36-hour period during which no liquid is added or subtracted to the tank. Because a shorter time period for testing reduces manual tank gauging's ability to detect UST leaks, the 36-hour period is required by the federal regulations. As the testing time period is extended, manual tank gauging is able to identify smaller leaks. Over a 36-hour testing period, manual tank gauging should be able to accurately identify a leak of 0.2 gal/h.

Testing → Analysis

Determine presence of water in the UST

A water gauge may be taken to determine whether water is present in the UST (see Chapter 2). The presence of water in an UST may indicate a leak. In addition, good management practice dictates the detection and removal of any water in an UST because water may enhance corrosion. A water-finding paste, which is unaffected by the stored product, but which will change color in water, is used to check for the presence of water at the bottom of USTs.

Testing → Analysis

Keep track of temperature fluctuations during the test period

Changes in temperature can affect the volume of the stored product and the UST; temperature increases and decreases can cause expansion or contraction, respectively, of the product within an UST. An increase in volume due to a temperature increase may mask a leak. Similarly, a decrease in volume due to a temperature decrease may imitate a leak. Temperature will have the least effect on dense liquids (e.g., used oil), which expand and contract a very small amount per degree of temperature change.

Because tank gauging is done over at least a 36-hour time period, during which product is not delivered or removed, temperature effects should be due only to ambient temperature changes. To minimize the impact of temperature, if the change in temperature is great, the testing period could be lengthened to 48 hours so that the beginning and ending measurements of the gauge can be taken at the same time of day. Temperature effects should be kept in mind as a potential source of error.

Calibration

Testing → Analysis

Ensure the calibration chart corresponds to the UST being tested

A calibration chart shows the number of gallons in the tank as represented by inch marks on the gauge stick. Each chart is calculated for a specific brand of tank of particular dimensions and capacity, and the chart used must correlate to the tank being gauged. If a chart is used that does not correspond properly, the tank volumes determined will not be accurate. Manufacturers will usually provide a calibration chart for their particular tank. Figure 7 on pages 40 and 41 shows a sample calibration chart. See Chapter 2 for additional discussion of calibration charts.

Testing → Analysis

Use the calibration chart correctly

If the calibration chart is read improperly, the volume of product in the tank may be estimated inaccurately.

API publication 1621 recommends the procedure shown below:

1. The chart should be read directly for all gauges which are to the exact inch or 1/16 inch above or below an exact inch mark.

2. For gauges of 1/8 inch (or more) over or under the exact inch the following procedure should be used:

a. The chart should be read for the exact inch on the scale above and below the actual gauge stick reading. For example, if the gauge stick reads 46 3/4 inches, the chart should be read at both 46 and 47 inches.

b. The smaller gallonage shown on the scale at these two readings should be subtracted from the larger, i.e., for a 1,000-gallon tank (diameter 64 inches; length 72 inches):

Chart reading at 47 inches = 789 gallons
Chart reading at 46 inches = 771 gallons
Subtracting = 18 gallons

c. This gallonage is then multiplied by the fraction of an inch shown on the original gauge, i.e.:

18 gallons times 3/4 = 13.5 gallons.

d. This gallonage (calculated in step c) is added to the gallonage shown on the chart for the lower whole inch reading, i.e.:

Gallons at 46 inches = 771 gallons
Gallons at 1/2 inch = 13.5 gallons
Total = 784.5 gallons

DEPTH	TANK CALIBRATION CHART							
Inches	550 Gal. 49 1/2"x5'5"	1000 Gal. 49 1/2"x10'	1000 Gal. 64"x6'	1500 Gal. 64"x9'	2000 Gal. 64"x12'	2500 Gal. 64"x15'	3000 Gal. 64"x18'	4000 Gal. 64"x24'
1	2	4	3	4	6	8	9	13
2	7	13	9	13	18	23	27	37
3	13	24	17	25	34	42	51	68
4	20	38	26	39	52	65	78	104
5	29	52	36	54	75	90	108	145
6	37	68	47	71	94	118	142	189
7	47	86	59	89	119	148	178	238
8	57	104	72	108	144	180	217	289
9	68	124	85	128	171	214	257	343
10	79	144	100	150	200	250	300	400
11	90	165	114	172	229	287	344	459
12	102	187	130	195	260	325	390	520
13	115	209	145	218	291	364	437	583
14	127	232	162	243	324	495	486	648
15	140	255	178	268	357	447	536	715
16	153	279	196	294	392	490	588	784
17	167	303	213	320	426	533	640	853
18	180	328	231	346	462	578	693	925
19	194	353	249	374	498	623	748	997
20	208	378	267	401	535	669	803	1070
21	222	403	286	429	572	715	858	1145
22	236	429	305	457	610	762	915	1220
23	250	454	324	486	648	810	972	1296
24	264	480	343	515	686	858	1030	1373
25	278	506	362	544	725	907	1088	1451
26	292	531	382	573	764	955	1147	1529
27	306	557	402	603	804	1005	1206	1608
28	320	583	421	632	843	1054	1265	1687
29	334	608	441	662	883	1103	1324	1766
30	348	633	461	692	922	1153	1384	1845
31	362	658	481	722	962	1203	1444	1925
32	375	683	501	752	1002	1253	1504	2005

33	389	707	521	781	1042	1303	1563	2085
34	402	732	541	811	1082	1353	1623	2164
35	415	755	561	841	1122	1402	1683	2244
36	428	778	580	871	1161	1452	1742	2323
37	440	801	600	901	1201	1501	1802	2402
38	452	823	620	930	1240	1550	1860	2481
39	464	844	639	959	1279	1599	1919	2559
40	476	865	659	988	1318	1648	1977	2637
41	486	885	678	1017	1356	1696	2035	2713
42	497	904	697	1046	1395	1743	2092	2890
43	507	922	716	1074	1432	1790	2149	2865
44	516	938	734	1102	1469	1837	2204	2939
45	524	954	753	1130	1506	1883	2260	3013
46	532	968	771	1157	1542	1928	2314	3085
47	539	980	789	1183	1578	1973	2367	3156
48	544	990	806	1210	1613	2016	2420	3226
49	548	997	823	1235	1647	2059	2471	3295
50	549	999	840	1260	1680	2101	2521	3361
51			856	1285	1713	2141	2570	3426
52			872	1308	1745	2181	2617	3490
53			887	1331	1775	2219	2663	3551
54			902	1353	1805	2256	2707	3610
55			916	1375	1833	2292	2750	3667
56			930	1395	1860	2325	2791	3721
57			943	1414	1886	2357	2829	3772
58			955	1432	1910	2388	2865	3820
59			966	1449	1932	2416	2899	3865
60			976	1464	1953	2441	2929	3906
61			985	1478	1971	2464	2957	3942
62			993	1490	1986	2483	2980	3973
63			999	1499	1998	2498	2998	3997
64			1002	1504	2005	2506	3008	4010

Figure 7. Sample of calibration chart. Source: API

Therefore, a tank gauge of 46 3/4 inches, for the given UST, represents 784.5 gallons of product. Computer programs are available to perform or check these calculations.

Recording

Testing → Analysis

Record the data completely and correctly

Tank gauging data should be carefully recorded. The format for data entry will vary greatly depending upon preference, number of USTs at a facility, and the interrelation of these USTs. All tank gauging recordkeeping systems should have a place to record all tank gauge readings, their average reading and associated volume, the time the gauge readings were taken, and a final comparison of the beginning and ending volumes. It may also be helpful to record the ambient temperature at the time of the readings. This information might be useful when investigating a possible release because temperature changes can be a source of error.

Interpretation

Testing → Analysis

Need to interpret the data properly

If tank gauging data are not interpreted properly, the tank may falsely be considered sound or leaking. All tanks using manual tank gauging must test weekly and check the average of the differences from the four previous weeks against the chart in Table 4.

Table 4
Monthly and Weekly
Manual Tank Gauging Standards

Nominal Tank Capacity/gallons	Weekly Standard (one test) gallons	Monthly Standard (four-test average) gallons
<550	10	5
551 - 1,000	13	7
1,001 - 2,000	26	13

After the tank is gauged for a given week, and the beginning and ending volumes for the time period have been determined, these two volumes must be compared to one another. The beginning volume should be subtracted from the ending volume, and the difference (including if it is a positive or negative number) should be recorded. If the difference is positive, the UST has an apparent gain. If the difference is negative, the UST has an apparent loss. The difference should then be compared to the information provided in Table 4 which correlates to weekly results. If either a positive or negative difference is greater than the numbers provided in Table 4, the tank has failed for that week.

Manual tank gauging results must also be checked against a monthly standard. To calculate an average monthly value, the four previous weekly differences are added (the positive or negative sign of the difference should be retained for this addition) and the sum is divided by four. The result of this calculation should then be compared to the monthly standard provided in Table 4.

If the difference in the weekly beginning and ending volume measurements, or the monthly average difference, is equal to or greater than those shown for the appropriate size of tank in Table 4, the UST may be leaking or may have holes that are allowing water to enter.

ENSURING EFFECTIVE MANUAL TANK GAUGING

Chapter 1 provides a general description of the types of oversight that can be used. The following sections discuss how these approaches may be applied specifically to manual tank gauging.

Site Inspections

Implementing agencies could perform site inspections to review the manual tank gauging records and to observe the staff performing the tank gauging. The records could be reviewed for correct length of test and proper recording and analysis of data.

Data Review

Implementing agencies could require that all manual tank gauging forms be submitted by the owner/operator to the agency to be reviewed for accuracy in recording and conversion of gauge measurements to volumes and to ascertain correct interpretation of results. Such an approach, however, would be very labor intensive. Computer programs could be developed to recalculate the submitted data. The records could be reviewed for only the one or two most important factors, such as the time between initial and ending measurements, to be sure the test was at least 36 hours long. Another approach would be to require submission of only some of the forms, such as twice each year.

Guidance and Training

Most errors in manual tank gauging take place because the tank is gauged improperly. The implementing agencies could hold seminars or training classes in proper gauging procedures for persons electing to use this release detection method. An alternative to providing training classes would be to provide guidance materials (e.g., a manual or a video tape) explaining the proper process.

Approval and Certification

An implementing agency could provide testing and certification for all persons using manual tank gauging. Such an approach would be time consuming.

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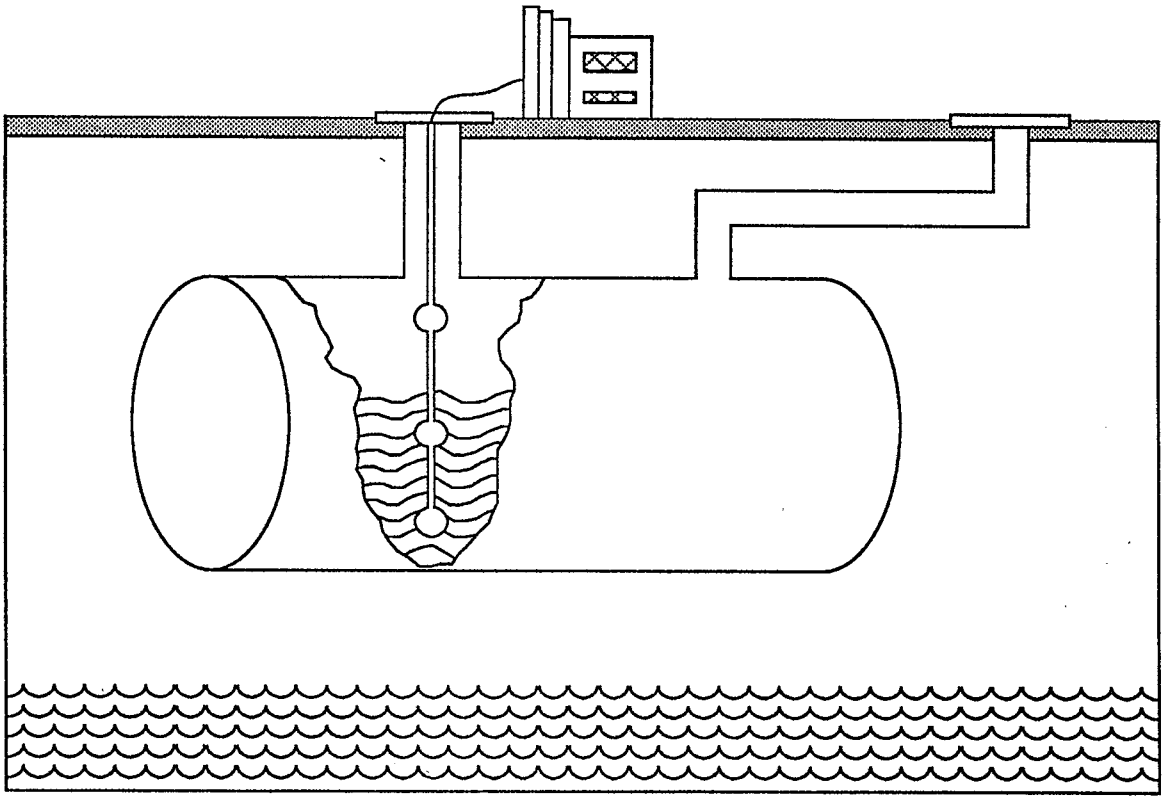
Chapter IV
Tank Tightness Testing



TANK TIGHTNESS TESTING IV

SUMMARY

EPA studies show that tank tightness testing can be done reliably and affordably. For many existing tanks it is the best available release detection option because permanent installation of equipment is not necessary, capital requirements are limited, and many commercial methods are available.

Release detection methods are a combination of equipment and procedure. EPA studies show that, for tank tightness testing, the equipment is generally reliable and meets the manufacturers' specifications. However, tank tightness testing procedures can be problematic. Getting effective tank tightness tests is a matter of focusing on the manufacturer's protocol and the testers adherence to the protocol. Consequently, this chapter explains key procedures, why they are important, and how some existing state UST programs have been ensuring that proper testing procedures are followed in their jurisdiction.

The discussion presented in this chapter covers a wide range of possible problems that may occur with tank tightness testing. This does not mean that all, or even most, of these problems will occur at the same time. Nor does it mean that all of the problems are of equal importance, in terms of frequency of occurrence or severity of impact to the effectiveness of tank tightness testing. Some problems, such as poor access, seldom occur, while other problems, such as interference from evaporation/condensation have limited impact. Experienced testers are well aware of these problems and how to deal with them. For example, an experienced tester can recognize the presence of vapor pockets. Release detection, however, is a growing industry, and new companies are being formed with less experience. This chapter presents the full range of potential problems for educational purposes, not to imply that they will always occur.

Many of the descriptions and principles provided below for tank tightness testing are also applicable to automatic tank gauging and to piping tightness tests. Those release detection methods are discussed separately in Chapters 5 and 9, respectively.

BRIEF DESCRIPTION

There are many commercial tank tightness test methods available. While there is great diversity in the equipment and analysis schemes used, all tightness test methods are based on the same general approach. This section focuses on the general principles behind tightness testing and on procedures, not on specifics or equipment. Details on many methods and their performance are available in other publications (Ref. 1 and 6), and manufacturers and vendors of equipment will provide literature on their equipment.

There are two main types of tank tightness tests: non-volumetric and volumetric. There are only a few non-volumetric methods available, and they are not covered in this document. Volumetric tightness test methods measure the change in product volume or level over time to determine if there is a leak. When a leak occurs in an UST, the loss of product causes a decrease in the volume of product in the tank and, thus, a decrease in the level of product. Other factors, such as changing product temperature, can also cause product volume or level changes. Tightness test methods differ in how they measure the volume or level change and how they account for the interferences.

The general procedure for conducting a volumetric tank test is quite similar from one test method to another (see Figure 8). The three procedural aspects common to all volumetric test methods are preparation, testing and analysis.

First, the physical layout and condition of the tank and piping must be evaluated to determine if tightness testing can be performed on that UST system. There are situations in which the test equipment cannot physically be placed into the tank. Other configurations may cause problems in obtaining meaningful results. Details of physical concerns are discussed in the problems section below.

To prepare for a test, the tank must first be filled to a gross approximation of the level required for testing. A waiting period must be observed to ensure that thermal effects and structural deformation resulting from filling the tank have stabilized. The instrumentation to measure product level and temperature can be installed during or after the waiting period. Next, fine adjustments may be made to the fluid level by adding or removing small amounts of product. If fine adjustments of product level are made, a second waiting period should follow.

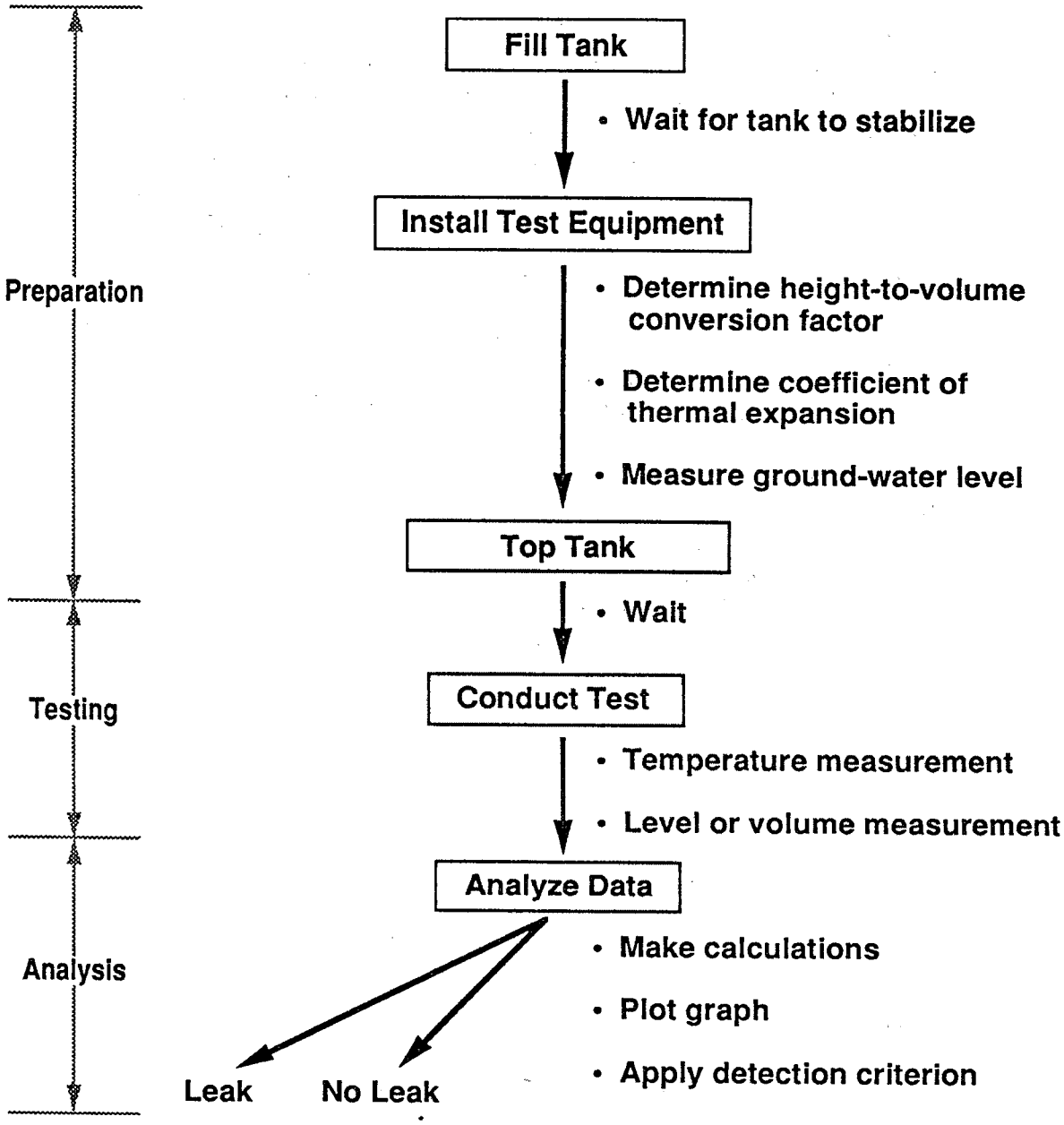


Figure 8. General procedure for conducting a volumetric tank test
Source: U.S. EPA 1989

Volumetric tank tests can be divided into two categories: overfilled and partially filled. Figure 9 presents the two types of tests. In an overfilled-tank test, the tank is filled until the level of the product reaches the fill tube or a standpipe located above grade. Level changes occur in a small surface area, so that small changes in volume cause relatively large changes in level. For example, in a 4-inch fill pipe, a volume change of 0.05 gallons will cause a level change of about 1 inch. In a partially filled tank, the test is conducted with the product level somewhere below the top of the tank. Level changes in these tests occur in large surface areas, where small changes in volume cause very small changes in level. For example, in a half-filled 10,000-gallon tank 8 feet in diameter, a volume change of 0.05 gallons will cause a level change of about 0.00006 inches. Level sensing devices must be considerably more sensitive for partially-filled-tank tests than for overfilled-tank tests in order to achieve the same accuracy.

During the waiting periods(s), the test operator must determine values for the height (level)-to-volume conversion factor and the coefficient of thermal expansion (see section below on problems during preparation for discussion of these terms). Finally, the tester should determine the height of the water table. The preparations are now complete, and testing can begin.

During the test, sensors take measurements of both the temperature and the level of the fluid in the tank. The respective measurements are taken repeatedly at specified intervals and are recorded for analysis at a later time. Data collection can be manual or automated. The end of a test is based on a criterion pre-determined by the manufacturer. Usually this criterion is expressed in terms of time; for example, the test ends 60 minutes after the start of the data collection.

By the time the test is complete, a considerable amount of data may have been gathered. Generally, the more data that are gathered, the better the test. Procedures for averaging the data, compensating for temperature, and computing a volume leak rate are usually well defined by the manufacturer of the test method. The end result of the analysis is a calculated volumetric "flow rate" that indicates how fast fluid is escaping from the tank.

The detection criterion (usually a single threshold value) is applied after the analysis has been completed and is used to determine whether the level changes are due to a leak or to normally occurring volume fluctuations. If the temperature-compensated volume change exceeds the detection criterion, a leak is suspected; if not, it is assumed that the tank is not leaking. The most common criterion is 0.05 gal/h.

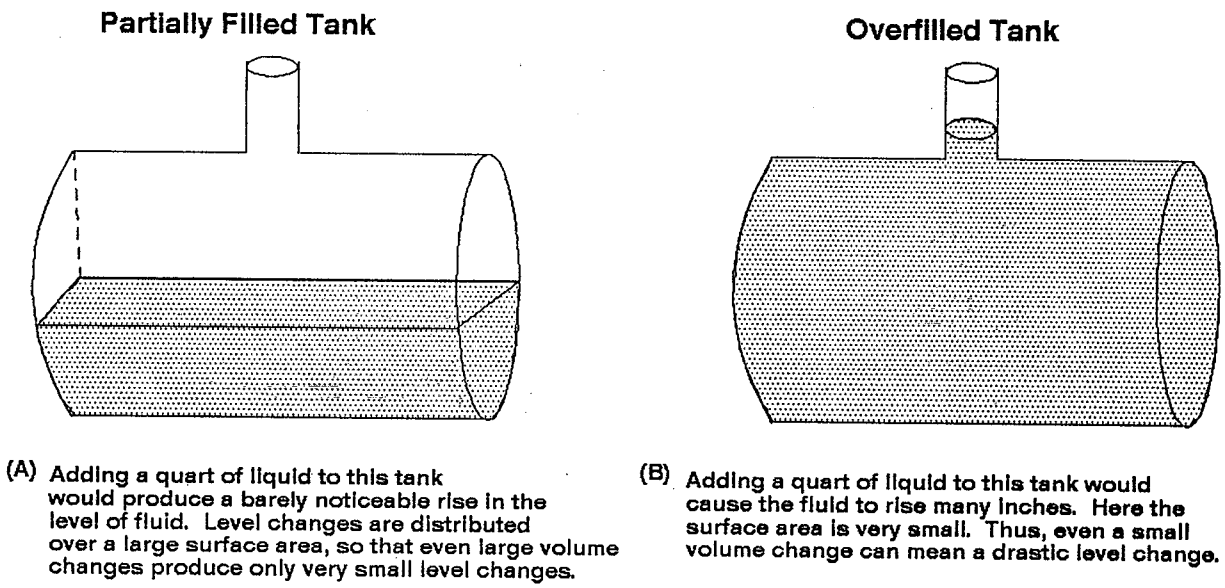


Figure 9. Comparison of partially filled and overfilled tanks.
Source: U.S. EPA (1989)

POTENTIAL PROBLEMS AND SOLUTIONS FOR TIGHTNESS TESTS

From the practice of tightness testing and studies performed by EPA, important procedural aspects have been identified. This section discusses the most important aspects of tightness testing and the errors and problems encountered. Table 5 presents a summary of the problems encountered during tank tightness testing, the indicators and solutions for these problems, and how implementing agencies might provide oversight to prevent or correct the problems. A number of agency solutions are offered for each problem, but not all of them need be undertaken. In the table, the problems that are most serious, either because of frequency or severity of impact, have been marked by an asterisk. The problems are discussed below in the order of the testing procedure presented in Figure 8 (page 49). There is no ranking implied by the order of discussion.

Site Considerations

Many "real world" factors concerning the installation and condition of the UST system can influence how well a tightness test performs and how much effort is involved in obtaining meaningful test results. Most physical factors can be accounted for with proper equipment and experienced testers. Tightness testing will be most effective and efficient if as much as possible is known about the setup and condition of the UST system prior to selecting the method or beginning the test. The correct equipment can be assembled beforehand, and any necessary modifications to the equipment, protocol, or site can be made.

Preparation → Testing → Analysis

Joints, bungs, and manways must be tight for overfill methods

Common problems with UST systems are (1) fittings and joints that were not tightened properly during installation; (2) gaskets at joints that were not installed, were installed incorrectly, or have deteriorated over time; and (3) joints that have become loose over time, such as piping connections dislodged during frost heaves. Often gaskets are not installed on manways. Also, temporary covers on openings used during delivery are frequently not replaced with permanent bungs during installation. During the overfill type of tightness test, the top of the tank and the piping are filled with liquid, and product will leak from any loose fittings or joints. Identification of these problems is desirable; however, leaks due to loose fittings obscure identification of possible leaks due to corrosion holes. Therefore, leaks due to loose fittings must be stopped before testing of the tank for corrosion holes can begin.

Table 5. Indicators and Solutions for Problems Encountered During Tank Tightness Testing

Problem	Indicators	Tester Solutions	Agency Oversight Options
Joints, bungs, and manways must be tight for overfill methods.	Top of tank or fittings are wet with product.	Check fittings and gaskets before testing. If results of test indicate possible leak, uncover tank, check fittings, and retest.	Observe test. Inspect site after test for new gaskets, etc., if claimed by tester.
Assure that manifolded tanks are tested appropriately.	Tank drawings. Owner/operator knowledge.	Disconnect tanks and test separately.	Review data sheets. Check site after test for evidence of disconnect.
Abandoned piping may require special treatment (for overfill methods).	Tank drawings. Owner/operator knowledge. Unexplained piping from top of tank. Very large losses when tank is overfilled.	Find out purpose of all piping. Install shutoff valves on piping with unknown purpose. Dig up runs of piping.	Review data sheets for test results. Check site after test for evidence of digging or shutoff valves.
Poor access may require use of another method.	Drawing of site showing tank near or under large structure.	Inspect site before testing to make necessary equipment modifications. Use other opening in tank. If unable to make necessary physical modification, decline to test.	Review site plans. Observe test.
Assure that drop tubes do not interfere with test method.	Object such as inventory stick placed through fill pipe hits sides of tube.	Replace with temporary drop tube. If permanent drop tube cannot be removed easily or cost-effectively, do not test.	Site inspection.
***Assure waiting time between delivery and testing is adequate.**	Erratic and large volume changes; short-term volume decrease that levels out.	Wait at least 6 hours after large product additions to tank and at least 3 hours after topping off.	Review data sheets for volume changes and testing times. Plot test data to observe trends.

Continued

Problem	Indicators	Tester Solutions	Agency Oversight Options
***Need to identify and remove vapor pockets.**	Erratic or sudden large volume changes; bubbles in fill pipe or stand pipe.	Add known volume to tank, and calculate expected and observed level changes. If different, bleed off vapor and start test over.	Review data sheets for volume changes.
***Accounting for presence of ground water.**	Water in the tank.	Check existing observation well or drill hole to level of bottom of tank. If present, raise liquid level in tank to counteract pressure of ground water, or do not test.	Review data sheets for ground-water data. Inspect site to be sure an observation well was available or drilled.
Assure accuracy of height-to-volume conversion factor for each tank.	None.	Add or withdraw known volume from tank, and observe level changes.	Review data sheets for calculation of conversion factor.
Use correct coefficient of expansion of product.	Used average coefficient for product type from published source.	Determine for each tank using API hydrometer and tables.	Review data sheets for calculation of coefficient. Compare coefficient to published average values.
Assure collection of sufficient test data.	Fewer than 25 data points collected.	Sample at least every 5 minutes for at least 2 hours.	Review data sheets for duration of test and sampling frequency.
***Provide adequate tempera-ture compensation during**	None.	Use at least three temperature equally spaced vertically, or mix the product and use one sensor. Or use method that measures a factor independent of temperature.	Observe test equipment as it is installed in the tank. Review product literature.

***Need to maintain constant product level during test (overfill methods).**	Constantly changing product level in fill pipe or stand pipe.	At frequent intervals, add or remove product to keep level constant.	Approve only methods whose protocol includes maintaining constant level. Observe tests. Provide guidance and education on the importance of constant product level. Review data sheets for evidence of additions and withdrawals.
Need to compensate for condensation and evaporation in very hot conditions.	Vapors above stand pipe or fill pipe or condensation on sides of pipe.	Minor problem. No need to compensate. Shade from direct sunlight.	None.
***The number of tests per tank should be fixed.**	High percentage of tanks declared "tight."	Protocol must include fixed number of tests.	Review data sheets for results of all tests. Compare tests conducted to protocol. Keep track of pass/fail ratios for each testing company.
Decisions left to tester should be minimized.	None.	Protocol should be as explicit as possible and cover as many potential situations as possible.	Compare activities on data sheets with published protocol. Observe during test. Approve for use only those methods with adequately defined protocols.
Need to follow protocol and use correct threshold value.	High percentage of tanks declared "tight" or "leaking.	Analysis scheme must be well defined. Criteria for declaring "tight" or "leaking" must be clear. Threshold value for declaring leak should be smaller than minimum detectable leak rate by a factor of at least 2.	Review data sheets and calculations to see if steps agree with protocol. Keep track of pass/fail ratio of each testing company.
Assure calculations are performed correctly.	A few data points are extremely different from the rest of a test.	A second person double-checks manual calculations. Computer program is reviewed and tested using known and verified data.	Manual or computer recalculation, from raw data to tightness declaration.

*** Indicates the most significant problems.**

Testing the tank separately from the piping will help to distinguish some of these causes of release. Any fittings on top of the tank that are visible without removing backfill should be checked before beginning the test for tightness and adequate seals/gaskets (e.g., on the manway) should be installed; any visibly deteriorated gaskets should be replaced. Checking all visible fittings on top of the tank during the test to see if any product is present will help to discriminate sources of release. If the visible fittings are not wet with released product but the test indicates a leak, it may be necessary to expose the rest of the fittings on top of the tank by removing the backfill. If an UST fails a tightness test and the fittings are subsequently found to be loose and are tightened, the UST may be tested again; if the UST is found to be tight, no report of a suspected release is necessary.

Preparation → Testing → Analysis

Manifolded tanks must be tested appropriately

Sometimes tanks at a site that hold the same product are connected together by piping. The siphon effect allows product to be drawn from all of the tanks that are manifolded together. For overfill types of tightness testing, it is possible to test manifolded tanks at the same time. However, the uncertainty associated with the necessary temperature measurements is high because it is unclear how to apply the temperature measurements from two or more different tanks to one common volume measurement. For test methods using partially filled tanks, there may be some slight "wave action" in the tanks when they are connected due to the siphoning effect of the connecting pipe. This variation in the level of the liquid in the tank interferes with accurate level determinations. For these reasons, manifolded tanks generally should be disconnected from each other and tested separately. If the piping between the tanks can be disconnected, either type of tightness testing can be used. This approach can be very convenient for the overfill methods because the extra product needed to overfill each tank is available from the tank manifolded to it.

Preparation → Testing → Analysis

Abandoned piping may require special treatment

At older sites or sites where the use of the UST system has changed frequently, there may be piping connected to the tank that is no longer used. Rather than digging up the entire run of old piping, only the end connected to the old pump or delivery source may have been removed. This abandoned piping may be left open-ended. When the overfill type of tightness test is used, this extra piping can cause several problems. First, vapors can become trapped in the piping, and locating vapor pockets in piping and removing them is very difficult. Second, if some

of the piping is open to the ground, large volumes of product will leak to the environment when the tester tries to fill the system. These problems can be overcome by using a nonoverfill tightness test method or by isolating the tank from the piping. Isolating the tank from old piping may involve digging up part of the piping to install some type of device that closes off the piping. Because an open-ended pipe is always a potential source of large product losses, abandoned piping should be removed or closed any time it is discovered, regardless of the type of release detection being used.

Preparation → Testing → Analysis

Poor access may require use of another method

Some UST systems are located in sites where it is difficult to set up the test equipment, such as near buildings or under other structures. The space available to set up the test equipment and maneuver during the test may be too limited for some tightness test methods. Another access problem is the location of the fill pipe relative to the tank itself. Remote fill pipes are sometimes used, where the actual opening is a long way from the tank and connected to the tank by a run of horizontal piping. Most tightness test methods rely on using the fill pipe to insert all of the necessary equipment and sensors into the tank and, therefore, such methods may be infeasible for a tank with a remote fill pipe. It may be possible for such a test method to use other openings on the top of the tank, such as the manway. Otherwise, another release detection method should be used.

Preparation → Testing → Analysis

Drop tubes must not interfere with test method

To avoid agitation, wave action, and splashing during filling, many tanks are equipped with a drop tube. This is a tube the diameter of the fill pipe that extends from the opening to near the bottom of the tank. The presence of a drop tube can interfere with proper temperature measurement because the product in the tube is isolated from that in the rest of the tank. The tube also can be an obstruction to placing equipment and sensors in the tank. Drop tubes interfere with product circulation for those tightness test methods that try to achieve even temperature distribution using a circulating pump. Some drop tubes are removable and, obviously, should be removed before a test is begun. A permanent drop tube can be replaced with a temporary tube. Such a replacement is difficult and expensive and may only be worth the effort if it is expected that tightness testing will be performed routinely on the tank for a long time. Otherwise, the tightness testing company should be questioned about the ability of the method to perform well with a permanent drop tube.

Testing Considerations

Preparation → Testing → Analysis

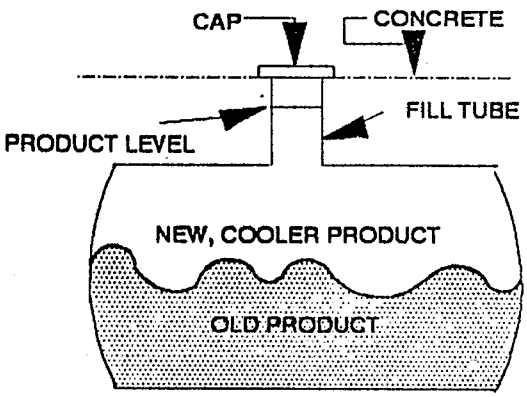
Adequate waiting time between product delivery and testing

The most common problem with tightness testing is not waiting long enough between adding product to the tank and beginning collection of temperature and level data. The fluctuating temperature and structural changes of the tank following the addition of product cause volume and level changes that are unrelated to changes caused by a leak. Not waiting for these changes to stop results in erroneous test results.

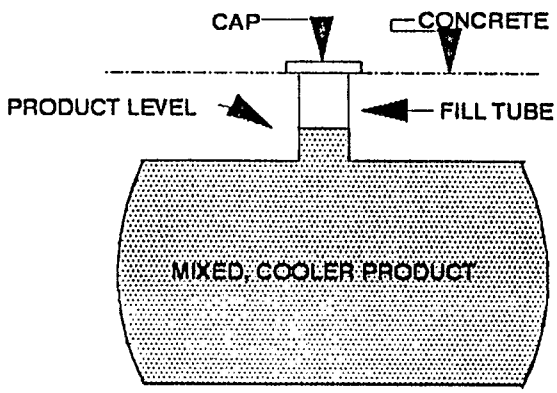
There are two times when product may be added to the tank: (1) gross product delivery, where thousands of gallons may be added to bring the product to approximate testing level; and (2) "topping off", where several gallons may be added to achieve the final level for testing. For the reasons discussed below, each addition of product and increase in product level causes changes within the tank that interfere with accurate test results.

When product is added to a tank, its temperature is at or near ambient air temperature. The temperature of the product already in the tank is at ground temperature. The difference between ambient air temperature and ground temperature varies with the season and location, but differences of 10 to 20 degrees Fahrenheit are not uncommon. For some time after delivery, the temperature of the product will fluctuate rapidly and widely as the product mixes and eventually achieves an equilibrium near ground temperature. As the temperature of the liquid in the tank increases or decreases, the volume of the liquid will increase or decrease, respectively (see Figure 10). For example, 1000 gallons of gasoline will shrink by 0.7 gallons when the temperature drops by one degree Fahrenheit. Increasing volume due to temperature increase may mask a leak while decreasing volume due to temperature decrease may falsely indicate a leak.

All tightness test methods must account for temperature changes. However, for a period of time following delivery, the thermal chaos in the stored product is too extreme to be adequately measured and accounted for. In addition, the temperature changes immediately following delivery are not the same at the ends of the tank as at the fill pipe. Consequently, no matter how many temperature sensors are added at the fill hole, the measured temperature at that point does not reflect the average temperature in the tank.



(A) Product has just been added to an underground tank that was already partly filled. The new product is cooler than the resident product, and temperatures fluctuate greatly.



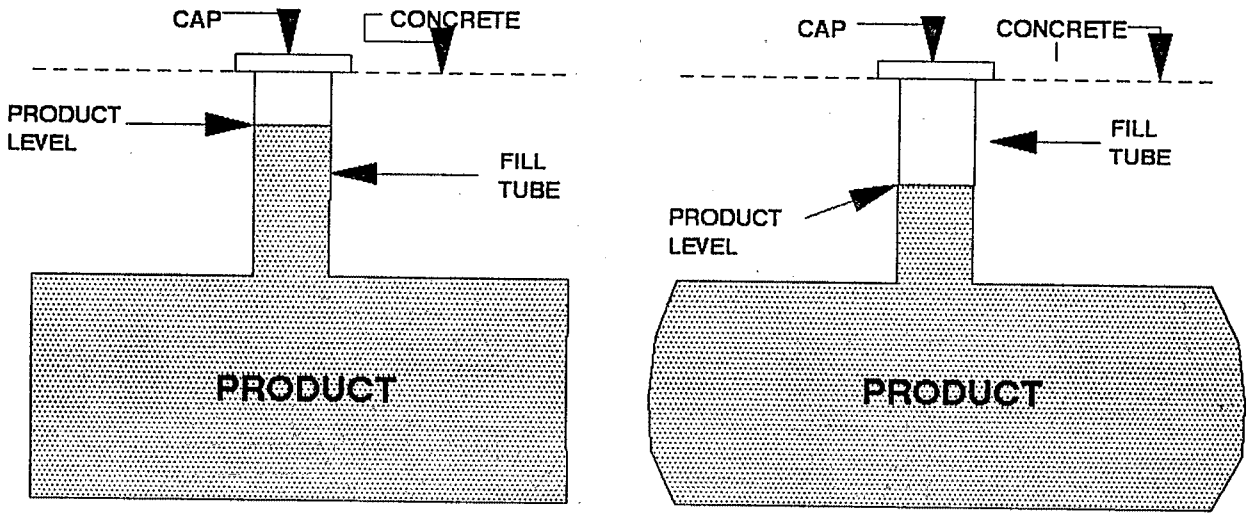
(B) As the old product cools and the new warms, equilibrium is reached. But the temperature as a whole is cooler, causing the product to contract and the level to go down. (The inverse is true when warmer product is added, causing the product to expand and the level to rise.)

Figure 10. How temperature changes can be mistaken for a leak.
Source: U.S. EPA (1989)

In addition to fluctuating temperature, the addition of product causes structural deformation of the tank. Whether it is constructed of steel or fiberglass and whether it is embedded in a dense backfill or in a loose one that has more "give," the tank itself expands and contracts in response to both temperature and level changes. When the tank expands, the level of the fluid inside it goes down; conversely, when it contracts, the level goes up (See Figure 11). The amount of volume change due to tank deformation varies with the material of construction and the type of backfill, but effects can easily be in the range of 1 to 10 gallons. Distinguishing between real volume changes and the apparent changes brought on by structural deformation is generally not possible, regardless of how accurate the equipment is.

The solution to the problems of temperature fluctuation and tank deformation following addition of product is to wait until these changes have stopped, i.e., until the product temperature has stabilized and the tank has completely expanded. The exact waiting time that is necessary will vary with the amount of product delivered and the temperature difference between added and original product. As a guideline, a minimum waiting time of about 6 hours should elapse after delivery of product in the range of hundreds or thousands of gallons and about 3 hours after topping off of the tank. These minimum times should be sufficient for both thermal fluctuations and tank deformation to stabilize. A few tightness test methods avoid the problem of temperature effects by measuring some aspect that is independent of temperature, such as the mass of the product.

To determine that sufficient time has elapsed for the tank to stabilize, the tester should watch the temperature and level changes. Preferably, temperature and volume measurements versus time should be plotted on a graph as the measurements occur. If the readings show large and erratic changes, conditions in the tank are probably still fluctuating. If the temperature-compensated level changes decrease and eventually level off, it is an indication that the tank ends were continuing to relax early in the test but finally stabilized. Some tightness test methods include statistical analyses of the data as they are collected and, from the randomness of the data, can determine that tank conditions are not stable enough to begin the test. Regardless of which method is used to determine tank conditions, any initial data indicating instability should not be used in the final evaluation, and the length of the test should be extended so that the minimum acceptable test duration occurs after the tank has stabilized. That is, if the test protocol says that

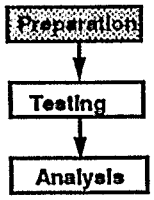


(A) An empty underground tank has just been filled with product.

