

Manual of Petroleum Measurement Standards Chapter 3—Tank Gauging

Section 3—Standard Practice for Level Measurement of Liquid Hydrocarbons in Stationary Pressurized Storage Tanks by Automatic Tank Gauging

FIRST EDITION, JUNE 1996

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Measurement Standards
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Measurement of Liquid
Hydrocarbons in Stationary
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Automatic Tank Gauging**

Measurement Coordination

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**American
Petroleum
Institute**



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FOREWORD

This publication covers standard practice for level measurement of liquid hydrocarbons on stationary pressurized storage tanks by automatic tank gauging, and supersedes all applicable sections of API Standard 2545, *Method of Gaging Petroleum and Petroleum Products* (October 1965).

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Suggested revisions are invited and should be submitted to the director of the Exploration and Production Department, Measurement Coordination, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

CONTENTS

SECTION 3—STANDARD PRACTICE FOR LEVEL MEASUREMENT OF LIQUID HYDROCARBONS IN STATIONARY PRESSURIZED STORAGE TANKS BY AUTOMATIC TANK GAUGING

1	SCOPE	1
2	REFERENCES	1
2.1	Standards	1
2.2	Safety Precautions	1
3	ACCURACY REQUIREMENT	2
3.1	Inherent Error of ATGs	2
3.2	Calibration Prior to Installation	2
3.3	Error Caused by Installation and Operating Conditions	2
3.4	Use of ATGs in Custody Transfer Service	3
3.5	Accuracy of ATGs in Custody Transfer Service	3
4	INSTALLATION OF ATGs.....	3
4.1	General	3
4.2	Mounting Location	3
4.3	Manufacturer's Requirements	3
4.4	Installation of ATGs	3
4.5	Still Pipe Design.....	5
5	INITIAL ADJUSTMENT AND FIELD VERIFICATION OF ATGs.....	7
5.1	Preparation	7
5.2	Initial Adjustment.....	7
5.3	Initial Field Verification	8
5.4	Record Keeping	8
6	OPERATION OF ATGs.....	8
7	MAINTENANCE OF ATGs.....	9
8	SUBSEQUENT VERIFICATION OF ATGs.....	9
8.1	General	9
8.2	Frequency of Subsequent Verification.....	9
8.3	Procedure for Subsequent Verification.....	9
8.4	Tolerance for Subsequent Verification of ATGs in Custody Transfer.....	9
8.5	Comparison of the ATG Readings From Current and Previous Verifications	9
8.6	Adjustment in Subsequent Verification	9
9	DATA COMMUNICATION AND RECEIVING.....	9
Figures		
1	—Installation of Intrusive ATG in a Pressurized Storage Sphere With Still Pipe.....	4
2	—Installation of Intrusive ATG in a Pressurized Storage Sphere Using Guide Wires.....	5
3	—Installation of Nonintrusive ATG in a Pressurized Storage Sphere With Still Pipe.....	6

Chapter 3—Tank Gauging

SECTION 3—STANDARD PRACTICE FOR LEVEL MEASUREMENT OF LIQUID HYDROCARBONS IN STATIONARY PRESSURIZED STORAGE TANKS BY AUTOMATIC TANK GAUGING

1 Scope

This standard provides guidance on the installation, calibration, and verification of automatic tank gauges (ATGs) used in custody transfer for measuring the level of liquid hydrocarbons having a Reid vapor pressure of 15 psi (103 kilopascals) or greater, stored in stationary, pressurized storage tanks. The standard also provides guidance on the requirements for data collection, transmission, and receiving.

This standard is not applicable to the following:

- Conversion of tank level to liquid volume.
- Measurement of free water or sediment lying under the liquid hydrocarbon.
- Measurement of temperature, density, or sediment and water (S & W). These measurements are discussed in the *API Manual of Petroleum Measurement Standards (MPMS)*, Chapters 7, 9, and 10.
- Sampling for determination of the properties of the liquid hydrocarbon. This is discussed in API MPMS Chapter 8.
- Detection of tank leaks.
- ATGs used for inventory control and plant operations.

Note: Converting net vapor space volumes to equivalent liquid volumes or mass is described in API MPMS Chapter 12. (The section covering calculation of vapor to liquid equivalent was in preparation at the time this standard was written.)

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 References

This section is applicable to all types of ATGs for pressurized storage tanks. Safety precautions are listed separately from general precautions that affect accuracy or performance.

2.1 STANDARDS

Unless otherwise specified, the most recent editions or revisions of the following standards, codes, and specifications shall, to the extent specified herein, form a part of this standard.

