Manual of Petroleum Measurement Standards Chapter 3—Tank Gauging

Section 4—Standard Practice for Level Measurement of Liquid Hydrocarbons on Marine Vessels By Automatic Tank Gauging

FIRST EDITION, APRIL 1995
REAFFIRMED, FEBRUARY 2006

American Petroleum Institute

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Measurement Coordination

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FOREWORD

This publication covers standard practice for level measurement of liquid hydrocarbons on marine vessels 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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Chapter 3—Tank Gauging

SECTION 4—STANDARD PRACTICE FOR LEVEL MEASUREMENT OF LIQUID HYDROCARBONS ON MARINE VESSELS BY AUTOMATIC TANK GAUGING

1 Scope

This standard provides guidance on the selection, installation, calibration, and verification of automatic tank gauges (ATGs) for measuring the level of liquid hydrocarbons having a Reid vapor pressure less than 15 pounds per square inch absolute (103 kPa), transported aboard marine vessels (tankers and barges).

Marine ATGs are not normally used in custody transfers because of the limitations described in Appendix A. However, level measurement by marine ATGs may be used in custody transfer when no other alternative measurement is available. The use of marine vessel-based ATGs for custody transfer normally requires mutual contractual agreement between the buyer and the seller and may be subject to government regulations.

This standard also provides guidance on the requirements for data collection, transmission, and receiving. The Appendix B briefly describes the operation of the most commonly used marine ATG equipment.

This standard is not applicable to the following subjects:

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

Safety and material compatibility precautions shall be taken when using marine ATG equipment. The manufacturer's recommendations on the use and installation of the ATG equipment should be followed. Users shall comply with all applicable national and international codes and regulations.

2 References

2.1 STANDARDS

Unless otherwise specified, the most recent editions or revisions of the following standards 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 2.8B, "Recommended Practice for the establishment of the Location of the Reference Gauge Point and the Gauge Height of Tanks on Marine Tank Vessels" *(in press)*
Chapter 3, "Tank Gauging"
Chapter 3.1A, "Standard Practice for Manual Gauging of Petroleum and Petroleum Products in Stationary Tanks"
Chapter 7, "Temperature Determination"
Chapter 8, "Sampling"
Chapter 9, "Density Determination"
Chapter 10, "Sediment and Water"
Chapter 17, "Marine Measurement"
Chapter 17.2, "Measurement of Cargoes on Board Tank Vessels"

2.2 OTHER REFERENCES

DOT[1]
33 *Code of Federal Regulations* Part 153.
46 *Code of Federal Regulations* Part 39.20
Guide for Electrical Installations on Merchant Vessels and Mobile Offshore Drilling Units

IMO[2]
International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code)
Chapter 13.1, *Gauging*

OCIMF[3]
International Safety Guide for Oil Tankers and Terminals

3 General

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

3.1 SAFETY PRECAUTIONS

The following safety codes and regulations shall be followed:

a. International Maritime Organization (IMO)—*International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk* (IBC Code) and IMO Chapter 13.1, *Gauging*.

[1]The *Code of Federal Regulations* is available from the U.S. Government Printing Office, Washington, D.C. 20402.
[2]International Maritime Organization, London, England.
[3]Oil Companies International Marine Forum, Portland House, Stag Place, London SW1E SBH, England.

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b. *International Safety Guide for Oil Tankers and Terminals (*ISGOTT).
c. U.S. Coast Guard (USCG) regulation—Title 33 of the *Code of Federal Regulations*, Part 153.
d. U.S. Coast Guard regulation—Title 46 of the *Code of Federal Regulations*, Part 39.20.
e. U.S. Coast Guard Marine Safety Center NVIC 2-*89 Basic Guidance for Electrical Installations on Merchant Vessels*.

Other applicable safety codes and regulations shall be complied with.

3.1.1 Tank Entry

Whenever a tank that has contained hydrocarbon liquids, vapors, or toxic material is entered, regulations on entry to confined spaces shall be followed.

3.1.2 Electrical Safety

Marine ATGs shall be specified and installed in accordance with the appropriate national [Underwriter's Laboratory (UL), Factory Mutual (FM), Federal Communications Commission (FCC), and so forth] and/or international [International Maritime Organization (IMO), International Electrotechnical Commission (IEC), Committee for Electrotechnical Standardization (CENELEC), International Organization for Standardization (ISO), and so forth] marine electrical safety standards.