(B) In response to the pressure and/or temperature of the product, the ends of the tank begin to deflect ("structural deformation"), and the level of the product goes down.

Figure 11. How structural deformation of the tank can be mistaken for a leak. Source: U.S. EPA (1989)

the test should last for 2 hours, the 2 hours of test data used in the analysis should be obtained after the tank has stabilized.



Vapor pockets in overfilled-tank tests identified and removed

In overfilled-tank tests, vapor pockets may form. Although most test operators claim to be able to identify vapor pockets easily, many tests continue to be invalid or yield incorrect results because the problem was not recognized or corrected.

Vapor pockets are almost always present after a tank has been filled to or above the top of the tank because vapor becomes trapped in the manways, deadend piping, etc. (see Figure 12). Temperature fluctuations change the volume of the vapor pocket, and the expansion and contraction of the vapor pockets changes the liquid level in the tank. For example, a temperature change of about 0.25 degrees Fahrenheit may change the volume of a 100-gallon vapor pocket by about 0.05 gallons. To a lesser extent, changes in barometric pressure also cause vapor pockets to expand and contract, causing changes in liquid level. An increase in liquid level due to expansion of a vapor pocket may mask a decrease in liquid level due to a real leak, while a decrease in level due to contraction of a vapor pocket would falsely indicate a leak or exaggerate the rate of an actual leak. Vapor pockets in quantities as small as 10 gallons can influence a test result.

The first step in solving this problem is to identify the presence of a vapor pocket. While it is virtually impossible to determine the exact size of the vapor pockets, there are several methods that can be used to check for their presence. The most easily identifiable indication of a vapor pocket is the presence of bubbling in the fill pipe or stand pipe during the test. Vapor pockets may also be indicated by a sudden large drop in product level, indicating a vapor pocket that just "released". If the temperature-compensated volume changes fluctuate over time with no obvious trend, then there may be a vapor pocket that is expanding and contracting, thus confounding the results. This indicator, however, is not conclusive unless sufficient waiting time has elapsed since addition of product for temperature and structural deformation changes to subside. Another method of identifying vapor pockets is to add a known volume (of product or a solid object) to the tank and compare the actual increase in product level to the increase that would be expected from the geometry of the tank. If the actual level change is less than the expected change, a vapor pocket may be present that compressed from the pressure of the added product.

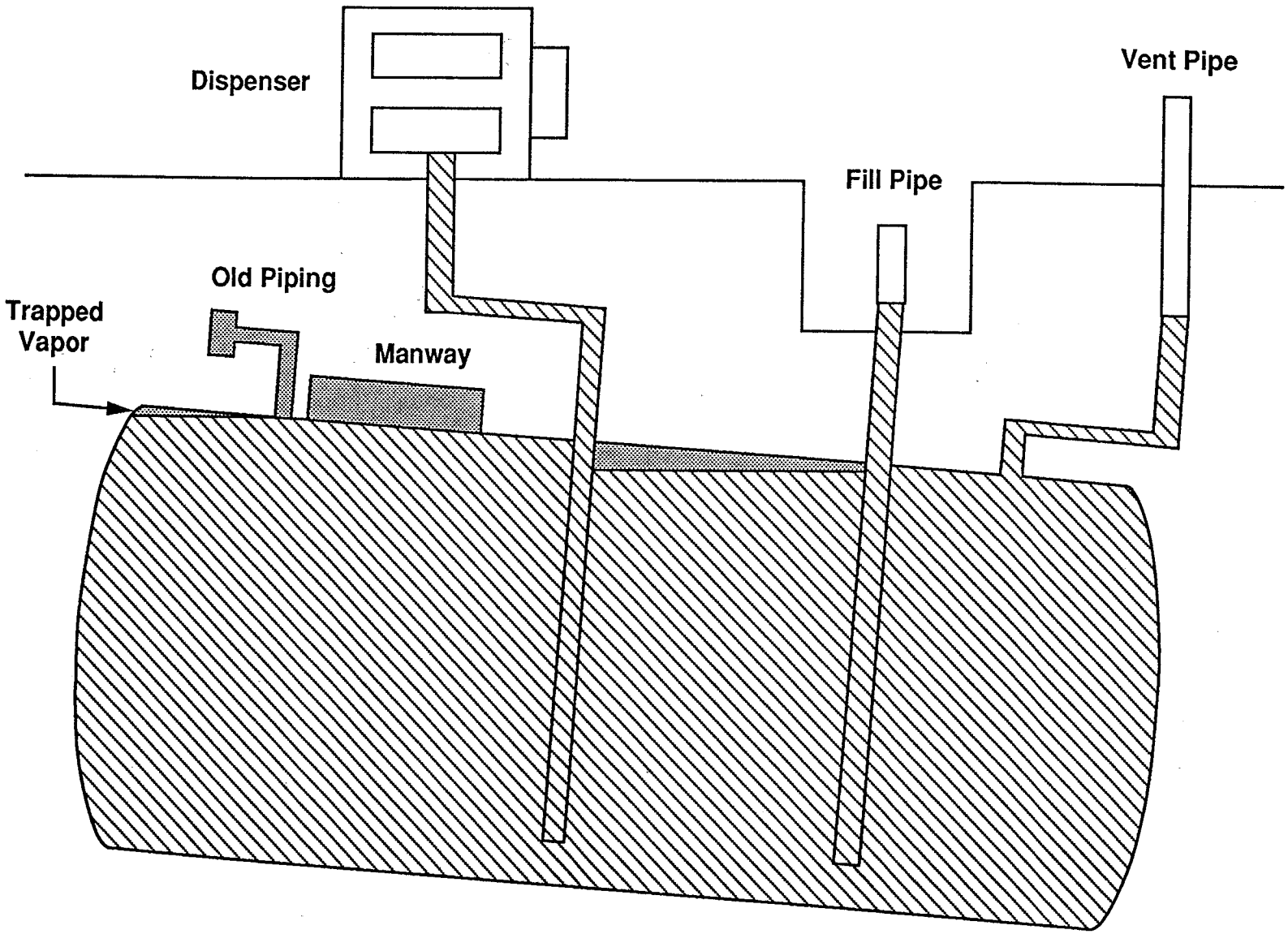
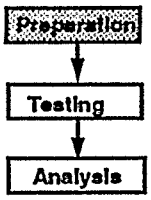


Figure 12. Location of vapor pockets in an overfilled tilted tank.
Source: Schwendeman and Wilcox (1987)

If a vapor pocket is shown to be present, it must be removed. One method of removal is to uncover the tank and install a bleed valve on the high end of the tank. As the vapor is bled off, product will fill the void. A relatively new method of removing vapor pockets involves inserting a hose and bladder into the tank, inflating the bladder so that it rises to the high end of the tank (where the vapor pocket is), and suctioning out the vapors. After a vapor pocket is removed, the test should be started over. Checking for signs of a vapor pocket should continue because not all of the vapor may have been removed or another pocket may have formed.



Accounting for the presence of ground water

The presence of ground water around the tank may completely mask an actual leak or at least slow the rate at which product is leaking. Failure to check for the presence of ground water and to take action when it is present make the results of a tightness test questionable. In the National Survey conducted by EPA at about 500 randomly selected sites around the U.S., ground water was above the bottom of the tank at about 25 percent of the sites.

The water table of the soil in which a tank is buried can vary in height depending on factors such as geographic location, season, and amount of precipitation. As the illustrations in Figure 13 show, the height of the water table in relation to the tank can have a direct effect on the leak rate measured during a test. If the water table is above the location of a hole or fissure in an underground tank, the ground water exerts a pressure on that hole which counteracts the pressure exerted on the same hole by the fluid in the tank. The best test results are obtained when the water table is below the level of the tank. Flow of the leak through the hole is then unrestricted, and measurement of the flow rate will not be influenced by ground water.

Because it is virtually impossible to determine the location of a hole in an underground tank, efforts must be concentrated instead on monitoring the ground-water level. The tester should determine the ground-water level or at least determine if it is below the bottom of the tank. Hydrogeological information may be available from agencies such as the U.S. Geological Survey or from boring logs from nearby sites, but such data do not necessarily indicate conditions at the tank being tested. There can be very localized hydrogeological formations that result in a "pocket" of water in a small area of a region otherwise characterized by deep ground water. The only sure way to determine if

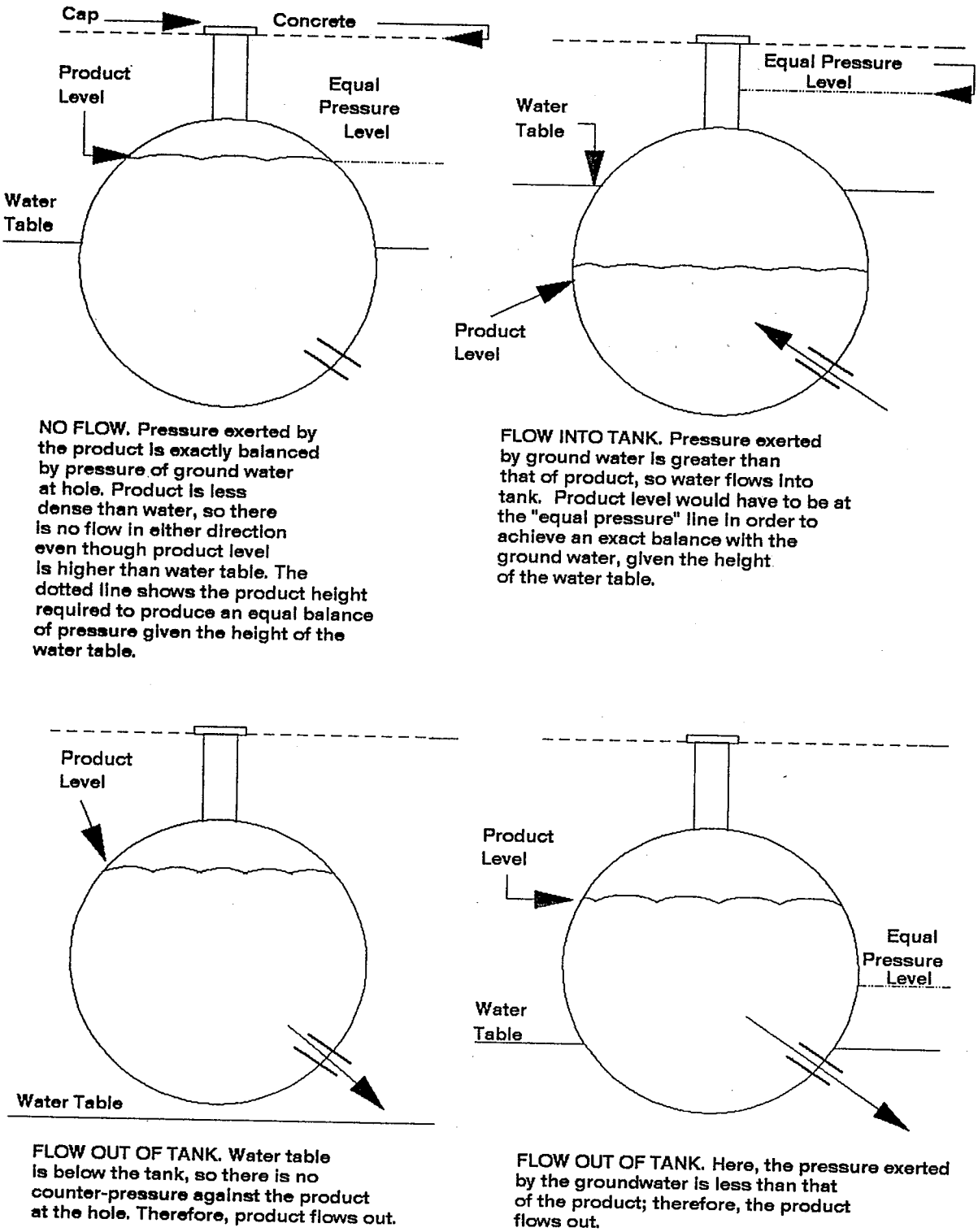


Figure 13. Effect of ground water on the rate of flow through a hole in an underground tank. Source: U.S. EPA (1989)

the tank is surrounded by water is to check observation wells near the excavation zone. If there are no existing wells, one can be made fairly easily with a hand auger. A well drilled just for checking water level during a tightness test does not have to be a formally installed observation well. The important point is to determine whether the tank is surrounded by water, so the well does not need to be completed to the water table, only to the bottom of the tank.

A tightness test method should include a formal procedure for dealing with high ground-water levels. For example, a test can be postponed until the water table drops below the level of the tank. This is often impractical, however. For overfilled-tank tests, another approach is to raise the level of the product above grade until the pressure on the bottom of the tank reaches a given level, such as 4 or 5 psi (the pressure must be within the safety margins of the design of the tank). Under this approach, the pressure of the liquid within the tank will be greater than that of the ground water surrounding the tank.

Some tightness test methods conduct two consecutive tests, each at a different fluid level within the tank, and compare the leak rates. If there is a leak in the tank, the leak rates will be different because the head pressures are different. Theoretically, no measurement of ground water is necessary because the test is independent of ground water, that is, the difference in leak rates will show up whether ground water is present or not. However, the difference in head pressure between two different test levels causes only a very small change in leak rate, and the differences in leak rate from changes in head pressure probably will be obscured by variations introduced by other factors such as temperature.

Effective tightness test methods should include a procedure for determining the presence of ground water and compensating for it. To ensure that testers follow these procedures, the state of Rhode Island checks all test reports for the information that the ground-water level was checked and how it was compensated for. Some test sites are visited after the test to check that a well is, in fact, present.

Preparation → Testing → Analysis

Accuracy of height-to-volume conversion factor for each tank

Most tightness test methods measure changes in product level over time. To calculate a leak rate in gallons per hour, these level measurements must be converted to changes in volume. The value used to make this conversion is called the height-to-volume conversion factor and will be different for each tank. If the wrong conversion factor is used, the volume change that is calculated will be wrong, resulting in an erroneous leak rate or even a false decision regarding the integrity of the tank.

The height-to-volume conversion factor should be determined specifically for each site because the geometry of each UST system is slightly different. The conversion factor can be derived mathematically based on the geometry of the tank. However, there can be differences between the manufacturer's specifications for the general type of tank and the actual tank that was installed, and there may be unknown factors that change the internal volume of the tank, such as tank end deflection or old piping that is still attached. For these reasons, theoretical calculations of the conversion factor are considerably less accurate than direct measurement. The conversion factor can be determined by adding and withdrawing known volumes to the tank and measuring the actual change in height of the product. The known volume added can be either product or some solid object such as a metal bar. For example, if 5 gallons is added to the tank and the height of the liquid in the fill pipe increased by 15 inches, a height of 3 inches would equal a volume of 1 gallon, making the height-to-volume conversion factor equal to 3 inches per gallon.

Preparation → Testing → Analysis

Correct coefficient of thermal expansion of product

The coefficient of expansion of a liquid relates changes in its volume to changes in its temperature. The coefficient of expansion is different for each product. The units of the coefficient are change in gallons per degree Fahrenheit. If the wrong coefficient of expansion is used, the calculated leak rate will be incorrect.

Some tightness test methods use average coefficients of expansion for general classes of product, such as gasoline or kerosene. However, the coefficient of expansion varies within each type of product, and the uncertainty inherent in assuming an average coefficient based on product type is at least 10 percent. To more accurately determine the

coefficient, the tester should take a product sample, measure its density using an API hydrometer, convert the density to standard temperature and pressure, and then read the coefficient from a set of API tables. The uncertainty inherent in a coefficient of expansion determined by measurement of the product density is about 5 percent.

Testing

Preparation → Testing → Analysis

Collection of sufficient test data

Another common problem with tightness testing is not collecting enough data to make an accurate and statistically significant determination of the status of the tank. Some tightness test protocols require sampling only every 15, 30, or 60 minutes. As discussed above, some important interferences to accurate tightness testing such as tank end deflection and thermal fluctuation should be monitored using the level and temperature data. If these data are taken only infrequently, important trends in the data may be missed and, thus, problems may not be identified. If the test does not last long enough, very small leaks may not be identified.

More data may be collected by either sampling more frequently or conducting longer tests. As a rule, obtaining more data increases the probability of correctly identifying the presence of a leak. Ideally, level data should be sampled at intervals of approximately one second; however, such a sampling frequency is not practical with most equipment. For manual tightness test methods, a sampling frequency on the order of 5 minutes is generally adequate. Studies have shown that tests at least 2 hours in duration (after appropriate waiting periods have been observed) provide more accurate results.

Preparation → Testing → Analysis

Adequate temperature compensation during test

Measurement of the average temperature of the product throughout the tank is important because the total volume of the product will change in response to changes in temperature. If the temperature changes in only one or two points in the tank are measured, incorrect total volume changes for the tank will be calculated.

The stored product will expand and contract in response to temperature changes. Once the appropriate waiting time has passed following product delivery, the product in the tank will usually be

stratified into layers of different temperatures. Very small temperature changes continue to occur in each of these layers, even after the tank is essentially stabilized. The extent and rate of temperature changes will vary layer by layer, and thus, the change in product volume will be different for each layer. The temperature in one layer is not indicative of changes in the other layers. Therefore, it is necessary to measure the temperature in as many layers as possible to obtain an accurate total volume measurement.

Because of the problem of temperature gradients within the tank, the tightness test method must have temperature sensors that provide adequate spatial coverage of the tanks, so that the data they record are representative of product conditions throughout the tank. A vertical array of at least five thermistors provides the best spatial coverage. An array of three sensors, arranged vertically, at the top, middle, and bottom of the tank is considered adequate. Although one sensor typically is not sufficient, methods that circulate the product in the tank can obtain satisfactory results with a single probe. By mixing the product, the problem of uneven temperature distribution in the tank is eliminated. Methods using temperature probes that average the temperature throughout the tank into a single value also eliminate this problem.

Preparation → Testing → Analysis

Constant product level maintained during overfill tests

Adding or removing product changes the hydrostatic pressure within the tank, causing the sides of the tank to expand or contract, changing the apparent volume of product in the tank. Even relatively small level changes that occur during data collection can cause some tank deformation, leading to erroneous test results.

Tank tightness test methods can be categorized into those that maintain a steady product level and those in which the product level is allowed to fluctuate. In constant-level tests, small amounts of product are added or removed periodically to maintain the product at a specified level. The product can be added or removed either manually or automatically. In variable-level tests, no such adjustments are made. When the fluid level is kept constant during the test, the tank will neither expand nor contract during the test in response to the level changes, thus removing an interfering factor, and measured volume changes will accurately represent actual volume changes. The amount of product added during constant-level tests is too small to introduce any error in the test results due to temperature-related effects.

Variable product level is a problem primarily with overfill tightness test methods. For underfill test methods, the changes in product level are too small to cause enough change in head pressure and, thus, deformation of the tank ends.

If the product level fluctuates during a test, it is impossible to compensate for the effects of tank deformation on volume. It is advisable, therefore, to eliminate from consideration for use any test conducted under variable hydrostatic pressure (i.e., variable product level).

Preparation → Testing → Analysis

Compensating for evaporation and condensation

Unless a tank and its fill tube are completely filled and no air or vapor pockets are present, it is likely that, as temperature changes, fluid will evaporate from the free product surface into the air space and/or will condense along the inner surface of the tank walls and drip back down. This activity produces volume fluctuations as liquid product evaporates and condenses. Although a few test methods attempt to account for the effect of evaporation and condensation, these effects are not believed to be significant enough to warrant special control or measurement during a tightness test. In an overfilled-tank test conducted under extremely hot conditions or with the standpipe in direct sunlight, it is possible that product may evaporate in the standpipe; however, such conditions are very rare. Shade could be provided for the standpipe, or testing delayed to a cooler day. A record of ambient air temperature during the test may help to pinpoint possible reasons for unusual test results.

Preparation → Testing → Analysis

Fixed number of tests in the testing protocol

When the results of a tightness test indicate that a tank is leaking but the leak rate is only slightly above the threshold value for declaring a leak, some testers repeat tests on the tank until the results of one test indicate that the tank is tight. This approach is a misuse of the "more data are better" axiom and reduces the probability of detecting a leak. A multiple-testing strategy is a valid approach to tightness testing but it must be performed correctly and all of the data must be considered, not just the data from the one test that gives the desired answer. For example, the testing protocol could require that five tests be performed and the tank declared tight if the

results of three of the tests are below the threshold. Under this approach, the minimum detectable leak rate is less than that for a single tightness test. A multiple-testing strategy must be a well-defined part of the testing protocol, and no deviation should be allowed from the total number of tests conducted.

Preparation → Testing → Analysis

Minimizing decisions left up to the tester

In some test methods, the procedures to be followed by the tester are ill-defined or are left to the tester to decide, such as the point at which to end the test. Some circumstances may not be included in the protocol at all, such as how to recognize vapor pockets. Much is left to the discretion and experience of the tester. However, not all testers have sufficient experience to make informed decisions. In addition, even relying on experienced testers may result in different decisions being made by different people in the same situation. These factors decrease the likelihood of a test method achieving accurate and consistent results.

The most reliable test methods are those least subject to operator influence. Any test method which requires or allows the operator to make subjective decisions during the test should be avoided. For example, the test operator should not be allowed to decide when to make a product-level adjustment or to decide how much product should be added or removed. Adjustments of any kind should be accomplished using a set, repeatable procedure, not an arbitrary one. As discussed above, the number of tests and their length should be specified by the test protocol and not left to the discretion of the tester.

Analysis

Preparation → Testing → Analysis

Protocol followed and correct threshold value used

Many test methods lack a defined data-analysis protocol and a clear criterion for deciding if a tank is leaking. This deficiency allows testers to make subjective decisions and leads to unclear or even false determinations of the status of the tank.

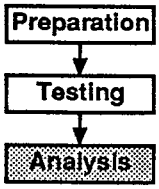
A reliable test method will have a well-defined procedure for analyzing the data, either manually or by computer. The necessary steps in a data analysis are presented here. The first step is to calculate the volumetric flow rate, which can be accomplished in

different ways. The goal of any calculation is to compute the *average* rate of change, or flow rate, that indicates how fast liquid is escaping from the tank. First, the level changes measured during the test are converted to volume changes using the height-to-volume conversion factor. Using the coefficient of thermal expansion, compensation is made for any temperature changes that were recorded. The temperature-induced volume changes are then subtracted from the measured volume change, yielding the temperature-compensated volume changes. These are used to determine the volumetric flow rate. If performed manually, these calculations must be explicitly defined for the tester.

The manufacturers of some test methods use all the data available when they perform the analysis. Others employ averaging techniques. One example of an averaging scheme is to subtract end-of-test data from start-of-test data and divide by the time that has elapsed between the two. Another example is to add all the cumulative volume changes and then divide this sum by the duration of the test. Finally, some manufacturers fit a line to the data; that is, the data points are expressed as dots on a graph, and a line is drawn as closely as possible through the points. Whatever analysis scheme is used, it must be well defined, and the tester must adhere to that protocol.

To determine if the tank is leaking or not, the volumetric flow rate must be compared to a threshold value, which has been predetermined as part of the test design. In order for a test method to perform well against small leaks, the threshold value must be smaller by a factor of 2 or more than the smallest leak to be detected. Let us assume, for example, that a tank is leaking at the rate of 2 gal/h. If the test method in question can discern leaks as small as 1 gal/h, it will almost certainly detect the 2-gal/h leak. However, if the tank is leaking at a rate of 0.5 gal/h, less than what is discernible by this test method, the leak will go undetected.

The most commonly used threshold is 0.05 gal/h. This threshold is often confused with the leak rate to be detected. If the threshold is equal to the leak rate to be detected, the probability of detecting a leak of that size is only 50 percent. The final federal regulation requires a tightness test method to have a minimum detectable leak rate of 0.1 gal/h. For a test method to meet this requirement, its threshold must be less than 0.1 gal h. For most test methods, this threshold will be around 0.05 gal/ h.



Calculations performed correctly

For test methods in which the volumetric flow rate is determined manually, one problem can be simple calculation errors, leading to an incorrect conclusion. A tester should always have someone else double check the calculations. In some local programs such as Nassau County, New York, copies of all tightness test records must be submitted to the implementing agency. Personnel at the agency double check the calculations, either by hand or using computer programs developed for the tightness test methods allowed in the county.

ENSURING EFFECTIVE TESTING

To ensure that testers follow the procedures necessary to prevent the problems described above from occurring, a number of state and local implementing agencies have developed programs to oversee the practice in their jurisdictions. Chapter 1 provided a general description of the four types of oversight that can be used. The following section summarizes briefly some of the specific actions taken by implementing agencies to ensure effective tank tightness testing.

Site Inspections

In Rhode Island, the ground water is frequently very high and, therefore, checking and compensating for its presence is very important. State agency personnel routinely follow up a number of tests by visiting the site and making sure that there is some way in which the ground-water level could have been checked. Either an observation well was already on-site for some other purpose or a hole was drilled by hand specifically for the tightness test.

In Nassau County, New York, testers must call county officials when level and temperature data collection is about to begin so that the official may visit the site and observe the test. Which tests to observe is left to the discretion of the regulator. In Austin, Texas, the owner/operator must notify the implementing agency before a test is performed and agency personnel observe all tests.

Data Review

Several states and counties, such as Rhode Island, Nassau County, New York, and Madera County, California, require tightness testers to submit test reports to the implementing agencies. Regulators then review these reports for adherence to key procedural elements such as: ground-water level, actual calculation of coefficient of expansion, length of test, number of data points, and appropriate testing levels. Recalculation of the test data is also performed on all or part of the test reports. Personal computers have been used to cut down on the time necessary for a review of test data. Nassau County, New York, has written a computer spreadsheet to be used with the data from two common test methods that double checks the tester's calculations using the tester's raw data. Rhode Island enters all test results into a computer program that performs statistical analysis on the pass/fail ratios of the test companies. Whenever a company is passing or failing a disproportionate number of tanks, the agency investigates.

Guidance and Training

Because proper procedure is so important to effective tank tightness testing and because it is the major source of error as currently practiced, training and guidance can be an important tool. Guidance can be aimed at implementing agency personnel, so that they can provide effective inspection and review, at owner/operators, so they can select and oversee effective testers, and at testing personnel, to ensure that they perform the tests correctly.

Approval and Certification

Some implementing agencies have tried to prevent tightness testing mistakes by only allowing methods and personnel that they feel are acceptable. Several different approaches are being used. Maryland requires that manufacturers submit performance evaluation results to the state for review, physically demonstrate the method to state personnel, provide information on their personnel training/certification program, and then, if accepted, train state agency personnel. In Nassau County, New York, regulators review the test procedure manual for specific directions addressing the key elements identified in NFPA 329. In Los Angeles County, California, all tightness testers must be tested and approved by an independent party.

In other states, one step in the method approval process requires that the manufacturer train agency personnel in the operation of the test method. Massachusetts requires that the manufacturer provide a video to be used for training. Rhode Island and Maryland require that testers train the implementing agency personnel.

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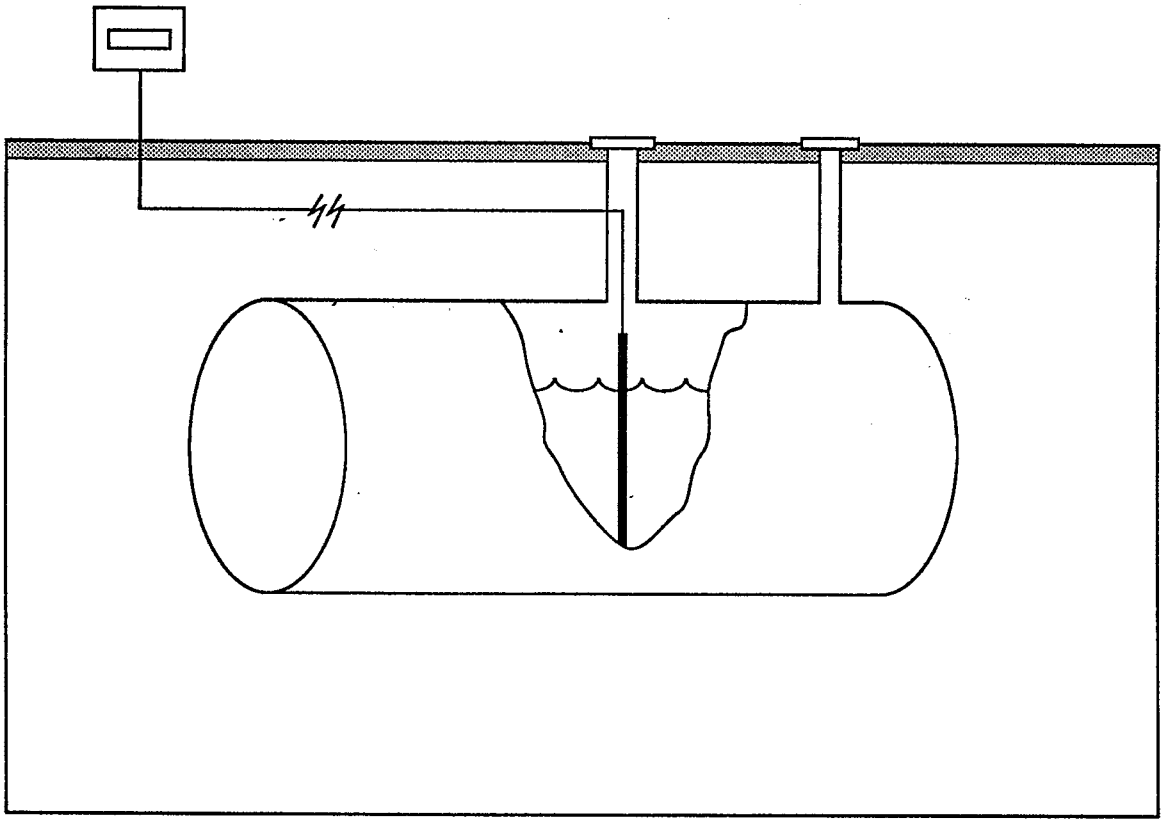
Chapter V
Automatic Tank Gauging



AUTOMATIC TANK GAUGING SYSTEMS V

SUMMARY

Automatic tank gauging (ATG) systems are permanently installed in underground storage tanks and provide both leak testing and inventory information. When the two modes are used together, ATG is an effective release detection method. Two studies conducted on ATG systems indicated that the leak test mode is capable of detecting leaks as small as 0.2 gal/h with a probability of detection of 95 percent and a probability of false alarm of 5 percent. The inventory mode of ATG systems is more accurate than the comparable manual method.

ATG systems are selected by owner/operators because such systems require minimal operator involvement, cause few service interruptions, and can provide frequent automated release detection. In addition, the inventory mode provides continuous product information helpful in business management. For UST operations that close at least once a month, which includes many sites, the leak test mode does not interrupt operation. The inventory mode provides nearly continuous monitoring for the large losses typically discovered by inventory methods and, depending on how the owner/operator elects to operate the ATG system, the tightness test mode can be used every time operations cease (e.g., nightly, at many service stations).

The discussion presented in this chapter covers a range of problems that may occur with ATG systems. This does not mean that all, or even most, of these problems will occur at the same time or at the same site. Nor does it mean that all of the problems are of equal importance, in terms of frequency of occurrence or severity of impact on the effectiveness of ATG systems. Some problems, such as blended fuel dispensers, seldom occur. Experienced ATG system vendors and installers are well aware of these problems and how to deal with them. For example, a reputable installer knows the proper wiring installation materials and methods and will follow them. Release detection is a growing industry, however, and new companies are being formed that bring less experience to the field. Presented in this chapter is a range of potential problems for educational purposes, not to imply that the problems will always occur.

BRIEF DESCRIPTION

General

Figure 14 presents a general schematic of an ATG system. All ATG systems are based on the same general approach. This section focuses on the general principles behind ATGs and not on specific equipment. For details on the specific equipment, manufacturers and vendors will provide literature.

ATG systems measure the change in product level within the tank over time to determine if there is a leak. When a leak occurs in an UST, the loss of product causes a decrease in the level of product. Other factors also can cause product level changes. The most important of the interferences are product temperature and tank deformation caused by addition or withdrawal of product. ATG systems differ primarily in how product level and temperature are measured.

ATG systems have two modes of operation: inventory control and leak testing. When the system is on, it is in one of these modes and can be switched to the other. The same equipment is used for both operations. Installation of the equipment and the operation of the inventory and test modes are described in the following sections. Figure 15 is a flow chart of the general operation of an ATG system.

Installation

Installation of an ATG system involves equipping each tank with a probe to measure product level and temperature. The probe is inserted into the tank through a separate fitting (not the fill pipe) on top of the tank. For most ATG systems, the fitting must be 3 or 4 inches in diameter. Some older USTs do not have extra openings or the existing bungs are too small; in this case, an opening of appropriate size for the probe must be made by the installer.

A remote monitor and microprocessor are installed in a nearby building to record the information read by the probe. The monitor usually has a keyboard for programming and a display for presenting the required data. Underground wiring is installed between each probe and the remote monitor. In some ATG systems, wiring is also installed between the dispensers and the monitor or the pump control console/point of sales device and the monitor. National electrical codes require that the

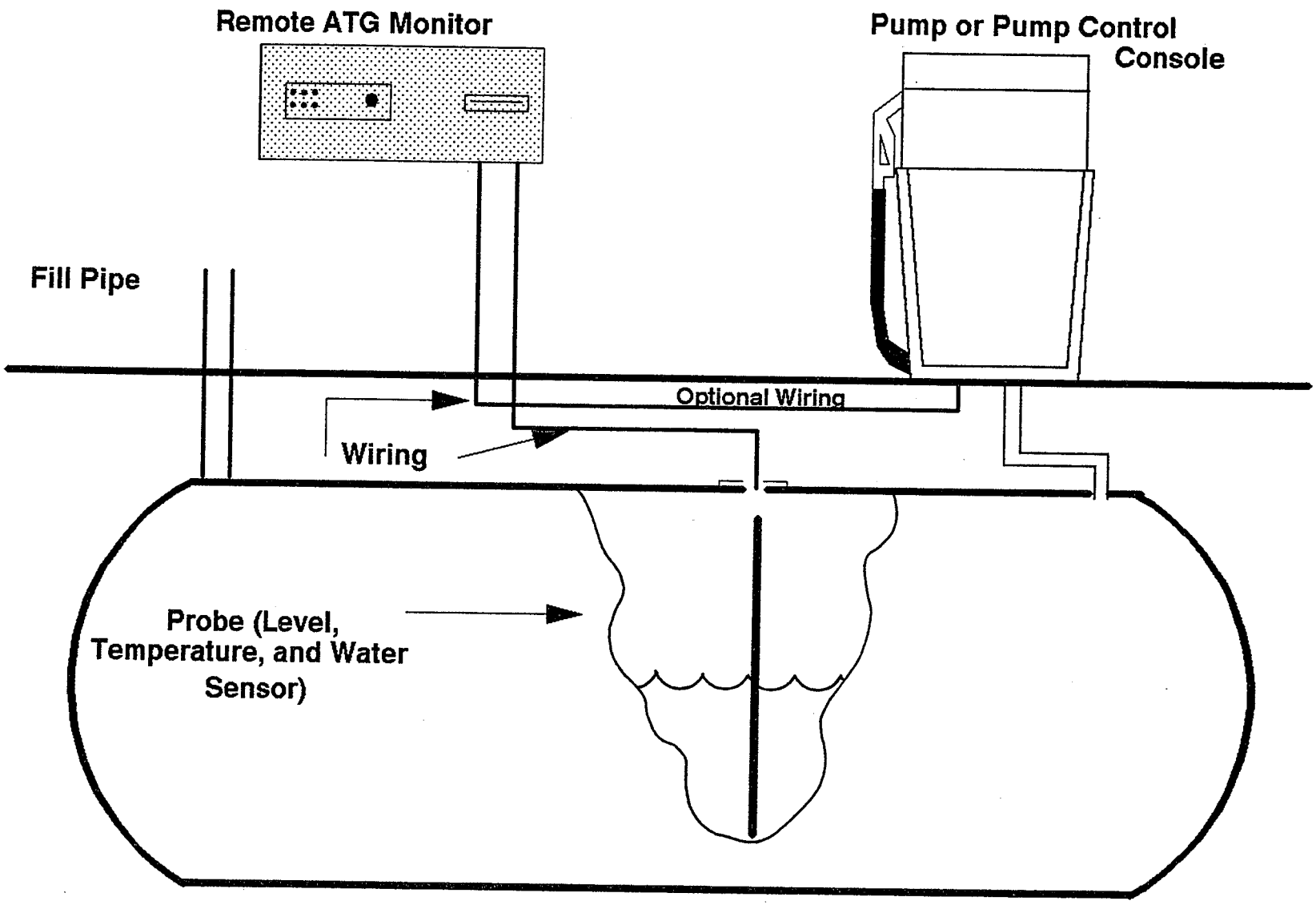


Figure 14. Schematic of automatic tank gauging system.

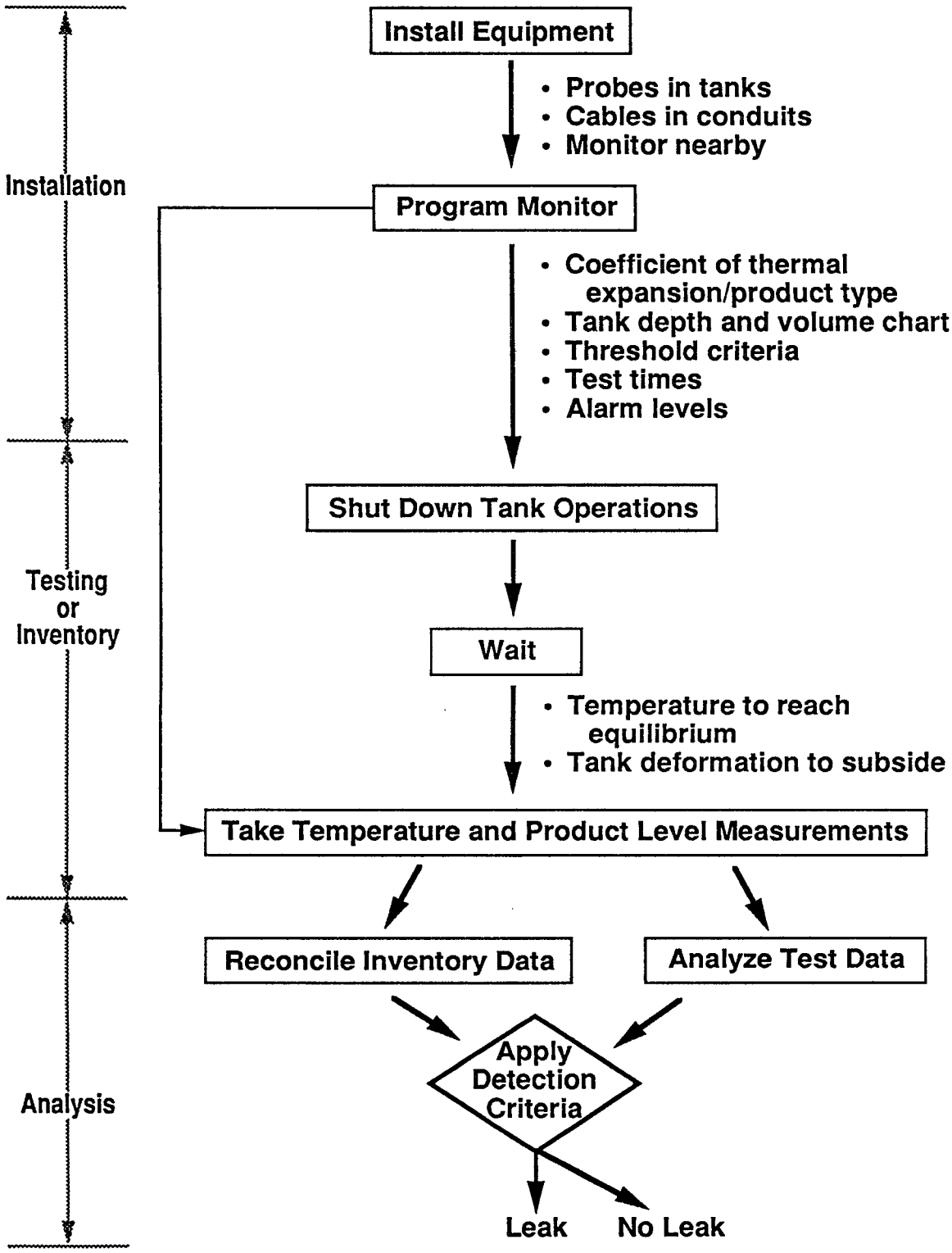


Figure 15. General procedure for ATG Systems

wiring be installed in some kind of conduit to protect it from dirt and moisture and isolate it from the surroundings. For most ATG systems, four to eight probes can be connected to one monitor. The height-to-volume conversion factor and the coefficient of thermal expansion (see Chapter 4 for definitions of these terms) must then be entered into the monitor by the installer.

Installation time varies with conditions at the site and the number of tanks being fitted with probes. For a four-tank site with no unusual problems, it typically takes about a day to install the conduits and wiring and a day to install the probes.

Leak Detect Mode

Tanks must be taken out of service when the ATG system is in leak detect mode. Most tanks, therefore, are tested at night when operations at the site typically shut down. Most ATG systems can be programmed at the monitor to automatically switch to the test mode at a preset time. Alternatively, on-site staff can manually switch the ATG system to test mode at the appropriate time. The test mode can be run as frequently as the owner/operator determines.

The test is conducted at whatever product level is in the tank at the time of the test. The large surface area of the product in an underfilled tank (product level below the top of the tank) means that any product loss due to a leak would result in a very small change in level. Because testing is performed on underfilled tanks, the product level is essentially constant during the test, which is necessary for an effective tank test (see Chapter 4 for a detailed discussion of constant-level vs. variable-level tests).

When the ATG switches to leak detect mode, temperature and level readings are taken automatically. The test can be programmed to last a predetermined length of time. Also, some ATG systems can be programmed for a desired minimum detectable leak rate; the microprocessor then determines the necessary sampling frequency for product level and temperature and for test duration. If a detectable leak rate below 0.2 gal/h is selected, the probability of detecting such a leak will probably decrease somewhat. Level and temperature readings are usually taken every 1 to 2 seconds and averaged every 30 to 60 seconds. The length of the test varies with the system and the level of sensitivity desired. Tests generally range from 1 to 6 hours in length, with most test lengths falling in the lower end of the range. As the number of probes

connected to the monitor increases, the frequency of readings and the test length decrease because the probes are "read" in series and it takes longer to complete a circuit of eight probes than to read two probes.

