

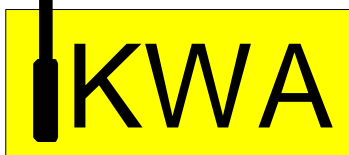
Evaluation of the TRM Sensors TRM-CC, TRM-CB and TRM-CBX sensors for use with the TRM Relay Unit Type-C and TRM-FLASHER-BE alarm consoles

Final Report

Tested in accordance with National Workgroup on Leak
Detection Evaluations (NWGLDE) and federal EPA
Requirements for Alternate Test Protocols

PREPARED FOR:
TRM Sensors LLC

November 9, 2015



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TRM-CB and TRM-CBX sensors for use with
the TRM Relay Unit Type-C and
TRM-FLASHER-BE alarm consoles**

Final Report

**PREPARED FOR:
TRM Sensors LLC
2320 Cheshire Way
Redwood City, CA 94061**

November 9, 2015


Preface

This report presents the results of an independent third-party evaluation of the TRM Sensors TRM-CC, TRM-CB and TRM-CBX Liquid sensors. The evaluation was done by Ken Wilcox Associates, Inc and was conducted in accordance with National Workgroup on Leak Detection Evaluations (NWGLDE) and federal EPA requirements described in the standard protocol "Alternative Test Procedures for Evaluating Leak Detection Methods: Evaluation of Liquid Level Sensors", September 1996. The official results of this evaluation are contained in Attachment A of this report on the EPA Results forms. All work was conducted by Ken Wilcox Associates, Inc. at the Fuels Management Research Center in Grain Valley, Missouri.

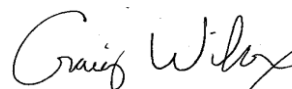
Although every effort was made to assure that this testing meets the requirements for Alternative Testing as described by the federal EPA, Ken Wilcox Associates, Inc. makes no claims that the evaluation will be accepted by any or all regulatory agencies. The test procedures are listed with the National Workgroup on Leak Detection Evaluations (NWGLDE) and meet the federal EPA requirements for Alternate Test Protocols as described in the forward to all of the standard EPA protocols for evaluating leak detection methods.

This report was prepared by Dr. Ken Wilcox, Ken Wilcox Associates, Inc. Technical questions regarding this evaluation should be directed to Kenneth McCoy, TRM Sensors LLC at (415) 860 2044

KEN WILCOX ASSOCIATES, INC



H. Kendall Wilcox, Ph.D., President
November 9, 2015



Craig Wilcox, Vice President
November 9, 2015

Table of Contents

<u>Section</u>	<u>Page No.</u>
Preface	ii
1.0 Background	1
2.0 Description of the Equipment	2
3.0 Evaluation Procedures	3
4.0 Test Results	4
Table 1	5
Attachment A. Results Forms for the Sensor	

1.0 Background

The federal Environmental Protection Agency (EPA) has provided a series of documents, which describe the procedures that are to be used to verify that leak detection equipment meets the performance requirements of the Federal Register. The requirements for evaluating liquid level sensors were not, however, included in those documents. It has therefore been necessary to develop independent methods for evaluating the performance of these systems. The objective is, of course, to provide an evaluation procedure which will provide testing which is at least as rigorous as those described for other types of leak detectors. At a minimum the evaluation method must determine the minimum liquid threshold for which a liquid level sensor will alarm.

To achieve this objective, the applicable sections of standard EPA protocols have been adapted to the specialized requirements of liquid level sensors. The test procedures followed in this evaluation are the KWA document "Alternative Test Procedures for Evaluating Leak Detection Methods: Liquid Level Sensors" September 1996. The procedures described in this document meet the requirements specified by the EPA for alternative test protocols and they were based on the procedures described in the EPA protocols. Additionally, the test procedures are listed with the National Workgroup on Leak Detection Evaluations (NWGLDE).

