Evaluation Protocol for Continuous Pressurized Piping Leak Detection Systems
Revision 1.1

March 31, 2009

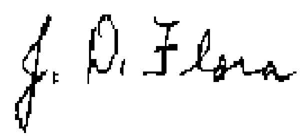
Evaluation Protocol for Continuous Pressurized Piping Leak Detection Systems
Revision 1.1

March 31, 2009

PREFACE

This report was prepared for Franklin Fueling Systems. This report contains an evaluation protocol for testing continuously operating pressurized piping leak detection systems for underground storage tank systems to see whether the leak detection system under test meets the EPA performance requirements. This protocol was developed by considering the requirements specified in the forward to existing EPA protocols. It uses approaches found in two existing protocols as well as specifications unique to the continuously operating feature of developing technologies. This protocol provides a standardized executive summary to provide required data in a standard format. It also includes data reporting forms.

Jairus D. Flora, Jr., Ph.D.



March 31, 2009

ACKNOWLEDGMENTS

This document was written by Dr. J. D. Flora, Jr. Dr. H. Kendall Wilcox, of Ken Wilcox Associates, Inc. provided technical input and review. Technical Reviewers included Steve Purpora, H. Kendall Wilcox, and Robert McKinney. The contribution of these technical reviewers is gratefully acknowledged. This protocol has been reviewed by the National Work Group on Leak Detection Evaluation and their careful review is also acknowledged. This protocol incorporates the revisions suggested by the NWGLDE.

CONTENTS

List of Tables

SECTION 1. INTRODUCTION

EPA regulations[1] specify performance standards for leak detection methods for underground storage tanks. In particular, monthly monitoring systems must be able to detect a leak of 0.20 gallon per hour or 150 gallons per month with a probability of detection, PD, of [at least] 95% while operating at a probability of false alarm, PFA, of [no more than] 5%. These leak detection systems must demonstrate that they can meet these performance standards. The EPA has provided a series of seven standard evaluation procedures for leak detection methods.[2] Six of these EPA protocols refer to leak detection methods mentioned specifically in the regulations. The other one, for Statistical Inventory Reconciliation (SIR) methods, was developed by EPA for a method that qualifies under the "other method" category. Several other standard protocols have been developed, reviewed by the National Work Group on Leak Detection Evaluations (NWGLDE), and approved by the NWGLDE for use in evaluating leak detection methods for specialized methods or situations. These are listed on the NWGLDE's web site: http://www.nwglde.org.

New technologies for leak detection can qualify under this other method category. In order to qualify, new leak detection methods must meet the performance standard given above. These new methods must demonstrate that they meet the performance standards. EPA, in the Forward to the leak detection protocols, has provided ways for this demonstration to be made:

EPA recognizes three distinct ways to prove that a particular brand of leak detection equipment meets the federal performance standards:

1. Evaluate the method using EPA's standard test procedures for leak detection equipment;

2. Evaluate the method using a national voluntary consensus code or standard developed by a nationally recognized association or independent third-party testing laboratory; or,

3. Evaluate the method using a procedure deemed equivalent to an EPA procedure by a nationally recognized association or independent third-party testing laboratory.[3]

---

[1] 40 *CFR* Part 280, Subpart D.

[2] "Standard Test Procedures for Evaluating Leak Detection Methods," EPA/530 UST-90/001-7. Seven different procedures were developed for different leak detection methods and released between March and October 1990.

[3] "Standard Test Procedures for Evaluating Leak Detection Methods: Automatic Tank Gauging Systems," U.S. EPA/530/90-006, Forward, page iv, March, 1990.

This last method is expanded on in the EPA Forward. The following section is quoted from that document.[4]

Alternative Test Procedures Deemed Equivalent to EPA's

In some cases, a specific leak detection method may not be adequately covered by EPA standard test procedures or a national voluntary consensus code, or the manufacturer may have access to data that makes it easier to evaluate the system another way. Manufacturers who wish to have their equipment tested according to a different plan (or who have already done so) must have that plan developed or reviewed by a nationally recognized association or independent third-party testing laboratory. . . . The results should include an accreditation by the association or laboratory that the conditions under which the test was conducted were at least as rigorous as the EPA standard test procedure. In general this will require the following:

1. The evaluation tests the system both under the no-leak condition and an induced leak condition with an induced leak rate as close as possible to (or smaller than) the performance standard. In the case of volumetric tank tightness testing, for example, this will mean testing under both 0.0 gallon per hour and 0.10 gallon per hour leak rates. In the case of ATG systems, for example, this will mean testing under both 0.0 gallon per hour and 0.20 gallon per hour leak rates. In the case of ground-water monitoring, this will mean testing with 0.0 and 0.125 inch of free product.

2. The evaluation should test the method under at least as many different environmental conditions as the corresponding EPA test procedure.

3. The conditions under which the method is evaluated should be at least as rigorous as the conditions specified in the corresponding EPA test procedure. For example, in the case of volumetric tank tightness testing, the test should include a temperature difference between the delivered product and that already present in the tank, as well as the deformation caused by filling the tank prior to testing.

4. The evaluation results must contain the same information and should be reported following the same general format as the EPA standard results sheet.

5. The evaluation of the leak detection method must include physical testing of a full-sized version of the leak detection equipment, and a full disclosure must be made of the experimental conditions under which (1) the evaluation was performed, and (2) the method was recommended for use. An evaluation based solely on theory or calculation is not sufficient.

New technologies currently being brought to the market require development of new protocols. One of these new technologies combined the automatic data collection features of Automatic Tank Gauging Systems (ATGS) with the sophisticated statistical

---

[4] *Ibid.*

data analysis used in Statistical Inventory Reconciliation (SIR) systems. This allows the new systems to monitor the tank continuously, using data collected continually that is reviewed for adequacy. These systems then can operate without interfering with normal tank operation. These new technologies have been referred to as "Continuous In-Tank Leak Detection Systems" abbreviated CITLDS, and a protocol for evaluating them can be found on the NWGLDE[5] web site.

Another new technology has been developed for leak detection for pressurized piping. It combines the continuous data collection of an electronic pressurized piping leak detector with the statistical analysis similarly to the CITLDS for tanks. This document is a standard method to evaluate this new leak detection method for pressurized piping. This method has been developed to parallel the CITLDS for in-tank leak detection systems. It is designed to work on pressurized piping that is in operation. It is designed to identify naturally occurring quiet periods when the pressurized piping is not in active use and collect data from those periods, then use a statistical procedure to combine the data from these periods in an analysis that estimates the leak rate and determines whether the data indicate a leak. This method will have a requirement for extensive data collected over days or weeks, will require an approach to its evaluation that is similar to the method in CITLDS.

This document presents an evaluation protocol designed for continuous pressurized piping leak detection systems (CPPLDS) that operate on liquid-filled pipelines. It combines approaches from the CITLDS, Pressurized Piping, and SIR protocols in ensuring that the 5 points quoted above are met.

5 http://www.nwglde.org

Section 2. Scope of Application

This document presents a standard protocol for evaluation of Continuous Pressurized Piping Leak Detection Systems (CPPLDS). These systems are designed to allow the pressurized piping to operate continuously or nearly continuously without interruption for leak detection tests. They typically have sensors permanently installed in the piping, combined with a microprocessor in a console. In addition, they may be connected to the dispensing meters, allowing for automatic recording and use of dispensing data. There may also be a provision for direct input of data from a keyboard or pad, to allow for entry of meter calibration, for example.

The operation of a CPPLDS is described to distinguish it from a regular PPLD. A CPPLDS may use the same hardware and sensors in a line as a similar PPLD to collect temperature and pressure measurements and report them to a console. However, whereas a standard PPLD requires a specified waiting time after a period of dispensing operations while it conducts a leak test (a shut-down period), the CPPLDS is designed to avoid such specified shut downs of normal dispensing operations. It does this by collecting data continuously. The software identifies segments of time when the line is not being used, identifies those segments that have stable data, stores these data, and combines numerous such segments to produce a leak rate estimate that is used to determine whether the line is tight or not. For high use systems, a period of several days or weeks may be needed for the system to acquire sufficient data to make its determination. Once an adequate database is obtained, a test can be conducted at any time by operator request. The test is based on the most recent data available. As new data are accumulated, older data are dropped, so that the leak rate estimate and test are based on the most current data. The total duration of the test period and the amount of data actually used in calculations will vary with the line use pattern, the type of test being run (e.g., monthly or annual), and the quality of the current data.

The system may default to a standard or “shut-down” pressurized piping leak detection test (requiring the line to be out of service for a few hours) at the end of the month if sufficient good quality data have not been obtained over the month. In low use lines, it may also revert to the previously evaluated “shut-down” test. These CPPLDS systems are designed primarily to meet the monthly monitoring performance standard of detecting a leak of 0.20 gallon per hour or 150 gallons per month with 95% probability and 5% false alarm. They could also be used for the annual performance standard of detecting a leak of 0.10 gallon per hour or 75 gallons per month. However, they are not intended to serve the function of the “hourly” test to detect a leak rate of 3 gallons per hour within one hour, since that function can be met with a very short test using existing systems. That is, adding the CPPLDS to an existing PPLDS will not change its function for detecting the “gross” leak of 3 gallons per hour within one hour.

Typically, CPPLDS are developed using a standard PPLD to collect and store the data. A specialized computer program developed by the vendor is used to analyze the data.

Most of the data collection may be done by using the existing line sensors to collect and store the data, with the analysis being done by a separate computer or board in the console. Alternatively, the complete system with the new software may be installed on site. The hardware and line probes used to collect the data must be the same as are to be used with the new program.

This nature of operation of a CPPLDS, using data collected continually both when the line is not actively in use and when dispensing and deliveries occur, means that third-party testing at a specialized test facility is impractical. In fact, because CPPLDS are explicitly designed to work in the presence of ongoing operations, testing under normal pipe system operation is a critical part of the evaluation of these leak detection systems.

The aim of this protocol is to provide a test plan to determine whether a vendor's CPPLDS meets the EPA performance standards for leak detection. The protocol uses data collected from operating installations with the CPPLDS installed in the field. The data from such installations may be collected in a computer file and the file used to test the performance of the method as is done with statistical inventory reconciliation methods. The basic approach assumes that the CPPLDS produces an estimated leak rate that can be compared numerically to an induced leak rate. However, if the CPPLDS only produces a qualitative (pass or fail) result, the protocol also provides for evaluation on that basis.

This protocol provides calculations to estimate the probability of false alarm, PFA, and probability of detection, PD(R), where R is a specified leak rate (for piping 0.10, or 0.20 gallon per hour). If the CPPLDS reports quantitative data, the reported leak rates are compared to induced leak rates. The differences are analyzed using a normal probability model for the errors to estimate the PFA and PD(R). If the CPPLDS reports qualitative data the PFA and PD(R) are estimated directly as the proportion of incorrect leak determinations under the tight line condition and the proportion of correct identifications of a leak of specified size, respectively.

Subject to the limitations listed on the Results of Evaluation Form, the results of this evaluation can be used to show that a CPPLDS method meets the requirements of 40 *CFR* Part 280. The Results Form reports the testing conditions. A list of required data elements is given in Section 5.

Section 3. Summary

The evaluation protocol for CPPLDS calls for an evaluating organization to arrange with the vendor for at least the data-collecting portion of the CPPLDS system to be installed in a number of lines at different geographical locations. The lines used for these installations should have some independent evidence that they are tight to prevent any problem with the evaluation being based on data from leaking lines. The lines used for the data acquisition are to be tested to ensure line tightness. If the CPPLDS performs only the monthly (0.2 gph) tests, then a line test certified to be capable of detecting a leak rate of 0.2 gph must be used on the line within 6 months (either 6 months before or up to 6 months after) of the data collection. If the CPPLDS performs to the annual standard of 0.1 gph, then the line must be shown to be tight using a line test certified to be capable of detecting a leak rate of 0.1 gph within 6 months of the data collection. As an alternative, an independent 3rd party may test the lines to these standards within 6 months of the data collection period using recognized methods and equipment.

Each individual CPPLDS used for data collection for the system evaluation must show that it is capable of basic functionality by demonstrating that it can detect an induced leak rate of 3 gph at the data collection site. This demonstration test must be performed with 6 months (before or after) of the data collection period.

These installations are used to run tests in the tight line condition and collect data that can be used for simulation of leaks. Some of the data collection may be done by existing LLDS without the continuous software, provided that the sensors and data recording are the same as to be used by the CPPLDS, but at least 20% of the data records must come from the full CPPLDS system. The geographical dispersion of the lines should be chosen to provide a variety of temperature conditions for the database. The lines should be of a variety of sizes and should include a variety of monthly product throughputs.

There are two approaches to obtaining the database for the evaluation.

Option 1: Random Selection of Records from a Large Data Base

This approach requires the vendor to provide the evaluator with a large number of raw data records, at least twice as many as are needed for the evaluation. This requires at least 100 records for quantitative systems and at least 240 for qualitative systems. The evaluator then randomly selects the test records from the larger set and uses the selected records in the evaluation.