3.1.3 Maintenance

All marine ATG equipment shall be maintained in safe operating condition. The manufacturer's maintenance instructions should be complied with.

3.1.4 Environment

All marine ATGs shall be capable of withstanding the pressure, temperature, and other environmental conditions likely to be encountered in marine service. When an ATG is installed in a corrosive service, any parts exposed to the liquid or vapors shall be of durable, corrosion-resistant construction.

3.1.5 Sealing

All ATGs shall be sealed to withstand the vapor pressure of liquid in the tank. ATGs mounted on vessels with an inert gas system (IGS) shall be designed to withstand the operating pressure of the IGS.

3.2 GENERAL PRECAUTIONS

The following general precautions affect the accuracy and performance of all types of marine ATGs. They shall be observed where they are applicable.

3.2.1 Speed of Response

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

3.2.2 Protection from Mechanical Damage

Marine ATGs should be designed to withstand damage caused by waves in the tanks due to ship movement. They should also be able to withstand damage from high velocity jets of water or oil used to wash the tanks.

Note 1: This protection may require mounting the ATGs in slotted still pipes.
Note 2: Alternately, this protection may require that the ATG float or displacer be raised to a *store* position when it is not being used. Note that such ATGs cannot be used during tank washing.

3.2.3 Manual Gauging

When an ATG is checked or calibrated by manual gauging, the manual gauging should be performed in accordance with API Chapter 3.1A.

3.2.4 Minimum Measurable Level

The ATG should be able to measure levels as near to the bottom of the tank as possible. This may require the provision of a sump in the tank bottom in vessels with double bottoms.

Note: The minimum measurable level of certain types of ATGs may limit their ability to measure small volumes remaining on board (ROB) and/or on-board quantities (OBQ).

3.2.5 Trim and List

For best accuracy, the vessel should be on an even keel and upright. In situations where both trim and list exist, every effort should be made to eliminate at least one condition, preferably list.

Trim and list corrections are not required on vessel tanks of cuboid shape, provided that the ATG is located at the geometric center of the deck area for the tank. Where the ATG is not so located, correction will be required. On vessel tanks that have curvature(s), such as the aft and forward wing tanks, trim and list corrections are recommended. Corrections for trim, list, and wedge is permissible by table or calculation, using the procedure set forth in API Chapter 17.

3.2.6 Product Temperatures

Product temperature should be measured at the same time as the tank level is measured. The temperature should be representative of the tank contents and should be measured in accordance with API Chapter 7.

3.2.7 Compatibility

All parts of the ATG in contact with the product should be compatible with the product, to avoid both product contam-

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ination and ATG corrosion. The ATG should be designed to meet its intended operating conditions.

3.2.8 Entrained Air and Vapors

Sufficient time should be allowed before gauging a tank to permit the liquid to free itself of entrained air or gas vapors.

3.2.9 Vessel Motion

During lightering or offshore operation or when the vessel is at an exposed berth, vessel motion causes waves on the surface of the product. At least three readings should be taken in minimum time and the readings should be averaged. If the vessel is in heavy motion due to large swells or waves, at least five readings should be taken in minimum time. Refer to API Chapter 3.1A.

Note: Some ATGs provide internal filtering algorithms as part of the readout to average the level readings over a time interval. The filtering time can be fixed or made adaptive to the encountered motion.

3.2.10 Use of Marine ATGs in Custody Transfer

Marine ATGs are not normally used in custody transfers because of the limitations described in Appendix A. However, level measurement by marine ATGs may be used in custody transfer when no other alternative measurement is available. The use of marine vessel-based ATGs for custody transfer normally requires a mutual contractual agreement between the buyer and the seller and may be subject to government regulations.

4 Installation of Marine ATGs

Marine ATGs should be installed in accordance with the ATG manufacturer's instructions.

4.1 LOCATION OF THE ATG

The ATG should be located to minimize the effect of surface turbulence and waves in the tanks. The location should be designed to avoid damage during tank washing. Mechanical, float-operated ATGs that cannot withstand waves or tank washing should be provided with the ability to *store* the float when the ATG is not in use.

For vessel tanks of cuboid shape, the ATG should be located at the geometric center of the tank, which usually eliminates the need for trim and list corrections. On vessel tanks that have curvature side(s), such as the aft and forward wing tanks, the ATG should be located nearer to the inboard bulkhead to avoid interference with the curvature of the vessel's tank bottom. For further information on reference gauge point location, see API Chapter 2.8B *(in press)*.