API

- Manual of Petroleum Measurement Standards*
- Chapter 1, "Vocabulary"
- Chapter 2, "Tank Calibration"

- Chapter 3, "Tank Gauging"
 - Chapter 7, "Temperature Determination"
 - Chapter 8, "Sampling"
 - Chapter 9, "Density Determination"
 - Chapter 10, "Sediment and Water"
 - Chapter 12, "Calculation of Petroleum Quantities"
 - RP 500 *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities*
 - RP 2003 *Protection Against Ignition Arising Out of Static, Lightning, and Stray Currents*
 - Std 2610 *Design, Construction, Operation, Maintenance, and Inspection of Terminals and Tank Facilities*
- GPA¹
- Std 8195 *Standard for Converting Net Vapor Space Volumes to Equivalent Liquid Volumes*

2.2 SAFETY PRECAUTIONS

The following recommended practices and guidelines on safety should be followed:

- API RP 500 *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities*.
- API RP 2003 *Protection Against Ignition Arising Out of Static, Lightning, and Stray Currents*.
- ISGOTT—*International Safety Guide for Oil Tankers and Terminals*.²

Other applicable safety codes and regulations should be complied with.

2.2.1 Electrical Safety

All electric equipment uses in ATGs for use in electrically classified areas should be appropriate to the classification of the area and should conform to appropriate national electrical safety standards (such as UL, FM, FCC, NEC).

2.2.2 Equipment Precautions

2.2.2.1 All of the ATG equipment should be capable of withstanding the pressure, temperature, and operating and environmental conditions likely to be encountered in the service.

¹Gas Processors Association, 6526 East 60th Street, Tulsa, Oklahoma 74145.

²Available from the Oil Companies International Forum, Portland House, Stag Place, London SW1E 5BH, England.

2.2.2.2 Measures should be taken to guarantee that all exposed metal parts of the ATG and its associated equipment have the same electrical potential as the tank.

2.2.2.3 All ATG equipment should be maintained in safe operating condition and manufacturers' maintenance instructions should be complied with.

Note 1: The design and installation of ATGs may be subject to the approval of a national measurement organization, which will normally have issued a type approval for the design of the ATG for the particular service for which it is to be employed. Type approval is normally issued after an ATG has been subjected to a specific series of tests and is installed in an approved manner.

Type approval tests may include the following: visual inspection, performance, vibration, humidity, dry heat, inclination, fluctuations in power supplies, insulation, resistance, electromagnetic compatibility, high voltage, pressure compatibility, and material certificates. Further fireproof certificates may be required.

Note 2: The design and installation may be subject to the approval or acceptance of national safety organizations dealing with pressure vessels and the

transfer service should provide security to allow sealing the calibration adjustment.

3 Accuracy Requirement

The accuracy of automatic level measurement is affected by inherent (intrinsic) error of the ATG, the effect of installation, and the effect of changes in operating conditions. Some of the factors described below also affect manual measurement, which may be used as part of the ATG setting and calibration.

3.1 INHERENT ERROR OF ATGS

The level measurement accuracy of all ATGs is affected by the inherent error of the ATG; for example, the error of the ATGs when tested under defined referenced conditions as specified by the manufacturers.

2.2.3 General Precautions

The following general precautions apply to all types of ATGs and should be observed where they are applicable.

2.2.3.1 The measurement of tank vapor pressure and

The reading of the ATG in custody transfer service should be calibrated prior to installation (in the factory or testing laboratory under controlled conditions) to agree with a certified reference (for example, a certified gauge tape) within $\frac{1}{4}$ inch or 1 millimeter over the entire range of the ATG.

- c. Random and systematic errors in level, liquid, vapor density, pressure, and temperature measurement.
- d. Operational procedures used in the transfer.
- e. Difference between opening and closing levels (minimum parcel size).

Note 4: Special consideration should be given to volume and mass measurements in pressurized tanks with respect to the amount of product present in the vapor space of the tank. API MPMS Chapter 12 and GPA Standard 8195 state the procedure and computation method to derive a compensated volume and mass assessment. (The section in API MPMS Chapter 12 covering calculation of vapor to liquid equivalent was in preparation at the time this standard was written.)

3.4 USE OF ATGS IN CUSTODY TRANSFER SERVICE

The total accuracy of level measurement by ATGs, as installed, is affected by the inherent error of the ATG, the effect of installation, and the effect of changes in operating conditions. Depending on the total (overall) accuracy of the ATG as installed (installed accuracy), ATGs may be used in custody transfer service. The use of ATG in custody transfer usually requires mutual contractual agreement between the buyer and the seller.

