Manual of Petroleum Measurement Standards
Chapter 3—Tank Gauging

Section 1B—Standard Practice for Level Measurement of Liquid Hydrocarbons in Stationary Tanks by Automatic Tank Gauging

SECOND EDITION, JUNE 2001

American Petroleum Institute

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CONTENTS

Manual of Petroleum Measurement Standards
Chapter 3—Tank Gauging

Section 1B—Standard Practice for Level Measurement of Liquid Hydrocarbons in Stationary Tanks by Automatic Tank Gauging

3.1B.1 Scope

This standard covers level measurement of liquid hydrocarbons in stationary, aboveground, atmospheric storage tanks using automatic tank gauges (A TGs). The standard discusses automatic tank gauging in general, accuracy, installation, commissioning, calibration and verification of ATGs that measure either innage or ullage. It covers both intrusive and non-intrusive ATGs used for either custody transfer or inventory control. The standard also covers the requirements for data collection, transmission and receiving.

This standard does not cover the following:

a. Hydrocarbons having a Reid vapor pressure above 15 pounds per square inch absolute (100 kPa).

b. Measurement of weight or mass with ATG equipment. This is covered in Chapter 3.6 and Chapter 16.2 of the *Manual of Petroleum Measurement Standards*

c. Measurement of level in underground tanks or in pressurized tanks storing liquid hydrocarbons.

d. Conversion of tank level to liquid volume. This is covered in Chapter 12.1 of the *Manual of Petroleum Measurement Standards*

e. Measurement of temperature, sampling, density and sediment and water (S & W), which are discussed in Chapters 7–10 of the *Manual of Petroleum Measurement Standards*

Safety and material compatibility precautions should be taken when using ATG equipment. Manufacturers' recommendations on the use and installation of the equipment should be followed. Users should comply with all applicable codes and regulations, API Standards and NFPA 70 *National Electric Code*

3.1B.2 Referenced Publications

API

Manual of Petroleum Measurement Standards (MPMS)

Chapter 1	"Vocabulary"
Chapter 2	"Tank Calibration"
Chapter 3.1A	"Standard Practice for Manual Gauging of Petroleum and Petroleum Products in Stationary Tanks"
Chapter 3.6	"Measurement of Liquid Hydrocarbons by Hybrid Tank Measurement Systems"
Chapter 7	"Temperature Determination"
Chapter 8.1	"Manual Sampling of Petroleum and Petroleum Products"
Chapter 8.2	"Automatic Sampling of Petroleum and Petroleum Products"
Chapter 9.1	"Hydrometer Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products"
Chapter 12.1	"Calculation of Static Petroleum Quantities, Part 1 Upright Cylindrical Tanks and Marine Vessels"
Chapter 16.2	"Mass Measurement of Liquid Hydrocarbons in Vertical Cylindrical Storage Tanks by Hydrostatic Tank Gauging"
Chapter 19.2	"Evaporative Loss on Floating roof tanks"
RP 500	*Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities*
RP 2003	*Protection Against Ignition Arising Out of State, Lightning and Stray Currents*

International Organization for Standardization

ISO 4266	*Petroleum and Liquid Petroleum Products—Measurement of Temperature and Level in Storage Tanks by Automatic Methods. Part 1: Measurement of Level in Atmospheric Tanks*

3.1B.3 Definitions

Refer to MPMS, Chapter 1, "V ocabulary", which lists all of the terms and definitions relating to measurement used in API standards on petroleum products and lubricants.

3.1B.4 General

This section applies to all types of ATGs.

This standard presents both Metric (SI) units and US Customary units and may be implemented in either system of units. The presentation of both units are for convenience of the user and are not necessarily exact conversions. The units of implementation are typically determined by contract, regulatory requirement, the manufacturer or the user's calibration program. Once a system of units is chosen for a given application, it is not the intent of this standard to allow arbitrarily changing units within this standard.

Safety precautions are listed separately from general precautions that affect accuracy or performance.

Note: The following precautions are given in addition to any existing federal, state, or local regulations (for example, the Occupational Safety and Health Administration) that govern practices described in this standard. Users of this standard should be familiar with all applicable safety and health regulations.

3.1B.4.1 SAFETY PRECAUTIONS

These safety precautions represent good practice. This list is not necessarily complete or comprehensive. Refer also to the safety precautions described in API Recommended Practice 2003.

3.1B.4.1.1 Tank Entry

Before a tank that once contained hydrocarbon liquids, vapors or toxic material is entered, all lines to the tank shall be disconnected or blinded and a gas-free certificate shall be obtained.

3.1B.4.1.2 Hazardous Areas

All regulations covering entry into hazardous areas shall be observed. Electric equipment for use in electrically classified areas shall meet the area classification. Refer to the following API Recommended Practices (RPs):

a. RP 500.

b. RP 2003.

3.1B.4.1.3 Maintenance

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

3.1B.4.1.4 Environment

All ATGs shall be capable of withstanding the pressure, temperature and other environmental conditions likely to be encountered in service.

3.1B.4.1.5 Sealing

All ATGs shall be sealed to withstand the vapor pressure of liquid in the tank.

3.1B.4.1.6 Manual Gauging

Manual tank gauging can be associated with exposure to immediately dangerous chemicals. When an A TG is checked or calibrated by manual gauging, the manual gauging should be done in accordance with MPMS Chapter 3.1A.

3.1B.4.1.7 Speed of Response

ATGs should have sufficient dynamic response to track the liquid level during maximum rates of tank filling or emptying.

3.1B.4.2 GENERAL PRECAUTIONS

The following general measurement precautions affect the accuracy and performance of all types of A TGs. They should be observed where they are applicable.

3.1B.4.2.1 Tank Temperatures

Tank temperature should be measured at the same time the tank level is measured. The tank temperature should be representative of the tank contents in accordance with MPMS Chapter 7.

3.1B.4.2.2 Recording Levels

Level measurements should be recorded as soon as they are taken, unless the remote readout equipment of the A TG system automatically records the levels periodically.

3.1B.4.2.3 Opening and Closing Gauges

The same procedures should be used to measure a tank level before the product transfer (opening gauge) and after the product transfer (closing gauge).

3.1B.4.2.4 Compatibility

All parts of the ATG in contact with the product or its vapor should be compatible with the product to avoid both product contamination and A TG corrosion. The A TG should be designed to meet the operating conditions.

3.1B.4.2.5 Settling Time

Refer to MPMS Chapter 3.1A for guidance on settling time before tank levels are measured.

3.1B.4.2.6 ATG Security

ATGs should provide security to prevent unauthorized adjustment or tampering. ATGs used in custody transfer applications should provide facilities to allow sealing for calibration adjustment.

