United States Environmental Protection Agency
Office of Underground Storage Tanks

Standard Test Procedures For Evaluating Release Detection Methods: Automatic Tank Gauging Systems

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List Of Acronyms And Abbreviations

ANOVA	analysis of variance
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
CITLDS	continuous in tank leak detection system
df	degrees of freedom
EPA	U.S. Environmental Protection Agency
°F	degree Fahrenheit
gal/hr	gallon per hour
K	tolerance coefficient
l/hr	liter per hour
LR	leak rate
MLC	minimum water level change
MSE	mean squared error
P(d)	probability of detecting a leak
P(fa)	probability of false alarm
SD	standard deviation
SE	standard error
SIR	statistical inventory reconciliation method
Th	threshold

TL	tolerance limit
UST	underground storage tank

Section 1: Introduction

1.1 Background

The federal underground storage tanks (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 the release detection category automatic tank gauging systems (ATGS).

This automatic tank gauging systems 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 Using EPA's Standard Test Procedures For Evaluating Release Detection Methods*. The general guidance provides an overview of the federal UST regulations, methods, and testing that may demonstrate that release detection methods are compliant with the regulatory performance standards. The general guidance is integral; it must be used with the test procedures.

The ATGS method must be capable of detecting a leak of 0.20 gallon per hour (gal/hr) with a probability of detection (P(d)) of (at least) 95 percent while operating at a false alarm rate of 5 percent or less. The federal regulation requires that for ATGS, the automatic product level monitor test must be able to detect a 0.20 gal/hr leak from any portion of the tank that routinely contains product and that its automatic inventory control function meets federal requirements for inventory control.

EPA's 1990 test procedures for ATGS intentionally did not address each aspect of the inventory control function of ATGS. In addition to the leak test function of the ATGSs, the 1990 test procedures only evaluated the water sensing function that is used for water measurement within the inventory control function of the ATGS. The leak test function and water sensing function are historically considered the primary leak detection modes of ATGS.

Through EPA's 1988 UST regulations Technical Compendium EPA, in 1993 allowed ATGS which met the performance standards for leak rate, probability of detection P(d), and probability of false alarm (P(fa) to be used without inventory control as another method under 40 CFR § 280.43(h). EPA updated this guidance in the 2015 federal UST regulation's Technical Compendium to state that ATGS must meet the water measurement requirement of the inventory control procedures. The 1990 test procedures for ATGS maintained the requirement for evaluation of the water sensing function

These revised test procedures for ATGS continue to evaluate the water sensing function of ATGSs by testing for minimum detectable water level and minimum detectable change in water level.

1.2 Objectives And Applications

The objective of the standard test procedures is to evaluate ATGS in a consistent manner. These test procedures only evaluate the leak test function and the water sensing function of ATGS since these functions are considered the primary modes to detect releases. UST owners and operators are required to demonstrate that the method of release detection they use meets the EPA performance standards of operating at (no more than) a 5 percent probability of false alarm (P(fa)) while having a P(d) of (at least) 95 percent to detect a leak of 0.20 gal/hr. These test procedures describe how this level of performance can be proven. In addition, by using lower leak rates with the same test design, an ATGS may be evaluated at a more stringent 0.10 gal/hr performance level.

The application of these test procedures evaluates methods that are installed in the tank and monitor product volume changes on a continuous basis during the test period. The evaluation will estimate the performance of the method's test mode and compare it with the EPA performance standards. These procedures provide tests to determine the threshold of water detection for the ATGS. The procedures also test the water ingress detection function to measure changes in the water level. The test results are compared to the EPA performance standard of 0.125 inch and are evaluated over a range of a few inches vertically from the bottom of the tank. The threshold and height resolution of the water detector are converted to gallons using the geometry of the tank.

The evaluator should determine whether a method is different enough from the originally tested model to warrant retesting. Some changes such as housing, cosmetic, or user interface are minor and would not warrant retesting. Other changes to the method that suggest improved performance or changes in the algorithm or equipment configuration should be retested.

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 these procedures to prove that the method meets the requirements of 40 CFR Part 280 and is subject to the limitations listed on the EPA’s standard evaluation form in Appendix B.

1.3 Evaluation Approach Summary

The ATGS is installed in the test tank and measures a leak rate under the no-leak condition (0.0 gal/hr) and with three induced leak rates of 0.10, 0.20, and 0.30 gal/hr for verification at 0.20 gal/hr. For the optional evaluation at 0.10 gal/hr, the ATGS will be used to measure a leak rate under the no-leak condition and with three induced leak rates of 0.05, 0.10, and 0.20 gal/hr. A total number of at least 24 tests are to be performed for both the 0.20 gal/hr and 0.10 gal/hr evaluation options.

The tank must be 50 percent full for half of the tests. It is refilled to about 90 to 95 percent full for the other 12 tests. A third fill level may be tested to demonstrate the lowest volume of product in the tank where the performance of the method still meets the regulatory performance requirements. The evaluator, using probe geometry, decides the fill level to test and thus establishes the low-level limitation.

When filling the UST, use product at least 10 degrees Fahrenheit (°F) (5.6 degrees Celsius [°C]) warmer than that in the test tank for one third of the fillings, product at least 10°F (5.6°C) cooler for another third of the fillings, and product at the same temperature for the third filling. The ATGS's ability to track 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. These differences are then used to calculate the performance of the method. Performance results are reported on the *Results of U.S. EPA Standard Evaluation Form* included in Appendix B.

The ability of the method to measure water entering a tank is tested by placing the water sensor in a standpipe containing a test product. Measured amounts of water are added to the tank and the sensor's ability to detect the water either at the bottom of the tank or entrained in the fuel is evaluated. The evaluation approach for where the water is detected at either of these two locations is similar except with what independent measurement device is used for comparison. Whether to monitor the bottom of the tank or the bulk fuel will depend on the miscibility of water with the test product. These results are also reported on the standard forms in Appendix B.

1.4 Organization Of This Document

The evaluation approach is presented in the following sections of this document:

- Section 2 presents a brief discussion of safety issues during testing
- Section 3 discusses the apparatus and materials needed to conduct the evaluation
- Section 4 provides step-by-step test procedures
- Section 5 describes the data analysis
- Section 6 provides the interpretation of results
- Section 7 describes how the results are to be reported. Two appendices are included in this document.
- Appendix A includes definitions for some technical terms
- Appendix B contains the forms for the data collection and reporting
    - Standard reporting form for the evaluation results
    - Standard form for describing the detection method
    - Data reporting forms
    - Individual test logs

Section 2: Safety

These test procedures only address the ATGS ability to detect leaks; they do not address testing the release detection method for safety hazards. The vendor should test and determine that the ATGS release detection method is safe for the intended products. Each release detection method should have a safety protocol provided by the vendor as part of its standard operating procedures. The protocol should specify requirements for safe installation and use of the method. In addition, all facilities hosting an evaluation of an ATGS should provide the safety policy and procedures to evaluating personnel on site. All safety requirements must be followed to ensure the safety of those performing the evaluation and those near the evaluation.

At a minimum, the following safety equipment should be available at the site:

- Two class ABC fire extinguishers
- One eyewash station (portable)
- Adequate quantity of spill absorbent
- Appropriate Safety signage such as No Smoking, Authorized Personnel Only, and Keep Out.

Personnel at the UST facility should wear safety glasses when working with product and steel-toed shoes when handling heavy pipes or covers. After the safety equipment has been placed at the site and before any work can begin, the area should be secured with appropriate signage.

All safety procedures appropriate for the product in the tanks and test equipment should be followed. The vendor should address key safety hazards such as fire, shock, intrinsic safety, product compatibility, etc. according to construction standards. Before testing, the evaluator should determine what safety procedures will be followed to ensure the test operation will be as safe as possible.

Section 3: Apparatus And Materials

3.1 ATGS Release Detection Method

The vendor will supply the ATGS. In general, an ATGS consists of a method for monitoring fuel volume or level, for compensating for temperature, and for detecting and monitoring water in the fuel. It will also typically include instrumentation for collecting and recording the data and procedures for using the data to calculate a leak rate and interpret the result as a passed or failed test.

The ATGS being tested should be operated by the evaluator personnel after the customary training. These test procedures evaluate methods of release detection and the water ingress detection separately.

Some vendors combine traditional release detection methods into hybrid methods. For example, some methods combine the automatic data collection features of ATGS with the sophisticated statistical data analysis used in statistical inventory reconciliation (SIR) methods. This allows the new methods to monitor the tank continuously, using data collected continually that are reviewed for adequacy. These methods then can operate without interfering with normal tank operation, whereas a traditional ATGS requires a shut-down period to conduct a leak test. These new technologies are collectively referred to as continuous in-tank leak detection systems (CITLDS). These hybrid methods may be evaluated using alternative test procedures. The National Work Group on Leak Detection Evaluations maintains a list of acceptable test procedures for reviewing third-party evaluations of equipment and methods to verify established performance standards are met.

3.2 Tanks

The standard test procedures require an UST known to be tight. A second tank or a tank truck is required to store product for the cycles of emptying and refilling. As previously stated, the tank must have been tested and shown to be tight. The tank should not have any history of problems. In addition, the test procedures call for an initial trial run with the test method under stable conditions. This test should confirm that the tank is tight; if it does not, there may be a problem with the tank or the test method that should be resolved before proceeding with the evaluation.

The tank facility used for testing must have at least one monitoring well, to determine the groundwater level. The presence of a groundwater level above the bottom of the tank would affect the leak rate in a real tank, that is, the flow of product through an orifice. The flow would be a function of the differential pressure between the inside and outside of the tank. However, in a tight tank with leaks induced to a controlled container separate from the environment, the groundwater level will not affect the evaluation testing. Consequently, it is not necessary to require that testing against the evaluation test procedures be done in a tank entirely above the groundwater level.

Testing may be conducted in any size UST. The results of the evaluation will be applicable to all smaller tanks; therefore, the larger the test tank used in the evaluation, the broader the applicability of the evaluation. The results are also applicable to larger tanks with the condition the tanks be no more than 50 percent larger in capacity than the test tank. This is a conservative and previously approved approach since there is no standard scaling method to apply here. Because the probe sensitivity to height is dependent on the tank geometry and volume, establishing a rule on volume is relatively arbitrary.

The test procedures call for filling or emptying the tank several times. Therefore, a second tank or a tank truck with the associated pumps, hoses, or pipes to transfer the product is needed to hold reserve product.

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, using at least 24 tests, are designed primarily to evaluate the methods with these widely marketed products

The evaluator and the vendor choose the test product, but it must be capable of being used with the release detection method. Products with similar physical and chemical characteristics may be used and results may, in some instances, be inferred to represent typical responses. Evaluating the method with a specific product verifies its performance with that product. Caution must be exercised in inferring that results represent typical responses across products with similar physical and chemical characteristics. The evaluator must justify the applicability of results to other products. However, since alcohol-based fuels and bio-blended fuels are appreciably dissimilar to petroleum-based fuels, the evaluation must specifically test a representative product under reasonable conditions likely encountered in the field, such as the presence of water from common sources like tank top sumps. Considerations such as water miscibility with the fuel blend, especially with alcohol-blended fuels, will require testing the functionality of the water ingress detection method used on the ATGS.

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 E-10, 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 ethanol-blended fuel, a separated aqueous phase will collect at the bottom of the UST. However, once the UST receives a fuel delivery mixing the contents, the water is absorbed into the fuel until it reaches saturation. This phenomenon has been shown to render traditional water detection floats unreliable unless the float composition density is adjusted in comparison with the density of the separated phase. Another alternative would be for the ATGS console to be programmed to recognize this reoccurring pattern of detected water followed by no detectable water.

As mentioned previously, water absorbed into the blended fuel will also increase the density and other physical parameters of the blend, thus making proper selection of volumetric correction factors difficult. In addition, a certain amount of water can be absorbed in alcohol 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. Therefore, an ATGS may be unreliable in detecting absorbed water, because the product volume will not accurately reflect the total volume of water that has entered a tank. An alternative means of determining water ingress may be required.

Given the variability of the proportion of bio-components in fuels, during testing the true proportion of ethanol, for example, or biodiesel to fuel needs to be determined and reported with the test results. Following the ASTM International standard methods presented below, or another national voluntary consensus code, an aliquot of the fuel must be analyzed for the biofuel content in order to characterize the fuel for listing the method. Table 1 below specifies the methods that may be used for bio-component analysis by fuel type.

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 method of inducing the leaks must be capable of being used with the release detection method and the product used during testing. Simulating leaks can be done by removing product from the tank at a constant rate, measuring the amount of product removed and the time of collection, and calculating the resulting induced leak rate. The experimental design described in Section 4 provides the nominal leak rates that are to be used.

Establishing the simulated leak may be achieved using a variety of equipment; however, a method that has been successfully used for inducing leaks in previous testing is based on a peristaltic pump. In this approach, an explosion-proof motor is used to drive a peristaltic pump head. The sizes of the pump head and tubing are chosen to provide the desired flow rates. A variable speed pump head is used so different flow rates can be achieved with the same equipment. The flow is directed through a rotameter so that flow can be monitored and kept constant. One end of the tubing is inserted into the product in the tank. The other end is placed in a container. Typically, volatile products are collected into a closed container in an ice bath.

The time of collection is monitored, the amount of product weighed, and the volume at the temperature of the tank is determined to obtain the induced leak rate. While it is not necessary to achieve the exact nominal leak rates, the induced leak rates should be within ±30 percent of the nominal rates. The induced leak rates should be carefully determined and recorded. The leak rates measured by the ATGS will be compared to the measured induced leak rates.

3.5 Water Ingress Sensor Test Equipment

A vertical standpipe is used to test the water sensor. The standpipe diameter should be large enough to accommodate the water sensor part of the ATGS and the height must be 8 inches or more. Minimizing waste is a consideration in determining the size of the water testing standpipe. The water sensor test setup needs to accurately measure the water phase height level to ±0.001 inch. The ATGS should be mounted so the water sensor is in the same relation to the bottom of the standpipe as it would be to the bottom of a UST. In addition, a means of adding water to the standpipe is needed. This can be accomplished by using a pipette or a peristaltic pump. Dispose of product miscible with water after the test. For water sensors used in alcohol-based fuels, an alternative means of determining water ingress is required. See Section 4.4 for suggested alternatives.

3.6 Miscellaneous Equipment

As noted, the test procedures require the partial emptying and filling of the test tank. One or more large capacity fuel pumps will be necessary to fill the tank in a reasonably short time. Hoses or pipes will be needed for fuel transfer and containers will be necessary to hold the product collected from the induced leaks. In addition, a variety of tools are necessary for making the necessary equipment connections.

Measuring the temperature of the product consistently is very important. One suggested way to measure the temperature of the product in the tank is to use a probe with five temperature sensors spaced to cover the diameter of the tank. The probe is inserted, or installed permanently, in the tank and the temperature readings of those sensors are used 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.

Section 4: Test Procedures

The test procedures for ATGS consist of two parts. The first evaluates the release detection function of the ATGS. The second evaluates its water ingress detection function and the method's resolution of sensing water ingress.

The overall performance of the ATGS is estimated by comparing the method's measured or detected leak rates to the actual induced leaks. Performance is measured over a variety of realistic conditions, including filling effects, such as potential loss of product from nozzle drips during filling operations. Extreme conditions, not represented in the testing, can cause any method to give misleading results. If the method performs well overall, then it may be expected to perform well in the field. The test procedures have been designed so that additional analyses can be done to determine whether the method's performance is affected by the product properties, the amount of product in the tank, or the size of the leak.