The level and temperature readings are fed to the microprocessor, which converts these readings to temperature-compensated volume measurements, analyzes the data according to some statistical algorithm, and determines a rate that indicates how fast product level is changing in the tank. This rate must then be compared to a threshold value to determine if the level changes are due to a leak or to normally occurring volume fluctuations. If the temperature-compensated volume change exceeds the threshold, a leak is suspected; if not, it is assumed that the tank is not leaking.

Inventory Mode

The same level and temperature readings taken during the test mode are taken in the inventory mode, which is in operation any time a test is not being run. In addition to taking product level and temperature readings in the tank and converting them to volume measurements, some ATG systems measure and record the amount of product dispensed. For other ATG systems, the dispenser information must be recorded manually by on-site staff. Product deliveries also are recorded by the ATG system. Increases in volume in the tank that are above a minimum rate and volume are interpreted as a delivery.

If the dispensing information is collected by the ATG system, the microprocessor automatically reconciles the inventory data at the interval programmed into the monitor; one hour is often selected as the interval. If staff record the dispensing information manually, the volume and delivery data from the ATG must be combined with the dispensing data and reconciled manually (see Chapter 2 on Inventory Control).

As part of the inventory mode, the probe in most ATG systems also measures the level of water in the bottom of the tank. This information is converted to a volume and used in the inventory reconciliation. Other features included in many ATG systems are alarms for high product level, low product level, high water level, and theft (indicated by sudden large loss of product). The levels at which these alarms are triggered are programmed into the monitor.

POTENTIAL PROBLEMS AND SOLUTIONS

This section presents a discussion of problems that have been encountered with ATG systems. Many of the problems and solutions are similar to those for tank tightness testing, which are discussed in Chapter 4. To avoid repetition, this chapter includes only a brief summary plus a reference to the relevant section of Chapter 4 for those problems that are common to both methods. Table 6 presents a summary of the indicators and solutions to problems with ATG systems as well as possible approaches that implementing agencies can use to prevent or overcome the problems. A number of agency solutions are offered for each problem, but not all of them need be undertaken. Table 6 and the discussion below are presented in the order of the flow chart (Figure 15 on page 80). There is no ranking implied by the order. In Table 6, the most serious concerns are indicated by an asterisk.

Installation

Installation → Testing or Inventory → Analysis

Ensure that equipment is installed properly

Most problems with the installation of ATG systems are associated with the installation of conduits for the wiring. National electrical codes require that the cables be isolated from other electrical wires. Most UST sites already have conduits containing wiring for other equipment, such as the dispensers, and this wiring is often contained within one main conduit. Installers of ATG systems sometimes use existing conduits for the ATG wiring because it is easier and less expensive than installing new conduits. If existing conduits containing wiring are used, the ATG wiring must be isolated in some manner, such as with flexible plastic casing. Any time wiring is found that is not isolated, power to the wiring should be immediately shut off and the problem fixed before the system is allowed to operate again.

Installers sometimes neglect to continue the conduit/isolating material around the wiring where the wiring enters the building and connects to the monitor. In addition, installers sometimes use sealing compound for the last several feet of wiring instead

Table 6. Indicators and Solutions for Problems Encountered With Automatic Tank Gauging Systems

Problem	Indicators	Tester Solutions	Agency Oversight Options
Assure correct installation of wiring.	No readings or erratic readings.	Isolate wire in separate conduits, or encase in isolating material.	Observe installation. Review installation plans.
Use correct coefficient of thermal expansion.	False alarm.	Whenever type of product changes, reprogram monitor.	Compare product type to program value during site inspecion or review of reports.
***Need for adequate waiting time before testing.**	Erratic and large volume changes. Short-term volume changes that level out.	Wait at least 6 hours after fuel delivery before testing. Wait as long as possible after UST operations stop to begin test. At 24-hour sites, test following period of lowest use.	Review printouts for product delivery and test times. Review and approve testing schedule.
***Need for adequate temperature compensation during the test.**	None.	Use at least three temperature sensors equally spaced vertically, or use temperature-averaging probe.	Observe installation. Review product literature. Approve only ATG systems with appropriate designs.
***Preventing interference due to evaporation and condensation.**	None.	Do not open any fittings on top of the tank for at least 6 hours before the test and during the test.	Observe test. Train/educate staff at UST site.
***The number of tests to be conducted at a tank must be fixed.**	High percentage of tanks declared "tight."	Protocol must include fixed number of tests. Use progammable monitor that can be locked.	Review printouts of tests; compare to protocol. Approve only programmable systems that cannot be overridden. Train/ educate staff at UST site.

Correct threshold must be used to determine leak status. (A threshold is a predetermined value; measurements made during a test are compared to this value.)	High percentage of tanks declared "tight."	Threshold value should be smaller than the minimum detectable leak rate by a factor of at least 2. Program monitor compares leak rate to threshold and triggers alarm if leak is suspected.	Keep track of pass/fail ratio of each type of ATG system. Approve systems with adequate thresholds or with alarm systems.
Accounting for the presence of ground water.	Water in the tank.	Water sensor in the tank as part of the ATG system.	Approve only ATG systems with water sensors. Observe installation. Review release detection plans and manufacturer's product descriptions.
Assuring testing at a range of product levels.	Monthly tests are always conducted at low product level.	Program tests to take place at varying product levels that cover the range typically stored.	Review printouts to compare range of product levels during the month to levels during tests. Review testing schedule with knowledge of delivery schedule and UST operations.
Use correct height-to-volume conversion factor.	None.	Add or withdraw known volume from tank, and observe level changes.	Review data sheets for calculation of conversion factor.
Assuring appropriate treatment at UST sites with blended fuel systems.	None.	Treat multiple tanks as one unit for purposes of reconciliation.	Inspect site before system installed. Review site plans before installation.
Assure calculations are correct.	Improbable results.	A second person double-checks manual calculations. Computer program is reviewed and tested using known and verified data.	Manual or computer recalculation. Approve only systems with automated inventory.

***Indicates the most significant problems.**

of for the last few inches. Both of these practices violate electrical wiring codes and are unsafe.

Sometime the conduits that are installed are too small for the amount of wiring that must run through them. It takes extra time and effort to install the wiring and creates the risk of damaging the cables. Generally, conduits should have an internal diameter of at least 3/4 inch.

Installation → Testing or Inventory → Analysis

Use correct coefficient of thermal expansion of the product

The coefficient of thermal expansion of a liquid relates changes in its volume to changes in its temperature. The units of the coefficient are change in gallons per degree Fahrenheit. The coefficient is used to convert changes in temperature readings taken by the probe to changes in volume as part of the determination of leak rate. The coefficient of expansion is different for each product. When an ATG system is installed, the "average" coefficient for the product type in the tank is programmed into the monitor. If the type of product stored in the tank is later changed (e.g., from gasoline to diesel) and the coefficient is not changed, the calculated leak rate will be incorrect. When the ATG system is installed, it is important that the installer inform the on-site personnel of the need to reprogram the monitor and inform them how to accomplish this should the product be changed.

Leak Test Mode

Installation → Testing or Inventory → Analysis

Allow adequate waiting time before beginning test

When product is added to a tank, the product in the delivery truck is at or near the air temperature while the product in the tank is at or near ground temperature. For some time after delivery, the temperature within the tank fluctuates rapidly and widely as the product mixes and eventually achieves equilibrium. The addition or withdrawal of product causes the ends of the tank to move outward or inward, respectively, in response to the changing head pressure of the liquid on the tank walls. The fluctuating temperature and structural changes of the tank following the addition of product cause volume and level changes that can be misinterpreted as changes caused by leaks. See Chapter 4 for additional discussion of these phenomena.

Unlike the tank tightness testing methods discussed in Chapter 4, product is not deliberately added to a tank before a test is conducted with an ATG system. Instead, the test is performed at the product level in the tank when the monitor is switched to the test mode. The level in the tank depends on routine product deliveries and withdrawals. No standard minimum waiting time between stopping tank operations and beginning to test will be applicable to all situations because the waiting will vary with the amount of use (i.e., number and amount of withdrawals) at that tank before operations ceased. The ATG system should be programmed to begin testing as long as possible after UST operations have stopped. If the UST site operates 24 hours per day, the test should be scheduled following the period of least use, such as late at night (at service stations). The tank to be tested must be shut down during the test. Any time product is delivered to an UST, at least 6 hours should elapse between delivery and testing.

Another temperature-related problem can occur when product is added that is significantly higher in temperature than the product in the tank. In this situation, ATG systems that determine product level using capacitance probes may respond with a false alarm during a leak test. Differences in temperature cause differences in densities, which in turn cause differences in the capacitance of the products. The waiting period discussed above should reduce the chance of false alarms caused by this problem. Most ATG systems using a capacitance probe also have a program built into the analysis that can usually detect this problem and declare the test invalid.

Installation → Testing or Inventory → Analysis

Adequate temperature compensation during the test

After the temperature in the tank stabilizes, the product is usually stratified into layers of different temperature. Each layer will continue to undergo small changes in temperature, the extent and rate of the change being different for each layer. If the temperature changes of only one or two layers is recorded during a test, the temperature-compensated volume changes calculated for the entire tank will be incorrect, resulting in an erroneous leak rate determination. For additional discussion of this issue, see Chapter 4.

For the reasons given, the temperature sensors in the ATG system probe must provide adequate spatial coverage of the tank, i.e., the data recorded must be representative of product conditions throughout the tank. At least five temperature sensors arranged vertically provide the best coverage, although three vertically arrayed sensors usually are adequate. One temperature sensor generally does not provide sufficient coverage of the tank, with one exception. At least one ATG system uses a temperature-averaging sensor that provides a single temperature value over the entire depth of the liquid.

Installation → Testing or Inventory → Analysis

Preventing interference due to evaporation and condensation

During a test with an ATG system, the tank is only partially filled with product. If there are at least 15 cm between the level of the liquid and the top of the tank, which is the case with most ATG tests, evaporation and condensation are potential problems. As temperatures change, fluid will evaporate from the product surface into the air space at the top of the tank and/or will condense along the inner surface of the tank walls and drip back down. Evaporation and condensation of the liquid product cause fluctuations in the product level that could mask or mimic a leak. Eventually, the evaporation and condensation between the liquid product surface and the air space above it will come into equilibrium and no further change in the liquid level will occur. If this equilibrium is upset, such as by opening the top of the tank or adding product to the tank, the liquid level will fluctuate until the tank regains equilibrium.

Before conducting an ATG test, the headspace of the tank must be allowed to come to equilibrium. To achieve this, none of the fittings on the top of the tank should be opened for at least 6 hours before the test begins. The equilibrium must be maintained during the test, again by not opening any of the fittings on the tank.

Installation → Testing or Inventory → Analysis

Fixed number of tests to be conducted

When the results of a test indicate a leak rate that is only slightly above the threshold value for declaring a leak, some owners may rerun the leak test mode on the tank until the results of one test indicate that the tank is tight. Because conducting a test with an ATG system is relatively simple and can be done during nonbusiness hours when the tank is not in use, this approach to

testing may be tempting. This approach, however, is a misuse of the system and reduces the probability of detecting a leak.

The same ease of testing that leads to this type of misuse also makes a *valid* multiple-testing strategy a likely option for ATG. In a multiple-testing strategy, a fixed number of tests are run, and the results of all the tests are used to determine the leak status of the tank. This strategy increases the sensitivity of the test and the likelihood of detecting a leak. An UST site that closes operations for the night or weekend could easily run several tests with the ATG system, and the microprocessor can be programmed to perform the necessary statistical analysis. Whether the ATG system uses a multiple-testing strategy or a single test, the key to successful leak detection is to define explicitly the number of tests and to carry them out. Many ATG systems can be locked after they are initially programmed so that the protocol cannot be changed except by the person with the key. The manufacturer of the ATG system must determine the number of tests to be run to meet the regulatory performance standards and provide this information.

Installation → Testing or Inventory → Analysis

Correct threshold value used to determine leak status

After reading and analyzing the product temperature and level data, the calculated volumetric leak rate in gal/h must be compared to a threshold value to determine if the tank is leaking. Some ATG systems just display the calculated leak rate and the comparison and determination of leak status is made by on-site personnel. Other ATG systems compare the calculated leak rate to a programmed threshold and display PASS or FAIL along with the leak rate. If the wrong threshold value is used, an incorrect determination will be made. For a test method to perform well in detecting small leaks, the threshold value must be smaller by a factor of two or more than the smallest leak to be detected. The federal regulation requires an ATG system to have a minimum detectable leak rate of 0.2 gal/h. For an ATG test to meet this requirement, its threshold must be less than 0.2 gal/h. For most systems, the threshold will be around 0.1 gal/h. The exact value for each system should be determined by the manufacturer and supplied to the owner/operator.

Installation → Testing or Inventory → Analysis

Accounting for the presence of ground water

The presence of ground water around any portion of the tank may lead to erroneous test results if there is a hole in the portion of the tank under water. The pressure of the ground water inward counteracts the outward head pressure of the leaking product, either slowing or completely stopping the leak. The ground-water level at a site generally fluctuates over time with the seasons and the amount of precipitation. For further discussion of the influence of ground water on leaking tanks, see Chapter 4.

ATG systems conduct tests at the level of product in the tank at the time of the test; therefore, the product level will be different for each test. The ground-water level is also likely to be different during each test. It is unlikely that for each test the levels of product and ground water will be such that the pressures are equal, preventing product from leaking out of the tank and water from entering the tank, particularly if tests are conducted daily or weekly. Therefore, the test mode will detect either a decrease in product level due to product leakage or an increase in water level inside the tank due to ground-water incursion. If at all possible, it is still preferable, however, to conduct the leak test at a time when the ground water is below the bottom of the tank.

It is also important to have a water level sensor as part of the ATG system and to program the monitor to trigger an alarm at some preset water level. Accumulation of water in the tank indicates a possible hole in the tank that must be investigated.

Installation → Testing or Inventory → Analysis

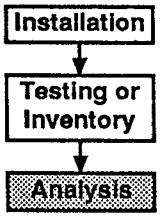
Ensuring testing at a range of product levels

ATG is conducted with the product level below the top of the tank. Some portion of the tank walls will not be below the product surface during a test and, therefore, will not be checked for holes. Either deliberately or by chance, the monthly tests may always occur at a very low product level, allowing a significant portion of the tank surface to go unmonitored.

Given the variability in tank use, it is unlikely that, by chance, the monthly ATG test would always be conducted at a low

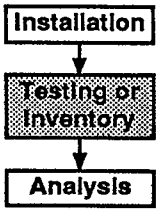
product level. Over the months, the tests probably will be conducted over the range of product levels normally held in the tank.

To counteract deliberate testing at low product levels, implementing agencies could require that data on the product levels in the tank throughout the month be submitted along with the product level during the test. A review of this information would show whether the tests are being conducted over the full range of product levels.



Correct height-to-volume conversion factor used

ATG systems measure changes in product level over time. To calculate a leak rate in gallons per hour, these level measurements must be converted to changes in volume. During installation of an ATG system, the tank manufacturer's tank calibration chart giving depth measurements and corresponding volumes is programmed into the monitor. Slight variations in the manufacturing process means that the chart is not precisely accurate for all tanks (see Chapter 2 for further discussion of tank charts and how to use them). Usually, these minor variations do not interfere with the accuracy of the ATG results. Occasionally, however, the tank can differ enough from the calibration chart to cause significant error. If repeated false alarms occur, one possible factor to check is the height-to-volume conversion. To do this, product should be added to the tank in known increments, usually of 100 to 500 gallons, and the level measured using the probe. These measured height-to-volume values should then be compared to those programmed into the monitor using the manufacturer's calibration chart. If they are substantially different, the actual measured values should be keyed into the monitor, replacing the calibration chart values. "Strapping" the tank is not performed at each ATG system installation because it is very time consuming.



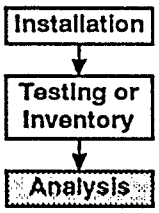
Inventory Mode

Ensure appropriate treatment at sites with blended fuels

At some service stations, the customer can select different blends of fuel at the same dispenser. One dispenser is connected

to more than one tank. The dispenser has several "blenders" that mix different fuels in preset ratios, such as 60/40. To perform accurate inventory control, the ATG system must have accurate values of the amount of product withdrawn from each tank. Some blenders do not have flow meters in the lines leading to the blender to provide accurate product volumes supplied by each tank. The blenders may have 1 to 2 percent error, so that applying the stated ratios to the total volume passed through the blender will not determine the actual volumes withdrawn from each tank.

If blended fuel dispensers are encountered that are not sufficiently accurate, one solution is to treat the product in all of the tanks connected to one dispenser as a single volume. Each tank must have a probe to measure product level and deliveries as usual, converting the level readings to volumes. These readings can then be combined and treated as one tank for purposes of inventory control. The total amount withdrawn from the dispenser is used to perform the reconciliation; no determination of the amount attributable to each tank is necessary because the tanks have been "combined." Combining the tank readings is applicable only to the inventory mode; the tanks must be tested separately in the leak test mode.



Ensure correct calculations

Some ATG systems are not connected to the dispensers. In this situation, the dispenser readings must be recorded manually. The delivery and tank volume data are taken from the ATG monitor, combined with the manual dispenser data, and the inventory reconciliation is performed by hand or the data may be entered into a computer spreadsheet. Chapter 2 provides information on how inventory data should be collected and analyzed. Math errors may result from the hand calculations or entry errors can occur when the data are input into the computer. Any reconciliation other than that performed entirely by the ATG system should be double-checked by another staff member.

ENSURING EFFECTIVE AUTOMATIC TANK GAUGING

The four general approaches that implementing agencies can use to ensure effective release detection are discussed in Chapter 1. The

following sections discuss how these approaches may be applied specifically to ATG systems.

Site Inspections

The site may be visited during installation of the ATG equipment. The most important features to inspect would be that (1) proper conduits are constructed for the cables; and (2) the proper values for the coefficient and the threshold were programmed into the microprocessor. After installation, random site visits might be made to check test records and inventory results. The microprocessor and monitor also could be inspected to ensure that no changes have been made in the programming.

Data Review

The implementing agency could require that information on how the ATG system is installed and programmed be submitted and approved prior to actual startup of the system. In addition, copies of the test and/or inventory results could be mailed to the agency for review. Most ATG systems can be connected to a printer so that little extra effort is needed on the part of the owner/operator to obtain copies. Agency personnel then could compare the leak rate values to the threshold value for the brand of ATG in use.

Similar to an approach used for tank tightness testing results (Chapter 4), the implementing agency could keep a tally of the number of passes and fails for each type of ATG system and investigate those systems with abnormally high proportions of passes.

Guidance and Training

Guidance materials aimed at the owner/operator should emphasize the proper timing of a test and the need to keep the tank closed both before and during a test. Guidance material aimed at manufacturers should emphasize the design needs, such as the number of temperature sensors and the water level sensor.

Approval and Certification

An implementing agency can elect to review ATG systems and approve for use in its jurisdiction only those systems that pass a review and

approval process. Los Angeles, California, requires data from an independent third party demonstrating that the system meets the performance standards. Massachusetts lists all of the elements that must be contained in the written request for approval, such as the principles of operation and whether the method tests the whole tank surface or just the surface below the product surface.

Another approach an implementing agency can use is to require certification or training of all ATG system installers. The agency could run the certification program or could require a minimum amount of training by the manufacturers of the equipment. Most manufacturers of ATG systems already have some type of training program in place.

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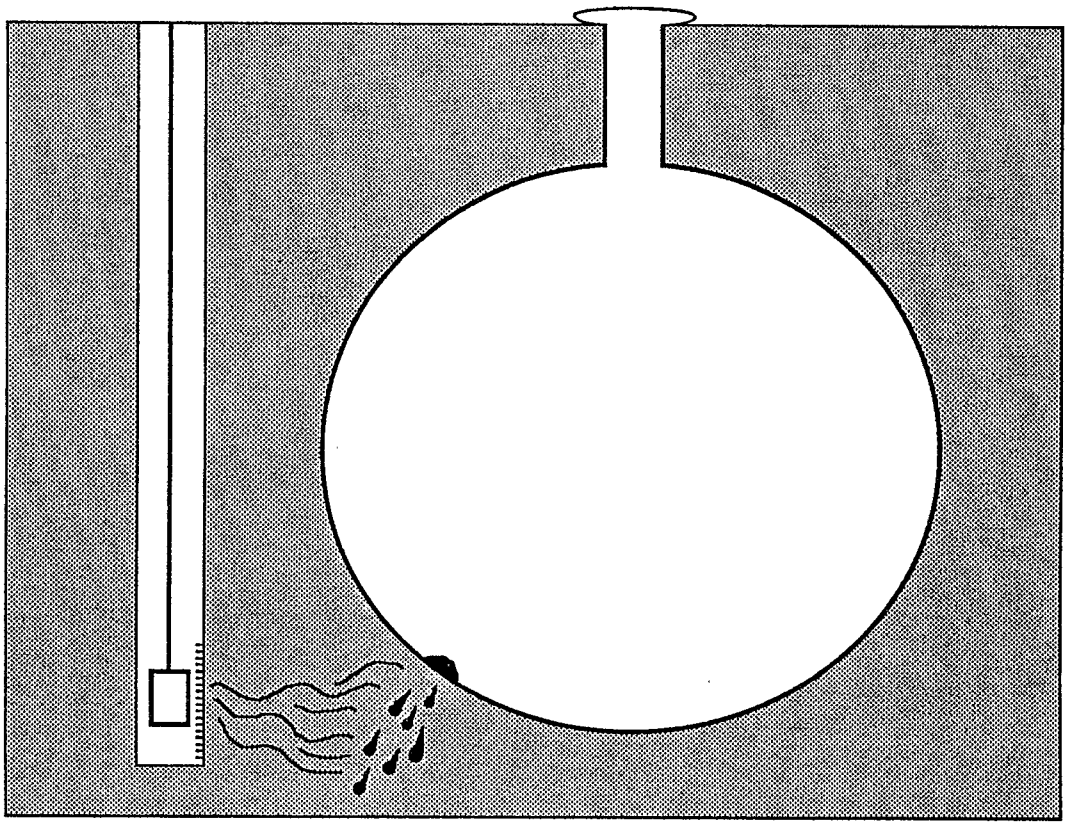
Chapter VI
Vapor Monitoring



VAPOR MONITORING VI

SUMMARY

Vapor monitoring is a relatively new release detection method that has been applied predominantly UST systems storing petroleum products. It has been used extensively in California, and in studies by the EPA it has been shown to detect small leaks quickly.

Before vapor monitoring is selected for release detection, a thorough site assessment should be conducted to ensure that it is appropriate to use this method at the site. Many of the problems that interfere with vapor monitoring can be addressed during the site assessment stage. If chosen as a release detection method, it should be noted that if a monitor indicates the presence of a high concentration of vapors, it does not necessarily mean there has been an UST release. Vapor monitoring results must be carefully interpreted to differentiate between spills, interferences, and releases.

The discussion presented in this chapter covers many of the possible problems that may occur with vapor monitoring. This does not mean that all, or even most, of these problems will occur. Nor does it mean that all of the problems are of equal importance in terms of frequency of occurrence or severity of impact to the effectiveness of vapor monitoring. Some problems, such as many of the environmental interferences mentioned, occur infrequently, while others have limited impact. Experienced vendors are well aware of these problems and how to deal with them. For example, an experienced vapor monitoring company knows better than to install a system in clay backfill or at a site where the monitor does not respond to the UST product. Release detection, however, is a growing industry, and new companies are being formed with less experience. This chapter presents the full range of potential problems for educational purposes, not to imply that they will always occur.

BRIEF DESCRIPTION

The two major components of a vapor monitoring system are the vapor monitoring well and the vapor monitoring device (sensor). Vapor

monitoring wells are small-diameter wells (typically 2 to 4 inches) placed in the backfill material near the UST which are used for collection of vapor samples. A monitoring device can be permanently or temporarily placed in the vapor monitoring well to collect vapor samples. A few monitoring devices are simply buried in the UST backfill and do not require a monitoring well.

Vapor monitoring works according to the principles of volatilization (i.e., the change of a substance from a liquid to a gaseous state) and diffusion (spreading of a gas). As a product leaks from an UST, some of the liquid volatilizes, and the liquid and vapor phases of the product spread throughout the surrounding soil. Vapor monitoring systems take advantage of this phenomenon and are designed to detect the volatile components of a stored substance. If the vapor sample that reaches a sensor is above some predetermined concentration, the monitor responds with an alarm.

A typical vapor monitoring system is depicted in Figure 16.

The successful implementation of a vapor monitoring system involves six different stages: (1) site assessment—an evaluation of the site is conducted to ensure vapor monitoring is an appropriate release detection method and to determine the site characteristics; (2) sensor selection—an appropriate type of vapor monitor is chosen; (3) network design—the proper placement (lateral and vertical) of vapor well(s) is planned; (4) construction and installation—vapor well(s) construction and installation are conducted; (5) operation and maintenance—the sensors are calibrated and monitoring begins; and (6) data interpretation—the monitoring results are evaluated and leak status of the UST is determined. The relationships among these six stages are shown in Figure 17.

POTENTIAL PROBLEMS AND SOLUTIONS

If vapor monitoring is installed and operated correctly, it can be an effective leak detection method. The following sections discuss problems and solutions related to each of the six stages of the implementation of a vapor monitoring system. The order of discussion is not intended to prioritize the importance of the problems, rather it is intended to follow the order in which they would occur according to the flow chart in Figure 17. The discussion of problems and solutions is summarized in Table 7, which starts on page 99; the more serious concerns are marked by an asterisk. A number of agency solutions are

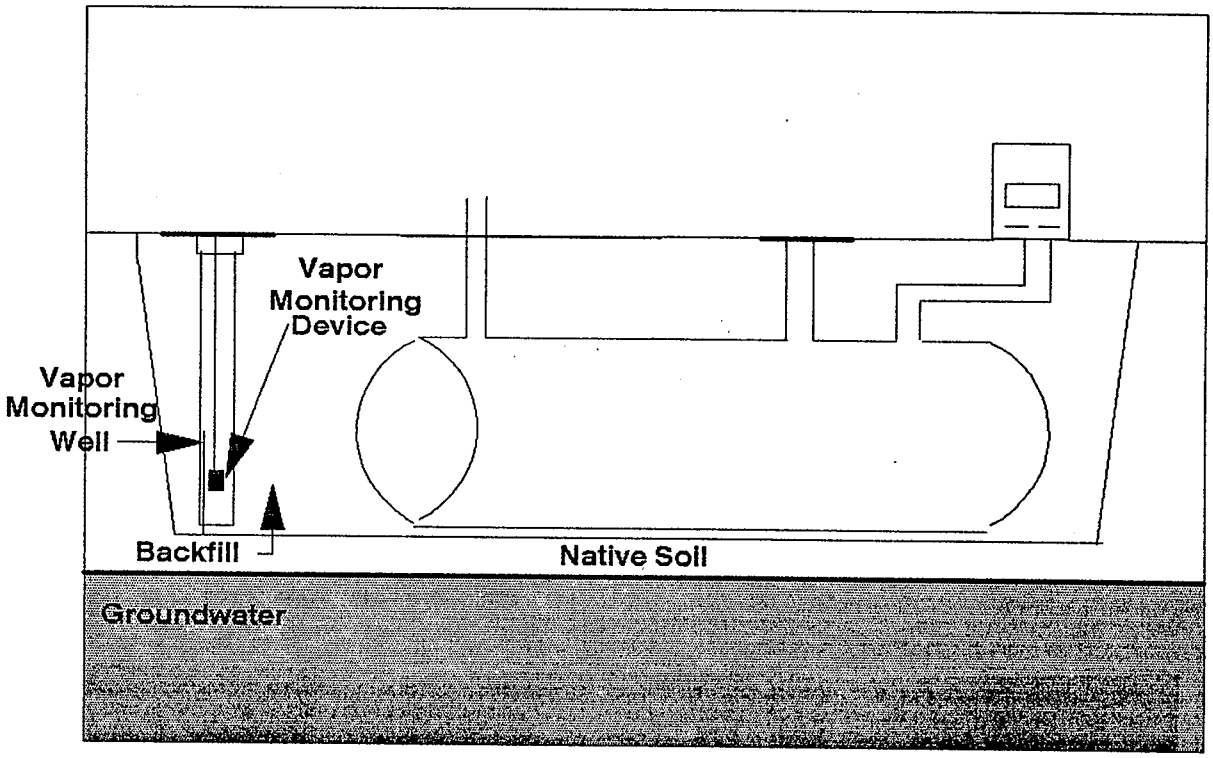


Figure 16. Underground storage tank system with vapor monitoring wells.

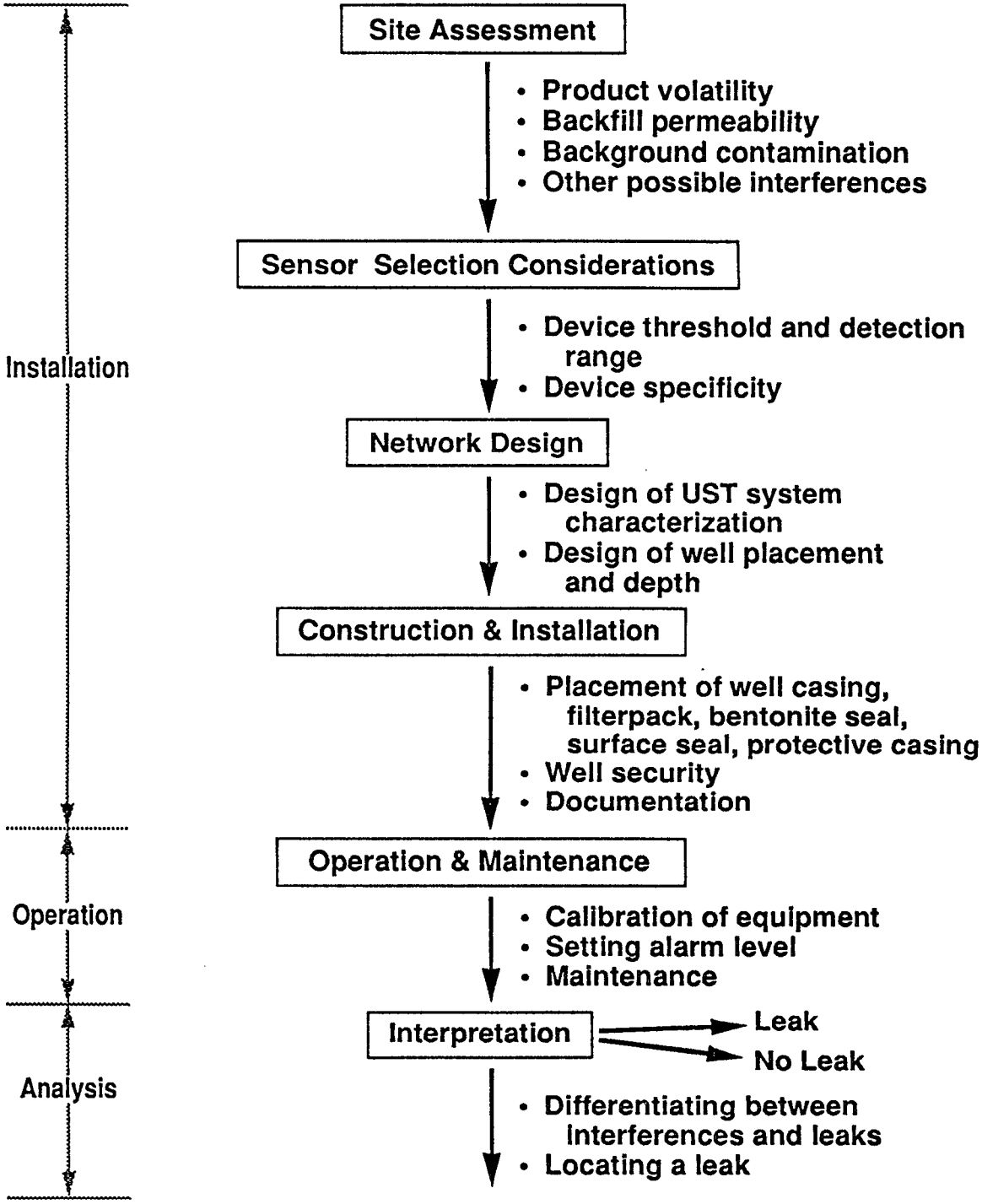


Figure 17. General procedure for vapor monitoring

Table 7. Indicators and Solutions for Problems Encountered During Vapor Monitoring

Problem	Indicators	Tester Solutions	Agency Oversight Options
Assure volatility of the stored substance.	None.	Choose proper monitoring system; consult manufacturer to verify that sensor responds to product. Add tracer compound.	Check product vapor pressure in chemical handbook; review manufacturer's literature. Verify response to tracer.
Assure UST backfill is permeable.	Backfill is not sand or pea gravel.	Test backfill permeability by conducting tracer test. Increase monitoring well diameter; use more wells or aspirated sensors.	Review results of backfill permeability test. Review monitoring system plans.
***Need to assess the level of residual vapors at the site.**	False alarms.	Add spill and overfill protection to the tank. Determine background concentrations. Set monitoring device threshold above background. Add tracer compound. Aerate the soil to reduce concentration	Review background determination. Check that threshold is above background level.
Assure low soil temperature won't interfere.	Low temperatures (below 0°C) for extended periods.	Install monitoring wells below frost line. Increase number of monitoring wells.	Review monitoring system plans; compare to expected soil temperatures.
Assure backfill that is saturated with water won't interfere.	Standing water in vapor wells.	For wet climates, use portable monitor in dry areas.	Review local water table data to ensure monitor is above high water table.
		Do not use for saturated sites; consider ground-water monitoring.	Require testing of water content of soils. Require monitor that detects the presence of water.
Assess possible interference from methane contamination.	False alarm.	Check site for methane. Choose monitoring system not sensitive to methane.	Require testing for methane in areas known to have problems.

Continued

Problem	Indicators	Tester Solutions	Agency Oversight Options
Assess possible interference from nearby UST sites.	False alarm at monitored site.	Install background monitoring well near site boundaries. Use tracer compound.	Check for nearby USTs that are not monitored. Test vapor concentrations near that site.
Assure device responds to the stored product.	Device does not react to product.	Use devices as recommended by manufacturers.	Test device during site inspection.
Assure device will respond to level of contamination.	Device shows erratic behavior or no response.	Use devices as recommended by manufacturers.	Check device during site inspection.
Identify UST configuration.	None.	Examine construction records. Use metal detector.	Request site plan with monitoring plan.
Assure monitoring wells are placed properly.	Delayed detection or no detection.	Install at least one sensor per tank in highly permeable backfill. Install at least two sensors per tank in less permeable backfill. Install sensors within 2 feet of bottom of tank.	Review monitoring system plans—compare well placement with local regulations or manufacturer's specifications.
Assure proper well construction.	Well collapses.	Construct well according to State codes.	Inspect well and documentation of well development.
Assure well screen is designed properly.	Well holds vacuum when purged with hand pump.	Use standard size No. 20 slots, and maximize length of well screen.	Review well designs (especially slot size or filter pack).
Assure filter pack is properly designed.	Well holds vacuum when purged with hand pump.	Use appropriately sized filter pack material.	Test with hand pump.
Assure well is sealed properly.	False alarms. Standing water or product in vapor wells.	Seal well properly with cement/ bentonite.	Review well design for proper seal; check well box for damage.
Properly secure and mark monitoring well.	False alarms. Standing product in vapor wells.	Mark and lock well.	Inspect site to see that well is distinguished from fill pipe and well cover is locked.

Need to document well construction.	Troubleshooting is time-consuming.	Provide well log or other construction data.	Require monitoring plans and well drawings be kept on-site or submitted to agency.
Assure equipment is properly calibrated.	False alarm or lack of detection.	Conduct at least annual calibrations using standard based on lightest compound of stored product.	Require calibration by approved contractor. Inspect calibration records.
Need to set the alarm level correctly.	False alarm or no detection.	Set at least 50% higher than background.	Review records of alarm level settings—compare with initial background levels.
Assure proper maintenance for equipment.	False alarm or no detection.	Maintain per recommendations of manufacturer.	Review maintenance records.
***Interpret monitoring results considering possible interferences.**	False alarm.	Verify proper operation of equipment. Take second reading. Check for spills, other contamination. Check trends in monitoring records.	Inspect monitoring records. Check to see if high readings correspond to deliveries or other possible spills.
Locate wells so that the leak source can be identified.		Check for possible spills. Use other methods to confirm. Increase number of monitoring wells. Use quantitative monitoring device.	If high readings do not appear to be a spill, require additional testing with other monitoring methods.

*** Indicates the most significant problems.**

offered in the table for each problem, however they are suggestions and not all of them need be undertaken.

Site Assessment

Installation → Operation → Analysis

Assure volatility of the stored substance

Volatility is the tendency of a product to change from a liquid to a gas under standard temperature and pressure. As discussed previously, vapor monitoring works according to the principles of volatility and diffusion. A stored substance must be sufficiently volatile or vapor monitoring will not work. Vapor monitors are not appropriate for UST systems that contain non-volatile products. The volatility of a substance is measured by its vapor pressure. Table 8 lists the vapor pressures of some common petroleum products.

Table 8
Typical Vapor Pressures of Petroleum Products

Product	Vapor Molecular Weight @ 60°F	True Vapor Pressure in psia at: 40°F	60°F	90°F
Gasoline	62	4.7	6.9	11.7
Gasoline	66	3.4	5.2	8.8
Gasoline	68	2.3	3.5	6.2
Jet naphtha	80	0.8	1.3	2.4
Jet kerosene	130	0.0041	0.0085	0.021
Distillate fuel No. 2	130	0.0031	0.0074	0.016
Residual oil No. 6	190	0.00002	0.00004	0.00013

The volatility of different products varies widely. For example, gasoline, which contains lighter hydrocarbons, is more volatile than diesel fuel, which is composed of heavier hydrocarbons. Typically, vapor monitoring is an appropriate monitoring method for most petroleum products.

Device manufacturers generally will provide a list of substances to which their vapor monitoring device will respond. To verify the manufacturer's claim, the monitoring device can be exposed to a known concentration of the stored substance and checked to see that the device gives an appropriate response. Several California counties require inspectors to check a device's response to the stored product before it is installed.

For less volatile products, a tracer compound may be combined with the stored product to satisfy the volatility requirement. A tracer compound is added solely for the purpose of providing a volatile component to the product. When a stored product containing a tracer is released, the tracer compound volatilizes more easily than the pure stored substance, making release detection by a vapor monitor easier. Freon or non-chlorinated compounds (e.g., Stoddard solvent) are often used for this purpose. If a tracer is used, it should be established that the chosen monitoring device is sensitive to the compound being used as a tracer, that the tracer and the stored substance can be mixed, and that the tracer will not interfere with the normal use of the stored substance. Under some circumstances when using a tracer, a leak rate of as low as 0.0005 gal/h can be detected.

Installation → Operation → Analysis

Assure UST backfill is permeable

Vapor monitors work best in permeable materials. If the backfill surrounding a tank is not sufficiently permeable, vapors may have difficulty moving throughout the monitored area. Loosely packed, large-grained soils are more permeable than tightly packed, fine-grained soils. For example, gravel is more permeable than sand, which is more permeable than silt, which is more permeable than clay. Sand, gravel, or other engineered backfills typically are recommended when vapor monitoring is to be used. However, many manufacturers of vapor monitoring devices have successfully operated their systems in clay materials. Figure 18 illustrates, for different types of soils, the speed with which gasoline vapors would reach a sensor.

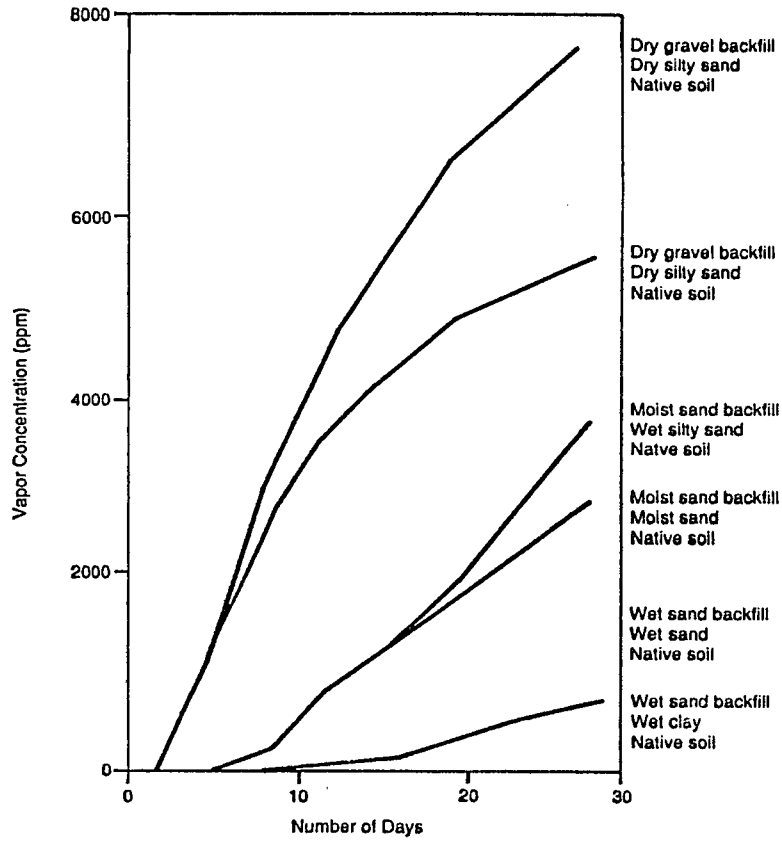


Figure 18. The effect of soil conditions on vapor concentrations at a well 8 feet deep located 6.4 feet from the source of the leak. Source: U.S. EPA (February 25, 1988).

Backfill at new UST installations should be sand or pea gravel, either of which ensures sufficient permeability. However, at existing sites the soil used to backfill an UST may not meet this criterion (e.g., the backfill may be either native soils, clay, or silt). Some jurisdictions in California check the permeability of the backfill at existing sites by using a tracer test. This is performed after wells are installed by injecting a tracer in one well and monitoring for its occurrence in another.