Presently, the combination of vessel design and ATG technology limits the use of ATGs to the measurement of partially or fully loaded vessels. Therefore, a second measurement location is required to accommodate the measurement of small volumes (ROB/OBQ). This second location can be for a manual gauge or a portable gauging device. This second gauge point location must be located at the end of the tank, in the normal direction of trim and should be far enough away from the bulkhead to avoid interference when gauging.

Note: On vessels that are fitted with ATGs and a second means of measurement, the gauge point for the second measurement location should have the same reference height (otherwise correction will be required) as well as be located in line longitudinally (forward to aft) with the ATG. This alignment allows for calibration of the ATG to manual gauges.

4.2 LOCATION OF MANUAL CALIBRATION CHECK POINT

To permit accurate comparison between manual gauging and automatic tank gauging, a manual calibration check point should be provided close (within 3 feet or 1 meter) to the ATG.

4.3 GAUGING OF INERTED TANKS

On tanks with an inert gas system (IGS), the ATG should be designed and installed so that it can be maintained and calibrated without depressurizing the IGS.

5 Calibration, Adjustment, and Verification of Marine ATGs

5.1 FACTORY CALIBRATION

Marine ATGs should be calibrated at the factory against a manual gauging tape or reference certified by the National Institute of Standards and Technology (NIST) or other appropriate national standards organizations. The ATGs should be calibrated to agree with the reference to within $\pm$⅛ inch (3 millimeters) at a minimum of three points covering its intended operating range under reference conditions.

5.2 INITIAL SHIPYARD ADJUSTMENT

Shipyard adjustment procedures should be in accordance with the ATG manufacturer's instructions. Shipyard adjustment normally consists of adjusting the ATG so that it reads correctly at the minimum level and at the setting point where the zero adjustment took place. The distances from the zero adjustment point to the zero point for the tank capacity table should be referenced.

The shipyard adjustment should confirm that the remote readout reads the same level (within $\pm$1/16 inch or 1 millimeter) as the level transmitter (if the ATG is provided with a local deck readout).

5.3 CHECK FOR SMOOTH OPERATION OF FLOAT GAUGES

After mounting ATGs that use floats (float-operated, inductive, or reed switch/voltage divider ATGs) and prior to

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calibration, the tape, the cable, and the connecting elements should be centered.

Float travel through the normal range from top to bottom of the tank should be smooth and free, with no binding or friction.

The tape, cable, guide pulleys, gauge head, and all components of float-operated ATGs should be checked by manually moving the tape or cable through the entire range to assure free operation. This check should be done slowly to simulate actual operation and to avoid damaging the ATG.

5.4 VERIFICATION BY INNAGE OR OUTAGE GAUGING

ATGs that measure outage level from the top down should be field calibrated by manual outage gauging. ATGs that measure innage level from the bottom up should be verified by manual innage gauging.

5.5 INITIAL VERIFICATION

After leaving the shipyard and before the maiden voyage, most vessels fill certain tanks with water to check the operation of the vessel's pumps, valves, and lines.

During this initial tank filling, the calibration of the ATGs should be checked against manual tank gauging performed in accordance with API Chapter 3.1A.

5.6 SUBSEQUENT VERIFICATION

Verification is designed to be carried out to confirm that the ATG is properly calibrated. After completion of cargo loading at a load port and prior to discharge at a discharge port, normal practice is to check the reading of the ATG against manual tank gauging. The manual gauging levels are normally used for the cargo reports.

To minimize the effect of vessel motion and adverse external conditions, verification should be performed with stable liquid level. The liquid level at which the ATG is verified should be within the intended operating range of the ATG.

Note: Where the reference gauge point for manual gauging is different from the ATG, apply the appropriate correction. Refer to API Chapter 3.1A.

5.6.1 Agreement between ATG reading and manual gauge reading

If the reading by ATG and the reading by manual gauging agree within ¼ inch (6 millimeters), no further action should be required.

5.6.2 Use of average gauge readings

If the reading by ATG and the reading by manual gauging differ by more than ¼ inch (6 millimeters), the ATG reading and the manual gauging should be repeated three times (or five times if there are waves in the tank) in accordance with API Chapter 3.1A. The average of the manual gauge readings and the ATG readings should be compared. For best accuracy, the vessel should be on an even keel and upright. In situations where both trim and list exist, every effort should be made to eliminate at least one condition, preferably list.