The test procedures introduce three main factors that may influence the method's test results: size of the leak, amount of product in the tank, and temperature variation. An additional factor is the method's ability to deal with groundwater level effects. This factor is evaluated when determining the method's water sensing threshold and resolution at the bottom of the tank or alternative means of determining water ingress is required.

The primary factor is the size of the leak. The method is evaluated on its ability to measure or detect leaks of specified sizes. If a method cannot closely measure a leak rate of 0.20 gal/hr or if the method demonstrates excessive variability on a tight tank, then its performance is not adequate. The ability of the method to track the leak rates can be compared for the different leak rates.

The second factor is the amount of product in the tank. Since ATGSs work at different levels of product in the tank, the required monthly test may be done at various levels. Two main levels have been chosen to represent these product levels:

- Half-full, which requires the most sensitive level measurement; and
- 90 to 95 percent full, which produces the most head pressure and the largest volume change given product temperature differentials.

For tanks that may routinely be operated at low volumes, an optional analysis is included for a third product level for vendors to demonstrate the lowest product level a test method can detect. This entails at least one test at each nominal leak rate and one at the 0.0 gal/hr leak rate, which total four additional tests. Details are provided in the supplementary analysis section (Section 5.3.6).

The third factor is temperature variation. The method is evaluated at ambient temperature and set temperature differentials to determine effects of temperature changes on the product.

In addition to varying these factors, environmental data are recorded to document the test conditions. These data may explain one or more anomalous test results.

The groundwater level is a potentially important factor in tank testing, and the method's means of addressing it must be documented. A method that does not determine and account for the groundwater level is not adequate. Groundwater levels are above the bottom of the tank at approximately 25 percent of UST sites nationwide, with higher proportions in coastal regions. The water sensing function of the ATGS is used to detect leaks in the presence of a groundwater level above the bottom of the tank. If the groundwater level is high enough so there is an inward pressure through most levels of product in the tank, then water will come into the tank if there is a hole below the groundwater level. Since an ATGS must operate at normal operating levels of product in the tank, it uses water incursion to detect leaks if there is a high groundwater level. These test procedures evaluate two aspects of the method's water sensing function: the minimum detectable water level and the minimum detectable change in water level. Together, these can be used with the dimensions of the tank to determine the ability of the method's water sensor to detect inflows of water at various rates.

4.1 Environmental Data Records

The test procedures, as referenced in 4.2.1, require that physical and environmental conditions and other test variables experienced or evaluated during the evaluation be reported. The following additional measurements should be reported (see the Individual Test Log in Appendix B):

- Ambient temperature, monitored at the beginning and end of each test
- Barometric pressure, monitored at the beginning and end of the test
- General weather conditions such as wind speed; sunny, cloudy, or partially cloudy sky, rain; snow; etc.
- Groundwater level
- Any special conditions that might influence the results

Both normal and unacceptable test conditions for each method should be described in the operating manual for the ATGS and provide a reference against which the existing test conditions can be compared. The evaluation should not be conducted under conditions outside the vendor's recommended operating conditions.

Pertaining to the tank and the product, the following items should be recorded on the Individual Test Log (see Appendix B):

- Type of product in tank
- Bio-component in product
- Tank volume
- Tank dimensions and type
- Amount of water in the tank (before and after each test)

- Temperature of product in the tank before filling
- Temperature of product added each time the tank is filled
- Temperature of product in the tank immediately after filling
- Temperature of product in the tank at start of test

4.2 ATGS Evaluation Test Procedures For Release Detection Mode

The following presents the test conditions and schedule to determine the performance of the ATGS.

4.2.1 Induced Leak Rates, Temperature Differentials, and Product Volume

Following a trial run in the tight tank, a minimum of 24 tests will be performed using a chosen fuel product according to the experimental design exemplified in Table 2. The fuel product tested must be a product that is expected to perform in a similar manner. Any product with similar physical and chemical characteristics may be used and results may be inferred to represent typical responses. The leak rates used will be randomized for each product volume. In Table 2, four nominal leak rates will be induced during the procedures and will be assigned randomly to the four leak rates LR_1- LR_4. These 24 tests evaluate the method under a variety of conditions. An option to perform testing at the lowest product level will add four more tests to the matrix and is described in more detail below.

Table 2. Product Volume Leak Rate And Temperature Differential Test Design

Product Volume (%)	Test No.	Pair No.	Set No.	Nominal Leak Rate (gal/hr)	Nominal Temperature Differential (°F)
	Trial Run	-	-	0.00	0
Fill to 90-95% full					
	1	1	1	LR_1	T_2
	2	1	1	LR_2	T_2
Empty to 50% full					
	3	2	1	LR_4	T_2
	4	2	1	LR_3	T_2
Optional: Empty to	*25*	*13*	*1*	LR_1	T_2
*lowest level**	*26*	*13*	*1*	LR_2	T_2
Fill to 90-95% full					
	5	3	2	LR_1	T_1
	6	3	2	LR_4	T_1
Empty to 50% full					
	7	4	2	LR_2	T_1
	8	4	2	LR_3	T_1
Fill to 90-95% full					
	9	5	3	LR_4	T_3
	10	5	3	LR_1	T_3
Empty to 50% full					
	11	6	3	LR_3	T_3
	12	6	3	LR_2	T_3
Fill to 90-95% full					
	13	7	4	LR_3	T_2
	14	7	4	LR_4	T_2
Empty to 50% full					
	15	8	4	LR_2	T_2
	16	8	4	LR_1	T_2
Optional: Empty to	*27*	*14*	*4*	LR_3	T_2
*lowest level**	*28*	*14*	*4*	LR_4	T_2
Fill to 90-95% full					
	17	9	5	LR_2	T_1
	18	9	5	LR_3	T_1
Empty to 50% full					
	19	10	5	LR_4	T_1
	20	10	5	LR_1	T_1
Fill to 90-95% full					
	21	11	6	LR_3	T_3
	22	11	6	LR_2	T_3
Empty to 50% full					
	23	12	6	LR_4	T_3
	24	12	6	LR_1	T_3

*The evaluator determines the lowest fill level with consideration for geometry of the equipment. If this option is used, the test numbers and pair numbers need to be updated.

Leak Rates

There are two possible evaluations, 0.20 gal/hr and 0.10 gal/hr. The following four nominal leak rates will be induced during the test procedures at the 0.20 gal/hr regulatory level:

English units (gal/hr)	**Metric units** (liters per hour[l/hr])
0.10	0.379
0.20	0.757
0.30	1.14

The following four nominal leak rates will be induced during the test procedures for a 0.10 gal/hr evaluation:

English units (gal/hr)	**Metric units** (l/hr)
0.0	0.0
0.05	0.189
0.10	0.379
0.20	0.757

Temperature Differentials

In addition, 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 will be used. These three temperature differentials are -5.6°, 0°, and +5.6 °C (-10°, 0°, and +10°F).

Product Volumes

The tests will be run in sets of two pairs, holding the temperature differential constant within a set of four tests but changing the leak rate within each pair. The product volume will alternate from pair to pair. The first pair of tests within a set will be run with the tank filled to 90 to 95 percent capacity. Then the tank will be emptied to 50 percent full and the second pair of tests in the set will be run. A third fill level, at the lowest product level a method is expected to measure, may be included by adding in a test at each of the four leak rates, increasing the number of tests to 28.

Randomization

The standard evaluation of 24 tests will be performed 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 two product volumes (50 percent full and 90 to 95 percent full) as outlined in Table 2. The evaluator is responsible for the randomization of the tests and achieves this by randomly assigning the nominal leak rates of 0.0, 0.10, 0.20 and 0.30 gal/hr to LR_1, LR_2, LR_3, and LR_4 and nominal temperature differentials of 0.0°, -5.6°, and +5.6 °C to T_1, T_2, and T_3, following the sequence of 24 tests as shown in Table 2. In addition, the evaluator will randomly assign the groups of four tests to the set numbers 1 to 6, without disturbing the order of the four tests within a set.

The vendor will install the ATGS and train the evaluator to operate it. After the trial run, the ATGS will be operated as it would be in a commercial facility. The evaluator will operate the ATGS and record its data. Note that since an ATGS operates automatically, it is not necessary to keep the induced leak rates blind to evaluator. The evaluator merely starts the release detection function of the ATGS at the appropriate time and records the results. 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 pairs of tests. Each pair of tests is performed using two induced leak rates, one induced temperature differential (temperature of product to be added - temperature of product in tank), and one in-tank product level. Each pair 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, that are 0.0, 0.10, 0.20, and 0.30 gal/hr, after randomizing the order, are denoted by LR_1, LR_2, LR_3, and LR_4. It is clear that these values cannot be achieved exactly in the field. Rather, these numbers are targets that should be achieved within ±30 percent.
The leak rates induced for each of the tests will be measured during each test. They will be denoted by S_1, S_2, ... S_{24}. These are the leak rates against which the leak rates obtained by the vendors performing their tests will be compared.

The leak rates measured by the ATGS during each of the 24 tests will be denoted 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 2). That is, for example, S_5 and L_5 correspond to the test results from the fifth test in the test sequence.

4.2.2 Testing Schedule

The vendor should be aware that the first test is a trial run, conducted with a tight tank in stable condition. The results of the trial run will be reported along with the other data but are not explicitly used in the calculations estimating the performance of the method.

The trial run has three purposes. One is to allow the vendor to check out the ATGS and provide instructions to the evaluator before starting the evaluation. As part of this check, any faulty equipment should be identified and repaired. The second purpose is to ensure that there are no problems with the tank and the test equipment. Practical field problems such as leaky valves or plumbing problems should be identified and corrected with this trial run. Finally, the trial run results provide verification that the tank is tight and a baseline for the induced leak rates to be run in the later part of the evaluation.

The evaluator performs the tests using a randomized arrangement of nominal leak rates, temperature differentials, and in-tank product levels as shown in Table 2. The time lapse between the two tests in each pair should be kept as short as practical. The date and time of starting each test are to be recorded and reported in the test log. Twelve pairs of tests will be carried out. After each pair of tests, the test procedure starts anew with either emptying the tank to half full or filling it up to 90 to 95 percent capacity, stabilizing, etc. Specific details of the testing procedures are presented in sequential steps in the following sections.

Step 1: **Randomize test variables.** For the 0.20 gal/hr evaluation, randomly assign the nominal leak rates of 0.0, 0.10, 0.20, and 0.30 gal/hr to LR_1, LR_2, LR_3, and LR_4. For the 0.10 gal/hr evaluation, randomly assign the nominal leak rates of 0.0, 0.05, 0.10, and 0.20 gal/hr. Also, randomly assign the temperature differentials of 0°, -10°, and +10°F to T_1, T_2, and T_3. Randomly assign the groups of four tests to the six sets.

Step 2: **Setup.** The vendor installs the ATGS and leak simulation equipment in the tank, making sure the leak simulation equipment will not interfere with the ATGS. The vendor also performs any calibration or operation checks needed with the installation of the ATGS and leak simulation equipment.

Step 3: **Trial run.** Following the vendor's standard operating procedure, fill the tank to 50 percent full, or any level within the operating range of the ATGS release detection mode, and allow for the stabilization period (or longer) as called for by the method. If product is added it should be at the same temperature as that of the in-tank product. Conduct a test on the tight tank to check out the tank system (tank, plumbing, etc.) and the ATGS. Perform any necessary repairs or modifications identified by the trial run.

During the trial run, record the temperature of the product in the test tank and that of any product added to fill the test tank. After the product has been added to fill the test tank, record the average temperature in the test tank.

Step 4: **Begin release detection testing.** Establish the tank fill height at 50 percent, if the product volume was above or below that level during the trial run.

Step 5: Fill the tank to between 90 and 95 percent capacity with product at the temperature required by the randomized test schedule. The temperature differential will be T_2 (Table 2, Test No.1). Record the date and time at the completion of the fill. Allow for the vendor-stated stabilization period, but not longer.

Step 6: Continue with the vendor's standard operating procedure and conduct a test on the tank, using the method's recommended test duration. Record the date and time of starting the test. This test will be performed under the first nominal leak rate of the first set in Table 2. This nominal leak rate to be induced is LR_1.

When the first test is complete, determine and record the actual induced leak rate, S_1, and the ATGS measured leak rate, L_1. Also record the data used to calculate the leak rate and the method of calculation. Retain all data sheets, computer printouts, and calculations. Record the dates and times at which the test began and ended and the length of the stabilization period. Report the data and environmental conditions for each test in the T Individual Test Log Form in Appendix B

Step 7: Change the nominal leak rate to the second in the first set, that is LR_2 (as in Table 2). **Repeat Step 6.** Note that there will be an additional period (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 (dates and times, measured and induced leak rates, temperatures, calculations, etc.).

Step 8: Empty the tank to 50 percent capacity (to within ± 5 percent of the tank midpoint). The temperature of the in-tank product will remain unchanged.

Step 9: Change the nominal leak rate to the third in the first set, that is LR_4. **Repeat Step 6.** Record all results.

Step 10: Change the nominal leak rate to the fourth in the first set, that is LR_3. **Repeat Step 7.** Record all results.

Optional step: Empty the tank to the evaluator-determined lowest fill level (to within ± 5 percent of the target height). The temperature of the in-tank product will remain unchanged.

Change the nominal leak rate to the first in the first set, that is LR_1. **Repeat Step 6.**

Change the nominal leak rate to the second in the first set, that is LR_2. **Repeat Step 7.**

Step 11: **Repeat Step 5.** The temperature differential will be changed to T_1.

Step 12: **Repeat Steps 6 through 10,** using each of the four nominal leak rates of the second set, in the order given in Table 2.

Steps 5 through 10, which correspond to a fill and empty cycle and one set of two pairs of tests, will be repeated until all tests are performed. After two neutral temperature test pairs, the tank is emptied to the evaluator-determined lowest product level and an additional pair of tests may be conducted. This entails at least one test at each nominal leak rate and one at the zero-leak rate, which totals four additional tests. Testing at low product levels involves reduced static head pressure. The low-level testing provides additional performance data of the method's ability to determine a leak under low product conditions.

4.3 Testing Problems And Solutions

Some tests may be inconclusive due to broken equipment, spilled product used to measure the induced leak rate, or other events that may interrupt the testing process. It is assumed that the evaluator would be able to judge whether a test result is valid. If a test is judged invalid during testing, then the following rules apply.

Rule 1: If a test is invalid, it needs to be rerun. The total number of tests must be at least 24. Report the test results as invalid with the reason and repeat the test.

Rule 2: If the method fails during the first test of a set of four tests and if the time needed for fixing the problem(s) is short (less than 20 percent of the average stabilization period or less than 1 hour, whichever is greater), then repeat that test. Otherwise, repeat the empty and fill cycle, the stabilization period, etc. and record all time periods.

Note: The average stabilization period is defined as the average time from filling to start of the test. The average, along with the range (shortest and longest periods), can be reported on the results of the EPA Standard Evaluation Form under Optional Test Results in Appendix B. If the delay would increase this time noticeably, then the test set should be redone.

Rule 3: If the method fails after the first test in a set of four has been completed successfully, and if the time needed for fixing the problem(s) is less than 8 hours, then repeat the test. Otherwise, repeat the whole cycle of empty and fill, stabilization, and test at the stated conditions according to applicable step.