3.1B.4.3 ACCURACY

3.1B.4.3.1 Intrinsic Accuracy of ATGs

The level measurement accuracy of all ATGs is affected by the intrinsic accuracy of the ATG, i.e., the accuracy of the ATG when tested under controlled conditions as specified by the manufacturers.

3.1B.4.3.2 Calibration Prior to Installation (Factory Calibration)

The reading of an ATG to be used for custody transfer application should agree with a certified measurement instrument within ±1 mm or (± 1/16 inch) over the entire range of the ATG. The certified measurement instrument should be traceable to the national standards and should be provided with a calibration correction table. The uncertainty of the reference should not exceed 0.5 mm or (1/32 inch), with the calibration correction applied.

The reading of an ATG to be used for inventory application should agree with a certified measurement instrument within ±3 mm (± 1/8 inch) over the entire range of the ATG. The certified measurement instrument should be traceable to the national standards and should be provided with a calibration correction table.

ATGs installed prior to the effective date of this document may not have factory calibration documentation. These ATGs are not required for re-test at the factory, but the installed accuracy of these ATGs should meet the requirements in 3.1B.7.3.3 for their intended application.

3.1B.4.3.3 Error Caused by Installation and Operating Conditions

The total error of an ATG in custody transfer service should not be affected by more than ±3 mm (± 1/8 inch) due to installation, to variation of operating conditions (refer to Section 3.1B.4.3.5) or variation of physical and electrical properties of the liquid and/or vapor, provided that these conditions are within the limits specified.

3.1B.4.3.4 Overall Accuracy of the Installed ATG

The overall accuracy of the installed ATG includes both the intrinsic accuracy of the ATG, as verified by factory calibration, and those effects caused by installation and operating conditions. The overall accuracy of an ATG in custody transfer service should be within ±4 mm (± 5/16 inch). The overall accuracy of an ATG in Inventory control service should be within ±25 mm (±1 inch).

3.1B.4.3.5 Accuracy Limitations of Tank Measurement

ATGs (and measurements derived therefrom, e.g., volume) are affected by the same inherent accuracy limitation as manual tank gauging measurements. It is imperative that the user understand these limitations, which are addressed in more detail in MPMS Chapter 3.1.A, but are listed here for convenience. Other limitations unique to ATGs are also listed.

3.1B.4.3.5.1 Accuracy limitations Inherent to both Manual Tank Measurement and ATGs

a. Accuracy of tank capacity table, including the effect of tank tilt and hydrostatic pressure.

b. Bottom movement.

c. Incrustation.

d. Movement of the manual gauging reference point or the ATG reference point during tank transfers or because of thermal expansion. Both affect ullage gauging.

e. The accuracy of measurements using innage-based ATGs is affected by vertical movement of the datum plate used to calibrate the ATG or vertical movement of the ATG reference point during tank transfers.

f. Random and system errors in level, density, and temperature measurement.

g. Expansion of the tank diameter due to temperature.

h. Operational procedures used in the transfer.

i. Minimum difference between opening and closing levels (parcel size).

j. Errors in measured level caused by sticking and/or cocking of floating roofs.

3.1B.4.3.5.2 Accuracy Limitations Unique to ATG Systems

a. Errors caused by the improper installation of the ATG.

b. Errors in transmitting the tank level and temperature information to the remote readout.

c. Errors in tank capacity table, physical property and other data input into the tank gauging system computer.

3.1B.4.4 USE OF ATGs FOR CUSTODY TRANSFER OR INVENTORY CONTROL

The overall accuracy of level measurement by ATGs, as installed ("installed accuracy"), is limited by the intrinsic error of the ATG equipment, the effect of installation methods and the effect of changes in the operating conditions.

Depending on the overall accuracy of the ATG, as installed, ATGs may be used either for custody transfer or for inventory control purposes. The use of ATGs for custody transfer normally requires mutual contractual agreement between the buyer and the seller and may be subject to federal, state and local regulations.

The use of A TGs in custody transfer application requires high accuracy. The use of ATGs for inventory control purposes often permits a lower degree of accuracy.

3.1B.4.4.1 Use of ATGs for Custody Transfer Purposes

3.1B.4.4.1.1 The ATG should meet the factory calibration tolerances prior to installation (refer to Section 3.1B.4.3.2).

3.1B.4.4.1.2 The ATG should meet the field verification tolerance for custody transfer (refer to Section 3.1B.7.3.3), including the effects of installation methods and changes in operating conditions (refer to Section 3.1B.4.3.3).

3.1B.4.4.2 Use of ATGs for Inventory Control Purposes

3.1B.4.4.2.1 The ATG should meet the factory calibration tolerances prior to installation (refer to Section 3.1B.4.3.2).

3.1B.4.4.2.2 The ATG should meet the field verification tolerance for inventory control (refer to Section 3.1B.7.3.3), including the effects of installation methods and changes in operating conditions.

3.1B.4.4.3 Remote Readout Custody Transfer

The remote readout, if used, should meet the requirements of this standard (refer to Section 3.1B.4.6).

3.1B.4.5 INSTALLATION OF ATGs

3.1B.4.5.1 Manufacturer's Requirements

The ATG and the associated electronics should be installed and wired in accordance with the manufacturers' instructions, NFPA *National Electrical Code* and/or local standards.

3.1B.4.5.2 Mounting Location of Ullage-ATGs

The mounting location of an A TG may affect its accuracy after installation. The mounting location of the A TG should be such that the ATG may be easily verified by manual gauging from the official gauge hatch.

For custody transfer accuracy, it is essential that the mounting location should be stable, with minimal vertical movement with respect to the tank reference (which is typically the joint where the tank shell and bottom meet). If the datum plate is found to be stable, it may be used to verify the stability of ATG mounting.

The stability of the mounting location is affected by the changes in liquid head, vapor pressure or loading of the roof or gauging platform.

For best accuracy, an ullage-A TG should be mounted on a properly supported, slotted (or perforated) still pipe, as illustrated in Figures 1 and 2.

3.1B.4.5.2.1 Top Mounting With a Slotted Still Pipe

Figure 1 shows an ullage-A TG mounted on a slotted still pipe supported by tank bottom. Figure 2 shows an ullage-ATG mounted on a slotted still pipe supported by a bracket.

Ullage-ATGs mounted on properly supported slotted still pipes, as illustrated in Figures 1 and 2, deliver higher accuracy because the slotted still pipe supported on stable location and A TG movement is minimized when the tank is filled or emptied.

3.1B.4.5.2.2 Top Mounting Without a Slotted Still Pipe

Alternatively, an ullage-ATG may be supported on the roof of a fixed-roof tank or on a "gallows" on a fixed or floating roof tank, as illustrated in Figure 3. This kind of mounting may cause the ATG to move vertically when the tank is filled or emptied. Ullage-A TGs mounted without slotted still pipes can be used for custody transfer or inventory control if the ATG as installed, can be verified to meet the requirements set forth in Section 3.1B.4.3.4.

