United States
Environmental Protection
Agency

Office of Underground Storage
Tanks

Standard Test Procedures For Evaluating Release Detection Methods: Volumetric And Non-volumetric Tank Tightness Testing

May 2019

Acknowledgments

The U.S. Environmental Protection Agency's Office of Underground Storage Tanks contracted with Battelle under Contract No. EP-C-10-001 to revise EPA's 1990 *Standard Test Procedures for Evaluating Various Leak Detection Methods*. Individual members of the National Work Group on Leak Detection Evaluations, as well as Ken Wilcox and Associates, reviewed this document and provided technical assistance. A stakeholder committee, comprised of approximately 50 representatives from release detection method manufacturers and various industry associations, also commented on this document.

Contents

Appendices

Figures

Tables

List Of Acronyms And Abbreviations

ASTM International	American Society for Testing and Materials (ASTM) International
ATGS	automatic tank gauging system
B	bias
°C	degree Celsius
CFR	Code of Federal Regulations
cm	centimeter
df	degrees of freedom
°F	degree Fahrenheit
gal/hr	gallon per hour
LR	leak rate
mL/min	milliliter per minute
MSE	mean square error
P(d)	probability of detecting a leak
P(fa)	probability of false alarm
ppmv	parts per million by volume
psi	pounds per square inch
SD	standard deviation
T	temperature differential
Th	threshold
TTT	tank tightness testing
UST	underground storage tank

Section 1: Introduction

1.1 Background

The federal underground storage tank (UST) regulation in 40 Code of Federal Regulations (CFR) Part 280 specifies performance standards for release detection methods. UST owners and operators must demonstrate that the release detection method they use meets the U.S. Environmental Protection Agency's (EPA) regulatory performance standards. This document provides test procedures for evaluating tank tightness testing (TTT) methods.

This tank tightness testing document is one of four EPA standard test procedures for release detection methods. The test procedures present performance testing approaches to evaluate various release detection method categories against the federal UST regulation in 40 CFR Part 280, Subpart D. To provide context for the four test procedure documents, EPA developed *General Guidance For Using EPA's Standard Test Procedures For Evaluating Release Detection Methods*. The general guidance provides an overview of the federal UST regulation, methods, and testing that may result in release detection methods listed as compliant with the regulatory performance standards. The general guidance is integral; it must be used with the test procedures.

Tank tightness testing methods must be capable of detecting a leak of 0.10 gallon per hour (gal/hr) with a probability of at least 95 percent, while operating at a false alarm rate of 5 percent or less. There are two categories of TTT methods:

- Volumetric testing methods, which quantify the leak rate in gal/hr, and
- Non-volumetric testing methods, which report the qualitative assessment of leaking or not leaking against a threshold.

These two categories require different testing and statistical analysis procedures to evaluate their performance. This document also presents testing of sensors as components of release detection systems for their performance, such as sensitivity and specificity. You may use this document to evaluate methods other than tank tightness test methods. Other certified leak rates may be used. For example, manufacturers may opt to evaluate leak rates other than those established in the federal UST regulation. In those scenarios, adjust the evaluation accordingly. The evaluator ensures reporting forms and other relevant documents are modified, as required, to indicate and provide appropriate details relevant to the UST system component evaluated.

1.2 Objectives And Applications

This test procedure addresses two objectives. It provides procedures to test TTT methods in a consistent and rigorous manner. Also, it allows the regulated community and regulatory authorities to verify compliance with the federal UST regulation. Tank owners and operators must demonstrate that the method of release detection they use meets EPA's performance standards.

This procedure evaluates methods that test tanks or tanks connected by siphon piping at a specific point in time. The procedure considers a number of factors encountered at UST facilities such as temperature and leak rate. Volumetric methods quantify leak rates to determine if a tank is leaking. Non-volumetric methods determine a yes or no answer to the question: *Is the tank leaking*? Commercially available non-volumetric methods rely on one or more physical results from a leaking tank to make this determination. These include acoustical, optical, tracer, and pressure decay methods. Some TTT methods use various sensors to detect the presence of liquid, vapor, or change in liquid level. We discuss the majority of sensor test procedures in Section 4.5; however, water ingress testing is in EPA's *Standard Test Procedures For Evaluating Release Detection Methods: Automatic Tank Gauging Systems*.

You can find information on sensor types and other general information regarding sensors in *General Guidance For Using EPA's Standard Test Procedures For Evaluating Release Detection Methods*.

Although safety is a consideration while conducting testing, these test procedures do not address the issue of safety specific to detection methods and their operating procedures, merely basic laboratory safety concerns and procedures. The vendor is responsible for conducting the testing necessary to ensure that method equipment is safe for operation and capable of being used with the intended product.

Ultimately, you can use the results from this procedure to prove that the method meets the requirements of 40 CFR Part 280 and is subject to limitations listed on EPA's standard evaluation form in Appendix B or C for volumetric and non-volumetric, respectively.

1.3 Evaluation Approach Summary

1.3.1 Volumetric TTT Methods

Set up a volumetric TTT method in the test tank to measure a leak rate under a no-leak or tight condition with three induced leak rates of 0.05, 0.10, and 0.20 gal/hr. You must conduct a minimum of 24 tests. You must partially empty the tank to half full or less, and then refill it to the 90-95 percent full level for at least every other test. When filling the tank to the test level, use product at these three different temperatures:

- At least 10 degrees Fahrenheit (°F) warmer than that in the tank for one third of the filling;
- At least 10°F cooler than that in the test tank for one third of the filling; and
- At the same temperature as the in-tank product for one third of the filling.

The volumetric test method's ability to track actual volume change is determined by the difference between the volume change rate measured by the test method and the actual induced volume change rate for each test. From these differences, you can calculate the probability of false alarm (P(fa)) and the probability of detecting a leak (P(d)). Report performance results on the *Results Of U.S. EPA Standard Evaluation Volumetric Tank Tightness Testing Method* form in Appendix B.

1.3.2 Non-Volumetric TTT Methods

Set up and use a non-volumetric TTT method test tank following the method's standard operating procedure. Conduct a minimum of 21 independent tests of the tank under the no-leak condition. Use the results of these tight tank tests to estimate the P(fa). In addition, induced leaks at rates not to exceed 0.10 gal/hr are simulated. Conduct a minimum of 21 independent tests with induced leaks. Keep the simulation condition of tight tank or induced leaks blind to the vendor and randomized in the test design. Compare this reported result with the actual condition of the tank during testing to estimate the P(fa) and P(d). Report performance results on the *Results Of U.S. EPA Standard Evaluation Non-Volumetric Tank Tightness Testing Method* form in Appendix C.

The method accurately detects a leak of the specified size, for example 0.10 gal/hr, in the presence of interference. Do not include sources of interference, such as product temperature changes that do not affect the operation of a method, in the testing. However, the evaluator must consider other sources of interference, such as vibrations from traffic, that may affect the operation of the method and include tests to determine whether the method can successfully overcome these sources of interference. These tests are designed to cover interference conditions encountered in approximately 75 percent of real-world tests. You do not need to include sources of interference that are rarely encountered in the field.

Some non-volumetric test methods use more than one approach to detect a leak. For example, some vacuum-based methods use a capacitance sensor to check for water ingress that would indicate a leak in the tank as well as check for an acoustic signal. Test and evaluate each approach to determine whether or under what conditions the method meets EPA's performance standards.

1.3.3 Sensors

These test procedures provide multiple test designs to evaluate release detection sensor capabilities. Depending on the equipment, its intended use by the vendor, and input from the evaluator, the appropriate test designs will provide data on the specificity and sensitivity of the sensor. In general, a sensor reacts to a change in the environment in which it is located. Many sensors do not come in contact with product and are not expected to perform differently with various products stored in an UST system. Many sensors are non-discriminating, in that they react to the change whether it is in contact with water or product. However, in cases where a sensor is designed to react to a change in electric potential, such as capacitance and conductivity sensors, in a system storing alcohol blends, the sensor may not function at a specific set point due to interference by water. Also, in cases where a sensor is designed to react to the presence of hydrocarbons and comes in contact with liquid or vapor product in a system storing ethanol blends, the sensor may not function if the ethanol component of fuel is high enough to dilute the hydrocarbon component. Furthermore, in high alcohol blends such as E85, ethanol could absorb enough water in a system that has an abundance of water where the sensor might not function as intended. The sensor might indicate water instead of fuel and an alarm condition associated with the presence of fuel could exist that could be missed by the sensor.

These test procedures evaluate methods that provide liquid level measurement either from a wet hydrostatic environment such as a brine-filled interstice, or a dry environment such as a sump pit or secondary containment under vacuum or ambient conditions. Sensor test procedures must evaluate the sensor's ability to identify that a liquid is present, detect a change in liquid, or identify either water or hydrocarbons specifically. Additionally, discriminating sensors are sensors monitoring wet or dry spaces that may detect product or product vapor.

Depending on the capabilities of the sensor, test liquid sensors by introducing liquid such as water or product into the dry vessel or into a vessel containing water or product. When product is on top of the water, determine the detection limit of the sensor by the thickness of the product layer. When you add water to product, test the sensors to detect water entrained in the product or in a separated phase on the bottom. In addition to the procedures provided in Section 4.5, the evaluator may use the test procedures for detecting water entering product as a separate phase or entrained in the fuel as presented in EPA's *Standard Test Procedures For Evaluating Release Detection Methods: Automatic Tank Gauging Systems*. Testing procedures for sensor functionality in systems with alcohol blends must include testing with a variety of amounts of water to determine whether water interferes with performance of sensors designed to react to a change in electric potential, such as for capacitance and conductivity sensors. At minimum, the evaluator must test the vendor's desired alcohol blend and that alcohol blend with three water mixtures: 80 percent alcohol blend and 20 percent water; 60 percent alcohol blend and 40 percent water; and 30 percent alcohol blend and 70 percent water. For sensors that discriminate between hydrocarbons and water intended to be used with alcohol blends, the evaluator must evaluate the discriminatory sensor both with alcohol blend fuel that is fully in solution with water, as well as with distinct phase separation layer with neat gasoline on top. The sensor may only detect a certain layer or layers.

Test vapor sensors in a more controlled and contained test chamber using various concentrations of hydrocarbon mixtures or hydrocarbon-alcohol blends for sensors used in alcohol blends to determine the performance parameters of the sensor. Where sensors are designed to detect the presence of liquid hydrocarbons intended to be used for alcohol blends, repeat the test procedures presented in Section 4.5 with a variety of blends as determined by the evaluator, with input from the vendor, to determine the accuracy and specificity of sensors range of operability in alcohol blends. At minimum, the evaluator must test the vendor's alcohol blend the sensor is intended to be used with and that alcohol blend with three water mixtures: 80 percent alcohol blend and 20 percent water; 60 percent alcohol blend and 40 percent water; and 30 percent alcohol blend and 70 percent water.

1.3.4 Effects Of High Groundwater Level And Considerations For Double Walled Tanks

The groundwater level is a potentially important variable in tank tightness testing. Groundwater levels may be above the bottom of the tank, particularly in coastal regions where tidal effects may cause fluctuations in the groundwater level during testing. If the groundwater level is above the bottom of the tank, the water pressure on the exterior of the tank tends to counteract the product pressure from inside the tank. If the tank has a leak or hole below the groundwater level, the leak rate in the presence of a high groundwater level will be less than with a lower groundwater level. If the groundwater level is high enough, water may intrude into the tank through the hole.

The evaluator must document how the method addresses the groundwater level or in the case of testing the primary containment of a double walled tank, how the presence of a liquid filled or closed interstice may affect the method. A method that does not account for groundwater level or interstitial issues for a double-walled tank is inadequate. If the groundwater or brine level is above the bottom of the tank, a testing condition must accommodate for the high groundwater or brine level. The evaluator can do this by ensuring the tank has an outward pressure throughout or that groundwater or brine exerts an inward pressure at all levels in the tank. If the method uses an alternative approach to compensate for groundwater or brine levels, the evaluator must perform an engineering evaluation of the approach to ensure it is adequate. If testing the primary containment of a double-walled tank with a vacuum or pressure method, the evaluator or method must assure that the interstice is open whether it is dry or not. If in doubt, the evaluator may require additional tests to those detailed in this document.

1.4 Organization Of This Document

This document is organized as follows:

- Section 2 presents a brief discussion of safety issues.
- Section 3 discusses the apparatus and materials needed for the evaluation of the test methods.
- Section 4 presents the step-by-step procedures for volumetric and non-volumetric test methods and sensors.
- Section 5 describes the data analysis.
- Section 6 provides some interpretation of the results.
- Section 7 describes how to report the results.

Four appendices are included in this document:

- Appendix A includes definitions of some technical terms.
- Appendix B presents forms for volumetric methods.
- Appendix C contains similar forms for non-volumetric methods.
- Appendix D contains forms for sensor testing and reporting.

The forms in Appendices B and C form the basis of the standard evaluation report including: a standard reporting form for the evaluation results, a standard form for describing the operation of the method, data reporting forms, and an individual test log.

Section 2: Safety

The vendor tests the TTT equipment and ensures it is safe for its intended use. As part of a standard operating procedure, the vendor provides a safety protocol for each release detection method. The protocol specifies requirements for safe installation and use of the method. In addition, all facilities hosting an evaluation provide a safety policy and procedure to the evaluator and staff on site. You must follow all safety requirements to ensure the safety of those performing the evaluation and those near the evaluation-testing site.

At a minimum, ensure this safety equipment is available at the site:

- Two class ABC fire extinguishers;
- One portable eyewash station;
- Adequate quantity of spill absorbent; and
- Appropriate safety signs such as *No Smoking*, *Authorized Personnel Only*, and *Keep Out*.

Follow all safety procedures appropriate for the product in the tanks and test equipment. Personnel working at the UST facility must wear safety glasses when working with product and steel-toed shoes when handling heavy pipes or covers. Place the safety equipment at the site; before work begins, post the *No Smoking*, *Authorized Personnel Only*, and *Keep Out* signs.

These test procedures only address the issue of the method's ability to detect leaks. They do not address testing the release detection method for safety hazards. The vendor is responsible for meeting other construction standards testing that addresses key safety hazards such as fire, shock, intrinsic safety, and product compatibility.

Section 3: Apparatus And Materials

3.1 Tank Tightness Test Method Equipment

The vendor supplies equipment for each TTT method tested. In general, the equipment includes a means of monitoring the tank using vacuum or pressure decay, acoustical methods, or detection of water to indicate a leak and instrumentation for collecting and recording the data to interpret the result as a pass or fail for the tank. For tracer methods, equipment includes a means for introducing the tracers into the tank or the backfill.

Trained personnel who regularly use the method and are deemed qualified by the vendor to perform commercial tests should conduct the test. This ensures the vendor's method is operated properly and eliminates problems that newly trained or untrained individuals may have with the equipment. If the equipment owner normally operates the method, then the equipment owner provides personnel to operate the method. If applicable, follow the vendor's standard quality control methods when performing the tests.

3.2 Tanks

The evaluation test procedures require that the UST is tight. You will need a second tank or a tank truck to store product for the emptying and refilling cycles. The tank must be tested and proved tight by another release detection method. The tank must not have a history of problems. In addition, the test procedures call for an initial trial run with the test method under stable conditions. Before testing begins, the trial run is used to confirm the tank tests tight; if it does not, there may be a problem with the tank or the test method, which must be resolved before proceeding with the evaluation.

The tank facility used for testing must have at least one monitoring or observation well. The primary reason is to determine the groundwater level. The presence of groundwater above the bottom of the tank will affect the leak rate in a real leak situation, that is, the flow of product through a hole in the tank wall. The flow is a function of the differential pressure between the inside and outside of the tank. It is not necessary to require that testing against the evaluation test procedure occur in a tank entirely above the groundwater level; however, it is important to record the groundwater level if an actual leak occurs during testing.

Volumetric methods that measure volume or level changes of liquid product occurring as a result of a leak generally perform worse as the size of the tank increases. The evaluation may use tanks of any size. The results of the evaluation are applicable to all smaller tanks; therefore, the larger the test tank, the broader the applicability of the evaluation. For the majority of methods, the results also apply to larger tanks, but are restricted to tanks no more than 50 percent larger in capacity than the test tank for single tanks and 25 percent larger for tanks connected by siphon piping. However, the accuracy of some test methods and test method categories are very volume sensitive while others are much less sensitive to volume. For that reason, it is appropriate to impose correspondingly more or less restrictive tank size applicability for certain methods. For example, upscaling results from test tank sizes used for vacuum decay-based methods are generally not appropriate. The evaluator must provide justification if upscaling is applied. Conversely, test tank sizes used for tracer-based methods presumably have no limit, provided that the dose applied is appropriately measured. Therefore, there should not be a limit to upscaling results. The evaluator must provide an explanation for applicability or non-applicability of upscaling results to larger tanks in the reporting form.

For both volumetric and non-volumetric methods, the evaluator determines the appropriate size limit based on subsequent testing, physical principles involved, and other available data and states the limit on the results forms. For example, tanks larger than 50,000 gallons may have a different construction and geometry than standard horizontal cylindrical tanks. The tank geometry and construction may impose limits rather than the size.

For tracer methods, the characteristics of a tank are less important. However, the test tank used for the evaluation must be tight. The primary purpose of the test tank is to provide an environment, which is representative of typical tank installations. The test tank is important for testing for false alarms. The procedure of adding and mixing tracer to the product is a potential source of false alarms from inadvertent release of tracer into the environment.

3.2.1 Tank-Related And Other UST System Components

It is also possible to perform a VTTT or NVTTT evaluation on tank-related and other UST system components such as a tank interstice, pipeline interstice, or containment sump. The technologies available include, but are not limited to liquid sensors, pressure sensors, vacuum sensors, level measurement devices, and optical devices. Many of the requirements for evaluating a tank tightness test method for tank-related and other UST system components are the same as when evaluating a method that tests the primary space of a tank. The evaluator determines whether thermal conditioning is needed to adequately evaluate a specific tightness test method and provides the rationale for the determination. For example, some leak detection methods are used primarily to perform a tightness test on a liquid filled interstice of a newly installed double-walled tank where no product is present in the primary space of the tank. It may be unnecessary to implement thermal conditioning for such a system, assuming that the tank has been installed in the ground for at least 24 hours. In addition to newly installed tanks, it may be unnecessary to implement thermal conditioning on a tightness test method that requires the tank to be stable without any fuel deliveries for 24 hours.

If thermal conditioning is necessary, then follow the test schedule on Table 3 for volumetric methods and Table 4 for non-volumetric methods. If thermal conditioning is required in addition to the test schedule to implement thermals, also consider the volume of test apparatus since that is a factor when measuring the level in the reservoir of the interstice. Consider the volume of the test vessel used in the evaluation where thermal conditioning is a factor and when placing a limit on the volume the tightness test method is applicable to when testing a tank interstice. Interstitial volumes smaller than the evaluation test vessel are acceptable. For larger interstitial volumes, limit the tightness test method to 50 percent larger than the test vessel used in the evaluation.

When performing an evaluation of a tightness test method for a liquid filled interstice, a test vessel with a liquid filled reservoir connected to the top of the vessel may be used in a lab environment. If the evaluator verifies that thermal conditioning is unnecessary and other potential sensitive parameters are determined to be negligible, then there is no volume limit placed on the test method when testing a tank interstice; that means, a test vessel of approximately 5 gallons or more may be used. However, if the evaluator determines that thermal conditioning is necessary or other potential sensitive parameters cannot be ignored, the volume of the test vessel must be carefully measured since there will be a limit placed on the volume that the test method is applicable to when testing a tank interstice. In this case, the test vessel can be of any volume ranging from 5 gallons up to 1,000 gallons or more, comparable to the interstitial space of actual tanks. The evaluator must explain on the reporting form about applicability or non-applicability of upscaling results to larger tanks.

When performing an evaluation of a tightness test method for a liquid filled interstice, you may use a test vessel of a known volume in a lab environment where temperatures can be constantly controlled. The test vessel can be any volume ranging from 5 gallons to 1,000 gallons with a liquid filled reservoir connected to the top of the test vessel. The size and surface area of the reservoir should be a size that is commonly used with a liquid filled double-walled tank interstice. Measure the size of the reservoir carefully in order to calculate the surface area. Typically, the larger the surface area of the reservoir, the longer the test duration will be, so you must report the surface area. You may also calculate the test time for some methods on reservoirs with a different size surface area.

When performing an evaluation on a tightness test method for containment sumps, you may perform the evaluation in a lab environment in a test vessel that is similar to the size and dimensions of a typical containment sump. It may be unnecessary for thermal conditioning when performing an evaluation on a containment sump. Perform a total of 42 tests on a non-volumetric test method including 21 tight condition tests and 21 with a leak present that is calibrated to 0.10 gal/hr or less. The federal UST regulation does not establish leak rates for liquid tight containment sump testing. You may evaluate for target leak rates other than 0.10 gal/hr. For a volumetric tightness test method, perform 24 tests including 6 tests in the tight condition and 18 tests with a leak present. Of the 18 tests, perform 6 at each of the required leaks rates of 0.05, 0.10, and 0.20 gal/hr for 0.10 and 0.20 gal/hr listed leak detection rates. The evaluator will choose appropriate leak rates for a target listed leak rate other than 0.10 or 0.20 gal/hr.

3.3 Product

The most common products in USTs today are motor fuels, particularly non-alcohol blended gasoline, alcohol-blended gasoline, diesel, and biodiesel fuels. These test procedures are designed to evaluate currently widely marketed products using at least 24 tests for volumetric methods and at least 42 tests for non-volumetric methods.

The evaluator and the vendor choose the product, but it must be capable of being used with the release detection method. Testing a method with a specific product verifies its performance with that product. However, you may use products with similar physical and chemical characteristics, but you must use caution when inferring that results represent typical responses across products.

The evaluator must justify the extent of applicability of results to other products. In general, the test is more stringent as density and viscosity decreases with various products.

Alcohol-based fuels and bio-blended fuels are appreciably dissimilar to petroleum-based fuels without alcohol; the evaluation must specifically test using a representative product and under reasonable conditions likely encountered in the field, such as presence of water from such common sources as tank top sumps. Considerations such as water miscibility with the fuel blend, especially with alcohol-blended fuels, will require testing the various sensors or functions of the TTT, tank-related, and other UST system component release detection methods, as applicable.

Because water is essentially immiscible in petroleum-based fuels, a very small addition of water to an UST storing petroleum-based fuels will cause a water phase to settle in the bottom of the tank. This makes it relatively simple to determine the presence of water in USTs storing petroleum-based fuels. However, low alcohol-blended fuels can hold approximately 0.5 percent of water before phase separation occurs. As fuel temperature is lowered, the amount of water needed before phase separation occurs is also lowered. Because water alters the solubility of alcohol in gasoline, when phase separation occurs in E10, for example, the separated phase consists of an ethanol-water mixture with a density greater than ethanol but less than water. If water entering an UST does not mix into a low alcohol-blended fuel, a separated aqueous phase will collect at the bottom of the UST. However, once the UST receives a fuel drop and the contents mix, the water is absorbed into the fuel until it reaches saturation.

As mentioned previously, water absorbed into alcohol-blended fuel will also increase the density of the alcohol blend as well as other physical parameters, thus making proper selection of volumetric correction factors difficult. In addition, a certain amount of water can be absorbed in ethanol without an increase in volume and without separating at the bottom of the tank. In a large volume of stored fuel, the amount of water absorbed into the alcohol fraction of an alcohol-blended fuel could be appreciable and undetected.

Given the variability of the proportion of bio-components in fuels during testing, evaluators should analyze the true proportion of alcohols such as ethanol or biodiesel to petroleum fuel and record their findings with the test results. Following the ASTM International standard methods presented below or another national voluntary consensus code, analyze an aliquot of the fuel for the biofuel content. This is to characterize the fuel for testing and listing the method. Table 1 below specifies the methods that may be used for bio-component analysis by fuel.

Table 1. Analytical Methods For Bio-Component Determination

Method Designation	Method Title	Fuel Product
ASTM D7371	Determination of Biodiesel (Fatty Acid Methyl Esters) Content in Diesel Fuel Oil Using Near Infrared Spectroscopy	Biodiesel
ASTM D4815	Standard Test Method for Determination of MTBE, ETBE, TAME, DIPE, tertiary-Amyl Alcohol and C1 to C4 Alcohols in Gasoline by Gas Chromatography	Alcohol blend up to 20%
ASTM D5501	Standard Test Method for Determination of Ethanol and Methanol Content in Fuels Containing Greater than 20% Ethanol by Gas Chromatography	Alcohol blend over 20%

3.4 Leak Simulation Equipment

The test procedures call for inducing leaks in the tank. The method of inducing leaks must be capable of being used with the release detection method. The test design in Section 4 gives the nominal leak rates that the evaluator should use. These leak rates refer to leak rates that would occur under normal tank operating conditions. The required leak rates for an evaluation on the primary space of a tank will also apply when performing an evaluation on a method designed to perform tightness testing on areas of the tank other than the primary space such as a tank interstice and pipeline interstice.