5.6.3 Adjustment of the ATG

If the difference between the average ATG reading and the average of the manual gauge reading exceeds ¼ inch (6 millimeters), the ATG should be adjusted to agree with manual gauging. These adjustments and the reasons for them should be recorded in the vessel's equipment maintenance log.

After adjustment, the ATG reading should be compared with manual gauge reading in accordance with the procedure described in 5.6.2. If the difference between the average ATG reading and the average manual gauge reading is less than ¼ inch (6 millimeters), no further action should be required.

If the ATG cannot be adjusted to agree with the average manual gauge reading, a correction may be used. The correction value should be posted near the ATG readout and used to correct the ATG reading. This correction should be documented by the vessel.

5.7 SCHEDULE FOR REGULAR ATG VERIFICATION

Vessels that do not routinely confirm ATG accuracy by comparison with manual gauging should perform the verification on a quarterly basis as a minimum.

5.8 ATG VERIFICATION RECORDS

ATG verification records should be documented and the record should be ready for inspection by involved parties. The records should be kept for a minimum period of one year.

6 Readout

6.1 GENERAL

The manufacturers of marine ATGs also make level transmitters that convert the level data into a signal for transmission purposes.

6.1.1 Resolution

The level resolution of the transmitter signal should typically be 1/16 inch (1 millimeter) for metric reading gauges.

6.1.2 Wiring

The wiring and the digital signals are proprietary to each ATG manufacturer. Provisions for signal security and transient/surge protection should meet or exceed the requirements set forth in Section 7 of this standard.

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6.1.3 Remote Readout

As a minimum, the remote readout by the receiver unit should meet the requirements set forth in Section 7 of this standard.

6.2 TRANSMITTER INSTALLATION

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

7 Requirements for Data Transmission and Receiving

7.1 GENERAL

The requirements for data transmission and receiving vary with the type and the make of the ATG equipment. The manufacturer's recommendations should be followed. Additional requirements may have to be met to provide proper security and protection of the measured data. Further, the installation should conform to all applicable national and international codes and regulations.

7.2 DATA TRANSMISSION

7.2.1 Interference from the AC Power Wiring

All AC power wiring should be run with at least 3 feet (1 meter) of separation from the signal wiring. Most ATG systems do not require electromagnetic shielding of the power wiring if current is less than 10 amps.

7.2.2 Radio Frequency Interference

Particular attention should be given to avoid radio frequency (RF) interference. Cable shielding and cable routing should be designed to minimize RF interference. Filtering may be required for equipment inputs.

7.2.3 Signal Wiring

Depending on the data transmission technology that the ATG uses, signals may be transmitted in pairs of twisted, shielded conductors in an insulated multi-pair cable installed in conduit. The line resistance should be calculated to ensure that it is less than the maximum resistance specified by the ATG manufacturer. Alternatively, signals may be transmitted via other media (for example, fiber optics, coaxial cables) as recommended by the manufacturers.

7.2.4 Grounding

Proper grounding is important to protect the ATG equipment from damage due to transients or surges, which can result in loss of measurement data. Grounding requirements vary by type and make of the ATG equipment. Manufacturer's recommendations should be followed explicitly.

7.2.5 Wiring Shields

The wiring shields may be made of copper, aluminum, or steel in accordance with manufacturer's recommendations. The overall shielding should be bonded together at all junction boxes and properly grounded to either a power line grounded neutral or a deck structure ground reference point.

7.2.6 Signal to Noise Ratio

The requirements covered in 7.2.2 to 7.2.4 should be followed to provide immunity to noise pick-up.

7.3 RECEIVING UNIT

7.3.1 General

The receiving unit is usually located in the ship's cargo control room. Its functions may include the following:

a. Scans all tanks monitored by the ATG system in a manner that meets the data acquisition requirements. Displays all variables (for example, level, temperature, gravity/density, inert gas pressure, as appropriate) on a real-time basis.
b. Accepts manual inputs, such as for gravity and S & W, as needed.
c. Alarms for such variables as high and low levels.
d. Contains the ship's tank calibration tables, volume correction table(s), trim and list tables, and all constants required in the measurement in these table(s).
e. Performs and/or displays computations and calculates quantities, such as gross and net volumes, transfers rates and quantities, tank inventories, and so forth.
f. Performs data validity checks and alerts the operator if errors are detected.

7.4 TRANSIENT AND LIGHTNING PROTECTION

7.4.1 Definition of Transient

The term *transient* used in this standard refers to high-voltage, fast rising, lower-energy pulses. The disturbances caused by transients usually have a duration of 0.2 seconds.