3.1B.4.5.2.3 Mounting Without a Slotted Still Pipe for Small Tanks

For small (less than 5000 barrels) tanks, an ullage-ATG may be mounted without a slotted still pipe. The Reference Height variation should be measured with the tank full and empty.

3.1B.4.5.3 Mounting Location of Innage-ATGs

The gauge head of an innage-A TG may be mounted in any suitable location. The mounting location of the A TG should be such that the ATG may be easily verified by manual gauging from the official gauge hatch.

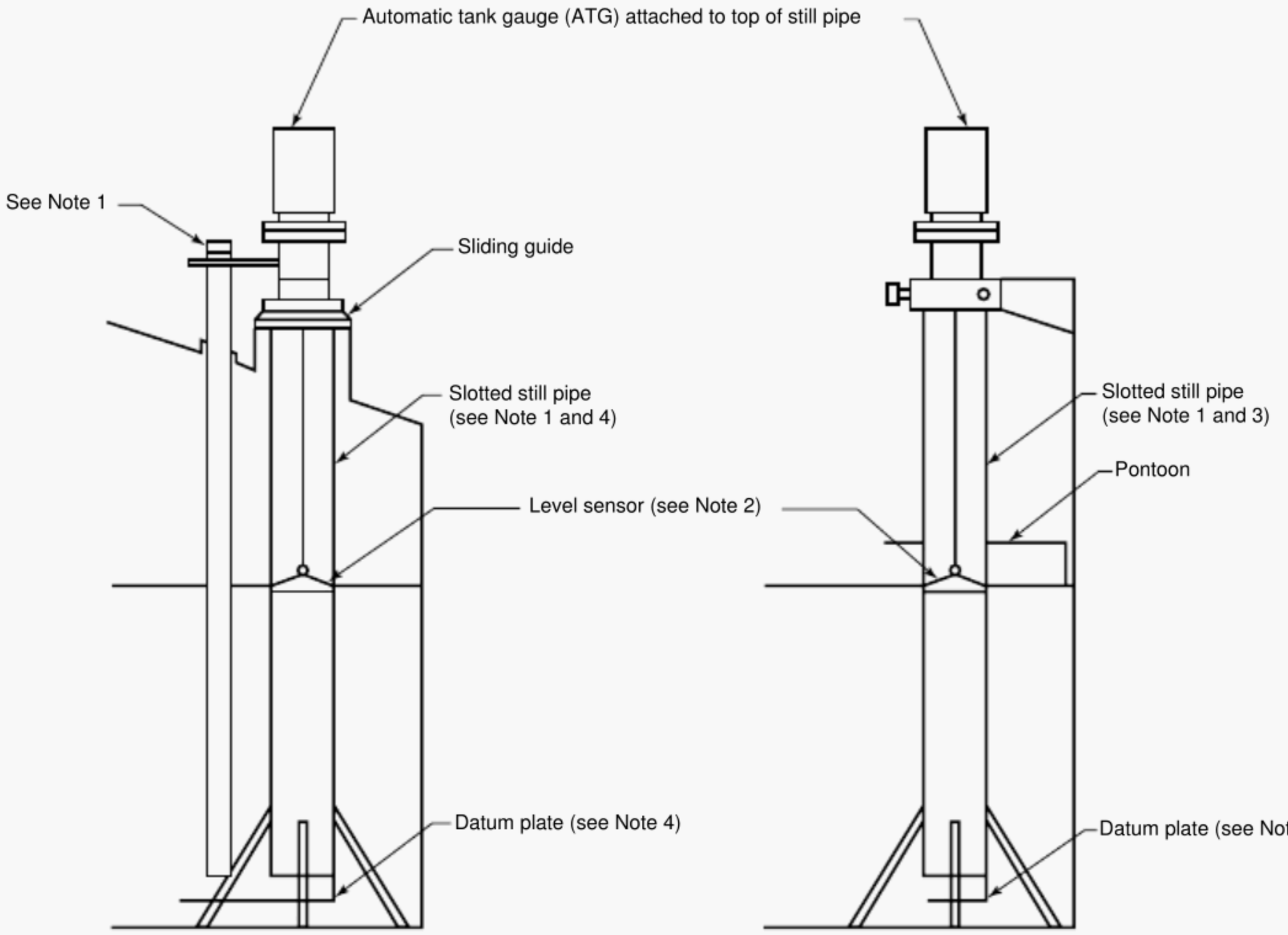
The zero point of the measuring element should be mounted at a stable location on the tank bottom that has minimal vertical movement with respect to the bottom corner (which is the joint where the tank shell and bottom meet).

3.1B.4.5.3.1 Mounting Innage-ATGs

Innage-ATGs usually do not require still pipes. If an innage-ATG is mounted on a still pipe, it should be slotted. Innage-ATGs should be mounted in accordance with the manufacturer's instructions. Refer to Figure 4.

3.1B.4.5.4 Avoiding Turbulence

If the measuring element is subjected to excessive turbulence, certain types of A TGs may be thrown out of calibration. The ATG should be located away from tank inlets, tank outlets and tank mixers. When this cannot be done, the level detecting element should be protected by means of a slotted still pipe to minimize the effect of turbulence and swirl.