Option 2: Prospective Identification of Line Systems and Data Collection

An alternative approach was defined to reduce the amount of data needed. This approach requires the evaluator and the vendor to identify the lines and sites to be used before data collection begins. After that, a continuous record of data is collected from each line and site and sent directly to the evaluator. With this approach only as many records as actually needed for testing (45 for quantitative systems and 120 for qualitative systems) are required, although a few extra might be advisable to allow for problems.

3.1 Continuity of Data Records

Each data record must be a continuous record of data from a given line. This is particularly important for Option 2, but should also be included in Option 1. With any long-term data collection effort, there may be factors that cause some gaps in the data records. For example, a power outage might cause loss of some data. If the data collection required a technician to initiate it, this could result in a substantial gap. With Option 1, many months of data might be collected from some lines. This might include much more data than needed. The evaluator might select months of data to get a seasonal distribution, leaving out some months. The evaluator might divide a record into subsets of fixed length, e.g. 1 month, for use in the evaluation. When the CPPLDS program is run on the data, it might reach a conclusion using different amounts of data. For example, a three-month record might be divided into three test segments of one month each. The first test might conclude after 5 days, leaving a 25-day gap before the next test begins. The reasons for any gaps in the data must be documented to show that there is justification for them. The point of the continuity requirement is to avoid the possibility of selectively dropping “bad” data sections.

3.2 General Properties of the Database

The data collected from each line and used by the CPPLDS to perform its test are collected in computer files. For a quantitative CPPLDS that reports an estimated leak rate, a minimum of 100 such data files are collected under the first option and about 50 such files are collected under the second option. For a qualitative CPPLDS, that only reports a tight or leak indication, at least 240 data files are collected under the first option and 120 under the second option. Under the first option, the evaluating organization will select a number of files at random for the evaluation, at least 45 for a quantitative system and 120 for a qualitative system. For a quantitative system the selected databases will be randomly divided into sets with different simulated leak rates. For a qualitative system the data bases will be randomly divided into two groups with approximately half of the data bases used as tight line records and the rest used as leaking line records with the target leak rate simulated.

Because of the anticipated long duration (days or weeks) of data collection for these systems, it will generally not be practical to physically induce leaks in the lines by removing product during the entire test period. If this is the case, the evaluation requires that the data collected by the system be logged and stored as a computer file. These records will then be used as the data set. Leaks will be mathematically simulated in some of the line data records, while others will be used as recorded. The data records will be submitted to the system's software as if the data were being received from an operating line. The system's algorithm would then provide the same analysis as if it were on line. Methods of simulating the leak must be appropriate to the system and the type of leak and are discussed in Section 6. At least one tests must be conducted with a physically simulated leak. This can be done at an operating site or at a special test facility. Of course, if it is feasible, leaks may be physically induced at some of the sites by removing product from the line and the results from the CPPLDS compared directly to the amount of product removed.

Some of the testing of CPPLDS systems could be done at a specialized test facility. However, an inherent part of these systems is their ability to operate during routine tank and line operations, particularly at systems that operate on a 24-hour basis. Some types of CPPLDS systems use part of the operations as an inherent part of their test. It is difficult and time consuming to simulate such operations at a test facility. Consequently, the protocol requires that some of the testing must be done using operating lines with characteristics similar to those of the population for which the system is intended to be used. Limiting testing at a test facility to about one month of operation and assuming that a test would require at least a few days of data would suggest a practical limit of at most 5 to 10 tests at a specialized facility as part of an evaluation. To demonstrate that the CPPLDS works in a variety of situations, testing must be done in a variety of tank and line systems and operating conditions. A limit of at most 10 tests on any one line is imposed to help assure an adequate distribution of lines and conditions.

3.3 Use of the Database

The method of simulating the leaks will depend on the type of CPPLDS system. Approaches to leak simulation are described in Section 6.

The database with simulated leaks is used with the software of the CPPLDS to produce the measured leak rates. These measured leak rates are then compared with the simulated leak rates introduced into each data file. The comparison of these measured and actual leak rates is used to estimate the performance of the CPPLDS system.

For a quantitative system the comparison is made on the basis of the difference between the estimated and simulated leak rates. These differences are analyzed with a statistical model to estimate the probability of false alarm, PFA and the probability of detection, PD of the target leak rate.

For a qualitative system, the proportion of tight lines incorrectly identified as leaking is used to directly estimate the PFA. A confidence interval for this proportion is also constructed. Similarly, the PD is estimated directly as the proportion of databases with a simulated leak that were correctly identified as leaking by the CPPLDS.

Section 4. Safety

The evaluation consists of analysis of data collected from field installations of the CPPLDS. Thus most of the evaluation will involve office work and calculations and for this no special safety considerations apply. It is possible that some field data collection may involve operating the CPPLDS or dealing with the product stored in the underground storage tanks and dispensed through the pressurized lines. Typically such data collection would involve retrieving data from the microprocessor. This might be done via telephone using a modem or might involve a data transfer to another computer or external disk. All appropriate safety protocols for using the CPPLDS or related computer equipment should be followed, in particular, the use of electrical connections around potentially flammable liquids should be considered.

The instructions for data collection specified by each vendor of the CPPLDS should address the safety issues involved with collecting these data. In addition, the operating procedures for the device should address the safe installation and operation of the device. The intrinsic safety of the device for its intended use is the responsibility of the vendor.

This test procedure only addresses the issue of the method's ability to detect leaks. It does not address testing the equipment for safety hazards. The manufacturer needs to arrange for other testing for construction standards to ensure that key safety hazards such as fire, shock, intrinsic safety, product compatibility, etc., are considered. The evaluating organization should check to see what safety testing has been done before the equipment is used for testing to ensure that the test operation will be as safe as possible.

Section 5. Apparatus and Materials

The evaluation uses data collected during the operation of the system in the field. A computer and associated data recording and transfer peripherals will be needed. Most likely, the data collected and analyzed by the system will need to be logged and stored for use on a separate computer. Thus, a means of recording or transferring the database from each line record from the CPPLDS system to an electronic data storage or transfer medium will be needed. A computer system capable of using the data in an analysis will also be needed.

Some of the testing of CPPLDS systems could be done at a specialized test facility. However, this protocol requires that some of the testing must be done using operating lines. The degree to which a test facility may be used depends somewhat on the type of CPPLDS. Up to 10 tests might be run at a test facility, if the system could complete a test in a few days. However, on an active line a CPPLDS would typically require two weeks to a month of normal operations data for a test. The amount of data needed would provide a practical limit on the number of tests to be run at a specialized test facility.

If a special test facility is used, the test tank should be equipped with a submersible pump of the type generally used in pressurized piping systems. In testing at a specialized facility, this type of pump and dispenser should be utilized to mimic the real world conditions as closely as possible.

A method of simulating a leak in an operating line in which the system is installed may be needed. This would require inducing or simulating the leak over an extended period of time, perhaps days or weeks. If physical leak simulation is to be accomplished, it will require a means of removing product from the line and transferring it to a storage container capable of safely holding enough of the product so that the system can run continuously for a day or so. The amount of product to be removed would be on the order of 5 gallons per day, corresponding to a leak rate of 0.2 gallon per hour. In addition, the leak simulation system must be capable of simulating the leak at a controlled rate and a method of accurately measuring the actual leak simulated must also be available. Further, a means of keeping the fact that a leak was being simulated and the amount of product withdrawn confidential from the vendor would be desirable, although since the CPPLDS operates automatically without operator intervention, it is not absolutely necessary.

Physical leak simulation can be accomplished by use of an orifice type simulator installed in the line. The product would have to be regularly or continuously removed from the orifice simulator. Alternately, product can be released from the piping through a valve that goes through a flow monitor. With either type of simulator, the product will need to be captured in a holding tank or container. The evaluating organization will be responsible for individually designing the leak simulator system to accommodate to the operations at that site.

Because of the extensive data requirements and the long length of time needed for collecting the data, it is anticipated that the evaluation will generally be based on using test data logged by computer from several sites. The data requirements for the data files collected are summarized below in Section 6.

Section 6. Test Procedure

Continuous leak detection methods typically require a long period of normal tank system operation to conduct the test. Consequently, testing of these leak detection methods at a special test facility is unlikely to be practical. The length of the data record required may range from a day to nearly a month or more for an annual tightness test, so physically withdrawing product from the lines at a constant rate to simulate leaks may be impractical. Further, these leak detection methods are generally designed to work with the normal operation of the tank system. An adequate test of the leak detection method must include its function with normal tank system operations.

This evaluation protocol is based on a combination of the alternative method for evaluating an automatic tank gauging system,[6] the protocol for evaluating a statistical inventory reconciliation system,[7] and the protocol for pressurized piping.[8] The database of line records used in the evaluation should be collected similarly to the alternative method for an ATG. Since it is expected that it will generally not be feasible to physically remove product from a line over an extended period to induce or simulate a leak, methods similar to those described in the EPA test method for SIR are appropriate. The reporting format is a combination of the relevant items from the ATG, SIR, and Pipeline protocols, augmented with some additional data specific to CPPLDS.

This protocol must remain flexible so that it can be used for different systems. The protocol requires two types of testing for a CPPLDS. One type of test is based on field data from operating installations. The other type is physical leak simulation, which may be done at an operating installation or at a special test facility. The purpose of the physical leak simulation is to demonstrate that the CPPLDS adequately responds to loss of volume from a line. If the CPPLDS system uses probes or measuring devices that have been developed and evaluated as part of a line leak detection test method, the requirement for physical leak simulation may be satisfied by referencing the appropriate evaluation report. If entirely new measurement technology is being employed, that has not been previously evaluated with an EPA protocol, then a limited series of physical leak simulation tests

---

[6] "Standard Test Procedures for Evaluating Leak Detection Methods: Automatic Tank Gauging Systems," EPA/530/UST/90-006, March 1990, Section 6.5.

[7] "Standard Test Procedures for Evaluating Leak Detection Methods: Statistical Inventory Reconciliation Methods," EPA/530/UST-90-007, June 1990, Section 6.

8 "Standard Test Procedures for Evaluating Leak Detection Methods: Pipeline Leak Detection Methods," EPA/530/UST/90-010, September 1990.

under controlled conditions is required. These are detailed in Section 6.5.3. Testing at a test facility should not require more than 3 or 4 weeks. In computing the line size limitation, include line sizes for all tests, including those at the test facility site (if a test facility was used) in calculating the 80th percentile.

Testing under this protocol may be done with any petroleum fuel type (including E-10 gasoline). Since the liquid product in pressurized pipeline testing is contained within the pipe, there should not be any need to consider different petroleum products. However, with the anticipation of bio-fuels, a concern has been raised about the coefficient of expansion for these products. If the system is to be used for products with coefficients of expansion greater than that of gasoline, then limited testing with those products is also required. See Section 7.6.4 for details.

Tests at a special test facility should simulate dispensing using a submersible pump. The reason for this is that pressurized piping systems use submersible pumps to pressurize the line. The conditions at the test facility should mimic those in the field as closely as possible and so must include a submersible pump.

The dispensing should follow a pattern typical of a high-throughput tank and line. A standard dispensing schedule for a 24-hour period is provided in Table 2. This schedule was developed from records from an operating tank system and corresponds to a monthly throughput of about 80,000 gallons. The schedule in Table 2 may be repeated on a 24-hour cycle for one test. Additional tests at a special test facility should use different dispensing schedules. These may be obtained by recording the dispensing schedule from one of the operational test sites. Again, a 24-hour dispensing cycle may be repeated for as many days as needed to obtain a completed test. It should be emphasized that the dispensing schedule used at a test facility should be derived from an actual operating schedule and should not be an artificially constructed schedule. A different, but real, pumping schedule should be used for each full test at a special test facility.

6.1. Data Base Definition

The CPPLDS should be installed in at least 5 sites and in at least 10 different lines. Sites and lines should be selected to provide a geographical distribution, climatic variability, and size and throughput ranges. A variety of product types may be used, but is not required (unless the system is to be applied to bio-fuels with larger coefficients of expansion than gasoline—see Section 7.6.4 for details). Each line should have some independent evidence that it is tight. Multiple tests may be run on each line using data from different times, but no more than 10 tests should be from the same line system, including that at a special test facility.

Some tank systems use a dispenser that blends different grades of product as it is dispensed to provide a mid-grade product. This should not affect CPPLDS systems, since they test the pressurized piping, which only has one type of product.

The requirements for the database are summarized in the list below. There are general requirements applicable to all systems. Following that are optional requirements that are applicable in some cases. The general concept is that the evaluation database, specifically those records used in the test set, should represent the population of line records that reflects the intended use of the system. This is accomplished by defining limitations on the use of the system to the population of line records actually used in the test set.

6.2. General Requirements for the Database

1. Data must be obtained from at least 10 lines located at a minimum of 5 different sites. No more than 10 evaluation tests may be from any one line.
2. At least 75% of the test records used in the evaluation must be from tank (and line) systems that operate and dispense fuel on a 24-hour basis.

It should be emphasized that the database requirements apply to the set of test data actually used for the evaluation calculations.

The distribution of characteristics of the line systems used in the test data set defines limitations on the application of the CPPLDS system. For example, the distribution of line sizes used provides a limit on the size of the lines. Similarly, the distribution of monthly throughputs provides a limit on the monthly throughput. Since the data actually used in the test set define the limitations, there is no need to impose the same limits on the full database. Vendors and evaluators will want to check that the database is representative of the intended use of the CPPLDS system. However, defining the limitations for the application of the system based on the actual test data ensures that the test database will be representative of the tank systems for which the CPPLDS is to be used.