2.0 Description of the Equipment

TRM-CC Sensor to be used with the TRM Relay Unit Type-C

The TRM Sensors TRM-CC detects the presence of hydrocarbon liquids wherever the sensor is installed. If the hydrocarbon liquid rises above the threshold of the TRM-CC sensor, both an audible and visible alarm is generated on the TRM Relay Unit Type-C console. This alarm would indicate there is hydrocarbon liquid present wherever the sensor is installed. The sensor can easily be removed, cleaned and reinstalled if an alarm is triggered or for periodic testing. The sensor ignores tap water and produced water (oil field brine).

TRM-CB Sensor to be used with the TRM Relay Unit Type-C

The TRM Sensors LLC TRM-CB detects the presence of hydrocarbon liquids and produced water(oil field brine) wherever the sensor is installed. If the hydrocarbon liquid or produced water rises above the threshold of the TRM-CB sensor, both an audible and visible alarm is generated on the TRM Relay Unit Type-C console. This alarm would indicate there is hydrocarbon liquid or produced water present wherever the sensor is installed. The sensor can easily be removed, cleaned and reinstalled if an alarm is triggered or for periodic testing. The sensor ignores tap water.

TRM-CBX Sensor to be used with the TRM-Flasher-BE console

The TRM Sensors TRM-CBX detects the presence of hydrocarbon liquids and produced water(oil field brine) wherever the sensor is installed. If the hydrocarbon liquid or produced water rises above the threshold of the TRM-CBX sensor, a visible alarm is generated on the TRM-Flasher-BE console unit. This alarm would indicate there is hydrocarbon liquid or produced water present wherever the sensor is installed. The sensor can easily be removed, cleaned and reinstalled if an alarm is triggered or for periodic testing. The sensor ignores tap water.

TRM Relay Unit Type-C and TRM-Flasher-BE alarm consoles

The TRM Sensors TRM Relay Unit Type-C and TRM-Flasher-BE alarm consoles were used in this evaluation. The TRM Type-C relay units alarm is indicated by an audible and visible alarm. The TRM-Flasher-BE console has a visible alarm.

3.0 Evaluation Procedures

Test Apparatus

The evaluation of this system was designed to determine if the liquid level sensor operates as described by the vendor. The sensor was mounted in a test container in which water, produced water(oil field brine), unleaded gasoline, diesel fuel, Jet A and API 28 crude oil (Kern County CA) .

Threshold Determination

A peristaltic pump was used to add or remove the liquid from the test cylinder containing the sensor until the sensor alarmed. The threshold was measured directly with a dial micrometer. This procedure was repeated a total of 6 times for each liquid on each of the sensors.

Detection Time

The time required for the sensor to respond to product levels beyond the sensor's threshold is the sensor's detection time. The average time to alarm for the six tests conducted for each product type is reported as the detection time.

Fall Times

The time required for the sensor to stop responding once the product level has been raised or lowered within the sensor's threshold is the sensor's fall time. The average fall time for the six tests conducted for each product type is reported as the fall time.

Specificity

The specificity defines the different products that liquid level sensors will respond to. Most sensors will respond to any liquid once the sensor's threshold level has been exceeded unless the sensor has been designed otherwise. Although this sensor will respond to any liquid, including bio-diesel and other types of fuel, the testing conducted for this evaluation determined the sensor's response to water, produced water(oil field brine), unleaded gasoline, diesel fuel, Jet A and crude oil.

4.0 Test Results

The data and results for the sensors are contained in Table 1.

Lower Detection Level (Threshold)

The sensor was only tested for its ability to detect liquid levels at the alarm levels.

Precision (Standard Deviation)

Six replicates were conducted for the liquid level for each sensor on water, unleaded gasoline, diesel fuel, Jet A, crude oil and produced water (oil field brine). The standard deviation was determined from these replicates.

Detection Time

The amount of time for the sensor to detect the liquid depends on the type of liquid in the reservoir. The time to detect a given liquid ranges anywhere from a few seconds for unleaded gasoline to 29 minutes for crude oil.