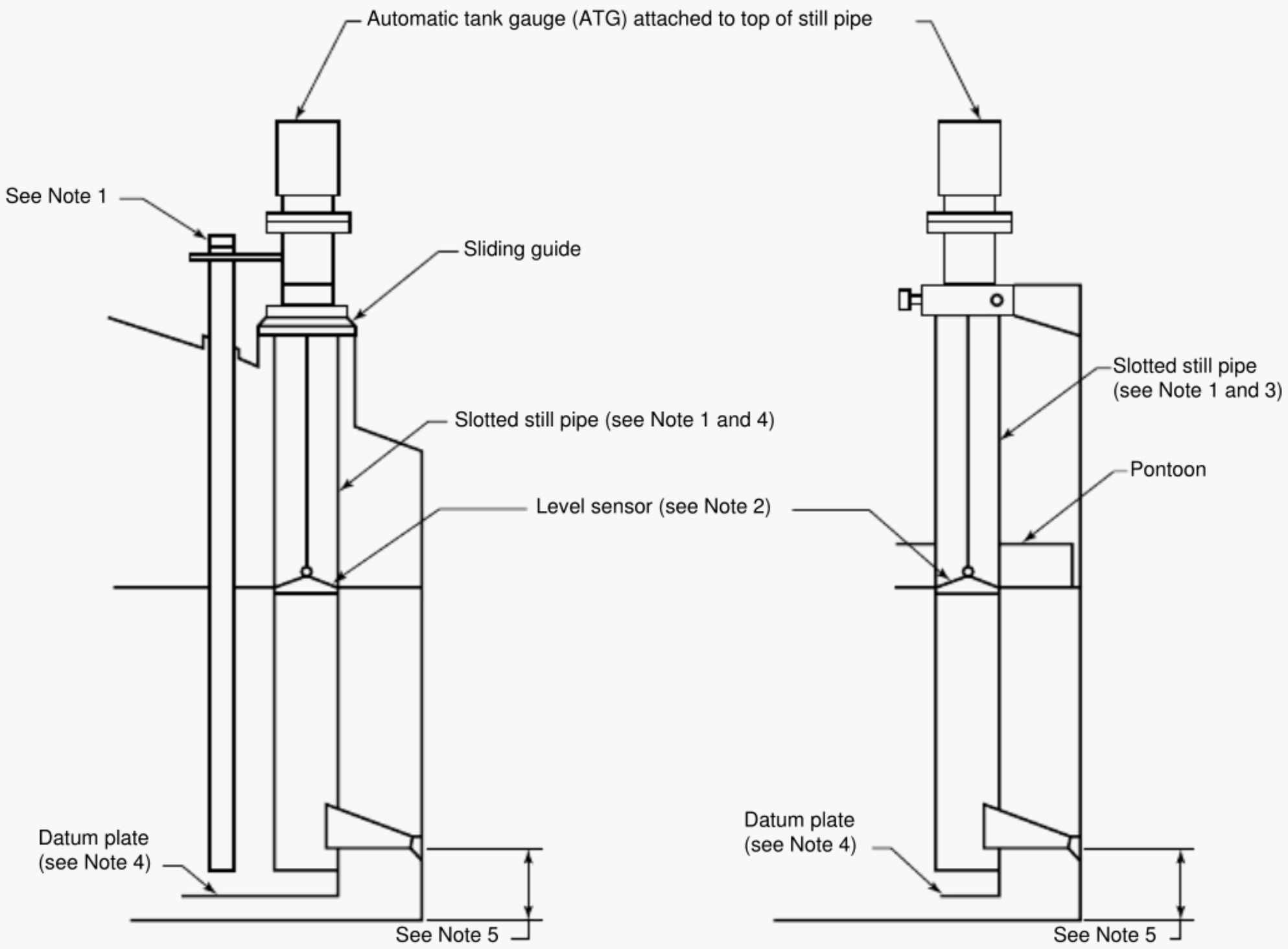


(a) Installation of top-mounted ATGs on fixed roof tanks with still pipe.

(b) Installation of top-mounted ATGs on external floating roof tanks or on internal floating roof tanks.

Notes:
1. Separate slotted still pipe(s) for manual gauging and temperature measurement may be installed adjacent to the ATG slotted still pipe.
2. Non-contact, top-mounted ATGs can be installed in a similar way.
3. Use of slotted still pipes for ATG, manual gauging, and temperature measurement on open floating tanks may be subject to environmental regulations. See MPMS Chapter 19.2.
4. Datum plate should be mounted on tank bottom, below the slotted still pipe or located 100 to 150 mm (4 to 6 inches) below the slotted still pipe (as shown).

Figure 1—Example of an ATG (Contact or Non-contact) Mounted on a Still Pipe Supported by Tank Bottom



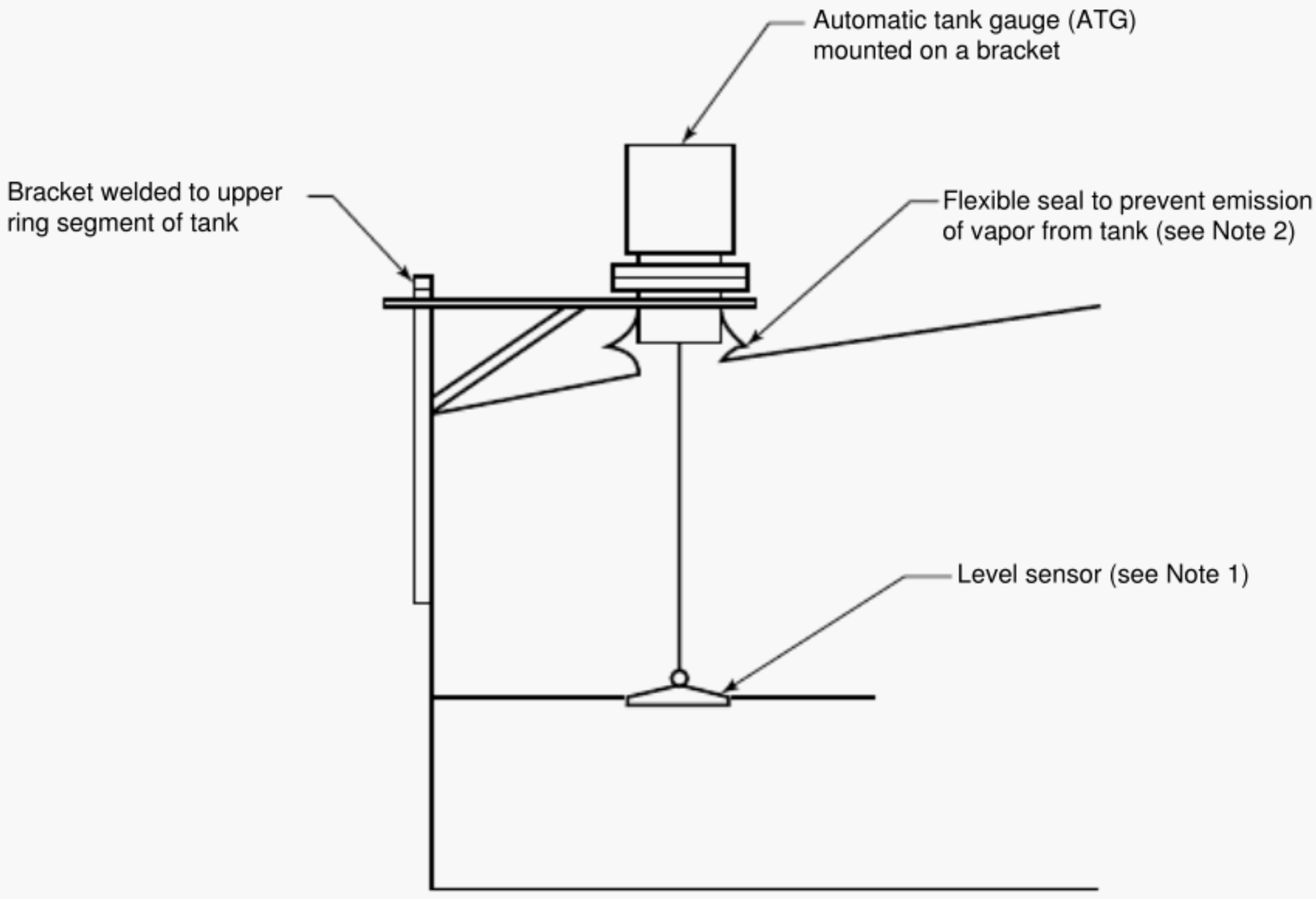
(a) Installation of top-mounted ATGs on fixed roof tanks with still pipe.