A test using a CPPLDS consists of a data collection period that may require several days or weeks. This is the period of line operation needed for the CPPLDS to collect enough data from intermittent, quiet periods in the line so that the CPPLDS can produce a valid estimate of the leak rate. For the evaluation, a test can be defined as this data collection period, accompanied by the result of the CPPLDS test. Test periods for the evaluation need to be non-overlapping periods, so that the results from each test are based on separate data. One way to accomplish this is to define non-overlapping periods of data (e.g. 3 or 4 weeks) to be used for tests.

For testing at a test facility, a test consists of the time from turning on the CPPLDS and initiating a dispensing schedule until the CPPLDS has concluded a leak test with a valid result. At that time, the CPPLDS should be reset to start a new test. A new simulated leak should be established and the next dispensing schedule started. Each such facility test will become one test record in the final database used for evaluation.

The test plan should use approximately equal numbers of tight line tests and each of the nominal leak rates. (If the CPPLDS only reports qualitative—pass or fail—results, then about half of the tests should be tight and the other half with simulated leaks.) Slightly more tight line tests than any given leak rate are recommended. This recommended schedule is better than that of the alternative ATG procedure in that it is more stringent in evaluating the system's performance when there are leaks. Note that tests done at a special test facility will generally have leaks physically induced.

6.3. Required Data Elements

The procedure for establishing a database for the CPPLDS evaluation calls for recording several data items. Some of these items relate to the line or site and do not change. These are referred to as line and site data. Other data are collected at short time intervals during the operation of the line. These data are referred to as raw data and are used by the CPPLDS algorithm in processing to estimate a leak rate. Still other data are obtained from the CPPLDS during or after it processes the raw data. These data are referred to as processed data and are used for documenting test conditions.

For each line basic data about the line are required. These include

- Diameter of the line
- Length of the line
- Material of the line (e.g. steel, FRP, flex)
- Bulk modulus of the line
- Approximate monthly throughput
- The site code or geographical location

The CPPLDS must provide certain minimum data elements in their computer files. It is expected that data will be logged frequently, typically every few seconds or minutes. At each time the data recorded in the log must include

- Date and time stamp for each record
- Line pressure
- An indication of whether or not the line is actively being used
- If the CPPLDS monitors product temperature, the product temperature and the product's coefficient of thermal expansion
- Any other data used by the CPPLDS in conducting the tests or analyzing the data

The test results produced by the CPPLDS system must include

- The monthly throughputs for each test period.
- The date and time of the start of the test period.
- The estimated leak rate for the test period (if a quantitative result is provided; otherwise, the determination of whether the line is tight or leaking).
- The ending date and time of the test period.

- The conclusion (the leak rate compared to the threshold to conclude whether the line is tight or leaking)

These items need special consideration in view of the continuous operation of the CPPLDS system. It is anticipated that the CPPLDS will measure or identify each of these items in its normal operation. However, it may be necessary to arrange to specifically include the items in a computer log. It is also possible that the continuous portion of the system may use some processed data from the standard LLDS, for example, an interim result for each quiet period.

The date and time of each test will be recorded, but these tests may cover data collected over periods ranging from one day to a month. Thus, the date and time will be used to determine the beginning and end of the data used in each evaluation test. These data will be used in conjunction with the location of the facility to summarize the environmental conditions during the test (e.g. hot weather, cold weather). It should be emphasized that the testing needs to cover the range of environmental conditions that the leak detection method is expected to encounter in application.

This protocol requires determination of the monthly throughput for each tank and reporting of some percentiles of this distribution. The distribution of the throughputs will impose a restriction on the use of the system. Any tests done at a special test facility are included in calculating these percentiles.

All of the EPA protocols require that the test tanks or lines have independent evidence that they are tight. In this case only the evidence that the lines are tight is relevant. Evidence that the lines are tight should be provided by use of an additional leak detection method besides that being evaluated. This could be an annual line tightness test or an operating electronic line leak detector. The requirement for evidence that the lines are tight is primarily a protection for the vendor. If a leaking line were inadvertently used in part of the evaluation, and the vendor's method indicated a leak when no leak was induced, this would appear in the data as a false alarm. Alternatively if a leak were induced, the results could appear as a large over-estimation of the leak rate. Thus, it is in the vendor's interest to ensure that the lines in the evaluation are tight. This requirement is therefore self-enforcing and regulators should not need any special evidence that it has been met. Thus, if a leaking line were used as a test line, the effect would be an apparent deterioration of the performance estimated for the system.

Since CPPLDS systems will operate continuously during normal tank and line system operation, it is expected that several days or weeks of data may be required to be collected in order for a leak rate to be estimated. This is especially true if the method operates in a tank and line system with a high throughput. Such tank systems are the motivation for the development of CPPLDS, since leak detection methods that take the line out of service are difficult to accommodate in such usage. Consequently, it may not be feasible to physically induce or simulate a leak in all the lines for the test. The method of introducing leaks into the data mathematically is similar to that provided in the SIR

Protocol.[9] A computer program can introduce the selected leak rates into the line records by computing the pressure change resulting from the specified volume loss from the leak rate over the intervals used by the CPPLDS (e.g. every 30 seconds) and can alter the line pressure reading by this amount cumulatively between dispensing operations or times when the submersible pump re-establishes the pressure.

An alternative leak simulation method can be used for systems that use some pre-processed data. For example, if the continuous system makes use of summarized leak rate estimates from each quiet period, the leaks may be simulated by altering those pre-processed data rather than going back to the original pressure data. The important thing is that the protocol simulate leaks in a manner that is appropriate for each CPPLDS.

6.4. Outline of the Evaluation

The following steps provide an outline of this method of evaluation.

Step 1: Identify a number of lines for installation of the CPPLDS system. The lines can be of varying sizes and throughputs, but the sizes and throughputs used in the evaluation will limit the applicability of the results. The requirements for the database are:

General Requirements for the Data Base

1. Data must be obtained from at least 10 lines located at a minimum of 5 different sites. No more than 10 tests may be from any one line.
2. At least 75% of the test records used in the evaluation must be from tank and line systems that operate and dispense fuel on a 24-hour basis.

The combination of geographical sites and dates should provide test periods during hot and cold weather conditions as well as mild weather conditions.

Step 2: Install identical CPPLDS systems in the line systems. Collect and record the line and site data defined in Section 6.1 for each line. Arrange to record the data to document the test conditions for each test. The data requirements were noted above.

Step 3: Operate the CPPLDS system to collect data used to conduct tests on each line system. It will be necessary to arrange to log the raw data defined in Section 6.1 used by the CPPLDS for its calculations. These raw data will be used in simulating leaks.

Step 4: Create a database from the records collected in Step 3 of the raw data recorded by the CPPLDS. The database should meet the requirements listed in Step 1. The

[9] "Standard Test Procedures for Evaluating Leak Detection Methods: Statistical Inventory Reconciliation Methods," EPA/530 UST-90/007, June, 1990.

data records collected should represent a continuous record from each line. Any gaps that occur must be justified. If the option of randomly selecting records from a large base is used, the database should include at least 100 tests (for quantitative systems; 240 for qualitative systems). If the option of defining the tank systems and collecting data prospectively is used, the database should include at least 45 records for quantitative systems or 120 records for qualitative systems. The database should be distributed over the line size, throughput, and test conditions representing the intended population of use.

Step 6: The evaluating organization will take the database of records collected on the test line population and (if using Option 1) randomly select a subset for use in the evaluation. The subset will be randomly allocated to tight and various leak rates for simulation. As an alternative to selecting a random subset from a larger population of test records, the evaluating organization may work with the vendor in identifying the sites, line records, and data test period (Option 2). All line records from the sites, tanks, and periods must be continuous and submitted to the evaluating organization for use. This would reduce the number of line records needed to conduct the evaluation. It should be recognized that some line records submitted in this manner may not be usable because of data recording difficulties. Such problems in recording large amounts of data should be expected and should not invalidate the evaluation. However, the evaluating organization would have all of the data for the period and lines selected, and would review all records to estimate the performance of the CPPLDS. The evaluating organization will then simulate the leak rates and produce data files altered to include the induced or simulated leak rates. The evaluating organization will operate the CPPLDS program on these data records. The CPPLDS will treat these as ongoing line records and produce leak rate estimates. The evaluating organization will record the results produced by the CPPLDS.

Step 7: If desired, a number of physical leak simulations may be incorporated into the test plan for evaluating a CPPLDS. These would replace some of the mathematically simulated leaks and may be done at field sites or at a special test facility. The number of tests done at a special test facility may range from 1 to 10. Physical leak simulation is required only for systems that use sensors that have not been previously evaluated.

Step 8: The data will be used to analyze the difference between the leak rates estimated by the CPPLDS and those introduced by the evaluating organization. Based on these differences, the PD and PFA will be calculated. If the CPPLDS system is qualitative, the proportions of errors will be calculated separately for tight line records and for those with induced leaks. These proportions will be used to estimate the PD and PFA.

Step 9: The data on test conditions will be summarized and reported together with the limitations on applicability of the CPPLDS system that result from the test conditions.

Step 10: If the system uses sensors that have been previously evaluated as part of another (non-continuous) leak detection system, that evaluation report must be referenced to document that physical performance of the sensors. If the system is based on new technology with sensors that have not been evaluated previously, then at least 6 physical leak simulations are required. These can be done in the field as part of Step 7, or they can be run at a special facility with the system operating to simulate a 24-hour dispensing operation.

Step 11: If the system has not been previously evaluated and can function as a stand-alone (i.e. non-continuous) line leak detector capable of detecting the "hourly" (3-gph) rate as well as either the "monthly" (0.2 gph) or "annual" (0.3 gph) rate, then a full EPA pressurized line leak detection evaluation must be performed (and referenced) as well as this evaluation of the continuous leak detection function.

Note: In the event that leaks can be physically simulated or induced at the lines in an appropriate manner, it might not be necessary to log the raw data collected and used by the CPPLDS. Or if the CPPLDS uses some summary data from the existing PLLDS, the simulation may be done on the summary data from the quiet periods. If leaks are physically simulated by withdrawing product from the lines, it would be necessary to ensure that the fact of this withdrawal and the size of the leak simulated is kept blind to the vendor. That is, it is not available for use by the vendor in modifying the system's results. It would also be necessary to ensure that the leak rate is measured accurately.

6.5. Test Schedule

The data from line records described above are used for the evaluation. A database of about twice the number of records to be used in the evaluation from the lines described above can be used to randomly select a subset for analysis. Alternatively the set of lines, records, and time can be selected with the evaluating organization and all records for the defined period submitted for evaluation. This will reduce the amount of data needed for the evaluation, while still assuring that the data represent the performance of the system. The data should be stratified by climate condition and by throughput and size.

6.5.1 General Test Schedule

Some testing may be done at a special test facility, but some field data tests from operating tank and line systems are also required. This protocol must remain flexible so it can be used for different systems. Thus, a variety of combinations of field tests and tests at a specialized facility is possible.

For a CPPLDS, only one physical leak simulation is required, provided that the probes and sensors were previously evaluated as part of a pressurized piping leak detection system. In that case, the previous evaluation report must be referenced. If the system uses sensors based on new technology with no previous evaluation, then at least 6 physical leak simulations must be run to demonstrate that the equipment does adequately track volume changes. These can be run in a test facility or at a field site.

It is anticipated that a vendor would develop CPPLDS software to apply to an existing (previously approved) pipeline leak detector. Such a system would be an augmentation of a previously evaluated system to allow for collection and analysis of long-term data for leak detection that would reduce or eliminate the need to take the pipeline out of service. However, it is possible that some vendor(s) might develop a new line leak detection system with this continuous capability.

If a vendor designs a completely new system that has never been evaluated according to the EPA line leak detection protocol and if the system produces the "hourly" 3-gph leak test results coupled with either the "monthly" (0.2 gph) or the "annual (0.1 gph) leak test results then the system must be evaluated according to the EPA (PLDS) line leak detection protocol. The continuous function of the CPPLDS must also be evaluated using this protocol. The PLDS evaluation must always be referenced in the CPPLDS report.

For a quantitative system, after stratification of the database by line size and throughput, randomly select 45 line records for use. The selected records are then randomly assigned average leak rates of nominally 0, 0.10 gallon per hour (gal/h) or 75 gallons per month, 0.20 gal/h (150 gallons per month), and 0.30 gal/h (225 gallons per month), for an evaluation of the CPPLDS as a monthly monitoring system able to detect a leak of 0.20 gal/h or 150 gallons per month. Fifteen (15) line records are assigned to the tight (zero leak) group and 10 to each of the other leak rates. At least 90% of the records must give valid test results.

It should be noted that the leak rates for monthly monitoring are averages. That is, they are designed to evaluate the system's ability to detect an average leak rate of 0.20 gal/h or 150 gallons per month as noted in the EPA regulations for other leak detection methods. If the CPPLDS is also to be evaluated as to its ability to detect a leak rate of 0.10 gal/h or 75 gallons per month on a monthly basis, an additional 10 records are needed, to which a nominal leak rate of 0.05 gal/h (37.5 gallons per month) is to be added. Consistent with the EPA performance standard, all leak rates are to be viewed as monthly average leak rates, with equivalent monthly total gallons lost.