Fall Time

The amount of time for the sensor to stop alarming after the liquid level drops below the sensors threshold depends on the type of liquid. The fall time for each sensor ranges anywhere from a few seconds for produced water, for the TRM-CB and CBX sensor, to a much longer period for hydrocarbons. Once a sensor is exposed to Diesel Fuel and Jet A the sensors will need to be removed and cleaned before it can be used again. For crude oil, the sensor may require extra cleaning or may require return to the factory for rework or replacement.

Specificity

The various sensors I respond to liquids somewhat differently depending on type. Type TRM CC responds to hydrocarbon liquids only and ignores water and brine. Type TRM CB and type TRM CBX respond to hydrocarbon liquids and produced water (brine) but ignores water. Tap water, produced water (brine), unleaded gasoline, diesel fuel, Jet A and crude oil were used for this evaluation.

Time to Alarm under Operating Conditions

The time for a liquid level sensor to alarm will depend on the size and geometry of the area in which it is installed and the rate of leakage into this space. The time to alarm can be calculated by dividing the volume necessary to reach the threshold by the leak rate.

Table 1. Test Results for the TRM Sensors LLC sensors

Test Results for the TRM-CC Sensor

Run #	Height at Alarm(inches)					
	Unleaded	Diesel	Crude Oil	Jet Fuel	Water	Produced Water
1	<1/16"	0.1695	0.1595	0.1605	No Response	No Response
2	<1/16"	0.174	0.156	0.17	No Response	No Response
3	<1/16"	0.1645	0.1615	0.1645	No Response	No Response
4	<1/16"	0.1695	0.164	0.159	No Response	No Response
5	<1/16"	0.178	0.159	0.1655	No Response	No Response
6	<1/16"	0.1665	0.1685	0.1635	No Response	No Response

Mean <1/16" **0.1703** **0.1614** **0.1638** **N/A** **N/A**
STDEV **0.0000** **0.0049** **0.0044** **0.0039** **N/A** **N/A**
Threshold <1/16" **0.1887** **0.1776** **0.1783** **N/A** **N/A**

Test Results for the TRM-CB Sensor

Run #	Height at Alarm(inches)					
	Unleaded	Diesel	Crude Oil	Jet Fuel	Water	Produced Water
1	<1/16"	0.1685	0.1595	0.165	No Response	0.456
2	<1/16"	0.1755	0.156	0.1725	No Response	0.451
3	<1/16"	0.1685	0.1615	0.1715	No Response	0.459
4	<1/16"	0.1685	0.164	0.164	No Response	0.455
5	<1/16"	0.178	0.159	0.1655	No Response	0.4625
6	<1/16"	0.1765	0.1685	0.163	No Response	0.4505

Mean <1/16" **0.1726** **0.1614** **0.1669** **N/A** **0.4557**
STDEV **0.0000** **0.0045** **0.0044** **0.0040** **N/A** **0.0046**
Threshold <1/16" **0.1894** **0.1776** **0.1819** **N/A** **0.4728**

Test Results for the TRM-CBX Sensor

Run #	Height at Alarm(inches)					
	Unleaded	Diesel	Crude Oil	Jet Fuel	Water	Produced Water
1	<1/16"	0.1865	0.1595	0.171	No Response	0.4045
2	<1/16"	0.198	0.156	0.169	No Response	0.397
3	<1/16"	0.191	0.1615	0.165	No Response	0.404
4	<1/16"	0.184	0.164	0.1715	No Response	0.393
5	<1/16"	0.1865	0.159	0.173	No Response	0.394
6	<1/16"	0.1985	0.1685	0.1645	No Response	0.399

Mean	<1/16"	0.1908	0.1614	0.1690	N/A	0.3986
STDEV	0.0000	0.0062	0.0044	0.0035	N/A	0.0049
Threshold	<1/16"	0.2139	0.1776	0.1821	N/A	0.4167

Attachment A

Results Forms for the TRM Sensors LLC sensors

TRM-CC, TRM-CB and TRM-CBX 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.