(b) Installation of top-mounted ATGs on external floating roof tanks or on internal floating roof tanks.

Notes:

1. Separate slotted still pipe(s) for manual gauging and temperature measurement may be installed adjacent to the ATG slotted still pipe.
2. Non-contact, top-mounted ATGs can be installed in a similar way.
3. Use of slotted still pipes for ATG, manual gauging, and temperature measurement on open floating tanks may be subject to environmental regulations. See MPMS Chapter 19.2.
4. Datum plate should be mounted on tank bottom, below the slotted still pipe or located 100 to 150 mm (4 to 6 inches) below the slotted still pipe (as shown).
5. The bottom bracket should be mounted approximately 250 mm (10 inches) from the bottom.

Figure 2—Example of an ATG (Contact or Non-contact) Supported by a Bracket Hinged to the Lower Tank Shell Plate



Notes:
1. This figure shows an intrusive ullage-ATG. Non-contact, top-mounted ATGs can be installed in a similar way. Mounting an ullage-ATG without a slotted still pipe may affect the accuracy.
2. The use of a flexible seal on fixed roof tanks may be subject to environmental regulations.

Figure 3—Example Installation of Top-Mounted ATGs on Fixed Roof Tanks Without Still Pipe (This installation may not be suitable for Custody Transfer)

3.1B.4.5.5 Proximity to the Gauging Hatch

Where not subject to turbulence, the ATG should be located near the gauging hatch so that its accuracy can be easily checked by manual gauging.

3.1B.4.5.6 Multiple Gauging Hatches

If the tank has more than one gauging hatch, the gauging hatch and datum plate used for manual reference innage gauging for calibration and verification should be the "official" gauging hatch used for referencing the tank strapping table.

3.1B.4.5.7 Slotted Still Pipe Design

3.1B.4.5.7.1 Support for the Slotted Still Pipe

The bottom corner of the tank, where the shell plate is welded to the bottom plate, is the stable point to which the datum plate is referred.

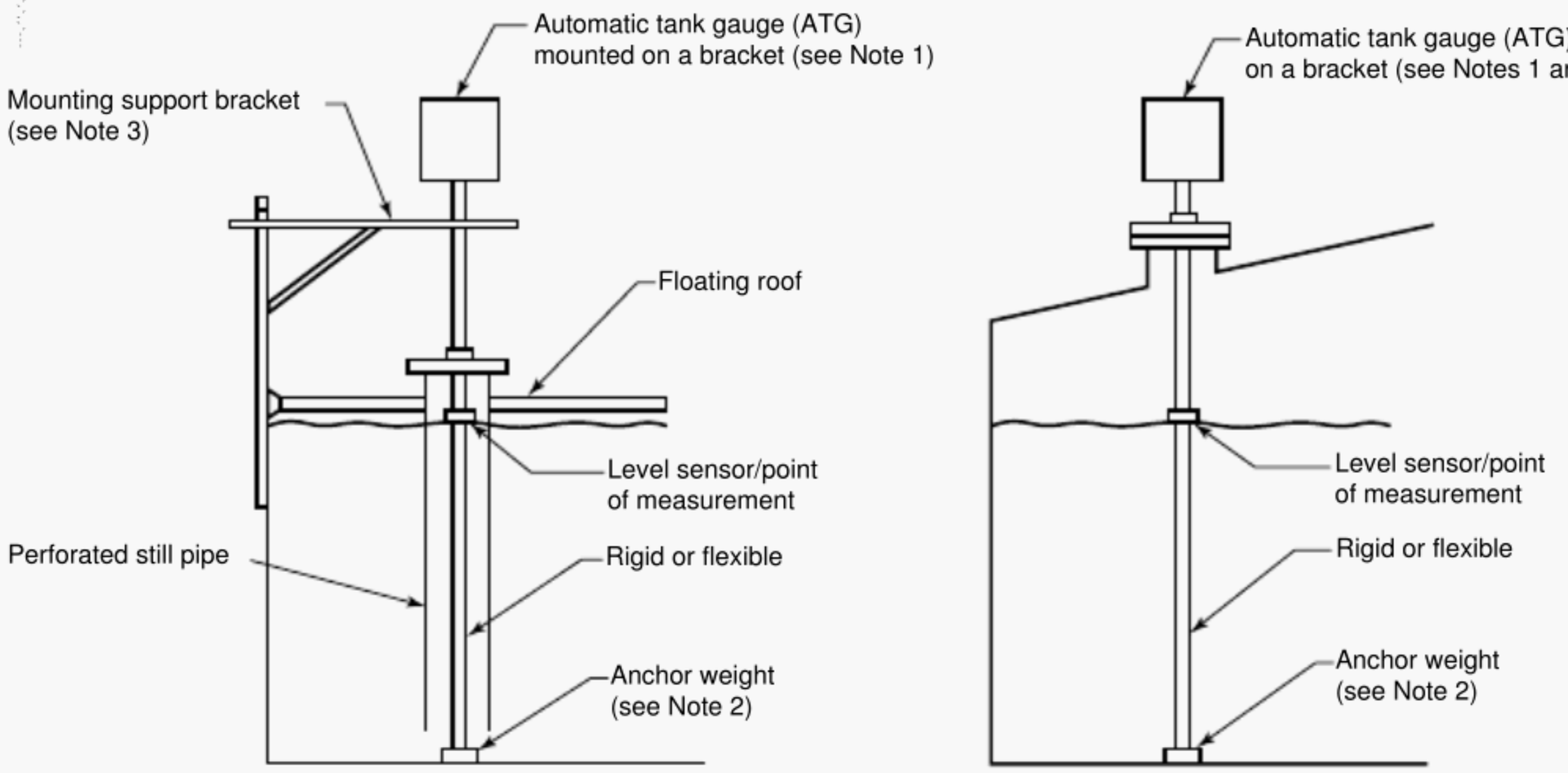
The still pipe may be supported on the bottom of the tank (Figure 1) or by a non-rigid trunnion or hinged bracket connected to the bottom course of the shell (Figure 2).

The upper end of the slotted still pipe and the sliding guide should be designed to allow vertical expansion of the still pipe when the tank shell bulges or moves vertically. The construction of the slotted still pipe and the top guide should not restrict vertical roof movement.

3.1B.4.5.7.2 Location of the Slotted Still Pipe

The slotted still pipe may be supported on the bottom of the tank, as shown Figures 1 and 2, if the tank bottom does not move in relation to the joint where the shell and bottom meet.