A random number may be added to each leak rate so that the simulated leaks are not predictable, exact leak rates. Rather, select rates at random with a uniform distribution specific to each nominal leak rate. Select a leak rate at random using a uniform distribution over the interval of [0.03, 0.07] gal/h or [22.5, 52.5] gallons per month for the nominal 0.05 gal/h (37.5 gallons per month) leak rate; select a leak rate at random with a uniform distribution from the interval of [0.08, 0.12] gal/h or [60, 90] gallons per month for the nominal 0.10 gal/h (75 gallons per month) leak rate; select a leak rate at random with a uniform distribution from the interval of [0.16, 0.24] gal/h or [120, 180] gallons per month for the nominal 0.20 gal/h or 150 gallons per month leak rate, and select a leak rate at random with a uniform distribution from the interval of [0.25, 0.35] gal/h or [187.5, 262.5] gallons per month for the nominal 0.30 gal/h or 225 gallons per month leak rate.

For a qualitative system, after stratification of the database by line size and throughput, randomly select 120 line records for use. Randomly select a number between 50 and 70 for the number of records to use as tight. The remainder will have leaks simulated of a size as close as practical to 0.2 gal/h or 150 gallons per month. Randomly divide the 120 records into the two groups with the size determined above. At least 90% of the records must give valid test results.

A test plan for a quantitative system is provided in Table 1. This plan includes the leak rates used for both the 0.10 gal/h (75 gallons per month) and the 0.20 gal/h (150 gallons per month) performance standards. If evaluation to only a single standard is desired, the appropriate 4 nominal leak rates may be used. That is, for an evaluation aimed at documenting the performance of the system in detecting the target leak rate of 0.20 gal/h or 150 gallons per month the records with induced leak rates of 0.05 gallon per hour or 37.5 gallons per month would be dropped.

The test plan included in Table 1 includes a total of 55 records. If evaluation to a single standard is desired, only the 45 records that apply to that standard are needed. Fifteen of these are for tight lines, and 10 are assigned each of the four induced leak rates. (One of the induced leak rates could be dropped if evaluation is to a single standard, but since often both levels of performance may be of interest, the full data matrix is recommended to provide for both performance levels within a single set of tests.) Table 1 includes the induced leak rates in ascending order so that the number of each can be clearly seen. In actual practice, the line records would be identified with line size and throughput. Then the records would be assigned induced leak rates at random, so that no pre-specified order would exist. The actual leak rates to be induced would then be constructed from the nominal leak rates by introducing some random variability as described above.

Table 1. Experimental Design

Test Number	Line Volume	Throughput	Leak Rate
1			0
2			0
3			0
4			0
5			0
6			0
7			0
8			0
9			0
10			0
11			0
12			0
13			0
14			0
15			0
16			0.05
17			0.05
18			0.05
19			0.05
20			0.05
21			0.05
22			0.05
23			0.05
24			0.05
25			0.05
26			0.10
27			0.10
28			0.10
29			0.10
30			0.10
31			0.10
32			0.10
33			0.10
34			0.10
35			0.10
36			0.20
37			0.20
38			0.20
39			0.20
40			0.20
41			0.20

42			0.20
43			0.20
44			0.20
45			0.20
46			0.30
47			0.30
48			0.30
49			0.30
50			0.30
51			0.30
52			0.30
53			0.30
54			0.30
55			0.30

6.5.2 Leak Simulation

If a leak is induced physically in a system, the liquid product is allowed to flow out of the pipe through a valve or an orifice through some sort of a flow meter and is collected in a vessel. The amount collected is divided by the time of collection to give an average leak rate. The flow meter is used to make sure that the leak rate is approximately the size desired. The leak is maintained for a period of time during which the leak detector conducts its test. Since flow varies with the pressure in the pipe, a physical leak may vary over the time of the test if the flow is large enough to reduce the pressure noticeably.

In order to mathematically simulate a leak in a pipeline, the following procedure is used. The original data consist of pressure readings (by the leak detector) at periodic times (e.g. once per minute). Two parameters of the pipe system are required: the bulk modulus, denoted by "B," and the volume of the pipeline, denoted by "V." The bulk modulus is in pressure units, typically PSI, while the volume could be in gallons or millimeters. The ratio, B/V, gives the amount of pressure change for a unit volume change. As an example (in the EPA pipeline protocol) the value of B/V might be 0.25 psi/ml.

Using the leak rate to be simulated and the time between each reading, one can calculate the volume of liquid product that leaks out of the pipeline in an interval between readings. A leak rate of 0.2 gal/h corresponds to a leak rate of 12.618 ml/min. The volume per minute is multiplied by the ratio B/V, to give a pressure change per minute for the line that corresponds to the leak rate. For example, a test line with three different segments has a bulk modulus measured as 23,292 psi and a total volume of 207.9 gallons. This gives a B/V ratio of 0.0296 psi/ml. Simulating a leak rate of 0.2 gal/h in this line would result in a drop in pressure of 0.373 psi the first minute. Since the leak rate from a pressurized pipe depends on the pressure, as the pressure in the pipe drops, the simulated leak rate would be reduced. The steps in simulating a leak are listed below, followed by a table illustrating a simulated leak.

In order to simulate a leak in the data, the following steps are followed.

1. First select the leak rate to be simulated.
2. Determine the pressure change that results from a given volume change (loss) by using the B/V ratio.
3. Apply the time interval from the first pressure reading to the second to the leak rate to determine the volume lost during that period.
4. Using the volume lost, compute the pressure change in the period using B/V and the volume change.
5. Modify the leak rate by multiplying the initial rate by the square root of the ratio of the reduced pressure to the initial pressure.
6. Apply this modified leak rate to the second time interval to determine the volume lost during that time interval.
7. Using the volume lost in the second time interval, compute the pressure change in that period using B/V and the volume change.
8. Repeat steps 5 through 7 until the end of the data period is reached.
9. Begin the process again for each data period.
10. Continue until the entire record has been modified.

Note that if the pressure change is quite small, it might not be necessary to adjust the leak rate for each time interval. If the effect over a data period would be to change the leak rate by less than 10%, this adjustment could be ignored. Table 2 shows an example of the leak simulation calculations. In the example, a leak of 0.2 gallon per hour at the operating pressure of 30 PSI is simulated. The data are taken every minute and the data period in this case is 15 minutes. The bulk modulus of the line was measured as 23,292 PSI and the line volume was 207.9 gallons, giving a B/V ratio of 0.0296 PSI/ml. Over the 15-minute data period, the line pressure dropped from 30 PSI to 25.452 PSI and the leak rate dropped from 0.2 gal/h (12.618 ml/min) to 0.0803 gal/h (11.436 ml/min). For the next data period, the pressure would be set to 30 PSI and the leak rate started again at 12.618 ml/min.

Table 2. Example Leak Simulation

Time (minutes)	Pressure (PSI)	Leak Rate (ml/min)	Drop in Pressure(PSI)
0	30.000	12.618	0.373
1	29.627	12.539	0.371
2	29.255	12.460	0.369
3	28.887	12.382	0.366
4	28.520	12.303	0.364
5	28.156	12.224	0.362
6	27.794	12.145	0.359
7	27.435	12.066	0.357
8	27.078	11.988	0.355
9	26.723	11.909	0.352
10	26.370	11.830	0.350
11	26.020	11.751	0.348
12	25.673	11.673	0.345
13	25.327	11.594	0.343
14	24.984	11.515	0.341
15	24.643	11.436	0.338

The next data period when no dispensing was occurring would start again at the initial line pressure and leak rate. In the simulation, the actual line pressure at the start of the period would be used as the pressure at the initial time. This would probably not be exactly 30 PSI. Similarly, if the time interval differs from one minute, the calculations would be done for the actual time intervals.

The simulation would continue until each data period had the leak rate simulated in it. Then the modified data would be submitted to the system's software for processing. Once the system processes the data and reports the leak rate (along with its conclusion), the measured leak rate and the simulated leak rate would be recorded. For a quantitative leak detection system, after all the tests were completed, the measured leak rates and simulated leak rates are compared to estimate the performance of the system. A statistical model is used to estimate the probability of a false alarm and the probability of detection of the simulated leak rate.

If the system uses pre-processed data from the line leak detector system, the leak may be simulated in these intermediate results. In this case, the effect of a leak rate on the intermediate results must be known. This effect would be applied and then the altered intermediate results would be submitted to the processing algorithm of the CPPLDS.

If the system is qualitative, then the simulated leak rate is recorded along with the conclusion of the system. When all the tests are concluded, the results are compared with the actual piping status (tight or simulated leak) and the proportion of simulated leaks detected estimates the probability of detection, while the proportion of false alarms is estimated directly from the proportion of times the system declared a leak when none was simulated.

6.5.3. Testing at a Special Test Facility

Tests at a test facility should simulate dispensing using a submersible pump. A submersible pump is required in order to pressurize the line. Table 3 contains a dispensing schedule for testing at a special test facility. The dispensing schedule was developed from dispensing records for an operating tank system, which had a monthly throughput of about 80,000 gallons. The daily total of about 2,600 gallons dispensed corresponds to this monthly total for a 31-day month. This dispensing schedule represents a realistic throughput for a 24-hour operation for which a CPPLDS is designed and which can be reasonably achieved at a special test facility. Field data may include higher throughputs. The schedule in Table 3 may be repeated as needed to complete a test. Alternatively, similar dispensing records may be recorded from the field installations and those could be used in place of Table 3.

In using this form of testing, the dispensing schedule should be followed continuously for each test. The schedule is reported for the 24-hour period beginning at midnight. In operation, the schedule can be started at any time during the day, by entering the table at the appropriate time and following the schedule from then on. When midnight is reached, return to the top of the schedule and continue with it.

Tests at a special test facility would usually include a physically simulated leak. This induced leak can be done by using a connection to the line that can be closed by a valve, then allowing the product to flow out into a collection device. The flow could be through a flow meter so the leak rate can be monitored. The amount of product leaked should be measured by volume or by weight to be converted to volume so that an accurate leak rate can be determined.

Table 3. Daily Dispensing Schedule For Test Facility Testing

Start of busy period		Duration with pump on (minutes)	Gallons dispensed	Duration of period with pump off (minutes)
Hour	Minute			
0	24.1	0.7	3.94	23.6
0	35.7	1.3	10.26	10.8
0	55.9	2.4	15.76	19.0
2	2.9	1.0	7.89	64.5
2	16.8	0.9	3.94	13.0
2	31.7	1.7	11.82	13.9
3	59.6	0.7	3.94	86.3
4	22.8	3.3	12.32	22.5
4	34.5	1.1	3.93	8.3
5	10.0	1.7	12.61	34.5
5	30.2	0.6	3.94	18.5
5	39.9	3.5	10.42	9.1
5	59.5	1.7	7.33	16.2
6	7.4	5.9	29.93	6.3
6	31.2	1.9	12.06	17.9
6	43.3	1.2	3.94	10.2
6	58.5	0.6	3.94	14.0
7	4.3	1.9	15.17	5.2
7	18.3	10.8	77.98	12.2
7	38.0	12.8	28.69	8.9
7	56.4	1.4	11.10	5.6
8	25.6	1.3	9.45	27.8
8	30.6	5.7	28.46	3.7
8	41.8	1.9	11.82	5.5

Start of busy period		Duration with pump on (minutes)	Gallons dispensed	Duration of period with pump off (minutes)
Hour	Minute			
8	49.4	1.7	9.20	5.7
8	54.1	4.0	37.39	3.0
9	2.6	1.5	11.89	4.5
9	31.3	1.8	9.85	27.2
9	36.2	1.0	5.52	3.1
9	41.9	5.6	32.00	4.7
9	51.9	0.6	3.94	4.4
9	59.7	3.8	30.25	7.1
10	10.8	0.6	3.94	7.2
10	13.9	4.8	46.96	2.5
10	23.2	2.4	26.00	4.6
10	29.8	2.8	16.56	4.2
10	35.3	6.0	64.78	2.7
10	49.5	2.9	18.18	8.1
10	55.6	1.0	10.25	3.2
10	56.6	10.0	15.14	0.0
11	17.9	15.8	83.46	11.3
11	36.2	3.4	26.50	2.5
11	49.0	5.4	25.68	9.4
12	0.1	2.1	12.50	5.8
12	17.8	1.3	9.18	15.6
12	28.8	2.4	14.92	9.7
12	33.7	13.0	59.69	2.6
12	58.1	0.8	3.95	11.4
13	4.3	0.8	1.46	5.4
13	12.5	4.6	32.90	7.4

