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Petroleum and liquid petroleum products — Measurement of level and temperature in storage tanks by automatic methods —

Part 1: Measurement of level in atmospheric tanks

Pétrole et produits pétroliers liquides — Mesurage du niveau et de la température dans les réservoirs de stockage par méthodes automatiques —

Partie 1: Mesurage du niveau dans les réservoirs à pression atmosphérique

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 28, *Petroleum and related products, fuels and lubricants from natural or synthetic sources*, Subcommittee SC 2, *Measurement of petroleum and related products*.

This second edition cancels and replaces the first edition (ISO 4266-1:2002), which has been technically revised.

The main changes are as follows:

— it has been specified in the scope that this document includes fiscal/custody transfer applications;

— in 4.3.2, it has been clarified that temperatures should be measured and recorded simultaneously with the level;

— in 6.5.7, the perforation distance on still-well's from 300 mm to 150 mm has been updated.

A list of all parts in the ISO 4266 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Petroleum and liquid petroleum products — Measurement of level and temperature in storage tanks by automatic methods —

Part 1: Measurement of level in atmospheric tanks

1 Scope

This document gives requirements and guidance on the accuracy, installation, commissioning, calibration and verification of automatic level gauges (ALGs). It applies to ALGs which are both intrusive and non-intrusive types, in fiscal/custody transfer applications for measuring the level of petroleum and petroleum products having a Reid vapour pressure less than 100 kPa, stored in atmospheric storage tanks.

This document is not applicable to the measurement of level in refrigerated storage tanks with ALG equipment.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1998 (all parts), *Petroleum industry — Terminology*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1998 (all parts) and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
automatic level gauge
ALG
automatic tank gauge
ATG
instrument that continuously measures liquid height [*dip* (3.2) or *ullage* (3.10)] in storage tanks

3.2
dip
innage
vertical distance between the *dipping datum plate* (3.3) and the liquid level

3.3
dipping datum plate
dipping datum point
dip-plate
horizontal metal plate located directly below the *gauging reference point* (3.5) to provide a fixed contact surface from which manual liquid-depth measurements are made

3.4
gauge-hatch
gauging access point
dip-hatch
opening in the top of a tank through which gauging and sampling operations may be carried out

3.5
gauging reference point
reference gauge point
point clearly defined on the *gauge hatch* (3.4) directly above the *dipping datum plate* (3.3) to indicate the position (and upper datum) from which manual dipping or ullaging should be carried out

3.6
innage-based automatic level gauge
automatic level gauge (3.1) designed and installed to measure the liquid dip, with an integral reference point at or close to the tank bottom, referenced to the *dipping datum plate* (3.3)

3.7
intrusive automatic level gauge
automatic level gauge (3.1) where the level-sensing device intrudes within the tank and makes physical contact with the liquid

EXAMPLE Float and servo-operated-type automatic level gauge.

3.8
non-intrusive automatic level gauge
automatic level gauge (3.1) where the level-sensing device may intrude within the tank, but does not make physical contact with the liquid

EXAMPLE Microwave or radar-type automatic level gauge.

3.9
still-well
still-pipe
vertical, perforated pipe built into a tank to reduce measurement errors arising from liquid turbulence, surface flow or agitation of the liquid

3.10
ullage
outage
distance between the liquid level and the *gauging reference point* (3.5), measured along the vertical measurement axis

3.11
ullage-based automatic level gauges
automatic level gauge (3.1) designed and installed to measure the *ullage* (3.10) distance from the upper automatic level gauge reference point to the liquid surface

4 Precautions

4.1 Safety precautions

International standards and government regulations on safety and material-compatibility precautions can apply when using ALG equipment. In addition, the manufacturer's recommendations on the use and installation of the equipment should be followed. It is presupposed that all regulations covering entry into hazardous areas are observed.

4.2 Equipment precautions

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

4.2.2 ALGs should be certified for use in the hazardous-area classification appropriate to their installation.

4.2.3 Measures should be taken to ensure that all exposed metal parts of the ALG have the same electrical potential as the tank.

4.2.4 All ALG equipment should be maintained in safe operating condition and the manufacturer's maintenance instructions should be complied with.