When a tank is filled, the bottom of the tank may be deflected upward by the angular deflection of the shell in the area immediately adjacent to the bottom joint. Further from the shell, the bottom is usually deflected downward. The



Notes:
1. A still pipe is often not required for innage-ATGs, especially in small tanks. Where a still pipe is provided for protection, for stability of mounting, and to minimize turbulence, it should be slotted (refer to this standard for more information on slotted still pipes).
2. Anchor weight or other means to secure and support the innage-ATG at the bottom should be provided.
3. When an innage-ATG is mounted on the fixed roof, mounting of the ATG should not be rigidly connected to the roof. The installation of the ATG should minimize or eliminate the effect of roof movement due to tank shell bulging, which is a result of liquid head stress.

Figure 4—Example Installation of Top-Mounted Innage-ATG on Fixed Roof or Floating Roof Tanks Without Still Pipe (This installation may not be suitable for Custody Transfer)

amount of deflection depends on the soil conditions and the foundation design. In most cases, the bulging of the shell ceases to cause bottom movement approximately 450–600 mm (18–24 inches) from the shell. For tank construction considerations, the centerline of the slotted still pipe should be located between 450 to 800 mm (18 and 30 inches) from the shell of the tank as shown in Figures l and 2.

After the tank has been hydrostatically tested, the slotted still pipe should remain vertical

3.1B.4.5.7.3 Nominal Diameter

The recommended minimum slotted still pipe diameter is 200 mm (8 inches). Smaller diameter still pipes may be used depending on the type and design of the ATGs used. If smaller diameter slotted still pipes are used, the design and construction should be checked for mechanical rigidity and strength. Larger diameter slotted still pipes may be required to accommodate larger level sensing elements for some types of ATGs.

3.1B.4.5.7.4 Depth

The slotted still pipe should extend within 300 mm (12 inches) of the bottom of the tank. The top of the slotted still pipe should be above the maximum liquid level.

3.1B.4.5.7.5 Slotted Still Pipes

The slotted still pipe should have one or two rows of slots or holes of about 25 mm (1 inch) width, on opposite sides and continuing above the maximum liquid level. The spacing between the slots or holes should be less than 150 mm (6 inches), or as recommended by the manufacturer of the A TG. The still pipe should be straight with internal burrs and welds removed. Evaporation losses will be reduced if the slots face parallel to the tank shell.

In certain locations, still pipes without slots ("solid" or "non-perforated") have been used to comply with local air pollution regulations. Solid still pipes can lead to serious errors in level and temperature measurements and may cause tank overfills. They should not be used for measurement. Alternatives to solid still pipes which meet air pollution regulations are available. Refer to MPMS Chapter 19.2.

3.1B.4.5.7.6 Datum Plates

Refer to MPMS Chapter 3.1A on manual tank gauging for details on installation of the datum plate.

3.1B.4.5.8 Mounting of ATGs

The ATG should be mounted securely to have minimal vertical movement with respect to the tank reference, which is the bottom corner or joint. The mounting should comply with manufacturer's instructions.

3.1B.4.6 REMOTE READOUT

3.1B.4.6.1 General

The manufacturers of ATGs also make associated electronics that convert the level information into an analog or digital electronic signal. The level resolution of the transmitted signal is typically 1 mm for Metric (SI) units or 1/16 inch for US Customary units.

Provisions for signal security and transient and surge protection are set forth in Section 3.1B10.

3.1B.5 General Procedures for Initial Setting and Initial Verification of ATGs in the Field

The initial setting is the procedure by which the A TG reading is set equal to the average tank level determined by reference manual level measurement (at a single level). The initial verification is the procedure that verifies or confirms that the installed accuracy of the A TG is appropriate for the intended service. It is performed by comparing the A TG against reference manual level measurements with the liquid at three different levels. The differences between the manual and the ATG readings should be evaluated.

3.1B.5.1 INITIAL REQUIREMENTS

Prior to initial setting or initial verification of a new or repaired ATG, the tank should be allowed to stand at a constant level long enough for air or vapor to be released from the liquid and for the tank bottom to reach a stable position as recommended in MPMS Chapter 2, "Tank Calibration." New tanks should be filled and allowed to stand to minimize the errors caused by initial bottom settlement. The tank mixer should be turned off long enough before adjustment to allow the liquid to come to rest. The tank should be run through at least one operational cycle, filling and emptying the tank within normal working limits of filling and discharge rate.

For electrostatic charge relaxation, refer to API Recommended Practice 2003.

3.1B.5.2 REFERENCE MANUAL LEVEL MEASUREMENT PROCEDURE

When an ATG is set to level or verified by comparison with reference manual level measurement, the manual measurements should be performed in accordance with MPMS Chapter 3.1A. Reference manual measurements should be performed by skilled operators.

3.1B.5.3 REFERENCE MEASUREMENT TAPE AND WEIGHT CERTIFICATION

The measurement tape and weight used for A TG setting or verification should be a reference master tape/weight (bob) combination certified by an accredited calibration laboratory and traceable to a national measurement standard, or a working tape/weight (bob) combination that has been recently compared with a certified reference tape and weight meeting the maximum permissible error limits specified in MPMS Chapter 3.1A. The calibration corrections for the tape/weight combination should be applied.

3.1B.5.4 EFFECT OF WEATHER

High winds, heavy rain, snow or severe storms may cause movements of the tank shell, the A TG mounting and/or the liquid surface. These movements can influence both manual and ATG readings. The effect on manual gauging may be different from that on the A TG. Setting and verification should not be carried out during high winds or severe storms.

3.1B.5.5 ATG TECHNOLOGY—SPECIFIC CONSIDERATIONS

There may be additional technology-specific considerations which can affect A TG verification. Specific, additional steps may be needed to prepare the A TG prior to the initial setting. Technology-specific considerations include, for example, the effect of physical and electrical properties of the liquid and vapor in the tank, the need of checking free-movement of the level sensor and other considerations. Refer to the ATG manufacturer's documentation.

3.1B.5.6 APPLICATION—SPECIFIC CONSIDERATIONS

In tanks storing heavy or viscous liquids (i.e., asphalt), it may be difficult to measure or verify the Reference Height. The procedures for measuring the Reference Height described in Section 3.1B.6 may not be applicable under these circumstances.

3.1B.6 Initial Setting of ATGs in the Field

3.1B.6.1 ULLAGE-BASED ATGS

a. With the tank contents static at a level between one third and two thirds full, record the stable ATG reading before the gauger arrives at the tank. Also record the ATG reading immediately before making the manual reference measurements. Check whether the presence of the gauger on the tank top affects the ATG reading. If the ATG reading varies by more than 1 mm ($\frac{1}{16}$ inch), investigate the cause and evaluate the impact before proceeding.

b. Measure the tank Reference Height at the official gauging access position until three consecutive measurements agree within a range of 1 mm ($\frac{1}{16}$ inch) or five consecutive measurements agree within a range of 3 mm ($\frac{1}{8}$ inch). Calculate the arithmetic average value for Reference Height (i.e., the average of the consecutive measurements) and compare with the calibration Reference Height. If the measured and calibration Reference Heights differ by more than 2 mm ($\frac{1}{8}$ inch), then difficulties may be experienced with the initial verification procedure. Investigate the cause before proceeding.

