Alternative Test Procedures for Evaluating Leak Detection Methods: Evaluation of Liquid Level Sensors

Prepared for General Use by Ken Wilcox Associates, Inc.
September 1996

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DISCLAIMER

Some of the procedures described in this document are different than those in EPA's Standard Protocols. Users are cautioned that although this alternative protocol may have been reviewed and accepted by some regulatory agencies, this does not mean that all agencies will necessarily find it acceptable. All regulatory agencies within the geographic area of application should be contacted prior to testing to assure that the results will be acceptable. KWA, Inc. makes no statement regarding the applicability, acceptability, or quality of results that may be obtained by other users, nor do we guarantee that the results will be accepted by any individual regulator or agency.

Users should feel free to copy or modify this protocol without restriction in any way that is acceptable to the cognizant regulatory agency.

ACKNOWLEDGMENTS

This document was written by J. Kendall Wilcox, M.S., and H. Kendall Wilcox, Ph.D. for use by anyone who wishes to manufacture or evaluate Liquid Level Sensors. The effort was funded entirely by Ken Wilcox Associates, Inc.

FOREWORD[1]

The US Environmental Protection Agency recognizes three distinct ways to prove that a particular vendor or leak detection equipment meets the federal performance standards:

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

The manufacturer of the leak detection method should prove that the method meets the regulatory performance standards using one of these three approaches. **For regulatory enforcement purposes, each of the approaches is equally satisfactory.**

The purpose of this document is to provide the details for an alternative evaluation procedure developed and utilized by Ken Wilcox Associates, Inc. There are several reasons why it has been necessary to develop these alternative procedures. These include the following:

1. Some leak detection systems cannot be evaluated using procedures described in the EPA Standard Methods for Evaluating Leak Detection Methods.
2. For some types of equipment (e.g., liquid float switch sensors, interstitial monitors, etc.) there is no EPA protocol available.
3. The costs to conduct an evaluation to the exact letter of the an existing EPA protocol may be prohibitive. Less costly approaches may be available that will meet the requirements for alternative evaluations.

Two important factors have been considered by KWA in developing alternative procedures to meet specialized test requirements: First, the EPA criteria for alternative test procedures deemed equivalent to EPA's; and second, the guidelines established by the American Society for Testing and Materials (ASTM) in their standard practice 1546E - 1993. The EPA guidelines are as follows:

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[1] Some material has been excerpted and adapted from the Foreword that appears at the front of each of the EPA Evaluation Protocols.

Alternative Test Procedures Deemed Equivalent to EPA's

The following general criteria must be met for an alternative procedure to be considered acceptable.

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 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 a 0.0 and 0.125 inch of free product.

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

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

National Consensus Code or Standard (ASTM 1526E - 1993)

This ASTM Practice provides general guidelines for performing evaluations on leak detectors designed for use on underground storage tanks. There are no specific requirements defined such as the number of tests to be conducted or specific variable such as temperature that should be included in the evaluation. None-the-less, the practice does proved a useful framework for developing alternative techniques.

Ken Wilcox Associates, Inc. Evaluation Procedures

Ken Wilcox Associates, Inc. is an independent, internationally recognized third-party evaluation laboratory. The procedures described in this document are based on operating experience, recognized scientific and engineering practices, and the guidelines provided by the EPA and ASTM. Existing procedures have been adopted when practical. Alternatives have been developed as necessary to meet the specialized requirements of leak detection systems that are not covered by the existing protocols. The complete reports include summaries of the test procedures, descriptions of the leak detection systems, and a full disclosure of the test results obtained from the testing. Questions regarding these procedures should be addressed to Dr. H. Kendall Wilcox, President, Ken Wilcox Associates, Inc., at (816) 443-2494.

September 1996

Table of Contents

1.0 Background

The USEPA does not have an officially approved method for testing liquid level sensors. This procedure was prepared by Ken Wilcox Associates, Inc. and is intended to meet the criteria for alternative testing as described in the Foreword to each of the EPA Evaluation Procedures. The procedures will be submitted to the National Workgroup for Leak Detection Evaluations for approval. Some modifications may be made. Users should be aware that this protocol may not be sufficient for some regulatory agencies.

2.0 Applicability

This evaluation method applies to liquid level sensors that operate that are used for underground storage tank applications. It does not apply to external groundwater monitoring detectors. These sensors may be used for sump monitoring, interstitial monitoring, high of low level reservoir monitoring, or other applications where on/off switching is appropriate. Additionally, testing of sensors alone is not adequate for meeting many regulatory requirements and therefore must be conducted on a complete system.