If a site has soil of moderate or low permeability (e.g., silt or clay), vapor monitoring can still be used if some modifications are made to the monitoring wells or the monitoring well network, or if the appropriate type of monitoring device is selected. Depending on the soil, one or a combination of these solutions may be necessary. The monitoring wells can be modified by increasing the well diameter to approximately six inches. The monitoring well network can be designed to include more wells than typically would be required, which provides a greater number of vapor sampling points. Typical monitoring well networks are discussed later in this chapter under the discussion titled "Assure monitoring wells are properly placed for effective vapor detection."

A modification to enhance vapor movement in moderate to low permeability soils is to choose an aspirated vapor monitoring device. Vapor monitoring devices are available in both aspirated and passive forms. Aspirated devices use suction to create a low pressure area around the sensor, thus drawing the vapors through the surrounding media to the probe. A passive device waits for vapor to migrate to the sensor naturally.

Installation → Operation → Analysis

Need to assess the level of residual background vapors at the site

Vapor monitors may respond to vapors remaining from previous spills or leaks, falsely indicating a current leak. Use of a vapor monitoring system is not recommended, without further investigation, at sites with high background concentrations (e.g., above 1,500 ppm for gasoline). A new site with clean backfill typically has levels of contamination that fluctuate between 0 and 500 ppm. The level of background contamination that renders a monitor unusable varies for different vapor monitoring devices. The manufacturer of a chosen sensor should be contacted to determine the level of background contamination that precludes the use of its sensor.

To determine background concentrations, a temporary vapor well can be installed within the UST excavation area, and the chosen monitoring device can be used to get an initial reading. If the monitor indicates that background concentrations are high (e.g., above 1,500 ppm for gasoline), further investigation should be undertaken to determine whether the concentrations are due to a current leak (levels above 4,000 ppm for gasoline may indicate this), a spill, or off-site interference.

When background contamination is due to a past release or off-site interference, vapor monitoring is still appropriate if the contamination levels are below the alarm threshold limit of the chosen monitor (i.e., the level at which a monitor is set to react to the presence of a substance as if there were a release, typically about 500-2500 ppm). Some instruments have adjustable threshold limits. If the background contamination levels exceed the instrument's threshold limit, the site can be injected with air to lower the level of contamination. This can be done by using an air pump to inject low levels of air through temporary wells into the soil. A vapor monitoring method should not be used when background contamination levels cannot be reduced below the instrument's threshold limit, unless a tracer compound is introduced. The use of a tracer avoids the problem of background contamination because the vapor monitor will react to the tracer compound, not to the compounds that are contained in the background contamination.

To prevent future background contamination, overfill protection and spill containment should be installed when vapor monitoring is used.

Installation → Operation → Analysis

Assure environmental conditions will not interfere

Temperature can be an inhibiting factor for proper vapor monitor operation at UST site; the colder the temperature, the less volatile a substance will be. Figure 19 illustrates the difference in volatilization rates for gasoline at different temperatures. Generally, for approximately every 20-degree Fahrenheit increase in temperature, the gasoline volatilization rate increases by about one-third.

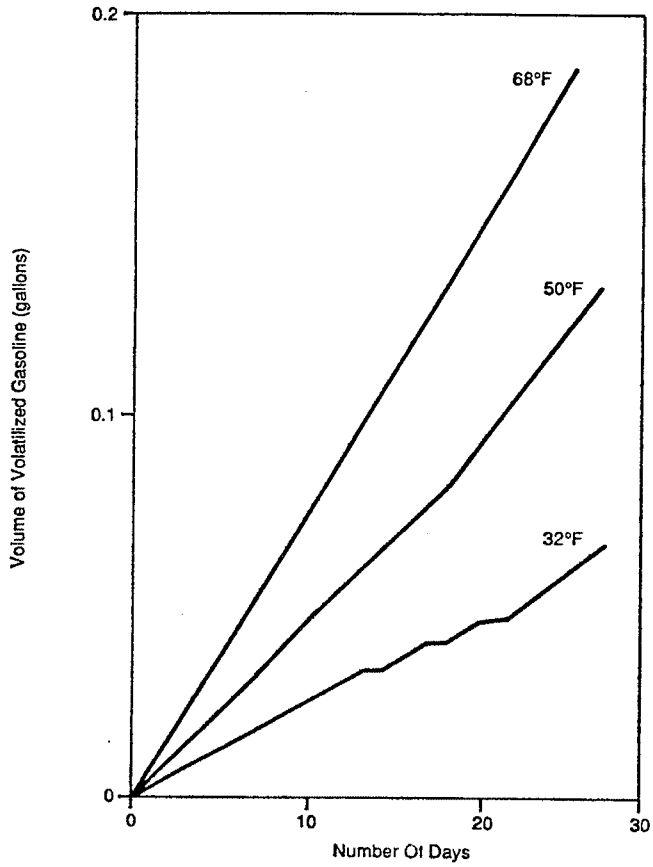


Figure 19. The effect of temperature on gasoline volatilization rates. Source: U.S. EPA (February 25, 1988)

When monitoring wells extend below the frost line, temperature is not a problem. Increasing the number of monitoring wells, s that there are more sampling points to pick up the lower levels of vapor, can compensate for continuous low temperatures.

If the backfill is saturated with water, because of a perched water table, fluctuating water table, rainfall, etc., vapor monitoring devices cannot be used. Saturated backfill conditions will inhibit vapor movement. Figure 20 on the following page illustrates the difference in the volatilization rate of gasoline for three different soil moisture conditions.

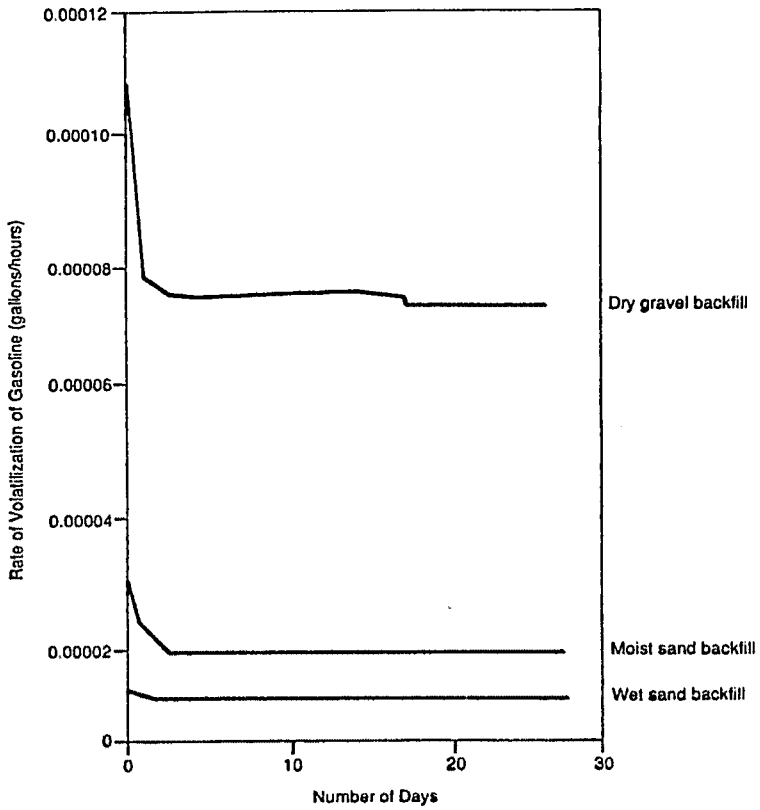


Figure 20. The effect of backfill moisture levels on gasoline volatilization rates. Source: U.S. EPA (February 25, 1988)

Additionally, if a vapor sensor is immersed in water, it will be rendered ineffective in most cases. Often a portable vapor monitor, rather than a permanent one, can be used in wet climates because the sensor is not actually installed in the vapor well.

Installation → Operation → Analysis

Assess possible interference from methane contamination

Some chemicals can interfere with the operation of a vapor monitor, causing it to react to their presence as if there were a release. Methane, which may migrate from near-by marshes, landfills, sewage lines or sewage treatment plants, is the most common chemical causing this reaction. Many vapor monitoring

devices are able to distinguish among different volatile compounds. If methane is present at a site, the chosen vapor monitoring device should not be one that reacts to methane. This information should be available from the manufacturer.

Installation → Operation → Analysis

Assess possible interference from nearby active or abandoned UST sites

If there is an active or abandoned UST site with a history of releases in proximity to the site being evaluated, it may cause interference with vapor monitoring. Vapors from a nearby site may travel to the monitored site causing the sensor to react as though there were a release from the monitored site when there is not. One way to differentiate between monitor alarms due to on-site releases and off-site interferences is to install a background well outside the excavation zone, on the side nearest the source of the potential interference. If the vapor levels increase in the background well while remaining relatively steady in the on-site wells, the monitor alarm is most likely due to outside interference.

Another method of differentiating between releases and off-site interferences is to introduce a tracer to the monitored UST system. The vapor monitor will then react specifically to the tracer, thus ensuring that when the monitor alarms, it is reacting to the monitored UST.

Sensor Selection

Installation → Operation → Analysis

Assure vapor monitoring device responds to the stored product

Specificity is the ability of a device to detect vapors from a particular substance being stored on site (e.g., hydrocarbons or a tracer). If the monitoring device does not react to the stored substance, it is totally ineffective. Equally important, of course, is a device's ability to avoid reacting to substances for which the site is not being monitored (e.g., methane).

To determine which vapor monitoring device is suitable for different stored products, literature provided by the device manufacturer should be consulted. Most vapor sensor manufacturers list the types of stored products that their device will effectively monitor.

Installation → Operation → Analysis

Assure selected device responds to the level of contamination

For a device to be effective at a site that has high background concentrations, it must be able to record and monitor a high level of vapors. Such a monitor is necessary because the background level at a contaminated site is significantly higher than zero, and the monitor must be able to evaluate and record levels higher than the threshold. If a device does not have a suitable threshold level or a broad enough detection range (i.e., the lowest and highest levels of vapor a monitor will detect), it will not accurately reflect changes in concentrations at a site, thus making the identification of a release difficult if not impossible.

The appropriate monitoring device to use when there are high background levels is one that is responsive to a high level of vapors. In any case, the level of background contamination and the desired range of detection should be considered before choosing a monitoring device. Specific information about a device's threshold and detection ranges should be available through the manufacturer.

Network Design

Installation → Operation → Analysis

Identify system configuration to prevent damage

The number and location of USTs and associated piping must be identified to help determine where the monitoring devices should be installed to ensure efficient leak detection and to avoid damaging the UST system during installation of the monitoring wells. Information about the UST system should be available from past installation records and construction plans.

Information obtained from available records should be reviewed with the site owner and operator to determine if any alterations not indicated in the records were made to the UST system. Additionally, a metal detector or ground penetration radar can be used to determine the general location of tanks and piping.

Installation → Operation → Analysis

Assure monitoring wells are placed for effective vapor detection

Improper location of vapor sensors will increase the amount of time before a release is detected and may, in extreme cases, allow a leak to go undetected. Detection time is a function of the distance between monitoring wells and a leak. The placement and depth of monitoring wells are affected by the configuration of the UST system, the mobility and volatility of the stored product, the permeability of the backfill and surrounding soil, and the type of vapor monitoring device.

The federal UST regulation requires that vapor sensors be placed in wells that are installed in the UST excavation area (backfill). In addition, vapor wells are normally placed as close to the tank as is technically feasible; sometimes this is accomplished by installing the wells at a slant instead of vertically.

Although travel times vary, a rule of thumb is that hydrocarbon vapors will migrate 15 feet in about 15 to 20 days in unsaturated sand or gravel backfill. This seems to be a reasonable assumption based upon sandbox experiments and computer models (U.S. EPA, February 1989). State and local agencies have adopted a variety of network design requirements for vapor monitoring (see Table 9).

Although the requirements are diverse, they tend to require wells to be separated by no more than 20 to 35 feet. These requirements seem reasonable based on EPA research and field experience indicating that a design that includes at least one well every 40 feet should be sufficient for gasoline tanks in a clean dry backfill. In general, this translates to one well for a single tank. If the backfill is not highly permeable (e.g., it is native fill material) or the migration of vapors is impeded by other factors, it is recommended that the number of sensors be increased by a factor of two.

The ideal depth of a vapor well, as indicated by industry recommendations, would be a depth at least equal to that of the base of the tank, and preferably one to two feet deeper. Even if vapor monitoring wells are installed at this ideal depth, few wells will be deeper than 10-15 feet. Research indicates that diffusion (spreading of vapor in many directions) is the dominant type of

Table 9
Typical State Network Design Requirements for Vapor Monitoring

State	Vapor Well Location Requirements	Vapor Well Depth Requirements
California		
Santa Clara County	General: every 35 feet of long dimension (if passive monitoring device, need more wells). At station: 1 per tank 1 piping 1 pump island	At least to bottom of tank
City of Torrance	For 1 tank: one at each end More than 1 tank: every 20 feet	N/A
City of Vernon	Design for 15 feet diameter of influence	N/A
Delaware	1 per tank within 5 feet of tank	2 feet below tank bottom or to ground water, whichever is less
Maine	According to manufacturer's specifications. At a minimum: - 1 within 5 feet of each dispenser - 1 at each piping joint - no piping run > 15 feet from well - 1 at each end of tank	Manufacturer's specifications
Iowa	- 1 at longitudinal ends of a single tank - if cluster of tanks where tanks ≤ 10 feet apart, at least 4 wells, 1 on each side of cluster - all wells > 1 feet from nearest tanks - all wells within excavation zone	2 feet below bottom of tank

Source: Reference 15.

vapor movement over time, but because most leaks occur in the bottom of the UST, a deeper monitoring well may reduce the leak detection time. Deeper wells, however, are not mandatory for effective leak detection. A rule of thumb is that the less permeable the backfill is, the closer the vapor well should be to the recommended ideal depth. Figure 21 gives a comparison of the time it takes for gasoline vapor to reach wells at various depths and distances from a release.

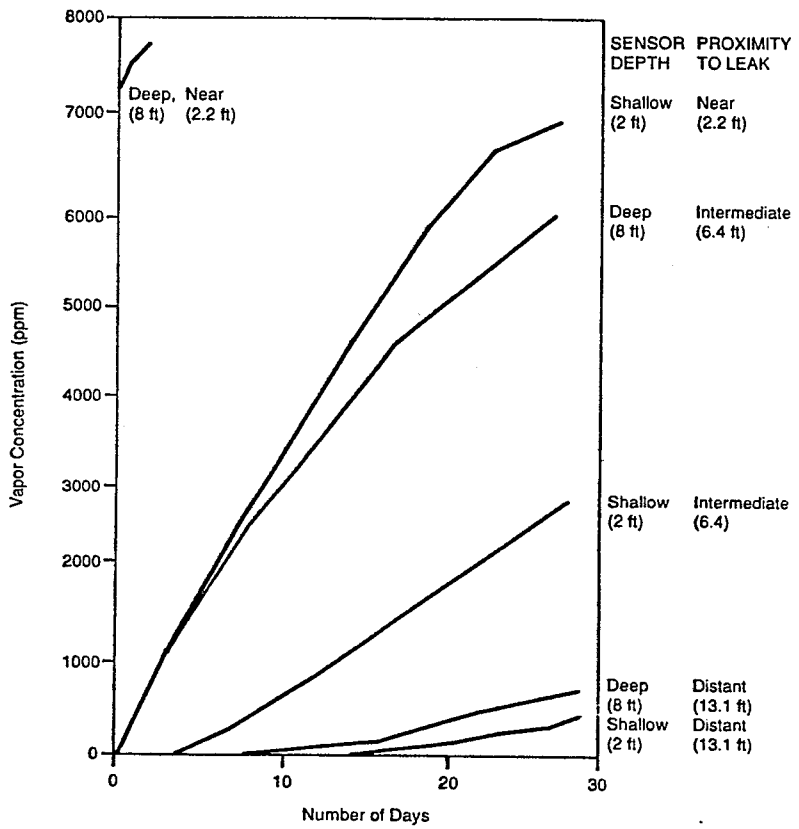


Figure 21. The effect of vapor sensor placement on leak detection time. Source: U.S. EPA (February 25, 1988)

Whether an aspirated or passive sensor is chosen also affects well depth and placement. For most soils, an aspirated system will detect vapors more quickly than a passive system at a given depth, since the aspirated system draws the vapor to the sensor. However, if the soil is very permeable (e.g., gravel), an aspirated sensor system and a passive sensor system will perform similarly

at the same depth. Some counties in California require slant wells that extend beneath the tank if a passive vapor monitoring device is to be used.

Figure 22 shows a typical configuration for well placement at a gas station. This configuration includes wells within the tank backfill area, and wells located so that sensors will detect releases from piping at the end of pump islands in the pipeline backfill area. A background well, although not necessary for effective leak detection, can be installed at a location upgradient from the pipelines and the tanks to evaluate surrounding soil vapor levels.

Construction and Installation

Installation → Operation → Analysis

Assure proper monitoring well construction

Improper construction of monitoring wells can render vapor monitoring ineffective (e.g., surface runoff could enter the well, the well casing could collapse, etc.). Construction of vapor monitoring wells and the installation of vapor monitoring devices should be done by a qualified contractor who is aware of any specific state requirements or any industry codes that may affect construction and installation. Figure 23 shows a cross-section of a typical monitoring well.

There has been discussion about monitoring well construction for vapor monitoring wells, especially when ground water in the area is deep and the wells are installed in the UST backfill. Santa Clara County in California has thousands of vapor monitoring wells that are modified in construction. In many cases a modified well structure, as shown in Figure 24, may be perfectly acceptable.

A typical vapor well is less than 6 inches in diameter. The casing may be polyvinyl chloride (PVC), cast iron, galvanized steel, polyethylene, polypropylene, fluorocarbon resins, Teflon®, or stainless steel. In choosing the type of casing, the local site conditions should be considered. For instance, galvanized steel casings deteriorate in corrosive environments. The most commonly selected materials for a monitoring well are PVC or stainless steel. Both of these materials meet the structural needs of the vast majority of vapor monitoring wells.

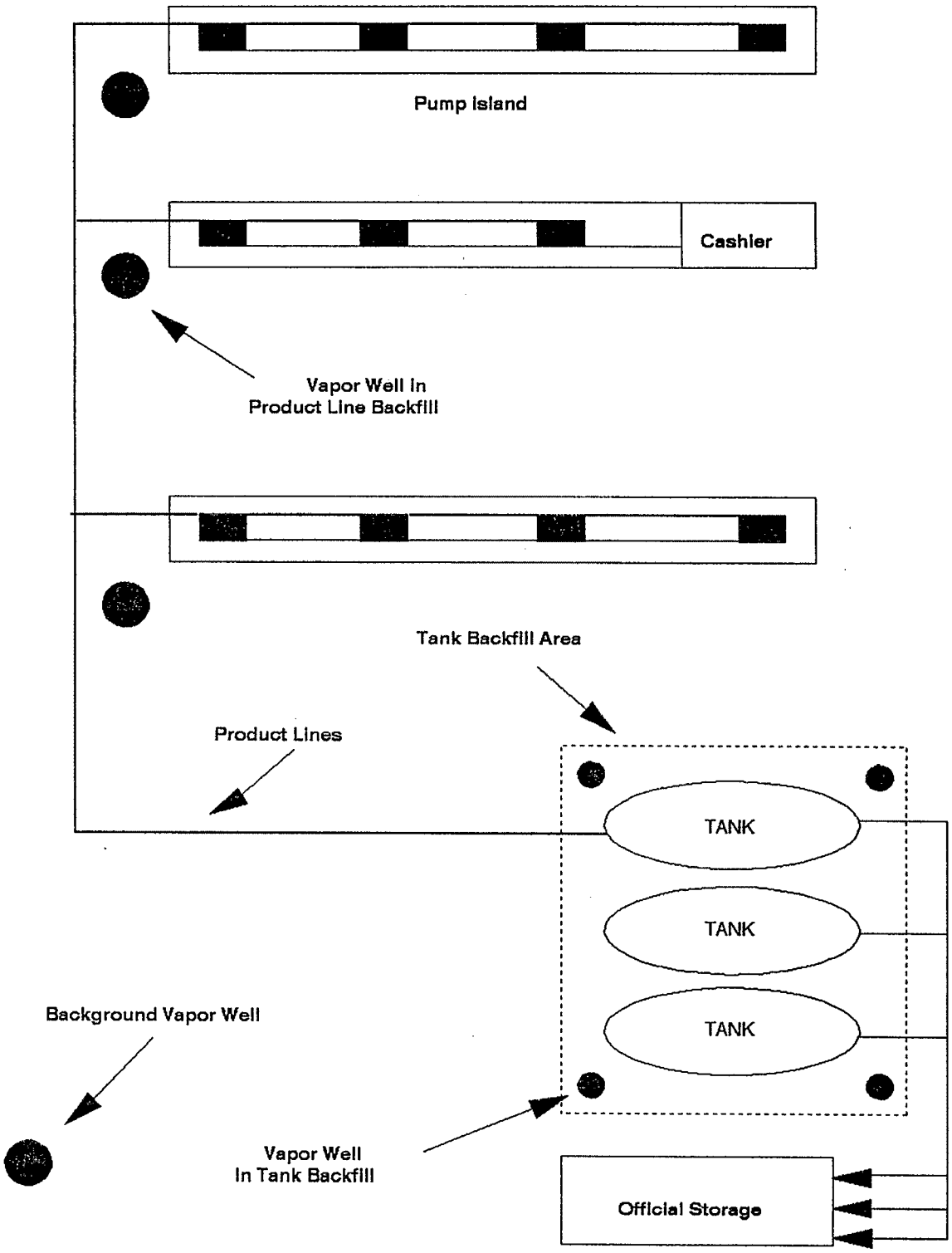


Figure 22. Sketch of typical underground storage tank site.

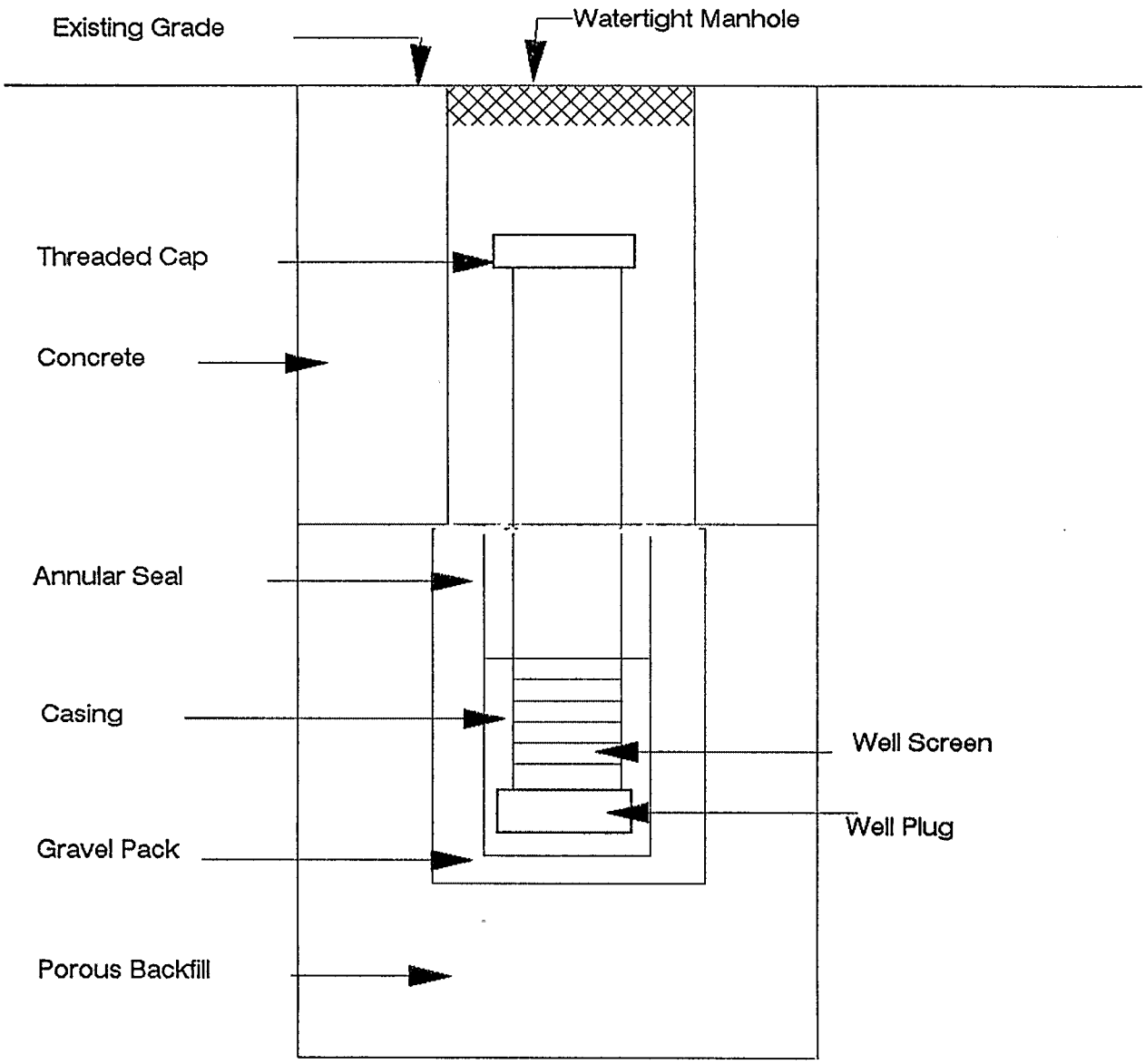


Figure 23. Typical vapor monitoring well cross section.

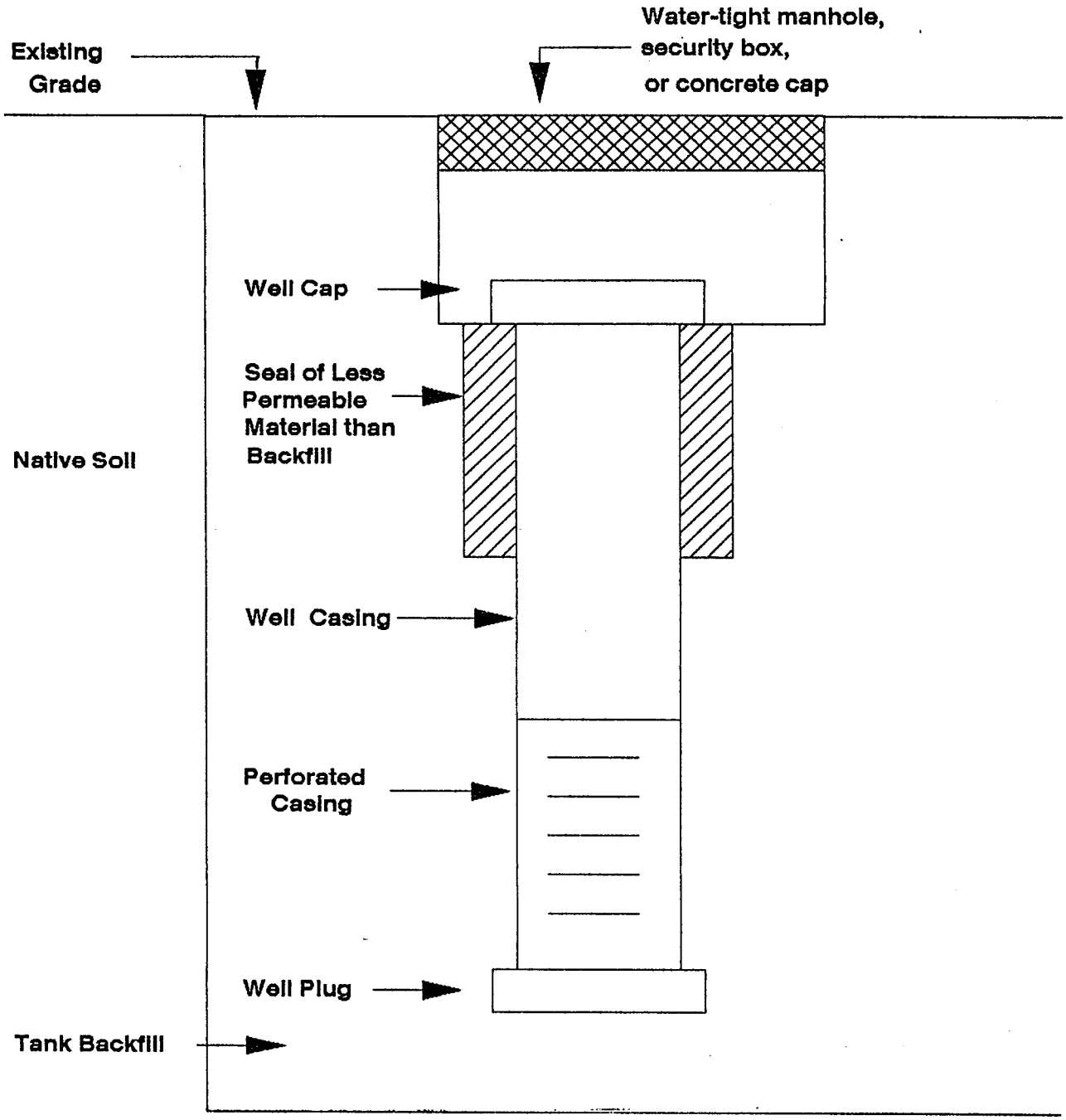


Figure 24. Modified vapor monitoring well cross section.

Installation → Operation → Analysis

Assure the well screen is designed for proper influx of vapors

The casing has a slotted or perforated section (called the well screen) that allows for influx of vapor to the monitoring device. If the well screen has perforations that are too large it may become clogged with surrounding soil particles, thus blocking the influx of vapors. Gathering vapor samples is similarly inhibited if the perforations are too small or only cover a short length. A typical well screen would have the standard size #20 slots. The well screen section usually begins from 2 to 5 feet below the ground surface and extends to the base of the casing. In general, the well screen extends over as much length as is possible.

Installation → Operation → Analysis

Assure filter pack is designed to prevent clogging of the well screen

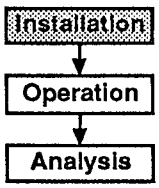
The well screen area should be surrounded by a filter pack that allows for passage of vapors while preventing passage of fine-grained soil particles that could clog the well screen. If the filter pack material is of too small a size, it may block the passage of vapors and clog the well screen; if it is too large, soil particles may migrate through the filter pack and clog the screen. Typically, several inches of filter pack are placed in the bottom of the borehole before the well casing is installed. The filter pack should extend 1-2 feet above the well screen. Materials other than carefully graded gravels that are acceptable for filter pack include clean quartz sand, silica, and glass beads.

Installation → Operation → Analysis

See that well is sealed to eliminate introduction of contaminants

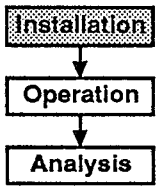
The area outside the casing, above the well screen, should be sealed (annular seal) to prevent contaminants such as infiltrating surface water or other liquids from entering the well that may interfere with monitoring or reach the ground water. A cement-bentonite mixture, bentonite chips, or antishrink cement mixtures are normally used for this purpose. The annular seal usually extends for 1 or 2 feet above the filter pack. A concrete seal is placed above the annular seal up to the ground surface to provide additional protection to the well casing from contamination and physical damage. Ideally, the interface of the bentonite seal and the cement seal should be located below the frost line to protect the well from damage due to frost heaving. A

protective steel casing of a diameter larger than the monitoring well can be placed in the cement seal to provide additional protection to the well.



Secure and mark vapor monitoring well properly

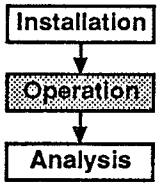
If a well is not secured and marked properly, it may be damaged accidentally causing interference with its integrity. Monitoring wells may be mistaken for other pipes, such as a tank fill pipe, in which case the well may be inadvertently filled with product. To prevent tampering, the well must be secured with a threaded cap, covered and locked. The well should be visibly marked to prevent accidental damage, and service stations should protect monitoring wells with a traffic box to prevent vehicle damage.



Document well construction properly

To aid in future identification of well problems and to prove that the monitoring wells comply with state codes, the design and construction of each monitoring well should be documented on a well completion diagram. This diagram indicates well design specifications, including the type and depth of filter pack, annular seal, concrete seal, well diameter, and well screen design. In addition, drilling and boring logs should be completed indicating the depth of the well and the type of backfill in which it was placed. This documentation should be useful to state or local agencies to determine whether correct procedures relating to design and installation were followed.

Operation and Maintenance



Calibrate equipment properly to detect vapors from stored product

The most important step for successful operation of a vapor monitor is the initial calibration of the device, which should be performed by a professional. Calibration consists of exposing the monitor to a pure gas standard to ensure that the monitor correctly responds to vapors. If a device is not calibrated correctly, it is likely to give either false positive or false negative results. False negatives occur when the device is calibrated to indicate low concentrations of vapor when a high concentration is present. False positives occur in the opposite situation.

Monitoring devices should be calibrated at least annually, specifically to the substance stored in the monitored UST, and preferably to the lightest component of that substance. The lightest component is that which volatilizes the easiest. Santa Clara County in California requires that devices used at sites containing petroleum products be calibrated annually using certified 1000 ppm isobutane (the lightest component of gasoline). Some areas require that tank owners use an approved contractor or agency to perform an annual calibration.

Installation → Operation → Analysis

Need to set the alarm level to avoid false alarms

An alarm level is the level of concentration of vapors in the soil that triggers an audible or visual alarm. The alarm level is determined by the professional after the device is installed. If an alarm level is set too low, the alarm will be triggered by small spills, interferences, or normal fluctuations and become a nuisance; if set too high, it will not be triggered by a real release. Some monitors do not have alarms, in which case the operator should be aware of the vapor reading level that indicates a possible leak.

To select an appropriate alarm level, a background reading is needed to determine the site's current condition. The alarm level should be set to a value at least 50 percent higher than the background concentration (EMSL-Las Vegas). In general, for gasoline, vapor levels of 3,000-4,000 ppm with an increasing trend will be indicative of a leak. However, this level will vary from site to site and for different brands of monitoring devices.

Installation → Operation → Analysis

Assure adequate maintenance for vapor monitoring equipment

Typically, maintenance of vapor monitoring systems includes cleaning, calibration, and operational checks. For manual systems, maintenance may consist of recharging the electrical component by plugging it into an electrical source or changing the batteries, and keeping the device clean. In addition, some systems may require periodic replacement of a filament or a lamp.

Automatic systems are often self-checking. Self-checking systems verify the integrity of the sensor outputs, inputs, power supply, alarms, and displays, thus ensuring every aspect of the system is operational at all times. If an automatic system is not self-checking, periodic calibration and checks of the electrical

system should be performed. The power source used for automatic systems should be periodically checked to ensure that the supply has not been cut off. The final maintenance item is simply the replacement of paper for the device's recorder.

For any type of vapor monitoring system, major maintenance items should be performed by a qualified professional following the manufacturer's instructions.

Interpretation

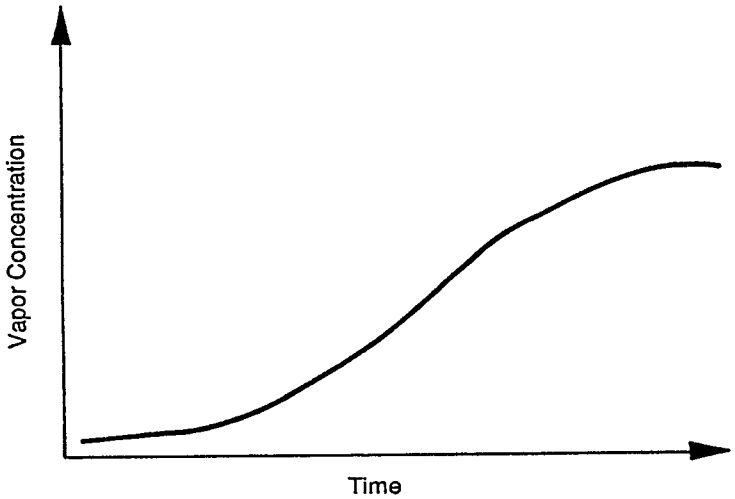
Installation
↓
Operation
↓
Analysis

Consider normal fluctuations and any other circumstances

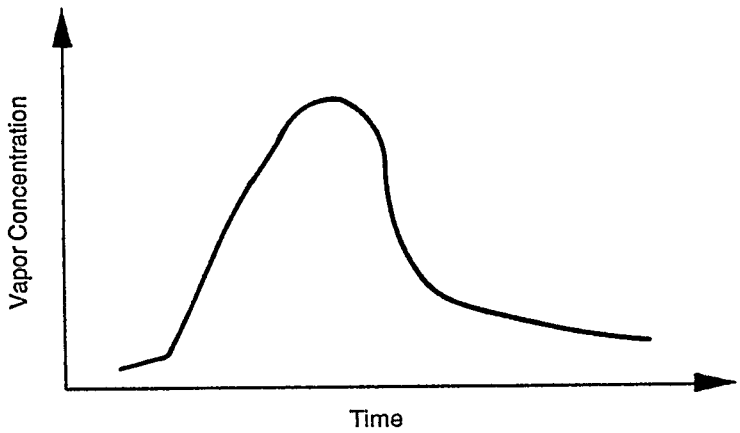
Interpretation of monitoring results is a critical step in vapor monitoring. Interpretation is hindered by normal vapor level fluctuations of 100-400 ppm over the course of a week. An alarm or a high reading does not necessarily indicate a leak; it may be the result of a spill, or simply be the result of background or other interference.

When an alarm level is recorded, the operator should first verify the vapor monitoring system's integrity. This entails determining that the system is working properly and that it is calibrated correctly. If after this initial check the monitoring device is found to be operating properly, an additional reading should be taken to verify the results. Should further monitoring confirm the preliminary results, any potential interfering factors (excessive rains, a spill from a product delivery, a leak from a nearby tank, etc.) should be evaluated next.

If no interfering factors are found and monitoring results have been confirmed, the monitoring alarm can be attributed to a tank release of some sort. Several owners have reported that an alarm always followed product deliveries before spill and overfill equipment was added. When there is not an obvious spill, one way of differentiating between leaks and spills is by looking at past monitoring records. Records typically apply only to the numerical information given by quantitative monitoring devices; differentiating between a spill and leak is more difficult when using a qualitative device which simply indicates the presence of vapor. Figure 25 show graphically the difference between a leak and a spill.



A Leak



A Spill

Figure 25. Interpretation of vapor monitoring results.

A leak is normally indicated by a gradual increase in vapor concentration that eventually reaches a high level plateau. Spills, on the other hand, are depicted by a sharp increase in vapor concentration, followed by a gradual decrease. If a manual vapor monitor is being used, readings taken on a daily basis following the recorded high vapor level (also the high point on the graph), should follow one of the trends indicated in the figure.

Installation → Operation → Analysis

Place monitoring wells so that leak location is identifiable

Generally, vapor monitoring is non-specific; a vapor monitor cannot locate the source of the vapor to which it is reacting. Because of this, confirmation of a release location (i.e., the release is attributed to the tank, piping, or interference) should always be done before corrective action begins to avoid unnecessary work.

Specificity of vapor monitoring can be greatly improved by increasing the number of monitoring wells and using a quantitative monitoring device. With these improvements, it is reasonable to assume that the well at which the highest vapor levels are recorded is also nearest the source of the release. To increase specificity, monitoring wells should be adjacent to individual tanks, not between two or more tanks.

APPROACHES TO ENSURING EFFECTIVE VAPOR MONITORING

Chapter 1 provides a general description of the four types of oversight that can be used. The following sections discuss how these approaches may be applied specifically to vapor monitoring systems.

Site Inspections

The site could be visited prior to installation of vapor monitoring to ensure that the method is appropriate for the specific site. Particular attention should be paid to the background concentrations found in the UST backfill, the type of UST backfill, and the volatility of the product stored in the UST. Site inspections could also take place during installation to confirm the proper location and installation of monitoring wells. Finally, periodic visits to ensure that vapor monitoring instruments are properly calibrated would be beneficial.

Data Review

Before vapor monitoring is implemented, the implementing agency could require that a pre-installation site assessment report and that the proposed monitoring well network design be submitted for review. Whenever a vapor monitor indicates a suspected release monitoring records and their determined interpretation could be submitted for

review. Because this may result in numerous submissions, records should only be required for releases that require reporting, not simply for any vapor monitoring alarm.

Guidance and Training

Guidance developed for owners/operators should emphasize proper calibration of equipment and the correct manner of interpreting results. Network design guidance would be useful for both owners/operators and installers.

Approval and Certification

One approach an implementing agency can use is to require certification of all vapor monitoring system installers, either through agency programs or those performed by manufacturers. Some vapor monitoring equipment manufacturers already train installers, and the implementing agency could review these programs. Another option for implementing agencies is to allow installation of only the types of vapor monitoring devices that meet specified requirements. This would involve setting up an approval program to which vendors could apply.

