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Refrigerated hydrocarbon and non-petroleum based liquefied gaseous fuels — General requirements for automatic tank gauges —

Part 3: Automatic tank gauges for liquefied petroleum and chemical gases on board marine carriers and floating storage

Hydrocarbures réfrigérés et combustibles gazeux liquéfiés à base non pétrolière — Exigences générales pour jauges de réservoir automatiques —

Partie 3: Jauges de réservoir automatiques pour pétrole liquéfié et gaz chimiques à bord des transporteurs de cargaison en mer et des stocks flottants

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 18132-3 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Subcommittee SC 5, *Measurement of refrigerated hydrocarbon and non-petroleum based liquefied gaseous fuels*.

This first edition of ISO 18132-3, together with ISO 18132-1:2011, cancels and replaces ISO 18132-1:2006, which has been technically revised.

ISO 18132 consists of the following parts, under the general title *Refrigerated hydrocarbon and non-petroleum based liquefied gaseous fuels — General requirements for automatic tank gauges*:

— *Part 1: Automatic tank gauges for liquefied natural gas on board marine carriers and floating storage*

— *Part 2: Gauges in refrigerated-type shore tanks*

— *Part 3: Automatic tank gauges for liquefied petroleum and chemical gases on board marine carriers and floating storage*

Introduction

Large quantities of liquefied petroleum and chemical gases are transported by marine carriers and traded by static measurement of the cargo on board by automatic tank measurement. The automatic tank measurement by a custody transfer measurement system (CTMS) involves determination of liquid/vapour interface, i.e. liquid level, temperatures of liquid and vapour, and vapour pressure. The volumetric quantity of the liquid and gas is given by the tank capacity table, on the basis of which the delivered quantity in terms of mass is calculated.

To ensure accurate quantitative determination of liquefied petroleum and chemical gases, custody transfer measurement usually takes place on board the gas carrier and floating storage, not at the shore tanks. Liquid level expressed in innage or ullage is one of the important measurement parameters needed to accurately determine the cargo on board.

Refrigerated hydrocarbon and non-petroleum based liquefied gaseous fuels — General requirements for automatic tank gauges —

Part 3:
Automatic tank gauges for liquefied petroleum and chemical gases on board marine carriers and floating storage

1 Scope

This part of ISO 18132 establishes general principles for the accuracy, installation, calibration and verification of automatic tank gauges (ATGs) used for custody transfer measurement of liquefied petroleum and chemical gases on board a gas carrier or floating storage.

The part of ISO 18132 also describes the technical requirements for data collection, transmission and reception. Specific technical requirements for various automatic tank gauges and accuracy limitations are given in the annexes.

2 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms, definitions and abbreviated terms apply.

2.1 Terms and definitions

2.1.1
automatic tank gauge
ATG
instrument that continuously measures liquid height (dip or ullage) in storage tanks

NOTE 1 An automatic tank gauge usually includes a level sensor, a gauge head and associated mounting hardware, and in some cases local display.

NOTE 2 Automatic tank gauges are also known as automatic level gauges (ALGs).

2.1.2
automatic tank gauging system
ATG system
system that includes ATGs at the cargo tanks and control/display unit that processes and displays output signals from the ATG along with any other parameters required to determine the liquid level, i.e. liquid/vapour interface

NOTE The ATG system can also compute the volume of LNG in tanks, using the values of cargo tank temperature and pressure, draft, and tank capacity table.

2.1.3
custody transfer measurement system
CTMS
system that processes inputs from an ATG system, thermometers, pressure gauges, etc., and provides custody transfer measurement information on board, generating documents with regard to custody transfer of LNG

NOTE The ATG system can be incorporated as part of a CTMS.

2.1.4
float-type ATG
ATG that uses a float to detect the liquid level

NOTE The float is guided by a tape or wire that is connected to a drum or a ratchet in the gauge head, where the level measured is displayed locally and/or remotely. See Annex D for more descriptions.

2.1.5
hydrostatic-type ATG
hydrostatic tank gauge
HTG
ATG that determines liquid level based on the differential of pressures measured by the pressure sensors vertically installed in a cargo tank with temperature sensors

NOTE See Annex E for further descriptions.

2.1.6
intrinsic error
inherent error
error of an ATG when it is tested against a reference standard under controlled conditions as specified by the manufacturer

2.1.7
magnetic-type ATG
ATG that measures the liquid level by magnetic reed switches with a float sensor including magnets, or by magneto-strictive principle

NOTE See Annex C for further descriptions.

2.1.8
radar-type ATG
microwave-type ATG
ATG that utilizes an antenna to transmit electromagnetic continuous waves toward the liquid in a tank, and to receive electromagnetic waves which are reflected at the surface of the liquid

NOTE See Annex B for further descriptions.

2.2 Abbreviated terms

ATG automatic tank gauge

CTMS custody transfer measurement system

EMC electromagnetic compatibility

FPSO floating production, storage and offloading

FSO floating storage and offloading

HTG hydrostatic-type ATG

IACS international association of classification societies

LNG liquefied natural gas

LPG liquefied petroleum gas

3 General safety precautions

3.1 Compliance with safety regulations, standards, and classification rules

This part of ISO 18132 may involve hazardous materials, operations, and equipment. This part of ISO 18132 does not purport to supersede any safety or operating practices recommended by applicable regulatory agencies and organizations. It is the responsibility of the user of this part of ISO 18132 to establish appropriate health and safety practices and determine the applicability of regulatory limitations prior to use.

3.2 Equipment precautions

3.2.1 General

All electric components of an ATG for use in electrically classified areas shall meet the electrical area classification (see IEC 60079-0). They shall conform to applicable sections of the national and/or international electrical safety standards. All ATGs shall be maintained in safe operating condition and manufacturers' maintenance instructions should be complied with.

3.2.2 Mechanical rigidity

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

Where an ATG is installed near a submerged pump or the end of a loading/unloading line in a cargo tank, appropriate measures shall be applied to prevent the ATG from being affected by the vortex or vaporization (i.e. boiling) of cargo caused by the cargo loading or cargo unloading operations.