4.4 ATGS Evaluation Test Procedures For Water Ingress Detection

The ATGS probe typically has a water sensor near the bottom of the tank. A standpipe to test the function of the water sensor consists of an independent height measurement capability accurate to ±0.001 inch. The ATGS probe is mounted so the water sensor is in the same relation to the bottom of the standpipe as to the bottom of a tank. Enough product is put into the standpipe so the liquid level sensor is high enough so as not to interfere with the water sensor. The vendor determines product or products used for testing based on the desired performance listing. The testing approach is the same regardless of the product's miscibility in water; however, the independent measurement must be appropriate for comparison to the method. For water detection at the bottom of a tank, a metered amount of water (equivalent to approximately 1/5th inch height increase per minute) is added to the standpipe until the water sensor detects it, at which time the water phase level is measured and recorded both independently and with the ATGS. Additional amounts of water are added to produce a measurable water phase level change of lesser than 1/16 inch or half of the vendor-stated resolution. Again, the independently-measured level change and the level change measured by the ATGS are recorded. This is done over the range of the water sensor or 6 inches, whichever is less. When testing is complete, the product and water are removed, separated or wasted (depending on the product water miscibility), and the process is repeated.

Depending on the water miscibility of the product, water entering a UST may or may not collect at the bottom of the tank. In this instance, ATGS vendors may adapt their water ingress detection methods to include detecting water ingress by monitoring the change in the total liquid level or a change in another characteristic of the bulk fuel, such as conductivity. An appreciable change in liquid level height can be interpreted as the detection of the increase of the total liquid volume in the tank. In the absence of a fuel delivery, that increase can be determined to be water and trigger an alarm. Again, in the absence of a fuel delivery, an appreciable change of another monitored fuel characteristic can be determined to be water and trigger an alarm. If an ATGS vendor claims the ability to detect water either entrained in the fuel or collecting at the bottom of the UST using liquid level sensor measurements or another bulk fuel sensor, follow the test procedures for water ingress detection and collect parallel independent measurements during the replicate tests. If the water ingress tests at the bottom of the tank do not use the 6 inches of height to detect, it may be necessary to continue the testing for this option up to 6 inches to observe the liquid level float or the bulk fuel monitor to detect the change and subsequently alarm.

Collect these data and the ATGS alarms associated with detecting water from the liquid level sensor measurements or another bulk fuel sensor. Note that a water sensor at the bottom of the tank and detecting water using liquid level measurements or another fuel characteristic may be tested simultaneously if the ATGS has both capabilities and differentiates the alarms for the operator. If the alarm does not differentiate the signals, the sensors would need to be evaluated separately as opposed to simultaneously.

The testing setup may need to be altered to accommodate the ATGS sensors and independent detectors. A larger and more rugged standpipe may be needed to gather the liquid level measurements by securing or burying the standpipe in a way that simulates the underground environment. Considerations such as material of construction of the standpipe need to be considered if glass is not strong enough to withstand simulating the underground environment. Finally, the method of independently measuring the characteristics of interest may need to be monitored using different technologies, for example if the sides of the standpipe are not visible for measurement with a ruler.

Another challenging operating condition with water detection due to water miscibility is when an ATGS water sensor detects the presence of water at the bottom of the tank, then a fuel delivery is received. Because the fuel delivery mixes water into the fuel, water is no longer detected at the bottom of the tank and the alarm stops. This alarm history could be repeated many times with or without the ATGS recognizing this pattern as an unusual operating condition that needs to be investigated. Again, in normal operations, all alarms indicating water detection should be investigated. If the ATGS can interpret this pattern and respond with an alarm, this capability can be evaluated as optional testing of the ATGS water detection mode. An additional step of simulating a fuel delivery is taken at the end of the water ingress test replicates (assuming the water sensor is in alarm from detecting a separated water phase).

To conduct the fuel delivery simulation, the standpipe needs to be large enough to hold the additional volume of fuel product to be added. The amount of fuel product to entrain the separated water should be mathematically calculated and will vary with the size of the standpipe, ethanol concentration of the product, and amount of water introduced during the test. The fuel volume calculated should be increased by 20 percent to ensure the water phase mixes during this portion of the test and to keep fuel use to a minimum. After the completion of all other water ingress testing for a replicate, dump the fuel into the standpipe and record the ATGS reaction. Repeat this simulation with all 20 replicates or until the ATGS recognizes and responds to the pattern of water being detected, mixing, and then not being detected.

The testing procedure for typical water ingress detection is given in detail below.

Step 1: Install the water sensor temporarily in the test standpipe with a diameter large enough to accommodate the water sensor. The water sensor test setup needs to be able to accurately measure the water phase level to ±0.001 inch.

Step 2: Fill the bottom section of the standpipe with the product (typically this will require a gallon or less). Enough product needs to be added so the product level is high enough not to interfere with the water sensor.

Step 3: Add water in increments or at a metered rate to the standpipe until the water sensor detects the presence of the water. Record the water phase level, the volume of water added and the water sensor reading until the sensor responds. The water sensor readings will be zero until the first sensor response. At that point, measure the water phase height, X_1, of water detected. Record all data on page 1 of the Reporting Form for Water Sensor Evaluation Data in Appendix B.

Step 4: Add enough water to the standpipe to produce a height increment (h) measured to the lesser of 1/16 inch or half of the claimed resolution. At each increment, record the water height (denoted by $W_{i,j}$ in Table 4 of Section 5.2) measured independently and by the water sensor. Use pages 2 and 3 of the Reporting Form for Water Sensor Evaluation Data in Appendix B as necessary. Repeat the incremental addition of water at least 20 times to cover the height of about 6 inches (or, the range limit of the water sensor, if less).

Step 5: Empty the standpipe, refill with product and **repeat Steps 2 and 3** 20 times to obtain 20 replications.

Collection of the additional data to evaluate other water detection capabilities can be simultaneous with the 20 replicate tests of water ingress testing. When the alarm for the detection of water ingress signals using the liquid level sensor, the height measurements are recorded on the data logs for evaluation. If this alarm is not triggered during a test or after 6 inches of water has been added, it is recorded as a false negative. When the alarm for the detection of an alarm pattern related to fuel delivery signals, the number of simulated fuel deliveries is recorded each time it alarms over the 20 replications.

Record all data using the reporting forms for ATGS water sensor data in Appendix B. The 20 minimum detectable water levels are denoted by X_j, j=1,…, 20. The water sensor reading at the i^{th} increment of the j^{th} test is denoted by $W_{i,j}$ as described in Table 4 and Section 5.2.

4.5 ATGS Alternative Evaluation Procedures For Release Detection Mode

Sections 4.1 to 4.4 provide test procedures that can be accomplished in about three calendar weeks. The standard approach described requires a tank that can be fully devoted to testing, which may be a difficult requirement. The following alternative approach uses in-service tanks. Only a limited amount of work is required that would prohibit using the tank for dispensing product.

The alternative approach consists of installing the ATGS in several tanks. Since the ATGS operates automatically, it can be programmed to perform a test whenever the tank is out of service for a long enough period, typically each night. With several available tanks, a large set of tests could be performed in a relatively short time. By selecting tanks in different climates or observing tanks over the change of seasons, tests can be performed under a wide variety of conditions. Thus, with little effort, a large database of test results on tanks assumed to be tight can be readily obtained.

This alternative approach will provide test data under a variety of actual conditions. In selecting the sites and times for the data collection, the evaluator should attempt to obtain a wide variety of temperature conditions and to conduct the tests at a wide variety of product levels in the tank as well as a variety of times after the tank receives a product delivery. This approach will produce data under conditions as observed in the field. The primary difference between the standard and alternative procedures is how the test conditions are attained. Both approaches attempt to conduct the evaluation testing under conditions representative of the real world. The standard approach does this by controlling the test conditions, while the alternative tests under a variety of situations and records the test conditions.

Supplement the database of ATGS test results on tight tanks with a limited number of tests using an induced leak. This demonstrates that the method can track an induced leak adequately and will respond to and identify a loss of product from the tank of the magnitude specified in the EPA performance standard. The combined data sets can then be analyzed to estimate the performance of the ATGS. If the resulting performance estimate meets the performance standard for an ATGS, that would constitute demonstration that the method meets the EPA standard.
The alternative approach will result in many tests on tight tanks, and relatively few tests under induced leak rate conditions. A suggested sample size is 100 tight tank tests and 10 induced leak rate tests. Larger numbers of either type of test can be used. It should be easy to collect tight tank tests; however, some work will be needed to prepare the database, recording the ancillary data. It will also be necessary to exclude some tests, for example those that were started, but had a delivery or dispensing operation during the test period.

The following steps provide an outline of the alternative approach to tank evaluation.

Step 1: Identify several tanks for installation of the ATGS. These tanks must be tight. The tanks can be of varying sizes, but the sizes used will limit the applicability of the results. The tanks should be at several sites, with a suggested minimum of five different sites and 10 different tanks.

Step 2: Install identical ATGSs in the tanks. Collect and record ancillary data to document the test conditions. The data needed are:

- Average in-tank product temperature prior to a delivery
- Time and date of each delivery
- Average in-tank product temperature immediately after a delivery
- Amount of product added at each delivery
- Date, time, and results of each test
- Product level when the test is run
- Tank size, type of tank, product contained, etc. (see the Individual Test Log for a form to record these data)

Step 3: Conduct tests in each tank for at least a two-week period. Tests should be run approximately nightly or as frequently as practical with the tank's use. Report the start and end dates of the test period. Record the test result along with the data listed in Step 2. The data above define the conditions of each test in terms of the time since the last fill (stabilization period), the product level, and the difference between the temperature of the product added and that of the product in the tank. Report all test results, even if some tests must be discarded because of product delivery or dispensing during the scheduled test period. Identify and report the reason for discarding any test data on the test log.

Step 4: Conduct tests with an induced leak at the rate between 0.10 and 0.20 gal/hr. These induced leak tests will generally require a person on site to monitor the induced leak rates and measure the rates achieved. A minimum of 10 tests is required, with some conducted shortly after a fill with a nearly full tank, and others conducted when the tank is about half full. The induced leak tests should be conducted on the largest available tanks to demonstrate the performance on the largest tank for which the ATGS is intended.

Step 5: At some time during the evaluation period, evaluate the performance of the water sensor function. This can be done at a separate site and does not require a tank. Follow the procedure described in Section 4.4.

Step 6: Using the resulting data, analyze the differences between the leak rate measured by the ATGS and the induced leak rate achieved (zero for the many tests on tight tanks) for each test to estimate the performance.

The resulting data can also be used to investigate the relationship of the error size (the leak rate differences) to each of the variables measured for the tests. These include tank size, length of stabilization period, temperature differential, product level, and presence of induced leaks. Multiple regression techniques can be used for these analyses, most of which would fall under the category of optional analyses. However, the data should be analyzed with the two groups of tight tank tests and induced leak rate tests separately to demonstrate that the method can determine the leak rates. Otherwise, it would be possible to have many tight tank tests with small errors that would obscure large errors on the small number of induced leak rates tests. An outline of the data analysis approach is given in Section 5.4.

Section 5: Calculations

From the results obtained after all testing is completed, the evaluation the method's performance will be calculated.

The evaluation of the ATGS in its release detection mode is presented first. These calculations compare the method's measured leak rate with the induced leak rate under a variety of experimental conditions. The P(fa) and P(d) are estimated using the difference between these two numbers. If the overall performance of the ATGS is satisfactory, analysis and reporting of results could end at this point. However, the experimental design has been constructed so the effects of stabilization period, product level, and temperature can be tested to provide additional information to the vendor.

A separate section (Section 5.2) presents the calculations to estimate the minimum detectable water level and the minimum water level change (MLC) the method can detect.

5.1 ATGS Release Detection Mode Performance Parameters

After all tests are performed according to the basic test design, a total of at least n = 24 data points each (4 leak rates x 3 temperature differentials x 2 fill levels) of measured leak rates and induced leak rates will be available. These data form the basis for the performance evaluation of the method. The measured leak rates are denoted by $L_1, \ldots, L_n$ and the associated induced leak rates by $S_1, \ldots, S_n$. These leak rates are numbered in chronological order. Table 3 summarizes the notation used throughout the test procedures, using the example test design in Table 2.

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

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

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

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

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 3. Notation Summary

Test No.	Pair No.	Set No.	Nominal Temperature Differential (°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}
Optional Lowest Level Tests							
25	13	8	T_2	LR_3	S_{25}	L_{25}	d_{25}
26	13	8	T_2	LR_2	S_{26}	L_{26}	d_{26}
26	14	9	T_2	LR_4	S_{27}	L_{27}	d_{27}
28	14	9	T_2	LR_1	S_{28}	L_{28}	d_{28}

Variance And Standard Deviation

The variance is obtained as follows:

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

Standard deviation (SD) is the square root of the variance.

Note: The differences between the measured and induced leak rates can be plotted against the time or the order in which they were performed. This data presentation detects any patterns that might exist, indicating potentially larger differences in the results from the first test of each set of tests, the three temperature differentials, or the in-tank product levels. The results 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. The differences between the measured and induced leak rates by induced leak rate can also be plotted against each other. This data presentation would graphically show the accuracy and precision of the ATGS at the various leak rates used during testing. (See Sections 5.3.3, 5.3.4, and 5.3.5 for appropriate statistical tests.)

Test For Zero Bias

To test whether the method is accurate – that is, the bias is zero – the following test on the bias calculated above is performed.
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) = degrees of freedom (df) and a two-sided 5percent 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 zero, and the bias is negligible. Otherwise, conclude the bias is statistically significant from zero.

5.1.2 False Alarm Rate, P(fa)

The normal probability model is assumed 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 the P(d) of a leak of 0.20 gal/hr.

The vendor will supply the threshold (Th) for interpreting the results of the ATGS test function. Typically, the leak rate measured by the ATGS is compared to Th and the results interpreted as indicating a leak if the measured leak rate exceeds the vendor stated Th. The P(fa) is the probability the measured leak rate exceeds Th 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 zero.

P(fa) With Negligible Bias

In the case of a nonsignificant B, 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, P(fa) is then obtained from the t-table, using n-1 df. P(fa) is the area under the curve to the right of the calculated value t_α.

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_α (see Figure 1). For example, with 23 df and $\alpha = 0.05$ (equivalent to a P(fa) of 5percent), $t_\alpha = 1.714$.

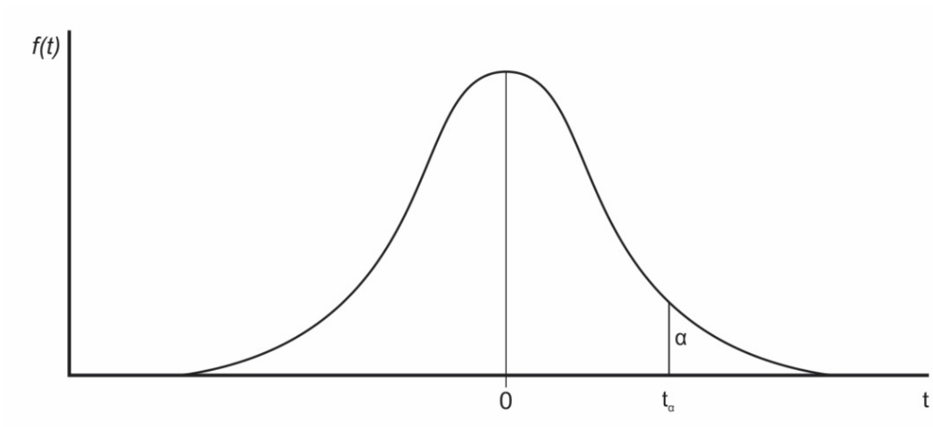

Figure 1. Student's t-Distribution Function

In this case, however, the area under the curve to the right of the calculated percentile, t_α, 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 on either side of the calculated statistic, t_α. The approach is illustrated next.