3.0 Equipment and Reagents

The following equipment and reagents are necessary for testing of liquid level sensors. Testing of flammable liquids should be conducted in a well ventilated area to minimize fire and health hazards.

1. Vertical cylinder with a measurable, uniform diameter from top to bottom. Must be large enough for the liquid sensor to be placed in the cylinder without touching the sides.

2. Burette accurate to the nearest 0.2 ml.

3. Stop watch

4. Water, unleaded gasoline, diesel fuel, or other applicable products that the liquid sensors can be expected to encounter in underground storage tank environments.

4.0 General Description of Liquid Level Sensors

Liquid level sensors generally operate by causing a switch contact to trigger when the level of liquid rises or falls to a certain level. The switch contacts normally can be wired to activate an alarm, disable a submersible pump, or perform other functions.

5.0 Parameters Determined by this Test Procedure

The following parameters which have been defined below will be determined by this test protocol. The official forms and tables in Appendix A of this protocol provide a space for each of these parameters to be recorded.

1. Threshold (Lower Detection Limit) - The smallest product thickness that the detector can reliably detect.

2. Precision (Standard Deviation) - Agreement between multiple measurements of the same product level.

3. Detection Time - Amount of time the detector must be exposed to product before it responds.

4. Fall Time - Amount of time before the detector stops responding after being removed from the product.

5. Specificity - Types of products that the sensor will respond to.

6.0 Test Procedures

With most liquid level sensors, the following procedure should be conducted with water, gasoline, and diesel fuel.

6.1 Determination of Threshold and Precision

1. Mount the sensor in a vertical cylinder with a known, uniform diameter from top to bottom. The sensor should be securely fastened so that it is in contact with the cylinder bottom in its normal orientation.

2. Add liquid (product or water) to the cylinder from a burette capable of reading volume to the nearest 0.2 ml. Liquid should be added in increments until the sensor responds to the liquid. Adequate time should be allowed between increments to all the sensor to respond if the response time is not instantaneous.

3. When the approximate threshold has been determined, the sensor should be removed and the cylinder emptied of liquid for a repeat measurement.

4. For subsequent measurements, liquid may be added quickly to just below the threshold level.

5. Liquid should then be added very slowly until the sensor responds.

6. Steps 3 through 5 should be repeated a minimum of 6 times for each liquid.

7. Record all information in an appropriate manner.

6.2 Determination of Detection and Fall Times

1. If it is practical, the procedures for determining the detection and fall times may be implemented with the previous procedures in Section 6.1.

2. Install the liquid sensor in the vertical cylinder in the same manner described in Section 6.2.

3. Add liquid to the cylinder until the threshold has been exceeded.

4. Using the stop watch, record the time required for the sensor to respond to the liquid after the threshold has been exceeded.

5. Remove a sufficient volume of liquid to lower the level below the threshold.

6. Using the stop watch, record the time required for the sensor to stop alarming after the liquid level has been lowered below the threshold.

7. The above procedures should be repeated a minimum of six times.

6.3 Determination of Specificity

The sensors are tested in the types of liquids that they would be expected to respond to under normal operating procedures. However, liquid level sensors should respond to any liquid after the liquid level exceeds the threshold and triggers the switch contact. If the evaluator finds that the sensor will not respond to a particular liquid type this should be noted on the official forms. The thresholds may vary slightly as the product density varies for float sensors.

7.0 Calculations

7.1 Cross Sectional Area of Test Cylinder

The cross sectional area of the test cylinder and the sensor must both be determined. The difference in cross section is used in the calculations. The test cylinder cross section is determined from the equation below:

$$A_C = \Pi r^2$$

where A_C is the cross section of the cylinder and r is the radius of the cylinder.

If the geometry of the sensor is uniform, it may be possible to calculate the cross sectional area using the appropriate equations. If the geometry is irregular, the displacement of the sensor must be empirically determined before the calculations can be completed. It is usually preferable to calculate the cross section whenever possible.

To measure the displacement of an irregular sensor, immerse the sensor in a graduated cylinder to the alarm depth. The volume before and after the immersion should be recorded. The difference in volume (V_D) is the displacement of the sensor at the threshold level. This displacement volume should be added to the test volume obtained from the burette before the calculations are conducted.