3.2.3 Gastight design

ATGs shall be designed such that the tank penetration for the ATG is of gastight construction in order to minimize the escape of vapour from the cargo tank. The gauge head or transmitter located on the deck shall be so constructed as to minimize leakage of vapour from the tank.

3.2.4 Compatibility with cargo

All parts of the ATG in contact with liquefied petroleum and chemical gases or their vapour shall be chemically compatible with the product, to avoid both product contamination and corrosion of the ATG.

3.2.5 Tolerance against low temperatures

ATGs shall be designed to withstand the low-temperature thermal contraction of their components and of the tanks. Additionally, level measurement errors caused by such thermal contraction shall be compensated for in an appropriate manner.

3.2.6 Type approval

The design and installation of ATGs shall be subject to type approval. Type approval is normally issued after an ATG has been subjected to a specific series of tests.

NOTE Type approval is normally performed by a national measurement organization or class society for environmental considerations (see IACS Unified Requirements E 10).

3.2.7 Use of an ATG in custody transfer service

ATGs, including those which use measurement technologies not listed in this part of ISO 18132, are considered acceptable for use in the custody transfer service of liquefied petroleum and chemical gases if they are judged to be compatible with those ATGs in this part of ISO 18132 by the parties to the sales contract of liquefied gases, and approval by national regulations.

4 Design requirements

4.1 General

The following design requirements apply to all types of ATGs on LPG carriers, FPSOs and FSOs. These requirements, which may be in addition to the technical specifications by the ATG manufacturer, should be met where they are applicable.

ATGs, except that of float-type, are normally connected to a computer system designed for processing their output signal, and displaying the level, as well as temperature and other parameters, thus forming a part of an ATG system. Complete design requirements for the ATG system are not specified in this part of ISO 18132.

4.2 Provisions for routine maintenance and verification

All ATGs shall be capable of withstanding vapour from cargo tanks, and allow routine maintenance to be performed without compromising the integrity of the tank. This includes means of verification whereby the ATG accuracy can be checked at high and low tank levels with the tank in service.

ATG shall be equipped with a provision which enables verification of proper functioning of the ATGs at the time of each custody transfer.

4.3 Provision against sudden malfunctions

ATGs shall be designed to minimize the frequency and severity of any malfunction and shall be provided with self-diagnostic features. Electronics essential for the proper functioning of the system should ideally be accessible from the deck and be serviceable with tanks in operation.

4.4 Dynamic response

ATGs shall have sufficient dynamic response to track the liquid level during maximum tank filling or emptying rates. Float-type ATGs are often installed in a pipe to protect them from surge of liquefied gas in a cargo tank. To ensure equalization of the tank level and that in the pipe, the bottom and top of the pipe shall be open and equipped with sufficient perforations throughout the length.

4.5 Minimum measurable level

Because liquefied gas carriers often retain a tank heel after a discharge, the ATG shall be able to measure levels as near to the bottom of the tank as possible.

4.6 Data filtering and averaging

The ATG system shall be designed to automatically scan, average/filter and display the level in each cargo tank.

A common practice is to use five consecutive readings to compute an averaged liquid level used to consult tank capacity tables for liquid volumes.

Internal filtering algorithms shall be provided in ATG systems to reduce the impact of interferences and also applied to readouts to enable level readings to be averaged over a set number of readings or a defined period of time. Such filters may result in a significant delay, potentially of several minutes, before a reading may be observed.

Filtering and automatic averaging features are recommended because a stable reading may not be available due to the vessel motion and the boiling effect of the cargo. If an automatic averaging feature is not available, multiple consecutive ATG readings corresponding to the high and low level of the wave of the cargo liquid surface shall be taken and the reading averaged for reporting.

4.7 Compensation for variation of cargo temperatures and/or composition

To ensure accurate measuring results, the liquid level obtained by an ATG shall be compensated for any effect of changes in temperature, pressure or cargo properties of the respective cargo components. The compensation is either carried out by the electronics in the ATG system or manually.

In particular, the ATG system shall be designed to compensate for measuring errors caused by thermal contraction/expansion of material used in the ATGs within the measurement function or by other equivalent means, and/or their installation, such as still pipe, supporting wave guides, float tapes or wires. Correction shall also be made for the thermal effects of the tank design/material.

The measurement of pressure and temperature of the vapour in the tank, liquid temperature, or any other relevant parameter should be time correlated with the tank level measurement. The tank liquid temperature should be representative of the liquid contents.

4.8 Sealing, security and unsealing

The ATG or ATG system shall provide means to prevent unauthorized adjustment or tampering. Specifically, an ATG or ATG system used in fiscal or custody transfer application shall provide security to allow sealing of the calibration adjustment. The security may include a physical seal and/or software password(s). Once the ATG or ATG system has been sealed, it shall not be unsealed until the next scheduled inspection.

Should unsealing become necessary for some unavoidable reason, the inspection organization shall be informed of such action prior to unsealing.

4.9 Redundancy

Usually, liquefied petroleum and chemical gas carriers are equipped with one ATG per tank. However, if a tank is divided athwart into two compartments, i.e. port and starboard, ATG in one of the compartments may act as the secondary ATG for the other compartment by opening the valve at the centre bulkhead so as to equalize the liquid levels of both compartments.

Where there are two ATGs in a tank, one of them shall be designated as the primary ATG and the other as the secondary ATG. In such a case:

a) failure of the primary ATG shall not affect the secondary ATG, or vice versa;

b) the secondary ATG shall always be in operation, which provides the secondary ATG for comparison to the primary ATG and a means to monitor the primary ATG for malfunction.

NOTE It is recognized that this procedure cannot verify the accuracy of an ATG to ensure it meets the maximum permissible error set forth in this part of ISO 18132. However, crosschecking and tracking the history provide an indication of the performance of the ATGs on the vessel.

4.10 Data communication

The ATG system shall be designed and installed such that its data transmission device and control/display unit:

a) does not compromise the accuracy of the measurement; where there is a local display, this criterion is defined as follows:

   1) for digital signal transmission, there shall be no difference between the local and remote reading;

   2) for analogue signal transmission, the difference between the local reading and remote reading shall agree within 3 mm (the local and remote readout may differ because of data transmission and/or data processing);

b) does not compromise the resolution of the measurement output signal from the level sensor;

c) provides proper security and protection of the measured data to ensure its integrity;

d) provides adequate speed to meet the update time required for the receiving unit/readout.