Suppose that the calculated $t_\alpha = 1.85$ and has 23 df. From Table A-1, obtain the following percentiles at df = 23:

t_α	Alpha (α)
1.714	0.05
1.85	X to be determined
2.069	0.025

Calculate X by linearly interpolating between 1.714 and 2.069 corresponding to 0.05 and 0.025, respectively.

$$X = 0.05 - \frac{(0.05 - 0.025)}{(1.714 - 2.069)} \times (1.714 - 1.85) = 0.040$$

Thus, the P(fa) corresponding to a t_α of 1.85 would be 0.040 or 4 percent.
A more accurate approach would be to use a statistical software package (e.g., SAS or SYSTAT) to calculate the probability.

P(fa) With Significant Bias

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

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

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 the B can be either positive or negative.

5.1.3 Probability Of Detecting A Leak Rate Of 0.20 gal/hr, P(d)

The P(d) with a leak rate of 0.20 gal/hr is the probability the measured leak rate exceeds Th when the true mean leak rate is 0.20 gal/hr. As for P(fa), one of two procedures are used in the computation of P(d), depending on whether the B is statistically significantly different from zero.

P(d) with Negligible Bias

In the case of a nonsignificant B – that is, the B is zero – compute the t-statistic:

$$t_3 = (C - 0.20)/SD$$

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 nonsignificant B except the B is included in the calculation. Compute the t-statistic.

$$t_4 = (C - B - 0.20)/SD$$

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).

5.1.4 Other Reported Calculations

This section describes other calculations needed to complete the Results of U.S. EPA Standard Evaluation Form (Appendix B).

Size Of Tank

The evaluation results are applicable to tanks of up to 50 percent larger capacity than the test tank and to all smaller tanks. Multiply the volume of the test tank by 1.5. Round this number to the nearest 100 gallons and report the result on page 1 of the results form (Appendix B). If the alternative approach for release detection testing is used, ~~r~~eference Section 5.4.

Tested Temperature Difference

Calculate the SD of the six actual temperature differentials achieved during testing (these six tests are the first in each of the six temperature sets) and reported with the testing details.

Average Waiting Time After Filling

Calculate the average of the time intervals between the end of the filling cycle and start of the test for the six tests that started immediately after the specified stabilization period (first test in each set). Note: If more than six tests are done immediately after the filling, use all tests. However, do not use the time to the start of the remaining three tests in a set as this would give a misleading waiting time. Report the average time as the waiting time after adding product on the results form. At the discretion of the evaluator, the median may be used instead of the average if there are 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 *n*. Report this time as the average data collection time per test.

5.2 ATGS Water Ingress Detection Mode Performance Parameters

Estimate two parameters for the water sensor: the minimum detectable water level or threshold that the water sensor can determine, and the smallest change in water level the sensor can record. These results specific to the product used during testing will also be reported on the Results of U.S. EPA Standard Evaluation Form in Appendix B. Additional data analyses collected under optional testing of the ATGS water detection is also presented below.

5.2.1 Minimum Detectable Water Level

The data obtained consist of 20 replications of a determination of the minimum detectable water level (see Section 4.4). These data, denoted by x_1,j=l,…, 20, are used to calculate the minimum water level that can be detected reliably by the method.

Step 1: Calculate the mean, $\overline{X}$, of the 20 observations:

$$\bar{X} = \sum_{j=1}^{20} X_j/20$$

Step 2: Calculate the SD of the 20 observations:

$$SD = \left[\frac{\sum_{j=1}^{20}\left(X_j - \bar{X}\right)^2}{20-1}\right]^{\frac{1}{2}}$$

Step 3: From a table of tolerance coefficients (K) for one-sided normal tolerance intervals with a 95 percent probability level and a 95 percent coverage, obtain K for a sample size of 20. The coefficient in this instance is K = 2.396. See Table A-2 for the appropriate K values for one-sided normal tolerance intervals.

Step 4: Calculate the upper tolerance limit (TL) for 95 percent coverage with a K of 95 percent:

$$TL = \bar{X} + K\,SD,$$

or

$$TL = \bar{X} + 2.396\,SD$$

TL estimates the minimum level of water that can be detected by the method. That is, with 95 percent confidence, the ATGS should detect water at least 95 percent of the time when the water depth in the tank reaches TL.

5.2.2 Minimum Water Level Change

The following statistical procedures provides a means of estimating the MLC the water sensor can detect, based on the testing described in Section 4.4.

Denote by $W_{i,j}$ the sensor reading (in inches) at the j^{th} replicate and the i^{th} increment ($i=1,\ldots,n_j$, with n_j being 20 or more in each replicate). Note the number of steps in each replicate need not be the same, so the sample sizes are denoted by n_j.

Denote by h (measured to the lesser of 1/16 inch or half the claimed resolution) the level change induced at each increment. Let m (greater than or equal to 3) be the number of replicates.

Step 1: Calculate the differences between consecutive test results. The first increment will be $W_{1,1}$-X_1 for the first replicate (j=1); more generally, $W_{1,j}$-X_j, for the j^{th} replicate. The second increment is $W_{2,1}$-$W_{1,1}$ for the first replicate; more generally, $W_{2,j}$-$W_{1,j}$ for the j^{th} replicate, etc.

Step 2: Calculate the difference, at each incremental step, between h, the level change induced during testing, and the difference obtained in Step 1. Denote these differences by $d_{i,j}$, where i and j represent increment and replicate numbers, respectively. Table 4 summarizes the notations.

Table 4. Notation Summary For Water Sensor Readings At The j^{th} Replicate

Increment No.	Independently Measured Level Change, h (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	$W_{3,j}$	$W_{3,j}$- $W_{2,j}$	$d_{3,j}$
•	•	•	•	•
•	•	•	•	•
•	•	•	•	•
•	•	•	•	•
•	•	•	•	•
•	•	•	•	•
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 depth (inches) detected for the first time during the j^{th} replication of the test.

Note the first result, X_j, may vary from replicate to replicate, so the number of differences $d_{i,j}$ will also vary. Let n_j be the number of increments necessary during replicate j.

Step 3: Calculate the average, D_j, of the differences $d_{i,j}$, i=1,…,n_j, separately for each replicate j, j=1,…, 20.

$$D_j = \sum_{i=1}^{n_j} d_{i,j}/n_j$$

Step 4: Calculate the variance of the differences, Var_j, i=1,…, n_j separately for each replicate j, j=1,…, m.

$$Var_j = \sum_{i=1}^{n_j} \frac{\left(d_{i,j}-D_j\right)^2}{(n_j-1)}$$

Step 5: Calculate the pooled variance, Var_p, of the m variancesVar_1,…, Var_m.

$$Var_p = \frac{(n-1)Var_1 + \cdots + (n_m-1)Var_m}{\sum_{j=1}^{m}(n_j-1)}$$

Step 6: Calculate the pooled SD_P.

$$SD_p = \sqrt{Var_p}$$

Step 7: From Table A-3 of K values for two-sided tolerance intervals with 95% probability and 95 percent coverage, obtain K for $(\sum n_j - m)$ df. A single set of 20 or more results can be used to estimate this SD, resulting in n – 1 df (19 if 20 are used, giving a K of 2.784.) For the suggested sample size of 20 increments, one might want to use different starting levels to make sure that the starting level does not adversely affect the ability to track level changes. Two starting levels would result in 20 increments. The factor of K is based on the df for the pooled SD. If two sets of 10 determinations are used, the df would be 18 and the corresponding K would be 2.189.

Step 8: Calculate the MLC the water sensor can detect.

$$MLC = K\ SD_p$$

or

$$MLC = 2.233\ SD_p$$

5.2.3 Water Ingress Detection With Liquid Level Measurements (Optional)

The 20 test results from this optional portion of testing identify water ingress using the liquid level measurement increase. These results will be calculated and reported as a percentage of the replicates where the increase was correctly identified as water ingress (qualitative).

5.2.4 Water Ingress Detection After Water Ingress Alarm, Mixing, Then No Alarm (Optional)

The 20 test results from this optional portion of testing identify water ingress after a simulated fuel drop. The results will be reported by the number of replicates of the cycle conducted until the unusual operating condition was detected by the ATGS. If detected multiple times within the 20 replicates, report the average number of cycles to detect.

5.2.5 Time To Detect A 0.20-Gal/hr Water Incursion (Optional)

The minimum detectable water level and the MLC can be used to determine a minimum time needed to detect a water incursion into the tank at a specified rate. This time is specific to each tank size and geometry and to product-water miscibility. The calculations are illustrated for an 8,000-gallon steel tank with a 96-inch diameter and 256 inches long. Any figure derived would also need to include the times that the given tank dimensions were measured.

Suppose there are x inches of water phase in the tank. The tank is made of quarter-inch steel, so the inside diameter is 95.5 inches, giving a radius, r, of 47.75 inches. The water phase surface will be 2d wide, where d, in inches, is calculated as

$$d = \sqrt{r^2 - (r - x)^2}$$

where x is the water phase depth. The area of the water surface at depth of x inches of water is then given by 255.5 x 2d $inch^2$. Multiplying this by the MLC and dividing the result by 231 $inch^3$ per gallon gives approximately the volume change in gallons the water sensor can detect reliably. This differs with the level of water phase in the tank. (For a somewhat more accurate approximation, calculate d at level x and at level x + MLC and average the two readings for the d to be used to calculate the change in volume of water phase that can be detected.)

To determine how long the ATGS will take to detect a water incursion at the rate of 0.20 gal/hr, divide the minimum volume change the water sensor can detect by 0.20 gal/hr. As a numerical example, suppose the depth of the water was 1 inch and the MLC were 1/8 inch. In an 8,000-gallon tank with inside diameter 95.5 inches and inside length 255.5 inches, the water surface width, d, is calculated as

$$d = \sqrt{(47.75)^2 - (46.75)^2} = 9.72\ inches$$

The volume, in inch^3, corresponding to a 1/8-inch increase is

$$V = 2(9.72) \times 255.5 \times (1/8) \text{ or}$$
$$V = 620.94\ inch^3$$

In gallons, the volume is

$$V = \frac{620.94}{231} = 2.688\ gallon$$

The time the water sensor will take to detect water incursions at the rate of 0.20 gal/hr will be

$$time = \frac{2.688\ gallons}{0.20 \frac{gal}{hr}} = 13.44\ hours$$

Thus, the sensor would detect water coming in at the rate of 0.20 gal/hr after 13.4 hours, or about half a day. The incursion of the water into the tank should be obvious on a day-to-day basis under these conditions. The analysis presumes that water ingress rate is constant at 0.2 gal/hr, which is unlikely given static head pressure changes caused by the tank being active and height of the groundwater outside the tank. This calculation also assumes the ATG probe is mounted at the midpoint of the tank, otherwise the tank tilt becomes a factor that has the potential to drastically increase or decrease this result.

5.3 Supplemental Calculations And Data Analyses (Optional)

Other information can be obtained from the test data. This information is not required for establishing the ATGS meets the federal EPA performance requirements but may be useful to the vendor of the ATGS. The calculations described in this section are therefore optional. They may be performed and reported to the vendor but are not required and are not reported on the results form. These supplemental calculations include determining a minimum threshold, a minimum detectable leak rate, and relating the performance to factors such as temperature differential, stabilization period, and product level. Such information may be particularly useful to the vendor for future improvements of their ATGS.

The experimental design tests the method under a variety of conditions chosen to be reasonably representative of actual test conditions. The tests occur in pairs after each fill cycle. A comparison of the results from the first of the pair with the second of that pair allows one to determine if the additional stabilization time improved the performance. Similarly, comparisons among the tests at each temperature condition allow one to determine whether the temperature conditions affected the performance. Finally, the performance under the four induced leak conditions can be compared to determine whether the method performance varies with leak rate.

The factors can be investigated simultaneously through a statistical technique called analysis of variance (ANOVA). The detailed computational formulas for a generalized ANOVA are beyond the scope of these test procedures. For evaluators unfamiliar with ANOVA, equations to test for the effect of stabilization period, temperature, and product volume individually are presented in detail, although the evaluator may to use the ANOVA approach to the calculations if they have the knowledge and computer programs available.

5.3.1 Minimum Threshold

The 24 test results can also be used to determine a threshold to give a specified false alarm rate of 5 percent, for example. This threshold may not be the same as the threshold (Th) pertaining to the method as reported by the vendor. Denote by $Th_{5\%}$, the threshold corresponding to a P(fa) of 5 percent. The following demonstrates the approach for computing $Th_{5\%}$. Solve the equation

$$P(fa) = P\left\{t > \frac{Th_{5\%} - B}{SD}\right\} = 0.05$$

for $Th_{5\%}$. If the bias is not statistically significantly different from zero (Section 5.1.1), then replace B with 0. From the t-table with n-1 = df obtain the 5th-percentile. This value is 1.714. Solving the equation above for $Th_{5\%}$ yields

$$\frac{Th_{5\%} - B}{SD} = 1.714$$

In the case of a nonsignificant bias, this would be $Th_{5\%}$ = 1.714 SD.

5.3.2 Minimum Detectable Leak Rate

With the data available from the evaluation, the minimum detectable leak rate, $LR_{5\%}$, corresponding to a P(d) of 95 percent and a calculated threshold, $Th_{5\%}$, can be calculated by solving the following equation for $LR_{5\%}$:

$$P(d(LR_{5\%})) = P\left\{t > \frac{C_{5\%} - LR_{5\%} - B}{SD}\right\} = 0.95$$

where $Th_{5\%}$ is the threshold corresponding to a P(fa) of 5 percent as previously calculated.

At the P(fa) of 5 percent, solving the equation above is equivalent to solving

$$\frac{Th_{5\%} - LR_{5\%} - B}{SD} = -1.714$$

or

$$LR_{5\%} = 1.714\ SD + Th_{5\%} - B$$

which, after substituting 1.714 SD for ($Th_{5\%}$–B), is equivalent to

$$LR_{5\%} = 2Th_{5\%} - 2B$$

Substitute 0 for B in all calculations when the B is not statistically significant. Otherwise, use the value of B estimated from the data.

Thus, the minimum-detectable leak rate with a P(d) of 95 percent is twice the calculated threshold, $Th_{5\%}$, determined to give a false alarm of 5 percent, minus twice the bias if the bias is statistically significant.

In summary, based on the 24 pairs of measured and induced leak rates, the minimum threshold, $Th_{5\%}$, and the minimum detectable leak rate, $LR_{5\%}$, are calculated as shown below.

If the bias is not statistically significant:

For a P(fa) of 5%	$Th_{5\%}$= 1.714 SD
For a P(d(R)) of 95%	$LR_{5\%}$ = $2C_{5\%}$

If the bias is statistically significant:

For a P(fa) of 5%	$Th_{5\%}$= 1.714 SD + B
For a P(d(LR)) of 95%	$LR_{5\%}$ = $2C_{5\%}$– 2 B

5.3.3 Test For Adequacy Of Stabilization Period

The performance estimates obtained in Sections 5.1.2 and 5.1.3 will indicate whether the method meets the EPA performance standards. The calculations in this section allow one to determine whether the method's performance is affected by the additional stabilization time the tank has experienced by the second test after each fill cycle. These statistical tests are designed primarily to help determine why an ATGS did not meet the performance standards.