The evaluator must disclose and validate the method used in the evaluation for simulating leaks. While it may not be possible to achieve the nominal leak rates exactly, the method used to induce the leak rates should be capable of being reasonably close to the nominal rates. Maintain and record the induced leak rates. Compare the leak rates measured by the release detection method to the induced leak rates.

Although certain leak simulation approaches may work for some non-volumetric methods, most methods will require a means of simulating leaks that is adapted to their specific principle of operation. It is the evaluator's responsibility to determine the appropriate leak simulation approach and adequately determine the performance of each specific tightness test method.

3.4.1 Leak Simulation Approach For Non-Volumetric Methods To Include Acoustical And Pressure-Vacuum Decay Methods

Some commercially available methods are based on corresponding pressure changes and acoustical signals generated when product flows through an orifice or when air is drawn through an orifice or hole in the tank that allows it to leak. In order to simulate a leak condition for such a method, you must introduce an orifice into the tank so that product or air can flow through it during the test. The orifice must be calibrated using diesel fuel with the equivalent pressure exerted by the weight of diesel fuel in an 8-foot column to the desired leak rate of 0.10 gal/hr. For desired leak rates other than 0.10 gal/hr for containment sumps, the orifice must be correspondingly calibrated using diesel fuel with the equivalent pressure exerted by the weight of diesel fuel in an 8-foot 3column to the desired leak rate.

Orifice Calibration

You may use a variety of components to create an orifice such as a syringe, precision drilled holes, a capillary tube or other devices that can be calibrated to allow liquid to flow through at the desired rate. Calibrate the orifice to a leak rate of 0.10 gal/hr or less using diesel fuel with the equivalent pressure exerted by the weight of diesel fuel in an 8-foot column to the desired leak rate of 0.10 gal/hr. For desired leak rates other than 0.10 gal/hr for containment sumps, the orifice must be correspondingly calibrated using diesel fuel with the equivalent pressure exerted by the weight of diesel fuel in an 8-foot column to the desired leak rate. For non-volumetric test methods, list the test method as capable of detecting leaks in liquids that are more viscous than the liquid used to calibrate the orifice, if the evaluator determines that no other factors need to be considered relative to the method's ability to detect a leak. The vendor may also choose to perform additional testing on tanks containing more viscous liquids using orifices calibrated accordingly. The same orifice calibration procedure applies to evaluating modes or methods of leak detection equipment intended for use in the wetted and non-wetted portions of the test tank.

3.4.2 Leak Simulation Approach For Tracer Methods

Two types of leak simulation equipment are required, depending on the type of tracer technique you are testing.

- For methods that rely on detecting the loss from the tank of product containing tracer, the simulation equipment must be capable of delivering a liquid containing the tracer into the backfill close to the tank. The rate of delivery controls the volume of product introduced in the backfill.
- For methods that rely on detecting the loss of gaseous tracer from the tank, the simulation equipment must be capable of delivering the tracer gas into the backfill in known quantities so the evaluator can evaluate the ability of the method to detect the tracer in the backfill.

In either case, the amount of tracer introduced into the backfill should reflect the amount that is released if the tank leaks at a rate of 0.10 gal/hr or less. To do this, the rate of delivery controls the amount of material introduced into the backfill. To simulate a 0 leak rate, introduce the tracer material into the test tank and mix with the product as appropriate. However, you can instead introduce a blank spike without a tracer into the backfill.

When testing tracer methods, additional considerations apply. While petroleum products spiked with tracer are ideal, introducing regulated products into the ground is prohibited in almost all situations. Therefore, for test purposes, the carrier for liquid tracers should be a non-regulated liquid such as vegetable oil. Evaluate the concentration of tracer in the carrier to reduce the actual volume of material introduced into the ground. The evaluator must separately determine that the tracer is readily soluble in the regulated product.

The evaluator can use direct injection of the tracer gas diluted in air to evaluate methods, which rely on the loss of tracer gases from the tank. The concentrations of tracers injected during the simulation process should approximate those contained in the tank during an actual test.

Other non-volumetric methods may use physical or chemical principles different from those of the methods in these examples. The evaluator must develop a method of leak simulation that is appropriate for the specific test method.

3.4.3 Leak Simulation Approach For Tightness Test Methods Using An Optical Device

For a tightness test method that uses an optical device such as a camera or a laser, the evaluator must develop a method of leak simulation that is appropriate for the specific test method. For optical devices, it is most likely that the method is a non-volumetric tank tightness test method which requires a total of 42 tests. Of these 42 tests, perform 21 tests with the tank in a tight condition and perform 21 tests with the tank simulating a 0.10 gal/hr or less leak. Tightness test methods with an optical device may include methods that look for a leak inside the primary space of a double-walled tank filled with dyed brine and contrasts with the color of the tank wall or in a containment sump. The evaluator must determine an appropriate leak simulation approach to ensure the method is properly evaluated.

Some optical tightness test methods, such as a camera based system, have a specified wait period where the camera system is simply waiting for any visible leak to develop within a specified amount of time, for example 60 or 120 minutes. Once the appropriate leak volume is simulated and blind to the vendor, the vendor can then perform the test to determine whether the tank or containment sump is tight or leaking. If an orifice is used, calibrate the orifice using diesel fuel with the equivalent pressure exerted by the weight of diesel fuel in an 8-foot column to the desired leak rate of 0.10 gal/hr. For desired leak rates other than 0.10 gal/hr for containment sumps, the orifice must be correspondingly calibrated using diesel fuel with the equivalent pressure exerted by the weight of diesel fuel in an 8-foot column to the desired leak rate.
For a tank tightness test method with a camera in a new tank not yet in service, the evaluator must take into account that many newly installed tanks may have ballast water at the bottom of the tank. If the method is capable of detecting leaks in a tank with ballast water, then the evaluation must include performing tests with and without ballast water present. If there is a limit on the amount of ballast water present in the tank for the method to perform properly, then the evaluator must note this limitation on the performance of the method. Leaks must be simulated in several areas including the top, bottom, end, and sides of the inside of the tank in order to ensure performance of the tightness test method is adequately evaluated on all areas of the tank. The number of tests for a VTTT or NVTTT on optical devices is the same as other tightness test methods, for example 24 for VTTT and 42 for NVTTT. If there are relevant limitations on the tightness test method found during the evaluation, the evaluator must note those limitations.

3.5 Sensor Evaluation Equipment

3.5.1 Liquid Sensor Test Vessel

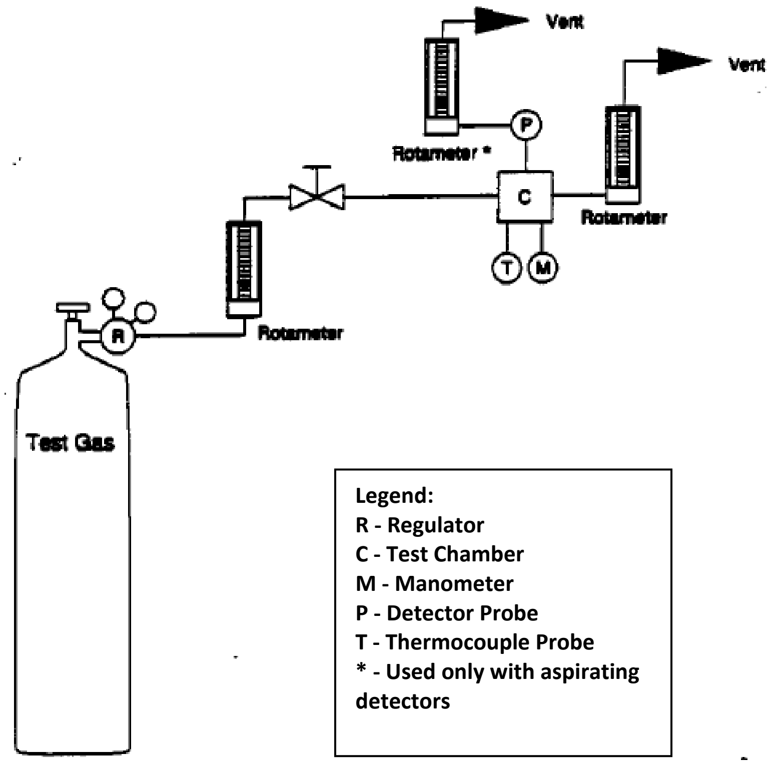
The equipment to test a liquid sensor consists of a test vessel large enough to accommodate the size of the sensor, typically a vertical cylinder standpipe. The height of the test vessel must be 8 inches or more. Product miscible with water must be treated or properly disposed at the conclusion of the test. Minimizing waste is a consideration in determining the size of the test vessel. Accurately measure the test vessel liquid height level to ± 0.001 inch. Mount the liquid sensor in the same relation within the test vessel as it would be in the UST system.

In addition, the evaluator needs a means of repeatedly adding a small measured amount of liquid such as product and water to the test vessel. You may establish the simulated ingress using a variety of equipment; however, a peristaltic pump has been successfully used in the past. With this approach, use an explosion-proof motor to drive a peristaltic pump head. Choose the appropriate size of the pump head and tubing to provide the desired flow rates or liquid height increase rate depending on the geometry of the test vessel and sensor. You should use a variable speed pump head so you can achieve different flow rates with the same equipment. Direct the flow through a rotameter so you can monitor and control the flow.

3.5.2 Vapor And Pressure Decay Test Vessel And Leak Simulation

The vapor test vessel equipment consists of compressed gas cylinders of test gases certified accurate to ± 2 percent and ultrahigh-purity air, pressure regulators of 0 psi to 15 psi, tubing, valves, tubing connectors, rotameter, test vessel, thermocouple of 0°C to 40°C to within ± 1°C, and manometer at least 0-10 inches of water ± 5 percent. All of the equipment must be constructed from materials that are inert with respect to the test gases. Use this equipment to minimize the potential interferences of temperature changes, high temperature, excessive test apparatus volumes, and leaks in the test vessel. Monitor the temperature and tests conducted at normal laboratory temperatures. Maintain the internal pressure of the test vessel at a constant pressure of ± 0.2 inches of water relative to ambient pressure. Keep the vessel volume as small as possible without interfering with the operation of the sensor. There must be an inlet and an outlet for flow of test conditions and fittings must allow connection to the sensor, a manometer, and a thermocouple. See Figure 1 for an example schematic of a vapor test chamber.

Figure 1. Example Schematic Of A Vapor Test Chamber



3.6 Miscellaneous Equipment

As noted, the test procedures may require the partial emptying and filling of the test tank. One or more large capacity fuel pumps may be required to accomplish the filling in a reasonably short time. The evaluator may need hoses or pipes for fuel transfer. Some test methods require reserve product for calibration or establishing a specified product level. In addition, containers may be necessary to hold this product as well as that collected from the induced leaks. You may need a variety of tools to make the necessary connections of equipment.

This procedure requires that before fuel is transferred to the test tank, a method of heating and cooling the fuel must be provided, such as pumping the fuel through a heat exchanger or by placing heating and cooling coils in the supply tank or tank truck.

Section 4: Test Procedures

The evaluator can measure the overall performance of the method by comparing the method's results of either leaking or tight tank to whether a leak was actually induced. The evaluator can measure performance under a variety of realistic conditions, including temperature changes and filling effects, if applicable. The evaluator is responsible for adding any other variables that may affect a specific non-volumetric method. The range of conditions need not represent extreme cases that might be encountered, because extreme conditions can cause any method to give misleading results. If the method performs well under various test conditions, then it should perform well in the field. Document the testing using the appropriate forms in Appendices B, C, or D for volumetric, non-volumetric, and sensors, respectively.

The test procedures have been designed so the evaluator can perform additional statistical analyses to determine whether the method's performance is affected by the size of the leak or other factors. Conduct these additional analyses only if the method makes a substantial number of mistakes so the proportion of errors is between 0 and 1 for some subsets of the data. Thus, the additional analyses are only relevant if the method does not meet the performance standard.

The basic test procedures introduce two main factors that may influence the test: size of leak and temperature effects.

- Size of leak – Evaluate the method on its ability to detect leaks of specified sizes. If a method cannot detect a leak rate of 0.10 gal/hr, which may vary for containment sump testing, or if the method identifies too many leaks when no leak is induced, then its performance is not adequate.
- Temperature effects – Three temperature conditions should be used: added product at the same temperature as the in-tank product, added product that is warmer than already in the tank, and added product that is cooler. The temperature difference should be 10°F and should be measured and reported to the nearest degree F. This establishes method performance over a large temperature range and encompasses the range of seasonal temperatures in many parts of the U.S. For some methods, the temperature difference is needed to ensure the method can adequately test under realistic conditions. Compare the performance under the three temperature conditions to determine whether these temperature conditions affect the method's performance. Note that some non-volumetric methods require an empty tank or do not require a specific product level. If the principle of the non-volumetric method is not affected by product temperature as determined by the evaluator, the test need not include this set of conditions, although the total number of tests remains the same.

Non-volumetric test methods operate on a wide variety of physical and chemical principles. Consequently, each method may have a different set of sources of interference related to its operating principle. The evaluator must consider possible sources of interference for the test method. Possible sources of interference might include noise, high water content, and turbidity. The evaluator must report the list of the sources considered and his or her conclusions.

The groundwater level is a potentially important variable in tank testing. The evaluator must, as applicable, document the method's means of dealing with groundwater in the test results.

If the method uses a water ingress method to account for high groundwater levels, use EPA's *Standard Test Procedures For Evaluating Release Detection Methods: Automatic Tank Gauging Systems*, to evaluate two aspects of the method's water sensing function: the minimum detectable water level and the minimum detectable change in water level. Together, you can use these with the dimensions of the tank to determine the ability of the method's water sensor to detect inflows of water at various rates.

Tank deformation may also be a potential interference the evaluator considers, especially if test results are inconsistent across multiple test sites. Even with this potential, deformation may be negligible and difficult to determine given other uncontrollable factors across different test tanks. If one tank is used for the entire evaluation, deformation is controlled.

4.1 Environmental Data Records

In general, the evaluation test procedures require that the evaluator record the conditions during the evaluation. In addition to all the testing conditions, document the groundwater level, if it is above the bottom of the tank, and any special conditions that might influence the test results, including weather changes.

When testing tracer methods, the evaluator should also document the tank environment as completely as possible. Prepare a detailed site diagram, which identifies the positions of the tanks, piping, and other features present at the site. Verify that the type of backfill and soil at the site is, at a minimum, porous enough to allow migration of vapors from the leak to the sensors. Do not conduct the evaluation under backfill conditions outside the range suggested by the vendor. The range of conditions must be listed in the report.

The operating manual should describe both normal and unacceptable test conditions for each method and should provide a reference against which the evaluator can compare the existing test. Do not conduct the evaluation under conditions outside the vendor's recommended operating conditions.

Record the following tank and product information, if applicable:

- Type of product in tank;
- Bio-component of product, if any;
- Type of tracers, for example liquid or gas;
- Tank volume;
- Tank dimensions and type;
- Amount of water in tank before and after each test;
- Temperature of product in tank before filling;
- Temperature of product added each time the tank is filled;

- Temperature of product in tank immediately after filling; and
- Temperature of product in tank at start of test.

4.2 TTT Evaluation Test Procedures

4.2.1 Volumetric TTT Methods

Following the trial run in the tight tank, conduct a minimum of 24 tests at the leak rates presented in Table 2 and similar to the example test design presented in Table 3 for volumetric TTT methods. If the vendor chooses the option to evaluate their method on tanks connected by siphon piping, an additional 24 tests can be performed following the test design in Table 3. In Table 3, LR_i denotes the nominal leak rates and T_i denotes the temperature differential conditions used in the testing. These 24 tests evaluate the method under a variety of conditions with the tank level at 90 percent or higher. If a method is to be evaluated at 50 percent, assuming the performance has been proven adequate at 90 percent and higher, an additional 12 tests can be performed at 50 percent. If a vendor chooses a method be evaluated at a level below 50 percent, assuming the performance has been proven adequate at 50 percent and higher, an additional 12 tests can be performed at the lowest level the method is capable of achieving.

These number of test requirements also apply to an evaluation performed on a method for tightness testing on a tank interstice or containment sump.

Leak Rates

Induce the following four nominal leak rates during the procedure to evaluate the method at 0.10 gal/hr leak rate.

Table 2. Leak Rates To Evaluate A Method At 0.10 gal/hr Leak Rate

English Units (gal/hr)	Metric Units (milliliters per minute)
0.0	0.0
0.05	3.2
0.10	6.3
0.20	12.6

Temperature Differentials

In addition, use three nominal temperature differentials between the temperature of the product to be added and the temperature of the product in the tank during each fill cycle. These three temperature differentials are -10, 0, and +10°F or -5.6, 0, and +5.6 degrees Celsius (°C). A national survey on typical tank testing conditions[1] found that for 57 percent of the tests, the difference in temperature between the product in the tank and the newly delivered product was less than 5°F and 86 percent of the tests for a temperature difference within 10°F of the product

[1] *Typical Tank Testing Conditions*, Flora, Jairus D., Jr., and Jean Pelkey, Report on Work Assignment 22, Task 13, EPA Contract No. 68-01-7383, Midwest Research Institute, December 2, 1988.

in the tank. Using a temperature differential of 10°F simulates the majority of the typical tank conditions.

Conduct the tests in sets, where the two tests in a set have the same temperature condition and fill, but differ in the time since filling and may have different leak rates.

It may be unnecessary to perform thermal conditioning when performing an evaluation on a tank tightness test method that tests dry tank related components such as a containment sump.

Randomization

Conduct 24 tests by inducing the 12 combinations of the four leak rates (LR_1, LR_2, LR_3, and LR_4) and the three temperature differentials (T_1, T_2, and T_3) at the method-specified product volume outlined in Table 3.

The evaluator is responsible for randomly assigning nominal leak rates of 0.0, 0.05, 0.10, and 0.20 gal/hr to LR_1, LR_2, LR_3, and LR_4 and nominal temperature differentials of -10°, 0°, and +10°F to T_1, T_2, and T_3.

After a trial run, the evaluator or vendor will operate the method as it would be in a commercial facility and record the data. The randomization is used to balance any unusual conditions and to ensure the vendor does not have prior knowledge of the sequence of leak rates and conditions to be used.

In summary, each test set consists of two tests. Conduct each set of tests using two induced leak rates and one induced temperature differential, which is the temperature of product to be added minus the temperature of product in tank. Each set of tests indicates the sequence in which the product volumes in gal/hr will be removed from the tank at a given product temperature differential.

Notational Conventions

The nominal leak rates of 0.0, 0.05, 0.10, and 0.20 gal/hr are randomly assigned LR_1, LR_2, LR_3, and LR_4. While you may not achieve these exact figures in the field, these rates are targets that should be achieved within ± 30 percent.

During each test, measure the induced leak rates, denoted by S_1, S_2, ... S_{24}, for each of the 24 tests. Compare these leak rates against leak rates obtained by the vendors.

Denote the leak rates measured by the TTT method during each of the tests by L_1, L_2, … L_{24} and correspond to the induced leak rates S_1, S_2, ... S_{24}.

The subscripts 1, … 24 correspond to the order in which the tests were performed; see Table 3. For example, S_5 and L_5 correspond to the test results from the fifth test in the test sequence.

Table 3. Leak Rate And Temperature Differential Volumetric Test Design (Example)

	Test No.	Set No.	Nominal Leak Rate (LR in gal/hr)	Nominal Temperature Differential (T in °F)
Trial run	-	-	0	0
Empty/Fill cycle				
	1	1	LR_2	T_2
	2	1	LR_1	T_2
Empty/Fill cycle				
	3	2	LR_3	T_3
	4	2	LR_2	T_3
Empty/Fill cycle				
	5	3	LR_1	T_3
	6	3	LR_4	T_3
Empty/Fill cycle				
	7	4	LR_3	T_1
	8	4	LR_1	T_1
Empty/Fill cycle				
	9	5	LR_2	T_1
	10	5	LR_4	T_1
Empty/Fill cycle				
	11	6	LR_4	T_3
	12	6	LR_1	T_3
Empty/Fill cycle				
	13	7	LR_1	T_2
	14	7	LR_4	T_2
Empty/Fill cycle				
	15	8	LR_1	T_1
	16	8	LR_2	T_1
Empty/Fill cycle				
	17	9	LR_3	T_2
	18	9	LR_2	T_2
Empty/Fill cycle				
	19	10	LR_4	T_2
	20	10	LR_3	T_2
Empty/Fill cycle				
	21	11	LR_2	T_3
	22	11	LR_3	T_3
Empty/Fill cycle				
	23	12	LR_4	T_1
	24	12	LR_3	T_1

4.2.2 Non-Volumetric TTT Methods

Following a trial run in the tight tank, conduct a minimum of 42 tests for non-volumetric TTT methods for single tanks as outlined in Table 4. If the vendor wants optional evaluation on tanks connected by siphon piping systems, perform an additional 42 tests. Table 4 presumes that temperature effects can interfere with the method. The tests on a tank system comprised of tanks connected by siphon piping requires monitoring and reporting of temperature.

In Table 4, LR_i denotes the nominal leak rates and T_i denotes the temperature differential conditions. These 42 tests for single tanks evaluate the method under a variety of conditions. The evaluator cannot establish the leak rate the same way for all TTT methods. Sections 3.4.1, 3.4.2, 3.4.3 and 3.5.2 describe a variety of leak simulation setups. As technology advances, other devices may be developed to simulate releases.

Arrange the base 42 tests in 21 sets of two tests each. Table 4 shows a possible ordering of the 21 sets. The evaluator should randomly rearrange the order of the sets so the leak rates are blind to the vendor.

Leak Rates

Of the 42 tests, conduct half under tight-tank conditions, that is, at a leak rate of 0.0 gal/hr. Conduct the remaining 21 tests with under induced leak conditions with leak rates not exceeding 0.10 gal/hr. Typically, all of these induced leak rates would be the same. The test schedule in Table 4 is an example of 21 tests at a 0.0 gal/hr leak rate (LR_1) and 21 tests at non-0 leak rates of LR_2 (0.10 gal/hr). For testing at leak rates other than 0.10 gal/hr., the evaluator will select comparable induced leak rates based on the target leak rate.

The most direct evaluation of a non-volumetric method uses only 0.0 and 0.10 gal/hr leak rates. This, assuming the test results had at most one error at each leak rate, provides the needed performance evaluation. However, a vendor may want to claim his method exceeds EPA's performance standards and establish the probability of detecting a smaller leak, for example 0.01 gal/hr rather than 0.10 gal/hr, is at least 95 percent. In that case, two approaches are possible. One is to use the smaller leak rate as the induced leak rate. However, if the nominal leak rate selected is close to or less than the leak rate the method can actually detect with 95 percent reliability, the testing may result in too many detection errors at that reduced leak rate. In order to demonstrate the method meets the performance standards, run the 21 induced leak rate tests again using a nominal leak rate larger than the example of 0.01 gal/hr, for example, 0.05 gal/hr.

With input from the vendor, the evaluator will select the most appropriate approach for the evaluation.

Temperature Differentials, If Applicable

If temperature differential is important for the test method, use three nominal temperature differentials between the temperature of the product to be added and the temperature of the product in the tank during each fill cycle. These three temperature differentials are -10, 0, and

+10°F (-5.6, 0, and +5.6°C). The temperature differential of 10°F is a minimum. You may use larger differences. When temperature differences are used, calculate and report the actual differences.

Randomization

Conduct 42 tests consisting of combinations of the two leak rates (LR_1 = 0.0 gal/hr, LR_2 = 0.10 gal/hr) and the three temperature differentials (T_1, T_2, and T_3). Arrange the 42 tests in sets, with each set consisting of two tests performed at the same temperature differential. However, the leak rates within a set must be randomly assigned to the first or second position in the testing order. Table 4 outlines the test schedule.