7.4.2 Protection Against Transients and Lightning

Transient and lightning protection should be provided, in accordance with applicable industry standards, to protect the transmitter and to provide secure transmission of the measurement data. The shields and proper grounding described in 7.2 often provide adequate protection. However, the manufacturer's recommendations should be followed if they are more restrictive.

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APPENDIX A—ACCURACY LIMITATIONS OF MARINE LEVEL AND VOLUME MEASUREMENTS

The contents of this appendix are intended for information on marine measurement. The contents are tutorial and are not considered to be requirements or recommendations.

A.1 ACCURACY LIMITATIONS OF MARINE LEVEL MEASUREMENTS

Level measurements using marine ATGs are limited by the following inherent limitations, regardless of the automatic tank gauge (ATG) used:

a. Measurement of small volumes (ROB or OBQ): The measurement of small volumes of ROB and OBQ by an ATG can be difficult.

b. Accurate determination of trim and list:

1. The accurate determination of trim and list is difficult and the trim and list corrections affect the accuracy of the marine level measurement.
2. If an automatic correction for trim and/or list is provided as part of the ATG readout, the correction should be used in accordance with API Chapter 17.2.

c. Effect of vessel motion causing waves in the tanks:

1. The waves in the tanks make it difficult to measure an average level. Many ATGs read the instantaneous level at the point of measurement, whereas manual level gauging tends to measure the height of the wave crests, making calibration of ATGs difficult when waves are present in the tanks.
2. Some ATGs provide internal filtering algorithms as part of the readout to average the level readings over a time interval. The filtering time can be fixed or made adaptive to the encountered motion.

d. Change of the tank dimensions due to oil or water temperature: The dimensions of a vessel's tanks change with water and oil temperature and other factors. This affects the conversion from tank level to volume. The change in the vertical tank dimension also changes the reference height that affects the level accuracy of ATGs that are mounted to the top deck structure.

e. Change of the tank dimensions due to hog or sag: Hogging or sagging changes the reference height that affects the level accuracy of ATGs that are mounted to the top deck structure.

A.2 ACCURACY LIMITATIONS OF MARINE VOLUME MEASUREMENTS

Volume measurement based on level on board marine vessels is affected by the following limitations that are inherent in marine measurement:

a. Tank capacity table accuracy: Some vessel capacity tables are accurate with nearly empty or nearly full tanks but contain significant errors for partially full tanks.

b. Clingage: Clingage is the liquid film that adheres to the inside walls (tank bulkheads) when the tank is emptied. Clingage does not affect the level measurement but may affect the transferred volume.

c. Sediment and water (S & W) and free water: The marine measurement of crude oil involves the measurement of both oil and water. The measured S & W and free water is deducted from the gross volume. An accurate S & W measurement requires accurate sampling, sample handling, and laboratory analysis. An accurate free water determination is difficult, particularly, the free water in the slop tank.

d. Temperature measurement: Temperature differences may exist because the tank bulkheads may be in contact with the ocean, making it difficult to determine an accurate average cargo temperature.

e. Contents of the vessel's lines: The volume of transferred liquid is affected by the volumes of liquid in the vessel's lines and pumps. An accurate measurement requires that these volumes be measured before and after the cargo transfer.

f. Vessel Experience Factor: The determination of vessel experience factor (VEF) from marine ATGs and from manual measurement may be different.

The limitations listed above may have a significant impact on the overall accuracy of volumes determined by marine manual tank gauging and by all types of marine automatic tank gauging.

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APPENDIX B—DESCRIPTION OF VARIOUS ATGS IN COMMON USE

B.1 STATEMENT OF PURPOSE

The following sections describe six different types of marine ATGs currently in common use. This is not intended to be a complete listing of the technologies that are available for marine automatic tank level measurement. The inclusion of the technologies described in this appendix should not be construed as endorsement by API.

This appendix is a tutorial that describes the principle of operation, typical installation methods, and specific requirements (in addition to those common to all marine ATGs). The information in this appendix is for use as a reference.

B.2 FLOAT-OPERATED AUTOMATIC TANK GAUGES

Float-operated ATGs are instruments that continuously measure liquid outage levels mechanically, using a float connected to a mechanical level indicator.

The float is guided by guide wires or cables. The float is connected by a perforated tape to the gauge head mechanism. The gauge head includes a take-up pulley that winds up or runs out the tape as the float moves up or down on the oil surface.