Start of busy period		Duration with pump on (minutes)	Gallons dispensed	Duration of period with pump off (minutes)
Hour	Minute			
13	19.9	2.2	16.56	2.7
13	37.3	1.0	9.46	15.2
13	41.7	3.8	32.66	3.4
13	50.8	3.4	7.88	5.3
13	57.7	30.3	164.18	3.5
14	33.0	1.4	11.83	5.0
14	41.6	5.8	31.39	7.2
15	1.1	14.5	111.50	13.8
15	21.6	1.2	9.86	6.0
15	27.2	10.1	84.26	4.3
15	40.2	15.6	58.58	2.9
15	59.8	1.0	6.50	4.0
16	7.8	3.2	11.04	7.0
16	13.9	0.9	6.31	2.9
16	23.9	2.9	17.14	9.1
16	31.5	2.6	26.02	4.7
16	37.1	1.2	9.06	3.0
16	42.5	10.8	53.67	4.1
16	57.8	19.2	87.54	4.6
17	21.1	2.2	10.96	4.1
17	30.4	16.1	137.82	7.1
17	49.5	8.1	37.06	3.0
18	0.7	10.3	49.25	3.1
18	15.7	4.8	30.45	4.7
18	23.2	0.9	5.52	2.7
18	30.8	2.2	11.95	6.7

Start of busy period		Duration with pump on (minutes)	Gallons dispensed	Duration of period with pump off (minutes)
Hour	Minute			
18	41.0	2.5	10.24	8.0
18	48.1	1.5	11.50	4.6
18	54.0	2.7	13.01	4.4
19	3.3	12.5	79.79	6.7
19	20.4	2.6	8.62	4.6
19	29.6	4.0	18.52	6.7
19	37.9	0.5	2.37	4.3
19	42.6	17.9	48.19	4.2
20	13.9	1.2	7.10	13.4
20	26.1	4.3	21.96	11.0
20	34.6	1.9	15.76	4.2
20	41.0	1.6	14.83	4.5
20	51.6	3.8	30.76	9.0
21	7.7	4.2	15.05	12.3
21	17.7	2.2	18.13	5.8
21	26.5	15.2	67.79	6.6
21	57.6	1.3	11.04	16.0
22	7.8	6.3	50.46	8.9
22	17.9	4.8	20.72	3.8
22	30.8	4.7	22.99	8.1
22	38.9	0.5	3.17	3.4
22	49.9	2.0	13.44	10.5
22	57.6	2.9	15.76	5.8
23	4.1	1.7	10.83	3.5
23	12.8	2.8	7.09	7.1
23	19.6	5.7	22.98	4.0

Start of busy period		Duration with pump on (minutes)	Gallons dispensed	Duration of period with pump off (minutes)
Hour	Minute			
23	35.1	2.4	21.31	9.8
23	42.2	2.1	11.83	4.7
23	54.6	2.9	17.34	10.3
24	0.0	0.5	3.94	2.5

The first two columns of Table 3 have the start of each busy period, that is, the time when the pump is turned on in hours and minutes. The next column has the duration of that busy period, or the length of time that the turbine should run in minutes. The next column contains the amount of product dispensed during that period in gallons, while the last column has the duration of the period with the pump off just prior to the start of the current active period. The time periods are given to the nearest $^1/_{10}$ of a minute, but following them to the nearest minute is sufficient. Similarly, the volume dispensed is reported to the nearest $^1/_{100}$ of a gallon, but dispensing to the nearest gallon is sufficient.

It is important that the duration of the quiet periods not be extended beyond those in the test schedule. The turbine of the pump should run during the entire busy period, even if product dispensing is completed in less time than indicated as the busy period.

Physically simulating a leak at a special facility can be done in the same way that it is done for a pressurized piping test method. The only difference is that a standard pressurized piping test method typically requires only an hour or two of test time (when no dispensing is allowed). For the CPPLDS, the leak must be physically induced all the time and a dispensing schedule followed for several days until the continuous line leak detection system can acquire enough data between dispensing operations to complete its test. Thus, the leak simulation may accumulate a substantial volume of product over this period and the container collecting this product may need to be measured and emptied several times.

If the CPPLDS has not been previously evaluated as a shutdown line leak detector, at least one physically simulated leak is required. If this is the case, the leak rate physically induced should be that of the required detection level, namely, 0.2 gal/h. If multiple physically induced leaks are used, then they should be spread over the three leak rates for a quantitative system. If the system is qualitative, all of the leak rates should be approximately the size required to be detected for a monthly monitoring system, that is, about 0.2 gal/h.

6.6. Summary of the Database Requirements

The following requirements apply both to the complete database, and, more specifically, to the database of records used to calculate the performance estimates.

- Data from at least 10 different lines from at least 5 different sites are required (one site may be a special test facility).
- At least 75% of the test records used in the evaluation must be from tank systems that operate and dispense fuel on a 24-hour basis.
- For Option 1, a total of 100 records is required for evaluation of a quantitative CPPLDS; 240 records are required for evaluation of a qualitative CPPLDS.
- For Option 1, a total of 45 data sets will be selected at random from 100 records for evaluating a quantitative CPPLDS; 120 data sets selected at random for evaluating a qualitative CPPLDS. (More may be used.) At least 90% of the data sets must result in valid leak detection tests.
- For Option 2, a total of 45 data sets used for evaluating a quantitative CPPLDS; 120 data sets used for evaluating a qualitative CPPLDS will be obtained prospectively. (More may be used.) At least 90% of the data sets must result in valid leak detection tests.
- The data records collected under either option must represent a continuous record from each line. Any gaps in the data records must be documented and justified.
- At least 1 physical simulation of a leak is required for CPPLDS (either at a field site or special test facility). This provides 1 of the 45 or 120 required test records.
- If the physical sensors of the system were part of a system with a previous evaluation, that evaluation report may be included by reference. If no previous evaluation of the measurement system has been done, then a series of at least 6 physical leak simulations is required.
- The records should be distributed over the line sizes and throughputs of the tank system population for which the CPPLDS is intended to be used. These distributions imply restrictions on the use of the system.
- Multiple records from each line from non-overlapping periods may be used, but no more than 10 records from any given tank system (including a test facility) may be used.
- The mathematical simulations are done by the evaluating organization, and the evaluating organization operates the CPPLDS program or system on the data records

without the vendor or the vendor may operate the CPPLDS program on the data records under the supervision of the evaluating organization.

6.7. Deviations from the Protocol

When a protocol such as this is first attempted, the evaluator often learns that some of the procedures are unwarranted or impossible to apply for a particular continuous system. Deviations from the protocol are permitted provided that the evaluating organization documents the deviations and gives a justification or rationale for each deviation. This is intended to improve the evaluation and make it faster to conduct and applicable to more leak detection systems.

Section 7. Statistical Analysis

The data reported in the Reporting Form For Leak Rate Data are used to calculate the performance estimates. The method of data analysis for a quantitative system is basically the same as in the ATG, volumetric tank tightness test, and SIR protocols. The data analysis for qualitative systems is the same as in the SIR and non-volumetric tank tightness test protocols. However, additional calculations are required to demonstrate that the performance is not adversely affected by larger line sizes or higher throughputs. Separate subsections are provided describing the data analysis for quantitative and qualitative methods.

7.1 Basic Statistics for Quantitative Systems

The n pairs of estimated and induced leak rate data are used to calculate the mean squared error, MSE, the bias, and the variance of the CPPLDS as follows.

7.1.1 Inconclusive or Invalid Results

It is possible, but unlikely, that a data record might not produce a valid result; that is, that the leak detection software of the CPPLDS determines that an operational problem has occurred meaning that the data are inadequate, so no valid leak rate can be estimated, and consequently that the test is not valid. If this should happen, the result will be noted and reported as an invalid result. The number and percent of any such results will be reported on the results form.

A minimum number of valid tests is required for the evaluation. For systems that report quantitative results, a minimum of 32 valid tests (out of the planned 45) is required. Further, no more that 30% of the results may be invalid in each nominal leak rate group. For systems that report on a qualitative basis, at least 90 valid tests (out of the planned 120) are required, with no more that 30% invalid in the tight line records and no more than 30% invalid in the simulated leak records.

7.1.2 Mean Squared Error

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

The mean squared error, MSE, is given by
where L_i is the estimate leak rate reported by the CPPLDS system and S_i is the actual induced leak rate, for i from 1 to n for the different databases.

The bias, B, is estimated by

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

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

7.1.3 Variance and Standard Deviation

The variance is found from the formula

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

Denote the standard deviation by SD. The standard deviation is the square root of the variance.

7.1.4 Test for Zero Bias

To test whether the CPPLDS system has a bias that is statistically significantly different from zero, the following statistical test on the bias, B, calculated above is performed. Compute the t-statistic

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

From a t-table, obtain the critical value corresponding to a t with $(n-1)$ degrees of freedom and a two-sided 5% significance level. For example, with n = 45, there are 44 degrees of freedom and the two-sided 5% significance level leads to a critical value of 2.015. Denote this value by t_c. Compare the absolute value of t to t_c. If the absolute value of the calculated t is less than the critical value, the bias is not significantly different from zero and the system is assumed unbiased. If the absolute value of the calculated value of t exceeds the critical value then the method has a significant bias. If the bias, B, is positive, the system systematically over estimates the leak rate. If B is negative, the system under estimates the leak rate.

7.2 Probability of a False Alarm, PFA

The probability of a false alarm, PFA, is the probability that the measured leak rate will exceed the threshold or criterion for indicating a leak when the line is actually tight. Generally, if the estimated leak rate exceeds a specified leak rate or threshold, C, (for example 0.12 gallon per hour), the line is judged by the CPPLDS to be leaking. If C denotes the criterion or threshold for indicating a leak, B, the estimated bias of the system, SD, the standard deviation, then the probability of a false alarm can be written as:

$$PFA = P\{\ t > (C — B)/SD\ \}, \qquad (7)$$

where the probability is calculated from a t-distribution with the number of degrees of freedom associated with the standard deviation, which would be 44 if there were 45 tests and would be 54 if the full set of 55 tests is used. This formula assumes that the errors are approximately normally distributed. If the bias, B, was not significantly different from zero, B is taken to be zero.

7.3 Probability of Detecting a Leak Rate of 0.20 Gallon Per Hour, PD

The probability of detection, PD, is the probability that the system will correctly identify a leak of specified size. In general for a leak rate of size R, PD is given by:

$$PD = P\{\ t > (C\text{-}R\text{-}B)/SD\ \}, \qquad (8)$$

where C, B, and SD are as before, and the probability is calculated from the t-distribution with degrees of freedom corresponding to the SD, which would be 44 if the usual set of 45 records is used. The degrees of freedom would be 54 if the full set of 55 tests is used.

7.4 Mean and Standard Deviation of The Tight Line Tests

The tests conducted under the condition of no leak (tight line) provide direct estimates of the performance of the system on a tight line. Calculate the mean and standard deviation for the tests on the tight line records by using the formulas above restricting the data to the data from the tight line records. The sample size, n, will also be reduced, to 15 if there are 15 records with no induced leak, for example.

7.5 Statistics for Qualitative CPPLDS

The basic results of the CPPLDS report are that the line is tight or leaking. As noted above, there is a possibility that some results might be invalid. These results can be tabulated in Table 4 to summarize the results.

Table 4. SUMMARY OF RESULTS FROM QUALITATIVE CPPLDS EVALUATION

Actual Status	Reported			
	Tight	Leaking	Invalid	Total
Tight	T_1	L_1	X_1	N_1
Leaking	T_2	L_2	X_2	N_2

The numbers in Table 4 are used to directly estimate the PFA and PD. The number of tight lines incorrectly identified as leaking, divided by the total number of tight lines estimates the PFA. That is

$$PFA = L_1/(N_1 - X_1), \tag{9}$$

where the letters in the cells of Table 4 denote the number of results in the category indicated by the cell label.

Similarly, the PD is estimated by the number of leaking line records correctly identified as leaking or,

$$PD = L_2/(N_2 - X_2). \tag{10}$$

In Table 4, N_1 is the number of line records from tight lines and N_2 is the number of line records with induced leaks. These numbers are each approximately 60, but are actually a random value between 50 and 70, for each evaluation.

The proportion of records declared invalid must also be reported separately for the tight and leaking records as well as for all records. These proportions are calculated as

$$PI(Tight) = X_1/N_1, \tag{11}$$

$$PI(Leak) = X_2/N_2, \tag{12}$$

and

$$PI(All) = (X_1 + X_2)/(N_1 + N_2) \tag{13}$$

for the proportion of invalid records among tight, leaking, and all records, respectively. The proportion of invalid records among all line records provides an estimate of the proportion of lines in a population represented by the evaluation data base for which this method cannot be used.

In order for the method to meet the EPA performance standard, PFA must be less than or equal to 0.05 (5%) and PD must be at least 0.95 (95%). If the number of records (either tight or leaking) were 60, the CPPLDS could make at most 3 mistakes out of the 60 records and still meet these requirements. It is possible that the system might not make any errors, giving an estimated PFA of 0 or an estimated PD of 1. Since no system is expected to have zero errors in practice, it is important to calculate a confidence interval for the discrete proportion of false alarms or detections to give an indication of what range should be expected for the PFA or PD in practice.

If no errors occur in the evaluation database, the confidence limit for PFA is found from

$$UL = 1 - \alpha^{1/N_1} \tag{14}$$

where $(1 - \alpha)$ is the confidence coefficient, which is generally set at 0.95. For one or more errors, the confidence limits are calculated from confidence limits for the parameter of a binomial distribution. These can be found in *CRC Handbook of Tables for Probability and Statistics*,[10] for example.