Note: This is not an inconsistency with other paragraphs, but is necessary to stay within the permissible tolerance.

c. Determine the reference manual ullage measurement of the tank contents from the same gauging access point (using the same measurement tape and weight) until three consecutive measurements agree within a range of 1 mm ($\frac{1}{16}$ inch) or five consecutive measurements agree within a range of 4 mm ($\frac{5}{16}$ inch). Calculate the arithmetic average value of the ullage measurement (i.e., the average of the consecutive measurements).

d. Determine the equivalent innage measurement by subtracting the average manual ullage measurement from the average measured tank Reference Height.

e. Record the ATG reading immediately after making the manual reference measurements and confirm that no change has occurred during the manual gauging. If the ATG reading has changed from that recorded during Step a, check that there has been no transfer either to or from the tank and that the tank valves are closed. Repeat the procedure from Step a.

f. Compare the ATG reading with the calculated equivalent innage measurement. If the two do not agree (within the resolution of the ATG), set the ATG so that it reads the same as the equivalent innage measurement.

3.1B.6.2 INNAGE-BASED ATGS

a. With the tank contents static at a level between one third and two thirds full, record the stable ATG reading before the gauger arrives at the tank. Also record the ATG reading immediately before making the manual reference measurements. Check whether the presence of the gauger on the tank top affects the ATG reading. If the ATG reading varies by more than 1 mm ($\frac{1}{16}$ inch), investigate the cause and evaluate the impact before proceeding.

b. Determine the level of the tank contents by reference manual innage measurements until three consecutive measurements agree within a range of 1 mm ($\frac{1}{16}$ inch) or five consecutive measurements agree within a range of 4 mm ($\frac{5}{16}$ inch).

c. Calculate the arithmetic average value of the innage measurement (i.e., the average of the consecutive measurements obtained in Step b.

d. Record the ATG reading immediately after making the manual reference innage measurements and confirm that no change has occurred during the manual gauging. If the ATG reading has changed from that recorded during Step a, check that there has been no transfer either to or from the tank and that the tank valves are closed. Repeat the procedure from Step a.

e. Compare the ATG reading with the average manual reference innage measurement. If the two do not agree (within the resolution of the ATG), set the ATG so that it reads the same as the average manual reference innage measurement.

3.1B.7 Initial Verification

3.1B.7.1 INTRODUCTION

Ullage-based ATGs are designed to measure the distance from the ATG reference point to the liquid surface. Some types of ullage-based ATG may be able to compensate for tank reference datum movement (where such movement has been quantified and found to be repeatable), but most traditional types of ullage based ATG cannot compensate for many of the accuracy limitations of tank level measurement described in Section 3.1B.4.3 of this standard.

Innage-based ATGs are designed to measure the liquid innage directly. They should be less prone to some of the tank stability problems that can cause level measurement errors with ullage-based ATGs, but they require the tank innage datum to be stable.

Apart from the effect of the stability of the ATG reference point and the manual gauging reference point on the accuracy of ATG and manual level measurements, several other factors may result in level measurement errors and should be considered during ATG verification. These include:

- Tank installation errors.
- Changes in operating conditions.
- Changes in physical properties of the liquid and/or vapor.

- Changes in electrical properties of the liquid and/or vapor.
- Changes in local ambient conditions.
- Manual gauging errors.
- Errors inherent in the ATG.

Following the initial setting of the ATG, its overall accuracy is verified by:

- Comparing the ATG against manual reference level measurement at three different levels and evaluating the differences between the ATG readings and the manual reference measurements.
- Measuring the tank Reference Height at each of the three levels and evaluating any change in tank Reference Height.

Depending on the results, the tank and ATG combination should be considered suitable for custody transfer or for inventory control purposes, if the applicable calibration/verification tolerances set forth in this standard are met.

3.1B.7.2 VERIFICATION CONDITIONS

The initial verification of an ATG requires measurement comparisons to be made with the liquid level within the regions of the tank corresponding to the upper, middle and lower thirds of the tank's working capacity. The middle level measurement may be the same one used during the initial setting procedure (Section 3.1B.6) or it may be repeated.

Verification comparisons should only be carried out under static conditions with no liquid being transferred to or from the tank.

The time interval between the verification measurement at the three different levels should be kept as short as practical.

3.1B.7.3 INITIAL VERIFICATION PROCEDURES

3.1B.7.3.1 Ullage-Based ATGs

a. After the initial setting of the ATG (Section 3.1B.6), a transfer should be made either to or from the tank so that the level is within either the upper or lower third of the tank working capacity (Section 3.1B.7.2).

b. Record the stable ATG reading before the gauger arrives at the tank. Also record the ATG reading immediately before making the manual reference measurements. Check whether the presence of the gauger on the tank top affects the ATG reading. If the ATG reading varies by more than 1 mm (inch), then investigate the cause before proceeding.

c. Measure the tank Reference Height at the official gauging access position until three consecutive measurements agree within a range of 1 mm (inch) or five consecutive measurements agree within a range of 3 mm (inch). Calculate the arithmetic average value for the tank Reference Height (i.e., the average of the qualified, consecutive measurements which agree within the specified tolerance) without rounding and compare with the calibration Reference Height. If the measured and calibration Reference Heights differ by more than mm inch), then investigate the cause before proceeding.

d. Determine the reference manual ullage measurement of the tank contents from the same gauging access point (using the same measurement tape and weight) until five consecutive measurements within a range of 4 mm (inch).

Note: A failure to achieve manual measurements within these tolerances may be due to adverse weather conditions, movement of the liquid surface, or inconsistencies in the measurement technique. The verification procedure should be repeated after corrective action has been taken.

e. Calculate the arithmetic average value of the ullage (i.e., the average of the qualified, consecutive measurements which agree within the specified tolerance). Do not round this result.

f. Determine the equivalent innage measurement by subtracting the average manual ullage from the average measured tank Reference Height. Do not round this result.

g. Record the ATG reading immediately after making the manual reference measurements and confirm that no change has occurred during the manual gauging. If the ATG reading has changed from that recorded during Step b, check that there has been no transfer either to or from the tank and that the tank valves are closed. Repeat the procedure from Step b.

h. Compare the ATG reading with the calculated equivalent innage measurement. The difference between these two measurements is referred to as the "Test Difference."

i. Arrange for another transfer to or from the tank so that the liquid level is within the other third of the tank's working capacity and repeat Steps b through h to determine the Test Difference at this level.