The ATGS conducts the test after a specific stabilization period to ensure the temperature is stable enough to perform the test. The rate of temperature change as the threshold for the stabilization period may also be accounted for by ATGS. As such, the stabilization period would be specific to the fuel being measured and not encompassed under a blanket stabilization period used for all tests.

The procedures outlined in Section 4 allow time for the tank to stabilize after fuel is pumped into the tank prior to the first test of each set. Thus, additional stabilization takes place between the first and second tests of the first pair in each set. The length of the stabilization period following refueling as well as the time between tests are specified by each ATGS vendor. The following statistical test is a means to detect whether the additional stabilization period for the second test improves performance. If the stabilization period prior to the first test in each set is too short, then one would expect larger discrepancies between measured and induced leak rates for these first tests as compared to those for the second tests.

Step 1: Calculate the absolute value of the 12 differences, d_j, between the measured (L) and induced (S) leak rates for the first 2 tests in each set (second to last column in Table 5).

Step 2: Calculate the average of the absolute differences for the first and second test in each set separately.

$$D_1 = (d_1 + d_5 + d_9 + d_{13} + d_{17} + d_{21})/6$$
$$D_2 = (d_2 + d_6 + d_{10} + d_{14} + d_{18} + d_{22})/6$$

Step 3: Calculate the variances of the absolute differences from the first and second test in each set separately.

$$S_1^2 = \{(d_1 - D_1)^2 + (d_5 - D_1)^2 + \cdots + (d_{21} - D_1)^2)\}/5$$
$$S_2^2 = \{(d_2 - D_2)^2 + (d_6 - D_2)^2 + \cdots + (d_{22} - D_2)^2)\}/5$$

Step 4: Calculate the pooled SD.

$$S_p = \sqrt{\frac{5S_1^2 + 5S_2^2}{10}} = \sqrt{\frac{S_1^2 + S_2^2}{2}}$$

Step 5: Calculate the t-statistic:

$$t = \frac{(D_1 - D_2)}{S_p\sqrt{\frac{2}{6}}} = \frac{\sqrt{3}(D_1 - D_2)}{S_p}$$

Step 6: From the t-table, obtain the critical value corresponding to a t with (6 + 6 - 2) = 10 df and a two-sided 5 percent significance level ($\alpha = 0.025$ in the table). This value is 2.228.

Step 7: Compare the absolute value of t, abs(t), to 2.228. If abs(t) is less than 2.228, conclude the average difference between measured and induced leak rates obtained from the first tests after stabilization is not significantly different (at the 5 percent significance level) from the average difference between measured and induced leak rates obtained from the second tests after stabilization. In other words, there has not been an additional stabilization effect between the beginning of the testing and the end. Otherwise, conclude the difference is statistically significant, meaning the method's performance is different with a longer stabilization period**.**

If the results are statistically significant, then the performance of the method is different for the tests with the additional stabilization period. If the performance is better, that is, if the absolute differences for the testing with additional stabilization are smaller than those for the tests with the minimum stabilization period, then the method would show improved performance if it increased its required stabilization period. If the method's overall performance did not meet the EPA performance standard, performance estimates with the additional stabilization can be calculated using only the 6 test results with the additional stabilization time. If the results indicate the method does not meet the EPA performance standard but could meet the EPA performance standard with the additional stabilization time, that conclusion should be reported. Note the method would still need to conduct the full 24 tests at the longer stabilization period before claiming to meet the EPA performance standard.

5.3.4 Test For Adequate Temperature Compensation

This section allows one to test whether the method's performance is different for various temperature conditions. A total of eight tests will have been performed with each of the three temperature differentials, T_1, T_2, and T_3 (the nominal values of 0°, -10°, and +10°F will have been randomly assigned to T_1, T_2, and T_3). The 24 tests have been ordered by temperature differential and test number in Table 5 for the example order of sets from Table 2. In general, group the tests by temperature condition. The test results from the three temperature conditions are compared to check the method's performance in compensating for temperature differentials. If the temperature compensation of the method is adequate, the three groups should give comparable results. If temperature compensation is not adequate, results from the conditions with a temperature differential will be less reliable than results with no temperature difference. The following statistical procedure (Bonferroni t-tests) provides a means of testing for temperature effect on the test results. With three temperature differentials considered in the test schedule, three comparisons will need to be made: T_1 vs. T_2, T_1 vs. T_3, and T_2 vs. T_3.

Table 5. Organization Of Data To Test For Temperature Effects

Test No.	Pair No.	Set No.	Nominal temperature differential (°F)	Absolute leak rate difference |L - S| (gal/hr)	Group No.
5	3	2	T_1	d_5	Group 1
6	3	2	T_1	d_6	
7	4	2	T_1	d_7	
8	4	2	T_1	d_8	
17	9	5	T_1	d_{17}	
18	9	5	T_1	d_{18}	
19	10	5	T_1	d_{19}	
20	10	5	T_1	d_{20}	
1	1	1	T_2	d_1	Group 2
2	1	1	T_2	d_2	
3	2	1	T_2	d_3	
4	2	1	T_2	d_4	
13	7	4	T_2	d_{13}	
14	7	4	T_2	d_{14}	
15	8	4	T_2	d_{15}	
16	8	4	T_2	d_{16}	
9	5	3	T_3	d_9	Group 3
10	5	3	T_3	d_{10}	
11	6	3	T_3	d_{11}	
12	6	3	T_3	d_{12}	
21	11	6	T_3	d_{21}	
22	11	6	T_3	d_{22}	
23	12	6	T_3	d_{23}	
24	12	6	T_3	d_{24}	

If the additional four tests were conducted at the lowest product level, include those in the appropriate temperature differential group.

Step 1. Calculate the average of the absolute differences in each group.

$M_1 = \sum_{g_1} d_i/n_{g1}$ where g_1 denotes the subscripts in Group 1
$M_2 = \sum_{g_2} d_i/n_{g2}$ where g_2 denotes the subscripts in Group 2
$M_3 = \sum_{g_3} d_i/n_{g3}$ where g_3 denotes the subscripts in Group 3

Step 2. Calculate the variance of the absolute differences in each group.

$$Var_1 = \sum_{g_1} (d_i - M_1)^2/df$$

$$Var_2 = \sum_{g_2} (d_i - M_2)^2/df$$

$$Var_3 = \sum_{g_3} (d_i - M_3)^2/df$$

Step 3. Calculate the pooled variance of Var_1, Var_2, and Var_3.

$$Var_p = \frac{dfVar_1 + dfVar_2 + dfVar_3}{n_{total} - 3}$$

or

$$Var_p = \frac{Var_1 + Var_2 + Var_3}{3}$$

Step 4. Compute the standard error (SE) of the difference between each pair of the means, M_1, M_2, and M_3.

$$\left[Var_p \left(\frac{1}{n_{g1}} + \frac{1}{n_{g2}}\right)\right]^{1/2}$$

or

$$SE = \frac{1}{2}\sqrt{Var_p}$$

Step 5. Obtain the 95th percentile of the Bonferroni t-statistic with (n_{total} - 3) = df and three comparisons. This statistic is t = 2.60 if 24 tests were conducted.[1]

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[1]Miller, Rupert G., Jr.1981.*Simultaneous Statistical Inference*. Second Edition. Springer-Verlay, New York, New York.

Step 6. Compute the critical difference (D) against which each pairwise difference between group means will be compared.

$$D = SE \times t$$

Step 7. Compare the absolute difference of the three pairwise differences with D.

$$Compare\ |M_1 - M_2|\ with\ SE \times t$$
$$Compare\ |M_1 - M_3|\ with\ SE \times t$$
$$Compare\ |M_2 - M_3|\ with\ SE \times t$$

If any difference in group means, in absolute value, exceeds the critical value of SE x *t*, then conclude the method's performance is influenced by the temperature conditions.

If the results are statistically significant, the method's performance is affected by the temperature conditions. If the overall performance evaluation meets the EPA standards, the effect of a 10°F temperature difference on the method does not degrade performance severely. However, this does not eliminate the possibility that larger differences could give misleading results. If the overall performance did not meet the EPA performance standards, and the temperature effect was significant, then the vendor needs to improve the method's temperature compensation or stabilization period to meet EPA performance standards. Again, an evaluation testing the modified ATGS would need to be conducted to document the performance before the ATGS could claim to meet the performance standards.

5.3.5 Test For Effect Of In-Tank Product Volume

The procedures outlined in Section 4 required the tank be either half full or filled to between 90 percent and 95 percent capacity. As shown in Table 2, 12 tests will have been run with the tank half full, and 12 tests with the tank full to 90 to 95 percent capacity. The 24 tests have been ordered by product volume and test number in Table 6 for the example order of tests from Table 2.

Compare the test results from the two volume levels to check for the effect of product volume on the method's performance. If the effect is negligible, the two groups of results should be comparable. If the method's performance is affected by the product level, then this calculation can identify which product level of the ATGS affects the overall results of meeting or not meeting EPA performance standards. If it does meet the performance standards at the levels in the standard 24 tests, it can be used in the test mode at any product level. However, if there is a significant difference in performance at the two levels, it might be advisable to recommend the ATGS be used in its test mode only for certain product levels or advisable to perform the additional four optional tests at the lowest detectable level. Note that this optional part of the test procedures may only be applicable for magnetostrictive probe technology. If the performance is not adequate for one of the product levels, the performance of the ATGS is probably marginal.

Table 6. Organization Of Data To Test For Product Volume Effect

Test No.	Pair No.	Set No.	In-tank Product Volume	Absolute Leak Rate Difference |L - S| (gal/hr)	Group No.
1	1	1	90-95% full	d_1	Group 1
2	1	1	90-95% full	d_2	
5	3	2	90-95% full	d_5	
6	3	2	90-95% full	d_6	
9	5	3	90-95% full	d_9	
10	5	3	90-95% full	d_{10}	
13	7	4	90-95% full	d_{13}	
14	7	4	90-95% full	d_{14}	
17	9	5	90-95% full	d_{17}	
18	9	5	90-95% full	d_{18}	
21	11	6	90-95% full	d_{21}	
22	11	6	90-95% full	d_{22}	
3	2	1	50% full	d_3	Group 2
4	2	1	50% full	d_4	
7	4	2	50% full	d_7	
8	4	2	50% full	d_8	
11	6	3	50% full	d_{11}	
12	6	3	50% full	d_{12}	
15	8	4	50% full	d_{15}	
16	8	4	50% full	d_{16}	
19	10	5	50% full	d_{19}	
20	10	5	50% full	d_{20}	
23	12	6	50% full	d_{23}	
24	12	6	50% full	d_{24}	
25	13	1	Lowest % full	d_{25}	Group 3
26	13	1	Lowest % full	d_{26}	
27	14	2	Lowest % full	d_{27}	
28	14	2	Lowest % full	d_{28}	

The operation of the test function could be restricted to the product level where the performance was adequate.

One of the consequences of using an ATGS to test at various levels of product in the tank is the test can only find leaks below the product level used in the test. The performance standard calls for detecting a leak from any portion of the tank that normally contains product. Ideally, the test should be run with the tank as full as it is filled in practice so that leaks can be detected from any part of the tank. If the test results were restricted to testing when the tank was half full, for example, the test could not find leaks in the upper half of the tank.

Step 1. Calculate the average of the absolute differences in the two groups.

$$M_1 = \sum_{g_1} \frac{d_i}{12}$$

where g_1 denotes the 12 subscripts in Group 1

$$M_2 = \sum_{g_2} \frac{d_i}{12}$$

where g_2 denotes the 12 subscripts in Group 2

Step 2. Calculate the variance of the absolute differences in the two groups.

$$Var_1 = \sum_{g_1} \frac{(d_i - M_1)^2}{11}$$

or

$$Var_2 = \sum_{g_2} \frac{(d_i - M_2)^2}{11}$$

Step 3. Calculate the pooled variance of Var_1 and Var_2.

$$Var_p = \frac{11Var_1 + 11Var_2}{24 - 2}$$

or

$$Var_p = \frac{Var_1 + Var_2}{2}$$

The following statistical procedures (two-sample t-test) provide a means for testing the effect of product volume on the test results.

Step 4. Compute the SE of the difference between M_1 and M_2.

$$SE = \left[Var_p\left(\frac{1}{12} + \frac{1}{12}\right)\right]^{\frac{1}{2}}$$

$$SE = \sqrt{\frac{Var_p}{6}}$$

Step 5. Calculate the t-statistic.

$$t = \frac{(M_1 - M_2)}{SE}$$

Step 6. From the t-table in Appendix A, obtain the critical value corresponding to a t with (12 + 12 - 2) = 22 df and α two-sided 5 percent significance level. This value is 2.074.

Step 7. Compare the absolute value of t, abs(t), to 2.074. If abs(t) is less than 2.074, conclude the average difference between measured and induced leak rates obtained with a tank half full is not significantly different (at the 5 percent significance level) from the average difference between measured and induced leak rates obtained with a tank filled to 90 to 95 percent capacity. In other words, the amount of product, in this given range, has no significant impact on the leak rate results. Otherwise, conclude the difference is statistically significant, that is, the method's performance depends on the amount of product in the tank.

5.3.6 Option To Test The Evaluator-Determined Minimum Fill Height Level

Four is the minimal number of additional tests, including the third fill level, that are needed to analyze of the effect of product volume. These tests include at least one test at each nominal leak rate and one at the zero-leak rate. Choose the order of these four additional tests comprising Group 3 (in Table 6) at random. The modification to the above described test procedures is then as follows:

Step 1. Calculate the average of the absolute differences in each group.

$M_1 = \sum_{g_1} d_i/12$ where g_1 denotes the 12 subscripts in Group 1
$M_2 = \sum_{g_2} d_i/12$ where g_2 denotes the 12 subscripts in Group 2
$M_3 = \sum_{g_3} d_i/4$ where g_3 denotes the 4 subscripts in Group 3

Step 2. Calculate the variance of the absolute differences in each group.

$$Var_1 = \sum_{g_1}(d_i - M_1)^2/11$$

$$Var_2 = \sum_{g_2}(d_i - M_2)^2/11$$

$$Var_3 = \sum_{g_3}(d_i - M_3)^2/3$$

Step 3. Calculate the pooled variance of Var_1, Var_2, and Var_3.

$$Var_p = \frac{11Var_1 + 11Var_2 + 3Var_3}{28 - 3}$$

Step 4. Compute the SE_1 of the difference between M_1 and M_2

$$SE_1 = \left[Var_p(\frac{1}{12} + \frac{1}{12})\right]^{\frac{1}{2}}$$

$$SE_1 = \sqrt{\frac{Var_p}{6}}$$

and the SE_2 of the differences between M_1 and M_3, and M_2 and M_3.

$$SE_2 = \left[Var_p(\frac{1}{12} + \frac{1}{4})\right]^{\frac{1}{2}}$$

Step 5. Obtain the 95th percentile of the Bonferroni t-statistic with (28-3) = 25 df and three comparisons. This statistic is t = 2.582.[2]

Step 6. Compute the critical differences, D, against which each pairwise difference between group means will be compared.

$$D_1 = SE_1 \times t = SE_1 \times 2.582$$
$$D_2 = SE_2 \times t = SE_2 \times 2.582$$

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[2] Miller, Rupert G., Jr. 1981. *Simultaneous Statistical Inference*. Second Edition. Springer-Verlay, New York, New York.