The take-up pulley keeps the tape under tension with a negator-spring, which compensates for the weight of the tape that is run out. The gauge head includes a display of the tank level, mechanically driven by the take-up pulley. The normal display is innage, but for heavy viscous products it may be outage.

Float-operated ATGs are not designed to withstand tank washing or the wave action in the tanks caused by vessel motion. The gauge head includes a crank to raise the float to a *store* position when the ATG is not in use.

B.3 RADAR TANK LEVEL GAUGES

Radar ATGs measure outage level by measuring the time taken for a free space propagated radar wave to go from the antenna on the top of the tank to the liquid surface and back again. The method depends on the stable velocity of radar waves in spite of different atmospheric conditions encountered in marine vessel tanks.

Typically, a deck-mounted radar ATG includes a radar transmitter, a radar antenna with a narrow vertical beam, a radar receiver, and signal processing and communication electronics. Only the fixed antenna structure is located in the tank environment.

Radar ATGs require a certain minimum free space for the narrow vertical radar beam directed into the tank. The manufacturer's recommendations concerning the influence of internal pipes and tank walls should be followed.

Radar ATGs are capable of operating during tank washing and are not damaged by waves in the tank.

B.4 HYDROSTATIC TANK GAUGES (HTGS)

Marine hydrostatic tank gauges (HTGs) use precision pressure and temperature sensors. Three pressure sensors are normally used for an HTG. One sensor is located at the bottom of the tank. A second, upper pressure sensor, is located between 50 and 80 percent of tank height. A top sensor measures inert gas pressure.

When the liquid level is below the upper sensor, the primary measurement is the liquid head that is measured by the bottom sensor. When the liquid level is above the upper sensor, this sensor is used for the primary measurement.

The difference between the readings of the bottom and the upper sensor allows calculation of liquid density. When the liquid level is between the bottom and the upper sensor, the system uses the previously measured density (or input density) to calculate level. The tank innage level is calculated from the liquid head and the density.

The sensors are usually installed on the after bulkhead because most vessels finish discharging with stern trim.
HTGs are capable of operating during tank washing and are not damaged by waves in the tank.

B.5 INDUCTIVE TANK LEVEL GAUGES

Inductive ATGs measure innage level using a measurement element that extends from the bottom to the top of the tank. A float is free to travel up and down the measurement element. The measurement element generates a digital level signal by inductive interaction with a transponder in the float. The measurement element consists of a number of conductors running the full length of the element and terminating in a digital transmitter. An excitation loop provides an inductive power source for the transponder in the float.

During the time period when the excitation loop is unpowered, the transponder electro-magnetically induces a low voltage into the coded conductors at the point of level measurement. By scanning each conductor, the transmitter determines the exact location of the float and transponder and hence the level.

Inductive ATGs are capable of operating during tank washing and are not damaged by waves in the tank.

B.6 RESISTANCE—TAPE TANK LEVEL GAUGES

Resistance-tape ATGs measure outage level using a measuring cable that extends from the top to the bottom of each tank. The cable contains an element that converts distance along its length into ohmic resistance. The sensor core is an insulated, stainless steel strip with a gold contact on one side. A nichrome helix is wound around the core. A polytetrafluoroethylene (PTFE) (or similar material) jacket encloses the assembly.

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Liquid pressure acting on the outer jacket forces the helix turns to short against the gold contact stripe from just below the liquid surface down to the sensor bottom end. As level varies, the length of unshorted resistance helix above the liquid forms an outage resistance that represents directly the distance from the sensor top down to the liquid surface.

The resistance-tape ATGs are usually suspended from above deck within 2 or 3 inch diameter still pipes. They can be inserted or removed without tank entry, and their outputs can be averaged to read level in the presence of waves.

Resistance ATGs are capable of operating during tank washing and are not damaged by waves in the tank.

B.7 REED SWITCH-VOLTAGE-DIVIDER TANK LEVEL GAUGE

Reed switch-voltage-divider ATGs measure innage level using a measuring cable that extends from the bottom to the top of the tank. The cable utilizes magnetic reed switches tapped into the voltage divider at regular intervals. A float containing a magnet travels up and down the cable and operates the reed switches as the level changes. The reed switches are connected to a transmitter and a remote receiver that indicates level.

Reed switch-voltage-divider ATGs are capable of operating during tank washing and are not damaged by waves in the tank if the measuring cable is installed in a protective pipe.

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