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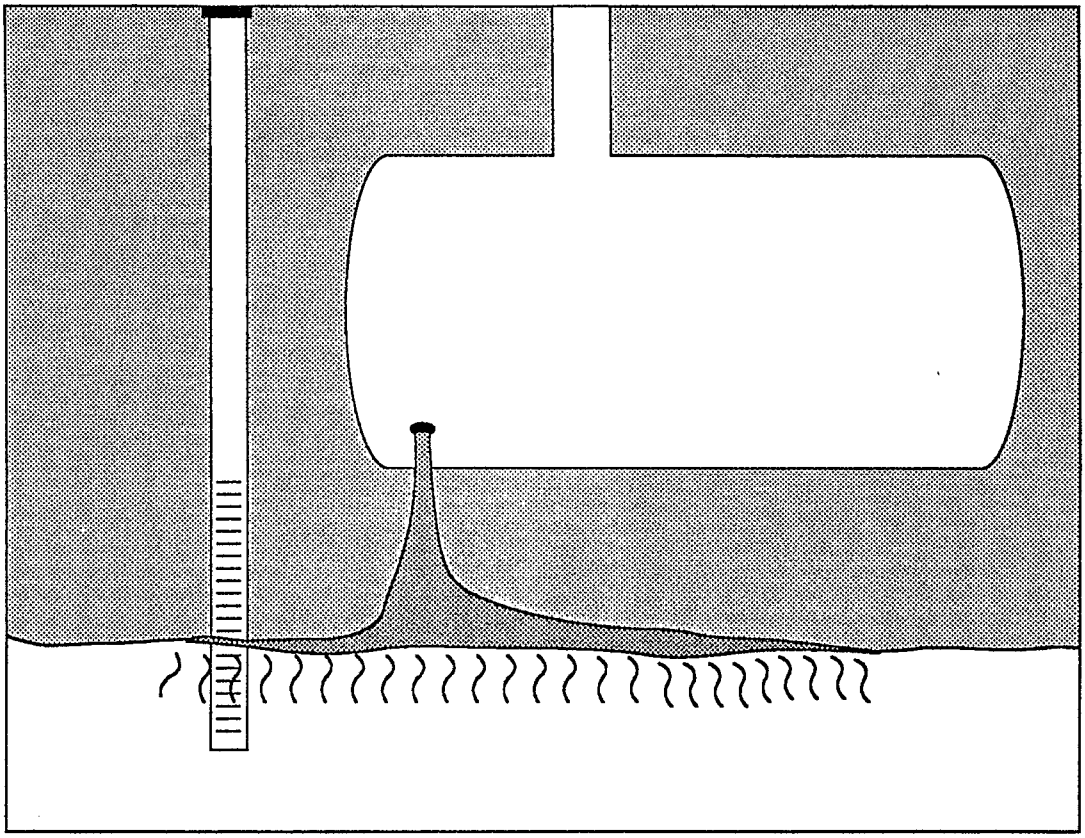
Chapter VII
Ground-water Monitoring



GROUND-WATER MONITORING VII

SUMMARY

The application of ground-water monitoring as an UST release detection method involves the use of one or more permanent observation wells that are placed close to the tank and are checked periodically for the presence of free product on the water table surface. When properly designed and installed, ground-water monitoring systems can result in effective detection of releases from UST systems.

Factors that have the greatest impact on the proper operation of a ground-water monitoring system are those associated with environmental conditions of the site (e.g., depth to ground water, range of ground-water table fluctuation), characteristics of the UST system (number and size of tanks, type of stored product), and the presence of other subsurface structures. These site-specific characteristics will determine the design and complexity of the monitoring well system.

In general, ground-water monitoring is most effective at sites where the water table is within or very near to the excavation zone of the tank. The method is also more effective at UST sites where no residual product is present in the subsurface materials due to prior releases.

The discussion presented in this chapter covers a range of problems that may occur with ground-water monitoring. This does not mean that all, or even most, of these problems will occur at the same time. Furthermore, the problems addressed below are not necessarily of equal importance, in terms of the frequency of their occurrence or in the severity of their impact on the effectiveness of ground-water monitoring.

Professionals experienced in ground-water monitoring will know how to identify and correct these problems. For example, a qualified firm would not install a ground-water monitoring system at a site where the water table is 50 feet below the ground surface. Release detection, however, is a growing industry and new companies with little experience in ground-water monitoring are opening up.

BRIEF DESCRIPTION

A ground-water monitoring system consists of two main components: the monitoring well and the free product detection device. Monitoring wells are constructed of small-diameter (2-4 inches) well casing extending from the ground surface to several feet below the lowest water table level. The portion of the well casing that is perforated (or slotted) is referred to as the well screen and extends from the bottom of the well to several feet above the water table surface, allowing liquids to enter the well. Figure 26 shows the components of a typical ground-water monitoring system.

When a leak occurs from an UST, the released product will migrate downward through the backfill material and underlying soil. When liquid-phase (free) products less dense than water encounter the ground-water table, they will float and spread out horizontally on the surface of the water table. Monitoring wells properly installed next to a leaking tank will intercept the free product layer that accumulates on the water table surface.

The presence of free product can be measured by sensing devices which can be either permanently installed in the monitoring well or manually inserted in the well to take a discrete measurement. Devices which are permanently installed can be operated automatically on a continuous basis.

Although EPA is requiring only that free product be detected when ground-water monitoring is used as a release detection method, free product monitoring wells also can be used for sampling and analysis of dissolved product. Several states have been conducting analysis of dissolved product in ground water as a requirement for release detection monitoring.

The process of designing, constructing, and installing a ground-water monitoring system can be separated into six phases:

1. Site assessment
2. Selection of a monitoring device
3. Design of the monitoring well network
4. Construction and installation of monitoring wells
5. Operation and maintenance of the monitoring system
6. Interpretation of the monitoring results

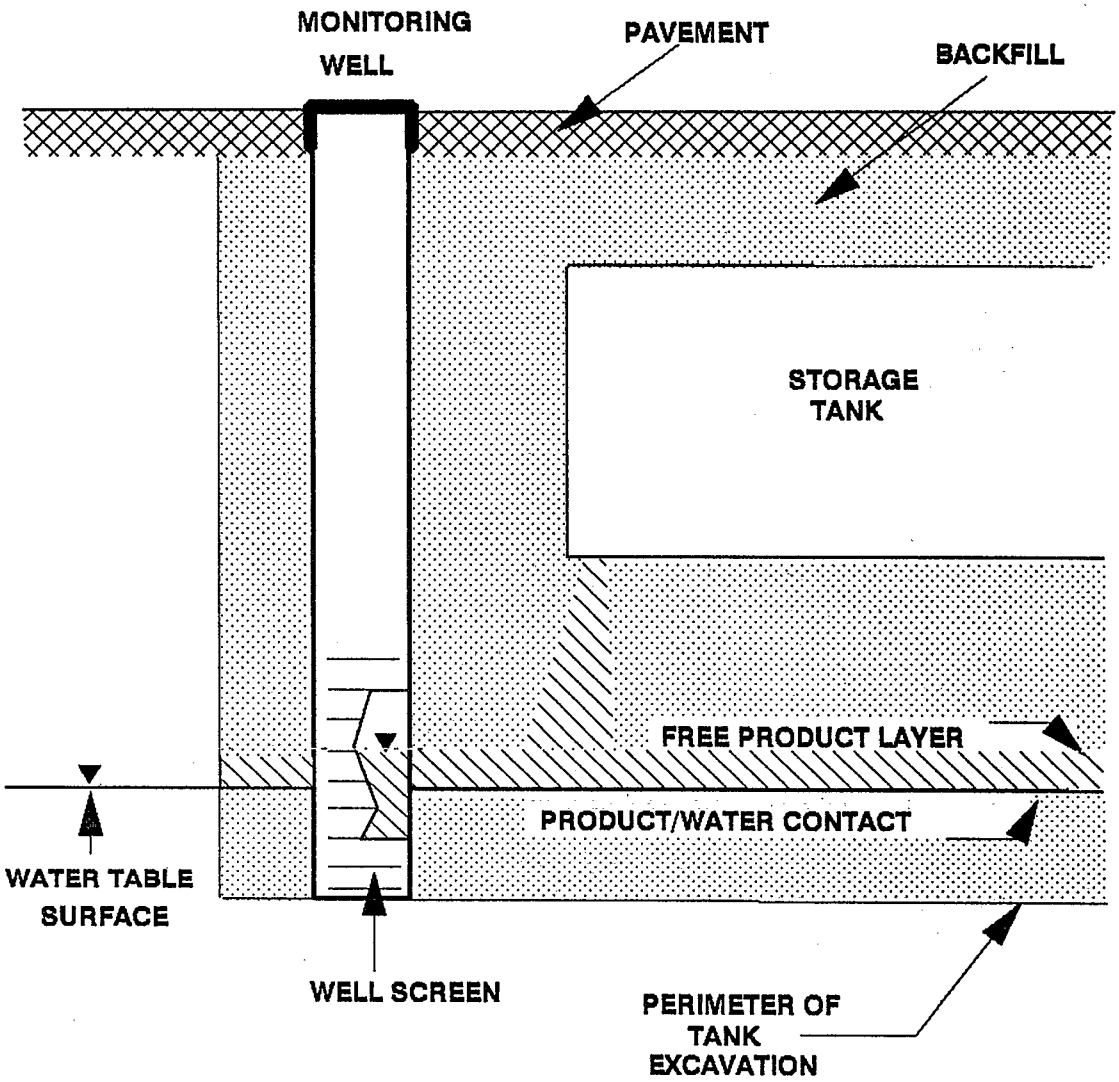


Figure 26. Monitoring wells installed in the excavation zone will quickly detect a release when the ground-water table is within the tank excavation. Source: U.S. EPA 1987

Figure 27 shows the relationship of each of these phases and identifies the important components of each phase.

POTENTIAL PROBLEMS AND SOLUTIONS

Successful operation of a ground-water monitoring system depends upon a number of factors. In general, operational problems will be due either to the monitoring well or to the product monitoring device. Operation of a monitoring well can be affected by a variety of site factors. Once identified, such site problems can sometimes be overcome by careful system design. Problems related to the monitoring device typically are easier to overcome than problems related to the monitoring well; another device better suited to the site-specific conditions usually can be selected.

Table 10 is a summary of the problems that may be encountered during the installation and operation of a ground-water monitoring system and ways to identify these problems. More than one solution may be offered to agency personnel for a particular problem and not all of the solutions need to be undertaken. The problems identified in Table 10 are presented in the order that the method process is implemented; the order does not indicate any prioritization or measure of importance of the problems. The most serious concerns are identified in the table by an asterisk.

Site Assessment

The characteristics of the site environment and of the stored product that may affect proper operation of a ground-water monitoring system are discussed below.

Assure that depth to ground water is less than 20 feet

Ground-water monitoring is a very effective release detection method for UST sites where the surface of the ground-water table is within the tank excavation zone (see Figure 26). This occurs at approximately 25 percent of UST sites based on results of EPA's national survey data (U.S. EPA 1986a). Product released from a tank will be quickly intercepted by monitoring wells placed in the backfill of the excavation.

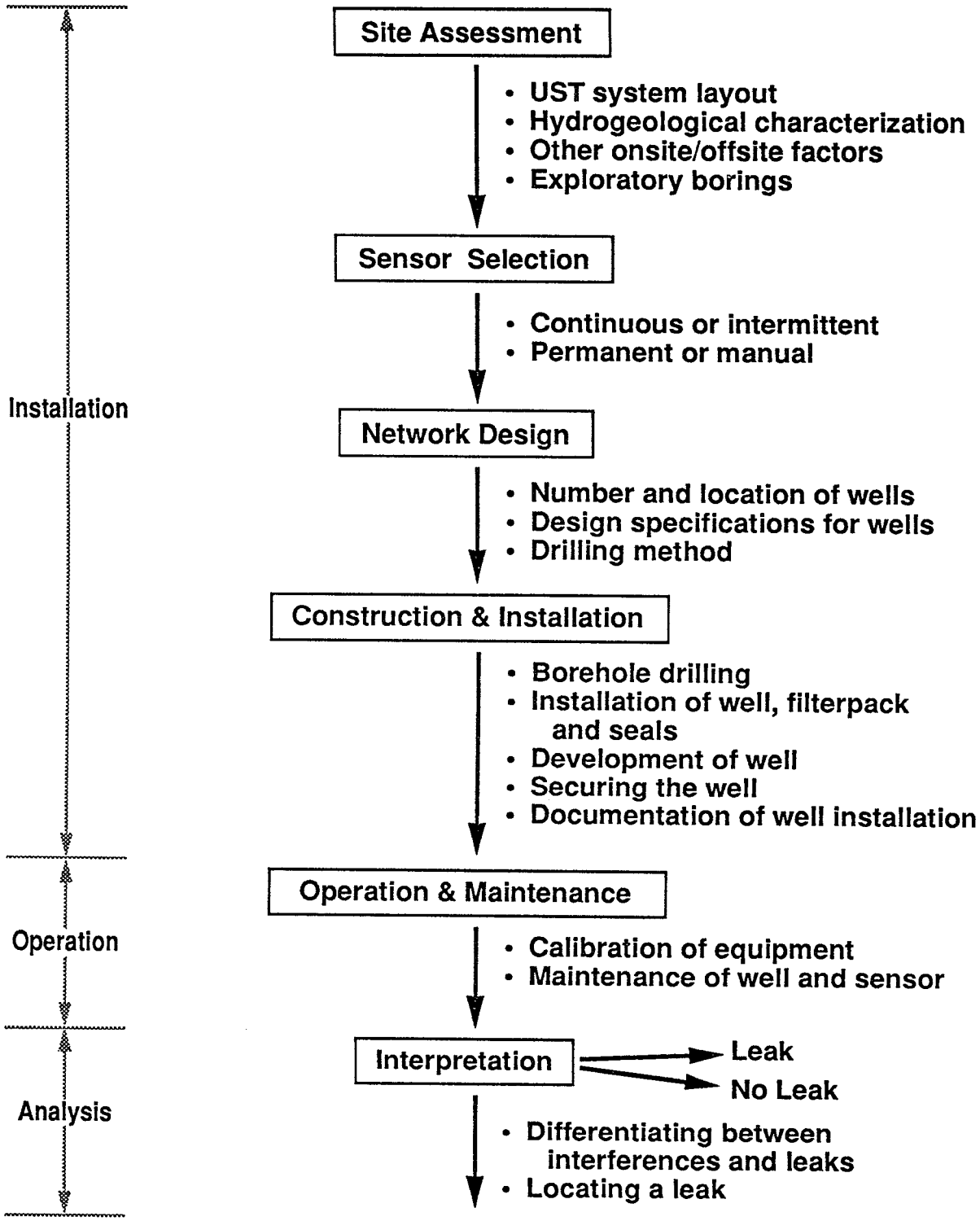


Figure 27. General procedure for ground-water monitoring

Table 10. Indicators and Solutions for Problems Encountered With Ground-Water Monitoring

Problem	Indicators	Tester Solutions	Agency Oversight Options
Assuring that ground water is less than 20 feet or greater than 3 feet deep.	None.	Take water level measurements. Perform exploratory borings. Use another release detection methods.	Review water level data. Oversee performance of exploratory borings.
Assuring that hydraulic conductivity is greater than 0.01 cm/sec.	None.	Inspect boring log. Perform slug test. Replace material with appropriate backfill. Select another release detection method.	Review boring logs. Review slug test data.
Assuring that water table fluctuation does not exceed well screen.	Well is dry. Water table is at top of well screen.	Replace well with one that is properly screened. Select another release detection method.	Inspect well boring and construction logs. Evaluate long-term water level data taken in same aquifer.
Responding to steep ground water gradient.	Ground surface slopes steeply.	Place wells downgradient of tanks.	Review water level data from a minimum of three wells. Review topographic map of site. Conduct site visit to observe topography.
Assuring that stored product is soluble in water.	Product mixes with water and is not observable as a separate liquid phase.	Obtain data on product solubility from chemical handbooks or from manufacturer. Select another release detection method.	Review solubility data. Review data from chemical/petroleum supplier.
Assuring that specific gravity of stored product is less than water.	Product is observable as a separate liquid phase and will not float on water surface.	Obtain data on product solubility from chemical handbooks or from manufacturer. Select another release detection method.	Review chemical data on specific gravity of product.
Determining presence of background contamination.	Stains are observed on ground surface. Contamination is found during performance of site assessment.	Cleanup residual product. Select another release detection method.	Review site assessment data collected by owner/operator. Conduct a site visit.
Assuring proper selection of a sensor.	Device is not sensitive to the stored product. Environment conditions adversely affect sensor operation.	Select another sensing device. Select another release detection method.	Review site assessment data collected by owner/operator. Review information on sensor from manufacturer.

Assuring adequate number of monitoring wells present.	Site-specific (see Table 7).	Install additional wells.	Review site assessment data. Conduct a site visit.
Assuring proper well placement.	Site-specific.	Install additional wells in proper location(s).	Review site assessment data. Conduct a site visit.
Determining if conduits are present near the tank field.	Product or vapors are observed in utility trench or basement.	Identify and mark location of utility lines. Install wells between tank field and subsurface conduits.	Review site plans and utility maps. Conduct a site visit.
***Assuring adequate maintenance of sensors.**	Sensor float is hung up on the well casing. Occurrence of false alarms.	Visually check sensor on a frequent basis.	Have owner/operator keep a record of sensor checks. Conduct a site visit to confirm that sensor is operating properly.
***Assure diameter of well casing is not too small.**	Sensing device will not fit into the well.	Select another sensing device. Install a new well of larger diameter.	Review well construction log. Conduct a site visit to observe well design.
***Assure well screen slot size is not too small.**	Flow rate of water into well is restricted. Well is dry.	Redevelop well to increase flow rate of water into well. Install a new well that is properly designed.	Review well construction log. Conduct a site visit to observe well design.
***Assure well screen slot size is not too large.**	Filter pack is collecting in the well.	Bail out well to remove particulate material. Install a new well that is properly designed.	Review well construction log. Conduct a site visit to observe well design.
***Assure well was properly developed.**	Flow rate of water into well is restricted. Well is dry.	Redevelop well to increase flow rate of water into well. Install a new well if flow rate cannot be increased.	Review well construction log to determine the method used to develop well and the length of time it was conducted.
***Ensuring proper interpretation of environmental influences.**	Recording of false alarms.	Check sensor to make sure that it is operating properly. Conduct a site assessment to determine if any background contamination is present.	

Review site assessment data.
Check maintenance schedule for sensors.

*** Indicates the most significant problems.**

Ground-water monitoring is not an allowable release detection method when the water table surface is greater than 20 feet below the ground surface (BGS). Although monitoring wells installed under this situation do not necessarily present an operational problem, a leak at a site with a deep water table could go undetected for months until the product migrates down to the water table. Restricting use of ground-water monitoring to sites where the water table is less than 20 feet deep will minimize the potential for widespread environmental contamination and ensure relatively rapid detection of a release.

Ground-water monitoring is also not recommended for use at UST sites where the water table is less than 2 to 3 feet BGS. Monitoring wells used for free product detection cannot be properly constructed (with a surface grout seal) when the water table is very shallow. Free product will be excluded from the well screen if the surface seal extends below the water table surface (see Figure 28). Monitoring wells that are not properly sealed may be susceptible to contamination from surface spills and runoff, which may result in the false reporting of a tank release (see Figure 29).

Depth to the water table can be determined at existing monitoring wells by taking water level measurements. Well boring and completion logs can be inspected to determine where the top and bottom of the well screen are located. An improperly constructed well should not be used for free product detection or for sampling of dissolved product.

At new UST installations, the depth to the ground-water table can be determined by taking water level measurements at wells located close to the site. Another alternative is to conduct exploratory borings on-site. If water is encountered at a depth less than 3 feet BGS or is not observed down to a depth of 20 feet BGS, ground-water monitoring would not be an appropriate release detection method.

Determine hydraulic conductivity of backfill or native soil

Monitoring wells may be placed in either the excavation backfill or in the soil surrounding the tank excavation. If the backfill material or the soils situated between the UST system and the

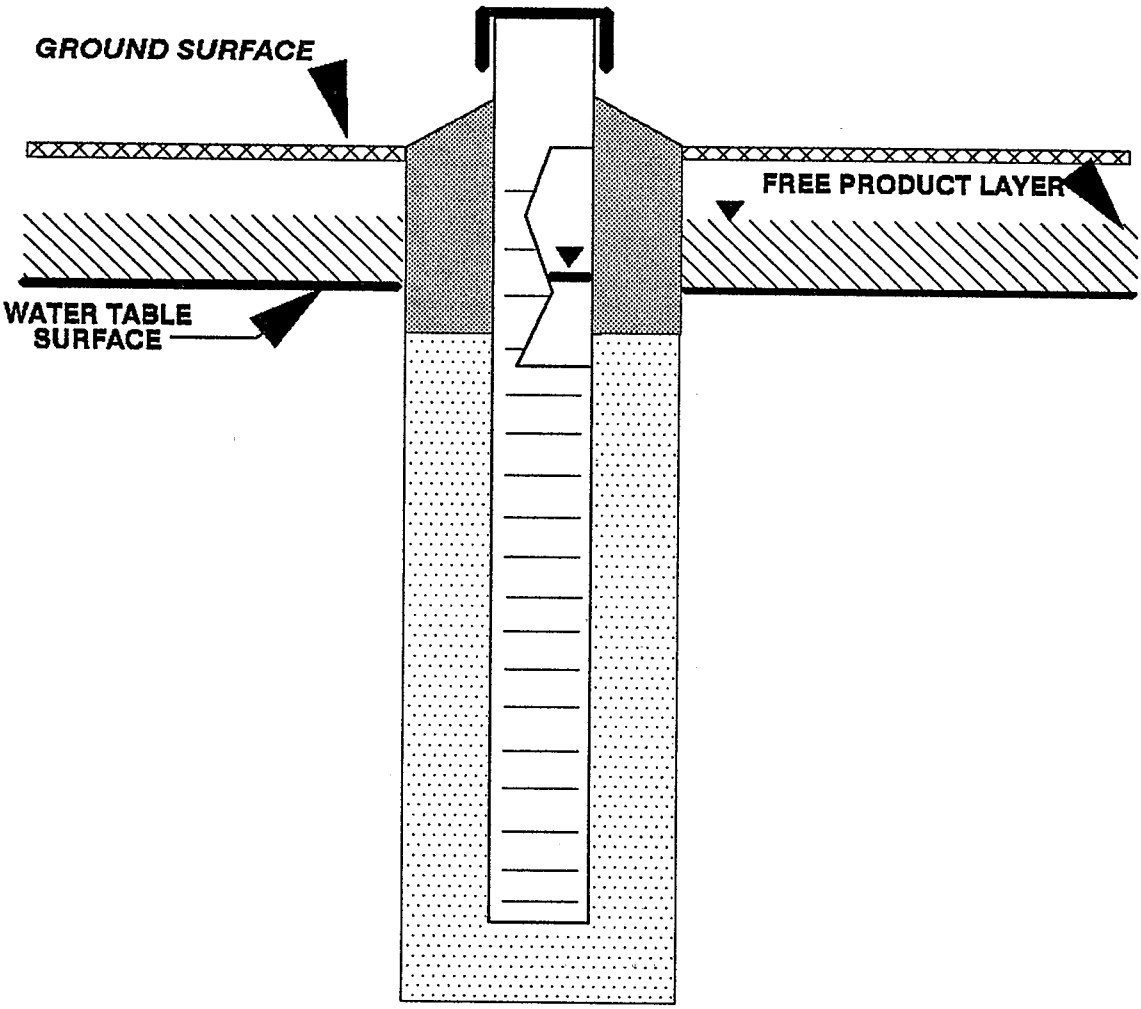


Figure 28. The well seal will prevent interception of free product when the water table surface is very shallow.
Source: U.S. EPA 1987

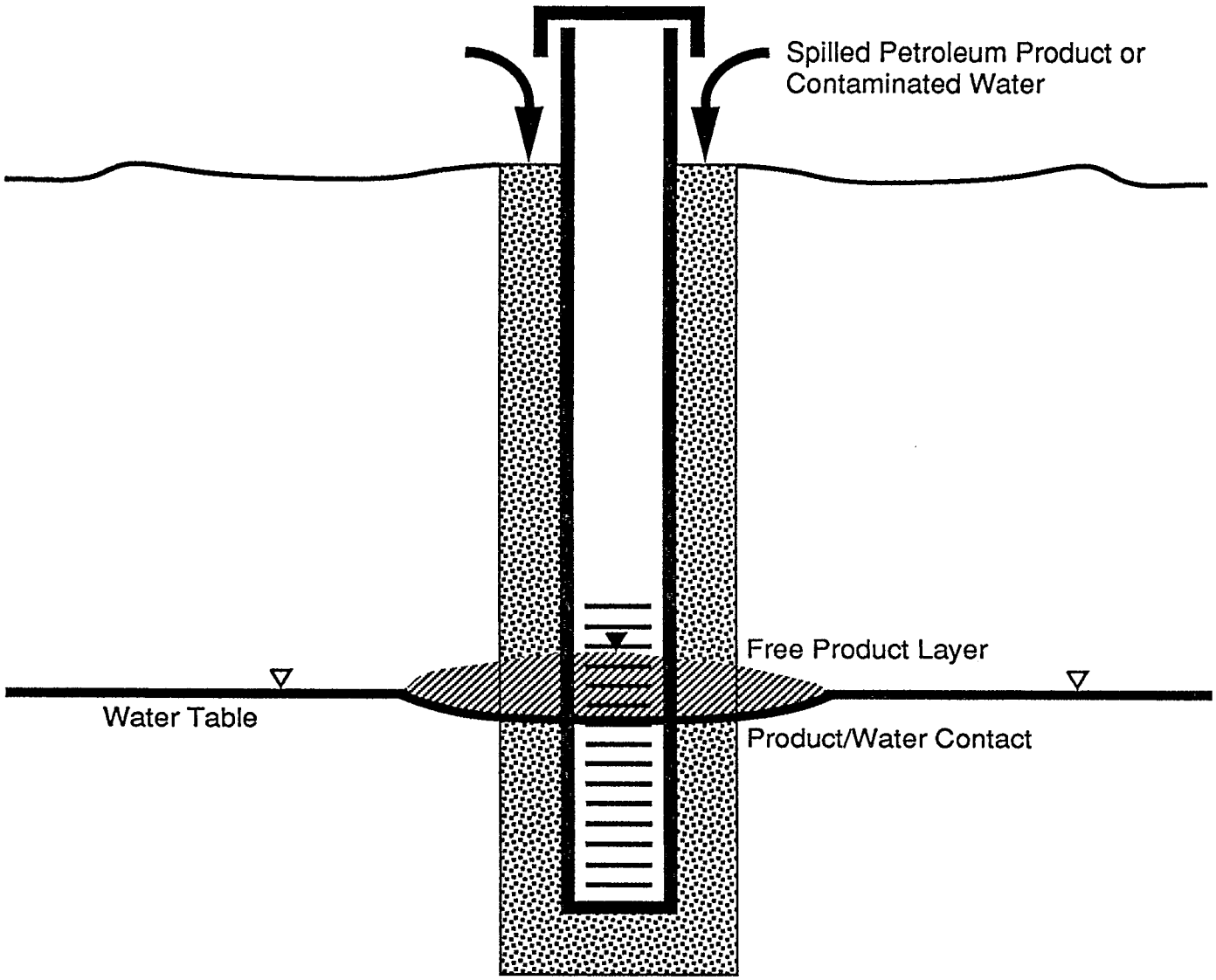


Figure 29. Monitoring well that does not have a proper surface seal placed above the filter pack will be susceptible to contamination from surface runoff.
Source: U.S. EPA 1987

monitoring well have a low hydraulic conductivity (less than 0.01 cm/sec), movement of product released from an UST will be restricted. Product released from an UST either will not reach the monitoring well or will reach the well only after a long period of time. Even though backfill or native soils with a low hydraulic conductivity may limit the amount of product that can be released from a tank (because the migration rate of the product away from the tank is very slow), a slow leak over a long time period may result in relatively high concentrations of dissolved product in the ground water.

Hydraulic conductivity is a measure of the rate of flow of a fluid in a porous medium and is a property of both the soil and of the stored product. In general, the hydraulic conductivity of a soil increases with an increase in soil porosity and grain size, and a decrease in fluid viscosity. The relative hydraulic conductivities of the major soil classes are: gravel > sand > silt > clay (see Figure 30). Materials that are considered to be suitable for backfill include clean, graded sands and gravels. Silts and clays are much less permeable than sand and gravel and are generally not appropriate for use as backfill.

Ground-water monitoring is most effective when the hydraulic conductivity of the backfill or soils situated between the tank and the well is greater than 0.01 cm/sec. The hydraulic conductivity of materials can be estimated from information provided on boring logs for wells installed onsite or near to the site. If materials consist of well-sorted sand or coarser, as is required by national installation codes for new tanks, the hydraulic conductivity is most likely greater than 0.01 cm/sec. If there is some uncertainty about the hydraulic conductivity of the medium, it can be estimated by conducting an *in situ* test, called a slug test, in the well.

The hydraulic conductivity of soils and backfill at existing sites can be improved only by replacement with materials having a greater permeability. A more cost effective solution may be the selection of another release detection method.

Need to evaluate the range of ground-water table fluctuation

Floating product will not be detected in a monitoring well if the surface of the ground-water table falls below the bottom, or extends above the top, of the well screen. When the ground-

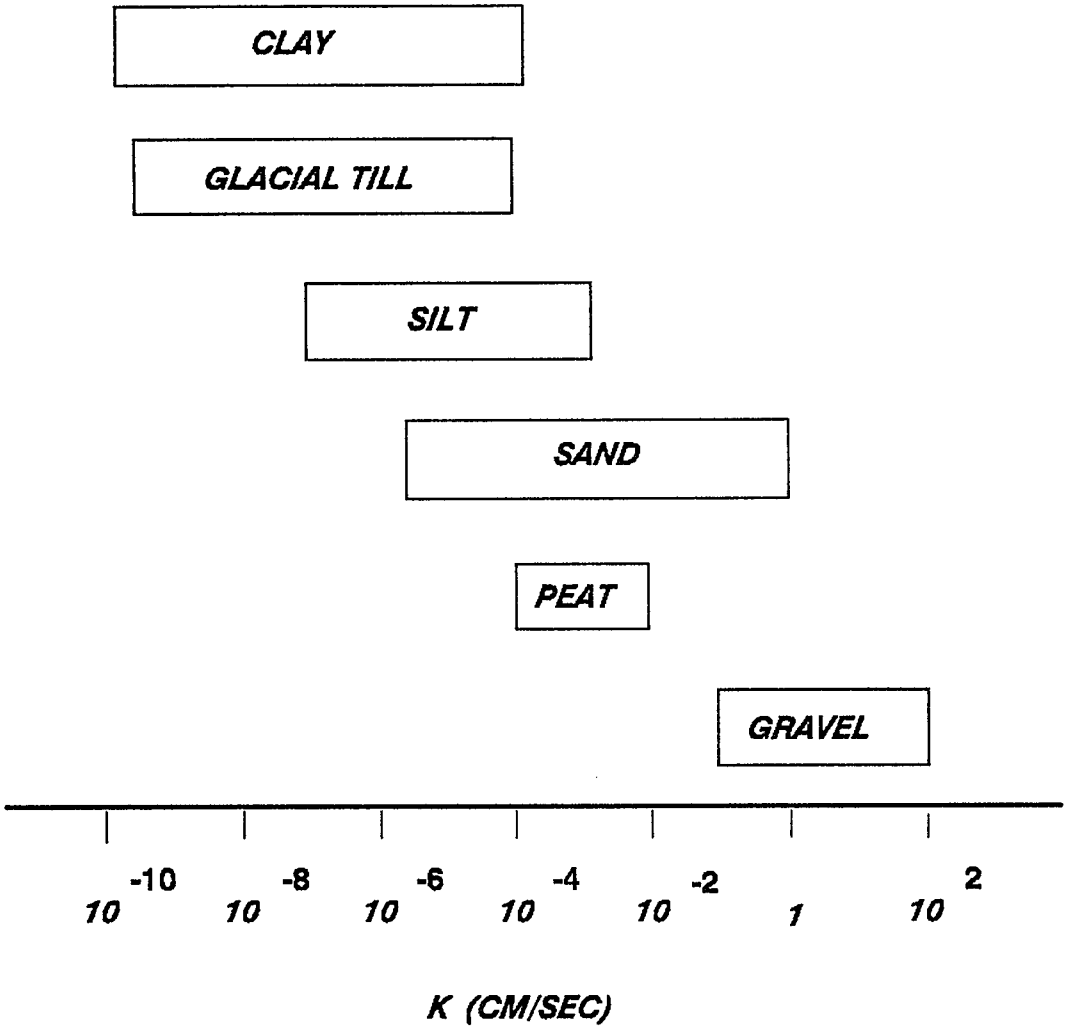


Figure 30. Range of hydraulic conductivities (K) for the major soil classes. Source: Dragun 1987

water level is below the bottom of the well screen, water will not be encountered in the well (the well is dry). When the water table surface is higher than the top of the well screen, product floating on the ground-water table will not be able to enter the monitoring well. Free product would enter the well once the water surface falls below the top of the well screen.

The surface of the ground-water table fluctuates in response to seasonal variations in ground-water recharge and other influences such as ground water extraction. The location and design of a monitoring system must consider the range of water table fluctuation at a site (see Figure 31). Wells should be screened over the entire interval of ground-water levels. The range of fluctuation can be determined based on long-term water table level measurements taken in the same aquifer. The high and low water table levels can sometimes be determined from soil characteristics such as color observed during drilling of the well borehole. To help the regulator identify problems with water table fluctuations, the owner/operator should obtain and record water level measurements on a monthly basis.

Need to assess the ground-water flow gradient

Monitoring wells placed upgradient of the tank field may not intercept a free product plume at UST sites where the ground-water table surface has a relatively steep slope. Product released from an UST under these conditions will migrate down through the soil to the ground-water table. When product reaches the water table it will generally migrate laterally in the direction of ground-water flow. Monitoring wells placed either upgradient of the UST system or perpendicular to the direction of ground-water flow may not intercept a product release under these conditions.

A rough estimate of the direction and gradient of ground-water flow can be made from observation of the ground surface gradient. For example, when there is a steep decline of the ground surface, ground water will most likely flow in the direction of the decline (downgradient). Ground water will also tend to flow towards surface waters, which are discharge points for ground water. The ground surface gradient can be determined from onsite observations and from information presented on topographic maps, which are available from the state or federal geological survey.

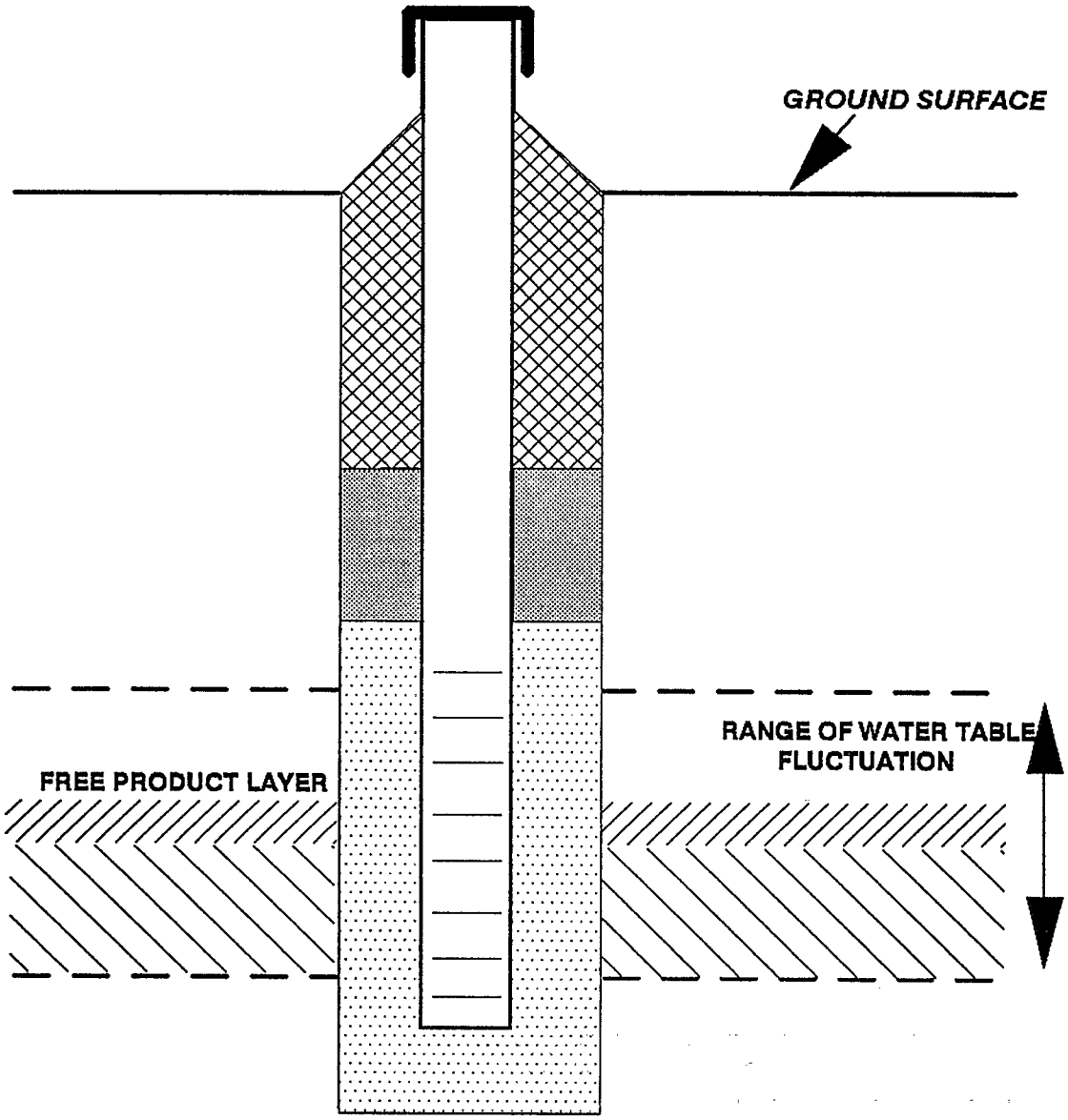


Figure 31. The well screen is placed to extend over the entire range of water table fluctuation.
Source: U.S. EPA 1987

The installation of monitoring wells on all four sides of the tank field is usually adequate to ensure detection of a release at sites located on a relatively steep gradient or if there is some uncertainty about the ground-water flow gradient.

Stored product must not be soluble in water

Products that are highly soluble in water will not be detectable as a separate liquid phase. When a soluble product is released from a tank and reaches the ground-water table, it will mix with the water and disperse throughout the aquifer. Therefore, ground-water monitoring for free product detection cannot be used when the stored product is highly soluble in water. Most petroleum products are not highly soluble in water. Though gasoline and diesel fuel are composed of many individual chemicals that are soluble to some extent in water, these products will be observable as a separate liquid layer.

The type of product stored in each tank should be recorded on the UST notification form. This form does not require reporting information on the solubility of each stored product, but this information can be found in standard chemical handbooks. The manufacturer of the product also should be able to provide this type of data.

Specific gravity of the stored product must be less than that for water

Products that are denser (heavier) than water (i.e., specific gravity is greater than 1.0) will not float on the water surface. Instead, these products will migrate down through the unsaturated and saturated (aquifer) zones until an impermeable zone is encountered. The free product will accumulate at the interface of an impermeable zone, such as a clay layer below the aquifer.

Products that are denser than water include the halogenated hydrocarbons (e.g., trichloroethene, dichloroethane) and coal tar. Ground-water monitoring is not an effective release detection method under these conditions since no product will enter the well. Furthermore, the presence of these types of products would be difficult to detect with most of the currently available free product sensors. As with product solubility, information on

density can be obtained from either chemical handbooks or from the manufacturer of the product.

Need to determine the presence of background contamination onsite

Ground-water monitoring is most effective for use as a release detection method when there is not any background contamination present due to prior spills or releases. Residual product present in soils above the water table (unsaturated) can reach ground water by vertical migration due to gravity forces and from infiltration of rainfall and surface runoff. Also, if the water table rises up to an area where residual product is located, free product may accumulate on the water table surface. The observation of free product in a monitoring well due to residual product will result in a false indication of a leak.

The site owner/operator should be interviewed to determine if any prior releases or large spills have occurred at the site or near to the site. Confirmation of background contamination can be made by conducting a preliminary site assessment involving investigation of the subsurface using field analysis techniques (e.g., soil vapor surveys). If residual free product is discovered, it should be removed prior to initiating ground-water monitoring.

Sensor Selection

Assure selection of appropriate sensor

Selection of an improper monitoring device may result in either a release not being detected or going undetected for a long time. For example, a monitoring device that is not sensitive to the stored product will not detect a release, regardless of the thickness of the product layer. A particular device may be adversely affected by some environmental conditions such as very low temperatures. The problem can be resolved by selecting a device that is appropriate for the site-specific conditions. Currently, however, free product sensing devices are not available for all types of stored products. Furthermore, as discussed in the previous section of this chapter, "Site Assessment," ground-water monitoring is not an appropriate release detection method for all stored products.

A variety of devices are available for measurement of free product. Devices may be permanently installed in the well for automatic, continuous measurements of product thickness. Manual devices range from grab samplers used for collection of a liquid sample for visual inspection of free product, to devices that can be inserted into the well to electronically indicate the presence of free product. None of these devices measure the leak rate from an UST system, however; they only indicate the presence of free product.

Any of the automatic sensors can be permanently installed in a monitoring well to take continuous measurements.

- Differential float devices operate using a system of two floats; one float reacts only to liquids with a density similar to water, and the other float responds to liquids lighter than water (most hydrocarbons).

- Product soluble devices are coated with or constructed from a material that degrades when exposed to hydrocarbons resulting in a change of pressure (i.e., an air leak) or a change in resistance (for electrical resistivity devices).

- Thermal conductivity devices measure heat loss when the floating probe comes into contact with a non-polar liquid. Thermal conductivity is the most commonly used continuous device.

Some of the manual devices that can be used include the following:

- Grab sampling devices, such as a bailer or bucket, obtain a ground-water sample from the well which is visually inspected for the presence of free product (i.e., a sheen on the surface of the water) or electronically analyzed on-site.

- Chemical sensitive pastes are attached to a weighted tape measure that is lowered into the well and which react (by a change in color) when hydrocarbons are present.

- Interface probes detect polar versus nonpolar substances using properties of thermal conductance and reflection/refraction of infrared light.

Network Design

The monitoring well network is designed after an initial assessment of the tank field layout and local hydrogeological conditions. This phase of the process involves determining the number and location of monitoring wells and their approximate depth. The well network design must be based on site-specific conditions and should be developed by a qualified professional. For common system configurations, however, a generic design recommended by the manufacturer is probably sufficient. Problems which may be encountered due to improper well network design are addressed below.

Ensure an adequate number of monitoring wells

If the number of monitoring wells at an UST site is inadequate, a release from a tank may not be intercepted and, thus, may not be detected. For example, if a monitoring well cannot be placed in the backfill and is situated in soils which are highly fractured, a release from the tank may not be intercepted by the well (see Figure 32).

In general, the use of a single monitoring well may be adequate for UST sites with only one tank. However, one well may not always be reliable in detecting free product. If the site consists of multiple tanks, more than one monitoring well should be provided. The exact number of wells should be based on the site hydrogeology and the UST system configuration. A general rule of thumb recommended by professionals is the placement of at least one monitoring well on each side or corner of the tank field.