Note: It is difficult to verify the level accuracy of ATGs in pressurized storage tanks by manual level gauging. If the level measurement by an ATG cannot be verified, the ATG should not be used for custody transfer level measurement.

3.5 ACCURACY OF ATGS IN CUSTODY TRANSFER SERVICE

3.5.1 The ATG should meet the pre-installation calibration tolerance of $\pm\frac{1}{16}$ inch or 1 millimeter (refer to 3.2).

3.5.2 Including the effects of the installation and changes in operating conditions of $\pm\frac{1}{8}$ inch or 3 millimeters, (refer to 3.3), the ATG should meet the field verification tolerance as defined in Sections 5 and 8.

3.5.3 The remote readout, if used, should meet the requirements of this standard not to exceed $\pm\frac{1}{16}$ inch or 1 millimeter (refer to Section 9).

4 Installation of ATGs

4.1 GENERAL

ATGs that use technology other than those described in this standard can be used in custody transfer if they provide the required accuracy for the intended application. Installation methods comparable to those described in this standard that allow the ATG to be verified with the tank in service should be available.

The following sections outline recommendations and precautions for the installation of ATGs.

4.2 MOUNTING LOCATION

4.2.1 The mounting location of an ATG may affect the installed accuracy. For custody transfer accuracy, the ATG mounting location should have minimal movement with

respect to the tank reference, due to changes in liquid head or vapor pressure.

4.2.2 The ATG should preferably be mounted as close as practical to the vertical centerline axis of the tank.

4.2.3 The level-sensing element should be protected against excessive turbulence caused by the product inlet or outlet. If this cannot be achieved, an installation with a still pipe should be considered.

4.3 MANUFACTURER'S REQUIREMENTS

The ATG and level transmitter should be installed and wired in accordance with the manufacturer's instructions.

4.4 INSTALLATION OF ATGS

4.4.1 Installation of Intrusive Ullage ATGs Mounted on Still Pipes

4.4.1.1 For installations shown in the example in Figure 1, the ATG should be mounted on a properly suspended still pipe. The still pipe protects the ATG level-sensing element from liquid turbulence and may provide the fixation point for the datum plate.

4.4.1.2 For ease of maintenance and verification, the ATG should be installed such that it can be isolated from the tank (through an isolation valve, for example). Adequate means (such as a calibration chamber equipped with an inspection hatch) should be provided for access to the level-sensing element.

4.4.2 Installation of Intrusive Ullage ATGs Using Guide Wires

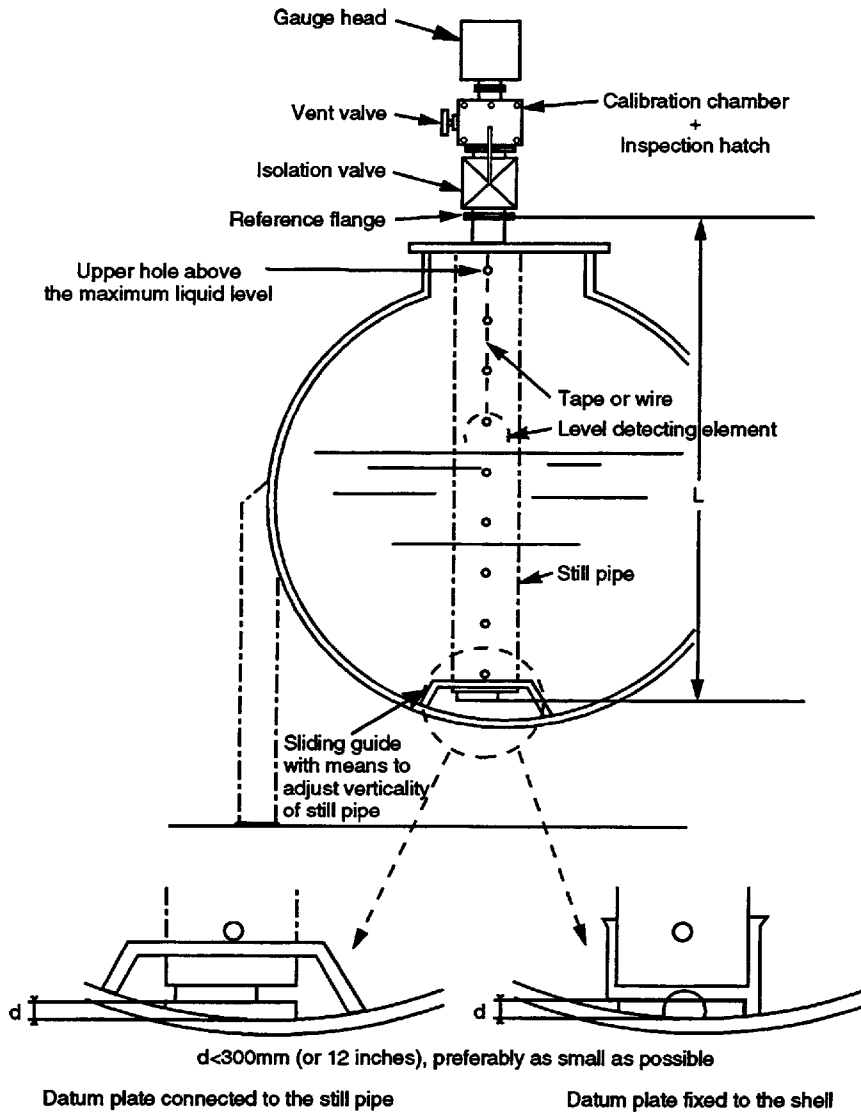
4.4.2.1 For installations shown in the example in Figure 2, the ATG should be mounted on a properly installed nozzle. The level-sensing element should be protected against excessive turbulence caused by the product inlet or outlet.