7.2 Height to Alarm

The alarm level can be calculated from the equation:

$$L = (V_B+V_D) * C$$

where L is the level at which alarm first occurs, V_B is the volume of the burette, V_D is the displacement volume of sensor at alarm level, and C is the conversion factor to convert volume to height (e.g., ml/in) for the test cylinder.

7.3 Threshold (Lower Detection Limit)

The threshold is calculated from the equation:

$$Threshold = Mean + 4.414*STD$$

where the mean is the average alarm level for each test set, and STD is the standard deviation for each data set. The tolerance coefficient for six data points (95% confidence) is 4.414.

7.4 Precision

The precision of liquid level sensors is obtained by calculating the standard deviation of the six liquid levels measurements required to make the sensor alarm. The variance and standard deviation can be calculated from the following equations:

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

where n is the number of tests conducted and L is the measured liquid level required to make the sensor alarm. The standard deviation is the square root of the variance. The standard deviation is equivalent to the is the precision and this calculated value should be recorded on the official forms.

7.5 Detection Time

The detection time recorded on the official forms should be the average time it took the sensor to alarm after the threshold was exceeded for the six tests conducted in Section 6.2. If the sensor response is not instantaneous, the response time for each liquid should be determined.

7.6 Fall Time

The fall time recorded on the official forms should be the average time it took the sensor to stop alarming after the liquid level was lowered below the threshold for the six tests conducted in Section 6.2. If the sensor response is not instantaneous, the response time for each liquid should be determined.

8.0 DATA INTERPRETATION

The results obtained from the testing of liquid level sensors do not fit the standard Probability of Detection/Probability of False Alarm results that are calculated for most of the leak detection methods. Unless there is a mechanical failure, liquid level sensors always alarm when the liquid level exceeds the threshold. Conversely, they do not alarm under conditions in which there is no product present.

The data obtained from this evaluation can be used to determine the applicability of a specific sensor to a particular environment.

8.0 REPORTING OF RESULTS

The reporting forms in Appendix A should be filled out at the conclusion of the testing. If the test data can be presented in a more appropriate manner, the evaluator may select to present some of the information on the official forms in a data table which can be attached to the forms.

APPENDIX A

REPORTING FORMS
FOR EPA TEST PROCEDURES
FOR LIQUID LEVEL SENSORS

Results of U.S. EPA Alternative Evaluation

Liquid Level Sensor

This form documents the performance of the liquid level sensor described below. The evaluation was conducted by the equipment manufacturer or a consultant to the manufacturer according to the U.S. EPA's requirements for alternative protocols. The full evaluation report also includes a report describing the method, a description of the evaluation procedures, and a summary of the test data. The results forms were modified from the Vapor-Phase Out-of-Tank Product Detectors.

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

Method Description

Name ____

Version ____

Vendor ____
(Name of Manufacturer)

____
(Address)

____
(City) (State) (Zip Code) (Phone)

Evaluation Parameters

The sensors listed above were tested for their abilities to respond to liquids when the sensors are installed in underground storage tank applications. The following parameters were determined from this evaluation.

Threshold (Lower Detection Limit) - The smallest product thickness that the detector can reliably detect.

Precision (standard deviation) - Agreement between multiple measurements of the same product level.

Detection Time - Amount of time the detector must be exposed to product before it responds.

Fall Time - Amount of time before the detector stops responding after being removed from the product.

Specificity - Types of products that the sensor will respond to.

Sensor Name: ____

Version Number(s): ____

Evaluation Results

Note: If the test data can be presented in a more appropriate manner, the evaluator may select to present the information below in a data table which can be attached to these forms.

Parameter	Product: *Gasoline*	*Water*	*Diesel*
Lower Detection Limit (inches)	________	________	________
Precision (inches)	________	________	________
Detection Time (hh:mm:ss)	________	________	________
Fall Time (hh:mm:ss)	________	________	________

Specificity - ____

Additional Limitations or Considerations - ________________________________

> Safety Disclaimer: This test procedure only addresses the issue of the methods ability to detect leaks. It does not test the equipment for safety hazards.

Certification of Results

I certify that the interstitial monitor was tested under conditions according to the vendor's operating instructions. I also certify that the evaluation was performed using methods described in the attached Alternative EPA Test Procedures for Interstitial Monitors, and that the results presented above are those obtained during the evaluation.

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