NOTE 1 The design and installation of ALGs can be subject to the approval of a national measurement organization, who normally have issued a type approval for the design of the ALG regarding the particular service for which it is to be employed. Type approval is normally issued after an ALG has been subjected to a specific series of tests and is subject to the ALG being installed in an approved manner.

NOTE 2 Type-approval tests can include the following: visual inspection, performance, vibration, humidity, dry heat, inclination, fluctuations in power supplies, insulation, resistance, electromagnetic compatibility, and high voltage.

4.3 General precautions

4.3.1 The general precautions given in 4.3.2 to 4.3.8 apply to all types of ALGs and should be observed where applicable.

4.3.2 Tank temperatures should be measured at the same time as the tank level is measured. The tank temperature should be representative of the tank contents. For more details on temperature measurement, refer to ISO 4266-4.

4.3.3 Levels measured for bulk transfer should be recorded promptly when they are taken.

4.3.4 Whenever determinations of the contents of a tank are made before the movement of a bulk quantity of liquid (opening gauge) and after the movement of a bulk quantity of liquid (closing gauge), the same general procedures should be used to measure the tank level.

4.3.5 All parts of the ALG in contact with the product or its vapour should be chemically compatible with the product, to avoid both product contamination and corrosion of the ALG.

4.3.6 ALGs should have a sufficient dynamic response to track the liquid level during maximum tank filling or emptying rates.

4.3.7 Following the transfer of the product, the tank should be allowed to settle before the tank level is measured.

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

5 Accuracy

5.1 Intrinsic error of ALGs

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

5.2 Calibration prior to installation

The reading of the ALG to be used in a fiscal/custody transfer application should agree with a certified reference (e.g. a certified gauge tape) within ±1 mm over the entire range of the ALG. It is presupposed that the certified reference is traceable to national standards. The certified reference should be provided with a calibration correction table.

NOTE Metrology requirements for uncertainty of the calibration reference can be more stringent.

5.3 Error caused by installation and operating conditions

The total error of the ALG in a fiscal/custody conditions transfer application should not be affected by more than ±3 mm due to installation, variation of operating conditions and variation of physical and electrical properties of the liquid and/or vapour, provided these conditions are within the limits specified by the ALG manufacturer.

The accuracy of measurements using ullage-based ALGs is limited by vertical movement of the gauging reference point used to calibrate the ALG or vertical movement of the ALG top mounting point during tank transfers. The accuracy can be affected by tank-shell bulging due to liquid head stress. Any vertical movement of the gauging reference point due to liquid head stress of the tank shell can be compensated by a correction in the ALG.

The accuracy of measurements using innage-based ALGs can be limited by any vertical movement of the dipping datum plate used to calibrate the ALG, or vertical movement of the ALG bottom mounting point during tank transfers.

Volume measurements using tanks are limited by the following installed accuracy limitations, regardless of the ALGs used. These limitations can have a significant effect on the overall accuracy of both manual level gauging and of all types of automatic level gauges, and/or on the accuracy of the quantity of the content of the tank. These limitations include:

a) Tank capacity table accuracy (including the effect of tank tilt and hydrostatic pressure).

b) Bottom movement.

c) Encrustation of the tank shell.

d) Expansion of the tank diameter due to temperature.

e) Random and systematic errors in level, density, and temperature measurements.

f) Operational procedures used in the transfer.

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

5.4 Overall accuracy

5.4.1 General

The overall accuracy of level measurement by ALGs, as installed, is limited by the intrinsic error of the ALG equipment, the effect of installation methods, and the effect of the operating conditions.

NOTE Depending on the overall accuracy of the ALG as installed ("installed accuracy"), ALGs can be used for fiscal/custody transfer purposes. The use of ALGs in fiscal/custody transfer applications requires the highest possible accuracy. The use of ALGs for other (i.e. stock control or for plant or terminal operations) purposes often permits a lower degree of accuracy.

5.4.2 Use of ALGs for fiscal/custody transfer purposes

The ALG should meet the calibration tolerance prior to installation (see 5.2).

The ALG should meet the field verification tolerance (see 7.4.3.3), as well the effects of installation methods and changes in operating conditions (see 5.3).