Note: Use of the spring-tensioned guide wire is intended to protect the ATG level-sensing element from liquid turbulence.

4.4.2.2 For ease of maintenance and verification, the ATG should be installed such that the level-sensing element can be isolated from the tank (through an isolation valve, for example). Adequate means (such as a calibration chamber equipped with an inspection hatch) should be provided for access to the level-sensing element.

4.4.3 Installation of Nonintrusive Ullage ATGs Mounted on Still Pipes

4.4.3.1 For installations shown in the example in Figure 3, the ATG should be installed on a properly supported still pipe. The still pipe should be designed to ensure that sufficient signal strength be obtained and interference be mini-



**Figure 1—Installation of Intrusive ATG
in a Pressurized Storage Sphere With Still Pipe**

mized under boiling conditions, which can occur during emptying a high-pressure tank.

4.4.3.2 A datum plate, which may serve as a deflector plate (shown in Figure 3), should be installed close to the tank bottom to avoid any disturbance echo. The plate should be constructed in such a way that accurate manual measurement of the distance (L), when practical, can be obtained.

4.4.3.3 The construction of the ATG may not require installation of an isolation valve for maintenance purposes when a permanent pressure seal that is transparent to the ATG is applied.

4.4.3.4 Adequate means should be provided (such as verification pins or calibration devices positioned on various heights in the still pipe) for maintenance and verification purposes. To