Tank owners using this 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 TRM Sensors LLC

Version number(s) TRM-CC. TRM-CB for use with TRM Sensors TRM Relay Unit

Type-C and the TRM-CBX for use with the TRM-Flasher-BE

Console

Vendor TRM Sensors LLC

(Name of Manufacturer)

2320 Cheshire Way

(Address)

Redwood City

(City)

CA

(State)

94061

(Zip Code)

(415) 860 2044

(Phone)

Evaluation Parameters

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

Threshold Levels – The liquid levels at which alarms are triggered.

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.

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.

TRM Sensors TRM-CC sensor data

Table 1. Results of the Evaluation of the TRM-CC Sensor with Unleaded

Parameter	Data
Threshold Level (inches)	< 1/16"
Precision - Standard Deviation (inches)	0.0000
Detection Time (minute)	< 1
Fall Time (minute)	22 minutes

Table 2. Results of the Evaluation of the TRM-CC Sensor with Diesel

Parameter	Data
Threshold Level (inches)	0.1887
Precision - Standard Deviation (inches)	0.0049
Detection Time (minute)	6 minutes
Fall Time (minute)	Must be cleaned

Table 3. Results of the Evaluation of the TRM-CC Sensor with Crude Oil

Parameter	Data
Threshold Level (inches)	0.1776
Precision - Standard Deviation (inches)	0.0049
Detection Time (minute)	29 minutes
Fall Time (minute)	Must be cleaned or sent to manufacturer

Table 4. Results of the Evaluation of the TRM-CC Sensor with Jet A Fuel

Parameter	Data
Threshold Level (inches)	0.1783
Precision - Standard Deviation (inches)	0.0039
Detection Time (minute)	5 minutes
Fall Time (minute)	Must be cleaned

Table 5. Results of the Evaluation of the TRM-CB Sensor with Unleaded

Parameter	Data
Threshold Level (inches)	<1/16"
Precision - Standard Deviation (inches)	0.0000
Detection Time (minute)	< 1
Fall Time (minute)	22 minutes

Table 6. Results of the Evaluation of the TRM-CB Sensor with Diesel

Parameter	Data
Threshold Level (inches)	0.1894
Precision - Standard Deviation (inches)	0.0045
Detection Time (minute)	6 minutes
Fall Time (minute)	Must be cleaned

Table 7. Results of the Evaluation of the TRM-CB Sensor with Crude Oil

Parameter	Data
Threshold Level (inches)	0.1776
Precision - Standard Deviation (inches)	0.0044
Detection Time (minute)	29 minutes
Fall Time (minute)	Must be cleaned or sent to manufacturer

Table 8. Results of the Evaluation of the TRM-CB Sensor with Jet A Fuel

Parameter	Data
Threshold Level (inches)	0.1819
Precision - Standard Deviation (inches)	0.0040
Detection Time (minute)	5 minutes
Fall Time (minute)	Must be cleaned

Table 9. Results of the Evaluation of the TRM-CB Sensor with Produced Water(Oil Field Brine)

Parameter	Data
Threshold Level (inches)	0.4728
Precision - Standard Deviation (inches)	0.0046
Detection Time (minute)	< 1
Fall Time (minute)	< 1

Table 10. Results of the Evaluation of the TRM-CBX Sensor with Unleaded

Parameter	Data
Threshold Level (inches)	<1/16"
Precision - Standard Deviation (inches)	0.0000
Detection Time (minute)	< 1
Fall Time (minute)	22 minutes

Table 11. Results of the Evaluation of the TRM-CBX Sensor with Diesel

Parameter	Data
Threshold Level (inches)	0.2139
Precision - Standard Deviation (inches)	0.0062
Detection Time (minute)	6 minutes
Fall Time (minute)	Must be cleaned

Table 12. Results of the Evaluation of the TRM-CBX Sensor with Crude Oil

Parameter	Data
Threshold Level (inches)	0.1776
Precision - Standard Deviation (inches)	0.0044
Detection Time (minute)	29 minutes
Fall Time (minute)	Must be cleaned or sent to manufacturer

Table 13. Results of the Evaluation of the TRM-CBX Sensor with Jet A Fuel

Parameter	Data
Threshold Level (inches)	0.1821
Precision - Standard Deviation (inches)	0.0035
Detection Time (minute)	< 5
Fall Time (minute)	Must be cleaned