5 Installation

5.1 General

All ATGs shall be installed in accordance with the manufacturer's instructions and marine classification society requirements.

5.2 Location of installation

Installation of ATGs shall have provisions to protect the ATGs and tank from physical damage.

5.3 Interference of ATGs in a cargo tank

Where there are two ATGs in a cargo tank, they shall not result in interference between the ATGs. This is in addition to the electromagnetic interference described in 3.2.5. Further, cargo tank structural design and other electrical devices within the cargo tank shall not interfere with the ATG measurement.

6 Accuracy

6.1 General

The accuracy of level measurement by an ATG is affected by the inherent (intrinsic) error of the ATG, the error due to installation (e.g. stability, location), the effect of changes in operating conditions, and vessel motion. Accuracy is also subject to the uncertainty associated with manual measurement during calibration.

6.2 Calibration reference

6.2.1 General

The calibration reference shall be traceable to a national metrology institute. The uncertainty of the certified reference should not exceed the tolerance described below, with the calibration correction applied.

6.2.2 Uncertainty of reference standard at factory acceptance test

For testing of the ATG prior to installation on board the vessel, the uncertainty of the reference standard shall be ±1 mm or better, with correction applied.

6.2.3 Uncertainty of reference standard at site acceptance test

For testing of the ATG after installation on board the vessel but prior to placing the tank in service, the uncertainty of the reference standard shall be 0,002 % of the ATG span, or 1 mm, whichever is larger, with correction applied.

6.3 Accuracy requirement

The accuracy of an ATG shall be as follows:

a) intrinsic error (intrinsic accuracy) of the ATG tested prior to installation and in a controlled test environment shall be within ±5 mm;

b) ATG accuracy after installation by the shipyard but prior to placing the tank in service shall be within ±10 mm.

NOTE See A.4 for the uncertainty of the calibration reference used.

For ATGs in inventory applications, with the agreement of all parties, intrinsic errors may exceed these errors.

6.4 Readout resolution

The ATG readout shall provide a minimum display resolution of:

a) 1 mm or better in calibration/verification mode, and

b) 1 mm during normal operation.

7 Recertification of ATGs

7.1 General

ATGs used in custody transfer shall be periodically recertified. This process normally involves verifying accuracy of the ATG, and if found to be needed, resetting/adjusting the ATGs against a calibration reference. Adjustment (calibration) should normally be made by an authorized service engineer with results certified by a qualified third party.

Where there are primary and secondary ATGs in the cargo tanks, comparison of these ATGs during operations, and comparison of an ATG against a fixed reference point at the tank, are considered an ATG verification. These two methods are not considered an ATG calibration as defined in this part of ISO 18132. An ATG should not be adjusted simply due to an observation of a large difference between the primary and secondary ATG during a custody transfer transaction.

Periodic recertification of ATGs in custody transfer application is normally required by local regulations and/or the parties to the gas sales contract.

7.2 Method of periodic certification

The method and procedure for the periodic calibration may vary depending on the technology of the ATG. The method may be subject to national regulations or International Standards, inspector certification requirements, and sales and purchase agreements.

7.3 Maximum permissible error

The maximum permissible error of the ATG and the uncertainty of the reference standard shall be the same as those described in 6.3 b) and 6.2.3 respectively.

7.4 Frequency of subsequent calibration and recertification

The frequency of subsequent calibration and recertification is sometimes agreed among the parties to the gas sales contract, and may be subject to national or local regulations and International Standards. Recertification is typically scheduled to coincide with classification society inspections. The frequency should also take into consideration recommendations by the ATG manufacturer.

8 ATG calibration records

All ATG calibration records shall be documented. Calibration and certification records shall be available for inspection by parties involved in custody transfer. All adjustments to the ATGs shall be documented in a re-calibration certificate.

Annex A
(normative)

Calibration and verification of various ATGs in common use

A.1 General

ATGs that use technologies other than those listed in this part of ISO 18132 may be used in the marine custody transfer of liquefied petroleum and chemical gases if they meet the tolerance specified in 6.3 and other general requirements in this part of ISO 18132. Use and installation of ATGs in the marine custody transfer of liquefied petroleum and chemical gases may be subject to approval by national regulations and sale and purchase agreement.

Clauses A.2 to A.4 describe the specific design, installation, and calibration of the following ATGs currently in common use:

a) radar-type ATG;

b) magnetic-type ATG;

c) float-type ATG;

d) hydrostatic-type ATG.

NOTE The list of ATGs is not inclusive of all potential technologies, and the order of the listing does not imply preference of the ATG technology.

A.2 Calibration and verification

Calibration and verification are performed at the following occasions and locations:

a) factory acceptance test at the manufacturer's shop, before shipment (see 6.2.2);

b) site acceptance test at the shipyard after installation on the vessel, but before placing the tank in service (see 6.2.3);

c) verification before custody transfer operation;

d) subsequent periodic calibration and recertification (see Clause 7).

A.3 Zero adjustment in calibration

Zero adjustment of ATGs shall be performed after installation of the ATGs on the vessel's tank, but before performance of the verification. The ATGs shall be adjusted so as to indicate the accurate depth of the liquid level measured from the bottom datum point located at the tank bottom, or occasionally the ullage measured from top reference point at the temperature, composition, and density of the cargo to be loaded.

A.4 Traceability of reference standards impacting accuracy tests

The International Organization of Legal Metrology (OIML) specifies traceability of a calibration tape as follows:

a) national reference (kept in national metrology department);

b) reference standard (calibrated tape traceable to the national reference and kept in the organization's head office registered to national metrology department);

c) working standard (calibrated tape in comparison with the reference tape which is traceable to the national reference and which is kept in the organization's branch offices).

The specific procedure varies depending on the ATG technology and/or design. Results of the accuracy test shall be consistent with the criteria set forth in the main body of this part of ISO 18132.