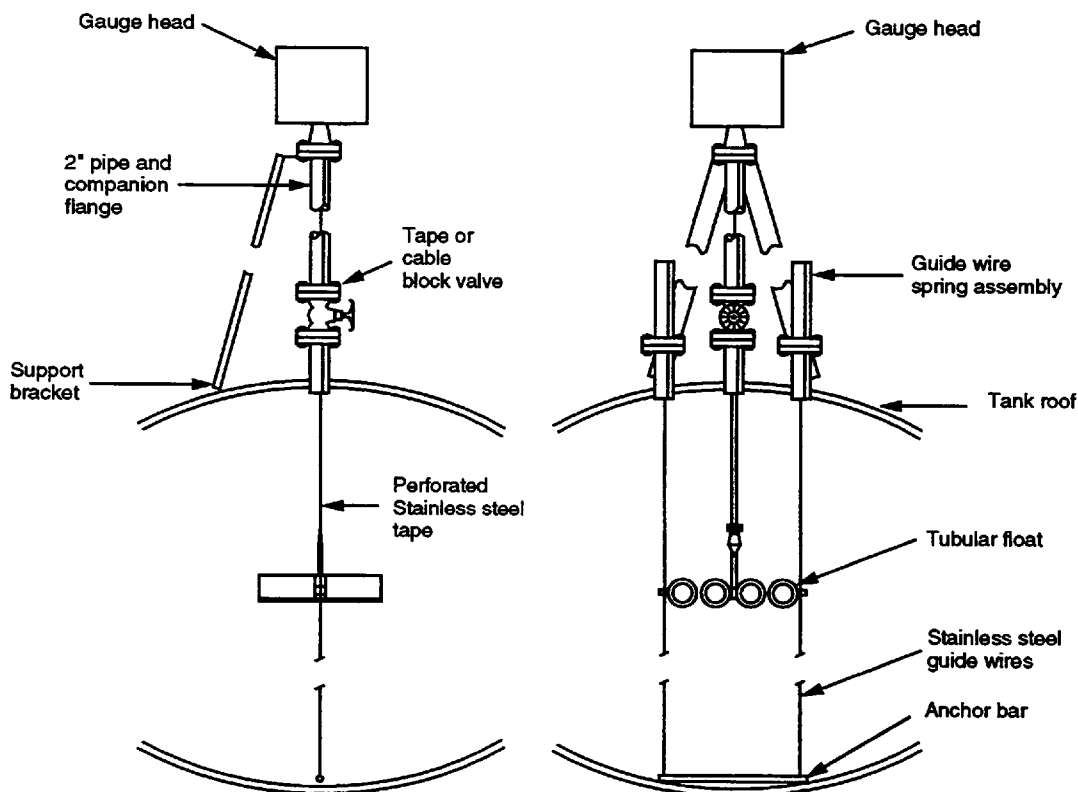


Figure 2—Installation of Intrusive ATG in a Pressurized Storage Sphere Using Guide Wires

allow adjustment when the tank is full, the highest pin should be positioned above the maximum filling height.

4.4.4 Location of Level-Sensing Element

The location of the level-sensing element with respect to inlets and outlets should be such that its proper functioning is not hampered by the liquid flow.

4.4.5 Installation of Other ATGs

Installation of ATGs other than those described in this standard should be consistent with the criteria of this standard.

4.5 STILL PIPE DESIGN

4.5.1 The still pipe should be suspended from the top of the tank. The lower end of the still pipe may be mounted in a receptor that permits vertical movement of the still pipe

due to hydrostatic deformation of the tank and minimizes the movement of the still pipe. If required, for instance, by the size of the tank, the construction should be such that the vertical alignment of the still pipe may be adjusted.

4.5.2 The diameter and thickness of the still pipe should be designed to have sufficient rigidity and strength for the intended application and for the type of ATG. If the still pipe is constructed from more than one piece of pipe, the entire still pipe must be internally straight and smooth (no burrs) after assembly.

4.5.3 The distance from the lower end of the still pipe to the bottom of the tank should be less than 1 foot or 300 millimeters. To maximize the measuring range, this distance should be as small as possible.