Step 7. Compare the absolute difference of the three pairwise differences with D.

$$Compare\ |M_1 - M_2|\ with\ SE_1 \times 2.582$$
$$Compare\ |M_1 - M_3|\ with\ SE_2 \times 2.582$$
$$Compare\ |M_2 - M_3|\ with\ SE_2 \times 2.582$$

If any difference in group means, or in absolute value, exceed the critical value, then conclude that the method's performance is influenced by the product fill height conditions.

Note that if the operator would like to increase the power of the above procedure to detect differences among the fill heights involving the evaluator-determined minimum, then additional tests at the nominal leak rates can be added. If there are a total r_3, tests conducted in Group 3, then make the following modifications to the above procedure:

$M_3 = \sum_{g_3} d_i / r_3$ where g_3 denotes the r_3 subscripts in Group 3

$$Var_3 = \frac{\sum_{g_3} (d_i - M_3)^2}{r_3 - 1}$$

$$Var_p = \frac{11Var_1 + 11Var_2 + (r_3 - 1)Var_3}{24 + r_3 - 3}$$

$$SE_2 = \left[Var_p(\frac{1}{12} + \frac{1}{r_3})\right]^{\frac{1}{2}}$$

And lastly the relevant Bonferroni t-statistic for three comparisons and $24 + r_3 - 3$ df can be found from the following table:

r_3	t-statistic
4	2.566
6	2.552
8	2.541

5.4 Outline Of Calculations For Alternative Approach

This section describes the data analysis required for the alternative approach described in Section 4.5.

The water sensor data will be identical to that obtained with the standard test procedure outlined in Section 4.4. Consequently, the same data analysis will be used. Refer to Section 5.2 for the details.

5.4.1 Calculation of P(fa) and P(d)

Using the leak rate reported by the ATGS and the actual leak rate (zero for tight tank tests, measured for the induced leak rate tests), calculate the differences between the measured and actual leak rates. Calculate the mean and SD of these differences as in Section 5.1.1. Perform the test for significant bias and estimate the P(fa) and the P(d) as described in that section.

Calculate the variances of the differences separately for the data from the tests on the tight tanks and those from the tests on tanks with induced leak rates. This calculation can be done as in Section 5.3.3, except the two groups are now defined by the leak status of the tanks and the sample sizes will not be equal. Let the subscript 1 denote the tight tank data set and 2 denote the data from the tests with induced leaks.

Let n_1 be the number of test results from tight tank tests and n_2 be the number of test results from induced leak rate tests. Denote by d_{ji} the difference between measured and induced leak rates for each test, where j=1 or 2, and i=1, …, n_1 or n_2. Then calculate

$$S_1^2 = \sum_{i=1}^{n_1} \frac{(d_{1_i} - \bar{d}_1)^2}{(n_1 - 1)}$$

and

$$S_2^2 = \sum_{i=1}^{n_2} \frac{(d_{2_i} - \bar{d}_2)^2}{(n_2 - 1)}$$

where the summations are taken over the appropriate groups of data, and where $\bar{d}_j$ denotes the mean of the data in group j, and is given by

$$\bar{d}_j = \sum_{i=1}^{n_j} \frac{d_{ji}}{n_j}$$

form the ratio

$$F = \frac{{S_2}^2}{{S_1}^2}$$

and compare this statistic to the F statistic with (n_2-1) and (n_1-1) df for the ratio at the 5% significance level. The larger S value should be in the numerator and the smaller S value in the denominator. If the calculated F statistic is larger than the F value in an F-Table (from a statistical reference book), conclude the data from the induced leak rate tests are significantly more variable than those from the tight tanks. If this is the case, it might impair the ability of the ATGS to detect leaks. Recompute the P(d) (see Section 5.1.3) using the SD calculated from just the induced leak rate tests, S_2, to verify that P(d) is still at least 95 percent.

5.4.2 Limitations On The Results

The limitations on the results must be calculated from the actual test conditions. Since the conditions were not controlled but rather observed, take the following approach to determine the applicable conditions.

Size Of Tank

Due to the variety in geometry and materials of tanks currently on the market, using one scaling factor does not consider all factors. The test method may be used for tanks with less volume and a smaller diameter than the one used during testing; however, scaling has historically been acceptable to tanks that are 50 percent larger than the test tank used in the evaluation. This 1.5 scaling factor will continue to be used as a simple approach.

Maximum Allowable Temperature Difference

Calculate the temperature difference between the product in the tank and that of newly added product for each delivery in the data set. Note the temperature of the delivered product can be calculated from the temperature of the product in the tank immediately before delivery, the temperature of the product in the tank immediately after delivery, and the volumes of product by the following formula:

$$T_D = \frac{T_A V_A - T_B V_B}{V_D}$$

The subscript A denotes product in tank after delivery, B denotes product in tank before delivery, D denotes product delivered, T denotes product temperature, and V denotes volume.

Calculate the SD of the temperature differentials and multiply this by 1.5. Report this result as the maximum temperature differential for which the ATGS evaluation is valid.

When the calculations are complete, enter the results on the standard results reporting form in Appendix B. Also check the box on that form to indicate the evaluation was done using the alternative approach.

Average Waiting Time After Filling

Use the time interval between the most recent fill or product delivery and each following test as a stabilization period. Order these times from least to greatest and determine the 20th percentile. Report this result as the minimum and maximum stabilization period.

Average Data Collection Time Per Test

The tests often have a constant or nearly constant duration prescribed by the ATGS. If so, simply report this duration as the test data collection time. If the ATGS software determines a test time from the data, report the average test time taken by the test and note the ATGS software determines the applicable test time.

Section 6: Interpretation

Each function of the ATGS is evaluated separately based on data analysis of experimental test results. This section covers the release detection function, water detection function, and measurement of maximum water level change (MLC). The entire evaluation process results in performance estimates for the release detection modes of ATGS. The results reported are valid for the experimental conditions during the evaluation, which have been chosen to represent the most common situations encountered in the field. These should be typical of most tank testing conditions, but extreme weather conditions can occur and might adversely affect the performance of the ATGS. The performance of the release detection function should be at least as good for tanks smaller than the test tank. However, the performance evaluation results should only be scaled up to tanks of 50 percent greater capacity than the test tank. The performance of the water sensor in terms of minimum detectable level and MLC are independent of the tank size. However, the volume that corresponds to these heights of water phase depends on tank size. It should be emphasized the performance estimates are based on average results obtained during the evaluation. Vendors are encouraged to provide a measure of the precision of a test, such as a SE for their calculated leak rate at that site, along with the leak rate and test results.

6.1 Release Test Function Evaluation

The relevant performance measures for proving that an ATGS meets EPA standards are the P(fa) and P(d) for a leak rate of 0.20 gal/hr. The estimated P(fa) can be compared with the EPA 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. However, reducing the false alarm rate may also reduce the chance of detecting a leak. The P(d) generally increases with the size of the leak. The EPA standard specifies that P(d) be at least 95 percent for a leak of 0.20 gal/hr. A higher estimated P(d) means there is less chance of missing a small leak.

If the estimated performance of the ATGS did not meet the EPA performance requirements, the vendor may want to investigate the conditions that affected the performance as described in Section 5.3. If the stabilization period, temperature condition, or the product level can be shown to affect the performance of the ATGS, these results can be used to improve the ATGS. It may be possible to improve the performance simply by changing the ATGS method procedure (e.g., waiting longer for the tank to stabilize) or it may be necessary to redesign the hardware. In either case, a new evaluation with the modified method is necessary to document that the ATGS meets the performance standards.

The relationship of performance to test conditions is primarily of interest when the ATGS did not meet the EPA performance standards. Developing these relationships is part of the supplementary data analysis that may be useful to the vendor but is not of primary interest to many tank owners or operators.

6.2 Water Level Detection Function

The minimum water level detected by the ATGS is estimated from the average threshold of detection, and the variability of the water level threshold is estimated by the SD of the test data.

The minimum water level that will be detected at least 95 percent of the time is the level to be reported. Statistically, this is a one-sided tolerance limit.

The tolerance limit calculated in Section 5.2.1 estimates the minimum water level the ATGS can detect above the bottom of the probe. If the installation of the ATGS leaves the probe at a specified distance above the bottom of the tank (for example, 1 inch), then this minimum distance needs to be added to the reported minimum detectable water level.

6.3 Minimum Water Level Change Measurement

Since ATGSs operate with the product at all levels of normal tank operation, the water sensor can be used to test for leaks in the event of a high groundwater level. If the groundwater level is above the bottom of the tank, there will be an inward pressure when the product level is sufficiently low, and if there is a hole in the tank, water will flow into the tank under these conditions. Based on the ability of the water sensor to detect a change in the level of water phase in the product and using the independently measured level, the evaluator can determine how much water must enter the tank for an increase in the water level to be detected. From this information the evaluator can conservatively calculate the size of a leak of water into the tank the ATGS can detect at a given time. It should also be noted that this water phase increase at the bottom of the tank is affected by the level of mixing and water miscibility of the product. Therefore, the increase in water phase at the bottom of the tank during testing is a better estimate than assuming no miscibility in the calculation; however, there may still be a large amount of variability.

The SD of the differences between the change in water phase level measured by the water sensor and the change independently measured during the tests is used to determine the ability of the water sensor to detect changes in the water level. A two-sided 95 percent tolerance interval is then calculated for this detection ability (Section 5.2.2).

The MLC that can be detected is used to compute a minimum change in water volume in the tank. This conversion is specific to the tank size. Using the minimum change in water phase volume the water sensor can detect, the time needed for the ATGS to detect an incursion of water at the rate of 0.20 gal/hr can be determined (Section 5.2.3). This calculation indicates the time needed for the water sensor to identify an inflow of water at the minimum leak rate and to alert the operator the water level has increased. If the ATGS has a water alarm, and if the conditions for activating the water alarm are specified, the length of time for that alarm to be activated can be calculated. This calculation assumes that the ATG probe is mounted at the midpoint of the tank; otherwise tank tilt becomes a factor that must be addressed.

6.4 Limitations

The limitations on the results of the evaluation are to be reported on the Results of U.S.EPA Standard Evaluation Form (Appendix B). The intent is to document that the results are valid under conditions represented by the test conditions. Section 5.1.4 describes the summary of the test conditions that should be reported as limitations on the results form. These items are also discussed below. The test conditions have been 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 vendors.

One practical 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, the results of the evaluation may be applied to tanks smaller than the test tank. The results may also be extended to tanks of 50 percent larger capacity than the test tank. Thus, if testing is done in a 10,000-gallon tank, the results may be extended to tanks up to 15,000 gallons in size.

A second limitation on the results is the temperature differential between the product added to the tank and that of the product already in the tank. Often a leak test must be performed shortly after a tank has been filled. The reported results are applicable provided the temperature differential is no more than that used in the evaluation. During the EPA national survey,[3] EPA found that temperature differentials were no more than 5°F for at least 60 percent of the tests. However, larger differences could exist. These test procedures are designed to use 10°F temperature differentials, reporting those actually used. The results cannot be guaranteed for temperature differentials larger than those used in the evaluation.

A third limitation on the results is the stabilization period needed by the ATGS. The Individual Test Logs call for recording the actual stabilization period used during the testing. The mean of these stabilization periods is reported, as are the shortest and longest periods. The results are valid for stabilization periods at least as long as those used in the evaluation.

The duration of the data collecting phase of the test is another limitation of the ATGS. If the collection time and amount of data collected is shortened during a test, the method's performance may be adversely affected and the results will be invalid. This is primarily of concern when documenting that a tank is tight. Results that clearly indicate a leak can sometimes be determined in less time than needed to document a tight tank, particularly if the leak rate is large. Thus, while the false alarm rate may be larger if the test time is shortened, this is not usually a problem if test results indicate a leak and efforts are made to identify and correct the source of the leak.

There is potentially an additional limitation on the results regarding the ability of the water sensor to function sufficiently with ethanol-blended fuels. The minimum depth of water phase the water sensor can detect and the minimum change in water level that the water sensor can detect is reported. Note that the calculations in Section 5.2 do not consider a water phase with ethanol and is therefore a conservative estimate of the time to detect water ingress at this rate. Depending on the test procedure applied in accordance with Section 4.4, any limitations or expected effect on performance regarding use of the water sensor with ethanol-blended fuels must be noted in applicable forms.

[3] Flora, J.D., Jr., and J.E. Pelkey, "Typical Tank Testing Conditions," EPA Contract No.68-01-7383, Work Assignment 22, Task 13, Final Report, December 1988.

Finally, the same reporting forms provided in Appendix B can be used to document limitations for the alternative evaluation described in Section 4.5. The data analysis for the alternative approach is described in Section 5.4. This analysis will result in reporting observed average conditions during the evaluation. The limitations are based on the observed conditions instead of experimentally controlled conditions, but the results are reported on the same form. The Individual Test Log form should be applicable to the induced leak rate tests under the alternative evaluation procedure. However, the evaluator may find it more efficient to design a different data collection form for recording the data from the many tight tank tests.

Section 7: Reporting of Results

Appendix B is designed to be the framework for a standard evaluation report. There are five parts to Appendix B, each with instructions for completion:

- Part 1: **Results of U.S. EPA Standard Evaluation Form**. This form, completed by the evaluator, is an executive summary of the findings and intended for the tank owner or operator that uses this method of release detection. The report should be succinct so the results form can be widely distributed.
- Part 2: **Description of the ATGS.** This form should be completed by the evaluator with help from the vendor.
- Part 3: **Reporting Form for Leak Rate Data.** This form summarizes the test results and contains the information on starting dates and times, test duration, leak rate results, etc.
- Part 4: **Individual Test Log**. This log should be used to record data in the field. While the completed daily test logs are optional in the standard report, the evaluator should keep copies for three years in case questions arise. These logs serve as the backup data to document the performance estimates reported.
- Part 5: **Reporting Form for Water Sensor Evaluation Data**. This form contains the minimum detectable water level data and records of the minimum water level changes. A separate form is filled out for each test. See Section 4.4.

If the optional calculations described in Section 5.3 are performed, they should be reported to the vendor. These results should be reported to the vendor in a supplemental report, distinct from the standard report. The vendor would still have the supplemental information available if needed and has the option to share the results.

Appendix A
Definitions And Notational Conventions

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

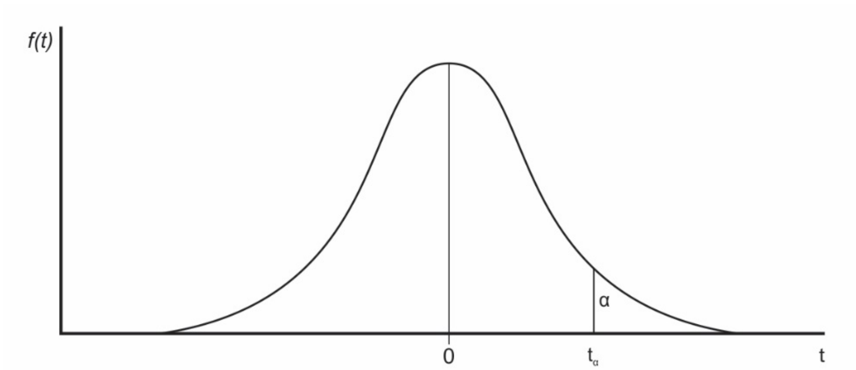
Accuracy:	The degree to which the calculated leak rate agrees with the induced leak rate on the average. If a method is accurate, it has a very small or zero bias.
Calculated Leak Rate, R:	A positive number, in gallons per hour (gal/hr), estimated by the ATGS method and indicating the amount of product leaking out of the tank. A negative leak rate could result from water leaking into the tank, miscalibration, or other causes.
False Alarm:	Declaring that a tank is leaking when in fact it is tight.
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.
Mean Squared Error, MSE:	An estimate of the overall performance of a test method.
Method Bias, B:	The average difference between calculated and induced leak rates. It is an indication of whether the ATGS method consistently overestimates (positive bias) or underestimates (negative bias) the actual leak rate.
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.
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 (missing) a leak rate R. Typically, the power of a test is expressed in percent, as 95 percent .
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.