Annex B
(normative)

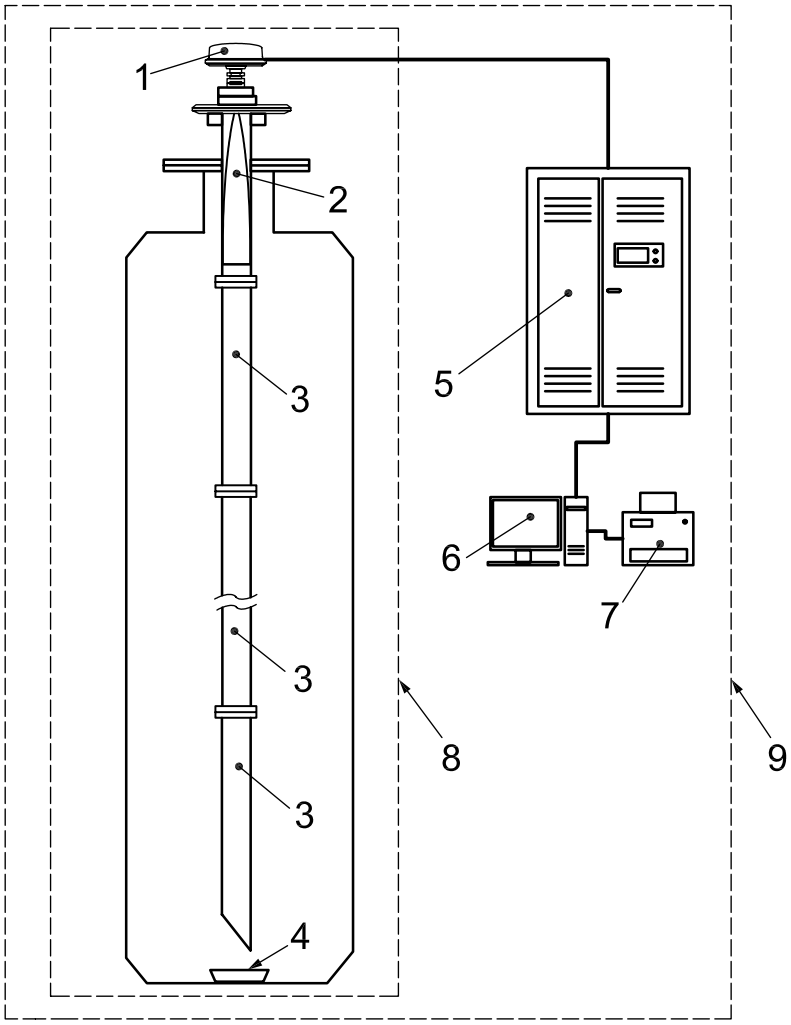
Calibration and verification of radar-type ATG

B.1 General

Radar-type ATGs consist of an antenna, microwave transceiver, and other required components (see Figure B.1).

The ATG shall provide, as a minimum, for a verification mode to allow for verification on board at a level near the normal safe fill height while the cargo tank is in service.

The error shall not exceed that described in the main body of this part of ISO 18132.



Key

1 radar transmitter
2 antenna
3 still pipe
4 attenuator
5 control unit
6 display unit
7 printer
8 ATG
9 ATG system

Figure B.1 — Example of radar-type ATG

In addition to the installation practice described in Clause 5, the following shall be considered:

a) the antenna shall be installed in a position such that the upper “dead zone” does not interfere with the accurate measurement of the liquid level when the level is near the normal safe fill height;

b) verification reference device(s) shall be provided to establish fixed reference points that equate to a precisely known distance from the gauge reference point to allow verification of the ATG;

c) provision shall be made to prevent adverse effects caused by signal echo from the tank bottom.

B.2 Factory acceptance test at the manufacturer's shop

See the calibration methods and procedures proposed by the ATG manufacturer. The ATG is tested at several points throughout the length of the still pipe. The ATG readings shall agree with the reference distances within the tolerance of the intrinsic error described in 6.2.2.

B.3 Calibration and verification after installation on board the vessel, but before being in service

See the specific procedure recommended by the ATG manufacturer. With the ATG installed:

a) activate the ATG to operate in the calibration/verification mode;

b) set the ATG to agree with the predetermined fixed reference point selected;

c) verify that the ATG readings agree with the reference value, i.e. they are within the error allowed in 6.3.

B.4 Verification before custody transfer operation

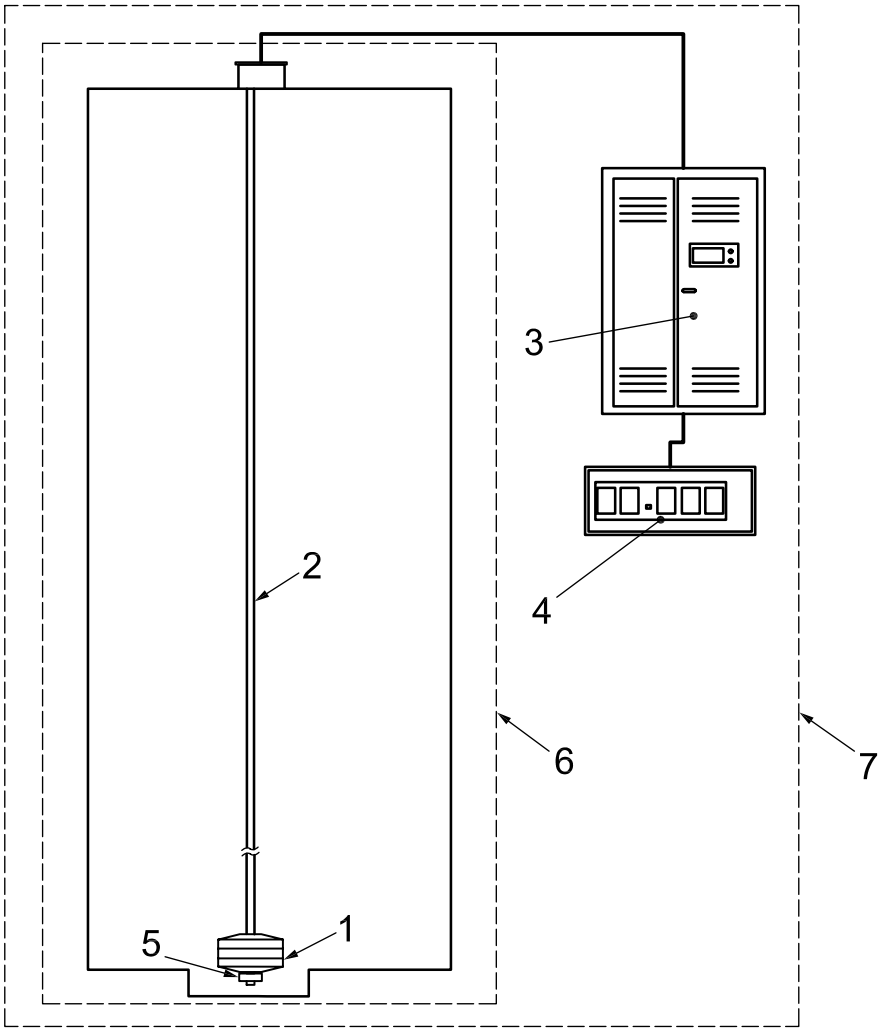
The verification process should involve comparison between the ATG reading(s) and fixed reference point(s), the position of which is known precisely. Depending on the ATG technology, verification should preferably be carried out near the normal fill height of the vessel cargo tanks with the tank in service, or by comparison at a reference point near the top or the bottom of the cargo tank.