A randomization of the test schedule is required to ensure the testing is conducted blind to the vendor. The evaluator is responsible for randomly assigning the leak rate of 0.10 gal/hr to LR_2 and nominal temperature differentials of -10°, 0°, and +10 °F to T_1, T_2, and T_3, following the sequence of 42 tests as shown in Table 4. In addition, the evaluator should randomly assign the set numbers of 1 through 21 to the 21 pairs of tests. The vendor should not know which induced leak rate is used or which temperature condition is present in advance. The vendor should test for the induced leak rate based on the instrumentation and standard operating procedure without knowledge of the induced conditions. Perform randomization separately for each method evaluated. In Table 4, it is assumed all tests are done at a product level appropriate for the leak detection method being tested. This level may be around 95 percent which is considered full, or it may be a level required by the specific leak detection method, such as 60 percent of liquid. For partially full tests, a supplemental test of the ullage area is recommended so the entire portion of the tank normally containing liquid is tested.

In summary, each test set consists of two tests performed using two induced leak rates and one induced temperature differential, which is the temperature of product to be added minus temperature of product in the tank. Each set indicates the sequence in which the induced rates are used to remove the product volumes in gal/hr from the tank at a given product temperature differential. In some cases, for example, when a partial vacuum is applied to the tank, the simulated leak will not actually remove product from the tank. In this case, the indicated rates are those at which product escapes or is removed from the tank if the induced condition is present under normal tank operating conditions.

Notational Conventions

The induced nominal leak rates are denoted by LR_1 = 0.0 gal/hr, LR_2, = 0.10 gal/hr. While you may not achieve these exact nominal leak rates in the field, these rates are targets that should be established by a calibration process. The maximum must be no more than 10 percent greater than the nominal 0.10 gal/hr.

Calibrate the leak rates induced for each of the 42 tests for each test series and denote the rates by S_1, S_2, … S_{42}. Denote the results of each test by L_1, … L_{42}, with each L_i being either tight or leaking. The L_i may be coded numerically, for example, L_i = 0 for tight and 1 for leaking, for convenience.

The subscripts 1, … 42 correspond to the order in which the tests were performed; see Table 4. For example, S_5 and L_5 correspond to the test results from the fifth test in the test sequence.

Table 4. Leak Rate And Temperature Differential Non-Volumetric Test Design (Example)

	Test No.	Set No.	Nominal Leak Rate (LR in gal/hr)	Nominal Temperature Differential (T in ° F)
Trial run			0	0
Empty/Fill cycle				
	1	1	LR_2	T_3
	2	1	LR_1	T_3
Empty/Fill cycle				
	3	2	LR_1	T_2
	4	2	LR_1	T_2
Empty/Fill cycle				
	5	3	LR_1	T_1
	6	3	LR_2	T_1
Empty/Fill cycle				
	7	4	LR_2	T_3
	8	4	LR_1	T_3
Empty/Fill cycle				
	9	5	LR_2	T_1
	10	5	LR_1	T_1
Empty/Fill cycle				
	11	6	LR_2	T_2
	12	6	LR_2	T_2
Empty/Fill cycle				
	13	7	LR_2	T_1
	14	7	LR_1	T_1
Empty/Fill cycle				
	15	8	LR_2	T_3
	16	8	LR_1	T_3
Empty/Fill cycle				
	17	9	LR_2	T_3
	18	9	LR_1	T_3
Empty/Fill cycle				
	19	10	LR_1	T_2
	20	10	LR_2	T_2
Empty/Fill cycle				
	21	11	LR_2	T_1
	22	11	LR_1	T_1
Empty/Fill cycle				
	23	12	LR_1	T_3
	24	12	LR_2	T_3
Empty/Fill cycle				
	25	13	LR_2	T_2
	26	13	LR_2	T_2
Empty/Fill cycle				
	27	14	LR_2	T_3
	28	14	LR_1	T_3

Table 4. Leak Rate And Temperature Differential Non-Volumetric Test Design (Example) (Continued)

	Test No.	Set No.	Nominal Leak Rate (LR in gal/hr)	Nominal Temperature Differential (T in °F)
Empty/Fill cycle				
	29	15	LR_1	T_1
	30	15	LR_2	T_1
Empty/Fill cycle				
	31	16	LR_1	T_2
	32	16	LR_1	T_2
Empty/Fill cycle				
	33	17	LR_1	T_3
	34	17	LR_2	T_3
Empty/Fill cycle				
	35	18	LR_1	T_2
	36	18	LR_2	T_2
Empty/Fill cycle				
	37	19	LR_2	T_1
	38	19	LR_1	T_1
Empty/Fill cycle				
	39	20	LR_1	T_2
	40	20	LR_2	T_2
Empty/Fill cycle				
	41	21	LR_1	T_1
	42	21	LR_2	T_1

T_x is the monitored temperature of the system.

4.3 Implementation Of The Test Procedures

The first test is a trial run. Inform the vendor that you are conducting this test with a tight tank in stable condition. Report the results of the trial run along with any other data, but these results are not explicitly used in the calculations estimating the method's performance.

There are two purposes to this trial run. One is to allow the vendor to check the tank testing method before starting the evaluation. As part of this check, the vendor should identify and repair any faulty equipment. A second part is to ensure there are no problems with the tank or the test equipment. Identify and correct common field problems such as loose risers, leaky valves, and leaks in plumber's plugs.

The results also provide additional verification the tank is tight and provide a baseline for the induced leak rates during the evaluation.

Conduct the testing using a randomized arrangement of nominal leak rates and temperature differentials as illustrated in Tables 3 and 4 above, unless the evaluator determines the filling or temperature changes are irrelevant for the particular non-volumetric method. The time lapse between the two tests in each set should not exceed 30 minutes and preferably be 15 minutes or less. After each set of two tests, the test procedure starts anew with emptying the tank to less than half-full, refilling, and stabilizing as necessary. The details of the testing procedure are as follows.

Step 1 Randomize the test conditions – The evaluator randomly assigns nominal leak rates LR_1, LR_2, LR_3, and LR_4. The evaluator also randomly assigns the temperature differentials of -10°, 0°, and +10 °F to T_1, T_2, and T_3. Keep these blind to the vendor performing the testing.

Step 2 Set up – If not already done, install the leak simulation equipment according to the installation procedures in the tank, ensuring the leak simulation equipment will not interfere with the test equipment.

Step 3 Trial run – Following the test method's standard operating procedure, fill the tank to the test method's recommended level and at a minimum allow for the stabilization period called for by the method. Product added should be the same temperature as the in-tank product. Conduct a test on the tight tank to check the system, such as tank and plumbing, and the method. Perform necessary repairs or modifications identified by the trial run.

Step 4 Empty tank – Partially empty the tank to half-full. Fill with product at the recommended temperature. The temperature differential will be T_i. Record the date and time after completing the fill. Allow for the recommended stabilization period, but not longer. Induce the appropriate leak condition.

Step 5 Conduct release detection method testing – Continue with the methods standard operating procedure and conduct a test on the tank, using the method's recommended test duration. Record the date and start time of the test. Perform this test under the first nominal leak rate of the **first** set.

When the first test is complete, determine and record the calibrated induced leak rate, S_1, and the method's reported leak rate, L_1. If possible, also record the data used to determine the leak condition and the method of calculation. Save all data sheets, computer printouts, and calculations. Record the beginning and ending dates and times of the test. Also, record the length of the stabilization period. Appendices B and C provide individual test log forms for reporting these data and environmental conditions.

Record the temperature of product in the test tank and temperature of the product added to fill the test tank; if not recorded, document why not on the log. After adding product to fill the test tank, record the average temperature in the test tank. One way to measure the temperature of product in the tank is to use a probe with five temperature sensors spaced to cover the diameter of the tank. Insert the probe or install it permanently in the tank; use the temperature readings of those sensors in the liquid to obtain an average temperature of the product. The temperature sensors can be spaced to represent equal volumes or the temperatures can be weighted with the volume each represents to obtain an average temperature for the tank.

Step 6 Change the nominal leak rate to the **second** in the first set – Repeat step 5. Note there will be an additional period, which is the time taken by the first test and the setup time for the second test, during which the tank may have stabilized. When the second test of the first set is complete, again record all results such as times and dates, induced leak rate and test result, temperatures, and calculations.

Step 7 Repeat step 4 – Change the temperature differential to the next in the test design.

Step 8 Change the nominal leak rate to the first in the second set – Repeat step 5. Record all results.

Step 9 Change the nominal leak rate to the second in the second set, if it is different – Repeat step 6. Record all results.

Step 10 Repeat step 4 – Change the temperature differential to the following one in the test design.

Step 11 Repeat steps 5 through 9, using each of the two nominal leak rates of the third set.

Repeat steps 4 through 9, which correspond to two empty and fill cycles and two sets of two tests until all tests are performed.

The operating manual should describe normal and unacceptable test conditions for each method and provide a reference for comparing the existing test. Do not conduct the evaluation under conditions outside the vendor's recommended operating conditions.

The evaluation must test all aspects of release detection the vendor claims that the method can detect. Examples of these aspects include in high groundwater and in questionably porous soils. At a minimum, the method must be tested to detect leaks from any portion of the tank that normally contains product. If a water ingress method is used, refer to EPA's *Standard Test Procedures For Evaluating Release Detection Methods: Automatic Tank Gauging Systems*. If other sensors are used, test procedures are included in Section 4.5 of this document.

4.3.1 Application Of The Test Procedure To Acoustical Methods

One category of commercially available non-volumetric test methods is based on acoustical principles. If the method relies on a person's hearing, within one year of testing, this method requires that testers undergo a hearing test and their results are within the normal range, 0 to 20 decibels (http://www.hopkinsmedicine.org/hearing/index.html). Use Occupational Safety and Health Administration regulation 29 CFR 1910.95 pertaining to occupational noise exposure for guidance. Testers using the TTT method should have their hearing tested regularly. If the acoustical method uses an automated or computer-based detection method that does not rely on human hearing, then hearing tests are unnecessary.

Acoustical methods use sensitive hydrophones to detect an acoustical signal from the tank. Record this signal and analyze it to identify a specific characteristic associated with a leak. One such method places the tank under a partial vacuum and investigates the acoustical signal for a characteristic bubble signature, induced when air is drawn from outside the tank, through an unobstructed hole in the tank wall, and into the liquid contained in the tank being tested. As stated in Section 3.3, the evaluator and the vendor choose the liquid used during the evaluation, but it must be capable of being used with the release detection method. Leaks in the ullage portion of the tank are identified by a particular frequency or whistle of air entering directly into the ullage space through holes in the tank wall. Another approach analyzes the acoustical signal for a characteristic sound of fluid flowing out of an orifice in the tank.

While these methods are called acoustical, they typically have additional modes of detecting leaks and are used in conditions of a high groundwater level. Generally, they rely on identification of water ingress to detect leaks in the presence of a high groundwater level. Acoustical methods can be used with a wide range of product levels in the tank. The temperature of the product in the tank does not affect these methods. You do not have to consider the sequence of temperature and filling conditions with these tests. Fill the tank to a level in the range specified by the method. Generally, it is assumed that acoustical tests do the testing at a single product level. If multiple levels are used, perform equal numbers of tests at each level.

To induce a leak for the acoustical methods, use a device that creates the same signal an actual leak would create. One way is to use an orifice-type leak simulator per Patent No. 5,168,748. This consists of a pipe inserted into the tank through one of the tank openings. The pipe is sealed to the tank. The bottom of the pipe is fitted with a cap that contains a calibrated orifice to allow product to leak into the pipe at the calibrated leak rate. The orifice must be calibrated using diesel fuel with the equivalent pressure exerted by the weight of diesel fuel in an 8-foot column to the desired leak rate of 0.10 gal/hr. For desired leak rates other than 0.10 gal/hr for containment sumps, the orifice must be correspondingly calibrated using diesel fuel with the equivalent pressure exerted by the weight of diesel fuel in an 8-foot column to the desired leak rate. This simulator works for either type of acoustical signal. Flow of liquid through the orifice produces the signal typical of liquid flow. If the tank is under partial vacuum, air is drawn into the tank through the orifice below the liquid level and produces bubbles. You need a means of closing the orifice so a 0 leak rate is induced and kept blind to the vendor.

Since temperature differential should not affect the acoustical methods, we simplified the approach discussed earlier in this subsection. The steps refer to Table 4, with the understanding there are no differences among T_1, T_2, T_3, and the partial emptying and refilling is unnecessary. It is assumed that acoustical tests use a single product level; see above.

Step 1 Establish leak rates to be tested – If only a single non-zero leak rate is used, select a leak rate between 0.0 and 0.10 gal/hr. If the vendor wants to establish a smaller detectable leak rate, you may use a value of less than 0.10 gal/hr.

Step 2 Randomize the test conditions – If only two leak rates – 0.0 and one other - are used, randomly assign one of them to LR_1 and the other to LR_2 as in Table 4. Randomly rearrange the order of the 21 pairs of tests listed in Table 4. This allows for additional randomization and provides better control on keeping the induced leak rates blind to the vendor.

Step 3 Set up – Have the vendor set up the test method in the tank. Assemble and install the required test equipment.

Step 4 Trial run – Following the test method's standard operating procedure, fill the tank to the recommended level. Have the vendor conduct a test with a known 0 leak rate and verify the method has been installed and is functioning correctly. This also confirms the tank is still tight and is capable of being used with the test method.

Step 5 Conduct release detection method testing – Induce the leak rate called for in the randomization developed above. Have the vendor test the tank with this induced leak rate and report the results. Record the calibrated induced leak rate and the vendor's results as either tight or leaking. Record the environmental conditions data and other ancillary data on the test logs; see Appendix B.

Step 6 When the first test is completed, change the leak rate to establish the second leak rate called for in the randomized series, per Table 4. When this induced rate is established, have the vendor test the tank. Record the environmental conditions data. After the vendor completes the test, record the reported result and the induced leak rate.

Step 7 Repeat step 6 until all 42 tests are complete.

In each case where the method declares a leak when the simulated leak is set to a tight condition, the evaluator must check to ensure the leak simulator is in the off position. Conversely, in each case where the method test result declares a tight condition and the simulated leak has been established, the evaluator must confirm the calibration of the simulated leak equipment immediately while minimizing actions that could impact the performance of the leak simulation equipment. If the calibration of the simulated leak equipment is not as expected, discard the test. As described in Section 5, the method can produce no more than one false alarm and still pass the standard evaluation. Thus, if a second false alarm occurs in the test series, the method fails, and you should terminate testing. Similarly, if only one non-zero leak rate is used, and if a second mistake is made with that non-zero leak rate, the method fails. At the point where the evaluator determines the method fails, consider concluding testing. However, you can continue testing to provide added information to the vendor. If you used a leak rate of less than 0.10 gal/hr, starting the test series again with a leak rate closer to 0.10 gal/hr may result in the method passing at that rate, but not at the smaller leak rate. If no errors occurred during 20 tight tank or 20 induced leak tests, the method passes.

4.3.2 Application Of The Test Procedure To Tracer Methods

The technical requirements for using tracers are described in the release detection section of the federal UST regulation on vapor monitoring; see 40 CFR 280.43(e). You must consider the following requirements in evaluating tracer methods:

- The backfill must be porous enough for a sensor to detect easily a low diffusion of vapors.
- The tracer must be volatile enough to produce vapor levels, which are detectable by the monitoring device.
- Groundwater, rain, or soil moisture must not interfere with operating the monitor.
- Background contaminations must not interfere with detecting releases from the tank.
- Optimize the number and positioning of the monitoring wells for detecting leaks from any part of the system.

Although these requirements are for continuous vapor monitoring devices, when a tracer technique is used as TTT, the requirements also apply. Accordingly, the test procedures consider these factors when evaluating tracer techniques.

There are many variables present in external monitoring, which are difficult to predict or control. These include the nature of the backfill material; moisture content of the soil; size of the excavation; type of soil surrounding the excavation; groundwater level; position of a leak relative to the sampling locations; and whether the method is aspirated or passive. In general, some minimum threshold concentration of tracer must be reached before a signal is generated. The lower the threshold, the more sensitive the method, but the more susceptible it will be to false alarms.

For test methods that involve the loss of product from the tank, design the induced leak rates to introduce the amount of tracer material into the soil that is released by leak rates of the specified size over the test period. Methods that add liquid tracer to the product specify a concentration of tracer in the product. Using a concentration of 10 ppm, a leak rate of 0.10 gal/hr, and a test and waiting time after introducing the tracer into the tank of 24 hours, you can calculate the amount of tracer that will be released. Release this amount during the leak simulation. One way to accomplish this is to make samples of a carrier, such as vegetable oil with tracer in the appropriate concentrations that can be introduced into the environment. Use these samples to spike the ground at small rates, giving the same amount of tracer released by the specified leak rates.

If the method uses gas tracers, they can be introduced into the ground to simulate leaks by using a flow meter to allow the gas to flow at the rate that will occur under the in-field testing conditions. For example, simulate a leak at 2 pounds per square inch (psi) and through an appropriately sized orifice, representing a hole that leaks liquid product at the designated leak rates of less than 0.10 gal/hr.

Note that once you introduce a tracer, gas, or liquid into the soil in a test, you must eliminate the tracer before the next test. You may use forced air to disperse the tracer to levels that are not detected and interfere with the method; you may conduct the next test with a different tracer or use a different site.

The following steps assume multiple tracers are available, one is used in the tank to investigate the false alarm possibilities, and others are used in leak simulations. Neither the temperature conditioning nor tank stabilization is an issue with tracer methods. Therefore, it is unnecessary to change fuel temperatures and fill and empty the tank frequently as part of the evaluation. At least 21 tests of the tank in the no-leak condition are required, as are at least 21 tests using the induced leaks.

Step 1 Establish leak rates to be tested – Decide whether to use a single non-zero leak or three non-zero leak rates and select these leak rates.

Step 2 Randomize the test conditions – Randomly assign the no-leak and leak conditions. Randomly rearrange the order of the 21 pairs of tests in Table 4 that result from assigning the leak rates.

Step 3 Prepare samples with carrier and tracer – Determine the rate of introducing tracer, if a gas, or liquid carrier and tracer, if a liquid, into the backfill to simulate the selected leak rates. If using a liquid tracer, prepare samples with the carrier and tracer in the needed concentrations, label these with the randomized test sequence, and provide them to the vendor. The vendor should not know whether or in what concentration the tracer is in the leak simulation samples.

Step 4 Prepare the tank – If using a liquid tracer, have the vendor introduce it at the desired concentration into the test tank and fill the tank to the desired level following normal operating procedures for the method. If using a gas tracer, empty the tank and have the vendor introduce the gas to the tank. The tank then serves to provide data on the 0 leak rates.

Step 5 Locate sampling ports – Have the vendor locate the sampling ports. Also, have the vendor locate a spiking port for leak simulation as far from the sampling ports and as close to the tank as possible. Be careful not to damage the tank when installing the ports in the backfill.

Step 6 Conduct the trial run – The trial run for a tracer verifies the method can be used under certain site conditions. Introduce a compound at the spiking port. Sample test locations to determine whether the compound is detected. The trial run verifies the soil or backfill conditions allow the tracer to migrate from the tank to the sensors; it determines the time needed for the migration and, thus, establishes a test time.

Step 7 Conduct release detection method testing – Have the vendor conduct a test of the tank for a 0 leak rate.

Step 8 Begin testing using the first non-zero leak rate – Have the vendor conduct a test. Note: If using two different tracers, it may be possible for the vendor to conduct the test on the tank at a 0 leak rate and the induced leak test at the same time.

Step 9 After completing the tests in steps 7 and 8, record the induced leak rate, the vendor's determination of tight or leaking, and the environmental conditions data on the test log; see Appendix C.

Step 10 Ensure you can use the test site for a second leak test by removing the current tracer or using a different one – Start the next induced leak rate as in steps 7 and 8 and have the vendor conduct another test. Record all results.

Step 11 Repeat step 10 until the test series is completed.

The vendor should be able to conduct tests on the tank containing the tracer repeatedly for the 0 leak rate tests. In conducting the repeated tests on the tight tank to estimate P(fa), repeat the steps of adding tracer to the product, which is actually a carrier, and mixing the tracer in the product, which is a carrier. The process of adding and mixing tracer is a likely cause of false alarms because it could lead to inadvertent release of tracer into the environment and be mistaken for a leak. The vendor should be able to simulate adding and mixing the tracer by using tracer-containing product or carrier and handling it in the same manner as the tracer solution.

Assuming that at least two tracers are available, you can run the tight tank tests and the simulated leak tests simultaneously. Prior to start of the test, prepare and code the containers of carrier. For each test, introduce the carrier sample in the spiking port. Half of them will contain tracer and half will not. Each test will consist of introducing one tracer, for example type A, into the tank and another sample, either a blank or tracer type B, into the spiking port. The vendor will sample the soil gas and report on the presence of any detected tracer. A finding of tracer A is a false alarm. A finding of tracer B when it was spiked is a correct detection. If using additional distinct tracer compounds, this process will continue spiking tracer C. A finding of both tracer B from a previous spike and tracer C from the current spike is a correct detection.

As described in Section 5, the method can record only one false alarm and still pass. If a second false alarm occurs in the test series, the method fails, and the evaluator may recommend to the vendor to end testing. Similarly, if using only one non-zero leak rate, and if a second mistake occurs with that non-zero leak rate, the method fails. At the point where the evaluator determines the method fails, you may conclude testing. If using a leak rate of less than 0.10 gal/hr, start the test series again with a leak rate closer to 0.10 gal/hr; this may result in the method passing at that rate, but not at the smaller leak rate.

4.4 Testing Problems And Solutions

Inevitably, some tests will be inconclusive due to broken equipment, spilling of product used to measure the induced leak rate, or other events that interrupt the testing procedure. Presumably, the field personnel can judge the validity of a test result. If a test is invalid, the following rules apply.

Rule 1 The minimum number of tests must be either 24 or 42 for volumetric or non-volumetric testing, respectively. If a test is invalid, report the reason and rerun the test. Note that the number of tests assumes all tests are done at a single product level. If using multiple levels, equal tests at each level are required and it may be necessary to increase the total number of tests.

Rule 2 If method fails during the first test, meaning the first test of a set of two, and if the time needed for fixing problems is less than 4 hours, then repeat that run. Otherwise, repeat the empty and fill cycle, as well as the stabilization period. Record all times.

Note: Report the average stabilization time or average time after introducing the tracer on the *Results Of U.S. EPA Standard Evaluation* form. If the delay increases this time noticeably, then rerun the test sequence.

Rule 3 If method fails during the second test, meaning after the first test in a set has been completed successfully, and if the time needed for fixing problems is less than 4 hours, then repeat the second run. Otherwise, repeat the whole sequence of empty and fill cycle, stabilization, and test at the given conditions.

Rules 2 and 3 apply only if the testing schedule requires temperature conditioning effects. Otherwise, the time between tests is unimportant.

4.5 Sensor Evaluation Test Procedures

When testing sensors, the operating principle of the sensor drives test design, and fuel products dictate the limitations of its use in UST systems. Since a sensor may perform differently when in contact with various fuel products, such as ethanol blends or ethanol blends contaminated with water, it is necessary to follow the appropriate procedures with a range of these blends and calculate the specificity and accuracy with each blend; see below. Results will show an operating range of hydrocarbon content or ethanol content that can be presented as limitations of use in the reporting forms. Test the sensors in the types of liquids that they would be expected to respond to under normal operating procedures. However, liquid level sensors should respond to any liquid after the liquid level exceeds the threshold. If the evaluator finds that the sensor does not respond to a particular liquid type, note this on the report forms. The thresholds may vary slightly as the product density varies for float sensors. The evaluator determines which blends and how many different blends to test. Testing procedures for sensor functionality in systems with alcohol blends must include testing with a variety of amounts of water to determine whether water interferes with performance of sensors designed to react to a change in electric potential, such as capacitance and conductivity sensors. At minimum, the evaluator must test the vendor's desired alcohol blend and that alcohol blend with three water mixtures: 80 percent alcohol blend and 20 percent water; 60 percent alcohol blend and 40 percent water; and 30 percent alcohol blend and 70 percent water. For sensors that discriminate between hydrocarbons and water intended to be used in alcohol blends, to determine reliability and accuracy of a sensor for a specific alcohol blend, the evaluator must evaluate the discriminatory sensor both with alcohol blend fuel that is fully in solution with water, as well as with distinct phase separation layer with neat gasoline on top. The sensor may only detect a certain layer or layers.

The following performance parameters, which are defined below, are determined by these test procedures. Report the data collected on these parameters, as applicable, on the forms and tables in Appendix D.

- Threshold, lower detection limit – The smallest product thickness that the detector can reliably detect.
- Precision, standard deviation – Agreement between multiple measurements of the same product level.
- Detection time – Amount of time the detector must be exposed to product or test condition before it responds.
- Recovery time – Amount of time before the detector stops responding after being removed from the product.
- Specificity – Types of products a sensor will detect.