A number of states and localities currently have specific requirements for design of a ground-water monitoring well network. Table 11 summarizes the network design criteria included in several regulations. Although the regulations each have a different approach, most require that single tanks have one to two wells and that typical multiple tank systems have three to four wells (or more for a larger tank field).

Identification of this problem is difficult and requires knowledge of the site hydrogeological characteristics. To assist the regulator in evaluating this type of problem, the owner/ operator

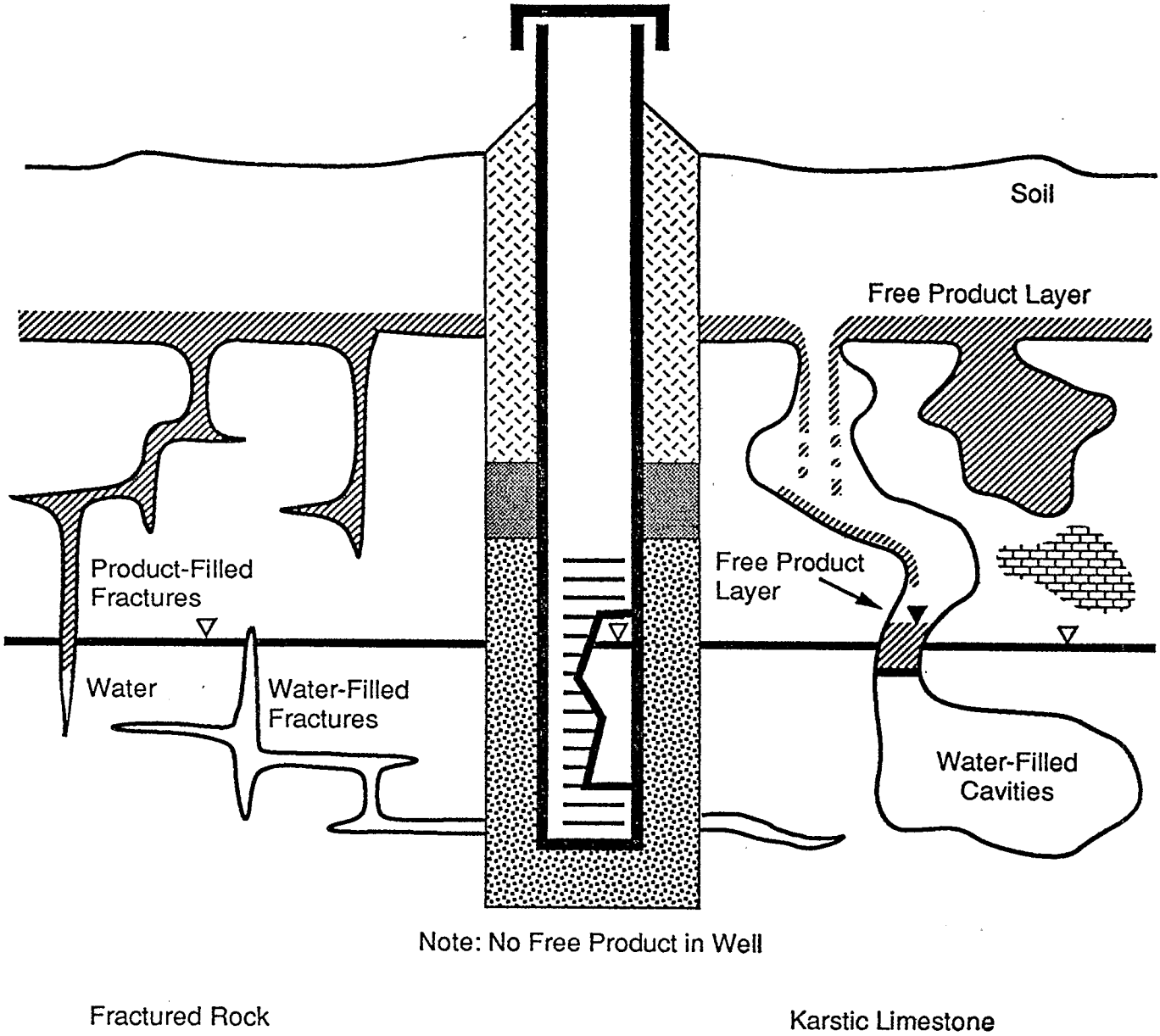


Figure 32. Free product will preferentially flow through fractures and cavitites; wells that do not intercept these structures will not detect product. Source: U.S. EPA 1987

Table 11

Typical Network Design Requirements for Ground-Water Monitoring

Fremont, California	Single tank: 1 downgradient well within 10 feet of the excavation perimeter
	Multiple tanks: 1 well placed every 35 feet on the longest dimension of the excavation with a minimum of two wells
Torrance, California	Single tank: 1 downgradient well. If the ground-water gradient is not known, 2 wells on opposite sides of the tank
	Multiple tanks: To be evaluated
Iowa	Single tank: 1 well at each longitudinal end of the tank
	Multiple tanks: 4 wells placed on each side of the tank field Wells must be placed within 1 to 20 feet of the nearest tank
Maine	Ground water < 15 feet: No fewer than 2 wells at either end of the tank
	Ground water > 15 feet: No fewer than 4 wells for each tank or for multiple tanks located in the same excavation, one well at both ends of each tank and at each end of the excavation
Nebraska	Ground water > 15 feet: 1 well per tank
	Ground water < 15 feet: 2 wells per tank
Delaware	New installations: 4 wells placed around tank excavation fields
	Existing installations: 3 wells placed in the excavation around the tank(s)
Vernon, California	Wells downgradient of tank(s) being monitored
Florida	4 wells placed in the excavation around the tank(s)
Maryland	2 wells placed at opposite corners of the tank field
South Carolina	Minimum of 2 wells placed every 30 feet
Wisconsin	3 wells required only for new UST installation

Source: Reference 11.

could be required to provide a site plan of the UST facility showing the layout of the UST system (number and size of tanks) and the locations of existing monitoring wells. Other useful information includes the ground-water flow gradient and geological characteristics of the site.

Assure proper placement of wells relative to the tank field

Improper placement of monitoring wells may result in delayed or missed detection of a product release. For example, monitoring wells placed too far away from the tank field may not detect a release until a large volume of product has leaked from the tank. Monitoring wells should be placed as close to the tank excavation as possible. Care needs to be taken when selecting a monitoring well site to ensure that the installation of the well will not interfere with any subsurface structures such as utilities or UST system piping. In some cases, the installation of a well upgradient of the UST system might protect owners from false alarms at sites where there are other (offsite) petroleum UST systems located near the site being monitored (see Figure 33).

Need to check for subsurface conduits near the tank field

Buried fill material or subsurface utility conduits (e.g., trenches constructed for telephone, power, gas, sewer, and water lines) may act as preferred pathways for free product migration. Free product generally will flow more easily through these open subsurface structures than through surrounding soils because the material is more permeable and offers less resistance to flow. Therefore, free product may not reach the ground-water table and will be channeled away from monitoring wells (see Figure 34).

This problem may be indicated when product or odors are observed in utility conduits but floating product is not observed in the monitoring well. At UST sites where there are subsurface conduits present, monitoring wells should be placed between the tank field and the conduit to ensure that product released from the tank is intercepted by the well before it reaches the conduit.

The locations of buried conduits can be found by examining site construction maps and maps of all utilities present in the area. The utility companies should be notified, prior to conducting

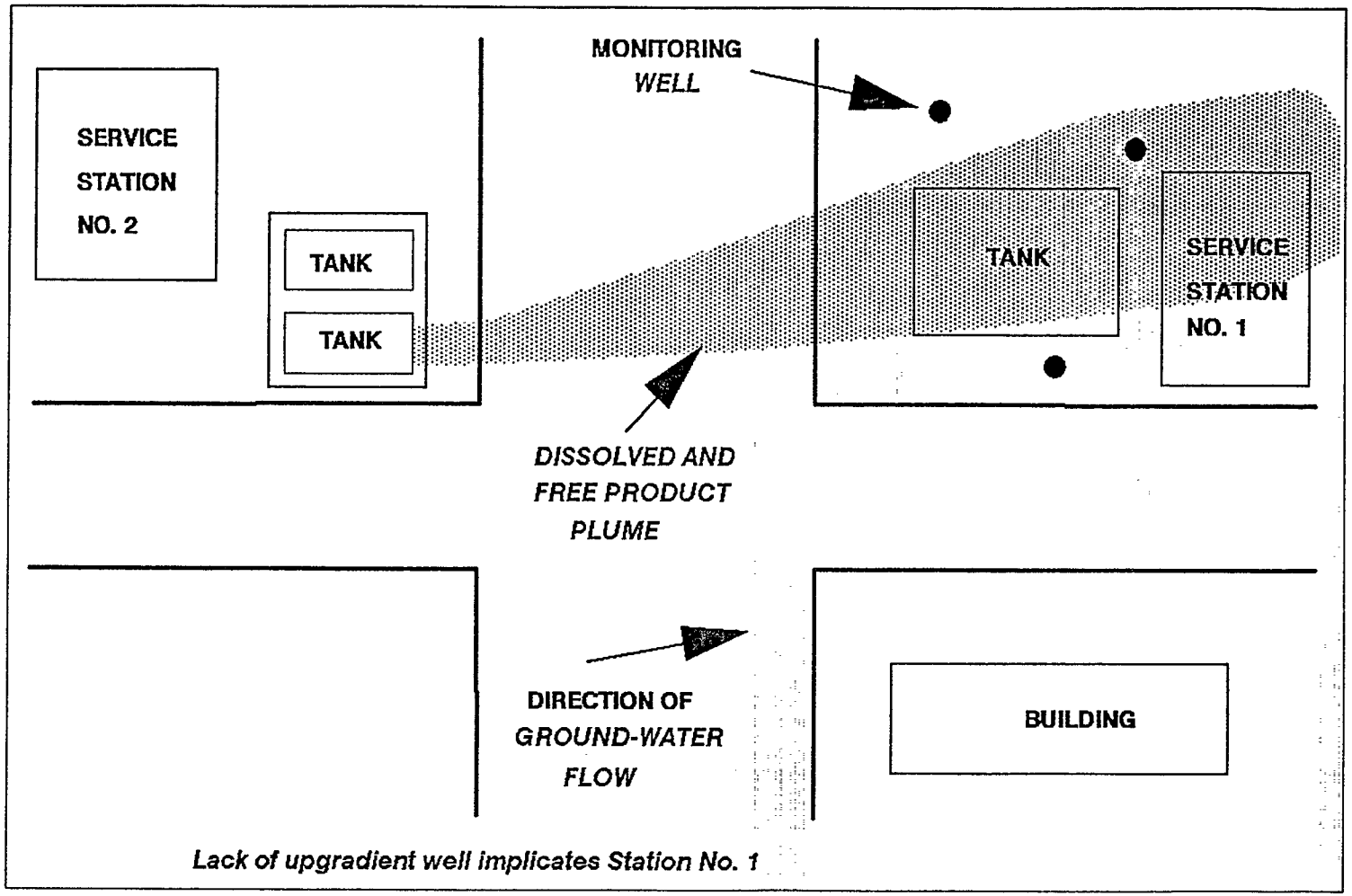


Figure 33. Off-site sources of contamination should be considered when designing the monitoring well network. Source: U.S. EPA 1987

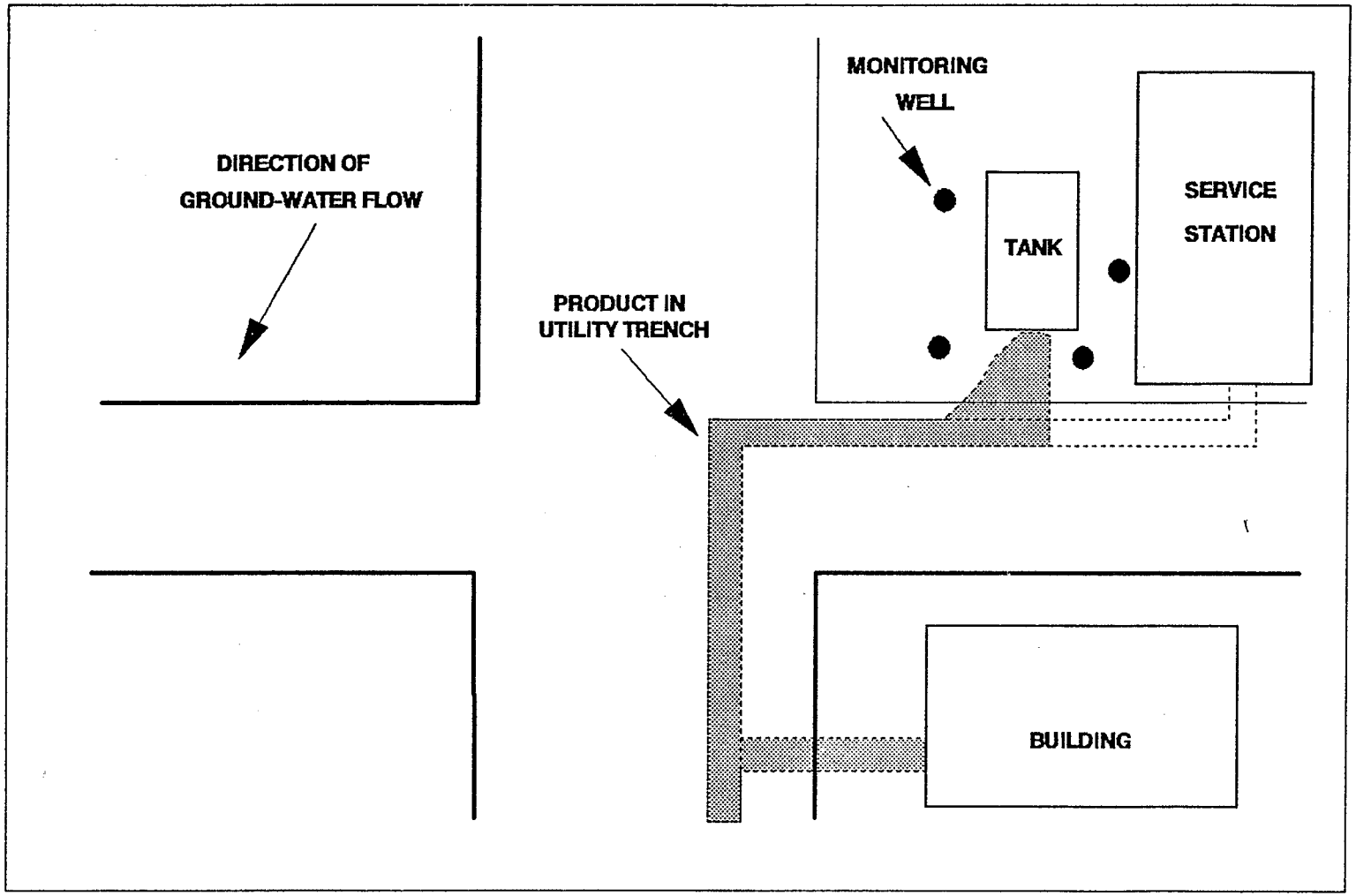


Figure 34. Subsurface utility conduits will act as a preferential pathways for free product migration.
Source: U.S. EPA 1987

well installation, that drilling will be performed at the site. To help troubleshoot any operational problems that may occur over the life of the monitoring system, the location of all subsurface conduits should be indicated accurately on a current site plan.

Construction and Installation

This section addresses problems that may occur as a result of poor or improper design, construction, or installation of a monitoring well. It is important to keep in mind that the design and construction requirements for a monitoring well used for free product detection are *not* the same as for a drinking water well or for a monitoring well constructed solely for sampling and analysis of dissolved product. The proper design and construction of a monitoring well is crucial to effective detection of free product and these tasks should be performed by an experienced hydrogeologist.

Assure proper design of the monitoring well

Improper design of a monitoring well may result in a release either not being detected at all or going undetected for months, resulting in widespread environmental contamination. Figure 35 shows the construction of a typical monitoring well used for free product detection. Design factors that are considered to be the most important to proper operation of a monitoring well are addressed below.

Before beginning design of a monitoring well, any specific state or local construction requirements should be identified. Some states, such as Florida and California, have developed specific criteria that must be met for length of well screen, screen slot size, filter pack specifications, etc.

Well casing and screen material: Most materials used for ground-water monitoring wells are compatible with petroleum hydrocarbon products. However, some materials, such as steel, may deteriorate in highly corrosive environments. This could result in the collapse of a well casing or infiltration of particulate material through holes created by corrosion.

A variety of materials are available for construction of the well casing and screen, including fluorocarbon resins, cast iron,

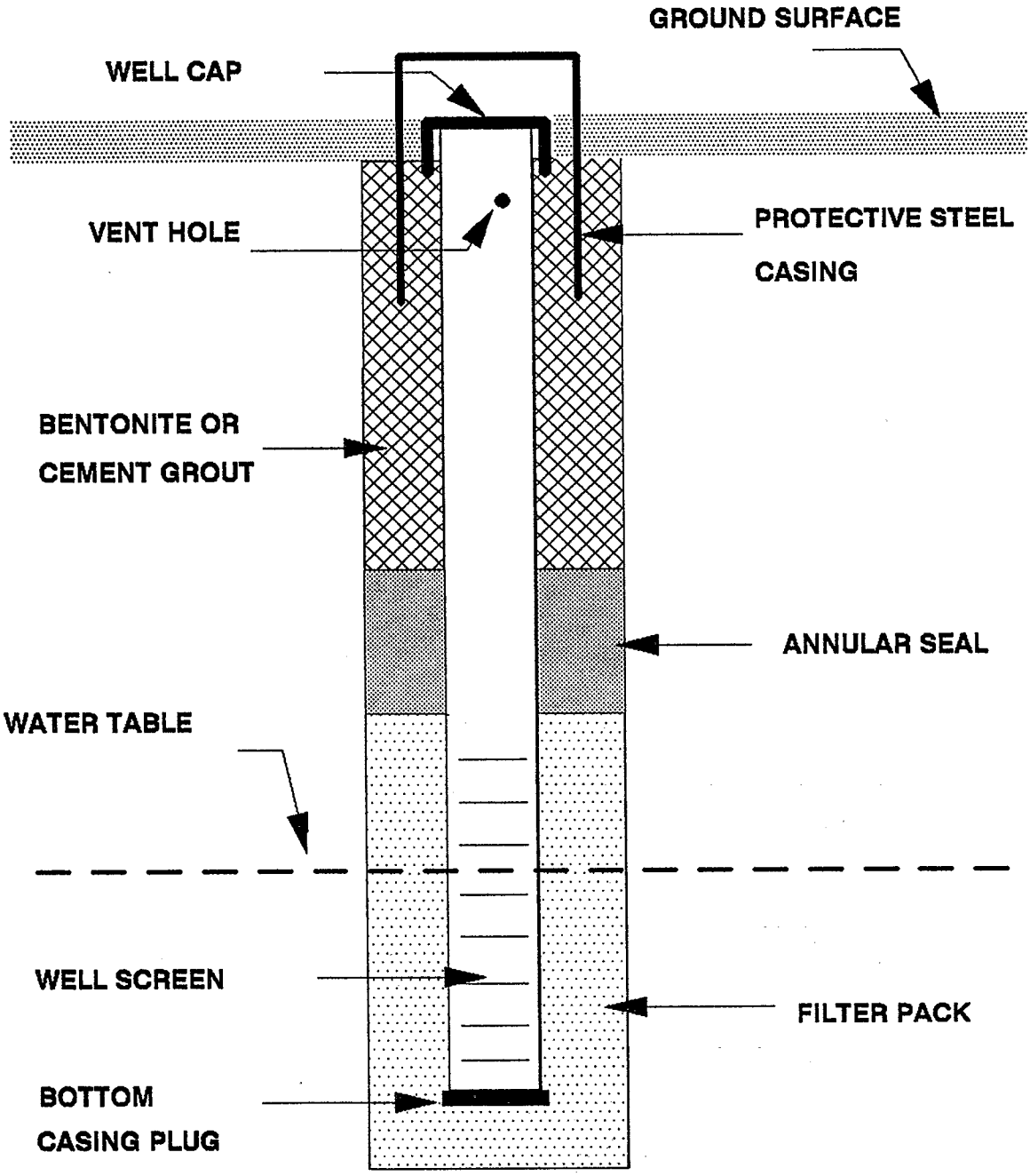


Figure 35. Components of a typical ground-water monitoring well installed in a borehole.
Source: U.S. EPA 1987

galvanized steel, polyethylene, polypropylene, Teflon®, stainless steel, and polyvinyl chloride (PVC). The selection of an appropriate material should be based on environmental conditions, structural requirements, and compatibility with the contaminants of interest.

Typically, the material of choice for monitoring well construction is PVC or stainless steel. Both of these materials meet the structural needs of a monitoring well. Some types of PVC will deteriorate when in continual contact with petroleum hydrocarbons. However, the use of an impervious PVC material is acceptable and is common for construction of monitoring wells. The type of material used for construction of the well screen and casing should be indicated on a well completion log that is kept onsite for inspection by the regulator.

Well diameter: The inner diameter of the well casing and screen typically ranges from 2 to 4 inches. Though smaller diameter casing is available, diameters less than 2 inches are not recommended. A monitoring well that is constructed of very small diameter casing could limit the type of hydrocarbon monitor selected for use. Monitoring devices are also more likely to get hung up on small diameter casing. Monitoring wells larger than 4 inches in diameter can be installed; larger diameter wells could later be used as extraction wells if remediation of ground water is required in the future due to a release incident.

The diameter of well casing and screen used should be documented on a well completion log. Regulators can refer to this log to determine the design of the monitoring well.

Screen slot size: The size of the well screen slots is very important to the proper operation of a monitoring well. If the slot size is too large, soil particles will be allowed to pass into the monitoring well, which may eventually become filled with soil. If the slot size is too small, it may prevent the flow of product into the monitoring well.

The slot size should be wide enough to permit the flow of ground water and free product into the well, but not so wide as to allow the passage of filter pack or fine-grained soils into the well. Therefore, the slot size should be determined based on the type and texture of surrounding soils and should be selected by

an experienced hydrogeologist. Premanufactured well screens are available in slot sizes typically ranging from 0.008 to 0.120 inches.

This problem can be evaluated by requiring the slot size of the well screen to be indicated on the well completion log. If the slot size of an existing well is inappropriate and causing an operational problem, the well should be properly closed and another well installed with the correct slot size.

Length of well screen: The total length of the well screen will depend on the depth to the water table and the range of water table fluctuation levels. The screen must extend over the entire interval of the high and low water table levels as discussed in the section of this chapter titled "Site Assessment."

Ensure proper installation of the monitoring well

The process of well installation involves borehole drilling and placement of well in borehole; installation of filter pack, bentonite seal, surface seal, and protective casing; well development; well security; and documentation of well construction and installation.

Borehole drilling generally does not need to be conducted for monitoring wells installed in the excavation field of new UST facilities. For these sites the well may be located during tank installation and the backfill placed around it. Operational problems associated with borehole drilling for ground-water monitoring wells installed outside of the excavation zone (typically for well installation at existing UST facilities) will not be discussed in this document. Though selection of an inappropriate drilling method could affect the hydraulic conductivity of the subsurface materials, this situation is not a common problem. A discussion on the types of available drilling methods is provided in U.S. EPA 1986.

The use of an inappropriate filter pack may allow the introduction of sediment into the well, eventually causing it to become filled or restricting the flow of fluid into the monitoring well. Typically, several inches of filter pack are placed in the bottom of the borehole before the well is installed. The filter

pack, which may consist of clean sand, silica, or glass beads, is placed in the borehole to extend 1 to 2 feet above the top of the well screen.

The annular space (the space between the wall of the borehole and the outer well casing) above the filter pack is then sealed to prevent migration of contaminants to the well screen. Materials such as a cement-bentonite mixture, bentonite chips, or antishrink cement mixtures can be used as the sealant in unsaturated zones. This seal should extend at least 2 feet above the filter pack.

The area above the annular seal should be filled to the surface of the ground with a cement-bentonite seal to prevent migration of liquids from the ground surface and to protect the well casing from structural damage. Ideally, the interface of the annular seal and the seal above it should be located below the frost line to protect the well from damage due to frost heaving. A well casing (referred to as a protective casing) with a diameter larger than that of the monitoring well (4 to 8 inches) can be placed in the cement seal around the monitoring well to provide additional protection from physical damage. This protective outer casing is typically made of black steel or PVC.

Monitoring wells installed in the backfill of new UST sites can be constructed using the backfill as the filter pack if the material meets the requirements of an appropriate filter pack (see Figure 36). These wells still should be constructed with a surface grout to prevent infiltration of contaminated runoff from migrating vertically down to the filter pack and to help stabilize the well casing and screen.

Flow of liquids into the well may be prevented or severely reduced if a monitoring well is not properly developed. The process of well development involves the surging (mixing) and removal of ground water from the well casing. The purpose of this procedure is to dislodge material trapped in the well screen, to remove sediment in the well introduced during the installation process, and to restore the natural flow rate of ground water (hydraulic conductivity).

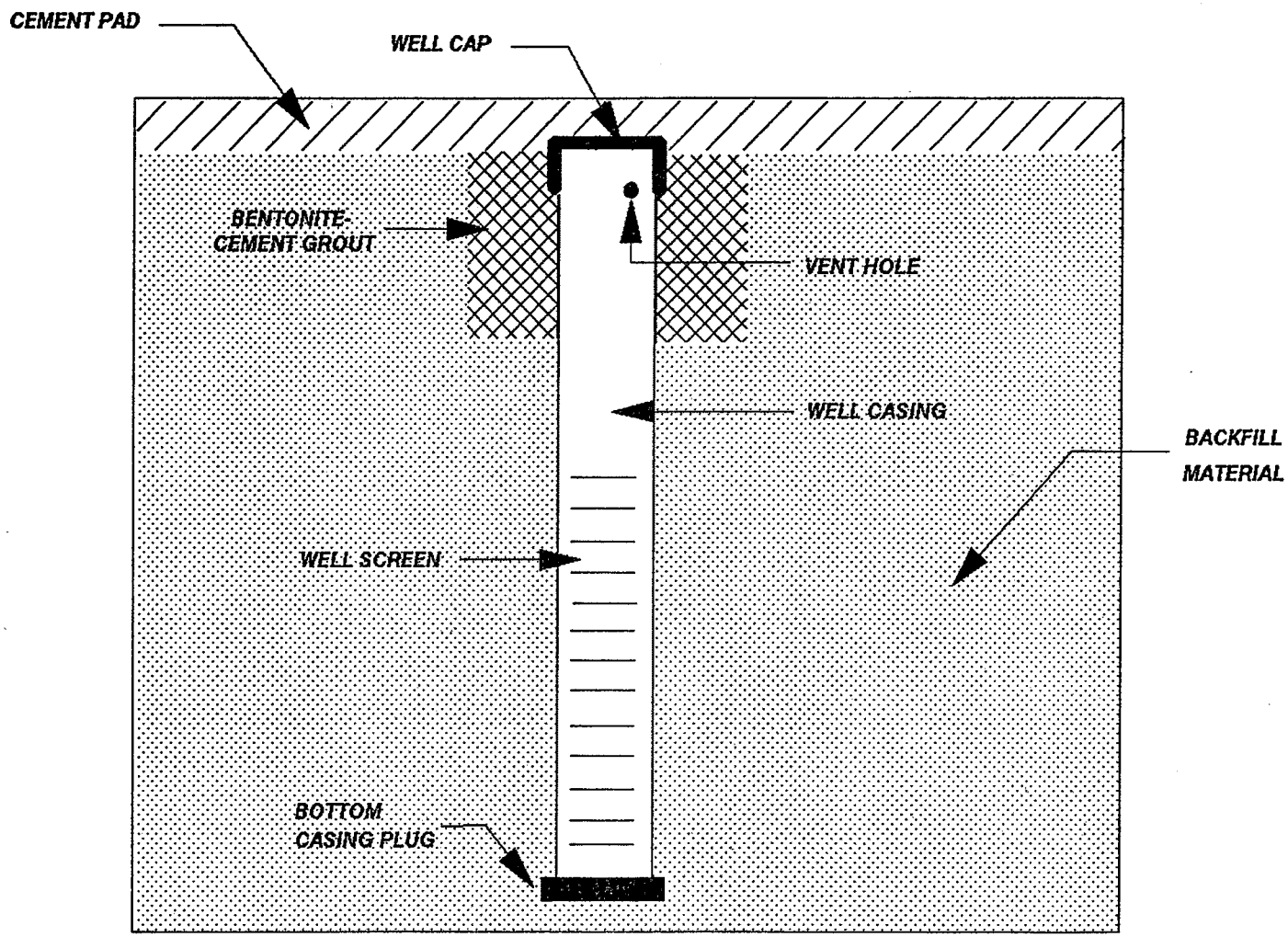


Figure 36. Components of a monitoring well constructed with the backfill material used as the filter pack. Source: U.S. EPA 1987

A variety of techniques can be used for well development. The well can be surged using surge blocks, bailers, or pumps. Well development is continued until ground water in the well is relatively free of turbidity (cloudiness).

If well development is not continued for an adequate length of time, the result will be a reduction in the flow of fluid into the well. This problem can be evaluated by inspecting the well completion log to determine how long the well was developed during installation. The problem can sometimes be corrected by redeveloping the well until the recharge rate of the well is improved.

Need to secure the monitoring well

A monitoring well that has not been properly secured is susceptible to tampering or accidental contamination. For example, product could accidentally be delivered to the monitoring well instead of the tank fill pipe. To secure a monitoring well, a threaded or flanged cap is placed at the top of the well to prevent the introduction of any foreign matter into the well. The well cap should be locked in place to prevent tampering. The well should be unlocked only when entrance to the well is required. The equipment used to secure a well should be documented on the well completion log. Monitoring wells should also be clearly marked (e.g., by color coding or labelling) to distinguish them from tank fill pipes. The security of a well can be easily checked by inspection of the well head.

Need to document well construction and installation

The first step that should be taken when a problem with operation of a monitoring well occurs is to obtain a copy of the boring log and well construction diagram for each well. It is much more difficult to troubleshoot operational problems if these documents are not provided. The boring log describes the soil types and texture of different geologic strata encountered and their interval depth, drilling method(s) used, depth to ground water, etc. The well construction diagram depicts the well design specifications, including the type and depth of filter pack, annular seal, cement seal, well diameter, and well screen design. This information should be documented on the well boring and completion logs for each monitoring well.

Operation and Maintenance

This section describes the most common operator-induced problems that will affect proper performance of ground-water monitoring. The most common types of human errors are described below.

Need for proper maintenance of sensors

Ground-water sensor devices that are improperly maintained can falsely indicate that a release has occurred or fail to detect a release. Inadequate maintenance of sensor devices can result in a build-up of ice or algae, which is a common problem with continuous monitoring devices. Thermal conductivity devices can get caught on the float. Ice also is a maintenance problem with product-soluble devices. Maintenance generally is not considered a problem with intermittent devices. To prevent maintenance problems with monitoring devices, inspections of the sensor should be conducted on a regular and frequent basis to ensure that it is operating properly.

Calibration of manual ground-water monitoring devices is typically not necessary. Automatic devices should be calibrated if this is recommended by the manufacturer, according to their specifications.

Ensure the integrity of sensor coatings

Electrical resistivity sensors and hydrocarbon-soluble devices use hydrocarbon sensitive coatings that degrade when exposed to hydrocarbon products. These coatings may also biodegrade over long periods of time. After the sensor has been exposed to hydrocarbon product, it must be replaced. If the sensor is not replaced, it will fail to detect a future release.

Interpretation

Ensure proper interpretation of environmental influences

False alarms in continuous monitoring systems are often caused by environmental influences. The most common error is failing to identify changes in electrical resistance that are due to equipment shorts or power surges. This is primarily a problem that affects thermal conductivity devices and can result in a false negative measurement.

Ensure proper interpretation of monitoring results

Another potential source of errors is the failure of the operator to determine that the source of an alarm or positive result is from an offsite source of contamination or from the accidental introduction of product into the monitoring well (e.g., surface spills). False alarms can also occur when the local water table rises and contacts residual product from previous spills (see the discussion in the section of this chapter titled "Site Assessment," addressing background contamination). This is more of a problem with intermittent devices because these devices rely on the results obtained from a discrete sample and not on data trends.

Malfunction of monitoring devices, in particular thermal conductivity devices, may result in false positives. Another potential source of errors is the long (up to 10 hours) response times exhibited by electrical resistivity sensors. Although this is not documented as a common error, an operator unaware of this time constraint may prematurely decide that a resistivity test indicates no leak. The response and lag times for all other continuously operating devices mentioned in this manual are less than 30 minutes.

The interpretation of monitoring results from ground-water monitoring wells does not require a high degree of technical expertise. Manual systems require inspection of a liquid sample obtained from the well, or the use of a sensor which will either electronically indicate the presence of free product (i.e., a change in thermal conductance) or will change color. Automated detection systems require the greatest degree of

interpretation. For systems with an alarm, the operator must determine if a triggered alarm is legitimate or a false alarm. Systems using a continuously operating strip chart recorder may require interpretation of the data trends indicated on the chart.

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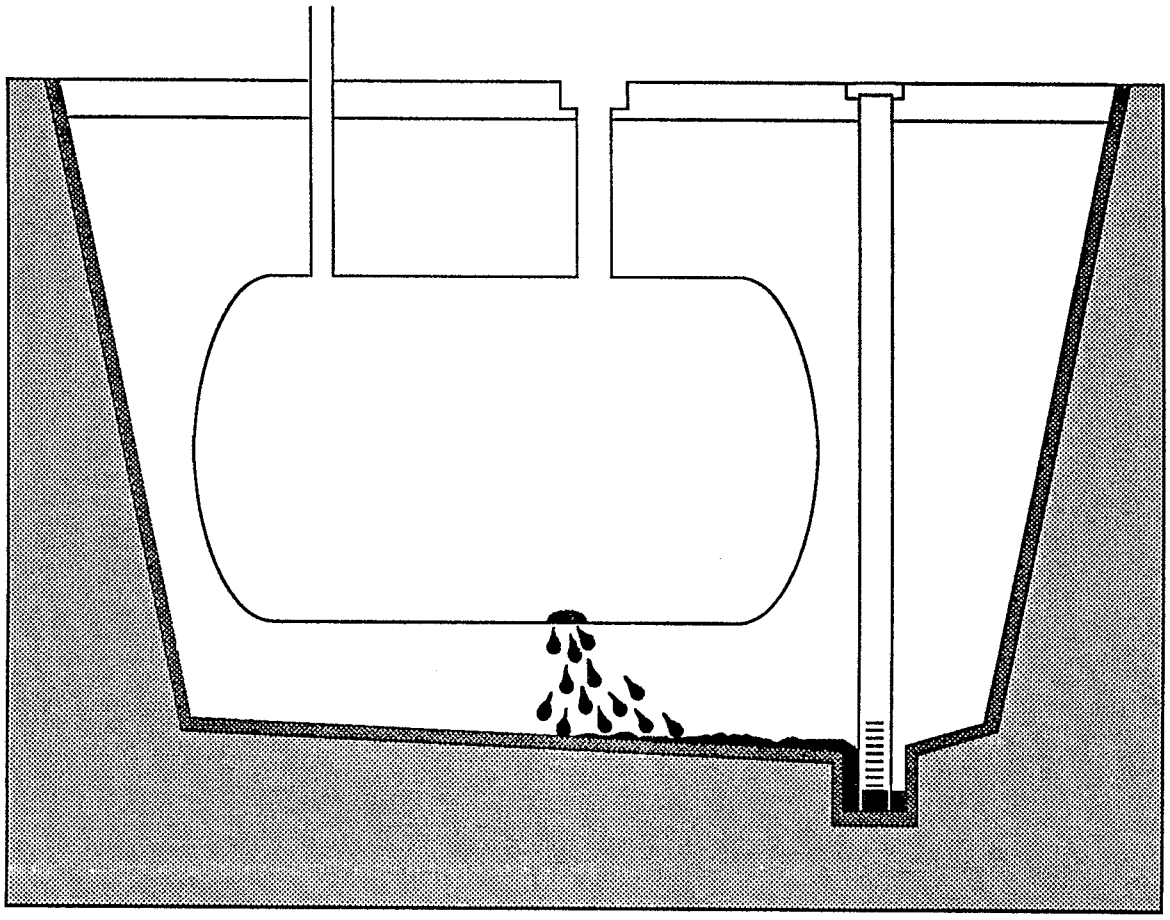
Chapter VIII
Secondary Containment with Interstitial Monitoring



SECONDARY CONTAINMENT WITH INTERSTITIAL MONITORING VIII

SUMMARY

The use of secondary containment with interstitial monitoring as an UST release detection method for petroleum storage tanks involves a barrier outside the primary tank with a release detection device between the inner and outer barriers. The space between the barriers is called the interstitial space. The outer wall or liner contains the leak long enough for it to be detected by the monitoring system. This method is required in several states and is considered to be the most protective of the environment because leaks are generally detected before they can contaminate the environment.

The factor that has the greatest impact on the proper functioning of secondary containment is installation. The factors that have the greatest impact on the interstitial monitoring systems are system installation and operation and maintenance factors.

The discussion presented in this chapter covers a range of possible problems that may occur with secondary containment with interstitial monitoring. This does not mean that all, or even most, of these problems will occur at the same time. Nor does it mean that all of the problems are of equal importance, in terms of frequency of occurrence or severity of impact. Some problems, such as false alarms caused by curing of fiberglass tanks, seldom occur, while other problems, such as residual contamination, may have limited impact. Experienced installers are well aware of these problems and how to deal with them. For example, an experienced installer would use waterproof electrical junction boxes to prevent detection system failure during precipitation. Release detection, however, is a growing industry, and new companies are being formed with less experience. This chapter presents a range of potential problems for educational purposes, not to imply that they will always occur.

BRIEF DESCRIPTION

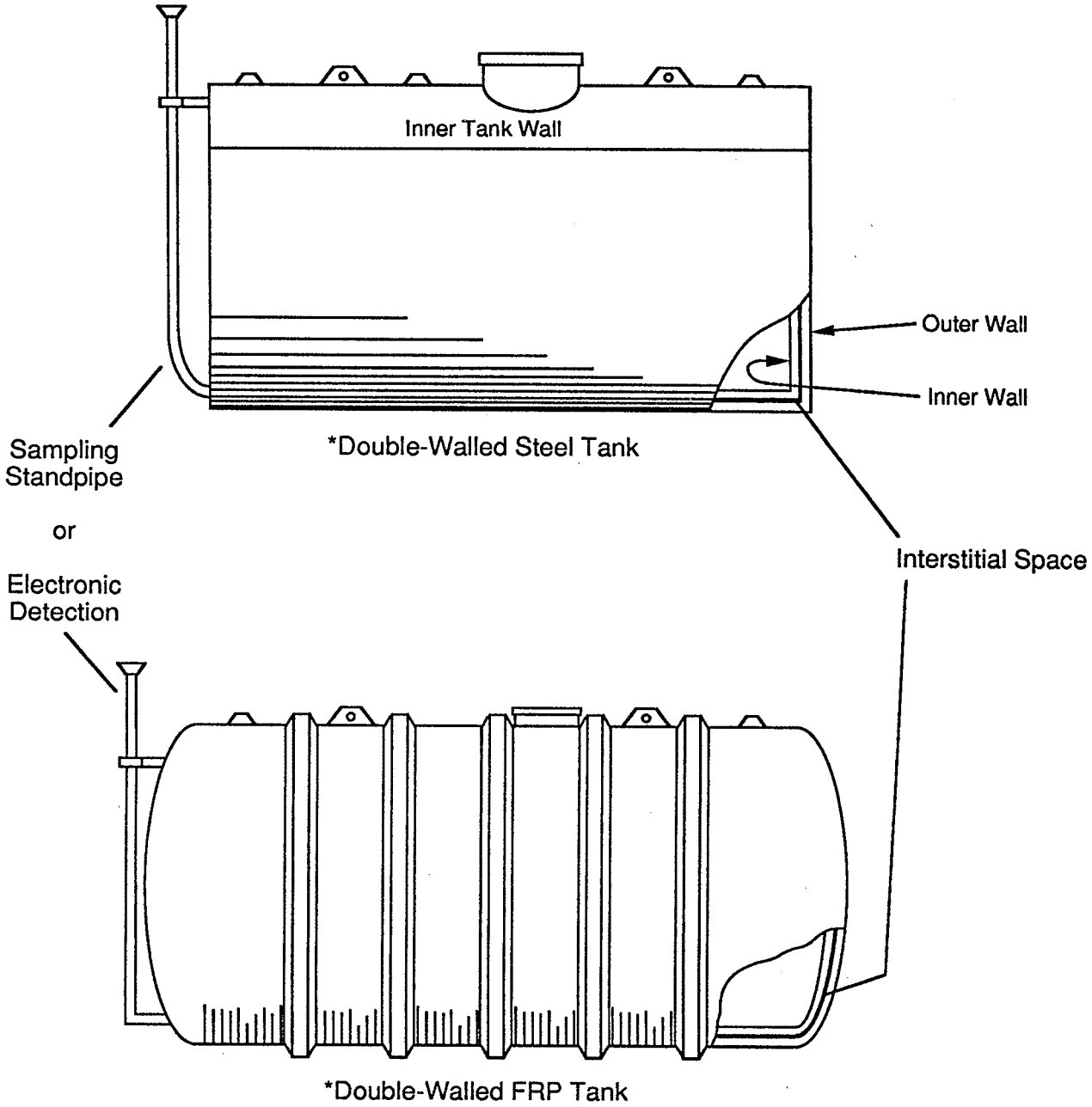
An interstitial monitoring system is intended to detect any leak from the tank under normal operating conditions and not to measure the leak rate. Secondary containment with interstitial monitoring for tanks consists of two components. The first is an outer barrier, which directs the leak toward the interstitial monitoring system. The purpose of the outer barrier is to retain the leak for a sufficient time so that it can be detected. The barrier is not required to contain the leak from a petroleum tank so that it does not contaminate the environment (as is required for hazardous substance tanks). The second component is the interstitial monitoring system, which detects the leak and alerts the operator.