Annex C
(normative)

Calibration and verification of magnetic-type ATG

C.1 General

Magnetic-type ATGs with a magnetic float level sensor (see Figure C.1) involves the opening or closing of magnetic switches assembled vertically in the guide pole, either through direct contact with the switch, or magnetic operation of a reed. With magnetically actuated float sensors, switching occurs when a permanent magnet sealed inside a float rises or falls to the actuation level. With a mechanically actuated float, switching occurs as a result of the movement of a float against a miniature (micro) switch. For both magnetic level sensors and mechanical float level sensors, chemical compatibility, temperature, density, buoyancy and viscosity affect the selection of the stem and the float.



Key

1 float
2 float guide with read switch
3 control unit
4 display unit
5 float stopper
6 ATG
7 ATG system

Figure C.1 — Example of magnetic-type ATG

For magnetic-type ATGs of magneto-strictive type, a sonic strain pulse is induced in a specially designed magneto-strictive waveguide by the momentary interaction of two magnetic fields. One field comes from a movable permanent magnet which passes along the outside of the sensor tube (also serves as a guide pole), the other field comes from a current pulse or interrogation pulse applied along the waveguide. The interaction of the two magnetic fields produces a strain pulse, which travels at sonic speed along the waveguide until the pulse is detected at the head of the sensor. The position of the magnet is determined by measuring the elapsed time between the application of the interrogation pulse and the arrival of the resulting strain pulse.

Larger floats should be used with liquefied petroleum gases which typically have density as low as 0,5 kg/l while still maintaining buoyancy. The choice of float material is also influenced by temperature-induced changes in density and viscosity, which are changes that directly affect buoyancy. In order to correct the reading of the ATG for changes in the immersion level of the float, the density of the liquid at the operating temperature shall be known.

Magnetic-float and magneto-strictive ATGs may incorporate temperature and pressure sensors in the float or the sensor tube (guide pole), to provide a spot and/or multiple spot measurement of these parameters. The accuracy of the temperature and pressure thus measured shall be verified to meet the respective performance requirements for custody transfer application, as they are used to determine the average liquid temperature, the vapour temperature and the hydrostatic pressure.

Correction tables, formulae or other suitable means shall be provided to compensate for the change of the float immersion due to change of liquid density.

The float tube (guide pole) and float shall be designed and installed to withstand damage caused by waves in the tanks due to ship movement.

C.2 Factory acceptance test at the manufacturer's shop

See the specific procedure recommended by the ATG manufacturer. The magnetic-type ATG shall be calibrated and the accuracy verified at the manufacturer's shop prior to shipment, such that it meets the intrinsic error specified in 6.3 a).

C.3 Installation in tank on board the vessel

Follow the manufacturer's recommendations for installation.

C.4 Calibration after installation on board the vessel, but before in service

Calibration at the shipyard typically consists of two steps: setting the ATG and verifying its accuracy after setting. See the specific procedure recommended by the ATG manufacturer.

a) Setting of magnetic-type ATG:

   1) Lower the level sensing element (i.e. float) to the lowest point of the support/guide pole or stopper (or the lower reference point).

   2) Set the ATG reading to agree with the predetermined reference point.

   3) Raise the level sensing element back to the upper reference point and compare the ATG readings at least every 2 m against a reference tape or other calibration reference. Record the readings. The difference between the ATG readings and the reference readings should be within 10 mm over the entire range.

   4) Lower the level sensing element to the datum plate (or the lower reference point) and confirm the ATG reading to agree with the predetermined reference point as established by point 2) above.

b) Verification of magnetic-type ATG after setting:

   1) The magnetic-type ATG shall be operated and verified, at 20 % and 80 % of its working range, by comparison against the certified reference such as certified measuring tape.

   2) The result shall be within the tolerance given in 6.3 b).

c) If this method is not feasible, an alternative test method of equivalent function or performance may be adopted.

C.5 Verification before custody transfer operation

Follow the manufacturer's recommendations.

Annex D
(normative)

Calibration and verification of float-type ATG

D.1 General

A float-type ATG includes a float, a drum at the gauge head on the deck and a tape or wire that connects the float and the drum. As the float reaches the liquid surface and partly immerses, change of the buoyancy force on the float allows detection of the liquid surface. Correction tables shall be provided to compensate for the change of the float immersion due to change of liquid density and shrinkage of the tape or wire of the float due to change of the vapour temperature.

Float-type ATGs shall be designed to withstand damage caused by waves in the tanks due to ship movement. The protection for this purpose may require installation of the float in a perforated still pipe. The float shall be raised to a top storage position when it is not used.