4.5.1 Liquid Phase Sensor Test Procedures

Before performing an evaluation testing with a sensor, ensure the sensor is functioning and properly calibrated. Properly calibrate all equipment making independent measurements during testing and ensure the equipment is in working order.

You can evaluate liquid sensors within a clear glass test vessel with a sufficiently large inner diameter to accommodate the sensor without being excessively wide. You will need a method to measure the liquid height. A simple way is to use a ruler, graduated in millimeters, affixed to the outside of the test vessel. Use an explosion-proof pump for the product ingress and a peristaltic pump to deliver water into the test vessel. When using a fuel pump, you must use tubing that is compatible with fuel. Secure the tubing in place so the liquids will flow along the side of the container to the bottom without touching the sensor. The fuel and water ingress rates are set to achieve a height increase rate of approximately 5 millimeters per minute (mm/min). Calculate the rate of height increase by taking into account the volume displacement of the sensor in the test vessel. Once the sensor and ingress lines are situated in the test vessel, cover the top of the vessel to minimize volatilization.

Before initiation of testing, configure the test vessel as described above and insert the sensor through the top of the test chamber. The sensor configuration with respect to the test vessel – for example, suspended, vertically or horizontally resting on the bottom of the test chamber – will be in concert with requirements of the vendor supplied literature and as close to intended field-operating configuration as possible. Operate all sensors according to vendor-supplied operations manuals and guidance including wiring, data collection, and maintenance. Additional measures may be appropriate to simulate the operating environment of the sensor, for example wrapping the test vessel to minimize light with optical sensors. Record this adjustment to the test set on the data collection form.

Collect the following data for sensor testing: test start time; sensor actuation time; liquid level height at activation; test end time; and test recovery time for each test condition. Use these data to calculate the metrics for the performance parameters of the test sensor.

Liquid Detection Test In Dry Space

The tests presented in this section simulate ingress of product or groundwater into a dry environment or secondary containment, such as an interstice. Non-discriminating sensors will respond to the presence of any liquid; however, incorporate at least three initial detection liquids into the test design for the specificity calculation. Use an evaluator-chosen diesel fuel, groundwater and gasoline or alcohol blend (as applicable), then perform 10 replicate tests on each liquid. Use the most common gasoline blend or alcohol blend at the time of testing. For testing sensors intended to be used in alcohol blends that are designed to react to a change in electric potential such as capacitance and conductivity sensors, at minimum, the evaluator must test the alcohol blend, in addition, that alcohol blend with three water mixtures: 80 percent alcohol blend and 20 percent water; 60 percent alcohol blend and 40 percent water; and 30 percent alcohol blend and 70 percent water.

After placing the sensor inside the empty test vessel and activating it for data collection as per the vendor instructions, monitor the output for 30 minutes as a blank test to establish the baseline signal. Pump the product or groundwater from the graduated cylinder into the test vessel at approximately 5 mm/min. Ensure the sensor is in place to detect this ingress of liquid and react with a positive test result or not react in a negative test result.

At the completion of the tests, remove the sensor and the liquid from the test chamber. Measure the liquid volume without the sensor and then handle the liquid appropriately by treating or disposing of it properly. Rinse the sensor with water or clean it by following the vendor recommended recovery procedure; monitor the recovery time.

With most liquid level sensors, conduct the following procedure with water, non-alcohol blended gasoline, and diesel fuel. If the sensor is to be used with alcohol blends, test with the desired alcohol blend. In addition, use the identified water, alcohol, and petroleum fuel mixtures identified above for sensors designed to react to a change in electric potential. To determine the threshold and precision of a sensor, follow the steps below.

Step 1 Set up – Mount the sensor in the test vessel with a known, uniform diameter from top to bottom. Fasten the sensor securely so it is in contact via its normal orientation with the liquid test vessel bottom.

Step 2 Blank test – Activate and monitor sensor for a minimum of 30 minutes to establish a baseline.

Step 3 Conduct liquid level testing – Add liquid such as product or water to the test vessel from a burette capable of reading volume to the nearest 0.2 ml or pump liquid into the vessel at a height increase of approximately 5 mm/min. Add liquid until the sensor responds to the liquid. Allow adequate time between increments for the sensor to respond if the response time is not instantaneous. Once the sensor activates, the initial detection test is complete.

If the sensor does not activate, bring the liquid height to 20 percent higher than the vendor stated actuation height and turn off the pump. Wait for 60 minutes without detection before aborting the test. If a specific wait time is required, the initial detection test is complete after the wait time has elapsed.

Step 4 When the approximate threshold has been determined, remove the sensor, and empty the cylinder of liquid, then perform a repeat measurement.

Step 5 For subsequent measurements, add liquid quickly to just below the threshold level.

Step 6 Add liquid very slowly until the sensor responds.

Step 7 Repeat steps 3 through 5 a minimum of 10 times for each liquid.

Step 8 Record all information in an appropriate manner.

The evaluator will determine if the sensor is affected by different product. To determine the specificity of the sensor, use multiple products following the same test procedures to collect a minimum of 10 replicates to compare the performance.

Test the sensors in the types of liquids they respond to under normal operating procedures. However, liquid level sensors should respond to any liquid after the liquid level exceeds the threshold and triggers the switch contact. If the evaluator finds that the sensor does not respond to a particular liquid type, record this finding on the report forms. The thresholds may vary slightly as the product density varies for float sensors.

Product Layer Detection On Top Of Water

Some external sensors are designed specifically not to alarm with water and to detect fuel product. In this case, for non-alcohol blends, water may accumulate in the space and if fuel is present, it will collect on top of the water creating a hydrocarbon layer. Install the sensor in the test vessel as it is used with water that has a layer of product on it. Test the sensor 10 times at each test product thickness of 0.0250 centimeters (cm) or 0.0625 in; 0.32 cm or 0.125 in; and 0.64 cm or 0.25 in on two different fuel products; note that these thicknesses are 1/16 inch, 1/8 inch, and 1/4 inch, respectively. Test diesel fuel and if the sensor is to be used with alcohol blends, test with the vendor chosen alcohol blend. To determine reliability and accuracy of a sensor for a specific alcohol blend, the evaluator must evaluate the discriminatory sensor both with alcohol blend fuel that is fully in solution with water, as well as with distinct phase separation layer with neat gasoline on top. The sensor may only detect a certain layer or layers. With input from the vendor, the evaluator chooses the product as to the intended purpose of the sensor. With the collected data, the evaluator determines the accuracy and precision of the sensor.

Visually, it is difficult to measure the thickness of the product layer on water, especially if the product is somewhat miscible in water. For non-alcohol blends, the evaluator may determine the layers mathematically under the assumption that there is no interaction of the product with water. Where product is appreciably miscible in water for fuels such as alcohol blends this assumption cannot be made. Regardless of type product, you must know the dimensions of the test vessel to calculate the thickness of the product layer. Conduct random tests and allow no more than 24 hours for the sensor to react.

After completing each test, rinse the sensor with water or clean it by following the vendor-stated recovery procedure; monitor the recovery time.

Step 1 Cross sectional area – Estimate the area of the cross section of the sensor that is parallel to and at the same level as the test product. Calculate the cross-sectional area of the test vessel.

Step 2 Set up – Mount the sensor in the test vessel. Securely fasten the sensor so it is in contact via its normal orientation with the liquid test vessel bottom.

Step 3 Blank test – Calibrate the sensor. Activate and monitor sensor for a minimum of 30 minutes to establish a baseline. If the output is unstable after 30 minutes, wait until it becomes stable.

Step 4 Add water – Add the appropriate volume of water, or approximately 2 liters, to the test vessel as stated by the vendor. The volume of water added must allow the sensor to be fully functional. The water should be within 2°C of room temperature, which should be between 15°C and 28°C.

Step 5 Determine the amount of product to add to the water – Calculate the volume of the product to add to the test vessel for each product layer thickness of 0.04 cm, 0.32 cm, and 0.64 cm with the following equations:

$$Volume\ (mL) = th \times (a_c - a_d)$$

Where *th* is the desired product thickness in cm; a_c is the test vessel cross sectional area in cm^2; and a_d is the estimated sensor cross sectional area in cm^2. Begin testing with the thickest layer and continue to the smaller layers.

Step 6 Add the product and conduct the testing – Add the calculated volume for the thickest layer to the test vessel without splashing or contacting the container walls. Cover the test vessel immediately to reduce product loss. Do not stir or otherwise disturb the test setup. Monitor the output of the sensor. For quantitative sensors, monitor the output at least until the signal becomes stable or 24 hours elapses, whichever is shorter. The period for detection time is from the start time to the time the sensor reaches 95 percent of its final stable output. For qualitative detectors, monitor the output until it activates or 24 hours elapse, whichever is shorter. Record the results.

Step 7 Clean vessel – Remove the liquid from the test vessel and rinse the vessel with water, then acetone to remove all product residue.

Step 8 Repeat steps 3 through 5 a minimum of 10 times for each product layer. Record all results.

4.5.2 Product Vapor Phase Sensor Test Procedures

For gasoline, test the sensor with at least two gases. The first gas must be either benzene or 2-methylbutane. The evaluator, with input from the vendor, will select the second gas. Include a justification for the chosen gas in the test results. For fuel types other than gasoline, the evaluator must select the test gases, with input from the vendor to closely match the fuel type for which the sensor will be used. Include a justification for the chosen gasses in the test results. The test gas concentrations by volume are nominally 0.005 percent of the lower explosive limit (LEL), 0.025 percent of the LEL, 0.05 percent of the LEL, and 0.01 percent of the LEL. For fuel types where test gas LEL is not applicable, the test gas concentrations by volume are nominally 5 percent of current test gas immediately dangerous to health or life (IDHL) value, 25 percent IDHL, 50 percent IDHL, and 100 percent IDHL. Randomly conduct the tests 10 times at each concentration for both gases. Allow the sensors up to 24 hours to respond to the test conditions.

When testing the specificity of the sensor, test multiple gasses with 10 replicates at one concentration of 0.005 percent of the LEL or 50 percent IDHL where applicable. For gasoline the suggested gasses are benzene, n-butane, n-hexane, isobutane, 2-methylpentane, 3-methlpentane, and toluene. The evaluator, with input from the vendor, may test other gases.

After completing each test, purge the vessel with high purity air and measure the time until a steady background or recovered response from the sensor is established. The nature of the recovery response depends on whether the detector gives a quantitative or qualitative response.

Step 1 Randomize the test conditions – Randomly arrange the order of the gases at the various concentrations for the test design.

Step 2 Set up – Install and calibrate the sensor into the vapor test vessel as stated by the vendor in relation to how it is installed at an UST facility. Calibrate all monitoring equipment. The seal between the sensor and the test vessel should be gas tight.

Step 3 Purge the test vessel for at least three minutes with ultrahigh-purity air at 0.2 L/min before each test.

Step 4 Introduce gas and conduct the testing – Add the test gas to the test vessel at the sufficient rate to produce a 0.2 L/min test system vent flow rate according to the random test design. Monitor the output of the sensor. For quantitative sensors, monitor the output at least until the signal becomes stable at ± 2 percent of full scale over 1 minute or 24 hours elapses, whichever is shorter. The period for detection time is from the start time to the time the sensor reaches 95 percent of its final stable output. For qualitative detectors, monitor the output until it activates or 24 hours elapse, whichever is shorter. Record the results.

Step 5 Repeat steps 3 and 4 a minimum of 10 times for each gas and concentration. Record all results.

4.5.3 Test Procedures For Tightness Testing Using A Vacuum Monitor On A Double-Walled Tank Interstice With Or Without The Addition Of A Liquid Sensor

This evaluation determines the ability of a leak detection system to detect an air leak, fuel leak, or water leak in the interstitial space of a double-walled tank. Results of this evaluation determine whether the system can detect a leak of 0.10 gal/hr in addition to the time required for the method to detect the induced leak. The leak must be calibrated using diesel fuel with the equivalent pressure exerted by the weight of diesel fuel in an 8-foot column to the desired leak rate of 0.10 gal/hr. For desired leak rates other than 0.10 gal/hr for containment sumps, the orifice must be correspondingly calibrated using diesel fuel with the equivalent pressure exerted by the weight of diesel fuel in an 8-foot column to the desired leak. The evaluation consists of testing both the vacuum sensor as well as testing the liquid sensor. When testing the vacuum sensor, use a test vessel of approximately 5 gallons to simulate the open space of a double-walled tank interstice where air ingress leaks are induced. If there is a liquid level sensor present at the low point of the interstitial space, there is no need for the vacuum sensor to be tested with product leaks since the liquid sensor will alarm with the presence of product or water. When testing the liquid sensor portion of the method, evaluate the liquid sensor following the liquid phase sensor test procedure requirements listed in Section 4.5.1.

If the leak detection method does not include a liquid sensor in the interstice, it will be necessary to perform additional tests with a simulated liquid leak into the test vessel to determine the methods ability to detect a liquid leak. The leak, which can be generated using a variable valve flow or an orifice, must be calibrated using diesel fuel with the equivalent pressure exerted by the weight of diesel fuel in an 8-foot column to the desired leak rate of 0.10 gal/hr. For desired leak rates other than 0.10 gal/hr for containment sumps, the orifice must be correspondingly calibrated using diesel fuel with the equivalent pressure exerted by the weight of diesel fuel in an 8-foot column to the desired leak rate.

After the test vessel is set up with the leak detection method, perform a baseline test to ensure there are no leaks in the system. Once the test vessel with the method is confirmed to be tight, begin the evaluation.

If the method is not an automated system, the vendor will specify the parameters that indicate a leak is detected.

During the vacuum sensor portion of the evaluation, perform 21 tests with the vessel in the non-leaking tight condition and 21 tests with an air ingress leak while inducing the pre-calibrated leak. Regardless of the vacuum level the vendor uses, the induced leak will not change from its pre-calibrated rate of 0.10 gal/hr using diesel fuel with the equivalent pressure exerted by the weight of diesel fuel in an 8-foot column.

Vacuum Sensor Test Procedure

Step 1 Set up – The evaluator must set up the test vessel and verify it is in a tight non-leaking condition. After verifying the vessel's tightness, then calibrate the leak at a rate of 0.10 gal/hr using diesel fuel with the equivalent pressure exerted by the weight of diesel fuel in an 8-foot column. Once the leak is calibrated, install the leak simulation device onto the test vessel. The vendor then installs and calibrates their sensor or vacuum gauge into the test vessel. Calibrate all monitoring equipment. Perform the tightness test as specified by the vendor.

Step 2 Conduct the testing – If the leak detection method includes the use of a liquid sensor, then perform a total of 42 tests. Of the 42 test total, perform 21 tests with a leak induced at the pre-calibrated leak rate of 0.10 gal/hr and perform 21 tests in a tight condition. If the leak detection method does not contain a liquid sensor, then 21 tests will need to be performed with each liquid the method might encounter including water, unleaded fuel and diesel fuel. For the leak induced tests, induce the calibrated leak allowing air or liquid to flow into the test vessel until reaching the specified alarm level of vacuum. Close the air inlet after the vacuum has decayed to the vendor specified level. Record the elapsed time from when the leak was induced until the system alarms or the specified alarm level of vacuum is reached. If the method fails to identify the tight or non-tight condition within the vendor's specified time frame, the method fails the evaluation test.

In each case where the method's test result declares a leak when the simulated leak is set to a tight condition, the evaluator must confirm the test vessel is not leaking. Conversely, in each case where the method's test result declares a tight condition and the simulated leak has been established, the evaluator must confirm the calibration of the simulated leak equipment. If the calibration of the simulated leak equipment is not as expected or if a leak is found in the test vessel, then discard the test. If a method incorrectly reports either a leak or tight condition and all of the equipment is operating as it should, then the method fails the evaluation test.

Step 3 Reestablish the vacuum – Reconnect the vacuum source and repeat the test by establishing the normal operating level of the vacuum in the test vessel.

Step 4 Repeat steps 2 and 3 a minimum of 21 times with an air leak induced, 21 times with no leak induced and, if required, 21 times with a liquid leak induced for any liquid that the method may encounter including water, unleaded fuel and diesel fuel.

4.5.4 Recovery Time

After the end of the individual tests, turn off the pumps and remove the sensor from the chamber. Rinse the sensor with water or follow the vendor-stated recovery procedure and monitor for recovery time.

Step 1 After individual test, remove the sensor from the test condition and follow the vendor-stated recovery procedure.

Step 2 Using a stopwatch or console, record the time required for the sensor to stop alarming after the alarm condition is reported. If the sensor results are an output signal, the recovery time is concluded when the sensor returns to within 5 percent of the baseline level.

Step 3 Repeat the above procedures a total of 42 times with 21 air leaks induced and 21 tests in the tight condition. If a liquid sensor is not included in the method, repeat the above procedures an additional 21 times for each type of liquid leak that the method might encounter including water, unleaded fuel and diesel fuel. Perform the leaks induced and the tight tests in a randomized order. Record the data on the individual test logs.

4.5.5 Test Procedures For Tightness Testing On A Liquid Filled Interstice Of A Double-Walled Pipeline Using A High Pressure And A Low Pressure Limit Switch Sensor

This section describes how to conduct testing on liquid filled interstitial monitors for double-walled pipelines. You may apply the results of this evaluation to any leak detection system that performs tightness testing on a pressurized liquid filled interstice of a double-walled pipeline using high and low pressure limit switches.

Since interstitial monitoring systems are highly dependent on the type of piping materials used, the performance of the tightness test method only applies to the type of pipeline and interstitial fluid used during the evaluation.

The evaluation procedures during this evaluation include 42 tests with 21 tests performed with the interstice in a non-leaking condition and 21 tests performed with a 0.10 gal/hr leak present. Calibrate the leak to 0.10 gal/hr at the pressure level that the method's high pressure limit switch uses.

One potential concern to evaluate for the method, other than the 42 leak performance tests, is making sure the thermal effects do not cause the pressure level to fluctuate beyond the pressure limit switches used to monitor for a leak. Two possibilities are: the pressure will drop too far and trigger a leak alarm or the pressure will rise too high and trigger a high pressure alarm. In addition to the 42 tightness tests, consisting of 21 leak and 21 tight, also perform tests to demonstrate the method can overcome thermal effects.

Applicability

Use this procedure to test any doubly contained pipeline system with a pressurized liquid filled interstice using a high and low pressure limit switch. Connect the sensors to some type of control panel that can be configured to provide the operator with an alarm or will shut down dispensing, if a leak occurs. If the system also uses a liquid sensor in any way, evaluate the liquid sensor following the liquid phase sensor test procedure requirements in Section 4.5.1.

Test Apparatus

Construction Of Test Line

To conduct these tests, construct or identify a pipeline with a known volume. You may perform the evaluation in any volume line up to 50,000 gallons. The results of the evaluation are applicable to all smaller pipelines of the same construction; therefore, the larger the test line, the broader the applicability of the evaluation. The results are also applicable to larger pipelines of the same construction with the restriction the lines be no more than 100 percent larger in capacity than the test pipeline. The test pipeline must include one of each of the types of fittings normally found in a service station and may be clustered together. Access to the ends of the test pipeline must be provided for inducing leaks, circulation of fluid through the primary pipeline, or other activities associated with the testing. The testing may be conducted in a laboratory or shop environment.

You can use water as the liquid in the primary space of the pipeline for all the tests performed for the evaluation. The liquid in the interstice must be of the same type used by the manufacturer for installed systems. Fill the interstice using the same procedures as specified by the pipeline manufacturer at a field installation or when pre-filled at the factory before shipping. This could include gravity feed, evacuation of the interstice prior to filling, or other technique designed to minimize the amount of air trapped in the interstice. When completed in a laboratory environment, insulate the laboratory line from the environment so that temperature of the system is not subject to rapid temperature fluctuations produced by the ambient conditions. You may use aluminized mylar bubble pack or other easy-to-handle material.

Test Equipment

Heating And Cooling

Provide for circulating hot and cold water through the primary pipe during the evaluation process. You can accomplish this by using the equipment described below or by another equivalent method that can maintain the circulation of water at a constant temperature for one hour or until the entire test assembly has reached thermal equilibrium.

Use an insulated 55-gallon drum or other suitable container as a reservoir. Lower the water temperature to a nominal temperature of 32°F by adding crushed ice to the reservoir. If an excess of ice is present, the temperature will be maintained at near 32°. Use a small, low-pressure pump to circulate the water through the primary pipe. The capacity of the pump must be sufficient to provide a water flow rate between 5-10 gallons per minute.

Heat the water by using a small flow through heater in the water return line. The heater must be capable of heating the water to at least 110°F and maintaining the temperature at 100°F during the circulation.

Pressurizing The Pipeline
To provide for the pressure testing, use a pump capable of delivering a pressure up to the pipeline system manufacturer's pressure limit, but not to exceed 45 psi. Connect the pump to the primary line at either the inlet or outlet of the test assembly.

Induced Leaks
Calibrate the leak to 0.10 gal/hr at the pressure level that the method's high-pressure limit switch uses. Induce leaks using any type device that adjusts with pressure fluctuations such as an orifice or variable valve flow meter.

Temperature Measurements
Temperature measurements should be made to 0.5°F using a temperature device with an accuracy of 0.5°F. The accuracy is less important than the resolution but calibrate all temperature devices to within 0.5° of each other. Take temperature measurements in the circulation reservoir and on the outside of the interstice under the insulation within 12 inches of the inlet to the primary pipe.

Pressure Measurements
Make pressure measurements to 1.0 psig or better. The pressure gauge should have a range of twice the expected pressure range of the testing and have an accuracy of at least 3 percent of full scale.

Evaluation Procedures

Primary Pipe Pressure And Thermal Effect Test
Several types of tests must be conducted to establish the characteristic of the pipeline under consideration. These include:

- Effects of pressure in the primary pipe on the interstitial pressure
- Effects of temperature on the pressure level in the interstice
- Effects of a catastrophic failure of the primary pipe
- Flow through the interstice

Conduct these tests by monitoring the pressure level in the interstice with a device capable of measuring the actual changes produced in the testing. The high and low pressure limit switch sensors used for monitoring cannot be used for these tests. The test procedures are summarized below.

Effects Of Pressure In The Primary Pipe On The Liquid Level
This test involves raising the pressure in the primary pipe from 0 psig to 45 psig. Monitor the liquid level in the reservoir at regular intervals during this time.

Step 1 Set the pressure level in the interstice at the level specified by the vendor while the pipeline temperature is at the ambient temperature of the testing facility.

Step 2 Raise the pressure in the inner pipe from 0 up to the maximum pressure specified by the piping manufacturer, but not more than 45 psi. Raise the pressure in 15 psi increments.

Step 3 Note the change in the interstitial pressure after each increment. This pressure is approximately 1.5 times the pressure expected at a typical service station installation.

Step 4 Hold the pressure at the highest pressure for at least 10 minutes before making the final level measurement.

Step 5 Return the line to ambient pressure and note the final pressure in the interstice.

If the pressure increase of the primary pipe causes the pressure in the interstice to exceed the high pressure limit switch, then the method fails the evaluation.

Effects Of Temperature On The Pressure Of The Interstice
This test involves circulating hot and cold water at a constant temperature through the primary pipe. Measure the temperature of the interstice by placing a thermocouple between the bubble pack insulation and the outer pipe. Measure the liquid level in the reservoir periodically during the circulation until attaining a constant interstitial temperature and interstitial pressure. The temperature of the circulated fluid should range from approximately 32°F, achieved by using ice for cooling, to 100°F, which is a temperature range of approximately 68°F.

Conduct the test as follows:

Step 1 Circulate water at a nominal temperature of 32°F through the primary pipe for at least 30 minutes. Maintain this temperature during the entire circulation period.

Step 2 Continue circulation until the interstice pressure is stable.

Step 3 Monitor the outer wall of the interstice with a thermocouple. If collecting data manually, take data every 5 to 10 minutes until you obtain stable readings.

Step 4 Ensure the interstitial temperature measurement is stable before beginning the temperature increase.

Step 5 Repeat this process using water heated to a nominal temperature of 100°F.

Step 6 Continue circulation until the interstice pressure is stable.

Step 7 You can also conduct this process starting at the high temperature and going down to the low temperature.

If the thermal effects cause the pressure in the interstice to exceed the method's high or low pressure limit switch, then the method fails the evaluation.

Effects Of A Catastrophic Failure Of The Primary Pipe

Conduct the effects of a catastrophic failure of the inner pipe at a minimum of two locations. The first should be within 3 feet of the liquid reservoir and the second at a point within 3 feet of the far end of the test line. Produce the catastrophic leak by introducing the interstitial liquid into the interstice at a pressure of 30 psi.

Step 1 Configure the test line to allow the introduction of interstitial liquid through a ball valve and into the interstice at a pressure of 30 psi.