The outer barrier can be either an outer shell (on a double-walled tank), a synthetic liner around the tank (a tank jacket), or a liner in the excavation of the tank system that is between the soil and the backfill material (Figures 37 through 39). The outer shell of a double-walled tank is generally made of the same materials as the tank, e.g., steel or fiberglass reinforced plastic (FRP), while a liner can be made of various synthetic materials, such as high-density polyethylene, polyester elastomers, epichlorohydrin, and polyurethane.

The outer barrier either completely surrounds the tank (the fully or completely enclosed design) or covers only the bottom half of the tank (partially enclosed design). In the completely enclosed (double-walled or jacketed) design, a leak from any part of the tank is trapped in the interstitial space between the inner and outer barriers and is detected. In the partially enclosed design, leaks from the bottom half of the tank would be contained for detection by the outer shell, but leaks originating above the outer shell could potentially enter the backfill and avoid detection by an interstitial monitoring system.

Excavation liner systems also may be either fully or partially enclosed. A fully enclosed liner system would have a liner section across the top of the tank that would be sealed to the sides of the excavation liner. A partially enclosed design might not have the top liner, and its excavation liner might not reach the top of the tank.

Concrete vaults are also used for secondary containment but are not commonly used for petroleum products because vaults are more costly to construct. Other references are available on concrete vaults, which are not discussed further in this chapter.



* A cross section of a double-walled tank is shown in Figure 40

Figure 37. Two double-walled tank configurations.
Source: U.S. EPA (January 1989)

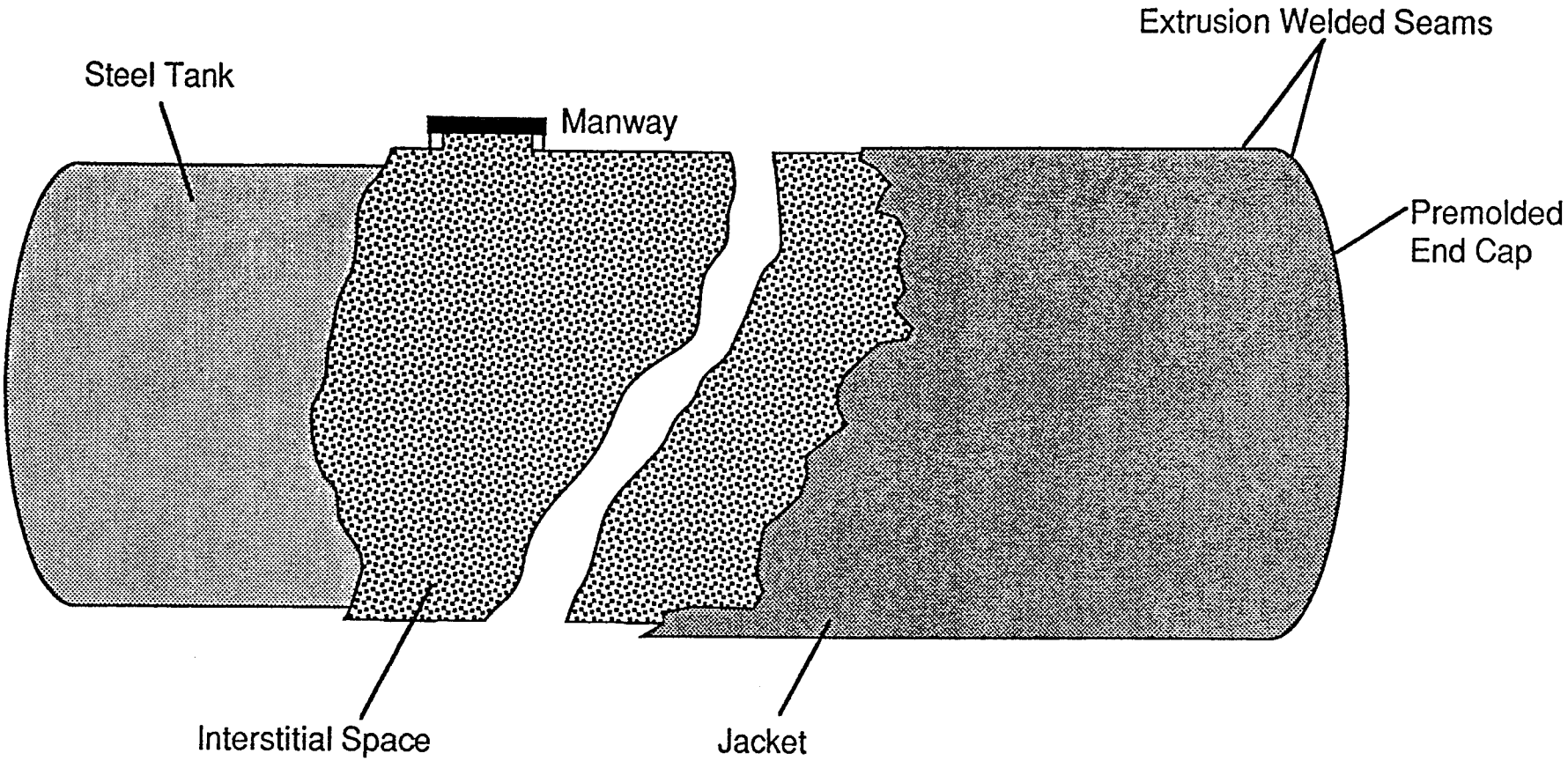


Figure 38. Jacketed tank. Source: U.S. EPA (August 23, 1986)

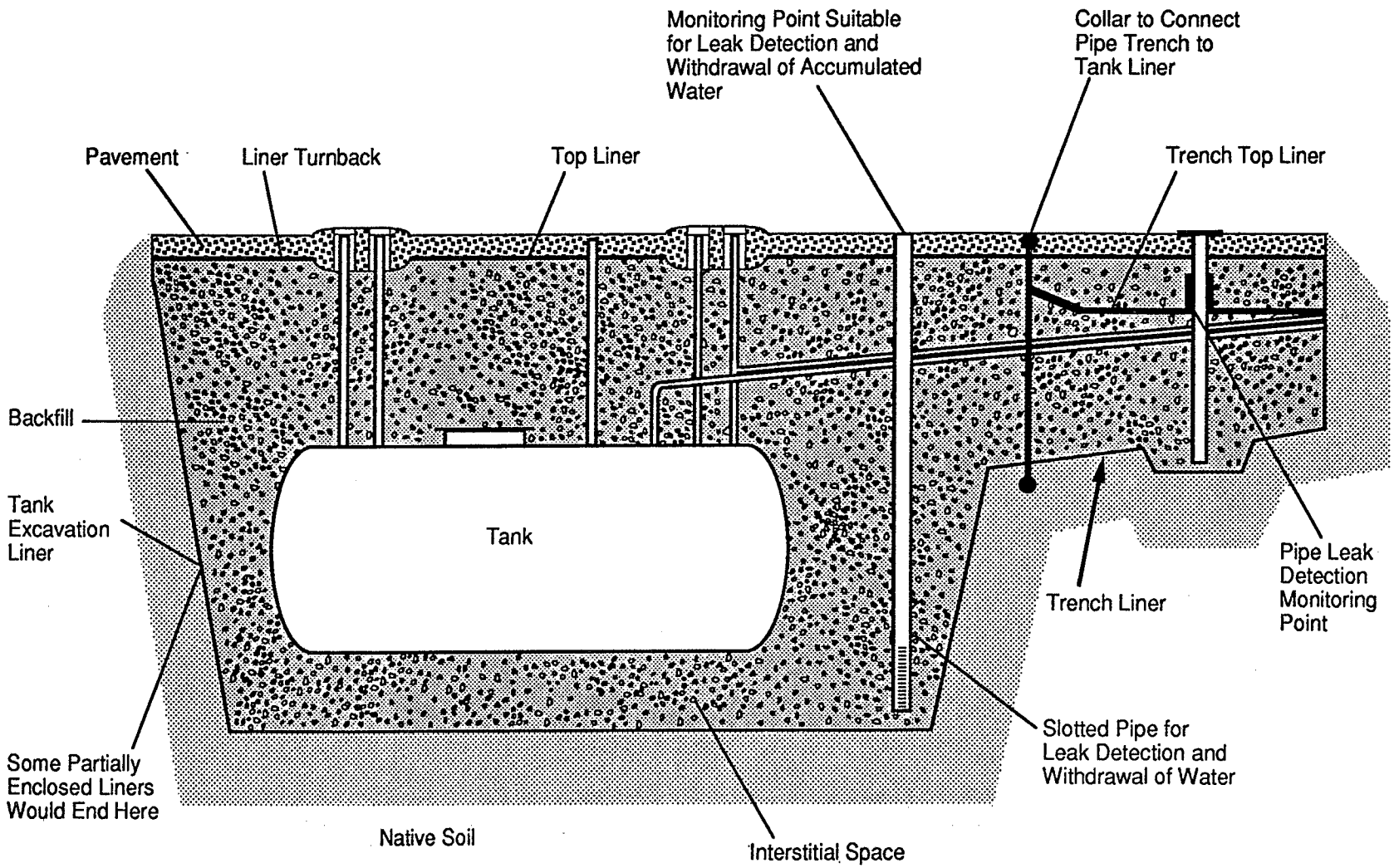


Figure 39. Tank with excavation liner. Source: U.S. EPA (August 22, 1986)

Interstitial monitoring systems operate to detect leaks based on the following mechanisms:

- Electrical conductivity
- Pressure sensing
- Fluid sensing
- Hydrostatic monitoring
- Manual detection
- Vapor monitoring

The applicability of the monitors to the types of secondary containment systems is summarized in Table 12.

Vapor monitoring is discussed in Chapter 6 of this handbook. Therefore, it will not be discussed in this chapter except where the problems are specific to interstitial monitoring systems.

The electrical conductivity monitor depends upon the leaked product changing the resistance of sensing wires that are placed in the interstitial space of tank systems. The leaked product completes an electrical circuit and allows current to flow, thus activating an alarm. Designs are available for both electrically conductive (e.g., water or a water-based detergent solution) and for non-conductive products (e.g., like petroleum). This type of system is used in secondary containment systems that utilize an excavation liner, a jacket, or a double-walled tank.

Pressure sensing systems are used only in the interstitial space of double-walled tanks. The space is either put under a vacuum or pressurized, and leaks are identified by the detection of pressure changes that occur when either the inner or outer tank shell develops a hole or crack.

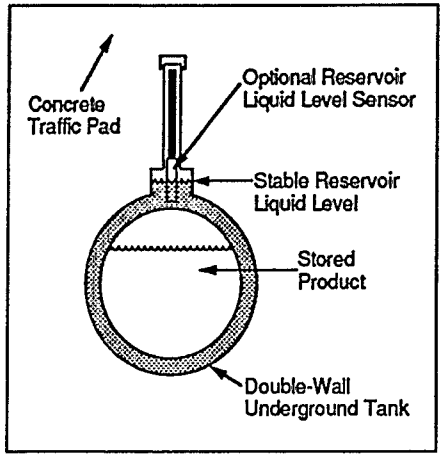
Fluid sensing systems are used in the interstitial space of double-walled tanks to detect a leak into the normally dry space of either the product in the tank or of ground water. One system uses an optical principle in which the change in the reflectance of a mirror is detected when the product or ground water leaks into the space and covers the mirror.

The hydrostatic method (Figure 40) is used in double-walled tanks and is based on detection of the change in level of a fluid that completely fills the interstitial space. When a breech in the inner wall occurs, the

Table 12
Applicability of Leak Detection Methods to Secondary Containment Systems

Containment	Electrical conductivity	Pressure sensing	Fluid sensing	Hydrostatic monitoring	Manual methods	Vapor monitoring
Full double-walled tank	X	X	X	X	X	X
Tank jacket	X		X		X	X
Partial double-walled tank	X	X	X		X	X
Fully enclosed excavation liner	X		X		X	X
Partially enclosed excavation liner	X		X		X	X

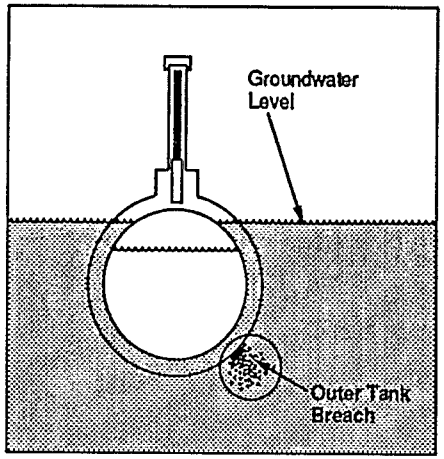
Source: U.S. EPA.



Normal Conditions

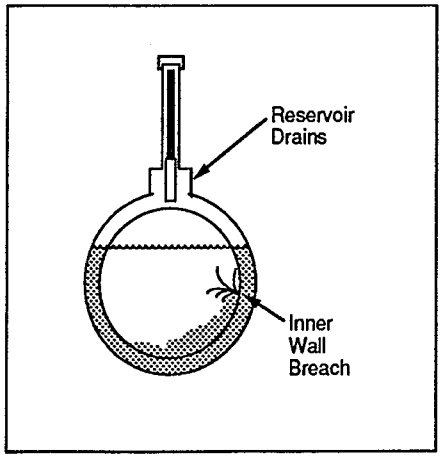
The reservoir liquid level will be stable if both the inner and outer tank are tight.

The optional reservoir sensor will activate an alarm if the reservoir drains or overfills.



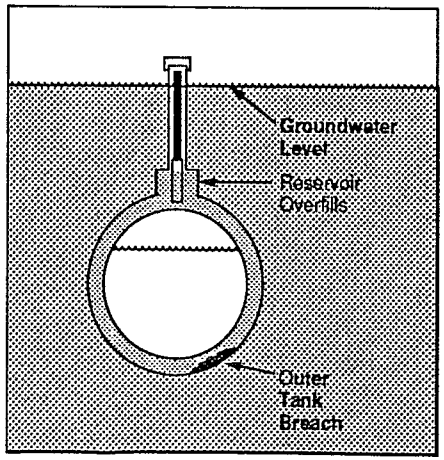
Outer Wall Breach

If the groundwater is below the tank top, the monitor fluid drains into the ground causing the reservoir to drain.



Inner Wall Breach

Monitor fluid drains into the primary tank causing the reservoir to drain. No petroleum product escapes from the primary tank to pollute the site.



If the groundwater is over the tank top, the reservoir will overfill with groundwater and activate the high level alarm on the reservoir sensor.

Figure 40. Hydrostatic monitoring system. Source: Owens Corning Fiberglass Corporation

fluid leaks into the tank, and the fluid level in the space is lowered. If the breech occurs in the outer wall, the fluid will leak into the surrounding soil, and the fluid level in the space will decrease, or ground water will leak into the interstitial space and cause it to overfill. Alarms are set so that either a decrease or an increase in fluid level will be detected.

The manual detection method is simply the use of a pole with a cloth or a petroleum-detecting paste on one end. When the pole is inserted in a pipe that extends into the interstitial space, any leak into the space can be detected from visual observation of the cloth or from a change in color of the paste. This method is used in both double-walled tanks and in liner systems of secondary containment.

To be successful, most methods rely on the leaked product being directed by the containment to the position of the sensing device so that detection can be accomplished. That is, the containment is usually sloped toward the sensor in such a way that leaks entering the interstitial space will be detected. Some electrical conductivity methods, however, rely on a continuous sensing wire that is capable of detecting leaks along the sensor's length and, thus, do not require a sloped containment.

The successful implementation of secondary containment with interstitial monitoring involves the following two phases: (1) installation, including site assessment, an evaluation of the site environmental conditions to assist in the determination of what type of secondary containment and interstitial monitoring system is appropriate; and (2) operation and maintenance. The relationship between these phases is shown in Figure 41 along with some of the important factors that should be considered for successful implementation. The problems associated with the use of a secondary containment system with interstitial monitoring are discussed below in reference to these two phases. The order of discussion does not necessarily reflect the priority of the problems discussed.

POTENTIAL PROBLEMS AND SOLUTIONS

The main problems in the implementation of an interstitial monitoring system result from inadequate attention to installation, such as an inappropriate choice of containment for the site conditions or faulty installation of the monitoring system or containment, and lack of attention to the system during operation. The major problems and some

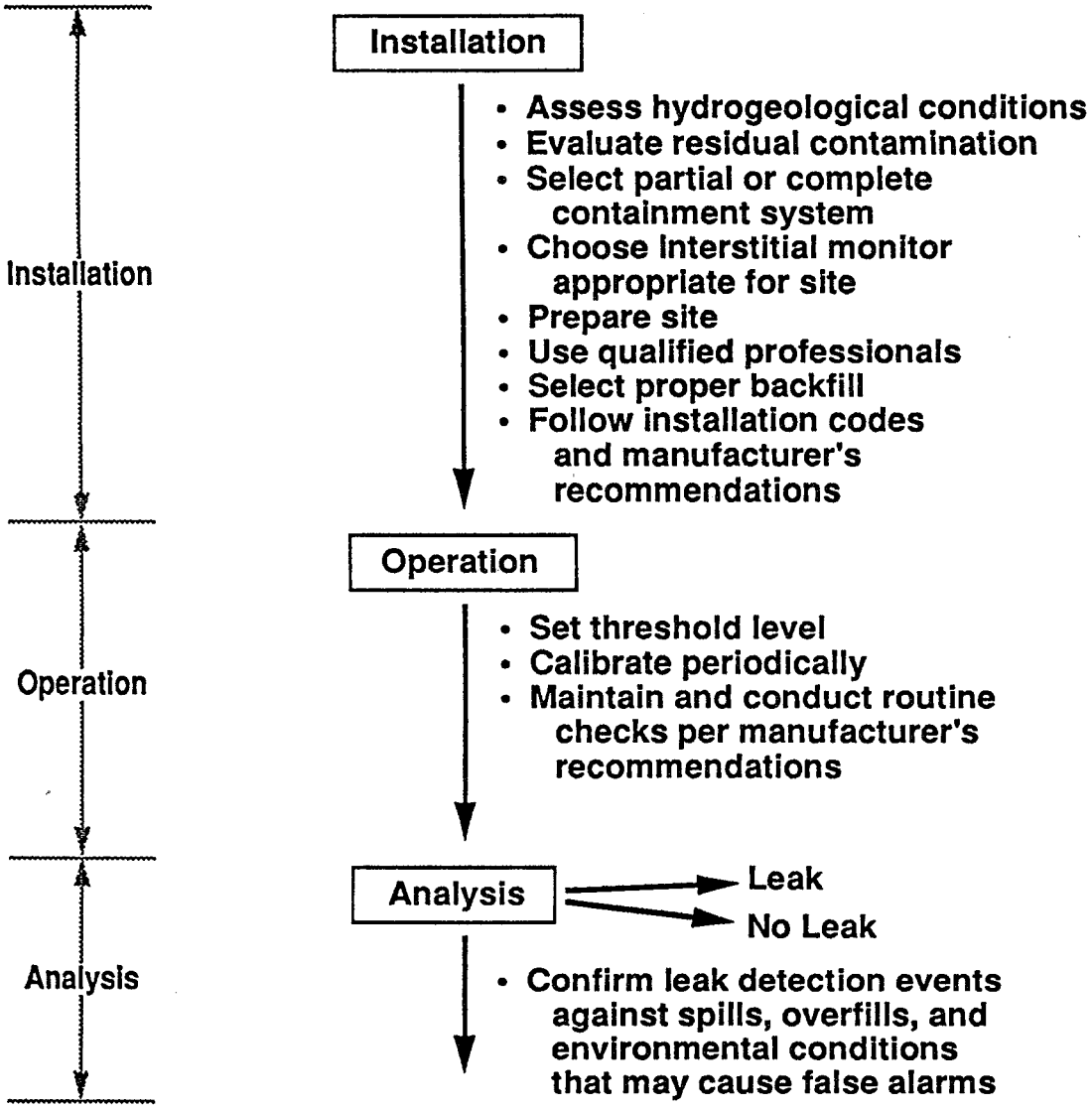
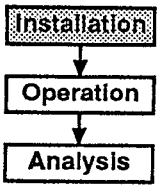


Figure 41. General procedure for secondary containment with interstitial monitoring

solutions are discussed below, including regulatory approaches to oversee the implementation effectively. A number of Agency solutions are offered for each problem, but not all of them need be undertaken. A summary of the problems and solutions is given in Table 13. An asterisk identifies the most serious concerns with containment and monitoring systems.

Installation



Assuring proper installation of secondary containment

The proper installation of secondary containment is important to the success of interstitial monitoring. If the containment fails to collect the leaked product, the monitoring system may be unable to detect the leak before it reaches soil and ground water.

For excavation liners, rocks, tree roots, or debris in the excavation may cause damage to the liners, which could cause leaks to go undetected. All rocks, tree roots, debris and other protruding objects should be removed prior to the installation of these secondary containment systems.

If improper backfill is used, two problems might arise. FRP double-walled tanks might not be supported sufficiently so that, when the tank is filled, the settling of the tank under the load of the fuel might cause cracks in the outer wall and produce leaks that escape detection. With excavation liner systems, if the backfill is not of sufficient permeability, leak detection may be delayed due to slow migration of the leaked product to the monitoring system. Both problems can be avoided by using sand or pea gravel as the backfill material. These materials both provide adequate support to double-walled tanks and are of sufficient permeability so that leak detection will not be delayed. To prevent excessive settling of double-walled FRP tanks, additional precautions should be taken, such as compaction of the backfill under the tank and the use of a filter fabric in the excavation to prevent the backfill from migrating in shallow ground-water or tidal areas.

Surface water run-on and precipitation can cause the backfill to become saturated. If this occurs, a vapor monitoring system will not function because the vapor cannot migrate to the monitoring system. Manual leak detection methods may also be adversely affected if the water is sufficient to float leaked product away from the monitoring

Table 13. Indicators and Solutions for Problems with Secondary Containment with Interstitial Monitoring

Problem	Indicators	Tester Solutions	Agency Oversight Options
Account for shallow ground water.	Ground water leaks into partial containment causing failure of vapor monitoring and manual methods.	Use double-walled tank, fully enclosed liner or jacket, or monitoring method not sensitive to water.	Require site assessment to establish ground water depth and fluctuation.
***Prevent faulty electrical installation.**	False alarm or inoperative system.	Use waterproof, corrosion-proof junction boxes; follow manufacturer's installation procedures and local codes; use manufacturer's representative to supervise.	Certify installers; review installation plans; inspect installation.
***Prevent faulty containment installation.**	Leaks escape detection. Sudden catastrophic product loss.	Install per local and national codes; use representative of manufacturer to supervise.	Review plans; inspect; certify installers; require supervision of installation by manufacturer's representative.
Prevent interference from surface water run-on or precipitation.	Water leaks into containment and causes failure of vapor monitoring or manual methods.	Cover containment with sloped, impervious synthetic membrane, or use method unaffected by water in containment.	Review manufacturer's literature to ensure sensor will respond or require test with the product.
Assure proper operation and maintenance.	System failure or false alarm.	**Electrical conductivity.** Replace sensor wires after detection. **Pressure systems.** Check tightness of plumbing connections on routine basis.	Review plans; train staff on monitoring systems; inspect; require demonstration of system and system tests before operation.

		Fluid sensing systems. Set threshold to distinguish product from water. **Hydrostatics monitoring systems.** Add fluid in hot weather; add anti-freeze in cold weather. **Manual detection.** Use consistent procedure. **Vapor monitoring.** Wait for tank to cure so that emission of gases in interstitial space ceases. Set threshold above gas concentration.	
Prevent false alarm due to residual (background) contamination.	False alarms.	Use system that can distinguish leak from background contamination. For site conditions where background would interfere with detection, use double-walled tank or other completely sealed secondary containment.	Require site assessment; review plans; require system tests to show that leaks can be distinguished from background contamination.

*** Most frequent causes of failure.**

location. To avoid this problem, a synthetic liner should be placed over the tank and its backfill to prevent water from entering the backfill. Another solution would be to use release detection methods that function adequately in water, such as electrical conductivity or ground-water monitoring methods.

Improper sealing of the seams of liners can result in leaks escaping the containment systems without being detected. The installation of liner systems should be conducted only by professional installers who are experienced in liner installation.

The installation of secondary containment should be supervised by a representative of the manufacturer or by an experienced professional who has been trained for the task in order to minimize the potential for damage to the containment and the consequent inability of the monitoring system to detect the leak. Some states, for example, California and Rhode Island, require that the installation be supervised by the manufacturer or by a representative of the manufacturer. Other regulatory agencies, such as Dade County, Florida, require inspection of secondary containment systems during installation. Dade County also requires prior agency review of the secondary containment design and installation plan. The City of San Jose requires integrity testing of all secondary containment systems before they are accepted for use.

In general, state and local installation codes are in effect that, when followed, will promote proper installation and that will help minimize the possibility of damage to the secondary containment system. State and local installation codes must be followed, and the reference section at the end of this chapter lists other national codes which may be used for guidance.

Installation → Operation → Analysis

Accounting for shallow ground water

Shallow ground water may adversely affect vapor monitoring and manual methods of interstitial monitoring. The problems related to vapor monitoring in shallow ground-water areas were discussed in Chapter 6. Vapor monitoring will not function properly in saturated soils because the movement of vapor is slowed or prevented. Manual methods might not detect a leak under high ground-water conditions if enough water is present to float the product away from the test location.

A site assessment to determine the depth to ground water and the ground-water fluctuation should be made to assist in the choice of an appropriate secondary containment system. If the ground water at any time is expected to reach the level of the containment, a fully enclosed containment system could be used to prevent the ground water from transporting the leaked product away from the detection system. The use of the fully sealed containment would also allow vapor monitoring to be used at sites where vapor monitoring normally would not be effective. Pressure sensors, fluid sensors, and hydrostatic methods are used in double-walled tank systems and, therefore, should not be adversely affected by ground water as long as the containment does not leak.

At sites where shallow ground water exists, the forces on both double-walled tanks and excavation liner systems caused by the ground water may cause shifting of the containment and consequent damage that would allow leaks to escape and go undetected. These sites should be dewatered before installation of the containment, and the containment should be properly anchored to prevent shifting.

Installation → Operation → Analysis

Preventing false alarms from background contamination

Background contamination of soils and ground water can cause false alarms in interstitial monitoring systems that are not completely sealed. When the site has been previously contaminated or when a threat of contamination exists from neighboring properties, it may be necessary to use a monitoring method that can distinguish a leak from background contamination or to use a double-walled tank, a tank jacket, or an excavation liner that is completely sealed. This precaution will ensure that detected leaks are only from the tank system of concern and did not originate elsewhere. The background contamination problem and its solutions are discussed in more detail in the ground-water monitoring and vapor monitoring chapters.

Installation → Operation → Analysis

Assuring selection of proper interstitial monitoring system

Interstitial monitoring systems that are inappropriate for the stored product will not allow detection of leaks. An understanding of the monitoring method and its ability to detect the specific product is necessary. For example, electrical conductivity systems function differently for conductive products than for non-conductive products such as petroleum. For petroleum products, one common design

(Figure 42) is based upon the ability of petroleum products to complete an electrical circuit by degrading a coating that separates two metal conductors. Another design (Figure 43) allows the petroleum product to penetrate a braided cover on an electrical cable, which causes a conductive polymer jacket to swell and contact conductive metal wires, thus completing an electrical circuit. A non-petroleum electrical conductivity monitoring system used in an UST containing petroleum might not detect a leak. The coatings and conductive polymers of these systems are formulated to be specific to non-petroleum products and will not allow detection of petroleum.

In addition, if the stored product is changed over the life of the tank an evaluation of whether to change the monitoring system also should be made to ensure that the system is appropriate for the new product. As discussed in the chapter on vapor monitoring, the vapor monitor's ability to detect a leak depends upon the volatility of the product. If the product were changed from gasoline to used oil during the tank's lifetime, the vapor monitor might not be able to detect leakage of the new product due to its lower volatility. All monitoring systems should be evaluated for use for the specific stored substance by checking the information available from the manufacturer and by asking the manufacturer to verify adequate response to the stored product, if necessary.

Installation → Operation → Analysis

Assuring proper installation of monitoring system

One major problem of all non-manual interstitial monitoring systems is improper electrical installation. If junction boxes are not waterproof and corrosion proof, short circuits may occur, which will cause system failure and inability to detect leaks. Waterproof junction boxes are more expensive than non-waterproof ones and, therefore, are sometimes left out of the as-built system by installation contractors to save money. Another common problem caused by "short cuts" taken by installation contractors is the use of two-conductor electrical cable in place of three-conductor cable. This substitution can cause a false alarm in some systems or may cause a diagnostic trouble alarm in other systems to alert the operator that a fault is present. Some systems require that bridge resistors be used to span the unused sensor channels on the system's electrical control board. When these bridge resistors are omitted, a false alarm also may be given. It is important, therefore, that the manufacturer's recommended procedures be followed during installation, that local electrical codes be adhered to, and that short

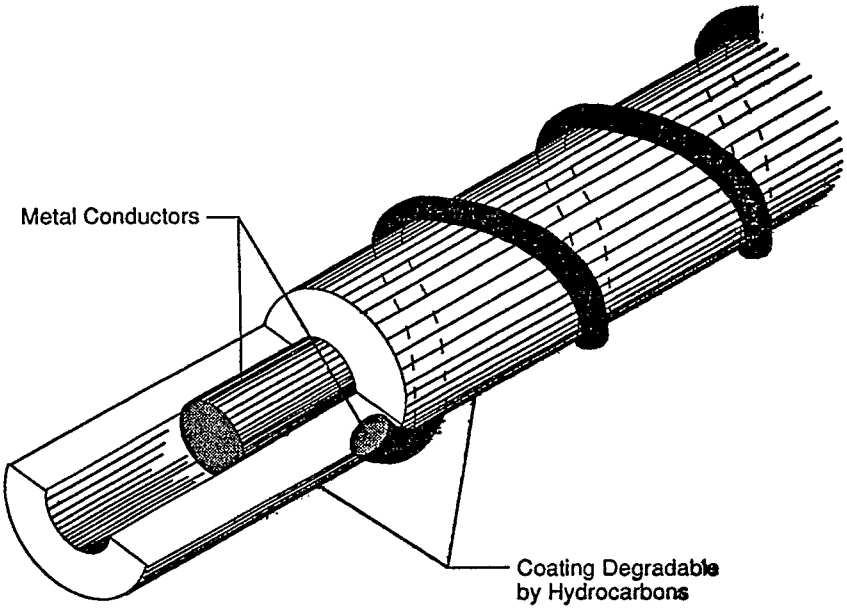


Figure 42. Cross section of electrical conductivity sensor using degradable coating. Source: DETEX Systems, Inc.

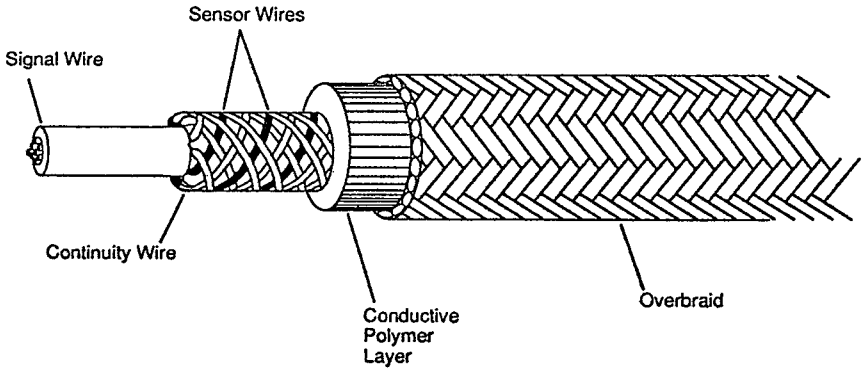


Figure 43. Cross section of electrical conductivity sensor using polymer jacket that swells. Source: Raychem Corporation

cuts that attempt to circumvent these recommendations and codes not be used.

When vapor monitoring systems are used in double-walled FRP tanks, the tanks must be allowed to cure a sufficient length of time so that outgassing of organic vapors from the tank interior walls will not cause false alarms. This outgassing should occur at the factory, but it occasionally does occur in the field. In the field, the primary solution is to set the threshold setting of the vapor monitor above the level of the gas being produced and then to check the threshold setting periodically to see if it can be lowered as the tank continues to cure. These periodic checks must be made or the potential will exist for small leaks to go undetected due to the higher threshold settings.

Operation

Preventing false alarms and undetected releases

False alarms and undetected releases may be caused by operational factors. These factors and some solutions are discussed below for the specific type of system in which they may occur.

Electrical conductivity systems. False alarms will result if electrical conductivity systems are not replaced after exposure to a leak. The degradable coating system sensing wires must be replaced after exposure to leaks; otherwise, the system will give a false alarm because the coating has been degraded. The sensor cable in a conductive polymer system also must be replaced after exposure because the conductive polymer has closed the electrical circuit by swelling and the cable can not be cleaned sufficiently to avoid a false alarm if reused.

Pressurized systems. Losses of pressure or vacuum in these systems will cause an alarm even if the leak that results in the pressure loss is not caused by leaking product. The pipe fittings, vacuum tubing, and vacuum or pressure gauges used in these systems can become loose due to vibration from traffic or due to physical contact with vehicles or with personnel. When a leak is detected, the first action should be to check all plumbing connections to the interstitial space, to retighten any loose fittings, and to re-establish the pressure or vacuum level. If the plumbing is tight, then it can be assumed that a leak in the inner or outer tank

wall has occurred because environmental conditions, such as temperature differences between the tank and the delivered product or the effect of barometric pressure, have not been found to cause false alarms.

Fluid sensing systems. Optical devices, which are a class of fluid sensing systems, allow the leaked product to deposit on a mirror. The reflectivity of the mirror is decreased by the deposits, and the amount of light reflected from a light source, thereby, can be detected and can cause an alarm to be actuated. Any deposit on the mirror, including condensation water, will cause the mirror's reflectivity to decrease. The system's threshold should be set so that condensation water can be distinguished from leaked product.

Hydrostatic monitoring systems. Temperature extremes may cause false alarms or system failure in hydrostatic monitoring systems. Because hydrostatic systems use fluids to detect leaks, precautions must be taken in hot and cold weather to ensure that evaporation does not cause false alarms and that freezing temperatures do not disable the system and prevent it from detecting leaks. During cold weather, an antifreeze solution that is compatible with the tank, the secondary containment, and the interstitial monitoring system should be used to prevent freezing of the fluid. Additional fluid must be added periodically to the interstitial space to compensate for evaporation during hot weather.

Manual detection. Manual methods may not detect a leak if improper operating procedures are used. Manual methods consist of using a pole with either a cloth or a petroleum-detecting paste to indicate that a leak has occurred. If the pole is not always inserted in the same manner into the access hole to the interstitial space, the pole may not sample leakage from the lowest point in the containment and, therefore, may miss leaks. Although this problem would probably not cause large leaks to go undetected for long, a small leak might not be detected within the required monthly monitoring period. Specific spots should be designated as test positions, these positions should be the lowest points in the containment to which all leaks will drain, and the process of inserting the pole should be done as consistently as possible from one test to the next. That is, the pole should not be inclined and should be inserted until it touches the bottom of the containment.

Vapor Monitoring. The primary solution is to set the threshold setting of the vapor monitor above the level of the gas being produced and then to check the threshold setting periodically to see if it can be lowered as the tank continues to cure.

APPROACHES TO ENSURING EFFECTIVENESS

Installation

Several options are available to regulators to allow them to check for installation errors in secondary containment and interstitial monitoring systems. For example, regulators could require site assessments and then review plans for secondary containment systems before installation to ensure that proper systems are chosen for shallow ground water and contaminated sites. A manufacturer's representative could supervise the installation or could certify installers. Inspection of the installations during construction and integrity testing are other alternatives.

The regulatory agency could review monitoring system plans and specifications before installation to check the selection of the monitoring system for specific site conditions, such as existing contamination.

Operation

Manufacturers of monitoring equipment could be requested to provide training on the equipment for regulatory personnel, as is done for tank tightness testing in Rhode Island. Regulators could also request that manufacturers submit videos on the use of their equipment, as is done in Massachusetts. In this way, agency personnel would become familiar with the equipment and would be better able to inspect monitoring systems and recognize both installation and operational problems that would affect monitoring.

Regulatory agency personnel could conduct periodic inspections of monitoring systems during operation, as is required by the city of Austin, Texas. This approach allows calibrations and threshold values

to be checked and maintenance and leak detection records to be examined to ensure that proper attention is being given to the system.

Regulatory agencies could also require demonstration of the monitoring system and a demonstration of the system tests on-site before operation and periodically thereafter to promote regular system checks by owners and operators and to ensure that the monitoring system is both responsive to any leaks and can distinguish existing contamination from leaks.

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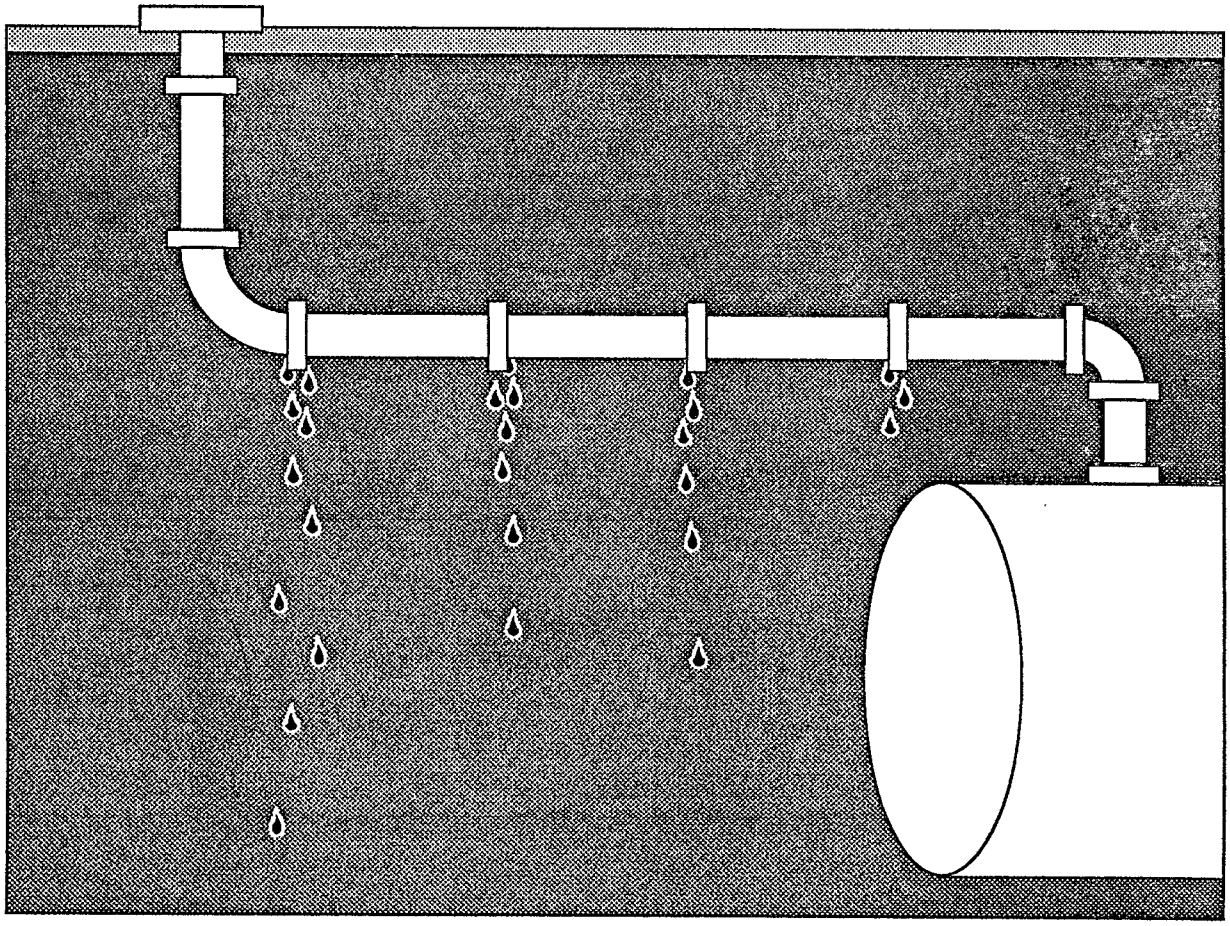
Chapter IX
Piping Release Detection Methods



PIPING RELEASE DETECTION METHODS IX

SUMMARY

Information collected by the U.S. Environmental Protection Agency demonstrates that about 25% of the underground storage tank systems in the United States are leaking. Piping and loose fittings are responsible for the majority of these leaks, and piping is responsible for most of the large, catastrophic releases. Thus, an important part of any release detection program is the use of equipment to prevent or minimize the releases from piping.

There are a number of piping release detection methods available, representing a wide variety of approaches. Each method has advantages that make it appealing under certain conditions.

- Flow restrictors provide nearly continuous release detection for a small capital investment. They are readily available and require little owner/operator involvement.

- Flow shutoff devices also provide nearly continuous leak detection and, because they are automated, require little effort from the on-site staff. As their name implies, these devices completely stop a leak when it is detected.

- Line tightness tests require no permanent equipment and, therefore, no capital investment. Performed infrequently, line tightness tests interfere little with the daily operation of an UST. Line tests can often be performed conveniently as part of a tank tightness test.

- Interstitial monitoring within secondary containment minimizes the environmental damage while providing sensitive release detection. Interstitial monitors can also be coupled with automatic sensors, shutoffs, and alarms.

- External monitoring of underground piping using ground-water or vapor monitoring can easily be integrated into external monitoring systems for USTs.

Available studies demonstrate that flow restrictors, flow shutoffs, and line tightness tests are capable of meeting the required performance standards when designed and operated properly.

The discussion in this chapter focuses primarily on the first three types of piping release detection: flow restrictors, flow shutoffs, and line tightness tests. Interstitial, vapor, and ground-water monitoring for lines are essentially the same as for tanks, and the discussions in the chapters covering these methods are applicable to piping. The aspects of those release detection methods that apply only to underground piping are included in the sections below.