Float-type ATGs typically include the following components (see Figure D.1):

a) float that follows the vertical movement of liquid level in the tank;

b) tape or wire attached to the float in order to measure its position;

c) still pipe, if any, to prevent horizontal movement of the float;

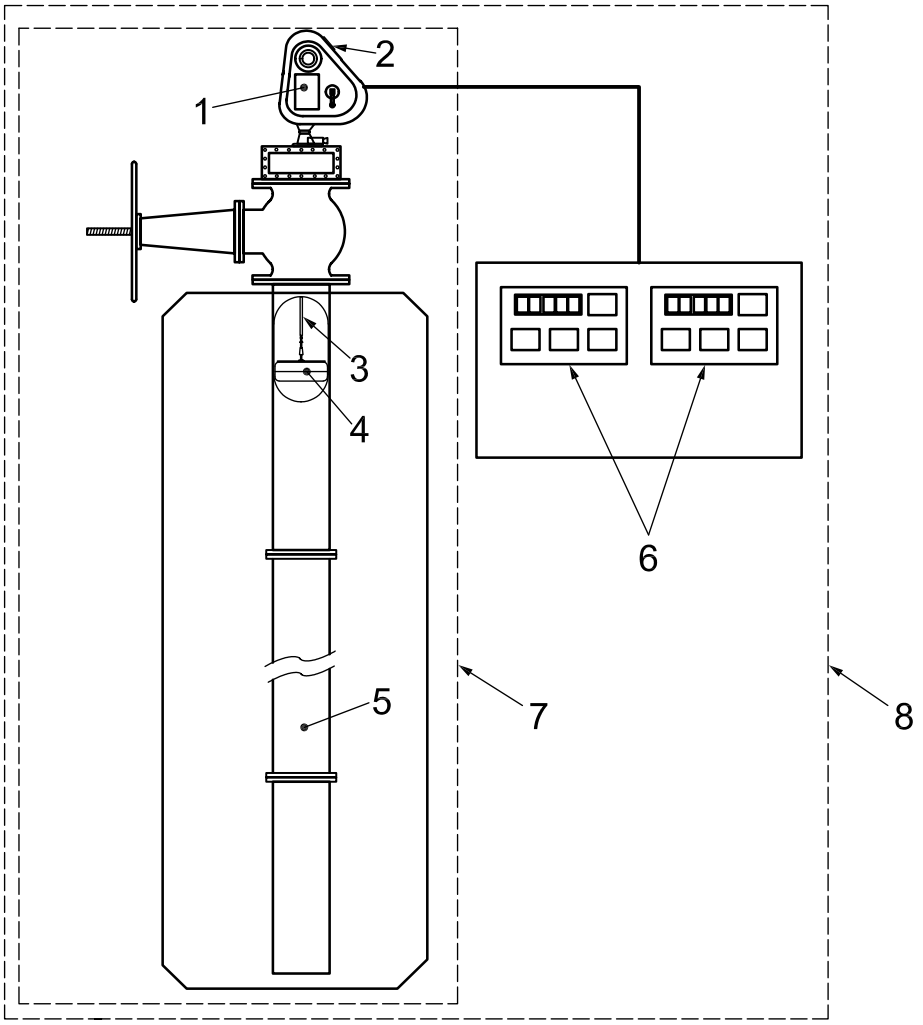
d) mechanical, electrical or electromechanical equipment for local and/or remote readout;

e) equipment to provide necessary tension to the tape or wire;

f) equipment to wind the float up and down;

g) equipment or apparatus to lock the float in position while it is not in use;

h) adequate provision in the tank to protect the tank bottom from damage by striking with a float.



Key

1 gauge head
2 local display
3 float tape
4 float
5 still pipe
6 remote display
7 ATG
8 ATG system

Figure D.1 — Example of float-type ATG

D.2 Factory acceptance test

Float-type ATGs shall be calibrated and their accuracy verified at the manufacturer's shop prior to the shipment, in order to establish the intrinsic error as specified in 6.3 a).

The following shall be measured or checked during the factory acceptance test:

a) dimensions of the float;

b) mass of the float itself;

c) immersion level of the float;

d) in the case of perforated tape, the pitch of the perforation;

e) length of the suspending tape or wire;

f) mass per unit length of the suspending tape or wire;

g) material of the suspending tape or wire;

h) function of constant tensioning spring;

i) proper centering of float at which tape or wire is connected.

See the specific procedure recommended by the ATG manufacturer.

D.3 Calibration and verification at the shipyard after installation on board the vessel

Calibration and verification shall be carried out as described below.

a) Lower the float to the datum plate.

b) Set the ATG reading on local and remote display to agree with the sum of H and h, such that

— H is the vertical distance between tank bottom and top surface of datum plate or stopper;

— h is the calculated immersion level of the float when it is buoyant on assumed LNG density.

c) Attach a certified calibration tape at the bottom of float with a jig. Wind up the float slowly by rotating the handle at gauge head until the display indicates 1 m. Read the measurement of the attached tape as the offset of measurement.

d) Wind up the float by the handle to approximately 20 % of tank height.

e) Hold the handle and compare the measurement of the attached tape and that of the local display taking the offset into account.

f) Wind up the float to 80 % of tank height. Repeat e).

g) Wind up the float until it stops at the top storage position. Record the indication of local display as the top reference point.

h) Lower the float to the tank bottom to detach the calibration tape.

i) From each reading, calculate the error of the float-type ATG both for local and remote displays. The result shall be within the tolerance given in 6.3 b).

NOTE 1 It is advisable to check the tape or wire, gauge head, and all components of a float-type ATG by winding the tape or cable through the entire range to assure smooth operation, doing the check slowly to simulate actual operation and to avoid damaging the float-type ATG.

NOTE 2 In-tank atmospheric temperature is measured for the compensation of the calibration tape.

NOTE 3 If the above method is not feasible, an alternative test method of equivalent function or performance can be adopted.

NOTE 4 In addition to the calibration uncertainty involved in the certified calibration tape (working standard), the above test procedure involves uncertainty due mainly to manual operation. The total uncertainty associated with the accuracy test of a float-type ATG is estimated to be ±2 mm (see Annex G for details).