Step 2 Ensure the inlet for the catastrophic leak is within 36 inches of the reservoir for one of the two tests.

Step 3 Rapidly open a valve capable of allowing a flow of at least 10 gal/min into the interstice.

Step 4 Ensure the alarm system is capable of shutting off the turbine.

Step 5 Repeat this process at the far end of the pipeline.

If the high level limit switch is not triggered with the interstice pressured to 40 psi, or whatever the evaluator deems appropriate based on the system's high level limit setting, then the method fails the evaluation.

Tightness Test Evaluation Procedures On The Interstice

This evaluation procedure determines the ability of the method to detect a leak with a rate of 0.10 gal/hr or smaller in the interstice of a double-walled pipeline.

Step 1 Set up – The evaluator must set up the pipeline and verify that the interstice is in a tight non-leaking condition. Fill the primary space of the pipeline with water. Calibrate the leak simulation device to a leak rate of 0.10 gal/hr at the pressure level to which the method's high pressure limit switch is set. Install the leak simulation device at the furthest point away from the pressure limit switches.

Step 2 Conduct the testing – Perform a total of 42 tests. Of the 42 tests total, perform 21 tests with a leak induced at the pre-calibrated leak rate of 0.10 gal/hr and perform 21 tests in a tight condition. For leak induced tests, induce the calibrated leak allowing interstitial fluid to flow out of the interstice through the leak simulation device until exceeding the specified alarm level of pressure.

Shut off the leak simulation device once the pressure has decayed beyond the vendor specified level. Record the elapsed time from when the leak is induced until the system alarms or the specified alarm level of vacuum is reached. If the method fails to identify the tight or non-tight condition within the vendor's specified time frame, the method fails the evaluation test.

In each case where the method's test result declares a leak when the simulated leak is set to a tight condition, the evaluator must confirm that the interstice is not leaking. Conversely, in each case where the method's test result declares a tight condition and the simulated leak is established, the evaluator must confirm the calibration of the simulated leak equipment. If the calibration of the simulated leak equipment is not as expected or if a leak is found in the interstice, then discard the test. If a method incorrectly reports either a leak or tight condition and all of the equipment is operating as it should, then the method fails the evaluation test.

Step 3 Repeat the next test by establishing the normal operating level of the pressure in the interstice.

Step 4 Repeat steps 2 and 3 a minimum of 21 times with a leak induced and 21 times with no leak induced. Record all results.

Section 5: Calculations

From the results obtained after testing volumetric and non-volumetric methods, evaluate the method's performance through a series of calculations presented in Section 5.1 and 5.2, respectively. If the method has more than one mode of release detection, then evaluate and report the performance of the method for each testing mode separately. If the performance is different for different modes, this may limit the conditions under which the method can be used and report these under the limitations section of the results form.

After performing tests according to the schedule outlined in Section 4, a minimum of 24 or 42 test results will be available. If the P(fa) and P(d) are not at the regulatory level with the tanks connected by siphon piping data included, the method is inappropriate for tanks connected by siphon piping and is limited to single tanks. In this case, to test the tanks, break the siphon connection in order to isolate each tank for separate testing.

5.1 Estimation Of The Volumetric Method Performance Parameters

After performing all tests according to the basic test design, a total of at least n = 24 data points each of 4 leak rates x 3 temperature differentials completed twice of measured leak rates and induced leak rates will be available. These data form the basis for the performance evaluation of the method. Denote the measured leak rates by $L_1, \ldots L_n$ and the associated induced leak rates by $S_1, \ldots S_n$. Number these leak rates in chronological order. Table 5 summarizes the notation used throughout this test procedure, using the example test plan of Table 3.

5.1.1 Basic Statistics

The number of tests is designated by n. Calculate the mean squared error (MSE), the bias (B), and the variance of the method as follows.

Mean Squared Error, MSE

$$MSE = \sum_{i=1}^{n} (L_i - S_i)^2 / n$$

Where L_i is the measured leak rate obtained from the i^{th} test at the corresponding induced leak rate, S_i, with i =1, … n.

Bias, B

$$B = \sum_{i=1}^{n} (L_i - S_i) / n$$

The B is the average difference between measured and induced leak rates over the number of tests. It is a measure of the accuracy of the method and can be either positive or negative.

Table 5. Notation Summary

Test No.	Pair No.	Set No.	Nominal Temperature Differential (degree F)	Nominal Leak Rate (gal/hr)	Induced Leak Rate (gal/hr)	Measured Leak Rate (gal/hr)	Absolute Leak Rate Difference |L - S| (gal/hr)
1	1	1	T_2	LR_1	S_1	L_1	d_1
2	1	1	T_2	LR_2	S_2	L_2	d_2
3	2	1	T_2	LR_4	S_3	L_3	d_3
4	2	1	T_2	LR_3	S_4	L_4	d_4
5	3	2	T_1	LR_1	S_5	L_5	d_5
6	3	2	T_1	LR_4	S_6	L_6	d_6
7	4	2	T_1	LR_2	S_7	L_7	d_7
8	4	2	T_1	LR_3	S_8	L_8	d_8
9	5	3	T_3	LR_4	S_9	L_9	d_9
10	5	3	T_3	LR_1	S_{10}	L_{10}	d_{10}
11	6	3	T_3	LR_3	S_{11}	L_{11}	d_{11}
12	6	3	T_3	LR_2	S_{12}	L_{12}	d_{12}
13	7	4	T_2	LR_3	S_{13}	L_{13}	d_{13}
14	7	4	T_2	LR_4	S_{14}	L_{14}	d_{14}
15	8	4	T_2	LR_2	S_{15}	L_{15}	d_{15}
16	8	4	T_2	LR_1	S_{16}	L_{16}	d_{16}
17	9	5	T_1	LR_2	S_{17}	L_{17}	d_{17}
18	9	5	T_1	LR_3	S_{18}	L_{18}	d_{18}
19	10	5	T_1	LR_4	S_{19}	L_{19}	d_{19}
20	10	5	T_1	LR_1	S_{20}	L_{20}	d_{20}
21	11	6	T_3	LR_3	S_{21}	L_{21}	d_{21}
22	11	6	T_3	LR_2	S_{22}	L_{22}	d_{22}
23	12	7	T_3	LR_4	S_{23}	L_{23}	d_{23}
24	12	7	T_3	LR_1	S_{24}	L_{24}	d_{24}

Variance And Standard Deviation

Obtain the variance as follows:

$$Variance = \sum_{i=1}^{n} [(L_i - S_i) - B]^2 / df$$

Standard deviation (SD) is the square root of the variance. Where df = degrees of freedom.

Note: Plot the differences between the measured and induced leak rates against the time or the order in which they are performed. This allows the evaluator to detect any patterns that might exist, indicating potentially larger differences in the results from the first test of each set of tests, among the three temperature differentials, or between in-tank product levels. This could suggest the method calls for an inadequate stabilization period after filling, the method does not properly compensate for temperature differences between in-tank product and product to be added, or the method is influenced by the product level.

Note: Tank tightness tests usually require testing at 90-95 percent full. If a lower level is used, the method is restricted to the lower level and you cannot use tanks that contain more product than the level tested, unless the tank ullage was tested by another method.

It may also be useful to plot the differences between the measured and induced leak rates by induced leak rate. This graphically shows the accuracy and precision of the method at the various leak rates used during testing. See Section 5.3 for appropriate statistical tests.

Test For 0 Bias

To test whether the method is accurate – that is, the bias is 0 – perform the following test on the bias calculated above.

Compute the t-statistic

$$t_B = \sqrt{n}B/SD$$

From the t-table in Appendix A, obtain the critical value corresponding to a t with (n - 1) = df and a two-sided 5 percent significance level. For 24 tests and 23 df, this t-value is 2.07.

Compare the absolute value of t_B, abs(t_B), to the t-value. If abs(t_B) is less than the t-value, conclude the bias is not statistically different from 0, and the bias is negligible. Otherwise, conclude the bias is statistically significant from 0.

5.1.2 False Alarm Rate, P(fa)

Assume the normal probability model for the errors in the measured leak rates. Using this model, together with the statistics estimated above, allows for the calculation of the predicted P(fa) and P(d) of a leak of 0.10 gal/hr.

The vendor will supply the threshold (Th) for interpreting the results. Typically, the leak rate measured by the method is compared to C and the results interpreted as indicating a leak if the measured leak rate exceeds the vendor stated C. The P(fa) is the probability the measured leak rate exceeds C when the tank is tight. Note that by convention, all leak rates representing volume losses from the tank are treated as positive.

P(fa) is calculated by one of two methods, depending on whether B is statistically significantly different from 0.

P(fa) With Negligible Bias

In the case of a nonsignificant B in Section 5.1.1, compute the t-statistic

$$t_1 = Th/SD$$

where SD is the SD calculated above and Th is the method's threshold. Using the notational convention for leak rates, Th is positive, obtain P(fa) from the t-table, using n-1 df. P(fa) is the area under the curve to the right of the calculated value t_1.

In general, t-tables are constructed to give a percentile, t_a, corresponding to a given number of df, df, and a preassigned area, alpha (α), under the curve, to the right of t_a; see Figure 2. For example, with 23 df and $\alpha = 0.05$ (equivalent to a P(fa) of 5 percent), $t_a = 1.714$.

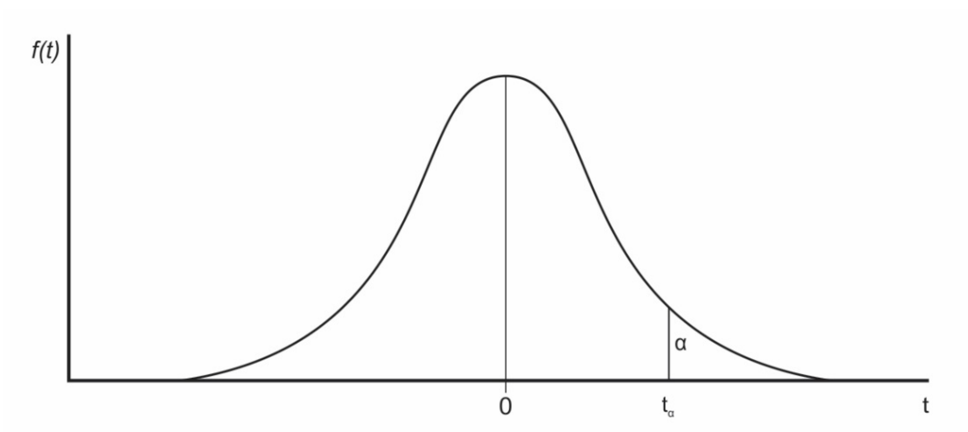


Figure 2. Student's t-Distribution Function

In this case, however, the area under the curve to the right of the calculated percentile, t_1, with a given number of df needs to be determined. This can be done by interpolating between the two areas corresponding to the two percentiles in Table A-1 in Appendix A on either side of the calculated statistic, t_1.

The approach would be to use a statistical software package, for example, Microsoft Excel™, SAS™ or SYSTAT™, to calculate the probability.

P(fa) With Significant Bias

The calculations are similar to those in the case of a non-significant B, except the B is included in the calculation. Compute the t-statistic including B as follows:

$$t_2 = (Th - B)/SD$$

P(fa) is then obtained by interpolating from the t-table, using n-1 = df. P(fa) is the area under the curve to the right of the calculated value t_2. Note that Th is positive, but B can be either positive or negative.

5.1.3 Probability Of Detecting A Leak Rate Of 0.10 gal/hr, P(d)

The P(d) with a leak rate of 0.10 gal/hr is the probability the measured leak rate exceeds Th when the true mean leak rate is 0.10 gal/hr. As for P(fa), use one of two methods in computing P(d), depending on whether the B is statistically significantly different from 0.

P(d) With Negligible Bias

In the case of a non-significant B – that is, the B is 0 – compute the t-statistic:

$$t_3 = (Th - 0.10)/SD$$

Next, using the t-table at n-1 = df, determine the area under the curve to the right of t_3. The resulting number is the P(d).

P(d) With Significant Bias

The calculations are similar to those in the case of a non-significant B, except the B is included in the calculation. Compute the t-statistic.

$$t_4 = (Th - B - 0.10)/SD$$

Next, using the t-table at n-1 = df, determine the area under the curve to the right of t_4. The resulting number is the P(d).

5.2 Estimation Of The Non-Volumetric Method Performance Parameters

5.2.1 False Alarm Rate, P(fa)

Use the results obtained from the tests performed under tight tank conditions to calculate P(fa). Let N_1 denote the number of these tests. Let TL_1 denote the number of cases where the method indicated a leak. If the test results, L_j, are coded as 0 when no leak is indicated and 1 when a leak is indicated, then

$$\mathrm{TL}_1 = \sum_{i=1}^{N_i} \mathrm{L}_i$$

where the sum is taken over the N_1 tests at 0 leak rate. The P(fa) is estimated by the ratio

$$\mathrm{P(fa)} = \mathrm{TL}_1/\mathrm{N}_1$$

In order for the method to meet the performance standards, the estimated P(fa) must be less than or equal to 5 percent. Thus, in order for the method to meet the performance standards, TL_1 must be no more than 1 if the standard number of tests are performed.

If the method did not identify the tank to be leaking when it was tight ($TL_1 = 0$), then the proportion of false alarms becomes 0 percent. However, this does not mean the method is perfect. The observed P(fa) of 0 percent is an estimate of the false alarm rate based on the evaluation test results and the given test conditions.

You can calculate an upper confidence limit for P(fa) in the case of no mistakes. Let N_1 be the number of tests performed under the tight tank condition. Choose a confidence coefficient, (1 - α), say 95 or 90 percent. Then the upper confidence limit, UL, for P(fa) is calculated as:

$$\text{UL for P(fa)} = 1 - \alpha^{\frac{1}{N_1}}$$

In the case of 0 false alarms out of 21 tests, the upper limit to P(fa) becomes 0.133 or 13.3 percent with a 95 percent confidence coefficient. That is, P(fa) is estimated at 0 percent, and with a confidence of 95 percent, P(fa) is less than or equal to 13.3 percent. In general, you can calculate the confidence interval for P(fa) from the binomial distribution with N_1 trials. Calculate and report the 95 percent confidence interval on the results form in Appendix C.

5.2.2 Probability Of Detecting A Leak, P(d)

Calculate the P(d) for a specific size of leak. Also report the size of leak that can be detected with this probability. Normally this will be 0.10 gal/hr, as required by the performance standards. The exception to this occurs if a method is tested using induced leak rates smaller than 0.10 gal/hr, for example 0.05 gal/hr. Report the probability of detection, P(d), together with the maximum leak rate used in the evaluation testing. The leak rate corresponding to the P(d) is 0.10 gal/hr or less.

Use the results obtained from the tests performed under induced leak conditions of leak rates less than or equal to 0.10 gal/hr to calculate P(d). Let N_2 be the number of such tests. Let TL_2 be the number of cases where the method indicated a leak. As before, the test results, L_i are coded as 0 when the tank is declared tight and 1 when the tank is declared to be leaking. Thus, TL_2 is calculated as

$$TL_2 = \sum_{i=1}^{N_2} L_i$$

where the sum is taken over the N_2 tests with induced leaks. Estimate the P(d) by the ratio

$$P(D) = TL_2/N_2$$

The estimated P(d) must be at least 95 percent for the method to meet the performance standards. Thus, TL_2 must be either 20 or 21 out of 21 tests for the estimated probability of detection to be at least 95 percent.

If the method identified the tank to be leaking in all tests where a leak was simulated, then the proportion detected becomes 100 percent. However, this does not mean the method is perfect. The P(d) of 100 percent is an estimate of the P(d), based on the evaluation test results and the given test conditions.

You can calculate a lower confidence limit for P(d) in the case of no mistakes. Let N_2 be the number of tests performed under the induced leak conditions. Choose a confidence coefficient, $(1-\alpha)$, for example, 95 or 90 percent. Then calculate the lower confidence limit, LL, for P(d) as:

$$\text{LL for P(d)} = \alpha^{1/N_2}$$

In the case of correct identification of the 21 tests performed under leak conditions, the lower limit to P(d) becomes 0.867 or 86.7 percent with a 95 percent confidence coefficient. P(d) is estimated at 100 percent, and with a confidence of 95 percent, P(d) is greater than or equal to 86.7 percent. Calculate the 95 percent confidence interval for P(d) based on the binomial distribution with N_2 trials and reported on the results form in Appendix C.

5.3 Other Reported Calculations

This section describes other calculations needed to complete the *Results Of U.S. EPA Standard Evaluation* form in Appendix C. Most of these calculations are straightforward and are described here to provide complete instructions for the use of the results form.

These sections are only required if they are applicable to the particular non-volumetric method being evaluated. If a section is not applicable or NA, skip the calculations and report NA on the results form.

Size Of Tank

The evaluation results apply to volumes of tanks, interstitial spaces, and sumps up to 50 percent larger capacity than the test volume for single tanks, interstices, sumps and other equipment, but 25 percent larger for tanks connected by siphon piping. The evaluation results also apply to all smaller volumes for single tanks and tank systems with tanks connected by siphon piping. Multiply the volume of the test volume by 1.5 for single tanks or other equipment and 1.25 for tank systems connected by siphon piping. Round this number to the nearest 100 gallons and report the result on page 2 of the results form. This allowance does not apply to all test methods such as vacuum decay methods.

Maximum Allowable Temperature Difference

This section only applies if temperature conditioning was needed and used as part of the evaluation procedure. If temperature does not affect the operation of the method, ignore this section and indicate NA on the results form.

Calculate the standard deviation of the temperature differences actually achieved during testing. These are the differences between the product in the tank and the product added to fill the tank at each fill. Multiply this number by the factor ± 1.5 and report the result as the temperature range on the limitations section of the results form. Notice that these temperature differences are generally larger than in previous evaluations because the current protocol calls for a third of the differences to be 10°F warmer than the product in the tank and a third of the differences to be 10°F cooler than the product in the tank. Previously the difference called for was ± 5°F. The ± 5°F difference was estimated to cover about 57 percent of the cases, while the ± 10°F range is estimated to cover about 86 percent of the cases.[2]

Average Waiting Time After Filling

Calculate the average of the time intervals between the end of the filling cycle and the start of the test for the 21 tests that started immediately after the specified waiting time. Note: If more than 21 tests are done immediately after the filling, use all such tests. However, do not use the time to the start of the second test in a set, as this would give a misleading waiting time. On the results form, report this average time as the waiting time after adding product. Note: You can use the median as the average instead of the mean if there are atypical waiting times.

For tracer methods, the average waiting time may more appropriately be the time from adding the tracer to the tank until completing the test.

Average Waiting After Topping Off

If the method fills the tank up into the fill pipe, calculate the average time interval between the time when the final topping off was completed and the start of the test. Calculate this average using data from all tests when this step was performed. Report the result on the results form as the waiting time after topping off to the final testing level. If this step is not performed, for example for a test with the tank at 95 percent of capacity, enter NA in the appropriate space on the results form. Note: You can use the median instead of the mean if there are some atypical waiting times.

Average Data Collection Time Per Test

Use the duration of the data collection phase of the tests to calculate the average data collection time for the total number of at least 42 tests. Report this time as the average data collection time per test.

Product Level

If all tests are done at the same product level, report that level on the results form. If testing was done at different levels, report the applicable product level as the acceptable range, for example from 60 to 90 percent full, used in the testing.

---

[2] "Typical Tank Testing Conditions," Flora, Jairus D., Jr., and Jean Pelkey, Report on Work Assignment 22, Task 13, EPA Contract No. 68-01-7383, Midwest Research Institute, December 2, 1988.

Minimum Total Testing Time

Finally, calculate an average total test time from the test data. This is the time it takes from the time the test crew arrives at the site until a test is completed, the method dismantled, and the tank returned to service. Typically, it is the time from initial setup of the method through the first test data collection, plus the time required to dismantle the equipment. Report this total time lapse on the results form as the minimum time the tank is expected to be out of service for a test of this type.

The intent of this is to provide an estimate of the time the testing requires. Testing generally means that a tank must be taken out of service with no dispensing or delivery during the duration of the test. Non-volumetric methods differ in those parts of their operation that require the tank to be out of service. Report the estimated testing time this method requires.

5.4 Supplemental Data Analyses (Optional)

This section discusses some additional data analyses that may be possible with the data, depending on the actual results. It also provides some rationale for the sample size selection.

One-Sided Confidence Limits On P(fa) And P(d)

It is possible to estimate the P(fa) and P(d) directly as done in Section 5.1 with any sample size. However, for fewer than 20 tests, the estimate of P(fa) is 0 or exceeds 5 percent, depending on whether any false alarms are found. Similarly, P(d) is 100 percent or less than 95 percent for sample sizes less than 20, depending on whether any leaks are missed or not. Thus, the sample size of 20 is the smallest that allows for one mistake in each case and still provides estimated performance meeting the EPA standards. The sample size of 21 was chosen from test design considerations to balance the different conditions.

Calculate confidence limits for P(fa) and P(d) based on the observed results and sample sizes. The formulas for perfect scores were given in Section 5.2.1 for P(fa) and in Section 5.2.2 for P(d). These also depend on the selected confidence coefficient. Table 6 below gives 90 and 95 percent one-sided confidence limits for P(fa) and P(d) based on samples of 21 tests for the case of no mistakes and one mistake, the two conditions under which the method meets the EPA performance standards, if evaluated with the minimum 21 tests.

Table 6. One Sided Confidence Limits For P(fa) And P(d)

Field Test Results	Confidence Coefficient 90%	95%
0 Error out of 21	P(fa) $\leq$ 0.104	P(fa) $\leq$ 0.133
1 Error out of 21	P(fa) $\leq$ 0.173	P(fa) $\leq$ 0.207
0 Error out of 21	P(d) $\geq$ 0.896	P(d) $\geq$ 0.867
1 Error out of 21	P(d) $\geq$ 0.827	P(d) $\geq$ 0.793

Table 6 shows the confidence limits start to become large for high confidence with even one error. Using a larger sample size improves the confidence limits, but adds significantly to the cost of testing. We selected the sample sizes as a compromise to provide reasonable estimates while not requiring excessively expensive testing.

5.5 Sensor Performance Calculations

From the results obtained after completing testing, perform a series of calculations to evaluate the sensor's performance. The results obtained from individual sensors do not fit the standard P(fa) and P(d) results that are calculated for most of the release detection methods. The goal of the testing is to determine the capabilities of each sensor to produce the correct sensor output depending on the test. Each sensor has different capabilities and, therefore, will have different data outputs. Table 7 presents the performance parameters and evaluation metrics are the means of determining the operability of each sensor.

Table 7. Performance Parameters

Performance Parameter	Evaluation Metric	Data To Be Recorded
Average detection time	Average and SD of the difference in actuation time and test start times	Test start time and actuation time calculated for each test condition
Liquid activation height (liquid only)	Average and SD of the activation height	Liquid height level at activation, calculated for each liquid
Specificity	% Specificity	Detection data calculated for each test condition by product
Accuracy (qualitative only)	Relative % accuracy	Detection data calculated for each test condition
Accuracy (quantitative only)	% Accuracy	Detection data calculated for each test condition
Precision (quantitative only)	% Coefficient of variation	Detection data calculated for each test condition
Average recovery time	Average and SD of the difference between recovery and test end times	Test end time and recovery time calculated for each test condition

Average Detection Time

Evaluate detection time for all sensors. Report the average detection time as the average ($\bar{x}$) and the standard deviation (SD) of the observed values for each repeated test condition.

Average Liquid Activation Height

Report the liquid activation height as the average and the SD of the observed values for each repeated test condition.

Table 8. Notation Summary For Water Sensor Readings At The jth Replicate

Increment No.	Calculated Level Change (inch) A	Sensor Reading (inch) B	Measured Sensor Increment (inch) C	Increment Difference Calculated-Meas. (inch) C-A
1	+ h	$W_{1,j}$	$W_{1,j}$-X_j*	$d_{1,j}$
2	+ h	$W_{2,j}$	$W_{2,j}$-$W_{1,j}$	$d_{2,j}$
3	+ h	$W_{1,j}$	$W_{3,j}$- $W_{2,j}$	$d_{3,j}$
•	•	•	•	•
•	•	•	•	•
•	•	•	•	•
•	•	•	•	•
•	•	•	•	•
•	•	•	•	•
n_j	+ h	$W_{n_j,j}$	$W_{n_j,j} - W_{n_j-1,j}$	$d_{n_j,j}$

* X_j is the water level in inches detected for the first time by the sensor during the jth replication of the test.