If no errors occur in the evaluation in detecting leaks, a lower confidence bound for PD can be calculated from

$$LL = \alpha^{1/N_2}, \tag{15}$$

where again $(1-\alpha)$ is the confidence coefficient, usually set at 0.95. For one or more errors in detecting leaks, the confidence limits for the binomial are used.[11]

7.6 Other Data Analysis and Limitations

There are a number of factors that can influence the results of the tests performed by a CPPLDS. This section contains additional statistics that should be calculated and reported about the conditions of the test data set. These conditions should be summarized in the same way whether the system is qualitative or quantitative. Statistics are calculated for the size of the lines used in the evaluation and the monthly throughput of product for these lines. The test conditions or characteristics of the database impose restrictions on the application of the system. These limitations are described in this section. Some of these statistics become the basis for limitations on the application of the system. These limitations are described next.

---

[10] Beyer, William H., editor, *Handbook of Tables for Probability and Statistics*, The Chemical Rubber Co. 1966, p.65.

[11] *Ibid.*

7.6.1 Line Size

The size of the line is an important consideration. The distribution of line volumes should be as nearly uniform as practical. In particular, the database should not emphasize small lines. The test data should represent the population of lines for which the system is intended to be used. The results of an evaluation can be extended to lines 50% larger than the 80th percentile of the line sizes in the data set used in the analysis[12] or to the size the "shut-down" version of the leak detector is approved for, whichever is larger. The line sizes used in the database should be reported Table 1.

These line volumes are to be ordered from least to greatest and various percentiles determined. The smallest, 25th, 50th (median), 75th, and 80th percentile, and the largest line volume are reported on the results form. To find a line size for a given percentile, take the percentile as a percentage of the sample size, and count up from the smallest line size until that number of line sizes is reached. For example, for the 25th percentile, with n=55 records, take 25% of 55 to get 13.75. Fractions are moved up to the next integer, 14 in this case. The 25th percentile is the 14th line size in the set of ordered line sizes, counting from smallest to largest. If the result of taking a percent of the sample size is not an integer, use the next larger integer.

In particular, the 80th percentile determines a limitation on line size. If there are 55 records, the 80th percentile is the 44th line size counting from the smallest to the largest. If a different number of records is used, the 80th percentile is the line size corresponding to the integer greater than or equal to 0.8n, where n is the number of records, again counting from the smallest line size to the largest.

The maximum permissible line size is calculated as 1.5 times the 80th percentile of line sizes used in the evaluation. That is, the line size for each record used in the evaluation is listed. These sizes are then ordered from least to greatest. The 80th percentile is the size such that 80% of the line sizes are less than or equal to this size. The 80th percentile is computed and multiplied by 1.5 to give the calculated size limitation.

To justify the extrapolation to the larger line sizes, the results for smaller lines and larger lines must be shown to be similar. To make this comparison, divide the data records into two groups based on line size. The two groups should be of nearly equal size, but if there are many records at one line size, it may not be possible to make the two groups exactly equal. For quantitative systems the number in each group is not particularly critical, but for qualitative systems there must be at least 21 tight records and 21 records with simulated leaks in each group.

For quantitative systems, calculate the mean and standard deviation separately for the two line size groups. This can be done by using the formulas in Sections 7.1 through

---

[12] See notes 5 and 6.

7.4 separately on the two line size groups. Use a two-sample F test to test whether the variances of the two groups are equal. Calculate

$$F = (SD_1 / SD_2)^2,$$

where SD_1 and SD_2 are the standard deviations calculated from the two groups. In forming the F ratio, use the standard deviation with the larger calculated value in the numerator. Compare the calculated value of F to the 95th percentile of an F-distribution with $(n_1 - 1)$ degrees of freedom in the numerator (corresponding to SD_1) and $(n_2 - 1)$ degrees of freedom in the denominator (corresponding to SD_2). The sample sizes are n_1 and n_2, respectively. If the calculated value of F is less than the tabled value, there is no significant evidence that the two population variances are different. In this case, there is justification for extrapolating to line sizes larger than those in the database.

If the calculated value of F exceeds the tabled value, the two variances are significantly different at the 5% significance level. This is evidence that the performance of the system is affected by line size. Assuming that the standard deviation for the larger line sizes is the larger, this indicates that the performance of the system is worse for larger lines. The line size limit should be reduced to the smaller of the largest line in the data or 1.25 times the 80th percentile.

If the standard deviations are not significantly different, test to see if the bias is different for the two groups of line sizes. Use a two-sample t-test to test whether there is any significant difference in the bias. Calculate

$$t_b = (B_1 - B_2) / (S_p \sqrt{(1/n_1 + 1/n_2)}),$$

$$S_p = \sqrt{[(n_1 - 1)\, SD_1^2 + (n_2 - 1)\, SD_2^2] / (n_1 + n_2 - 2)}$$

where S_p is the pooled standard deviation of the two groups and is calculated from Compare t_b to a two-sided 5% critical value from a t-distribution with (n_1+n_2-2) degrees of freedom. If the absolute value of t_b does not exceed the critical value then there is no evidence that the bias is different for different line sizes. In this case, extrapolation to 1.5 times the 80th percentile of line sizes is justified.

If the absolute value of t_b does exceed the percentile from the t-table, then the system has a significantly different bias for the different line sizes. The line size limit should be reduced to the smaller of the largest line in the data or 1.25 times the 80th percentile.

For qualitative systems, at least 21 tight and 21 simulated leak records are required in each group. Compute the PFA and PD as described in Section 7.5 separately for each group. If both groups meet the performance standard, extrapolation to the larger line size (1.5 times the 80th percentile) is justified. If one of the groups does not meet the performance standard, but the combined data do meet the performance standard, then the line size limit should be reduced to the smaller of the largest line in the data or 1.25 times the 80th percentile.

If a significant difference was found, note this and the reduced line size extrapolation in the other limitations section of the results form.

It occasionally happens that the limitation of line size would result in the system not being qualified for some of the larger lines that were used in the evaluation. If this is the case, then the evaluating organization may extend the application to the maximum size line used in the evaluation. The evaluating organization should provide a justification for that extension. This might include the finding that the calculated PD and PFA were better than the 95% and 5% required.

7.6.2 Monthly Throughput

The volume of product dispensed from the tank or through the line in a month is referred to as the monthly throughput. This could be an important factor in that the higher the monthly throughput the fewer and shorter the periods of quiescence for the line. This would affect the time needed to get a valid test, the relative noise levels of the test, and the amount of data available for the test. Again to the extent practical, the test database should represent the distribution of monthly throughputs for the population of lines for which the system is intended to be used. As with the line sizes, the distribution of throughputs should be approximately uniform.

The monthly throughputs for the line records in the database should be determined and reported in a form such as Table 1. If a test is for less than a month, the throughput for the duration of the test should be determined from the record and scaled up to one month.

The maximum allowable monthly throughput is calculated as 1.5 times the 80th percentile of the throughputs in the evaluation data. The monthly throughput for each record used in the evaluation is calculated. For records that are less than one month, determine the recorded throughput for that record. Divide the throughput by the number of days in the record (use fractions if appropriate), then multiply by 31 to get the equivalent monthly throughput. Order these monthly throughputs from least to greatest and compute the 80th percentile. Multiply this by 1.5 to determine the throughput limit for the system.

To justify the extrapolation to the larger throughputs, the results for smaller throughputs and larger throughputs must be shown to be similar. To make this comparison, divide the data records into two groups based on monthly throughput. The two groups should be of nearly equal size. For quantitative systems the number in each group is not particularly critical, but for qualitative systems there must be at least 21 tight records and 21 records with simulated leaks in each group.

For quantitative systems, calculate the mean and standard deviation separately for the two throughput groups. This can be done by using the formulas in Sections 7.1 through 7.4 separately on the two throughput groups. Use a two-sample F test to test whether the variances of the two groups are equal. Calculate

$$F = (SD_1 / SD_2)^2,$$

where SD_1 and SD_2 are the standard deviations calculated from the two groups. In forming the F ratio, use the standard deviation with the larger calculated value in the numerator. Compare the calculated value of F to the 95th percentile of an F-distribution with $(n_1 - 1)$ degrees of freedom in the numerator (corresponding to SD_1) and $(n_2 - 1)$ degrees of freedom in the denominator (corresponding to SD_2). The sample sizes are n_1 and n_2, respectively. If the calculated value of F is less than the tabled value, there is no significant evidence that the two population variances are different. In this case, there is justification for extrapolating to throughputs larger than those in the database.

If the calculated value of F exceeds the tabled value, the two variances are significantly different at the 5% significance level. This is evidence that the performance of the system is affected by throughput. Assuming that the standard deviation for the larger throughputs is the larger, this indicates that the performance of the system is worse for higher throughput lines. The throughput limit should be reduced to the smaller of the largest throughput in the data or 1.25 times the 80th percentile.

If the standard deviations are not significantly different, test to see if the bias is different for the two groups of throughputs. Use a two-sample t-test to test whether there

$$t_b = (B_1 - B_2) / (S_p \sqrt{(1/n_1 + 1/n_2)}),$$

is any significant difference in the bias. Calculate

$$S_p = \sqrt{[(n_1 - 1)\, SD_1^2 + (n_2 - 1)\, SD_2^2] / (n_1 + n_2 - 2)}$$

where S_p is the pooled standard deviation of the two groups and is calculated from Compare t_b to a two-sided 5% critical value from a t-distribution with (n_1+n_2-2) degrees of freedom. If the absolute value of t_b does not exceed the critical value then there is no evidence that the bias is different for different throughputs. In this case, extrapolation to 1.5 times the 80th percentile of throughputs is justified.

If the absolute value of t_b does exceed the percentile from the t-table, then the system has a significantly different bias for the different throughputs.

For qualitative systems, a minimum of 21 tight and 21 simulated leak records is required in each group. Compute the PFA and PD as described in Section 7.5 separately for each group. If both groups meet the performance standard, extrapolation to the higher throughput (1.5 times the 80th percentile) is justified. If one of the groups does not meet the performance standard, but the combined data do meet the performance standard, then the throughput limit should be reduced to the smaller of the highest monthly throughput in the data or 1.25 times the 80th percentile.

If a significant difference in the performance for different throughputs was found, note this fact and the reduced throughput limit in the other limitations section of the results form.

It occasionally happens that the limitation of line size would result in the system not being qualified for some of the larger throughputs that were used in the evaluation. If this is the case, then the evaluating organization may extend the application to the maximum throughput used in the evaluation. The evaluating organization should provide a justification for that extension. This might include the finding that the calculated PD and PFA were better than the 95% and 5% required.

7.6.3 Test Duration

The amount of time the system must collect data before it has a valid test is of importance. This required time may be a function of the line size and the throughput. From the test data, find the length of time from the initiation of the test until the CPPLDS system completed the test. Record these data on the Reporting Form for Leak Rate Data. Also determine and report the mean and standard deviation of the test durations. The evaluating organization should note any special conditions that might affect the time needed for the system to complete a test under the comments section on the Results Form.

7.6.4 Applicable Fuel Types

If the CPPLDS system is to be used to detect leaks in pipelines used for fuel types other than gasoline (including E-10) or diesel (such as bio-fuels; e.g. bio-diesel or E-85), then the (alternative) fuel's coefficient of expansion range must be compared to that of gasoline. If the coefficient of expansion is found to be greater than that of gasoline, then at least 6 of the test records used in the evaluation must come from lines containing that type of fuel. That is, in order for the system to qualify for a type of product with a coefficient of expansion greater than that of gasoline, the CPPLDS must be tested (at least 6 tests) on that type of product.

7.7 Summary of The Data Analysis Requirements and Limitations

- At least 44 valid test results are required for a quantitative system; at least 108 valid results are required for a qualitative system. No more than 10% may be invalid in any leak rate group.

- The records must be divided into groups at the median line size (volume). The results for the small and large lines must be compared. If no significant differences are found, the system is qualified for lines up to 1.5 times the 80th percentile of the line sizes used in the evaluation. If the results are different, extension is limited to the smaller of 1.25 times the 80th percentile, or the maximum line size in the evaluation.

It occasionally happens that the limitation of line size would result in the system not being qualified for some of the larger lines that were used in the evaluation. If this is the case, then the evaluating organization may extend the application to the maximum size line used in the evaluation. The evaluating organization should provide a justification for that extension. This might include the finding that the calculated PD and PFA were better than the 95% and 5% required.

- The throughputs for the data records are to be divided at the median. A comparison of results for the small and large throughput records is done. If no statistical significant difference is found, the system is qualified for throughputs up to 1.5 times the 80th percentile of the throughputs in the evaluation. If there are differences, the limitation is 1.25 times the 80th percentile or the largest throughput in the data, whichever is less.

It occasionally happens that the limitation of line throughput would result in the system not being qualified for some of the larger lines that were used in the evaluation. If this is the case, then the evaluating organization may extend the application to the maximum throughput used in the evaluation. The evaluating organization should provide a justification for that extension. This might include the finding that the calculated PD and PFA were better than the 95% and 5% required.

- If the system uses sensors that have been previously evaluated, the previous evaluation must be referenced. Alternately physical leak simulations are required, which may be done with a minimum of 6 tests at a test facility or a field site or a combination.