4.5.4 The slots, holes, spacing, and diameter of the still pipe should conform to ATG manufacturer's recommenda-

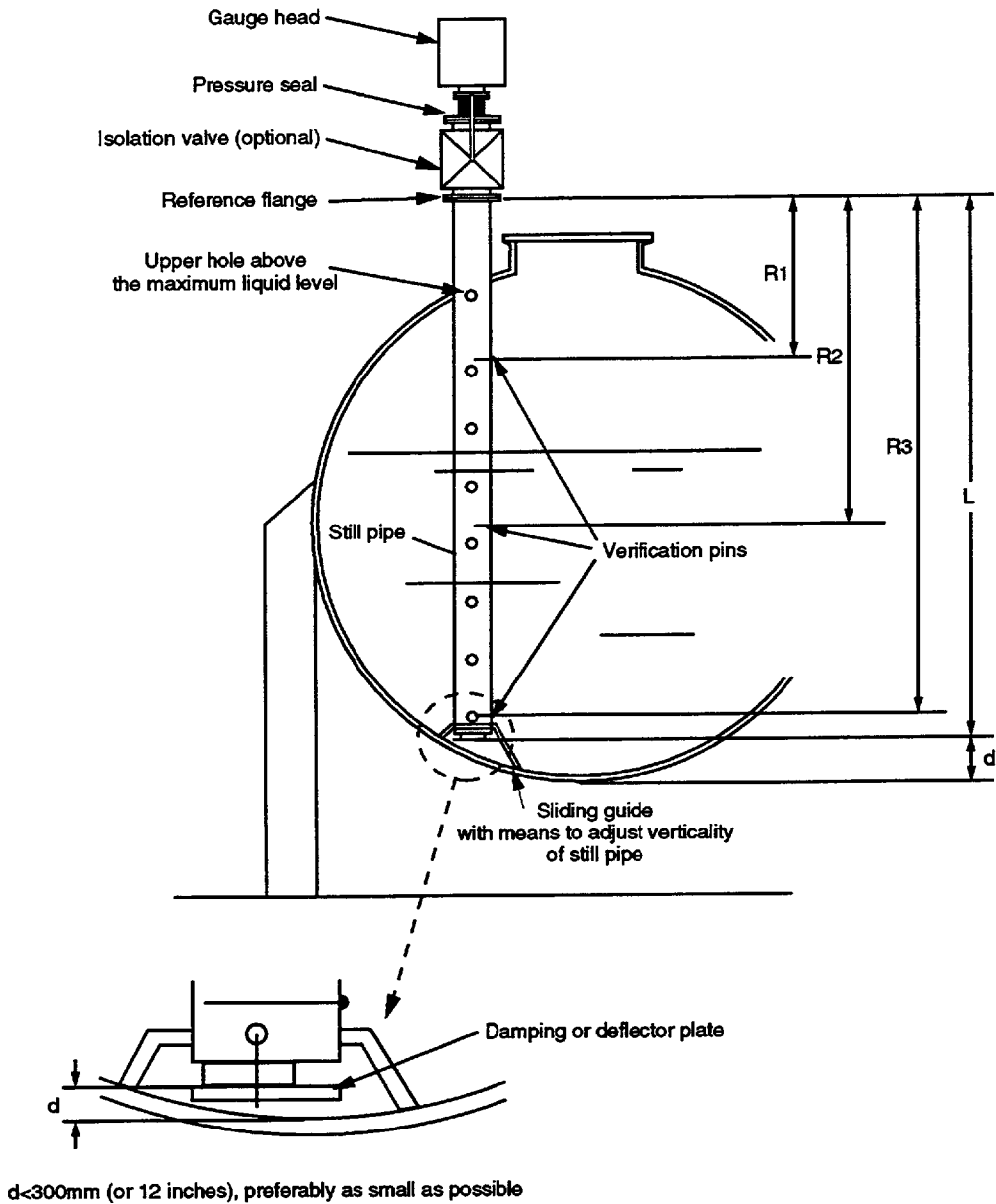


Figure 3—Installation of Nonintrusive ATG in a Pressurized Storage Sphere With Still Pipe

tions. Use of still pipes without slots or holes can lead to serious level measurement errors.

4.5.5 After the tank has been hydrostatically tested, the still pipe should be checked to ensure it remains vertical.

5 Initial Adjustment and Field Verification of ATGs

5.1 PREPARATION

5.1.1 Check for Critical Reference Distances

Before pressurizing the tank or filling the tank with product, the following critical reference distances, if applicable to the type of ATG, should be measured to $\frac{1}{8}$ inch or 1 millimeter. Using the examples in Figures 1-3, and depending on the ATG type, these distances can include the following:

- The distance (d) between the position of the datum plate and the tank bottom. (See Figures 1 and 3.)
- The distance (L) between the datum plate and the reference flange on which the ATG assembly will be or is mounted. (See Figures 1 and 3.)
- The distances (R1), (R2), and (R3) between the reference flange (on which the ATG assembly will be or is mounted) and the individual verification pins or similar methods. The pins should be located to cover the intended operating range of the ATG.

Note: Some ATGs require measurement of orientation of the verification pins (or similar calibration devices). The uncertainty of this measurement should follow the ATG manufacturer's recommendation.

5.1.2 Check for Free Movement of the Level-Sensing Element of Intrusive ATGs

For intrusive ATGs, the travel of the level-sensing element through the normal range from top to bottom of the tank should be smooth and free, with no binding or friction. After mounting a new or repaired ATG and prior to adjusting or setting the sensing element (sensor float), the guiding mechanism (including the tape, cable, and connecting elements) should be checked to ensure the ATG level-sensing element can operate freely and smoothly over the entire operating range. This check should be performed slowly to simulate actual operation and to avoid damaging the ATG sensing element mechanism.

5.1.3 Check for the Influence of Changes in Physical and Electrical Properties of the Product

Most ATG technologies are affected, in one way or another, by a change in the physical and electrical properties of the liquid and vapor in the tank. The manufacturer should quantify these influences.

5.2 INITIAL ADJUSTMENT

5.2.1 General

The adjustment or setting of an ATG usually consists of setting a single point on the calibrated span to match the height of a reference point. In general, such a point can be one or more of the following:

- The reference point in a calibration chamber.
- The top of the isolation valve, or the point where a reference pin is located.
- The tank datum plate.

The value(s) of this(these) point(s) should be recorded.

Note 1: When more than one point may be accessed, these points should be measured and recorded for later verification purposes.

Adjustment and verification of ATGs other than those described in this standard should be consistent with the accuracy verification criteria described in the standard.

Note 2: Many ATGs are calibrated prior to installation, and the span cannot be adjusted in the field. Therefore, many ATGs are verified rather than calibrated in the field.