Specificity

Calculate the percent or % specificity using the following equation for each liquid individually as follows:

$$\text{Specificity, \%} = 100 \times \left(\frac{\bar{x}}{x_t}\right)$$

$\bar{x}$ = mean of observed values, cm
x_t= the theoretical value, cm

Accuracy For Qualitative Sensors Only

Determine the accuracy for the qualitative liquid and vapor sensors by calculating the percent accuracy of replicates of the tested products individually as follows:

$$\text{Accuracy, \%} = 100 \times \left(\frac{r}{n}\right)$$

r = the number of positive responses
n = the number of tests for a particular liquid or test gas

Relative Percent Accuracy For Quantitative Sensors Only

Use the following equation to compute the accuracy in measuring the liquid level for each replicate measured of the tested product:

$$\text{Accuracy, \%} = \frac{|M - D|}{M} \times 100$$

M = measured liquid level, cm, or established gas concentration, ppmv
D = detected liquid level, cm, or detected gas concentration, ppmv

Similarly, compute the vapor sensors relative percent accuracy for each set of replicates under a test condition.

Precision For Quantitative Sensors Only

Calculate precision as the percent coefficient of variation, or %CV, for quantitative liquid and vapor sensors as follows:

$$\%CV = 100 \times \left(\frac{SD}{\bar{x}}\right)$$

SD = standard deviation of n values, cm or ppmv
$\bar{x}$ = mean of observed values, cm or ppmv

Average Recovery Time

For liquid sensors, the recovery time is how long it takes the sensor to return to an inactivated state after it is removed from the testing condition. Record, average, and report this time. Some sensors are instantaneous and can be reported as such. Others take time to be prepared for the next test condition.

For vapor sensors, the recovery time is dependent on whether a sensor gives a quantitative or qualitative response. The recovery time for a quantitative sensor is when the output returns to within 5 percent of the original stable baseline level. Calculate the 5 percent stable baseline level according to the following equation.

$$\text{5\% Stable baseline output, ppmv} = BL + (HL - BL) \times 0.05$$

BL = stable baseline output, ppmv
HL = stable high level output, ppmv

The recovery time for a qualitative output sensor is defined as when the sensor goes from activated state to an inactivated state.

Section 6: Interpretation

The results reported are valid for the test design conditions during the evaluation, which have been chosen to represent situations commonly encountered in the field. These should be typical of most tank testing conditions, but extreme conditions can occur and might adversely affect the performance of the method. It is emphasized that the performance estimates are based on average results obtained in the tests. An individual test may not do as well. Some individual tests may do better.

6.1 Basic Performance Estimates

The relevant performance measures for proving that a TTT method meets EPA standards are the P(fa) and P(d) for a leak rate of 0.10 gal/hr. Compare the estimated P(fa) with EPA's standard of P(fa) not to exceed 5 percent. In general, a lower P(fa) is preferable, since it implies the chance of mistakenly indicating a leak on a tight tank is less. A general goal is to reduce the number of false alarms. However, reducing the false alarm rate may also reduce the chance of detecting a leak. The probability of detection generally increases with the size of the leak. EPA's standard specifies that P(d) be at least 95 percent for a leak of 0.10 gal/hr. A higher estimated P(d) means there is less chance of missing a small leak.

The discrete nature of the data implies that only a few values of P(fa) or P(d) are possible. With the standard 21 tests for each test condition of a tight or leaking tank, the possible values are 0, 1/21, 2/21, etc. Consequently, the reported estimates are only precise to about 5 percent. The confidence limits reported in the case of a perfect score indicate the expected range of the true P(fa) or P(d). For example, a method that achieved 0 false alarms throughout testing would not be expected to have a 0 false alarm rate. Instead, its false alarm rate should be less than 10.4 percent with 95 percent confidence.

If testing is done at an induced leak rate less than 0.10 gal/hr, the P(d) may be reported at the smaller leak rate actually used. The standard test, using an induced leak rate of 0.10 gal/hr, would report P(d) for the rate of 0.10 gal/hr. In general, a method that can detect a smaller leak with high probability is preferred because it identifies a potential problem earlier. This may reduce the amount of pollution and the cost of remedial action.

6.2 Limitations

Report the limitations on the evaluation results section of the *Results Of U.S. EPA Standard Evaluation* form. The intent is to document that the results are valid under conditions represented by the test conditions. The test conditions were chosen to represent the majority of testing situations, but do not include the most extreme conditions under which testing could be done. The test conditions were also selected to be practical and not impose an undue burden for evaluation on the evaluator.

For volumetric methods, one limitation of the results is the size of the tank. Tests based on volumetric changes generally perform less well as the size of the tank increases. Consequently, you may apply the results of the evaluation to tanks smaller than the test tank. The results may also be extended to volumes of tanks, interstitial spaces, and sump of 50 percent larger capacity than the test volume for single tanks or other equipment and 25 percent larger capacity for tank systems connected by siphon piping.

Optional testing on tanks connected by siphon piping evaluates the method's performance in different tank configurations. The requirement for an evaluation on tanks connected by siphon piping is to perform 24 tests for volumetric methods or 42 tests for non-volumetric methods. If the estimated probabilities are within the regulatory limit with the additional tests, you may use the method in siphoned systems. The results are limited to one more tank in the siphoned configuration than used in the evaluation testing.

Another limitation on the results is the temperature differential between the product added to the tank and that of the product already in the tank. The temperature differential is a factor when performing a test shortly after a tank is filled. The reported results are applicable provided the temperature differential is no more than that used in the evaluation. The results cannot be guaranteed for temperature differentials larger than those used in the evaluation.

Non-volumetric TTT methods based on different operating principles have different factors that can interfere with their performance. Consequently, the limitations on the applicability of the performance estimates also vary with the method. However, there may be interfering factors other than those listed in the test design that affect a particular test method. If so, those additional factors might limit the applicability of the method. The reporting form provides a place to identify other sources of interference and to state the test conditions for them.

Some non-volumetric test methods use more than one mode of operation. If so, different limitations may apply to each mode of release detection. It is possible that one mode of operation may be unaffected by size of tank, but that another may depend strongly on tank size. For example, a water sensor may be used to test for leaks in the presence of a high groundwater level. It may do so by sensing water incursion, in which case it must be able to detect water incursion at the rate of 0.10 gal/hr. Since the time required for the water level to be detectable at a fixed rate of incursion will be a function of the size of the tank, this mode of release detection is dependent on tank size.

6.3 Additional Calculations

If the performance estimates do not meet the performance requirements, the vendor may want to investigate the conditions under which errors occurred. Calculating the percent of errors by size of leak, temperature condition, and length of stabilization time may suggest ways to improve the method. This may be as straightforward as identifying conditions that lead to poor performance and revising the operating procedure to avoid those, or it may require redesign of the method.

The relationship of performance to test conditions is primarily of interest when the method does not meet EPA's performance standards. Developing these relationships is part of the optional or supplementary data analysis that may be useful to the vendor, but not to many tank owners or operators.

Section 7: Reporting Of Results

Appendices B and C are designed to be the framework for a standard report for volumetric and non-volumetric TTT methods, respectively. There are four parts to the results report, each with instructions for completion.

- *Results Of U.S. EPA Standard Evaluation* form – This form is an executive summary of the findings and is for tank owners or operators who use this method of release detection. The results form is easy to reproduce for wide distribution.

- Description (volumetric or non-volumetric) tank tightness method – The evaluator, assisted by the vendor, completes the description form.

- Reporting form for leak rate data – This table summarizes the test results and contains the information on starting dates and times, test duration, and leak test results.

- Individual test log – While the individual test log is designed to be flexible, you may need to modify it for some test methods. Use this to record data in the field. The evaluator must maintain test logs but they are not mandatory for the standard report. These serve as the backup data to document the performance estimates reported.

A method that uses more than one mode of release detection may achieve different performance results for the different modes of operation. The results form is structured to allow for reporting the P(fa) and P(d) separately for different modes of release detection. The method meets EPA's performance requirements only if all modes of release detection meet those requirements. The statement of compliance with EPA's performance standards must be consistent with stated limitations on the form and with the standard operation of the method as described on the description form.

Suppose that a method has two modes of testing, a basic one and an ancillary one for testing in the presence of a high groundwater level. Suppose the test method when evaluated in the case of high groundwater level does not meet EPA's performance requirements, but the basic one does. Then you can issue a report, stating the method meets EPA's performance requirements, but cannot test when the groundwater level is above the bottom of the tank.

Non-volumetric methods may require some modification of the forms. If the forms need to be modified, the evaluator makes the required modifications and uses the resulting forms. Record the conditions during the evaluation tests and the factors that affect the performance of the method. Test conditions actually used and reported may limit the performance results.

Appendix A

Definitions And Student's t Distribution

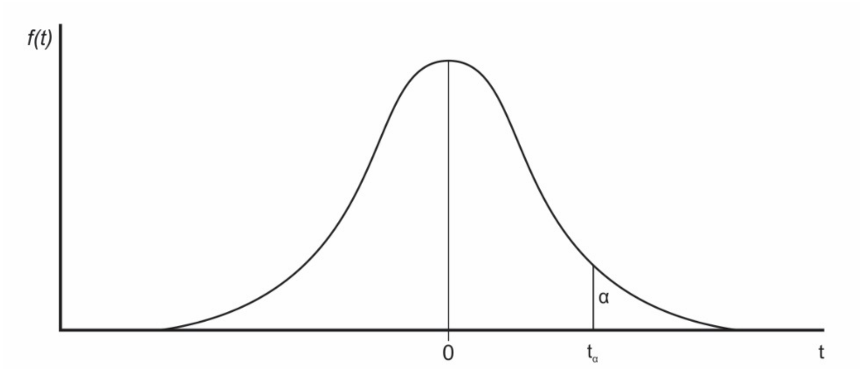
Definitions of terms used throughout the test procedures and the Student's t distribution table in Table A-1 are presented here. For more information on the statistical approach and relationships between the statistics calculated in these test procedures see *General Guidance For Using EPA's Standard Test Procedures For Evaluating Release Detection Methods*.

Calculated Leak Rate, R	A positive number, in gallons per hour (gal/hr), estimated by the TTT method and indicating the amount of product leaking out of the tank. A negative leak rate could result from water leaking into the tank, miscalibration, or other causes.
Induced Leak Rate, S	The actual leak rate, in gal/hr, introduced in the evaluation data sets, against which the results from a given method will be compared.
Threshold, Th	The leak rate above which a method declares a leak. It is also called the threshold of the method.
False Alarm	Declaring that a tank is leaking when in fact it is tight.
Probability Of False Alarm, P(fa)	The probability of declaring a tank leaking when it is tight. In statistical terms, this is also called the Type I error, and is denoted by alpha (α). It is usually expressed in percent, as 5 percent.
Probability Of Detection, P(d)	The probability of detecting a leak rate of a given size, R gal/hr. In statistical terms, it is the power of the test method and is calculated as one minus beta (β), where beta is the probability of not detecting or missing a leak rate R. Commonly the power of a test is expressed in percent, as 95 percent.
Method Bias, B	The average difference between calculated and induced leak rates. It is an indication of whether the TTT method consistently overestimates as a positive bias or underestimates as a negative bias the actual leak rate.
Mean Squared Error, MSE	An estimate of the overall performance of a test method.
Root Mean Squared Error, RMSE	The positive square root of the mean squared error.
Precision	A measure of the test method's ability in producing similar results, that is, in close agreement, under identical conditions. Statistically, the precision is expressed as the standard deviation of these measurements.

Accuracy The degree to which the calculated leak rate agrees with the induced leak rate on the average. If a method is accurate, it has a very small or 0 bias.

Variance: A measure of the variability of measurements. It is the square of the standard deviation.

Table A-1. Percentage Points Of Student's t Distribution



df	α = .10	α = .05	α = .025	α = .010	α = .005
1	3.078	6.314	12.706	31.821	63.657
2	1.886	2.920	4.303	6.965	9.925
3	1.638	2.353	3.182	4.541	5.841
4	1.333	2.132	2.776	3.747	4.604
5	1.476	2.015	2.571	3.365	4.032
6	1.440	1.943	2.447	3.143	3.707
7	1.415	1.895	2.365	2.998	3.499
8	1.397	1.860	2.306	2.896	3.355
9	1.383	1.833	2.262	2.821	3.250
10	1.372	1.812	2.228	2.764	3.169
11	1.363	1.796	2.201	2.718	3.106
12	1.356	1.782	2.179	2.681	3.055
13	1.350	1.771	2.160	2.650	3.012
14	1.345	1.761	2.145	2.624	2.977
15	1.341	1.753	2.131	2.602	2.947
16	1.337	1.746	2.120	2.583	2.921
17	1.333	1.740	2.110	2.567	2.898
18	1.330	1.734	2.101	2.552	2.878
19	1.328	1.729	2.093	2.539	2.861
20	1.325	1.725	2.086	2.528	2.845
21	1.323	1.721	2.080	2.518	2.831
22	1.321	1.717	2.074	2.508	2.819
23	1.319	1.714	2.069	2.500	2.807
24	1.318	1.711	2.064	2.492	2.797

df	α = .10	α = .05	α = .025	α = .010	α = .005
25	1.316	1.708	2.060	2.485	2.787
26	1.315	1.706	2.056	2.479	2.779
27	1.314	1.703	2.052	2.473	2.771
28	1.313	1.701	2.048	2.467	2.763
29	1.311	1.699	2.045	2.462	2.756
30	1.310	1.697	2.042	2.457	2.750
40	1.303	1.684	2.021	2.423	2.704
60	1.296	1.671	2.000	2.390	2.660
120	1.289	1.658	1.980	2.358	2.617
inf.	1.282	1.645	1.960	2.326	2.576

Appendix B

Volumetric Methods Reporting Forms

Volumetric Method Evaluation Forms

Appendix B provides four sets of blank forms. Once completed, these forms provide the framework for a standard report. They consist of:

1. Results Of U.S. EPA Standard Evaluation – Volumetric Tank Tightness Testing Method
2. Description Of Volumetric Tank Tightness Testing Method
3. Reporting Form For Leak Rate Data – Volumetric Tank Tightness Testing Method
4. Individual Test Logs – Volumetric Tank Tightness Testing Method

Each set of forms includes instructions on how to complete the forms and who should complete them. The following is an overview on various responsibilities.

1. Results Of U.S. EPA Standard Evaluation – The evaluator completes this form at the end of the evaluation.
2. Description Of Volumetric Tank Tightness Testing Method – The evaluator assisted by the vendor or a field crew completes this form at the end of the evaluation.
3. Reporting Form For Leak Rate Data – The evaluator or statistician analyzing the data completes this form. You can develop a blank form on a personal computer, generate the database for a given evaluation, and merge the two on the computer. You can also complete this form manually. The input for the form consists of the field test results recorded by the evaluator's field crew on the individual test logs discussed below and the vendor's test results.
4. Individual Test Logs – The evaluator completes these forms. Keep these forms blind to the vendor's field crew. Reproduce a sufficient number of at least 24 copies of the blank form provided in this appendix and produce a bound notebook for the complete test period.

After completing the evaluation, the evaluator collates all the forms into a single standard report in the order listed above.

Distribution Of The Evaluation Test Results

The evaluator performing the evaluation prepares a report for the vendor describing the results of the evaluation. The evaluator of the release detection method provides the report to the vendor. The vendor is responsible for distributing the results to tank owners or operators and to regulators.

This report consists primarily of the forms in this appendix. The first form reports the results of the evaluation. This two-page form is designed to be distributed widely. Provide a copy of this two-page form to each tank owner or operator who uses this method of release detection. The owner or operator must retain a copy of this form as part of his recordkeeping requirements. The owner or operator must also retain copies of each tank test performed at his facility to document the tanks passed the tightness test. The vendor distributes this two-page form to regulators who must approve release detection methods for use in their jurisdiction.

The evaluator submits the completed report, consisting of all the forms in Appendix B, to the release detection method vendor. The vendor may distribute the complete report to regulators who wish to see the data collected during the evaluation. The vendor may also distribute the report to release detection method customers who want to see additional information before deciding to select a particular release detection method.

The evaluator reports to the vendor any optional calculations made regarding the release detection method. The vendor may use this report to understand the details of the performance and perhaps improve the method. The vendor has the discretion to distribute this form.

Results Of U.S. EPA Standard Evaluation
Volumetric Tank Tightness Testing Method

Instructions For Completing The Form

The evaluator must fill out this form after completing the evaluation of the method. This form contains the most important information relative to the method evaluation. Fill out all items and check the appropriate boxes. If a question is not applicable to the method, write NA in the appropriate space.

This form consists of five main parts:

1. Method Description
2. Evaluation Results
3. Test Conditions
4. Limitations On The Results
5. Certification Of Results

Method Description

Indicate the commercial name of the method, the version, and the name, address, and telephone number of the vendor. Some vendors use different versions of their method when using it with different products or tank sizes. If so, indicate the version used in the evaluation. If the vendor is not the party responsible for developing and using the method, then indicate the home office name and address of the responsible party.

Evaluation Results

The vendor supplies the method's Th (threshold). This is the criterion for declaring a tank to be leaking. Typically, a method declares a tank to be leaking if the measured leak rate exceeds Th.

P(fa) is the probability of false alarm calculated. Report P(fa) in percent rounded to the nearest whole percent.

P(d) is the probability of detecting a leak rate of 0.10 gallon per hour (gal/hr) and is calculated. Report P(d) in percent rounded to the nearest whole percent.

If the P(fa) calculated is 5 percent or less and if the P(d) calculated is 95 percent or more, then check the does box. Otherwise, check the does not box.

Test Conditions During Evaluation

Insert the information in the blanks provided. Request the nominal volume of the tank in gallons and the tank material, for example, steel or fiberglass. Also, give the tank diameter and length in inches. Report the product used during the testing. If a level lower than a 90-95 percent full level is used, justify the use and note that the method is limited to testing a tank below the liquid level used. **This also restricts use of tanks tested by this method to no more than the level for which the method is approved.** Give the range of temperature differences actually measured, as well as the standard deviation of the observed temperature differences. Also, indicate the level in the tank at which the testing was done.

Limitations On The Results

The size in gallons of the largest tank to which these results can be applied is calculated as 1.5 times the size in gallons of the test tank. This allowance does not apply to all test methods such as vacuum decay methods. For tank systems with tanks connected by siphon piping, the results are limited to the number of tanks in the manifold used in testing. The volume limit applies to the total volume of the tank system with tanks connected by siphon piping.

If the method compensates for groundwater levels above the bottom of a tank, then check the can box. Otherwise, check the cannot box.

Certification Of Results

The evaluator provides his or her name and signature, and the name, address, and telephone number of the organization.

Results Of U.S. EPA Standard Evaluation
Volumetric Tank Tightness Testing Method

This form tells whether the tank tightness testing method described below complies with the performance requirements of the federal underground storage tank regulation. The evaluation was conducted by the vendor according to the U.S. EPA's *Standard Test Procedure for Evaluating Release Detection Methods: Volumetric Tank Tightness Testing Methods*. The full evaluation report also includes a form describing the method and a form summarizing the test data.

Tank owners using this release detection system should keep this form on file to prove compliance with the federal UST regulation. Tank owners should check with regulatory authorities to make sure this form satisfies their requirements.

1. Method Description

Method name ____________________

Version number ____________________

Vendor ____________________

____
Street address

____
City, state, zip

____
Telephone number

2. Evaluation Results

a. This method, which declares a tank to be leaking when the measured leak rate exceeds the threshold of __________gallon per hour, has a probability of false alarms [P(fa)] of __________%.

b. The corresponding probability of detection [P(d)] of a 0.10 gallon per hour leak is ________%.

c. Therefore, this method

☐ does ☐ does not

meet the **federal** performance standards established by the U.S. Environmental Protection Agency of 0.10 gallon per hour at P(d) of 95% and P(fa) of 5%.

3. Test Conditions During Evaluation

a. The evaluation testing was conducted in a _____________ gallon

☐ steel tank ☐ fiberglass tank

________ inches in diameter

________ inches in length

b. The tests were conducted with the tank __________ % full.

c. The temperature difference between product added to fill the tank and product already in the tank ranged from

_________ °F to _____________

with a standard deviation of: ______ °F

d. The product used in the evaluation was

____

4. Limitations On The Results

- The method has not been substantially changed.
- The vendor's instructions for using the method are followed.

Results Of U.S. EPA Standard Evaluation
Volumetric Tank Tightness Testing Method

- The tank is no larger than __________ gallons.
- The tank contains a product identified on the method description form.
- The waiting time after adding any substantial amount of product to the tank is at least ___________ hours.
- The temperature of the added product does not differ more than ______________ degrees Fahrenheit from already in the tank.
- The waiting time between the end of topping off, if any, and the start of the test data collection is at least _______ hours.
- The total data collection time for the test is at least ___________ hours.
- This method can be used on up to _____ of tanks connected by siphon piping with a total volume of ______.
- This method

  ☐ can ☐ cannot

  be used if the groundwater level is above the bottom of the tank.
- Other limitations specified by the vendor or determined during testing:

  ____

  ____

Safety disclaimer: This test procedure only addresses the issue of the method's ability to detect leaks. It does not test the method for safety hazards.

Additional explanations or comments

5. Certification Of Results

I certify that the tank tightness test method was operated according to the vendor's instructions. I also certify that I performed the evaluation according to the procedure specified by EPA and that the results presented in the report were obtained during the evaluation.

Printed name	Organization performing evaluation
Signature	Street address
Date	City, state, zip
Phone number	

Description Of Volumetric Tank Tightness Testing Method

Instructions For Completing The Form

The evaluator, with assistance from the vendor, must fill out this form upon completion of the evaluation of the method. This form provides supporting information on the principles behind the method or on how the method works.

To minimize the time to complete this form, we provide the most frequently asked questions. For answers that depend on site conditions, give answers that apply in typical conditions. Write in any additional information about the testing method you believe is important.

There are seven parts to this form:

1. Method Name and Version
2. Product Description
    - Product type
    - Product level
3. Level Measurement
4. Temperature Measurement
5. Data Acquisition
6. Procedure Information
    - Waiting times
    - Test duration
    - Total time
    - Identifying and correcting for interfering factors
    - Interpreting test results
7. Exceptions

Indicate the commercial name and the version of the method in the first part.

Note: The version is provided for methods that use different versions of the method for different products or tank sizes.

For the six remaining parts, check all appropriate boxes for each question. Check more than one box per question if it applies. If you check the other box, use the space provided to specify or briefly describe the matter. If necessary, use the white space next to a question for a description.

Description
Volumetric Tank Tightness Testing Method

1. Method Description

Method name ___________________________

Version name ___________________________

2. Product Description

Product type

a. For what products can this method be used? Check all applicable.

☐ Gasoline	☐ Diesel
☐ Aviation fuel	☐ Fuel oil #4
☐ Fuel oil #6	☐ Solvent
☐ Waste oil	☐ Other, list

____

Product level

b. What minimum product level is required to conduct a test?

☐ Above grade	☐ Within the fill pipe
☐ Greater than 90% full	☐ Greater than 50% full
☐ Other, specify	_________________________

c. Is a method used to add or withdraw product to maintain a constant level of product?
☐ Yes ☐ No

d. Does the method measure inflow of water as well as loss of product at gallons per hour?
☐ Yes ☐ No

e. Does the method detect the presence of water in the bottom of the tank?
☐ Yes ☐ No

3. Level Measurement

a. What technique is used to measure changes in product volume?

☐ Directly measure the volume of product change	☐ Changes in head pressure
☐ Changes in buoyancy of a probe	☐ Mechanical level measure; for example, ruler, dipstick
☐ Changes in capacitance	☐ Ultrasonic

☐ Change in level of float; specify principle, for example, capacitance, magnetostrictive, and load cell

____

____

☐ Other, describe briefly

4. Temperature Measurement

a. If product temperature is measured during a test, how many temperature sensors are used?

☐ Single sensor, without circulation ☐ Single sensor, with circulation

☐ 2-4 sensors ☐ 5 or more sensors

☐ Temperature-averaging probe

b. If product temperature is measured during a test, what type of temperature sensor is used?

☐ Resistance temperature detector (RTD) ☐ Bimetallic strip
☐ Quartz crystal ☐ Thermistor
☐ Other, describe

c. If product temperature is not measured during a test, why not?

☐ The factor measured for change in level or volume is independent of temperature, for example, mass
☐ The factor measured for change in level or volume self-compensates for changes in temperature
☐ Other, explain briefly

5. Data Acquisition

a. How are the test data acquired and recorded?

☐ Manually ☐ By strip chart
☐ By computer

Description
Volumetric Tank Tightness Testing Method

6. Procedure Information

Waiting times

a. What is the minimum waiting period between adding a large volume of product to bring the level to test requirements and the beginning of the test, for example, from 50 percent to 95 percent capacity?