Section 8. Reporting

This section describes the reporting of the results. As a minimum, the report must include an executive summary, the completed results form, the description form, and the appropriate data reporting forms. Instructions for completing each standard form are included in this section.

8.1 Executive Summary

The executive summary is suggested as a guide designed to include the information required by the reviewer. The evaluator who uses this format should insert the appropriate data where indicated. When an item appears in italics, either insert the appropriate name, words, or requested data, or choose the appropriate statement. Where a blank is indicated, insert the requested data. When sections for quantitative and qualitative options appear, use the appropriate sections and remove the others. Add additional information as necessary, e.g., to describe the method of leak simulation.

This executive summary, the results form, the description form, and Tables A1, A2, and A3 (or A4 for qualitative data) described below comprise the minimum report required for a CITLDS evaluation. Note that this summary and set of instructions merely provides a standardized report format for data that are required by the protocol. No new data or procedures are required. Data on leak simulation, etc., are tabulated in the executive summary using table numbers S-1, etc. Table A1 is the table of the complete database used to select records for evaluation. Table A2 summarizes the data actually used, Table A3 gives the leak rate results for quantitative data, and Table A4 reports the leak rate results for qualitative data systems.

8.2 Results Form

The results form is designed to be provided to each installation using the CPPLDS. It provides the documentation that the CPPLDS has been evaluated and shown to meet the EPA requirements. First enter the name, version number, and vendor's name, address, and telephone number. The name and version are repeated on each page.

The evaluation results consist of several sections. Review each section to determine which are applicable and complete those sections. Place a check mark or "X" in the box(es) indicating inapplicable sections and leave these blank otherwise.

The first section reports quantitative results from a line leak simulation. Report the mean and standard deviation in the blanks provided. Enter the system's threshold and calculated probabilities of false alarm and detection in the appropriate cells of the table. The method of calculation is described in Sections 7.1 to 7.3. Indicate the size of the leak detected to correspond to the probability of detection. If the system uses more than one threshold for different levels of operation, use one line for each and enter the corresponding size of the leak rate detected for each.

If any results were invalid, enter the appropriate numbers and percentages as indicated. If there were no invalid results, enter zero.

The next section is applicable for qualitative results from line leak simulations. Report the number of records in each category as indicated in the table. Report the estimated PFA and PD resulting from the calculations described in Section 7.5. Include reporting of any invalid records.

The next section reports test conditions. Test condition requirements are summarized in Section 6.4. Analysis requirements relating test conditions to limitations are summarized in Section 7.8. In the first table, enter the percentiles of the line sizes (volumes) used in the evaluation. In the second table, enter the percentiles of the monthly throughputs.

Indicate the overall result by marking the appropriate box with a check or "X" according to whether the system meets the EPA performance standards for monthly monitoring.

The limitations section indicates the conditions under which the system should be used. The line volume to be indicated is one and one-half times the 80th percentile of the line sizes in the evaluation data, unless data analysis indicates a smaller limit is needed. The monthly throughput is limited to 1.5 times the 80th percentile of the throughputs observed in the evaluation data, unless the analysis indicates a smaller limit. Enter the minimum number of days for a valid result for the length of the data records. Use the blank lines to enter any other restrictions, conditions, or explanations.

In the certification of results, indicate whether there were any deviations from the database definitions summarized in Section 6.4 and whether there were any deviations from the computations summarized in Section 7.8. Finally, provide the name and address of the evaluating organization, together with the individual who directed the testing.

8.3 Description Form

This form is provided to provide a summary description of the system. Most of this information will be supplied by the vendor. Enter the name and version number of the product. Mark the appropriate boxes for each question. Use the white space to provide any explanations for questions that are not completely applicable or that require elaboration.

8.4 Table A1: Complete Data Base For Evaluation

Table A1 documents the database used. It contains all of the line records for the entire period that were available for selection. It includes the data needed for the evaluator to stratify to select records that provide the appropriate number of large and small lines, large and small throughputs, product types, etc. These data should be sorted by line. For each line, include separate periods that could be used as a line record in the evaluation in order, so that the continuity of the record from each line can be seen.

This table would also supply the reviewer with the information about how many periods of data were available for each line and each site, together with the line size, material, throughput, product, etc. The reviewer could verify the continuity of the data record for each line in the original database. Note that inherent in the way that lines are operated is the fact that there are relatively few high throughput tanks and lines. At a retail gasoline station, the unleaded product will typically have a throughput much higher than any other product. Thus, it will generally be necessary to sample large lines and high throughputs with a higher sampling rate than small, low throughput tanks or lines.

Detailed instructions for completing Table A1 are provided below in Table 5.

Table 5. Instructions for Table A1.

Column #	Description of Information to be Provided
1	Test Number. **The test data must be sorted by line.** The number of the tests selected for the evaluation should be entered in Column 1. Test records that were not selected are left blank.
2	Line Information, Site ID to identify line.
3	Line number at site
4	Line Sizes. Enter the maximum nominal volume of all sections of the lines in the record or test.
5	Date and Time of Start of Record. Give the date and time of the beginning of the test record.
6	Date and Time at End of Record. Give the date and time of the end of the test record. The time is the time that the system stopped collecting data, not just the last time that quiet period data were available. If the next test record from this line does not start immediately, an explanation for the gap must be provided. For example, if a test ends at 10 pm on July 30 and the next test does not begin until 8 am on July 31, an explanation for the 10-hour gap must be provided.
7	Number of days in the test record. This is the number of days of data available for the record, not the number actually used by the CPPLDS.
8	Approximate throughput. This is the number of gallons of fuel dispensed through the line for the month of the test. The information should be normalized to a 30-day month if the entire month of data is not available.
9	Product. Give the product type, e.g. gasoline, diesel, or other.
10	If the station is open 24 hours a day, enter “Y.” If it is closed part of the day enter “N”

8.5 Table A2: Test Data Used in the Evaluation

Table A2 documents test records selected and used in the evaluation. Table 6 contains the instructions for completing Table A2.

Table 6. Instructions for completing Table A2.

Column No.	Description of Information to be Provided
1	Test Number – Test number for the tests used in the evaluation should be the same as in Table 1 to prevent confusion over the numbering of the tests. The data should be sorted by test number.
2	Enter the nominal volume of the line system in gallons.
3	Enter the start date for the first quiet period used in the estimation of a leak.
4	Enter the time of the first quiet period used in the estimation of a leak.
5	Enter the start date for the last quiet period used in the estimation of a leak.
6	Enter the start time for the last quiet period used in the estimation of a leak.
7	Enter the total duration of quiet periods for the test. If the manufacturer fixes this value as part of the system, all entries will be the same.
9	Enter the number of deliveries that occurred during the test period.

8.6 Table A3: Reporting Form for Leak Rate Data (Quantitative).

Table A3 contains the data reporting the leak rates induced in the tests and the results obtained by the CPPLDS system. The instructions for completing Table A3 are provided in Table 7.

Table 7. Instructions for Completing Table A3.

Column #	**Description of Information to be Provided**
1	Enter the test number. This must correspond to the number in Tables A1 and A2.
2	Enter the site identification.
3	Enter the induced leak rate (enter zero if it is a tight line test).
4	Enter the reported leak rate for a quantitative system. If the system is qualitative enter the pass/fail or tight/leak indication.
5	If the system is quantitative, enter the difference between the induced leak rate and the reported leak rate (subtract the induced leak rate from the measured leak rate). If the system is qualitative indicate a correct result (pass for zero leak) or incorrect result (fail for zero leak).

8.7 Table A4. Reporting Form for Leak Rate Data (Qualitative)

The instructions for completing Table A5 are provided in Table 8.

Table 8. Instructions for Completing Table A4.

Column #	**Description of Information to be Provided**
1	Enter the test number that corresponds to a test used in the evaluation. This should match the test numbers in Tables A1, A2, and A3.
2	Enter the date the test began: day, month, and year.
3	Enter the duration of the test, indicating the time units used (e.g. days)
4	Enter the line volume in gallons.
5	Enter the monthly throughput in gallons.
6	Enter the season as hot (H), mild (M), or cold (C).
7	Enter a Y or N to indicate whether or not a leak was induced.
8	Enter the test result: Tight or Leaking.
9	Indicate whether the CPPLDS made the correct call (Y) or not (N).
10	Enter any notes about the test.

STANDARD REPORTING FORMS

Executive Summary CPPLDS Evaluation

Results of Alternative Evaluation:
Continuous Pressurized Pipe Leak Detection System (CPPLDS)

Description: Continuous Pressurized Pipe Leak Detection System (CPPLDS)

Table A1: Complete Data Base for Evaluation

Table A2: Test Data used in Evaluation

Table A3: Reporting Form for Leak Rate Data (Quantitative)

Table A4: Reporting Form for Leak Rate Data (Qualitative)

Executive Summary CPPLDS Evaluation

________*(Name of Evaluating Organization),* acting as an independent third party, conducted an evaluation of the ________*(Name of CPPLDS Method)* for ______*(Name of Vendor)*. The evaluation was conducted from _______(*give dates*.) The ______ *(Name of CPPLDS Method)* is a continuous monitoring method of leak detection for pressurized piping.

EVALUATION DATA

The evaluation used data selected from a database with _____*number* lines at __ *(number)* sites. (See Section 6.1.) The sites were located in ____*(number)* states and included data from ________ *(specify periods for line records).* The data collected covered the period of _____ *(give months and years).* The available database is documented in Table A1 of the data reporting tables. Table A1 includes information on the line characteristics including volume, material, etc. The test data selected used data from ____(*number)* lines at ____*(number*) of sites in _____*(number)* states. The test data were from the periods as indicated in Table A2. In Table A2, the test numbers correspond to the line period numbers in Table A1. __________________________ *(Indicate whether option 1 or option 2 was used for the data base. If option 1 was used, describe how the test data were selected from the complete data set, e.g., by stratifying on throughput, product, and line size, then randomly selecting from the strata.)*

Evidence that the lines were tight was provided by _______*describe (see Section 6.1).* The sites were selected by______(*describe how the sites were chosen and who made the selection.)* A _________ *(give Name and model number of CIPPDS Method)* made by ______*(give vendor)* was installed at each site. The evaluating organization obtained the data from the lines by _______*(specify e.g. modem, on-site, from vendor, etc*.)

___________*(Summarize any site visits, physical leak simulations, or other relevant information.)*

DATA QUALITY

The original data records for each line submitted to the evaluator *(were/were not)* continuous. *Provide an explanation for any data gaps.*

LEAK SIMULATION *(see Section 6.5.2)*

(Explain briefly how the mathematical leaks were induced. A possible format is suggested.) The leak simulation was done by introducing a pressure change corresponding to the volume loss by the induced leak rate. This pressure was computed for each time interval between data recorded by the CPPLDS system. The volume was converted to a pressure change by using the bulk modulus and line volume *(specify method used.*)

The data records for simulated leaks were modified using an algorithm developed by _____(*specify vendor or evaluator*.) The evaluator checked the algorithm by _____ *(specify how*, e.g. by computing the leak rates for _____ hours on ____ line records and finding that they differed from the induced leak rates by less than ______ percent.)

STATISTICAL RESULTS

The statistical results that are reported depend on whether the CPPLDS is a quantitative or a qualitative system. The __________ *(give name of CPPLDS system* is a *quantitative/qualitative* system. *Complete the appropriate section and indicate Not Applicable in the other section.)*

Quantitative systems *(see Section 7.1)*

Line Size *(see Section 7.7.1)*

The lines were divided into large and small lines at the median size of _____gallons, giving _____large and _____ small lines. The bias was computed separately as _____ for large and _____ for small lines. The standard deviation of the difference between measured and induced leaks was computed separately as _____ for large and _____ for small lines. The t-test comparing the bias was _____, which (*was / was not)* significant. The F-test for comparing the variances of the two groups was _____, which (*was / was not)* significant. As a result of this comparison, the line size limitation is *1.5 times the 80th percentile of the line sizes (if the F-test was not significant) or 1.25 times the 80th percentile of the line sizes (if the F-test was significant).*

Product Throughput *(see Section 7.7.2)*

The lines were divided into large and small throughputs at the median throughput of _____gallons, giving _____ records with large and _____ records with small throughputs. The bias was computed separately as _____ for large and _____ for small throughputs. The standard deviation of the difference between measured and induced leaks was computed separately as _____ for large and _____ for small throughputs. The t-test comparing the bias was _____, which (*was / was not)* significant. The F-test for comparing the variances of the two groups was _____, which (*was / was not)* significant. As a result of this comparison, the throughput limitation is *1.5 times the 80th percentile of the throughputs (if the F-test was not significant) or 1.25 times the 80th percentile of the throughputs (if the F-test was significant).*

Qualitative Systems *(see Section 7.5)*

Line Size

The lines were divided into large and small lines at the median size of _____gallons, giving _____ large and _____ small lines in the test. Separate tables for estimating the PD and PFA were constructed for small and large lines and are reported below. *Both groups met the PD and PFA requirements, so line size can be extrapolated to ______ (1.5 times the 80th percentile)* or *Only the _____ group met the PD and PFA requirements, so the line size is limited to ________ (the minimum of 1.25 times the 80th percentile or the largest line size in the data).*

Table S-4. Qualitative Results for Small Lines

Actual Status	Reported Status -- Small Lines			
	Tight	Leaking	Invalid	Total
Tight				
Leaking				

Table S-5. Qualitative Results for Large Lines

Actual Status	Reported Status -- Large Lines			
	Tight	Leaking	Invalid	Total
Tight				
Leaking				

Product Throughput

The lines were divided into large and small throughput groups at the median throughput of _____gallons, giving _____ test records with large and _____ test records with small throughputs. Separate tables for estimating the PD and PFA were constructed for small and large throughputs are the data are reported below. *Both groups met the PD and PFA requirements, so throughput can be extrapolated to ______ (1.5 times the 80th percentile)* or *Only the _____ group met the PD and PFA requirements, so the throughput is limited to______ (the minimum of 1.25 times the 80th percentile or the largest throughput in the data.*

Table S-6. Qualitative Results for Low Throughput Tests

Actual Status	Reported Status -- Low Throughput			
	Tight	Leaking	Invalid	Total
Tight				
Leaking				

Table S-7. Qualitative Results for High Throughput Tests

Actual Status	Reported Status -- High Throughput			
	Tight	Leaking	Invalid	Total
Tight				
Leaking				

Product Type

The ________ CPPLDS was tested on the following products. *List the products or fuel types used in the evaluation.* Based on this testing, it can be used for these products and other similar products, provided that their coefficient of expansion is no greater than that of gasoline (or the largest coefficient of expansion for which the CPPLDS was tested).