D.4 Verification before custody transfer measurement

The float that has been stored in the top housing during transportation to avoid damage due to the ship's motion is lowered onto a liquid surface in order to stabilize the temperature. Before custody transfer measurement, wind up the float until it stops automatically at the top storage position and compare the readings of local and remote displays with the record at the time of initial calibration.

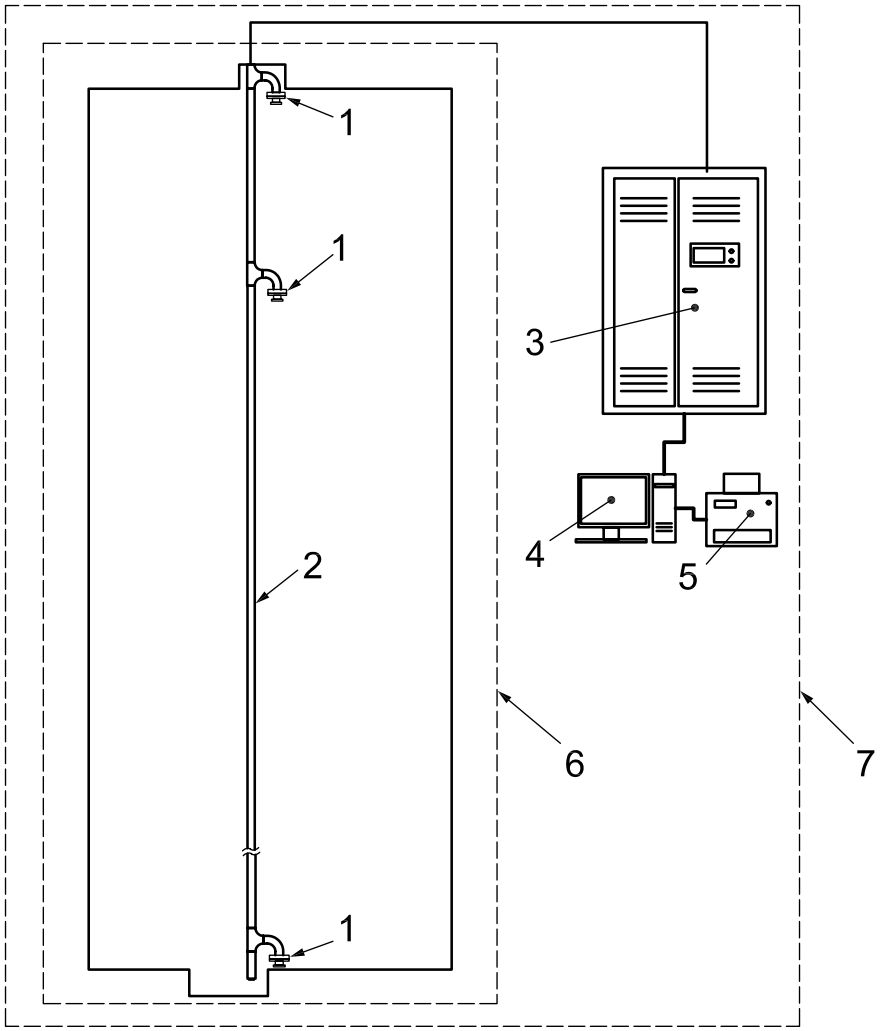
Annex E
(normative)

Calibration and verification of hydrostatic-type ATG

E.1 General

A hydrostatic-type ATG (see Figure E.1) typically includes three or more pressure sensors, and temperature sensors. One of the pressure sensors is located in the vapour phase to measure the vapour pressure. The sensors of hydrostatic-type ATGs shall be designed to withstand damage caused by waves in the tanks due to ship movement.

NOTE The level computed by a hydrostatic-type ATG can be affected by density stratification and temperature stratification of the cargo (liquid) in the tank.



Key

1 pressure sensor
2 support pipe
3 control unit
4 display unit
5 printer
6 ATG
7 ATG system

Figure E.1 — Example of hydrostatic-type ATG

Correction tables, formulae or other suitable means shall be provided to compensate for the change of the pressure sensor locations due to thermal contraction of the still/support pipe on which the pressure sensors are mounted.

A direct ullage level gauge may be added to the hydrostatic tank gauge to form a hybrid tank measurement system. See ISO 15169 for the principle of operations.

E.2 Factory acceptance test at the manufacturer's shop

See the specific calibration procedure recommended by the hydrostatic-type ATG manufacturer. The pressure sensors of hydrostatic-type ATGs shall be fully calibrated at the manufacturer's testing facilities or outside

testing laboratory, where they shall be calibrated at a temperature near the expected cargo temperature during operation. Zero and span calibration of the hydrostatic-type ATG is as follows:

a) connect the pressure sensors with the reference pressure source to simulate operating conditions;

b) vary the pressure output signal of the reference to cover the minimum pressure and maximum pressure of the intended application: the maximum pressure should be the full scale of the pressure transmitter as specified.

The repeatability of the pressure sensor should meet manufacturer's performance specifications. The full scale of the pressure sensor (transmitter) should be selected so that the accuracy of the pressure sensor, which is usually measured as a percentage of the full scale, can be optimized for the intended application.

The intended range of the pressure transmitter should be less than the full-scale or upper-range value of the transmitter. The intended operating range should include zero and the maximum level conditions.

The overall accuracy of the pressure transmitter depends on both the zero and linearity errors. The zero error is an absolute error expressed in terms of pressure. The linearity error is typically stated as a percentage of the reading. The accuracy requirements of the pressure sensor depend on the intended application (e.g. for volume or mass custody transfer) of the hydrostatic-type ATG. The maximum values of allowable zero and linearity errors in Table E.1 are recommended for various configurations of hydrostatic-type ATGs in custody transfer service.

Table E.1 — Recommended maximum permissible error of pressure sensor

Pressure transmitter		Application	
		Volume	Mass
Below the normal fill height	zero error, Pa	100	50
	linearity error, %	0,10	0,07
Above the normal fill height	zero error, Pa	40	24
	linearity error, %	0,50	0,20

NOTE 1 The zero error of a pressure transmitter is the indication of the gauge pressure transmitter when no pressure difference between input pressure and ambient pressure is applied to the pressure transmitter. It is expressed in terms of pressure.