- ☐ No waiting period
- ☐ < 3 hours
- ☐ 3-6 hours
- ☐ 7-12 hours
- ☐ > 12 hours
- ☐ Variable, depending on tank size, amount added, operator discretion

b. What is the minimum waiting period between topping off the tank by adding a small amount of product to fine tune the desired level for testing, for example, from 2 inches to 5 inches above grade and beginning the test?

- ☐ No waiting period
- ☐ < 1 hours
- ☐ 1-2 hours
- ☐ > 2 hours
- ☐ Variable, depending on the amount of product added

Test duration

c. What is the minimum time for collecting data?

- ☐ < 1 hour
- ☐ 1 hour
- ☐ 2 hours
- ☐ 3 hours
- ☐ 4 hours
- ☐ 5-10 hours
- ☐ More than 10 hours
- ☐ Variable

Total time

d. What is the total time needed to test with this method? This includes setup time plus waiting time plus testing time plus time to return tank to service.

__________ Hours __________ Minutes

e. What is the sampling frequency for the level and temperature measurements?

- ☐ More than once per second
- ☐ At least once per minute
- ☐ Every 1-15 minutes
- ☐ Every 16-30 minutes
- ☐ Every 31-60 minutes
- ☐ Less than once per hour
- ☐ Variable

Identifying and correcting for interfering factors

f. How does the method determine the presence and level of the groundwater above the bottom of the tank?

- ☐ Observation well near tank
- ☐ Information from USGS
- ☐ Information from personnel on-site

- ☐ Presence of water in the tank
- ☐ Level of groundwater above bottom of the tank not determined
- ☐ Other, describe briefly

____

g. How does the method correct for the interference due to the presence of groundwater above the bottom of the tank?

- ☐ Head pressure increased by raising the level of the product
- ☐ Different head pressures tested and leak rates compared
- ☐ Method tests for changes in water level in tank
- ☐ No action
- ☐ Other, describe briefly

____

h. How does the method identify the presence of vapor pockets?

- ☐ Erratic temperature, level, or temperature-compensated volume readings
- ☐ Sudden large changes in readings
- ☐ Statistical analysis of variability of readings
- ☐ Not applicable; underfilled test method used
- ☐ Not identified
- ☐ Other, describe briefly

____

i. How does the method correct for the presence of vapor pockets?

- ☐ Bleed off vapor and start test over
- ☐ Identify periods of pocket movement and discount data from analysis
- ☐ Not corrected
- ☐ Not applicable; underfilled test method used
- ☐ Other, describe briefly

____

j. Are the temperature and level sensors calibrated before each test?

☐ Yes ☐ No

k. If not, how often are the sensors calibrated?

- ☐ Weekly
- ☐ Monthly
- ☐ Yearly or less frequently
- ☐ Never

Description
Volumetric Tank Tightness Testing Method

Interpreting test results

l. How are level changes converted to volume changes; that is, how is height-to-volume conversion factor determined?

- ☐ Actual level changes observed when known volume is added or removed, for example, liquid, metal bar
- ☐ Theoretical ratio calculated from tank geometry
- ☐ Interpolation from tank vendor's chart
- ☐ Not applicable; volume measured directly
- ☐ Other, describe briefly

____

m. How is the coefficient of thermal expansion (Ce) of the product determined?

- ☐ Product sample taken for each test and Ce determined from specific gravity
- ☐ Value supplied by vendor of product
- ☐ Average value for type of product
- ☐ Other, describe briefly

____

n. How is the leak rate of gallon per hour calculated?

- ☐ Average of subsets of all data collected
- ☐ Difference between first and last data collected
- ☐ From data to last ________ hours of test period
- ☐ From data determined valid by statistical analysis
- ☐ Other, describe briefly

____

o. What threshold value for product volume change of gallon per hour is used to declare a tank is leaking?

- ☐ 0.05 gallon / hour ☐ 0.10 gallon /hour
- ☐ 0.20 gallon / hour
- ☐ Other, describe ____________________

p. Under what conditions are test results considered inconclusive?

- ☐ Groundwater level above bottom of tank
- ☐ Presence of vapor pockets
- ☐ Too much variability in the data of standard deviation beyond a given value
- ☐ Unexplained product volume increase

☐ Other, describe briefly

____

7. Exceptions

a. What are acceptable deviations from the standard testing test procedures?

☐ None ☐ Length the duration of test

☐ Other, describe ________________________

b. What are the conditions under which a test should not be conducted?

☐ Groundwater level above bottom of tank
☐ Presence of vapor pockets
☐ Large difference between ground temperature and delivered product temperature
☐ High ambient temperature
☐ Invalid for some products, specify

____

☐ Other, describe briefly

____

c. What elements of the test procedure are determined by testing personnel on-site?

☐ Waiting period between filling tank and beginning test
☐ Length of test
☐ Determination of presence of vapor pockets
☐ None
☐ Other, describe briefly

____

____

Additional explanations or comments

Reporting Form For Leak Rate Data
Volumetric Tank Tightness Testing Method

Instructions For Completing The Form

The evaluator must fill out this form upon completion of the evaluation of the method. A single sheet provides for 24 test results, the minimum number of tests required in the test procedures. Use as many pages as necessary to summarize all of the tests attempted.

Indicate the commercial name and the version of the method and the period of evaluation above the table. You may use different versions of the method for different products or tank sizes.

The evaluator or the statistician analyzing the data completes this form. Develop a blank form on a personal computer, generate the database for a given evaluation, and merge the two on the computer. You can complete the form manually. The input for the form consists of the field test results recorded by the evaluator's field crew on the individual test logs and the vendor's test results.

The table consists of 11 columns. One line is provided for each test performed during evaluation of the method. If a test was invalid or aborted, list the test with the appropriate notation, such as invalid, on the line.

The test number in the first column refers to the test number from the randomization design determined according to the instructions in Section 6 of the test procedures. Since some changes to the design might occur during the course of field-testing, the test numbers might not always be in sequential order.

Note: Report the results from the trial run here as well.

The following list matches the column input required with its source, for each column in the table.

Column No.	**Input**	**Source**
1	Test number or trial run	Randomization design
2	Date at completion of last fill	Individual test log
3	Time at completion of last fill	Individual test log
4	Date test began	Individual test log
5	Time test began	Individual test log
6	Time test ended	Individual test log
7	Product temperature differential	Individual test log
8	Nominal leak rate	Randomization design
9	Induced leak rate	Individual test log
10	Measured leak rate	Vendor's records
11	Measured minus induced leak rate	By subtraction

Reporting Form For Leak Rate Data
Volumetric Tank Tightness Testing Method

Method name and version ____

Evaluation period from ______________ to ______________ (dates)

Test No.	Date At Completion Of Last Fill (m/d/y)	Time At Completion Of Last Fill (military)	Date Test Began (m/d/y)	Time Test Began (military)	Time Test Ended (military)	Product Temperature Differential (°F)	Nominal Leak Rate (gal/hr)	Induced Leak Rate (gal/hr)	Measured Leak Rate (gal/hr)	Meas.-Ind. Leak Rate (gal/hr)
Trial Run						0	0	0		
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										

Reporting Form For Leak Rate Data
Volumetric Tank Tightness Testing Method

Method name and version ____

Evaluation period from ______________________ to ______________________ (dates)

Test No.	Date At Completion Of Last Fill (m/d/y)	Time At Completion Of Last Fill (military)	Date Test Began (m/d/y)	Time Test Began (military)	Time Test Ended (military)	Product Temperature Differential (°F)	Nominal Leak Rate (gal/hr)	Induced Leak Rate (gal/hr)	Measured Leak Rate (gal/hr)	Meas.-Ind. Leak Rate (gal/hr)
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										
36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										
48										

Individual Test Log
Volumetric Tank Tightness Testing Method

Instructions For Completing The Form

The evaluator's field crew fills out this form. Complete a separate form for at least 24 individual tests. Keep the information on these forms blind to the vendor during the period of evaluation of their method.

The form consists of nine parts:

1. Header information
2. General background information
3. Conditions before testing
4. Topping off records, if applicable
5. Conditions at beginning of test
6. Conditions at completion of testing
7. Leak rate data
8. Additional comments, if needed
9. Induced leak rate data sheets

Fill out all items and check the appropriate boxes. If a question is not applicable, then indicate as NA. The following provides guidance on the use of this form.

Header Information

Repeat the header information on all five pages, if used. If a page is not used, cross it out and initial it. The evaluator's field operator needs to print and sign his or her name and note the date of the test on top of each sheet.

The test number is the number obtained from the randomization design. It is not the sequential running test number. If you repeat a test, indicate the test number on the test log, for example, test no. 5 repeat.

General Background Information

Indicate the commercial name of the method. Include a version identification if the method uses different versions for different products or tank sizes. Prior to testing, obtain the vendor's recommended stabilization period. This is important since it will influence scheduling of the evaluation. All other items in this section refer to the test tank and product. Indicate the groundwater level at the time of the test.

Theoretically, this information remains unchanged for the whole evaluation period. However, weather conditions could change and affect the groundwater level, or the evaluator could change the test tank.

Conditions Before Testing

Fill in all the blanks. If obtaining the information by calculation – for example the amount of water in the tank is obtained from the stick reading and then converted to volume – do this after completing the test. Indicate the unit of all temperature measurements by checking the appropriate box.

Topping Off Records, If Applicable

If topping off is not part of the procedure, indicate as NA. Fill in all the blanks.

Conditions At Beginning Of Test

Indicate the date and time when the vendor begins setting up his test equipment. This is not the start of the test data collection itself.

The evaluator's field crew starts inducing the leak rate and records the time on pages 4 and 5. Record all leak simulation data using the form on pages 4 and 5.

Once the evaluator's field crew is ready with the induced leak rate simulation and the vendor's crew starts the actual testing, record the date and time the vendor's test data collection starts. Also, indicate the product temperature at the time. Fill out the weather condition section of the form. Indicate the nominal leak rate obtained from the randomization design.

Conditions At Completion Of Testing

Indicate date and time the test is completed.

Again, stick the tank and record the readings and the amount of water in the tank. Record all weather conditions.

Leak Rate Data

The evaluator's statistician or analyst performing the calculations fills out this section. He can complete this section as the evaluation proceeds or at the end of the evaluation.

The nominal leak rate is obtained from page 2; see test conditions at beginning of test. Check it against the nominal leak rate in the randomization design by matching test numbers.

The induced leak rate is obtained by calculation from the data reported by the evaluating field crew on pages 4 and 5, if needed, of this form. The vendor's crew reports the measured leak rate.

Calculate the difference by subtracting the induced from the measured leak rate.

Additional Comments, If Needed

Use this page for comments, such as adverse weather conditions, method failure, and reason for invalid test pertaining to test.

Induced Leak Rate Data

The evaluator's field crew completes this form on pages 4 and 5. From the randomization design, the crew will know the targeted nominal leak rate. They will know the induced leak rate at the end of the test. However, the test procedures require the induced leak rate be within 10 percent of the nominal leak rate.

Individual Test Log
Volumetric Tank Tightness Testing Method

Name of field operator ______________________

Signature of field operator ______________________

Test no. __________ Date ______________________

Instructions: Use one log for each test. Fill in the blanks and check the boxes, as appropriate. Keep test log even if test is inconclusive.

1. General Background Information

Method name and version

____

Product type ______________________

Type of tank ______________________

Tank dimensions (nominal)

Diameter: __________ Inches

Length: __________ Inches

Volume: __________ Gallons

Groundwater level

_______ Inches above bottom of tank

Recommended stabilization period before test, per vendor SOP

__________ Hours __________ Minutes

2. Conditions Before Testing

Date and time at start of condition test tank

__________ Date __________ Military time

Stick reading before partial emptying of tank

- Product

  __________ Inches __________ Gallons

- Water

  __________ Inches __________ Gallons

Temperature of product in tank before partial emptying

__________ ☐ °F ☐ °C

Stick reading after partial emptying of tank – product

__________ Inches __________ Gallons

Amount of product removed from tank determined by subtraction __________ Gallons

Stick reading after filling to test level

- Product

  __________ Inches __________ Gallons

- Water

  __________ Inches __________ Gallons

Amount of product added to fill tank determined by subtraction __________ gallons

Temperature of product added to fill tank

__________ ☐ °F ☐ °C

Temperature of product in tank immediately after filling

__________ ☐ °F ☐ °C

Date and time at completion of fill

__________ Date __________ Military time

3. Topping Off Records, If Applicable

Date and time at completion of topping off

__________ Date __________ Military time

Approximate amount of product added

______ Gallons

If tank overfilled, height of product above tank

_______ Inches

Individual Test Log
Volumetric Tank Tightness Testing Method

Name of field operator ______________________________
Signature of field operator ______________________________
Test no. ____________ Date ______________________________

4. Conditions At Beginning Of Test

Date and time vendor began setting up test equipment

Date	Military time
__________	________

Complete induced leak rate data sheet; use attached pages 4 and 5

Date of test data collection

Start time of test data collection
________________ Military

Temperature of product at start of test
______________ ☐°F or ☐°C

Nominal leak rate
____________Gallon per hour

- Weather conditions at beginning of test

Ambient temperature	Barometric pressure
______________ ☐ °F or ☐ °C	______________ ☐ mm Hg ☐ inches Hg
Wind ☐ None ☐ Light ☐ Moderate ☐ Strong	Precipitation ☐ None ☐ Light ☐ Moderate ☐ Heavy
Sky condition ☐ Sunny ☐ Partly cloudy	 ☐ Cloudy ☐ Dark

Nominal leak rate _______ gal/hr

5. Conditions At Completion Of Testing

Date and time at completion of test data collection

Date	Military time
__________	________

Stick reading at completion of test data collection

- Product

  ________ Inches ________ Gallons

- Water

  ________ Inches ________ Gallons

- Weather conditions at end of test

Ambient temperature	Barometric pressure
______________ ☐ °F or ☐ °C	______________ ☐ mm Hg ☐ inches Hg
Wind ☐ None ☐ Light ☐ Moderate ☐ Strong	Precipitation ☐ None ☐ Light ☐ Moderate ☐ Heavy
Sky condition ☐ Sunny ☐ Partly cloudy	 ☐ Cloudy ☐ Dark

Date and time test method is disassembled, if done for this test, and tank is ready for service

Date	Military time
__________	________

Individual Test Log
Volumetric Tank Tightness Testing Method

Name of field operator ____________________
Signature of field operator ____________________
Test no. __________ Date ____________________

6. Leak Rate Data; Not To Be Filled Out By Field Crew

Nominal leak rate __________ gal/hr
Induced leak rate __________ gal/hr

Leak rate measured by vendor's method
__________ gal/hr

Difference measured rate minus induced rate
__________ gal/hr

Additional explanations or comments

____

____

____

____

____

____

____

Name of field operator ____

Signature of field operator ____ Test no. _______

Date of test ___________________________ **Induced Leak Rate Data Sheet**

	Time At Product Collection (military)	**Amount Of Product Collected (mL)**	**Comments, If Applicable**
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			

Appendix C

Non-Volumetric Methods Reporting Forms

Non-Volumetric Methods Evaluation Forms

Appendix C provides five sets of blank forms. When completed, these forms provide the framework for a standard report. They consist of:

1. Results Of U.S. EPA Standard Evaluation – Non-volumetric Tank Tightness Testing Method
2. Description – Non-volumetric Tank Tightness Testing Method
3. Reporting Form For Leak Test Results – Non-volumetric Tank Tightness Testing Method
4. Individual Test Log – Non-volumetric Tank Tightness Testing Method
5. Reporting Form For Water Sensor Evaluation Data – Non-volumetric Tank Tightness Testing Method

Each set of forms includes instructions on how to fill out the forms and who should complete them. Below is an overview of various responsibilities.

1. Results of U.S. EPA Standard Evaluation – The evaluator completes this form at the end of the evaluation.
2. Description of Non-volumetric Tank Tightness Testing Method – The evaluator**,** assisted by the vendor, completes this form by the end of the evaluation.
3. Reporting Form For Leak Test Results – The evaluator or the statistician analyzing the data completes this form. You can develop a blank form on a personal computer, generate the database for a given evaluation, and merge the two on the computer. The evaluator can also fill out this form manually. The evaluator's field crew inputs field test results and vendor's test results on the individual test logs as discussed below.
4. Individual Test Logs – The evaluator's field crew completes these forms. Keep these forms blind to the vendor during testing. The evaluator should reproduce at least 42 copies of the blank form provided in this appendix and produce a bound notebook for the complete test period.

   Non-volumetric methods may require some modification of the test log. We designed the form in this appendix from a volumetric test log. It is the responsibility of the evaluator to design the appropriate forms with input from the vendor. It is important to include in the test logs all parameters relevant to the evaluation of a specific method. In particular, it is necessary to document the induced leaks.

After completing the evaluation, the evaluator collates all the forms into a single standard report in the order listed above.

Distribution Of The Evaluation Test Results

The organization performing the evaluation prepares a report to the vendor describing the results of the evaluation. This report consists primarily of the forms in this appendix. The first form reports the results of the evaluation. This two-page form is designed to be distributed widely.

Provide a copy of this form to each tank owner or operator who uses this method of release detection. The owner or operator must retain a copy of this form as part of his record keeping requirements. The owner or operator must also retain copies of each tank test performed at his facility to document the tanks passed the tightness test. Distribute this two-page form to regulators who must approve release detection methods for use in their jurisdiction.

The evaluator submits the completed report consisting of all the forms in Appendix C to the vendor of the release detection method. The vendor may distribute the complete report to regulators who wish to see the data collected during the evaluation. The vendor may also distribute the report to customers of the release detection method who want to see additional information before deciding to select a particular release detection method.

The evaluator reports the optional part of the calculations, if conducted, to the vendor of the release detection method. The vendor may use these calculations to understand the details of the performance and perhaps improve the method. The vendor can decide whether to distribute this form.

The evaluator of the release detection method provides the report to the vendor. Distribution of the results to tank owners or operators and to regulators is the responsibility of the vendor.

Results Of U.S. EPA Standard Evaluation
Non-volumetric Tank Tightness Testing Method

Instructions For Completing The Form

The evaluator fills out this from after completing the evaluation of the method. This form contains the most important information relative to the method evaluation. Complete all items and check the appropriate boxes. If a question is not applicable to the method, write NA in the appropriate space.

This form consists of six main parts:

1. Method description
2. Evaluation results
3. Test conditions during evaluation
4. Limitations on the results
5. Certification of results
6. Additional evaluation results, if applicable

Method Description

Indicate the commercial name of the method, the version, and the name, address, and telephone number of the vendor. Some vendors might use different versions of their method when using it with different products or tank sizes. If so, indicate the version used in the evaluation. If the vendor is not the party responsible for the development and use of the method, then indicate the home office name and address of the responsible party.

Evaluation Results

Report the evaluation results separately for each detection mode if the method operates in different detection modes depending on field conditions. Describe the mode of detection for which the results are applicable.

Calculate P(fa), which is the probability of false alarm.

Report the number of false alarms and the number of tight tank tests, and report the 95 percent confidence interval based on the binomial distribution with N_1 tests.

In the blank, insert the leak rate used in the evaluation. This is the leak rate corresponding to the reported P(d) below.

Calculate P(d), which is the probability of detecting a leak of the size induced of no more than 0.10 gal/hr.

Report the number of correct detections and the number of simulated leak tests, and report the 95 percent confidence interval based on the binomial distribution with N_2 tests.

If the calculated P(fa) is 5 percent or less and if the calculated P(d) is 95 percent or more, check the does box. Otherwise, check the does not box. Note: the P(fa) and P(d) requirements apply to each release detection mode used by the method.

Indicate whether this method operates under more than one mode of detection. Check the appropriate box and complete page 4 regarding additional evaluation results, if applicable.

Test Conditions During Evaluation

Insert the information in the blanks provided. The nominal volume of the tank in gallons is requested, as is the tank material of steel or fiberglass. Also, report the backfill material in the tank excavation, for example clean sand or pea gravel. Give the tank diameter and length in inches. Report the product used in the testing. Give the range of temperature differences actually measured, as well as the standard deviation of the observed temperature differences. Report the groundwater level for the test tank in inches above the bottom of the tank. Report 0 for groundwater at or below the bottom of the tank.

Other sources of interference may affect non-volumetric methods. Report any sources of interference specific to the method on the lines provided. Also, report the range of test conditions for the indicated interference source. If no additional sources of interference are identified, check none.

Limitations On The Results

Where applicable, the size in gallons of the largest tank to which these results can be applied may be calculated as 1.5 times the size in gallons of the test tank. There are methods, such as vacuum decay methods, where this is not applicable.

Determine the temperature differential, the waiting time after adding product until testing, and the total data collection time using the results from calculations. Alternately, if the principle of operation of the method is unaffected by product temperature changes, check the box indicating temperature is not a limiting factor and give the justification.

Certification Of Results

The evaluator indicates which test procedure was followed and provides his or her name and signature, and the name, address, and telephone number of the organization.

Additional Evaluation Results, If Applicable

If checking the yes box relating to other release detection modes on page 1, then provide the necessary information for the P(fa) and P(d) for the additional release detection mode. Calculate these probabilities, based on the evaluation results obtained in detection mode.

Results Of U.S. EPA Standard Evaluation
Non-volumetric Tank Tightness Testing Method

This form tells whether the tank tightness testing method described below complies with the performance requirements of the federal UST regulation. The vendor or a consultant to the vendor conducted the evaluation according to U.S. EPA's *Standard Test Procedures For Evaluating Release Detection Methods: Volumetric and Non-volumetric Tank Tightness Testing*. The full evaluation report also includes a form describing the method and a form summarizing the test data.

Tank owners using this release detection method should keep this form on file to prove compliance with the federal UST regulation. Tank owners should check with regulatory authorities to make sure this form satisfies their requirements.

Method Description

Name ____

Version ____

Vendor ____

____

Street address

____

City State Zip

Evaluation Results

This method, which declares a tank to be leaking when ___________________________________

____

has an estimated probability of false alarms or P(fa) of__% based on the test results of___false alarms out of____________tests. A 95% confidence interval for P(fa) is from

_______ to ___________%.

The corresponding probability of detection or P(d) of a _gal/hr leak is___% based on the test results of___ detections out of _____________simulated leak tests. A 95% confidence interval for P(d) is from _______to _____%.

Does this method use additional modes of release detection? ☐ yes ☐ no. If yes, complete additional evaluation results on page 3 of this form.

Based on the results above and on page 3 if applicable, this method ☐ does ☐ does not meet the federal performance standards established by the U.S. Environmental Protection Agency of 0.10 gal/hr at P(d) of 95% and P(fa) of 5%.

Test Conditions During Evaluation

The evaluation testing was conducted in a ____________- gallon ☐ steel ☐ fiberglass tank, which was _______inches in diameter and ________inches long, installed in ______________backfill.

The groundwater level was ___________inches above the bottom of the tank.

Non-volumetric TTT method ____
Version ____

Test Conditions During Evaluation (continued)

The tests were conducted with the tank ________ % full.

The temperature difference between product added to fill the tank and product already in the tank ranged from ________°F to __________°F, with a standard deviation of _________°F.

The product used in the evaluation was ____________________________.

This method may be affected by other sources of interference. List these interferences below and give the ranges of conditions under which the evaluation was done. Check none if not applicable.

☐ none

Interferences	Range Of Test Conditions
____	___________________________
____	___________________________
____	___________________________

Limitations On The Results

The performance estimates above are only valid when

- The method has not been substantially changed.
- The vendor’s instructions for using the method are followed.
- The tank contains a product identified on the method description form.
- The tank capacity is __________gallons or smaller.
- The difference between added and in-tank product temperatures is no greater than + or - _degrees Fahrenheit.
- This method can be used on up to _____ of tanks connected by siphon piping with a total volume of ______.

☐ check if applicable
Temperature is not a factor because ____
____

- The waiting time between the end of filling the test tank and the start of the test data collection is at least _______hours.
- The waiting time between the end of topping off to final testing level and the start of the test data collection is at least __________hours.
- The total data collection time for the test is at least ____________ hours.
- The product volume in the tank during testing is _______% full.
- This method ☐ can ☐ cannot be used if the groundwater level is above the bottom of the tank.

Other limitations specified by the vendor or determined during testing

____
____

Non-volumetric TTT method ____
Version ____

Safety disclaimer: This test procedure only addresses the issue of the method's ability to detect leaks. It does not test the method for safety hazards.