3.1B.7.3.2 Innage-Based ATGs

a. After the initial setting of the ATG (Section 3.1B.6), a transfer should be made either to or from the tank so that the level is within either the upper or lower third of the tanks working capacity (Section 3.1B.7.2).

b. Record the stable ATG reading before the gauger arrives at the tank. Also record the ATG reading immediately before making the manual reference measurements. Check whether the presence of the gauger on the tank top affects the ATG reading. If the ATG reading varies by more than 1 mm (inch), investigate the cause before proceeding.

c. Determine the reference manual innage measurement of the tank contents from the same gauging access point (using

the same measurement tape and weight) until three consecutive measurements agree within a range of 1 mm (1/16 inch) or five consecutive measurements agree within a range of 4 mm (3/16 inch).

Note: A failure to achieve manual measurements within these tolerances may be due to adverse weather conditions, movement of the liquid surface or inconsistencies in the measurement technique. The verification procedure should be repeated after corrective action has been taken.

d. Calculate the arithmetic average value of the innage measurement (i.e., the average of the qualified, consecutive measurements which agree within the specified tolerance). Do not round this result.

e. Record the ATG reading immediately after making the manual reference measurements and confirm that no change has occurred during the manual gauging. If the ATG reading has changed from that recorded during Step b, check that there has been no transfer either to or from the tank and that the tank valves are closed. Repeat the procedure from Step b.

f. Compare the ATG reading with the average manual innage measurement. The difference between these two measurements is referred to as the "Test Difference."

g. Arrange for another transfer to or from the tank so that the liquid level is within the other third of the tank's working capacity and repeat Steps b through f to determine the Test Difference at this level.

3.1B.7.3.3 Verification Tolerance for ATGs in Custody Transfer or Inventory Control

3.1B.7.3.3.1 General

The purpose of the custody transfer verification is to ensure that the ATG, as installed, can sense and indicate level over its measuring range as accurately as properly performed reference manual tank level measurement.

The purpose of the inventory control verification is to ensure that the ATG, as installed, can sense and indicate level over its measuring range to somewhat lower accuracy than properly performed reference manual tank level measurement.

Inventory control has less rigorous accuracy requirements than custody transfer. Since inventory control is largely for internal use, the user can substitute more or less rigorous requirements.

Where loss-control or inventory accounting balances require it, the maximum inventory control ATG tolerance should be reduced to less than 25 mm (1 inch). The final maximum accuracy should be established by the user to meet his internal requirements.

3.1B.7.3.3.2 Tolerance for ATGs in Custody Transfer Application

If the Test Difference is not greater than 4 mm (3/16 inch) at any of the three test levels, the ATG should be considered to be suitable for custody transfer.

3.1B.7.3.3.3 Tolerance for ATGs in Inventory Control Application

If the Test Difference is not greater than 25 mm (1 inch) at any of the three test levels, the ATG should be considered to be suitable for inventory control.

3.1B.7.3.3.4 ATGs Found Out of Tolerance

If the test difference exceeds the limits for the proposed application at any of the three test levels, check for the stability of the manual gauging reference point and for possible problems with the ATG installation.

3.1B.8 Record Keeping

Full records should be kept of the initial setting, initial verification, and subsequent verification of each ATG used. Records of maintenance work should be kept.

3.1B.9 Subsequent Verification of ATGs for Custody Transfer or Inventory Control

3.1B.9.1 GENERAL

A verification program should be established for ATGs used for custody transfer or inventory control. Use of statistical quality control methods to monitor the performance of ATGs are recommended, especially for ATGs in Custody Transfer applications.

3.1B.9.2 FREQUENCY OF SUBSEQUENT VERIFICATION

ATGs used for either custody transfer or inventory control should be verified on a regular basis. The liquid level where the ATG is verified should be randomly chosen and should be within the normal opening and closing gauge readings of the tank.

3.1B.9.2.1 ATGs in Custody Transfer Application

ATGs used in custody transfer service should be inspected and its accuracy verified at a single level at least once per month.

3.1B.9.2.2 ATGs in Inventory Control Application

ATGs used in inventory control service should be inspected and its accuracy verified at a single level 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.

3.1B.9.3 PROCEDURE FOR SUBSEQUENT VERIFICATION

3.1B.9.3.1 ATGs in Custody Transfer Application

For ATGs used in custody transfer service, the initial verification procedures in Section 3.1B.7 should be followed, except that the ATG accuracy is verified at a randomly chosen single level close to normal opening and closing gauge reading (i.e., liquid level).

3.1B.9.3.2 ATGs in Inventory Control Application

For ATGs used in inventory control service, the initial verification procedure in Section 3.1B.7 should be followed, except that the ATG accuracy is verified at a randomly chosen single level close to normal opening and closing gauge reading.

3.1B.9.4 TOLERANCE FOR SUBSEQUENT VERIFICATION

For ATGs used in custody transfer service, the Test Difference described in Section 3.1B.7.3.3, 4 mm ($\frac{5}{16}$ inch) should be used as the tolerance. If this tolerance is met, the ATG should be considered within calibration and suitable for custody transfer.

For ATGs used in inventory control service, Test Difference described in Section 3.1B.7.3.3, 25 mm (1 inch) should be used as the tolerance. If this tolerance is met, the ATG should be considered within calibration and suitable for inventory control.

3.1B.10 Data Communication and Receiving

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

The ATG system should be designed and installed such that the data transmission and receiving unit should:

a. 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 ±1 mm ($\frac{1}{16}$ inch);

b. not compromise the resolution of the measurement output signal;

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

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

e. be electromagnetically immune.

APPENDIX A—SAFETY PRECAUTIONS: PHYSICAL CHARACTERISTICS AND FIRE CONSIDERATIONS

Personnel involved with handling petroleum-related substances and other chemical materials should be familiar with the materials' physical and chemical characteristics, including potential for fire, explosion, and reactivity and appropriate emergency procedures. These personnel should comply with safe operating practices of the individual company and local, state and federal regulations, including use of proper protective clothing and equipment. Personnel should be alert to potential sources of ignition and should keep containers of materials closed when not in use.

Note: Information regarding particular materials and conditions should be obtained from the employer, manufacturer, or supplier of that material, or the material safety data sheet.

APPENDIX B—ACCURACY REQUIREMENTS FOR ATGS
(See Note)

Requirement	Custody Transfer	Inventory
Factory calibration	1 mm (1/16 inch)	3 mm (1/8 inch)
Effect of installation	3 mm (1/8 inch)	n.a.
Initial verification	4 mm (3/16 inch)	25 mm (1 inch)
Subsequent verification	4 mm (3/16 inch)	25 mm (1 inch)
Frequency of verification	monthly	quarterly

Note: This table is for reference only. Please refer to the entire document.

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1220 L Street, Northwest
Washington, D.C. 20005-4070
202-682-8000

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