The discussion presented in this chapter covers a range of possible problems that may occur with each piping release detection method. This does not mean that all, or even most, of these problems will occur at the same time or at the same site. Nor does it mean that all of the problems are of equal importance, in terms of frequency of occurrence or severity of impact to the effectiveness of the release detection method. Some problems, such as use of incorrect threshold value, happen less often, and other problems, such as tampering, are relatively easy to fix. Experienced testers, vendors, and installers are well aware of the problems and how to deal with them. For example, an experienced tester recognizes a vapor pocket in the line and knows the methods to use to try to remove the vapor pocket. Release detection, however, is a growing industry, and new companies are being formed with less experience. This chapter presents a range of potential problems for educational purposes, not to imply that they will always occur.

BRIEF DESCRIPTION

To understand the workings of the piping release detection technologies, it is important to understand how the different types of UST piping systems work. This section presents descriptions of common piping systems followed by descriptions of piping release detection technologies.

Piping Systems

Figure 44, which follows on the next page, has been prepared to illustrate the following discussion of UST piping systems.

Pressurized lines

In a pressurized piping system, a submerged centrifugal pump located near the bottom of the tank moves the stored product from the tank to the point of end use (e.g., a dispenser at a service station). The delivery piping lines extend from the pump discharge point to the dispenser. The product is essentially "pushed" from the tank, typically at positive pressures of 28 to 32 pounds per square inch (psi), although some piping systems are pressurized up to 60 psi. Very large releases can occur very quickly if a hole or break occurs in a pressurized UST pipeline because the pump continues to push product through the line and through the hole or break. The higher the operating pressure of a line the higher the leak rate when a hole is formed. Pressurized systems generally are chosen for high-volume sites because the product can be delivered very quickly.

Suction lines

Typical suction systems use a positive displacement pump at or near the point of end use to draw the product from the tank to the pump. The pump creates a lower pressure at the pump end of the pipe, thereby allowing atmospheric pressure to push the product along the pipe to the delivery point. Typical suction lines in the U.S. operate at a vacuum of 3 to 5 psi. When the pump is shut off or a hole or break develops, suction is interrupted, and the product flows backwards through the pipe, away from the dispenser and towards the tank. One or more check valves in the pipe close when product begins to flow backwards through the pipe. Product is held in the pipe between the check valve and the point of end use or between check valves if more than one is present. Product in the pipe between the tank and a check valve drains back into the tank.

Suction systems are characterized as "European" or "American" systems. In the European system, the check valve is located immediately below the pump. When the pump is turned off or

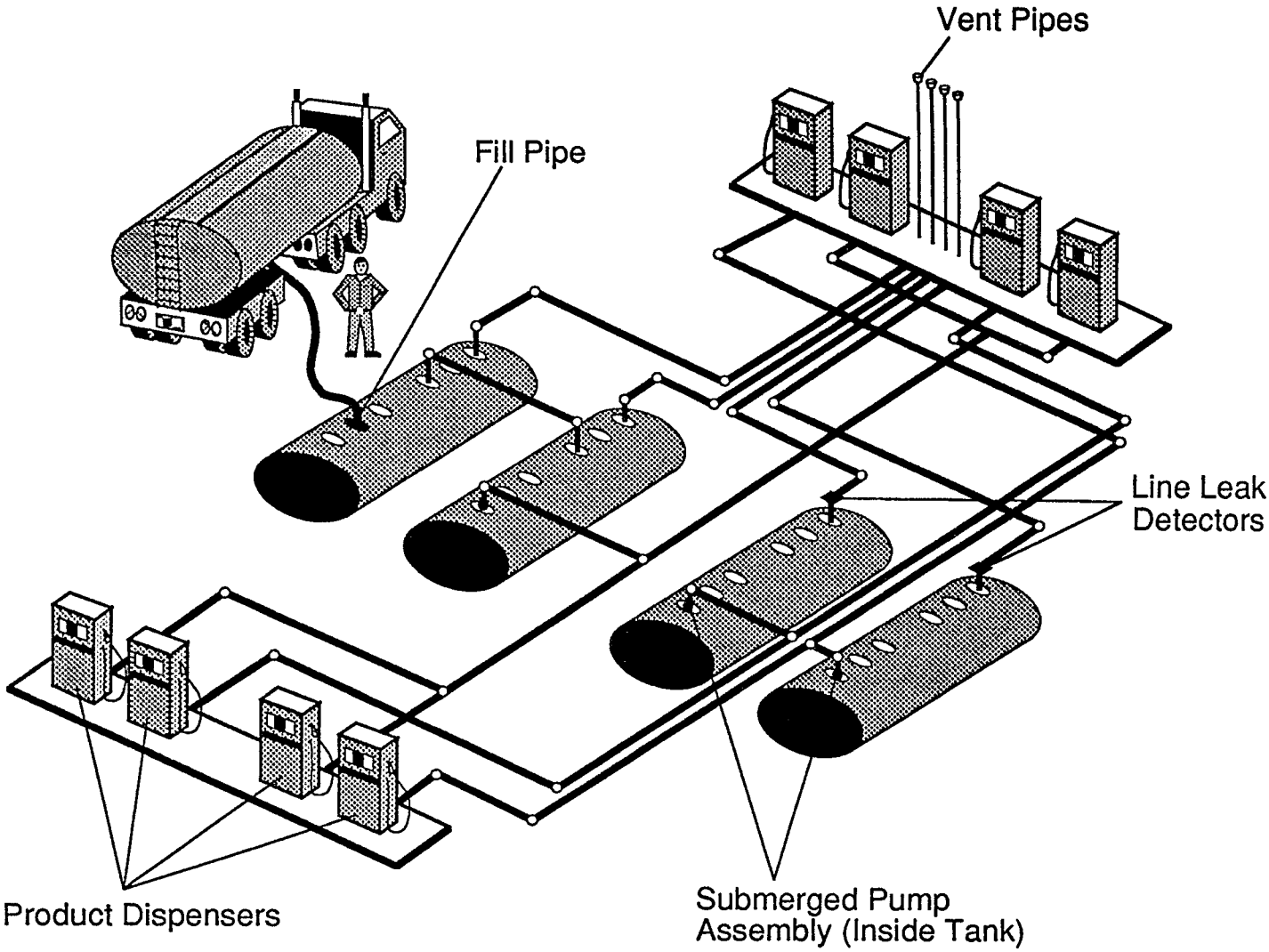


Figure 44. Typical retail gasoline station.

there is a line failure, suction is broken and most of the product drains directly back into the tank. In the American system, the check valve is located near the top of the tank, where it is often called an angle check, or at the bottom of the suction line within the tank, where it is called a foot valve. When there is a line failure, product cannot drain into the tank and is released to the environment. Although the total release is small, it can occur each time product is dispensed over a long period, resulting in a significant cumulative effect.

Although suction piping is environmentally safer than pressurized systems, it has some limitations, including:

- Potential to vapor lock at high altitudes and high ambient temperatures;

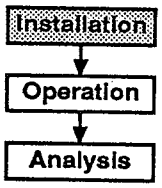
- Tank location restricted to within 50 feet of the pumps for proper operation;

- Slower delivery of product from the UST to the point of end use than with pressurized systems; and

- Larger diameter (higher cost) pipe than required for pressurized systems.

Piping Release Detection Technologies

Figure 45 is a flow chart of the process used for establishing release detection systems for underground piping.



Automatic flow restrictors

Currently, most UST systems with pressurized piping delivery systems use a device that restricts the flow of product from the pump to the point of end use in the event of a leak. These devices are installed only on pressurized lines and do not entirely shut off the flow of product. Flow restrictors are self-contained mechanical devices installed directly in the pipe using special fittings or in the pump housing. The device has a diaphragm or piston that is activated by the pressure in the pump delivery system. Each time the pressure in the piping system drops below a preset threshold, typically 1 to 2 psig, a test of the system is performed. No leak test is conducted if the system pressure remains above the threshold.

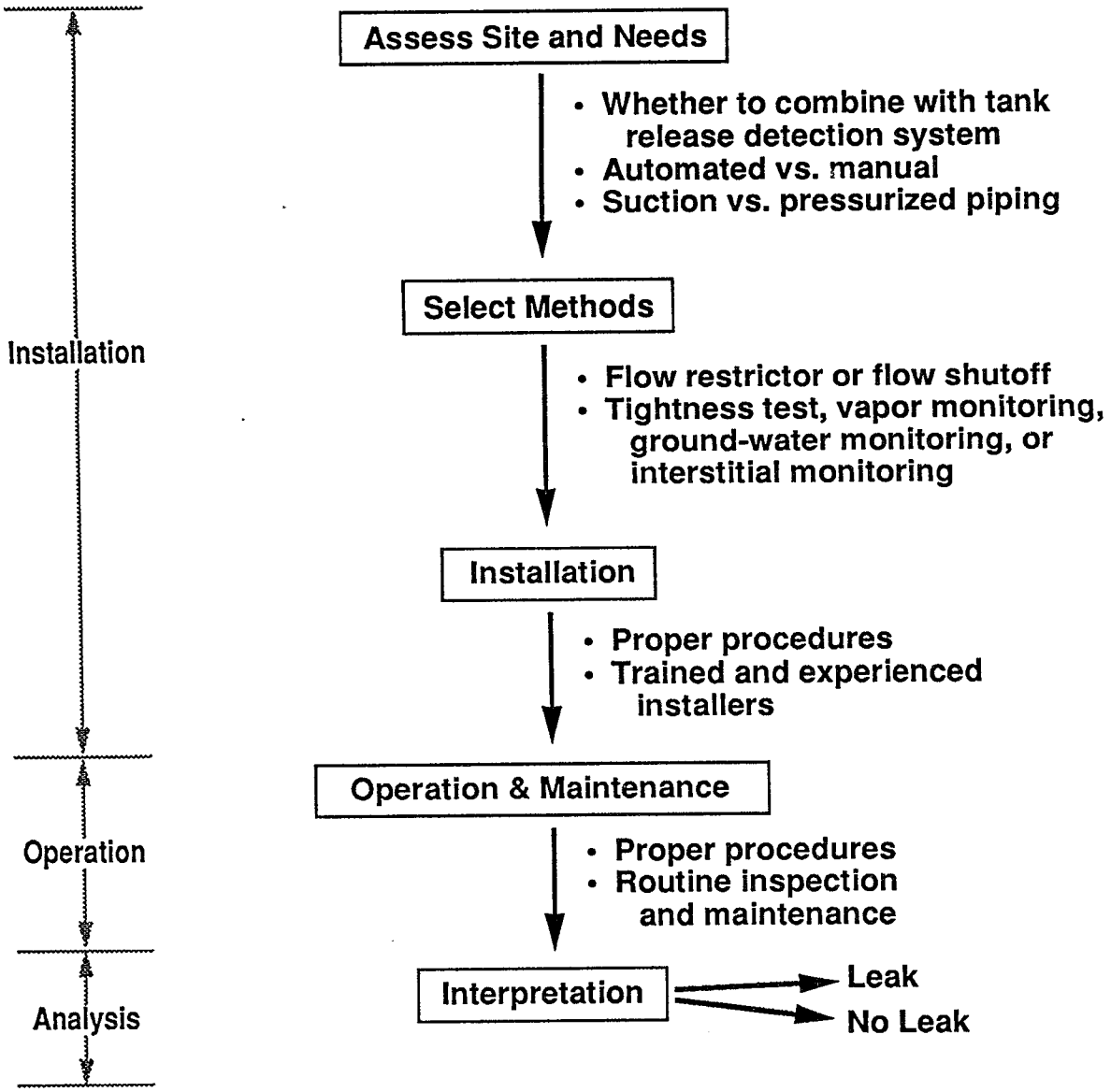


Figure 45. General procedure for piping release detection

After the dispenser is turned on, product flows through the line at 1.5 to 3 gal/h. If there is no leak in the line, the line pressure reaches about 10 psig in about 2 seconds, and the diaphragm or piston opens completely, allowing full product flow and pressurization of the line. If there is a leak of at least 3 gal/h, the line pressure will not reach 10 psi, and flow is restricted to 3 gal/h. Leaks smaller than 3 gal/h are indicated if more than 2 seconds are required to fully pressurize the line. Reference No. 5 cited at the end of this chapter contains a more complete description of the workings of a flow restrictor.

Installation → Operation → Analysis

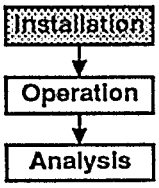
Automatic flow shutoff devices

Automatic shutoff devices are relatively new piping release detection devices and have had limited actual use at operating UST sites. Shutoff devices can be used only on pressurized lines. Several types of shutoffs are available, but all rely on detecting changes in line pressure. There are essentially two groups of shutoffs: those that monitor pressure increases and those that monitor pressure decreases. These devices respond to a suspected leak by completely shutting off the flow of product. All shutoff devices are permanent installations. The degree of automation can vary. Some systems are run entirely by personal computers and, once a leak is suspected and the piping has been shut down, cannot be overridden by the on-site staff.

One group of shutoff devices checks for leaks by monitoring line *pressure decrease* over time. A pressurized line will not be able to maintain a constant pressure in a static situation if a leak is present. Some shutoff devices monitor the decay of line pressure over 5-minute intervals and shut off the line if the rate of decay exceeds predetermined values (e.g., from 16 psi to 6 psi in 5 minutes). At least one shutoff device measures the time it takes for pressure to decay from one predetermined value to another (e.g., time to go from 10 psi to 5 psi). Most of these shutoff devices require more than one test indicating a leak before shutting off the line. Tests of the line are not run while the product dispenser is on, and most of the shutoff devices require a minimum amount of time between dispensings to run a test. Another type of shutoff system combines a pressure decay test with the flow restrictor described above.

Another shutoff device monitors the rate of *pressure increase* in a piping system once the pumps are activated. A leak in a

pressurized line will cause the line to pressurize at a slower rate than usual. For any given length of piping between the pump and the dispenser, the amount of time it should take for the length of piping to become fully pressurized can be calculated and programmed into the detection device. Should the pressure not rise quickly enough, a leak will be indicated, and the system will be shut down.



Line tightness testing

A variety of line tightness tests are available. The following descriptions are specific to pressurized lines. The tests may be performed on suction lines using variations on these procedures. Tightness tests on suction lines are typically performed at about 7 psi positive pressure (not vacuum).

No single pressure value is recommended for a line tightness test. The method must be capable of detecting a leak of 0.1 gal/h at 1.5 times the line operating pressure. However, the actual line test may be done at any pressure as long as the detectable leak rate is mathematically equivalent to the federal performance standard. This means that the evaluation to demonstrate that a line tightness test meets the performance standards can be conducted at any line pressure and then converted to a value equivalent to 1.5 times the typical line operating pressure.

In a direct volumetric line tightness test, a hand pump or the dispenser and the submerged pump is used to pressurize the piping leading back to the pump in the tank. Under one approach to line tightness testing, if pressure decreases in the piping system, product is added to the piping system to bring the pressure back to the level at the beginning of the test. The amount of product added over time is recorded to estimate the leak rate. Another approach to volumetric line testing observes the volume of product lost over time in a tube above ground that is connected to the pressurized piping, and no attempt is made to maintain constant line pressure. An alternative approach is to pressurize the line pressure using a pressure gauge on the hand pump or temporarily installed on the dispenser. Some method of converting pressure change over time to a leak rate is necessary. The conversion method will be specific to the type of test and will be supplied by the manufacturer.

In an indirect line tightness test, the piping is tested as a component of a full system test. First, a tightness test is performed of the entire UST system, as described in Chapter 4. An overfill test method must be used in order to include the piping. If no leak is indicated by the test results, then both the tank and the lines are assumed to be nonleaking. If the total system test indicates a leak, the tank is isolated from the piping and tested by itself using the same test procedure. If the results of the tank tightness test indicate that the tank is tight, then the leak is presumably from the piping. If the tank is found to be leaking, then the condition of the piping is unknown, and the lines must be tested directly. The indirect approach is not a practical approach to conducting a line tightness test if the line is the only part of the UST system of concern at the time of the test.

A relatively new type of line tightness test is the helium gas test, in which helium gas is injected into an empty product line. While the line is pressurized, a tester holding a portable helium detector walks over the piping route to detect the presence of helium rising from the ground. This method not only indicates a possible leak, it helps to locate where along a run of piping the leak is occurring.

Installation → Operation → Analysis

Interstitial monitoring within secondary containment

Another method of detecting leaks from underground piping is to place a monitor in the interstitial space between the piping and an outer barrier. The containment is a barrier between the piping containing the product and the environment. If a hole forms in the piping and the product leaks into the interstitial space, the barrier will direct the release towards the monitor, which detects the release. The types of barriers and interstitial monitors for piping are essentially the same as those for tanks, and the details are given in Chapter 8. A summary of the information applicable to underground piping is provided below.

When secondary containment is used for piping, care must be taken that the containment extends the full length of piping, from the connection to the tank directly to the dispenser. Containing either end of a piping run is the most difficult portion and is often neglected as a result.

One common method of secondarily containing underground piping is the use of trench liners (see Figure 39). The trench that is dug to install the piping can be lined with a flexible membrane

liner that is impervious to the stored product. The backfill and piping then are placed within the lined trench. The liners often are thermoplastic or polymeric sheets, typically 50 mm thick. Instead of flexible liners, rigid U-shaped pieces of plastic may be used to line the bottom and sides of the piping trench. When liners are used, the trench may be sloped away from the tank excavation to help differentiate between tank leaks and pipe leaks.

The interstitial space to be monitored is the backfill between the trench liner and the piping. The simplest monitor consists of a sump at the lowest point of the piping system to "collect" the liquid from any leaks. This sump can be monitored by visual inspection, a dipstick, hydrocarbon sensors such as those used in ground-water monitoring, or vapor monitors in the airspace of the sump. A single monitor at the sump may indicate that a leak has occurred but does not help to locate the leak along a run of piping. Interstitial monitors placed at intervals along the run of piping can help to identify the location of the leak so that less piping must be dug up.

When vapor monitoring is used, a typical well may be used that extends to the bottom of the trench; such a well will be shorter than that used for tank monitoring. Another approach is to use a horizontal slotted tube at or below the level of the piping rather than the conventional vertical well; these horizontal wells may be up to 10 feet long.

Another form of secondary containment for piping is double-walled piping. The primary, or inner, piping that carries the product is contained within an outer pipe of larger diameter. The inner and outer piping both may be made of fiberglass-reinforced plastic (FRP) or the inner pipe may be made of galvanized steel and the outer pipe of FRP. In a few specialized cases, both pipes may be made of steel. Care must be taken that the product in the lines is compatible with the FRP. For service stations, the diameters of the inner and outer piping often are 2 and 3 inches, respectively.

A monitor is placed in the space between the inner and outer pipe. Double-walled piping is often sloped to a containment structure or observation well that can be monitored for the presence of hydrocarbon liquids or vapors. Small sumps may be placed periodically along the run of piping and monitored for liquids or vapors.

Installation → Operation → Analysis

External monitoring

Both ground-water and vapor monitoring can be used to monitor for releases from underground piping. The descriptions provided in Chapters 6 and 7 for tanks are applicable to piping. For both methods, wells a couple of inches in diameter are installed at intervals along the run of piping. For ground-water monitoring, the wells extend below the ground water, and a sensor detects the presence of free product floating on the water. For vapor monitoring, any leaked product will evaporate and diffuse through the soil, and the vapor monitor will detect its presence. It is theoretically possible to connect piping monitoring wells to shutoff devices, so that whenever a predetermined hydrocarbon liquid or vapor level is detected, the delivery of product is halted. At least one automated piping shutoff system has been designed to incorporate a vapor monitoring system.

POTENTIAL PROBLEMS AND SOLUTIONS

This section presents a discussion of problems that have been encountered with piping release detection methods. Some of the problems and solutions are similar to those for tank release detection methods. To avoid repetition, this chapter includes only problems unique to the piping release detection methods; for additional potential problems, see the discussions in Chapters 4 and 6 through 8. The problems for each release detection method are presented generally in the order of importance. Table 14 presents a summary of the indicators and solutions to common problems as well as possible approaches that implementing agencies can use to prevent or overcome the problems with piping release detection methods. A number of agency solutions are offered for each problem, but not all of them need be undertaken. The most serious concerns are indicated by an asterisk. Table 14 and the discussion below are presented in the order of the flow chart (Figure 45 on page 188), not in order of importance. The most serious concerns have been indicated in Table 14 by an asterisk.

Automatic Flow Restrictors and Shutoff Devices

In addition to meeting the regulatory requirement for continuous monitoring of large line leaks, automatic shutoff devices may also be used to meet the regulatory requirement for less frequent monitoring for

Table 14. Indicators and Solutions for Problems Encountered During Piping Release Detection

Problem	Indicators	Tester Solutions	Agency Oversight Options
• Flow Restrictors and Shutoffs			
Need to prevent tampering.	None.	Lock restrictors or shut off control panel. Educate staff.	Inspect and perform test to see if device functions.
***Need to identify and remove vapor in the line.**	Slow product delivery.	Increase pressure to absorb vapor. Flush line with product at high rate.	None.
Assure that necessary line conditions for a valid test are reached.	None.	Select device based on knowledge of device design and UST operations.	Review plans prior to installation.
***Need for properly functioning check valves.**	False alarms.	Replace, clean, or repair valves and retest.	Observe test. Check that valves are actually replaced or repaired.
• Line Tightness Testing			
Assure sufficient waiting time between filling line and beginning test.	Erratic readings. Readings that increase or decrease, then level off.	Wait at least 3 hours between filling lines and starting data collection.	Review test reports for reasonable waiting times and data trends. Observe test.
Assure that sufficient test data are collected.	None.	Collect data for at least 1 hour.	Observe test. Review test results.
***Need to recognize and remove vapor pockets.**	Excess product from line after test.	Empty line, valve off blind ends, and retest. Increase pressure to absorb vapor. Flush line with product at high rate.	Observe test. Review test results.

Number of tests to be conducted must be fixed.	High percentage of lines declared "tight."	Develop clear protocol with specific number of tests and follow it.	Approve multiple-testing strategies. Observe tests. Receive test results, and track pass/fail ratios for companies and methods.
Assure use of proper protocol and correct threshold.	High percentage of tanks declared "tight."	Criteria for determining "tight" or "leaking" must be clear. Threshold value for declaring leak should be smaller than minimum detectable leak rate by a factor of at least 2.	Review test results and calculations to see if they agree with protocol. Keep track of pass/fail ratios for companies and methods.
***Need for properly functioning check valve.**	False alarms.	Replace, clean, or repair valves and retest.	Observe test. Check that valves are actually replaced or repaired.
• Interstitial Monitoring Within Secondary Containment			
***Assure correct installation of containment.**	Product observed outside containment.	Follow manufacturer's specifications, with special attention to seams and joints. Pressure-test double-walled pipes.	Observe installation. Certify/license installers. Review pressure test results.
• External Monitoring (Ground-Water and Vapor)			
***Assure that monitoring wells are properly placed.**	None.	No more than 40 feet between wells. Conduct site assessment before installation.	Review site plans and monitoring plan before installation.

*** Indicates the most significant problems.**

smaller leaks. Shutoffs may be used in place of line tightness testing, ground-water monitoring, or vapor monitoring if they are sensitive enough to meet the performance standard for line tightness testing.

Installation → Operation → Analysis

Need to prevent tampering

Even when there is no leak in the line, flow restrictors can cause slight delays in the delivery of product after the dispenser is turned on. When a leak occurs in a line with a flow restrictor, the delay of delivery is even longer, causing the rate of delivery to be much lower than usual. When a shutoff device detects a leak, product flow stops altogether. Such conditions can cause customers to complain about poor service. At production facilities, the delayed delivery of product from an UST may slow down production. In reaction to the slow-down, production facility sometimes deactivate the line leak detectors by removing them completely, thus defeating the purpose of their operation.

A seal that can be installed on flow restrictors to indicate that tampering has occurred has recently become available. Shutoff devices usually are automated, and the control box can be programmed and locked so that only management personnel with keys can override the shutoff function. Training on-site staff in the importance of piping leak detection and the proper response to warning signals also helps to overcome the problem of tampering.

One approach that owner/operator representatives or implementing agency personnel can use to combat the problem of tampering is to perform periodic checks on the line to see how the restrictor or shutoff performs. Proper operation can be checked by simulating a leak in the system and monitoring the line pressure. A defective device will not restrict or shut off the flow of product. Some shutoff devices have an automatic test mode that will perform this type of test.

Installation → Operation → Analysis

Need to identify and remove vapor in the line

At high altitude or high temperature, liquids volatilize more quickly. As a result, product vapors may form in the piping. These vapors can significantly increase the amount of time required for the product to reach operating pressure because additional product and time are needed to compress the vapor pocket. Such delays may be interpreted falsely by the device as leaks, and product flow will be restricted or shut off. If additional time is spent

pressurizing the line, the vapors may eventually be absorbed back into the liquid.

Installation → Operation → Analysis

Line conditions need to be right for a valid test

As described above, most flow restrictors and shutoff devices have minimum requirements for line conditions that must be met to conduct a valid test, such as a period of at least 5 minutes in which the line is not being used or a decrease in line pressure below a threshold level (e.g., 2 psi). At a busy service station, there may not be enough time between dispensings to conduct a test with some types of restrictors or shutoff devices. A fully pressurized line without a leak or without large thermal changes may not drop as low as 2 psi for days, even with no withdrawals occurring in the line.

The level of use of an UST system and the design of the restrictors or shutoffs should be considered together when selecting the line leak detection device. If a device requires a minimum amount of time to conduct a test, the typical time between dispensings at the UST should be determined before selecting that device. For systems that require the line pressure to fall below 2 psi to conduct a test, if there is a leak in the line, the pressure will decrease after a dispensing so that a test can be performed. High pressure can be maintained in a line for long periods of time only if there is no leak.

Installation → Operation → Analysis

Need for properly functioning check valves

As described above, there are usually check valves in a line that prevent product from draining backwards towards the tank any further than the valve. During a line tightness test, the pressure is being maintained between the check valve and the hand pump or dispenser. If the check valve does not close tightly, it may allow product to seep through the valve and drain to the tank. For line leak detection methods such as flow restrictors and shutoffs that rely on pressurizing the line, this loss of product (and corresponding loss of line pressure) due to a bad check valve would falsely indicate a leak.

If the flow restrictor or shutoff indicates a leak but there are no other indications that the line is leaking, it is possible to service the check valve(s) in the line and retest the line. If a check valve is faulty, it must be replaced. Sometimes, dirt or foreign particles

become trapped in the check valve, preventing it from sealing completely. In this case, cleaning the valve should be sufficient. If the line tests tight after the replacement or repair, then no additional work is needed.

Line Tightness Testing

This section discusses the problems of tightness tests that are performed only on the line. When lines are checked for leaks as part of tank tightness testing, the problems are the same as those discussed in Chapter 4 on tank tightness testing.

Installation → Operation → Analysis

Need to allow sufficient time between filling and testing

The pressure in a pipeline is a function of the temperature, coefficient of thermal expansion of the product, and the compressibility of the product. For line tightness testing, temperature is the single most important variable. As the temperature of the product increases or decreases, the volume of the product also increases or decreases, thus changing the line pressure. Shrinking of product as it cools may imitate a leak because the line pressure is decreasing, and swelling of product as it warms may mask a leak because of the increased line pressure. When product moves from the tank into a line, there may be a temperature gradient between the product and the surrounding backfill. If the product remains in the line, as it does during most line tests, its temperature changes towards that of the backfill. The extent and rate of this change vary with the material of piping construction, the backfill material, and the product in the line. For a 2-inch steel pipe in gravel backfill, if the temperature differential between the product and the backfill is 5 to 15 degrees Centigrade, the temperature in the product may take 3 hours to stabilize. Temperature changes of 0.1 to 0.5 degrees Centigrade can cause a 5 to 10 psi change in pressure. The maximum changes in product temperature occur immediately after product has been delivered to the tank, when the differential between product and backfill temperatures is the greatest.

The solution to this problem with line tightness testing is to wait at least 3 hours after filling the line with product before beginning data collection for the test. This time period allows the temperature of the product to stabilize. An increasing or decreasing trend in the data that eventually levels off indicates that

the temperature continued to change during part of the test but it eventually stabilized and that there is no leak. Determination of leak status should use only those data obtained after the readings have leveled off.

Installation → Operation → Analysis

Ensure that sufficient test data are collected

As discussed in Chapter 4 on tank tightness testing, insufficient test data may not allow important trends in the data to be identified and, thus, problems or leaks may be missed. In addition, if the test does not last long enough, small leaks may be missed.

As a rule, obtaining more data increases the probability of correctly identifying the presence of a leak. For line tightness tests, data should be collected for at least one hour.

Installation → Operation → Analysis

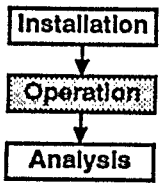
Need to recognize and remove vapor pockets

Another factor that may affect the results of a line tightness test is the presence of vapor pockets. When a line is completely filled with product, vapor may become trapped in some areas, such as deadend piping, bends in piping, or vertical stubs. This vapor expands and contracts in response to temperature and pressure changes more quickly and to a greater degree than the product in the lines. Changes in vapor pocket size affect the line pressure, thus masking or imitating a leak. Any test conducted with a vapor pocket in the line is invalid. For further discussion of vapor pockets, see Chapter 4.

One approach to determining if a vapor pocket is present is to measure the amount of product that drains from the line when the pressure is released after the test. If no vapor pocket is present, only a small amount of product will drain out as the walls of the piping relax under the reduced pressure. If a vapor pocket was present, a larger amount of product (at least 0.05 gal) will drain out because the vapor pocket was compressed significantly under pressure and expands when the pressure is released, pushing more product from the line.

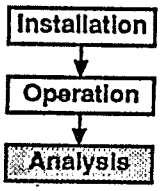
There are several approaches to removing vapor in a line that can be tried. Sometimes increasing the line pressure will recondense the evaporated product. Sometimes flushing the lines with high velocity product using the dispenser will remove vapors. Sometimes pulling a vacuum on the line will remove the vapors,

although if there are any slight cracks in the line or if the pump is exposed, air will be drawn back into the line. These approaches will not work if the air is trapped in piping stubs. In that case, it may be possible to uncover those portions of the piping and install valves that shut off the blind end from the main run of piping. Whatever method is used to try and remove the vapor, the line should be retested after the 3-hour wait between filling and data collection. It is not always possible to remove trapped vapor from piping and conduct a valid tightness test.



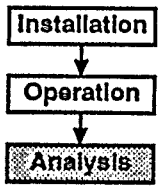
Need for properly functioning check valve

The problems with bad check valves for line tightness testing are the same as for flow restrictors and shutoff devices. The preceding section contains a discussion of these problems (page 197).



Number of tests must be fixed in the protocol

When the results of a line tightness test indicate that the line is leaking but the leak rate is only slightly above the threshold value for declaring a leak, some testers repeat tests on the line until the results of one test indicate that the line is tight. As discussed in Chapter 4 on tank tightness testing, this approach is invalid and reduces the probability of detecting a leak. A multiple-testing strategy is a valid approach to line tightness testing, but all of the data from all of the tests must be used in the analysis unless the protocol specifically excludes them (e.g., vapor pockets, bad check valves). The number of tests to be performed and how the data are analyzed must be explicitly defined in the line testing protocol, and no deviations should be allowed from the protocol.



Proper protocol and correct threshold must be used

As discussed in Chapter 4 on tank tightness testing, lack of a well-defined data analysis protocol and clear criterion for declaring a leak allows testers to make subjective decisions, leading to unclear or false determinations of the status of the line. A reliable data-analysis protocol will have clear and detailed instructions on how to convert raw data on pressure or volume changes to an estimated leak rate. The protocol should specify how to determine which data to use; when, if ever, it is permissible to discard data;

what conversion factors to use; how to determine the conversion factors; and what mathematical computations are needed.

To determine if the piping is leaking, the estimated volumetric leak rate must be compared to a threshold value. This threshold value must be predetermined as part of the test design and its use must be well defined in the test protocol. Discretion on the part of the tester in determining the leak status should not be allowed.

As discussed further in Chapter 4, in order for a test method to perform well in detecting small leaks, the threshold value must be smaller by a factor of 2 or more than the smallest leak to be detected. The federal regulation requires a line tightness test method to have a minimum detectable leak rate of 0.1 gal/h. For a test method to meet this requirement, its threshold must be less than 0.1 gal/h. The most commonly used threshold for line tightness testing is 0.025 gal/h.

Interstitial Monitoring Within Secondary Containment

The problems and solutions specific to interstitial monitoring for piping are discussed below. Additional information on interstitial monitoring for tanks that may be applicable to piping is included in Chapter 8.

Installation → Operation → Analysis

Ensure correct installation of secondary containment

As discussed on pages 191 and 192, there are two types of secondary containment: trench liners and double-walled piping. Incorrect installation is a problem for both types.

Incorrect installation of the liner is the most important potential problem with trench liners. Piping trenches are very narrow and long, and piping usually joins to a building or dispenser. To cover a very narrow trench and difficult areas such as near buildings or dispensers usually requires piecing together smaller pieces of liner. Seams are the most vulnerable to leakage, and trench liners can have many seams. A trained and experienced professional is necessary to ensure that the liner is designed for as few seams as possible for the site and that the liner is installed correctly.

Incorrect installation also is a problem with double-walled piping. Joining segments of piping so that the joint is tight is more difficult for double-walled than for single-walled piping. As part of the installation procedure, the inner pipe should be tested before the outer pipe is installed and tested. The inner pipe should be tested at 50 psi or 1.5 times the working pressure of the system. The outer piping should be tested at 5 psi. In addition, double-walled piping sometimes left "pen" (single-walled) where it joins the tank or dispenser. Sumps may need to be placed at these points if complete containment cannot be installed. Trained and experienced personnel should be used to install double-walled piping.

External Monitoring

The problems and solutions specific to using ground-water or vapor monitoring as release detection for piping are discussed below. The problems with external monitoring of piping that are the same for external monitoring of tanks are discussed in Chapters 6 and 7.

Installation → Operation → Analysis

Assure that monitoring wells are properly placed

The area that a monitoring well network must cover for piping is very large because piping runs can be very long, and leaks can occur in any portion of the line. Detection is, in part, a function of the distance between the monitoring wells and a leak. Because of the large area covered by piping systems, monitoring well networks are sometimes designed with too few wells, to reduce the cost. If monitoring wells are placed too far from each other or from the pipe, the amount of time before a leak is detected may increase or, in extreme cases, a leak may go undetected.

Table 15 presents a summary of the requirements for various states on the placement of vapor and ground-water monitoring wells with regard to piping. Although the requirements are diverse, in general, wells must be separated by no more than 20 to 35 feet. These requirements are reasonable based on EPA research indicating that a design that includes at least one well every 40 feet should be sufficient for gasoline tanks in a clean, dry backfill. If the backfill is not highly permeable (e.g., it is native fill material) or the migration of liquid product or vapors is impeded by other factors, the number of sensors should be increased by a factor of two.

Table 15

Typical State Network Design Requirements For Vapor and Ground-Water Monitoring of Piping

Maine Vapor	According to manufacturer's specifications At a minimum: 1 well at each piping joint No piping run > 15 feet from well
Santa Clara County, California Vapor, aspirated systems	
	General: 1 well every 35 feet At station: 1 well for each set of piping 1 well at each pump island
South Carolina Ground water	Minimum of 2 wells every 30 feet
Vernon, California Vapor	Design network for 15-foot diameter of influence

Source: U.S. EPA

The Federal regulation requires that ground-water monitoring wells for tanks be placed as close as possible to the tank and that vapor monitoring wells be installed in the backfill. These placement criteria should be followed for piping leak detection as well.

For additional information on monitoring well design and installation, see Chapters 6 and 7.

Site Inspections

Site inspections could provide useful oversight for several of the piping release detection methods. Proper installation of secondary containment is crucial to successful interstitial monitoring, so observation during installation could be a powerful tool. Development and use of a checklist of important elements of proper installation during the inspection would increase the usefulness of the site visit. The City of San Jose, California, has developed several secondary containment inspection techniques. In one technique, a lined piping trench is filled with water, the water level immediately after filling is marked, and the water level 24 hours later is measured; 1/4 inch of water loss due to evaporation is assumed. If returning the next day is infeasible, then paper can be placed under the seams of the trench liner before it is filled with water. A leak will mark the paper within minutes; and the effects of evaporation are avoided. For double-walled pipes, the City of San Jose performs either a hydrostatic or pneumatic pressure test. If a pneumatic test is performed, soapy water is applied to all pipe connection during the test. A leak will be indicated by bubbles.

If selected as the release detection method, line tightness tests are required annually or every 3 years, so the number of tests that would be conducted within a jurisdiction each year is relatively small. Implementing agency personnel could be onsite for some of these tests to ensure that the proper waiting time and test duration are observed and that no vapor pockets are present.

For sites where external monitoring is planned, a visit to the site before installation to ensure that conditions are, in fact, appropriate is an option. A checklist of pertinent features, collection of soil samples, and measurement of the depth to ground water might be considered while on site.

Because tampering is the primary problem with automatic flow restrictors, random inspections by agency personnel to check for tampering would be effective. At a minimum, the seal on the restrictor should be checked. It is also possible to simulate a leak in the part of the line under the dispenser and observe the response of the restrictor. The records of monitoring results and repair and maintenance could be checked whenever a site visit is made.

Data Review

The implementing agency could require that all line tightness test results be submitted to the agency for review and recalculation. See Chapter 4 for discussion of the types of data review and compilation that could be useful. In particular, the length of the waiting and test times should be checked.

The agency could also require submittal of the results of external and interstitial monitoring. Because these methods are performed each month, the volume of data may be overwhelming. In this case, only the results of tests from every other month or every six months could be required.

Guidance and Training

Education of owner/operator staff on the importance of piping leak detection might help prevent some problems such as tampering. Education in how the methods work might help owner/operators provide meaningful oversight during installation of equipment or operation of a method. Review of manufacturers' in-house training programs is another possible oversight mechanism.

Approval and Certification

For external and interstitial monitoring the design of the release detection system is particularly important to its success. For these methods, it may be appropriate to require submittal of the plans for review and approval prior to any installation. The plans should include a site map and pertinent hydrogeological data, manufacturer's information, and the installer's recommendations.

Because proper installation is so important to interstitial monitoring with secondary containment, certification or licensing of installers could be required. Either the implementing agency could run the program or they could require that installers have a minimum amount of training by third parties, such as manufacturers. Similarly, line tightness testers could be licensed or certified to conduct tests to ensure that they understand the important aspects of the testing and analysis protocol. Line tightness testing is often performed in conjunction with tank

tightness testing. If there is an existing licensing program for tank testers, it would be relatively easy to include line testing.

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This addendum to *Straight Talk On Tanks: A Summary of Leak Detection Methods for Petroleum Underground Storage Tanks Systems* describes a leak detection method not included in the original publication.

Statistical Inventory Reconciliation

Will I be in compliance?

Statistical inventory reconciliation (SIR), when performed according to the vendor's specifications, meets *Federal* leak detection requirements for new and existing underground storage tanks (USTs) and piping as follows. SIR with a 0.2 gallon per hour leak detection capability meets the Federal requirements for monthly monitoring for the life of the tank and piping. SIR with a 0.1 gallon per hour leak detection capability meets the Federal requirements as an equivalent to tank tightness testing. SIR could, in some cases, meet the Federal requirements for line tightness testing as well. (For additional leak detection requirements for piping, see the sections on leak detection for piping.) You should find out if there are *State* or *local* limitations on the use of SIR or requirements that are different from those presented below.

How does it work?

Statistical inventory reconciliation analyzes inventory, delivery, and dispensing data collected over a period of time to determine whether or not a tank system is leaking.

- Each operating day, you measure the product level using a gauge stick or other tank level monitor. You also keep complete records of all withdrawals from the UST and all deliveries to the UST. After data have been collected for the period of time required by the SIR vendor, you provide the data to the SIR vendor.
- The SIR vendor uses sophisticated computer software to conduct a statistical analysis of the data to determine whether or not your UST may be leaking. The SIR vendor provides you with a test report of the analysis results.

What are the regulatory requirements?

- To be allowable as monthly monitoring, a SIR method must be able to detect a leak at least as small as 0.2 gallons per hour and meet the Federal regulatory requirements regarding probabilities of detection and false alarm. Data must be submitted monthly.
- To be allowable as an equivalent to tank tightness testing, a SIR method must be able to detect a leak at least as small as 0.1 gallons per hour and meet the Federal regulatory requirements regarding probabilities of detection and false alarm.
- The individual SIR method must have been evaluated with a test procedure to certify that it can detect leaks at the required level and with the appropriate probabilities of detection and false alarm.
- If the monthly test report is inconclusive, you must take the steps necessary to find out conclusively whether your tank is leaking.
- You must keep on file both the test reports and the documentation that the SIR method used is certified as valid for your UST system.

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Will it work at my site?

- Generally, few product or site restrictions apply to the use of SIR.
- A SIR method may be used on tanks with up to 1.5 times the volume at which that method was evaluated. If you are considering using a SIR method for tanks greater than 18,000 gallons, discuss its applicability with the vendor.
- Water around a tank may hide a hole in the tank or distort the data to be analyzed by temporarily preventing a leak. To detect a leak in this situation, you must check for water at least once a month.

What other information do I need?

- Data, including product level measurements, dispensing data, and delivery data, should all be carefully collected according to the SIR vendor's specifications. Poor data collection may produce inconclusive results and non-compliance.
- The SIR vendor will generally provide forms for recording data, a calibrated chart converting liquid level to volume, and detailed instructions on conducting measurements.
- Statistical inventory reconciliation should not be confused with other release detection methods that also rely on periodic reconciliation of inventory, withdrawal, or delivery data. Unlike manual tank gauging, automatic tank gauging systems, or inventory control, SIR uses a sophisticated statistical analysis of data to detect releases. This analysis can only be done by competent vendors of certified SIR methods.
- You should "shop around," ask questions, get recommendations, and select a method and company that meet the needs of your site.

How much does it cost?

- There are no installation costs. Equipment costs are minimal, although you should ensure that dispensing meters are in calibration and that your gauge stick or other tank level monitor is in good condition. Annual costs for the service may depend on your data quality, how you provide data to the vendor (paper, diskette, or modem) and the number of tanks and sites you have.
- Here are possible costs for a typical station with three tanks:
  - Used as a monthly monitoring method (with 0.2 gallon per hour leak detection capability), SIR could cost $840 to $1200 yearly; or
  - Used as the equivalent to tank tightness testing (with 0.1 gallon per hour leak detection capability), SIR could cost $225 to $540, to test three tanks one time. If piping is also tested using SIR, additional costs would be added.