5.2.2 Setting of Intrusive ATGs

5.2.2.1 To set an intrusive ATG (float- and servo-operated) on an empty tank or adjust ATGs that can measure the distance to the datum plate when the tank is in operation, follow these steps:

- Lower the level-sensing element to the datum plate (or the lower reference point).
- Set the ATG reading to agree with the predetermined reference point.
- Raise the level-sensing element back to the upper reference point (see 5.2.1). Then lower the level-sensing element to the datum plate (or the lower reference point) and record the reading.
- Repeat step c. to obtain a total of three consecutive readings. These readings should not exceed a range of $\frac{1}{8}$ inch or 3 millimeters for both reference points. Reset the ATG if necessary to agree with the predetermined reference point(s).

Note: If only one reference point is accessible, the ATG is set against the available reference point. It is recommended that the lowest reference point above the liquid surface be used to set the ATG.

5.2.2.2 To set an intrusive ATG (float- and servo-operated) with the tank in operation or set an ATG that cannot measure the distance to the datum plate when the tank is in operation, follow these steps:

- Raise the level-sensing element to the upper reference point (see 5.2.1) and record the ATG reading.
- Lower the level-sensing element back to liquid surface.
- Repeat steps a. and b. to obtain a total of three consecutive readings. These readings should not exceed a range of $\frac{1}{8}$ inch or 3 millimeters. Reset the ATG if necessary to agree with the upper reference point.

5.2.3 Setting of Nonintrusive ATGs

5.2.3.1 To set a nonintrusive ATG (microwave or radar based) on an empty tank, follow these steps:

- a. Compare the ATG measurement to the verification pins (or similar verification devices).
- b. Take three ATG readings at each verification pin. The maximum spread of the ATG readings should not exceed $\frac{1}{4}$ inch or 3 millimeters at each pin. Set the ATG to the correct value for the location of the lowest verification pins.

5.2.3.2 To set a nonintrusive ATG (microwave or radar based) with the tank in service, follow these steps:

- a. Compare the ATG measurement to a verification pin (or similar verification device). The tank should preferably be less than half full so that the lower verification pin can be used.

Note: It is recommended that the lowest available reference point (the verification pin) above the liquid surface be used to set the ATG.

- b. Take three ATG readings at each verification pin. The maximum spread of the ATG readings should not exceed $\frac{1}{4}$ inch or 3 millimeters at each pin. Set the ATG to the correct value for the location of the lowest verification pins.

5.2.4 Other ATGs Not Described in This Standard

ATGs other than those described in this standard should be set so that the ATG reading agrees with predetermined and stable reference point(s). The procedure, which may vary depending on the ATG technology and/or design, should be consistent with the criteria described above to meet the intent of the ATG setting.

5.3 INITIAL FIELD VERIFICATION

5.3.1 Introduction

The purpose of the initial field verification is to ensure that the ATG, as installed, can measure as accurately as properly performed manual gauging, if manual gauging were possible. Verification is the procedure that verifies or confirms that the installed accuracy of the ATG is appropriate for the intended service.

Note: ATGs are designed to measure the distance from the ATG reference to the liquid surface. They cannot compensate against all limitations of the accuracy of tank level measurement described in the standard. The following fundamental influences, which may affect the accuracy of the level measurement, should be considered:

- a. Tank installation errors.
- b. Changes in operating conditions.
- c. Errors inherent to the principle of operation of the ATG.

Following the adjustment of the ATG, the overall accuracy of the ATG is verified by these steps:

- a. Comparing the ATG readings against the recorded levels used during the calibration procedure.

- b. Measuring the reference height, if the ATG permits such a measurement.

5.3.2 Verification Procedure

The following sections describe initial field procedures for various types of ATGs to be used in custody transfer service.

5.3.2.1 Round-Off of ATG Readings

ATG readings should not be rounded off to whole numbers. The maximum resolution of the ATG should be used.

5.3.2.2 Procedure

The initial field verification is carried out by taking three consecutive ATG readings against one (or more) available reference point(s) with the tank in service. Follow the procedures described in 5.2 to obtain ATG readings. The verification should be performed with the tank in service.

The maximum spread of three consecutive ATG readings for the reference point is used to evaluate the repeatability of the ATG.

5.3.2.3 Resetting or Readjustment of an ATG During Initial Field Verification

Depending on the ATG type, the procedures described in 5.2 are used to obtain the ATG readings; however, the ATG should not be readjusted or reset during the initial field verification. If the ATG failed the tolerance described below, the ATG may be readjusted or reset, but it should then be reverified.

5.3.3 Initial Verification Tolerance for ATGs in Custody Transfer Service

The maximum spread between any two of the three consecutive ATG readings taken during the initial verification should not exceed $\frac{1}{4}$ inch or 3 millimeters.

Note: Verification of the datum plate or bottom may provide information about possible deformation of the tank under operational conditions.