Additional Evaluation Results, If Applicable

This method, which declares a tank to be leaking when ____

____

has an estimated probability of false alarms or P(fa) of ________% based on the test results of ___false alarms out of _________tests. Note: A perfect score during testing does not mean the method is perfect. Based on the observed results, a 95% confidence interval for P(fa) is from 0 to _________%.

The corresponding probability of detection or P(d) of a ____gal/hr leak is____% based on the test results of _____detections out of ______simulated leak tests. Note: A perfect score during testing does not mean the method is perfect. Based on the observed results, a 95% confidence interval for P(d) is from 0 to _______%.

Water Detection Mode, If Applicable

Using a false alarm rate of 5%, the minimum water level the water sensor can detect with a 95% probability of detection is ____________inches.

Using a false alarm rate of 5%, the minimum change in water level the water sensor can detect with a 95% probability of detection is ________inches.

Based on the minimum water level and change in water level the water sensor can detect with a false alarm rate of 5% and a 95% probability of detection, the minimum time for the method to detect an increase in water level at an incursion rate of 0.10 gal/hr is ____________minutes in a __________ gallon tank.

Certification Of Results

I certify the non-volumetric tank tightness testing method was installed and operated according to the vendor's instructions. I also certify the evaluation was performed according to the standard EPA test procedure for non-volumetric tank tightness testing methods and the results presented above are those obtained during the evaluation.

Printed name	Organization performing evaluation
Signature	City, state, zip
Date	Phone number

Description Of Non-volumetric Tank Tightness Testing Method

Instructions For Completing The Form

The evaluator, with assistance from the vendor, fills out this form, as part of the evaluation of the method. This form provides supporting information on the principles behind the method or on how the method works.

To minimize the time to complete this form, we provide possible answers to the most frequently expected questions. For those answers dependent on site conditions, give answers that apply in typical conditions. Write in any additional information about the testing method you believe is important.

There are seven parts to this form. They are:

1. Method Name and Version
2. Product
    - Product type
    - Product level
3. Principle of Operation
4. Temperature Measurement
5. Data Acquisition
6. Procedure Information
    - Waiting times
    - Test duration
    - Total time
    - Other important elements of the procedure or method
    - Identifying and correcting for interfering factors
    - Interpreting test results
7. Exceptions

Indicate the commercial name and the version of the method in the first part.

Note: The version is provided for methods that use different versions of the method for different products or tank sizes.

For the six remaining parts, check all appropriate boxes for each question. Check more than one box per question if it applies. If a box other is checked, complete the space provided to specify or briefly describe the matter. If necessary, use all the white space next to a question for a description.

Complete the section about other important elements of the procedure or method completed carefully. List here any other important elements of the method that could affect its performance. For example:

- If the pressure in the ullage space is different from atmospheric during testing, indicate whether a negative or positive pressure was applied. Report pressure and its units.
- If the method used is a tracer method, clearly document the process of adding the tracer to the tank and in the spiking port.
- If a tracer is added to the product in the tank, provide information on these items:
    - type of tracers
    - tracer concentration in the product
    - type of carrier
    - time between spiking and starting the test
    - type of sampling, for example, whether sampling is active or passive; in other words, how does the tracer reach the sampling ports? by natural diffusion process? is the process enhanced by adding forced air?
    - other relevant items
- When sampling ports are installed for tracer methods, measure the distances between any parts of the tank to its nearest sampling port. Report the largest of these distances.

Description
Non-volumetric Tank Tightness Testing Method

This section describes briefly the important aspects of the non-volumetric tank tightness testing method. It is not intended to provide a thorough description of the principles behind the method or how the method works.

Method Name And Version

____

Product

Product type

For what products can this method be used? Check all that apply.

- ☐ gasoline
- ☐ diesel
- ☐ aviation fuel
- ☐ fuel oil #4
- ☐ fuel oil #6
- ☐ solvents
- ☐ waste oil
- ☐ other, list ____

Product level

What product level is required to conduct a test?

- ☐ above grade
- ☐ within the fill pipe
- ☐ greater than 90% full
- ☐ greater than 50% full
- ☐ empty
- ☐ other, specify____

Principle Of Operation

What principle or principles are used to identify a leak?

- ☐ acoustical signal characteristic of a leak
- ☐ identification of a tracer chemical outside the tank system
- ☐ changes in product level or volume
- ☐ detection of water inflow
- ☐ other, describe briefly____

Temperature Measurement

If product temperature is measured during a test, how many temperature sensors are used?

- ☐ single sensor, without circulation
- ☐ single sensor, with circulation
- ☐ 2-4 sensors
- ☐ 5 or more sensors
- ☐ temperature-averaging probe

If product temperature is measured during a test, what type of temperature sensor is used?

- ☐ resistance temperature detector (RTD)
- ☐ bimetallic strip
- ☐ quartz crystal
- ☐ thermistor
- ☐ other, describe briefly ____

If product temperature is not measured during a test, why not?

- ☐ the factor measured for change in level or volume is independent of temperature, for example mass
- ☐ the factor measured for change in level or volume self-compensates for changes in temperature
- ☐ other, explain briefly ____

Data Acquisition

How are the test data acquired and recorded?

- ☐ manually
- ☐ by strip chart
- ☐ by computer

Procedure Information

Waiting times

What is the minimum waiting period between adding a large volume of product to bring the level to test requirements and the beginning of the test, for example from 50% to 95% capacity?

- ☐ not applicable
- ☐ no waiting period
- ☐ less than 3 hours
- ☐ 3-6 hours
- ☐ 7-12 hours
- ☐ more than 12 hours
- ☐ variable, depending on tank size, amount added, and operator discretion

Test duration

What is the minimum time for collecting data?

- ☐ less than 1 hour
- ☐ 1 hour
- ☐ 2 hours
- ☐ 3 hours
- ☐ 4 hours
- ☐ 5-10 hours
- ☐ more than 10 hours
- ☐ variable

Total time

What is the total time needed to test with this method?

Calculate setup time plus waiting time plus testing time plus time to return tank to service.
______________hours_________minutes

Other important elements of the procedure or method

List other elements that could affect the performance of the procedure or method; for example, positive or negative ullage pressure, tracer concentration, and distance between tank and sampling ports

____

____

____

____

Identifying and correcting for interfering factors

How does the method determine the presence and level of the groundwater above the bottom of the tank?

- ☐ observation well near tank
- ☐ information from USGS or others
- ☐ information from personnel on-site
- ☐ presence of water in the tank
- ☐ other, describe briefly ____
- ☐ level of groundwater above bottom of the tank not determined

How does the method correct for the interference due to the presence of groundwater above the bottom of the tank?

- ☐ head pressure increased by raising the level of the product
- ☐ different head pressures tested and leak rates compared
- ☐ tests for changes in water level in tank

- ☐ other, describe briefly ______________________________
- ☐ no action

Does the method measure inflow of water as well as loss of product in gal/hr?
- ☐ yes
- ☐ no

Does the method detect the presence of water in the bottom of the tank?
- ☐ yes
- ☐ no

How does the method identify the presence of vapor pockets?
- ☐ erratic temperature, level, or temperature-compensated volume readings
- ☐ sudden large changes in readings
- ☐ statistical analysis of variability of readings
- ☐ other; describe briefly ______________________________
- ☐ not identified
- ☐ not applicable, under filled test method used

How does the method correct for the presence of vapor pockets?
- ☐ bleed off vapor and start test over
- ☐ identify periods of pocket movement and discount data from analysis
- ☐ other, describe briefly ______________________________
- ☐ not corrected
- ☐ not applicable, under filled test method used

Are the method's sensors calibrated before each test?
- ☐ yes
- ☐ no

If not, how often are the sensors calibrated?
- ☐ weekly
- ☐ monthly
- ☐ yearly or less frequently
- ☐ never

Interpreting test results

What effect is used to declare the tank to be leaking? List all modes used by the method.

____

____

____

____

If a change in volume is used to detect leaks, what threshold value for product volume change in gal/hr is used to declare a tank is leaking?

- ☐ 0.05 gal/hr
- ☐ 0.10 gal/hr
- ☐ 0.20 gal/hr
- ☐ other____

Under what conditions are test results considered inconclusive?

- ☐ groundwater level above bottom of tank
- ☐ presence of vapor pockets
- ☐ too much variability in the data with standard deviation beyond a given value
- ☐ unexplained product volume increase
- ☐ other, describe briefly ____________________________________

Exceptions

Are there any conditions under which a test should not be conducted?

- ☐ groundwater level above bottom of tank
- ☐ presence of vapor pockets
- ☐ large difference between ground temperature and delivered product temperature
- ☐ extremely high or low ambient temperature
- ☐ invalid for some products, specify ______________________________
- ☐ soil not sufficiently porous
- ☐ other, describe briefly____________________________________

What are acceptable deviations from the standard testing test procedure?

- ☐ none
- ☐ lengthen the duration of test
- ☐ other, describe briefly ____________________________________

What elements of the test procedure are left to the discretion of the testing personnel on site?

- ☐ waiting period between filling tank and beginning test
- ☐ length of test
- ☐ determination of presence of vapor pockets
- ☐ determination of outlier data may be discarded
- ☐ other, describe briefly ____________________________________
- ☐ none

Reporting Form For Leak Test Results
Non-volumetric Tank Tightness Testing Method

Instructions For Completing The Form

The evaluator fills out this form after completing the evaluation of the method in each of its release detection modes. This form provides for 60 test results, although the minimum number of tests required in the test procedure is 42. Use as many pages as necessary to summarize all of the tests attempted. Report the results for each release detection mode on separate forms.

Indicate the commercial name and the version of the method and the period of evaluation above the table. The version is provided for methods that might use different versions of the method for different products or tank sizes. Also, indicate the release detection mode for which these results were obtained.

In general, the statistician analyzing the data completes this form. You may develop a blank form on a personal computer, generate the database for a given evaluation, and merge the two on the computer. You can also complete this form manually. The input for the form consists of the field test results recorded by the evaluator's field crew on the individual test logs and the vendor's test results.

The table consists of 10 columns. One line is provided for each test performed during evaluation of the method. If a test is invalid or aborted, list the test with the appropriate notation, for example invalid on the line.

The test number in the first column refers to the test number from the randomization design determined according to the test procedures. Since some changes to the design might occur during the course of the field-testing, the test numbers might not always be in sequential order. Report the results from the trial run need here as well.

The following list matches the column input required with its source, for each column in the table.

Column No.	Input	Source
1	Test number or trial run	Randomization design
2	Date at completion of last fill, if applicable	Individual test log
3	Time at completion of last fill, if applicable	Individual test log
4	Date test began	Individual test log
5	Time test began	Individual test log
6	Time test ended	Individual test log
7	Product temperature differential, if applicable	Individual test log
8	Nominal leak rate	Randomization design
9	Induced leak rate	Individual test log
10	Leak test results	Vendor's test result

Note: The product temperature differential in column 7 is the difference between the temperature of the product added and of the product in the tank, each time the tank is filled. This temperature differential is the actual differential achieved in the field and not the nominal temperature differential.

Reporting Form For Leak Test Results
Non-volumetric Tank Tightness Testing Method

Method name and version ____ Release detection mode ________________________

Evaluation period from ____________to ________________ (dates)

Test No.	If Applicable Date At Completion Of Last Fill (m/d/y)	If Applicable Time At Completion Of Last Fill (military)	Date Test Began (m/d/y)	Time Test Began (military)	Time Test Ended (military)	If Applicable Product Temperature Differential (° F)	Nominal Leak Rate (gal/hr)	Induced Leak Rate (gal/hr)	Tank Tight? (Yes, No, Or Test Invalid)
Trial Run						**0**	**0**	**0**	
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

Reporting Form For Leak Test Results
Non-volumetric Tank Tightness Testing Method

Method name and version ____ Release detection mode ______________________

Evaluation period from ____________to ______________ (dates)

Test No.	If Applicable Date At Completion Of Last Fill (m/d/y)	If Applicable Time At Completion Of Last Fill (military)	Date Test Began (m/d/y)	Time Test Began (military)	Time Test Ended (military)	If Applicable Product Temperature Differential (° F)	Nominal Leak Rate (gal/hr)	Induced Leak Rate (gal/hr)	Tank Tight? (Yes, No, Or Test Invalid)
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									
33									
34									
35									
36									
37									
38									
39									
40									

Reporting Form For Leak Test Results
Non-volumetric Tank Tightness Testing Method

Method name and version ____ Release detection mode ____________________________

Evaluation period from ______________to ___________________ (dates)

Test No.	If Applicable Date At Completion Of Last Fill (m/d/y)	If Applicable Time At Completion Of Last Fill (military)	Date Test Began (m/d/y)	Time Test Began (military)	Time Test Ended (military)	If Applicable Product Temperature Differential (° F)	Nominal Leak Rate (gal/hr)	Induced Leak Rate (gal/hr)	Tank Tight? (Yes, No, Or Test Invalid)
41									
42									
43									
44									
45									
46									
47									
48									
49									
50									
51									
52									
53									
54									
55									
56									
57									
58									
59									
60									

Individual Test Log
Non-volumetric Tank Tightness Testing Method

Instructions For Completing The Form

The evaluator's field crew completes the test log form. Fill out a separate form for each individual test including the trial run; that means at least 43. Keep the information on these forms blind to the vendor during the period of evaluation of the method. Adapt the form as needed to document the evaluation data.

The form consists of nine parts:

1. Header information
2. General background information
3. Conditions before testing
4. Topping off records, if applicable
5. For tracer methods only
6. Conditions at beginning of test
7. Conditions at completion of testing
8. Leak rate data
9. Additional comments, if needed
10. Data sheet for leak simulation for tracer methods
11. Data sheet for induced leak rate calibration

All items are to be filled out and the appropriate boxes checked. If a question is not applicable, then indicate as NA. The following provides guidance on the use of this form.

Header Information

Repeat the header information on all five pages, if used. If a page is not used, cross it out and initial it. The evaluator's field operator must print and sign his or her name and note the date of the test on top of each sheet.

Obtain the test number from the randomization design. It is not the sequential running test number. If a test must be rerun, indicate the test number of the test being rerun and indicate that on the test log, for example, test no. 5 repeat.

General Background Information

Indicate the commercial name of the method. Include version identification if the method uses different versions for different products or tank sizes. Prior to testing, obtain the recommended stabilization period, if applicable, from the vendor. This is important since it influences scheduling the evaluation. All other items in this section refer to the test tank and product. Indicate the groundwater level at the time of the test.

Theoretically, this information remains unchanged for the whole evaluation period. However, changing weather conditions can affect the groundwater level or the evaluator can change the test tank.

Conditions Before Testing

Fill in all the blanks. If the information is obtained by calculation, this can be done after the test is completed. An example is the amount of water in the tank is obtained from the stick reading and then converted to volume. Indicate the unit of all temperature measurements by checking the appropriate box.

Note: The term conditioning refers to all activities undertaken by the evaluating field crew to prepare for a test. As such, the term refers to emptying or filling the tank, heating or cooling product, and changing the leak rate. In some cases, all of the above are performed; in others, only one parameter might change. For tracers, conditioning refers to preparation of the tank for testing. It includes determining the time to wait between spiking and testing.

Topping Off Records, If Applicable

If you perform this step, fill in the appropriate blanks.

For Tracer Methods Only

Fill in the appropriate information. Follow the instructions and complete the form on page 4.

Conditions At Beginning Of Test

The evaluation organization's field crew calibrates the leak simulation equipment prior to the test. Document all leak rate calibration data need using the form on pages 4 or 5, as appropriate. Refer to previous calibration if done previously. Adapt the form as necessary.

Once the evaluator's field crew has the induced leak rate simulation, and the vendor starts the actual testing, record the date and time the vendor's test data collection starts. Also, indicate the product temperature at the time. Fill out the weather condition section of the form. Indicate the nominal leak rate, obtained from the randomization design.

Conditions At Completion Of Testing

Indicate date and time when the test is completed.

Again, stick the tank and record the readings and amount of water in the tank. Record all weather conditions as requested.

Leak Rate Data

The evaluator's statistician or analyst performing the calculations fills out this section. Therefore, he can complete it as the evaluation proceeds or at the end of the evaluation.

Obtain the nominal leak rate from page 2 under conditions at beginning of test. Check the rate against the nominal leak rate in the randomization design by matching test numbers.

Obtain the induced leak rate from the simulation data reported by the evaluating field crew on pages 4 or 5 of this form.

The vendor obtains the test result.

Identify the mode on the line following the test answer if the method uses more than one mode of release detection.

Additional Comments, If Needed

Use this page for any comments pertaining to the test. Examples include adverse weather conditions, method failure, and reason for invalid test.

Leak Simulation Form For Tracer Methods

For tracer methods, use the form on page 4 to document and measure delivery of the carrier with the appropriate concentration of the tracer to the spiking ports. Indicate the tracer used and the concentration of tracer in the carrier in the appropriate spaces. Report the distances between spiking port and all sampling ports. Record the time and amount of material released in the spiking port to document the leak simulation for tracer methods. Use as many pages as needed.

Induced Leak Rate Calibration Form

For acoustical methods, use the form on page 5 to calibrate the liquid flow through the simulator under a standard set of conditions. The induced leak rate is the rate at which the liquid will flow at a specified head or depth of product. Determine this rate by calibration and use it as the leak rate for detection. Perform the calibration at a different time than and preferably before, the testing. Calibrate for each distinct leak rate. After completing the calibrations, document on each daily test log the simulation conditions and reference the appropriate calibration data sheets, which should be attached to the daily test log that first uses the given induced leak rate.

Individual Test Log
Non-volumetric Tank Tightness Testing Method

Name of field operator ____
Signature of field operator ____ Test no. ______

Date of test ________________

Instructions
Use one log for each test.
Fill in the blanks and check the boxes, as appropriate.
Keep test log even if test is inconclusive.

General Background Information

Method name and version ____

Product type ____

Type of tank ____

Tank dimensions nominal measurement

Diameter ____________inches

Length _______ inches

Volume _____________inches

Groundwater level ___________inches above bottom of tank

Recommended stabilization period before test, per vendor standard operating procedure

_____________hours ________minutes

Conditions Before Testing

Date_________and military time ____________at start of conditioning test tank

Stick reading before partial emptying of tank

Product ______inches _____gallons

Water ________inches _____gallons

Temperature of product in tank before partial emptying _____________ °F ☐ or °C ☐

Stick reading after partial emptying of tank

Product_______inches _____gallons

Amount of product removed from tank using subtraction _____________gallons

Stick reading after filling tank to test level

Product_______inches _____gallons

Water________inches _____gallons

Amount of product added to fill tank using subtraction ________gallons

Name of field operator ____

Signature of field operator ____ Test no.______

Conditions Before Testing (Continued)

Temperature of product added to fill tank __________°F ☐ or °C ☐

Temperature of product in tank immediately after filling __________°F ☐ or °C ☐

Date ________and military time __________at completion of fill

Topping Off Records, If Applicable

Date ________and military time __________at completion of topping off

Approximate amount of product added _______gallons

If tank overfilled, height of product above tank _______inches

For Tracer Methods Only

Date ________and military time __________tracers added to product in test tank

Tracer used ___________________________

Amount of tracer used _____________

Amount of product in test tank _______gallons

Complete The Tracer Leak Simulation Form, Use Page 4

Date ________and military time __________ at start of test

Date ________and military time __________at conclusion of test

Conditions At Beginning Of Test

Date ________and military time __________vendor began setting up test equipment

Document Induced Leak Rate Determination, Use Page 5

Date ________and military time __________at start of vendor's test data collection

Temperature of product in tank at start of test __________°F ☐ or °C ☐

Weather conditions

Temperature ________°F ☐ or °C ☐

Barometric pressure ________mm Hg ☐ or ____________in. Hg ☐

Wind	None ☐	Light ☐	Moderate ☐	Strong ☐
Precipitation	None ☐	Light ☐	Moderate ☐	Heavy ☐
Sunny ☐	Partly cloudy ☐		Cloudy ☐	

Nominal leak rate __________gal/hr

Name of field operator ____

Signature of field operator ____________________________________ Test no. ______

Conditions At Completion Of Testing

Date _________and military time ____________at completion of test data collection

Stick reading at completion of test data collection

Product_______inches________gallons

Water ________inches ________gallons

Date of test _________________

Conditions At Completion Of Testing (Continued)

Temperature of product in tank at start of test _____________°F ☐ or °C ☐

Weather conditions

Temperature _________°F ☐ or °C ☐

Barometric pressure __________mm Hg ☐ or _______________in. Hg ☐

Wind	None ☐	Light ☐	Moderate ☐	Strong ☐
Precipitation	None ☐	Light ☐	Moderate ☐	Heavy ☐
Sunny ☐	Partly cloudy ☐		Cloudy ☐	

Date _________and military time ____________test method is disassembled, if done for this test, and tank is ready for service

Leak Rate Data

Release detection mode ____

Nominal leak rate ____________gal/hr

Induced leak rate _____________gal/hr

Findings for tracer methods

☐ No tracer found ☐ Tracers found

If tracers found, list ____

____

____

____

Test answer ☐ Leaking ☐ Tight ☐ Inconclusive

Additional Comments, Use Back Of Page If Needed

Name of field operator ____
Signature of field operator ____

Date of test ____________________________ Test no. ____________

Leak Simulation Form For Tracer Method
Reproduce Form, If Needed

Tracer used ____________________________
Carrier _________________________
Concentration of tracer in carrier ________________________

Distance from spiking port to

Sampling port 1 ______	Sampling port 5______
Sampling port 2______	Sampling port 6______
Sampling port 3______	Sampling port 7______
Sampling port 4______	Sampling port 8______

Name of field operator ____

Signature of field operator ____

Date of test ______________________________ Test no. ____________

Induced Leak Rate Calibration Form
Reproduce Form, If Needed

	Time (military)	Amount*	Comments
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			

*Indicate all measurement units.

Appendix D

Sensor Evaluation Forms

Results Of U.S. EPA Alternative Evaluation
Sensors

This form documents the performance of the sensor described below. The vendor, or a consultant to the vendor, conducts the evaluation according to the U.S. EPA's requirements for alternative protocols. The full evaluation report includes a report describing the method, a description of the evaluation procedures, and a summary of the test data.

Tank owners using this release detection system should keep this form on file to prove compliance with the federal UST regulation. Tank owners should check with regulatory authorities to make sure this form satisfies their requirements.

Method Description

Name ______________________________

Version______________________________

Vendor ______________________________

____
Street address

____
City State Zip

Sensor output type______________________________
Sensor operating principle______________________________
General description of the sensor ______________________________
____

Evaluation Results

The sensor listed above was tested for its ability to respond to a change in condition when tested in a controlled test vessel. The following parameters were determined from this evaluation.

- Precision standard deviation – Agreement between multiple measurements of the same product level.
- Detection time – Amount of time the detector must be exposed to product before it responds.
- Recovery time – Amount of time before the detector stops responding after being removed from the product.
- Specificity – Types of products that the sensor will respond to.

Parameter	Ethanol-blended Gasoline (_____ %)	Water	Diesel
Average detection height in inches			
Precision in inches			
Average detection time as hh:mm:ss			
Recovery time as hh:mm:ss			

Specificity			

Limitations On The Results

Limitations specified by the vendor or determined during testing

____

____

Certification Of Results

I certify the sensor was operated according to the vendor's instructions. I also certify the evaluation was performed according to the standard EPA test procedure for tank tightness testing methods and the results presented above are those obtained during the evaluation.

______________________________	______________________________
Printed name	Organization performing evaluation
______________________________	______________________________
Signature	City, state, zip
______________________________	______________________________
Date	Phone number

Reporting Form For Liquid Sensor Evaluation Data

Method name and version ______________________________

Date of test ______________________ Name of field operator ______________________

Product type ______________________ Signature of field operator ______________________

Test No. A	Volume Of Liquid Added (mL) B	Calculated Liquid Height Increment, h (in) C	Sensor Reading (in) D	Increment Difference Calc-Meas. (in) C-E
Minimum Level Detected, X:			**inches**	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Note: This form provides a template for data reporting. Use as many pages as necessary.

Reporting Form For Vapor Sensor Evaluation Data

Method name and version ____

Date of test ______________________ Name of field operator ______________________

Vapor type ______________________ Signature of field operator ______________________

Test No. A	Baseline Test Detection Time/ Recovery Time	250 PPM Detection Time/ Recovery Time	500 PPM Detection Time/ Recovery Time	1000 PPM Detection Time/ Recovery Time
Minimum Level Detected, X:				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Note: This form provides a template for data reporting. Use as many pages as necessary, one per vapor type.

United States Environmental Protection Agency
Land And Emergency Management 5401R
EPA 510-B-19-003
May 2019
www.epa.gov/ust