SYSTEM HARDWARE

List the manufacturer and the model number of each of the systems or probes installed in the field or at a test facility and used to generate data for this evaluation. Use as many lines as needed.

Table S-10. Manufacturer and Model Numbers for Systems used in the Evaluation

System Number	Manufacturer	Model Number(s)
1		
2		
3		

The *system name* was previously evaluated as a shut-down line test under the name and version _________. The results of that evaluation are found in ________ *give reference to full evaluation report with complete name, date, and title*.

Or,

The *system name* uses equipment that has not been previously evaluated. Physical leak simulations were run during tests (*give test numbers with physical leaks)*______. The mean difference between the measured and simulated leak rates during the ___ physical leak simulations was _____ and the standard deviation was _____. Thus, the physical leak simulations confirmed the function of the system equipment.

CONCLUSIONS

Based on these tests, the *name of system* manufactured by *vendor name* (*meets/does not meet)* the EPA standard for monthly monitoring. See the results reporting form for limitations and more details.

Name of CPPLDS ____________________

Version ____________________

Results of Alternative Evaluation

Continuous Pressurized Piping Leak Detection Systems

This form tells whether the continuous pressurized pipe leak detection system (CPPLDS) described below complies with the performance requirements of the federal underground storage tank regulation. The evaluation was conducted by the equipment manufacturer or a consultant to the manufacturer according to the Continuous Pressurized Pipe Leak Detection System Evaluation Protocol. This protocol is deemed equivalent in stringency to the EPA Evaluation Protocols. The full evaluation report also includes a form describing the method and a form summarizing the test data.

Tank and line owners using this leak detection system should keep this form on file to prove compliance with the federal regulations. Tank system owners/operators should check with State and local agencies to make sure this form satisfies their requirements.

CPPLDS Description

Name ____________________

Version Number ____________________

Vendor ____________________

(street address)

____

(city) (state) (zip) (phone)

Evaluation Results

Quantitative Results For Line Leak Simulation (Complete this section based on the line leak simulation data if the CPPLDS reports a leak rate. If this section is not applicable, check here ☐ and leave the section blank.)

This CPPLDS declares a line to be leaking when the measured leak rate exceeds a threshold. The threshold, probability of false alarm, PFA, and probability of detection, PD, of detecting an average leak rate of 0.20 gallon per hour or 150 gallons per month, are given in the table below.

The mean difference between the measured and reported leak rate was ________ gph. The standard deviation was _____ gph.

Threshold	Probability of False Alarm (FA)	Probability of Detection (PD) of leak __ gph

Any results that were invalid due to operational difficulties are to be reported. If the data included any invalid results, record that fact here. If not, indicate that. There were ______ invalid results out of records in the data, or ____%. This means that the system may not provide a conclusive test result ____% of the time.

Qualitative Results for Line Leak Simulation (Complete this section based on the line leak simulation data if the CPPLDS reports on a pass/fail basis. If this section is not applicable, check here ☐ and leave the section blank.)

	Reported			
Actual Status	Tight	Leaking	Invalid	Total
Tight				
Leaking				

The estimated PFA was _____ with a 95% confidence interval from _____ to _____.

The estimated PD for detecting a leak rate of 0.20 gallon per hour (150 gallons per month) was _____ with a 95% confidence interval from _____ to _____.

Name of CPPLDS ____________________

Version ____________________

Any results that were invalid due to operational difficulties are to be reported. If the data included any invalid results, record that fact here. If not, indicate that. There were ____ invalid results out of _____ records in the data, or _____%. This means that the system may not provide a conclusive test result ____% of the time.

Test Conditions During Evaluation

The data evaluation set included data from lines of the following sizes:

	Min.	25	Median 50	75	80	Max.
Percentile of Records						
Line Size (gal)						

The lines had various monthly throughputs:

	Min.	25	Median 50	75	80	Max.
Percentile of Records						
Monthly throughput (gal)						

The duration of the CPPLDS tests ranged from _______ to _______, with an average duration of (specify appropriate time units, e.g., day or hours).

Based on the results reported on pages 1 and 2 of this form, the reported method ☐ does ☐ does not meet the **federal** performance standards established by the U.S. Environmental Protection Agency of an average leak rate of 0.20 gallon per hour or 150 gallons per month from lines (mark applicable boxes) at PD of 95% and PFA of 5%.

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 CPPLDS are followed.
- The line contains a product identified on the method description form.
- The line is no larger than _____ gallons.
- The data records cover _____ days or more.
- The monthly throughput is _______ gallons or less.

- The lines contain one of the products listed here, or a similar product with a coefficient of expansion no greater than the largest of the listed products: __________________________.

____

____

- Other limitations specified by the vendor or determined during testing:

____

____

____

> **Safety disclaimer: This test procedure only addresses the issue of the method's ability to detect leaks.**

Certification of Results

I certify that the results presented on this form are those obtained during the evaluation. I also certify that the evaluation was performed according to the proposed test procedure for Continuous Leak Detection Systems. In particular, the requirements summarized in Section 6.4 for the data base and in Section 7.8 for the data analysis were followed. Any exceptions are noted below:

- Exceptions to Sections 6.4 and 7.8. If none, state "None."

____

____

____

This test procedure is deemed equivalently stringent to EPA published evaluation protocols.

______________________________	______________________________
(printed name)	(organization performing evaluation)
______________________________	______________________________
(signature)	(city, state, zip)
______________________________	______________________________
(date)	(phone number)

Description
Continuous Pressurized Piping Leak Detection System

This section describes briefly the important aspects of the continuous leak detection system (CPPLDS). It is not intended to provide a thorough description of the principles behind the system or how the equipment and software work.

CPPLDS Name and Version

____

Product

> Product type

For what products can this CPPLDS be used? (check all applicable)

- ☐ gasoline
- ☐ diesel
- ☐ aviation fuel
- ☐ fuel oil #4
- ☐ fuel oil #6
- ☐ solvents
- ☐ waste oil
- ☐ other (list) ______________________

What pressure is required to conduct a test?

- ☐ Line operating pressure
- ☐ One and one-half times normal operating pressure
- ☐ other (specify) ______________________

Measurement

What technique is used to measure changes in product volume?

- ☐ directly measure the volume of product change
- ☐ changes in pressure
- ☐ changes in buoyancy of a probe
- ☐ ultrasonic ______________________
- ☐ other (describe briefly) ______________________

Temperature Measurement

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

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

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

- [ ] resistance temperature detector (RTD)
- [ ] bimetallic strip
- [ ] quartz crystal
- [ ] thermistor
- [ ] other (describe briefly)

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

- [ ] the factor measured for change in level/volume is independent of temperature (e.g., mass)
- [ ] the factor measured for change in level/volume self-compensates for changes in temperature
- [ ] other (explain briefly) ______________________________

Data Acquisition

What data does the CPPLDS collect and analyze for its test? (check all that apply)

- [ ] Line pressure
- [ ] product temperature
- [ ] time
- [ ] product deliveries
- [ ] dispensing records
- [ ] other (specify) ______________________________

Procedure Information

> Waiting times

What is the minimum waiting period between use of the line and the beginning of a test

- [ ] no waiting period
- [ ] less than 3 hours
- [ ] 3-6 hours

☐ 7-12 hours
☐ more than 12 hours
☐ variable, depending on line size, amount added, operator discretion, etc.

> Test duration

What is the typical time required for the CPPLDS to acquire enough data for a valid test?

________ (hours/days).

What factors influence the time required for the CPPLDS to acquire and analyze enough data for a valid test?

____

____

What is the sampling frequency for the measurements?

☐ more than once per second
☐ at least once per minute
☐ every 1-15 minutes
☐ every 16-30 minutes
☐ every 31-60 minutes
☐ less than once per hour
☐ variable (explain) ____

> Identifying and correcting for interfering factors

How does the CPPLDS determine when temperature is stable following delivery of product?

☐ wait a specified period of time before beginning test
☐ watch the data trends and begin test when decrease in product level has stopped
☐ other (describe briefly) ____

Are the temperature and pressure sensors calibrated before each test?

☐ yes
☐ no

If not, how frequently are the sensors calibrated?

- ☐ weekly
- ☐ monthly
- ☐ yearly or less frequently
- ☐ never

> Interpreting test results

How are pressure changes converted to volume changes?

- ☐ actual pressure changes observed when known volume is added or removed
- ☐ theoretical ratio calculated from volume and bulk modulus
- ☐ other (describe briefly) ______________________________
- ☐ not applicable; volume measured directly

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

- ☐ 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 (describe briefly) ______________________________

How is the leak rate (gallons per hour) calculated?

- ☐ 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 (describe briefly) ______________________________

Is the leak status reported in terms of a leak rate (e.g., gal/h or gal/day)?

- ☐ yes
- ☐ no
- ☐ If the answer to the above question is "No", how are the results reported?

Explain ______________________________

What threshold value for product volume change (gallons per hour) is used to declare that a line is leaking?

- ☐ 0.05 gallon per hour
- ☐ 0.10 gallon per hour

☐ 0.15 gallon per hour
☐ other (list) ______________________________

Under what conditions are test results considered inconclusive?

☐ too much variability in the data (standard deviation beyond a given value)
☐ unexplained product volume increase
☐ other (describe briefly) ______________________________

Exceptions

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

☐ large difference between ground temperature and delivered product temperature
☐ extremely high or low ambient temperature
☐ invalid for some products (specify) ______________________________
☐ other (describe briefly) ______________________________

What are acceptable deviations from the standard testing protocol?

☐ none
☐ lengthen the duration of test
☐ other (describe briefly) ______________________________

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

☐ when to conduct test
☐ length of test
☐ determination of "outlier" data that may be discarded
☐ other (describe briefly) ______________________________
☐ none

Table A1. Complete Data Base (Sorted by Line) for Evaluation

CPPLDS Name ___________________________

Version_________________________________

Test No.	Site ID, City, State	Line No. at Site	Line Sizes	Date and Time of Start of Record	Date and Time at End of Record	No. Days in Test Record	Approx. Through-put	Product	24-hr Site?

Table A2. Test Data Used in the Evaluation

CPPLDS Name ___________________________

Version_________________________________

1	2	3	4	5	6	7
Test No.	Line Size (gal)	First Quiet Period		Last Quiet Period		Total Duration of Quiet Periods
		Start Date	Start Time	Start Date	Start Time	

Table A3. Reporting Form for Leak Rate Data (Quantitative)

CPPLDS Name ___________________________

Version_________________________________

Test No.	Site ID, City, State	Constant Leak		
		Induced Leak	Calc. Leak	Dif. (Const.)

Table A4. Reporting Form for Leak Rate Data (Qualitative)

CPPLDS Name and Version:

Evaluation Period:

Page _____ of

Test No.	Date Test Began (DMY)	Duration of Test (indicate units)	Line Volume (gal)	Monthly Throughput (gal)	Season (H, M, C)	Leak Rate Induced (Y/N)	Test Result (Tight or Leaking)	Correct Call (Y/N)	Notes

Page ______ of

Test No.	Date Test Began (DMY)	Duration of Test (indicate units)	Line Volume (gal)	Monthly Throughput (gal)	Season (H, M, C)	Leak Rate Induced (Y/N)	Test Result (Tight or Leaking)	Correct Call (Y/N)	Notes

Page _____ of

Test No.	Date Test Began (DMY)	Duration of Test (indicate units)	Line Volume (gal)	Monthly Throughput (gal)	Season (H, M, C)	Leak Rate Induced (Y/N)	Test Result (Tight or Leaking)	Correct Call (Y/N)	Notes

Page ______ of

Test No.	Date Test Began (DMY)	Duration of Test (indicate units)	Line Volume (gal)	Monthly Throughput (gal)	Season (H, M, C)	Leak Rate Induced (Y/N)	Test Result (Tight or Leaking)	Correct Call (Y/N)	Notes