5.4 RECORD KEEPING

Complete records should be kept of the initial setting (see 5.2), initial field verification (see 5.3), and subsequent verification (see Section 8) of each ATG used in custody transfer.

6 Operation of ATGs

Operating personnel should be provided with complete instructions for operating and reading ATGs appropriate for the type of ATG and remote indication installed. Details of the methods to be used for checking the operation of the ATG, the use of remote readings, the reporting of readings, the method of making any necessary adjustments for

changes in operating conditions, and the necessary correction factors should be included.

Operating personnel should also be provided with complete instructions for the reporting of faults in operation.

7 Maintenance of ATGs

A maintenance schedule based on the manufacturer's recommendations should be put into force for each ATG installation. The schedule should ensure that each ATG is inspected at regular intervals. Remote indication equipment should be included in the schedule. Records of maintenance work should be kept.

8 Subsequent Verification of ATGs

8.1 GENERAL

A verification program should be established for ATGs used in custody transfer. The ATG installation should be checked as recommended by the manufacturer's instructions.

8.2 FREQUENCY OF SUBSEQUENT VERIFICATION

ATGs used for custody transfer level measurement should be verified on a regular basis. The ATG should be verified at least once per quarter. If operating experience confirms stable performance within the verification tolerance, the verification schedule can be extended to once a year.

The frequency of subsequent verification may also be established by the use of a verification tolerance control chart based on statistical quality control.

8.3 PROCEDURE FOR SUBSEQUENT VERIFICATION

8.3.1 The liquid level at which the ATG is verified in a subsequent verification should preferably be different from the level at which the previous verification was performed.

8.3.2 The subsequent verification can be performed by taking three consecutive ATG readings against the selected reference point with the tank in service, following the procedure outlined in 5.3. The maximum spread of three consecutive ATG readings for the reference point is used to evaluate the repeatability of the ATG.

8.3.3 During subsequent verification, the average ATG reading should also be compared with the average ATG reading from the last verification and the original ATG setting, provided that these comparisons are made against the same reference point(s).

Note: These comparisons are intended to evaluate any long-term drift of the ATG, the effect due to movement of the reference point(s), and any change of operating conditions.

8.4 TOLERANCE FOR SUBSEQUENT VERIFICATION OF ATGS IN CUSTODY TRANSFER

8.4.1 The tolerance described in 5.3.3 should be followed. If the tolerance is met, the ATG should be considered within calibration and suitable for custody transfer.

If the ATG failed the tolerance, the cause should be investigated. If the ATG needs to be readjusted or reset, it should then be reverified following the procedure described in this standard.

8.5 COMPARISON OF THE ATG READINGS FROM CURRENT AND PREVIOUS VERIFICATIONS

During subsequent verification, the average ATG reading should be compared with the average ATG reading from the last verification and with the original ATG setting, provided that these comparisons are made against the same reference point(s).

8.5.1 Compare the average ATG reading from the current verification against the average ATG reading from the last verification. The maximum difference between the average ATG reading from the current verification and the average ATG reading from the last verification should not exceed $\frac{1}{4}$ inch or 6 millimeters.

8.5.2 Compare the average ATG reading from the current verification against the original ATG setting. The maximum difference between the average ATG reading from the current verification and the original ATG setting should not exceed $\frac{1}{2}$ inch or 12 millimeters.

8.5.3 If any of the above tolerances (see 8.5.1 and 8.5.2) is exceeded, the accuracy of the ATG installation should be considered questionable and may not be suitable for custody transfer. The ATG installation should be checked to determine whether this is caused by movement (or change) of the reference point(s), change of operating conditions, or the inherent, long-term drift of the ATG.

8.6 ADJUSTMENT IN SUBSEQUENT VERIFICATION

The ATG should not be readjusted or reset unless either a malfunction necessitates it or a graph or tabulation of verification readings indicates a positive or negative trend.

9 Data Communication and Receiving

This section provides recommendations for the specification of the communication between level transmitter(s) and receiver(s) and vice versa. The measurement data by an ATG may include other information.

The ATG system should be designed and installed such that data transmission and receiving units are capable of the following:

a. They do not compromise the accuracy of the measurement. The difference between the level readings displayed by the remote receiving unit and the level readings displayed (or measured) by the ATG at the tank should not exceed $\pm \frac{1}{16}$ inch or 1 millimeter.

b. They do not compromise the resolution of the measure-

ment output signal.

c. They provide proper security and protection of the measured data to ensure its integrity.

d. They provide adequate speed to meet the update time required for the receiving unit.

e. They are electromagnetically compatible.

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