Root Mean Squared Error, RMSE: The positive square root of the mean squared error.

Threshold, Th: The leak rate above which a method declares a leak. It is also called the threshold of the method.

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
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

df	α = .10	α = .05	α = .025	α = .010	α = .005
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

Table A-2. One Sided Normal Tolerance Limits, Confidence Interval, K

	100γ=95%		
	100(1-α)		
df	**90%**	**95%**	**99%**
2	20.58	26.26	37.09
3	6.156	7.656	10.55
4	4.162	5.144	7.042
5	3.407	4.203	5.741
6	3.006	3.708	5.062
7	2.756	3.4	4.642
8	2.582	3.187	4.354
9	2.454	3.031	4.143
10	2.355	2.911	3.981
11	2.275	2.815	3.852
12	2.21	2.736	3.747
13	2.155	2.671	3.659
14	2.109	2.615	3.585
15	2.068	2.566	3.52
16	2.033	2.524	3.464
17	2.002	2.486	3.414
18	1.974	2.453	3.37
19	1.949	2.423	3.331
20	1.926	2.396	3.295
21	1.905	2.371	3.262
22	1.887	2.35	3.233
23	1.869	2.329	3.206
24	1.853	2.309	3.181
25	1.838	2.292	3.158
30	1.777	2.22	3.064
35	1.732	2.167	2.995
40	1.697	2.126	2.941
50	1.646	2.065	2.863
60	1.609	2.022	2.807
80	1.559	1.965	2.733
100	1.527	1.927	2.684
200	1.45	1.837	2.57

100γ is the confidence level in percent

100(1-α) is the percentage of population below (or above) tolerance limits

Table A-3. Two-Sided Normal Tolerance Limits, Confidence Interval, K

	100γ=95%		
	100(1-α)		
df	**90%**	**95%**	**99%**
2	32.02	37.67	48.43
3	8.38	9.916	12.86
4	5.369	6.37	8.299
5	4.275	5.079	6.634
6	3.712	4.414	5.775
7	3.369	4.007	5.248
8	3.136	3.732	4.891
9	2.967	3.532	4.631
10	2.829	3.379	4.433
11	2.737	3.259	4.277
12	2.655	3.162	4.15
13	2.587	3.081	4.044
14	2.529	3.012	3.955
15	2.48	2.954	3.878
16	2.437	2.903	3.812
17	2.4	2.858	3.754
18	2.366	2.819	3.702
19	2.337	2.784	3.656
20	2.31	2.752	3.615
21	2.286	2.723	3.577
22	2.264	2.697	3.543
23	2.244	2.673	3.512
24	2.225	2.651	3.483
25	2.208	2.631	3.457
26	2.193	2.612	3.432
27	2.178	2.595	3.409
28	2.164	2.579	3.388
29	2.152	2.554	3.368
30	2.14	2.549	3.35
35	2.09	2.49	3.272
40	2.052	2.445	3.213
50	1.996	2.379	3.126
60	1.958	2.333	3.066
80	1.907	2.272	2.986
100	1.874	2.233	2.934
200	1.798	2.143	2.816
500	1.737	2.07	2.721
100	1.709	2.036	2.676
∞	1.645	1.96	2.576

100γ is the confidence level in percent
100(1-α) is the percentage of population included between tolerance limits

Appendix B
Reporting Forms

Appendix B provides five sets of blank forms. Once filled out, these forms will provide the framework for the standard report. The forms consist of the following:

1. **Results of U.S. EPA Standard Evaluation – Automatic Tank Gauging System**
2. **Description – Automatic Tank Gauging System**
3. **Reporting Form for Leak Rate Data – Automatic Tank Gauging System**
4. **Individual Test log – Automatic Tank Gauging System**
5. **Reporting Form for Water Sensor Evaluation Data – Automatic Tank Gauging System**

Each set of forms is preceded by instructions on how the forms are to be filled out and by whom. The following is an overview on various responsibilities.

1. **Results of U.S. EPA Standard Evaluation.** The evaluator is responsible for completing this form at the end of the evaluation.

2. **Description of Automatic Tank Gauging System.** The evaluator assisted by the vendor will complete this form by the end of the evaluation.

3. **Reporting Form for Leak Rate Data.** The evaluator completes this form. In general, the statistician analyzing the data will complete this form. A blank form can be developed on a personal computer, the database for a given evaluation generated, and the two merged on the computer. The form can also be filled out manually. The input for that form will consist of the field test results recorded by the evaluator's field crew on the Individual Test logs (below) and the ATGS test results.

4. **Individual Test Logs.** The evaluator completes and uses these forms. These forms need to be kept blind to the vendor during testing. The evaluator should reproduce a sufficient number (at least 24 copies) of the blank form provided in this appendix and produce a bound notebook for the complete test period. The individual log sheets are optional in the evaluation report and should be archived with the evaluator if not included.

5. **Reporting Form for Water Ingress Sensor Evaluation Data.** These forms provide a template for the evaluation data. They are to be used and completed by the evaluator. The evaluator should reproduce a sufficient number (at least 20 copies) of the blank form provided in this appendix and produce a bound notebook to be used in the field.

At the completion of the evaluation, the evaluator will collate all the forms into a single standard report in the order listed above except for the test logs (that may be archived and not part of the final report). If the evaluator performed additional, optional calculations (see Section 5.3 of the test procedures), those results can be attached to the standard report; however, there is no reporting requirement for these optional calculations.

If the alternative EPA test procedures described in Section 4.5 was followed, then the reporting is essentially the same as that for the standard evaluation procedure.   The major difference is that the Results of U.S.EPA Standard Evaluation form will be completed using the results of the calculations described in Section 5.4. A box is provided to indicate which evaluation procedure was used. Archive individual test logs should questions arise during review of the report. Summarize the tank test results (no-leak and induced leak rate conditions) on the Reporting Form for Leak Rate Data. There will be no changes in the reporting of the water sensor performance since only one testing procedure is presented.

Distribution Of The Evaluation Test Results

The organization performing the evaluator will prepare a report to the vendor describing the results of the evaluation. This report consists primarily of the forms in Appendix B. The first form reports the results of the evaluation and is designed to be distributed widely. A copy of this form will be supplied to each tank owner and operator who uses this system of release detection. The owner and operator must retain a copy of this form as part of their record keeping requirements. The owner and operator must also retain copies of each tank test performed at the facility to document that the tank(s) passed the tightness test. This form will also be distributed to regulatory authorities who must approve release detection methods for use in their jurisdiction.

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

The evaluator provides the optional part of the calculations (Section 5.3), to the ATGS vendor. This is intended primarily for the vendor's use in understanding the details of the performance and perhaps suggesting how to improve the method. It is left to the vendor whether to distribute this form.

The evaluator provides the report to the vendor. Distribution of the report to tank owners, operators, and implementing agencies is the responsibility of the ATGS vendor.

Results Of U.S. EPA Standard Evaluation
Automatic Tank Gauging System (ATGS)

Instructions For Completing The Form

The evaluator fills out this form upon completion of the evaluation of the ATGS. This form will contain the most important information relative to the ATGS evaluation. All items are to be filled out and the appropriate boxes checked. If a question is not applicable to the ATGS, write 'NA' in the appropriate space.

This form consists of five main parts.:

ATGS description

- Evaluation results
- Test conditions during evaluation
- Limitations on the results
- Certification of results

ATGS Description

Indicate the commercial name of the ATGS, the version, and the name, address, and telephone number of the vendor. Some vendors use different versions of their ATGS 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 ATGS, then indicate the home office name and address of the responsible party.

Evaluation Results

The ATGS's threshold (Th) is supplied by the vendor. 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 C.

P(fa) is the probability of false alarm calculated in Section 5.1.2. Report P(fa) in percent. P(fa) may be rounded to the nearest whole percent.

P(d) is the probability of detecting a leak rate of 0.20 gal/hr and is calculated in Section 5.1.3. Report P(d) in percent. P(d) may be rounded to the nearest whole percent.

The minimum detectable water level and the minimum detectable water level change (MLC) that the water sensor can detect will have been obtained from the calculations in Sections 5.2.1 and 5.2.2.

If the P(fa) calculated in Section 5.1.2 is 5 percent or less and if the P(d) calculated in Section 5.1.3 is 95 percent or more, then check the first 'does' box. Otherwise, check the first 'does not' box. If the MLC calculated in Section 5.2.2 is less than or equal to 1/8 inch, then check the second ‘does’ box. If the MLC exceeds 1/8 inch, then check the second *does not* box.

Test Conditions During Evaluation

Insert the information in the blanks provided. Fill in the nominal volume of the tank in gallons as well as the tank material, steel or fiberglass. Also, indicate the tank diameter and length in inches. Report the product used during the testing. Give the range of temperature differences measured as well as the standard deviation of the observed temperature differences. Note, if more than one tank, product, or level was used in the testing, indicate this and refer to the data summary form where these should be documented.

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.

The temperature differential, the stabilization period after adding the product until testing, and the total data collection time should be completed using the results from calculations in Section 5.1.4.

If the alternative evaluation procedures described in Section 4.5 have been followed, then report the results obtained from the calculations in Section 5.4.

Certification Of Results

The evaluator certifies which test procedures were followed and provides his or her name and signature, and the name, address, and telephone number of the evaluator’s organization.

Results Of U.S. EPA Standard Evaluation
Automatic Tank Gauging System (ATGS)+

This form presents whether the automatic tank gauging system (ATGS) described below complies with the performance requirements of the federal underground storage tank (UST) regulation. The evaluation was conducted by the vendor according to EPA's *Standard Test Procedures for Evaluating Release Detection Systems: Automatic Tank Gauging Systems*. The full evaluation report also includes a form describing the ATGS method and a form summarizing the test data.

UST owners and operators using this release detection method should keep this form on file to prove compliance with the federal UST regulation. UST owners and operators should check with the implementing agencies to make sure this form satisfies their requirements.

ATGS Description

Name ____

Version number ____

Vendor ____________________________________Phone____________________

____

(street address) (city) (state) (zip)

Evaluation Results

This ATGS, which declares a tank to be leaking when the measured leak rate exceeds the threshold of ______ gallon per hour (gal/hr), has a probability of false alarms (P(fa)) of ______ ______percent.

The corresponding probability of detection (P(d)) of a ☐ 0.20 or ☐ 0.10 gal/hr leak is __ ______percent. The minimum water level in the tank that the ATGS can detect is _______ inches.

The minimum change in water level that can be detected by the ATGS is _______ inches (provided that the water level is above the minimum water level).

Therefore, this ATGS ☐ does ☐ does not meet the federal performance standards established by the U.S. Environmental Protection Agency (0.20 gal/hr at P(d) of 95% and P(fa) of 5%), and this ATGS ☐ does ☐ does not meet the federal performance standard of detecting water in the bottom of the tank to the nearest 1/8 inch.

Optional Testing Results

The lowest product level the ATGS can detect is ____________ inches. The test results of these tests are included in the above (P(d) and P(fa) results.

The stabilization period from when product was added to the beginning of the test ranged from__ minutes to__________ minutes, with an average of _______ minutes.

The liquid level sensor detected water ingress ______percent of the tests.

Water was detected by the pattern of water detection, simulated fuel delivery, then no water detection after ______ average number of cycles.

Test Conditions during Evaluation

The evaluation testing was conducted in a ________ gallon ☐ steel ☐fiberglass tank that was ____________ inches in diameter and _______________________ inches long.

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

The tests were conducted with the tank product levels ___________ and ________ percent full. If the option of evaluating the ATGS at the third product level was conducted, that level was ___ percent full.

Limitations On The Results

The performance estimates above are only valid when:

- The method has not been substantially changed.
- The vendor's instructions for installing and operating the ATGS are followed.
- The tank contains a product identified on the method description form.
- The tank is no larger than _________ gallons.
- The tank is at least _________ percent full.
- The stabilization period after adding any substantial amount of product to the tank is____ ______ hours.
- The temperature of the added product does not differ more than _________°F from that already in the tank.
- The total data collection time for the test is at least________ hours.
- Other limitations specified by the vendor or determined during testing: ____

Certification of Results

I certify that the ATGS was installed and operated according to the vendor's instructions and that the results presented on this form are those obtained during the evaluation. I also certify that the evaluation was performed according to one of the following:

☐ Standard EPA test procedures for ATGS ☐ Alternative EPA test procedures for ATGS

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

Description Of Automatic Tank Gauging System

Instructions For Completing The Form

The evaluator completes this form with assistance from the vendor, as part of the evaluation of the ATGS. 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, the most frequently expected answers to the questions have been provided. For those answers that are dependent on-site conditions, please give answers that apply in typical conditions. Write in any additional information about the testing method that may be important.

There are seven parts to this form. These are:

1. ATGS name and version
2. Product
   - Product type
   - Product level
3. Level measurement
4. Temperature measurement
5. Data acquisition
6. Procedure information
   - Stabilization 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 ATGS in the first part.

NOTE: The version is provided for ATGS 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, please 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.

Description
ATGS Background Information

This section describes briefly the important aspects of the automatic tank gauging system (ATGS). It is not intended to provide a thorough description of the principles behind the system or how the equipment works.

1. ATGS Information

Commercial Name: ____________________

ATGS Version: ____________________

2. Product Information

- Product Type-ATGS Compatibility? (check all that apply)
  - ☐ Gasoline
  - ☐ Diesel
  - ☐ Aviation fuel
  - ☐ Fuel oil #4
  - ☐ Fuel Oil #6
  - ☐ Solvents
  - ☐ Waste oil
  - ☐ Other ____________
- Product Level
  Test Product Level:
  - ☐ > 90% full
  - ☐ > 50% full
  - ☐ Other: __________

Does the ATGS measure inflow of water as well as loss of product (gal/hr)? ☐ Yes ☐ No

Does the ATGS detect the presence of water in the bottom of the tank? ☐ Yes ☐ No

3. Level Measurement

- Technique used to measure changes in product volume
  - ☐ Directly measure the volume of the product change
  - ☐ Changes in head pressure
  - ☐ Changes in buoyancy of a probe
  - ☐ Mechanical level measure (e.g. ruler, dipstick)
  - ☐ Changes in capacitance
  - ☐ Ultrasonic
  - ☐ Change in level of float. Specify operating principle (capacitance, magnetostrictive, load cell, etc.): ____________________
  - ☐ Other: ____________________ ____________________

4. Temperature Measurement

- Product Temperature Sensor (check those that apply).