NOTE 2 The linearity error of a pressure transmitter is the deviation of the indicated value of the pressure transmitter from the applied pressure as input to the transmitter. It does not include the zero error and is expressed as a fraction or percent value of the applied pressure reading.

NOTE 3 The uncertainty of the calibration reference used for factory calibration does not exceed one third of the above maximum permissible errors.

The span of the pressure transmitter for measurement of vapour pressure should be much smaller than the span chosen for the sensor located below the normal fill height because the gauge vapour pressure is typically limited.

Other wetted components, such as the associated temperature sensors, shall be tested, at similar conditions.

The calibration shall be followed by the accuracy verification prior to shipment such that it meets the intrinsic error specified in 6.3 a).

E.3 Installation in tank on board the vessel

Follow the manufacturer's recommendations for installation.

E.4 Calibration after installation on board the vessel, but before in service

See the specific procedure recommended by the hydrostatic-type manufacturer. After mounting the hydrostatic-type ATG and support pipe on which pressure sensors are normally mounted, verify the location of the pressure sensors against the pre-configured data. If the pressure sensors are mounted on the support pipe at the shipyard, the location of each pressure sensor shall be measured to within 1 mm, and the data shall be used in the configuration of the hydrostatic-type ATG.

Verify the reference point of the hydrostatic-type ATG relative to the reference points in the cargo tank capacity table.

Check the zero value of all pressure sensors after installation, and re-zero the pressure sensors. Record the as-found zero value before re-zeroing the pressure sensor. Investigate large drift of the factory-set zero value, and see the manufacturer for recommendation.

The accuracy of a hydrostatic-type ATG thus calibrated is typically verified by the following procedure.

a) Zero adjustment: the transmitter should be zeroed with the high pressure port vented to atmosphere. The zero error after this adjustment should be approximately zero.

b) Linearity verification: for high precision pressure transmitters, it may be difficult or impractical to adjust transmitter linearity under field conditions, i.e. at the shipyard, or on board an LPG carrier or FPSO/FSO. In this situation, linearity verification and adjustment may not be required.

   If verification is performed, the linearity should be verified using a high precision pressure calibration reference traceable to the national standard. The linearity verification should be performed at a minimum of two test pressures of approximately 50 % and 100 % of range. The linearity error is determined by calculating the difference between the pressure sensor indication (minus any observed zero error) and the pressure reference. This value is divided by the applied reference pressure to give a fractional linearity error, which may be converted to a percentage. The resulting linearity error shall not exceed the maximum linearity error as specified in Table E.1 for any of the test pressures.

   The uncertainty of the calibration reference used for linearity verification shall not exceed one third of the maximum permissible errors in Table E.1.

c) After the pressure transmitters have been zeroed and verified for linearity, a final check should be performed to determine if the zero error remains within the maximum permissible errors specified in Table E.1. The zero reading and linearity error “as left” values should be documented.

E.5 Verification before custody transfer operation

The tolerance stated above does not include these effects, which vary depending upon the operating conditions.

Annex F
(informative)

Accuracy limitations of level measurement of LPG and chemical gases

F.1 General

Level measurement by ATGs on board liquefied petroleum and chemical gas carriers, FPSO or FSO is affected by the following inherent limitations, regardless of their type.

F.2 Accurate determination of trim and list

Accurate determination of trim and list is difficult, and the trim and list corrections affect the accuracy of the marine level measurement. Due to hog and sag, twists and bends, it can be necessary to take a multipoint draft, and then use a trim correction appropriate to that of the tank. If automatic correction for trim and/or list is provided as part of the level gauge readout, the correction should be verified to its uncertainty.

F.3 Effect of vessel motion causing waves in the tanks

Waves in the tanks make it difficult to measure an average level. Many ATGs read the instantaneous level at the point of measurement, and 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 a fixed value or programmable to adapt to the encountered motion.

Averaging filters commonly in use for the level measurement when the operation is affected by sea swells may provide a reading that is significantly delayed (up to several minutes) of the real time reading.

F.4 Change of the tank dimensions due to cargo temperature and cargo gravity effects

The dimensions of a cargo tank can change with temperature and other factors. This affects the conversion from tank level to volume. The change in the vertical dimension also changes the pre-established gauge reference point previously stored in the ATG system. Lack of correction affects the accuracy of ATGs which are mounted on the top deck structure.

F.5 Corrections for cargo and tank conditions

The cargo composition and/or cargo physical data (e.g. density, dielectric constant) and tank conditions (e.g. vapour pressure, vapour and liquid temperature) may affect the level accuracy depending upon type of ATG. A correction should be made for any such effect.

Annex G
(informative)

Uncertainty associated with accuracy test of float-type ATG

Table G.1 shows the elements of uncertainty involved in the accuracy test of a float-type ATG on board a liquefied petroleum and chemical gas carrier after its installation at the shipyard, but prior to placing the tank in service. Table G.1 can be referred to when subsequent periodic accuracy tests are carried out.

Table G.1 — Uncertainty associated with accuracy test of float-type ATG

Source of uncertainty		Uncertainty mm	Type
Attributable to the steel tape	Resolution of scale	0,29	B
	Uncertainty of calibration of steel tape	0,40	B
	Effect of steel tape weight	0,06	B
	Individual variation	0,25	A
Attributable to the ATG	Resolution of scale	0,29	B
	Instability of fixing the handle	0,29	B
	Expansion of float tape	0,33	B
	Scale reading by individual variation	0,29	B
Others	Thermometer	0,32	B
	Connection of float and steel tape by jig	0,14	B
Combined uncertainty		0,89	—
Coverage factor		2	—
Extended uncertainty		1,78	—

NOTE 1 The average of three measured values is expected within 2 mm from the average of the population at a 95 % level of confidence.

NOTE 2 Type A is the method of evaluation of uncertainty by the statistical analysis of a series of observations.

NOTE 3 Type B is the method of evaluation of uncertainty by means other than the statistical analysis of a series of observations.

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