Table 14. Results of the Evaluation of the TRM-CBX Sensor with Produced Water(Oil Field Brine)

Parameter	Data
Threshold Level (inches)	0.4167
Precision - Standard Deviation (inches)	0.0049
Detection Time (minute)	< 1
Fall Time (minute)	< 1

Specificity –This testing performed during this evaluation was done with water, diesel fuel, jet A fuel, produced water (oil field brine), crude oil and unleaded gasoline. However, the sensor will respond to any hydrocarbon liquid, including bio-diesel and other types of fuel, after its threshold is exceeded.

Additional Limitations or Considerations - None

< Safety Disclaimer: This test procedure only addresses the issue of the methods ability to respond to liquids. It does not test the equipment for safety hazards.

Certification of Results

I certify that the liquid level sensor 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 Liquid level sensors, and that the results presented above are those obtained during the evaluation.

H. Kendall Wilcox, Ph.D., President
(printed name)

Craig Wilcox, Vice President
(printed name)

H. Kendall Wilcox

Craig Wilcox

(Signature)

Ken Wilcox Associates, Inc.
(Signature)

Ken Wilcox Associates, Inc.
(organization performing evaluation)

Grain Valley, MO 64029
(city, state, zip)

November 9, 2015
(date)

(816) 443-2494
(phone number)

Laboratory Data

Test Results for the TRM-CC Sensor

Run #	Height at Alarm(inches)					
	Unleaded	Diesel	Crude Oil	Jet Fuel	Water	Produced Water
1	<1/16"	0.1695	0.1595	0.1605	No Response	No Response
2	<1/16"	0.174	0.156	0.17	No Response	No Response
3	<1/16"	0.1645	0.1615	0.1645	No Response	No Response
4	<1/16"	0.1695	0.164	0.159	No Response	No Response
5	<1/16"	0.178	0.159	0.1655	No Response	No Response
6	<1/16"	0.1665	0.1685	0.1635	No Response	No Response

Mean	<1/16"	0.1703	0.1614	0.1638	N/A	N/A
STDEV	0.0000	0.0049	0.0044	0.0039	N/A	N/A
Threshold	<1/16"	0.1887	0.1776	0.1783	N/A	N/A

Test Results for the TRM-CB Sensor

Run #	Height at Alarm(inches)					
	Unleaded	Diesel	Crude Oil	Jet Fuel	Water	Produced Water
1	<1/16"	0.1685	0.1595	0.165	No Response	0.456
2	<1/16"	0.1755	0.156	0.1725	No Response	0.451
3	<1/16"	0.1685	0.1615	0.1715	No Response	0.459
4	<1/16"	0.1685	0.164	0.164	No Response	0.455
5	<1/16"	0.178	0.159	0.1655	No Response	0.4625
6	<1/16"	0.1765	0.1685	0.163	No Response	0.4505

Mean	<1/16"	0.1726	0.1614	0.1669	N/A	0.4557
STDEV	0.0000	0.0045	0.0044	0.0040	N/A	0.0046
Threshold	<1/16"	0.1894	0.1776	0.1819	N/A	0.4728

Test Results for the TRM-CBX Sensor

Run #	Height at Alarm(inches)					
	Unleaded	Diesel	Crude Oil	Jet Fuel	Water	Produced Water
1	<1/16"	0.1865	0.1595	0.171	No Response	0.4045
2	<1/16"	0.198	0.156	0.169	No Response	0.397
3	<1/16"	0.191	0.1615	0.165	No Response	0.404
4	<1/16"	0.184	0.164	0.1715	No Response	0.393
5	<1/16"	0.1865	0.159	0.173	No Response	0.394
6	<1/16"	0.1985	0.1685	0.1645	No Response	0.399

Mean	<1/16"	0.1908	0.1614	0.1690	N/A	0.3986
STDEV	0.0000	0.0062	0.0044	0.0035	N/A	0.0049
Threshold	<1/16"	0.2139	0.1776	0.1821	N/A	0.4167