Quantity of Sensors:
- ☐ Single sensor, without circulation
- ☐ Single sensor, with circulation
- ☐ 2-4 sensors
- ☐ 5 or more sensors
- ☐ Temperature–averaging probe

Type of Sensors:
- ☐ Resistance temperature detector (RTD)
- ☐ Bimetallic strip
- ☐ Quartz crystal
- ☐ Thermistor
- ☐ Other: ____________________

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

- ☐ The factor measured for change in level/volume is independent of temperature (mass)
- ☐ The factor measured for change in level/volume self-compensates for changes in temperature
- ☐ Other: ______________________________

5. Data Acquisitions

- Method of Data Acquisition and Record:
  - ☐ manually ☐ strip chart ☐ computer

6. Procedure Information

- Minimum Waiting Period between adding product and the beginning of a test
  - ☐ No wait period
  - ☐ < 3 hours
  - ☐ 3-6 hours
  - ☐ 7-12 hours
  - ☐ >12 hours
  - ☐ Variable (explain): ____________________
- *Test Duration*

- ☐ < 1 hour
- ☐ 1 hour
- ☐ 2 hours
- ☐ 3 hours
- ☐ 4 hours
- ☐ 5-10 hours
- ☐ >10 hours
- ☐ Variable (explain): ____________

➢ *Total Time*

What is the total time needed to test with this ATGS after delivery?

_________ hours _________ minutes

Sampling frequency for level and temperature measurements:

- ☐ > once per second
- ☐ Every 1-15 minutes
- ☐ Every 16-30 minutes
- ☐ Every 31-60 minutes
- ☐ < once per hour
- ☐ Variable (explain): ____________

➢ *Identifying and correcting for interfering factors*

a. Method of determining the presence and level of the groundwater:

- ☐ Observation well near tank
- ☐ Information from USGS, etc.
- ☐ Information for personnel on-site
- ☐ Presence of water in the tank
- ☐ Level of ground water above bottom of the tank not determined
- ☐ Other (explain): ____________

b. Methods of correction for inferences caused by the presence of groundwater about the bottom of the tank:

- ☐ Method tests for water incursion
- ☐ Different product levels tested and leak rates compared
- ☐ Other (explain): ____________
- ☐ No Action

c. Method of determining tank deformation after delivery of product:

- ☐ Wait a specified stabilization period before beginning test
- ☐ No procedure
- ☐ Watch the data trends and begin test when decrease in product level has stopped
- ☐ Other (explain): ____________

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

☐ Yes ☐ No

e. If not, how frequently are the sensors calibrated?

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

➢ *Interpreting Test Results*

a. Method of converting level changes to volumes changes

- ☐ Actual level changes observed when known volume is added/removed
- ☐ Theoretical ratio calculated from tank geometry
- ☐ Interpolation from tank vendor's chart
- ☐ Not applicable; volume measure directly
- ☐ Other (explain): ____________

b. Method of determining coefficient of thermal expansion (Ce)

- ☐ Actual sample taken for each test and Ce determined from specific gravity
- ☐ Value supplied by vendor of product
- ☐ Average value for type of product
- ☐ Other (explain): ____________

c. Method to calculate leak rate (gal/hr)

- ☐ Average of subsets of all data collected
- ☐ Difference between first and last data collected
- ☐ From data from last __________ hours of test period
- ☐ From data determined to be valid by statistical analysis
- ☐ Other (explain): ______________________

d. Threshold value used to declare a leaking tank

- ☐ 0.05 gal/ hr
- ☐ 0.20 gal/hr
- ☐ 0.10 gal/hr
- ☐ Other (explain): ______________________

e. Under what conditions are test results consider inconclusive

- ☐ Too much variability in the data
- ☐ Unexplained product volume increase
- ☐ Other (explain): ______________________

7. Exceptions

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

- ☐ Water in the excavation zone
- ☐ Large difference between ground temperature and delivered product temperature
- ☐ Extremely high or low ambient temperature
- ☐ Invalid for some products (explain): ______________________
- ☐ Other (explain): ______________________

b. What are acceptable deviations for the standard test procedures?

- ☐ None
- ☐ Lengthen the duration of the test
- ☐ Other (explain): ______________________

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

- ☐ Product level when test is conducted
- ☐ When to conduct test
- ☐ Waiting period between filling tank and beginning test
- ☐ Determination of "outlier" date that may be discarded
- ☐ None
- ☐ Other: ______________________

Additional Explanations or Comments:

____

____

____

____

____

____

____

____

____

____

____

Reporting Form For Leak Rate Data
Automatic Tank Gauging System (ATGS)

Instructions For Completing The Form

The evaluator fills out this form upon completion of the evaluation of the ATGS in its release detection mode. A single sheet provides for 28 test results, the minimum number of tests required in the test procedures, plus the optional 4 tests at the lowest fill height. Use as many pages as necessary to summarize all the tests attempted.

Indicate the commercial name and the version of the ATGS and the period of evaluation above the table. The version is provided for ATGS that use different versions of the method for different products or tank sizes.

A blank form can be developed on a personal computer, the database for a given evaluation generated, and the two merged on the computer. The form can also be filled out manually. The input for that form will consist of the field test results recorded by the evaluator's field crew on the Individual Test Logs and the ATGS test results.

The table consists of 11 columns. One line is provided for each test performed during evaluation of the ATGS. If a test was invalid or was aborted, the test should be listed with the appropriate notation (e.g., 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 4.1 of the test procedures. Since some changes to the design might occur during the field testing, the test numbers might not always be in sequential order.

Note that the results from the trial run need to be reported 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	ATGS records
11	Measured minus induced leak rate	By subtraction

The product temperature differential (column 7) is the difference between the temperature of the product added and that of the product in the tank each time the tank is filled from 50 percent full to between 90 to 95 percent full. This temperature differential is the actual differential achieved in the field and not the nominal temperature differential. The difference can be calculated by one of two methods. If the evaluator measured the temperature of the product added and that of the product in the tank just prior to filling, then take the difference between these two temperatures. If the evaluator measured the temperature of the product in the tank before and after filling and recorded the amount of product added, then calculate the temperature differential based on volumes and temperatures according to the formula in Section 5.4. The data necessary for these calculations should be provided on the Individual Test Log.

Reporting Form For Leak Rate Data
Automatic Tank Gauging System (ATGS)

ATGS 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										

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)	Measure d Leak Rate (gal/hr)	Meas. – Ind. Leak Rate (gal/hr)
21										
22										
23										
24										
25										
26										
27										
28										

Individual Test Log
Automatic Tank Gauging System (ATGS)

Instructions For Completing The Form

The evaluator completes the test log form. A separate form is to be filled out for each individual test including the trial run (at least 25). The information on these forms is to be kept blind to the vendor during the period of evaluation of the ATGS. These raw data forms are not needed when submitting the evaluation report; however, they must be retained and archived for a minimum of three years should any questions arise.

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

1. **Header Information**

The header information is to be repeated on all five pages, if used. If a page is not used, cross it out and initial it. The evaluator needs to print, sign, and date the top of each sheet. The test number is the number obtained from the randomization design. It is not the sequential running test number. If a test needs to be rerun, indicate the test number of the test being rerun and indicate that on the test log (e.g., Test No.5 repeat).

2. **General Background Information**

Indicate the commercial name of the ATGS. Include a version identification number if the ATGS uses different versions for different products or tank sizes. The vendor's recommended stabilization period (if applicable) must be obtained from the vendor prior to testing. This is important since it will impact on the 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 would remain unchanged for the whole evaluation period. However, weather conditions could change and affect the ground-water level. Also, the evaluator could change the test tank.

3. **Conditions Before Testing**

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

Note that the term conditioning refers to all activities undertaken by the evaluating field crew to prepare for a test. This includes emptying or filling the tank, heating or cooling product, and changing the leak rate. In some cases, all the above is performed, in others, only one parameter might be changed.

Special Case Reporting

Use the Individual Test Log form to record all data pertaining to the trial run. Next, when emptying the tank to half full and then filling to 90 to 95 percent capacity before performing the first test, note on the form that this has been done. Indicate on page 1 the dates, time, and volumes when product was removed and then added. This is the only case where emptying and filling are performed in sequence without a test being performed in between. Record all other information (e.g., temperature of product added) as applicable.

4. **Conditions At Beginning Of Test**

The evaluator's field crew starts inducing the leak rate and records the time. All leak simulation data are to be recorded using the form.

Once the evaluator is ready with the induced leak rate simulation, and the testing begins, record the date and time that the ATGS test data collection starts. Also, indicate the product temperature at that time. Fill out the weather condition section of the form. Indicate the nominal leak rate which is obtained from the randomization design.

5. **Conditions At Completion Of Testing**

Indicate date and time when the test was completed.

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

6. **Leak Rate Data**

The evaluator’s statistician or analyst who performed the calculations should complete this section. The nominal leak rate is obtained from page 2 (Conditions at Beginning of Test). It should be checked 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 page 4 (and 5, if needed) of this form. The measured leak rate is that recorded by the ATGS for that test. The difference is calculated by subtracting the induced from the measured leak rate.

7. **Additional Comments (if needed)**

Use this page for any comments (e.g., adverse weather conditions, equipment failure, reason for invalid test, etc.) pertaining to that test.

8. **Induced Leak Rate Data**

The evaluator should complete this form. From the randomization design, the crew will know the nominal leak rate to be targeted. The induced leak rate will be known accurately at the end of the test. However, the test procedures require that the induced leak rate be within 30 percent of the nominal leak rate.

Individual Test Log
ATGS

Name of Evaluator, or Designee _____________________ Test Number______

Signature of Evaluator or Field Crew ________________ Date of Test______

Instructions:
Use on 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

a. ATGS name and version:
____

b. Product type: ______________________

c. Type of tank: ______________________

d. Tank dimensions:

Diameter (inches)	Length (inches)	Volume (gallons)

e. Groundwater level
__________ inches above bottom of tank

f. If applicable, recommended stabilization period before test (per vendor):
____

2. Conditions Before Testing

a. Start of conditioning test tank
Date: __________ Military Time: _________

b. Stick reading before conditioning test tank
Product _______ inches ______ gallons
Water _______ inches ______ gallons

c. Temperature of product in test tank before conditioning
___________________ ☐ °F or ☐ °C

d. Stick reading after conditioning tank
Product _______ inches ______ gallons

e. Amount of product (check **one only**):

☐ no change in product level
☐ removed from tank (by subtraction): __________ gallons
☐ added to tank (by subtraction): __________ gallons

3. Conditions At Beginning of Test

a. Test conditions

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

b. Weather conditions at beginning

Ambient temperature:
____
☐ °F or ☐ °C

Barometric pressure:
____
☐ mm Hg
☐ inches Hg

Wind:
☐ None
☐ Light
☐ Moderate
☐ Strong

Precipitation:
☐ None
☐ Light
☐ Moderate
☐ Heavy

Sky condition:
☐ Sunny
☐ Partly Cloudy
☐ Cloudy
☐ Dark

c. Complete the induced leak rate data sheet

Individual Test Log
ATGS

Name of Evaluator, or Designee _____________________ Test Number______

Signature of Evaluator or Field Crew _______________ Date of Test______

4. Conditions at Completion of Test

a. Test conditions

Date of Test Data Collection: __________
Time Test Data Collection was Completed:
_________________ (military)

Stick Reading at Completion:
Product ________ inches _______ gallo
Water ________ inches _______ gallo

b. Weather conditions at end

Ambient temperature: ________________
☐ °F
☐ °C

Barometric pressure: ________________
☐ mm Hg
☐ inches Hg

Wind:
☐ None
☐ Light
☐ Moderate
☐ Strong

Precipitation:
☐ None
☐ Light
☐ Moderate
☐ Heavy

Sky Condition:
☐ Sunny
☐ Partly Cloudy
☐ Cloudy
☐ Dark

5. Leak Rate Data

- **Filled out by the statistician or analyst who performed the calculation.**

a. Nominal leak rate
___________________ gallons per hour (gal/hr)

b. Induced leak rate
___________________ gal/hr

c. Leak rate measured by ATGS
___________________ gal/hr

d. Difference (ATGS measured rate minus induced rate)

___________________ gal/hr

Additional Explanations or Comments:

____
____
____
____
____
____

Individual Test Log
ATGS

Name of Evaluator, or Designee _____________________ Test Number______

Signature of Evaluator or Field Crew ________________ 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			

Reporting Form For Water Sensor Evaluation Data
Automatic Tank Gauging System

The evaluator's field crew completes this form when evaluating the performance of the ATGS water sensor. A separate form is to be filled out for each individual test (at least 20 replicates). The form provides a template to record the data and consists of three parts. These are:

1. Header information
2. Template for recording the data obtained to determine the minimum water level that the sensor can detect in each replicate
3. Template for recording the data obtained when determining the minimum water level change (MLC) that the sensor can detect in each replicate.

Header Information

The header information is to be repeated on all four pages, if used. If a page is not used, cross it out and initial it.

Indicate the commercial name of the ATGS. Include the version identification if the ATGS uses different versions for different products or tank sizes. Complete the date of test and product type information. The alcohol content of the product will be reported on the first test form filled out and referenced on the subsequent forms. Indicate the test (replicate) number on each sheet for each test.

The evaluator, or designee, collecting the raw data needs to print, sign and date of the test on top of each sheet.

Minimum Detectable Water Level Data

Follow the test procedures described in Section 4.4 and record all data on page 1 of the form. When the water sensor first detects the water, stop testing for this replicate. The minimum detected water level is calculated from the total amount of water added until the first sensor response and the geometry of the probe and the standpipe. This calculation can be done after all testing is completed and is generally performed by the statistician or other person responsible for data analysis.

Minimum Water Level Change (MLC)

After the first water sensor response, continue with the test procedures as described in Section 4.4. Record all amounts of water added and the sensor readings at each increment using the table as necessary. The data to be entered will be calculated once all testing is completed. Again, the evaluator, or designee, will compute these data and enter the calculated minimum water level detected in that replicate run.

Reporting Form For Water Sensor Evaluation Data
Automatic Tank Gauging System

ATGS Name and Version:____
Date of Test:________________ Name of Evaluator: ___________________________________
Product Type: ______________ Signature of Evaluator: ________________________________
Product Alcohol-content _____________ as measured by method _____________. (May be determined on bulk product for all the tests.)

Increment No.	**Water Phase Height (inch)**	**Sensor Reading (inch)**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
Total Height (inch)		

Test No. ____________

NOTE: This form provides a template for data reporting. Since the number of increments is not known from the start, the length of the report form will vary from test to test.

Calculated Minimum Detectable Water Level (inches)

Reporting Form For Water Sensor Evaluation Data
Automatic Tank Gauging System

ATGS Name and Version:____

Date of Test:________________ Name of Evaluator: ________________________

Product Type: ______________ Signature of Evaluator: ______________________

Test No. Increment No.	Water Phase Height Increment, h (in) A	Sensor Reading (in) B	Measured Sensor Increment (in) C	Increment Difference (in) B-C
Minimum water level detected, X: inches				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

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

Reporting Form For Water Sensor Evaluation Data
Using Liquid Level Measurements And Delivery Simulation
Automatic Tank Gauging System

ATGS Name and Version:____________________________________

Date of Test:________________ Name of Evaluator: __________________________

Product Type: ______________ Signature of Evaluator: __________________________

Test No. ____________

Increment No.	**Liquid Level Height Increment, h (in) A**	**Liquid Level Sensor Reading (in) B**	**Measured Liquid Level Sensor Increment (in) C**	**Increment Difference (in) B-C**
Minimum water level detected, X:		**inches**		
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

NOTE: This form provides a template for data reporting.

Description and Observations of Fuel Delivery Simulation:

United States Environmental Protection Agency
Land And Emergency Management 5401R
EPA 510-B-19-002
May 2019
www.epa.gov/ust