The remote readout, if used, should meet the recommendations of this document (see Clause 9).

6 Installation of ALGs

6.1 General

6.2 to 6.5 outline recommendations for the installation of ALGs.

6.2 Mounting location

The mounting location of an ALG can affect the installed accuracy. For fiscal/custody transfer accuracy, the ALG mounting location should be stable, with minimal vertical movement under all practical operating conditions, which can arise, for example, due to changes in liquid head, vapour pressure and loading of the roof or gauging platform (see 6.5.)

6.3 Manufacturer's requirements

The ALG and level transmitter shall be installed and wired according to the manufacturer's instructions.

6.4 Installation

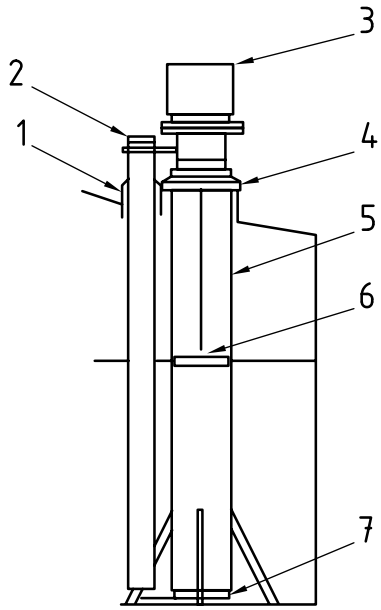
6.4.1 For fiscal/custody transfer accuracy, an ullage ALG should be mounted on a properly supported, perforated still-well, as illustrated in Figures 1 and 2.

6.4.2 As an alternative, an ullage-based ALG may be mounted on the roof or on a "gallows" supported from the top course of the shell. The ALG's calculation procedure for liquid level should include a means which compensates or corrects for movement of the ALG with respect to the gauging reference point (due to liquid height and temperature). Various types of "gallows" designs are used. An example of this type of installation is shown in Figure 3. Installation of some other ullage-based ALGs can involve a mounting attached to the outside of the tank shell near the tank bottom. An example of this type of installation is shown in Figure 4.

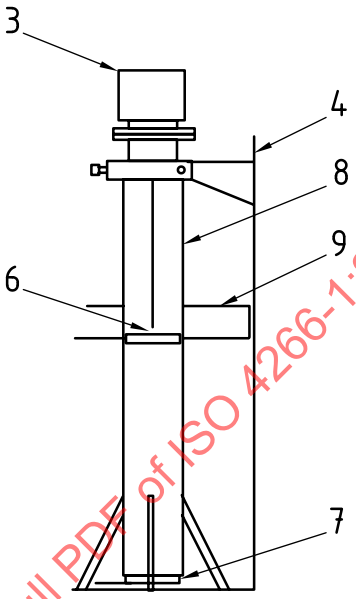
NOTE An ALG can include a programme to compensate or correct for the movement of the ALG due to liquid height and temperature.

6.4.3 Innage-based ALGs should be mounted at a stable location at the tank bottom where any effects due to liquid turbulence and/or tank bottom movement are minimized. An example of this type of installation is shown in Figure 5.

6.4.4 Where possible, the ALG should be located in close proximity to the manual gauge-hatch and should be accessible from the gauger's platform so that the ALG's accuracy can be easily verified by manual gauging. The ALG mounting and the gauging reference point of the manual gauging hatch should be rigidly connected to avoid errors due to differential and unpredictable movement.



a) Installation of top-mounted ALG on fixed-roof tanks with still-well



b) Installation of top-mounted ALG on external floating-roof tanks or on internal floating-roof tanks with still-well

Key

1 flexible weather seal
2 separate still-well (see note 1)
3 automatic level gauge (ALG) attached to top of still-well
4 perforated still-well sliding guide
5 perforated still-well (see notes 1 and 5)
6 level-detecting element (see note 2)
7 datum plate (see note 4)
8 perforated still-well (see notes 1 and 3)
9 pontoon

NOTE 1 Separate still-well(s) for manual gauging and temperature measurement can be installed adjacent to the ALG still-well.

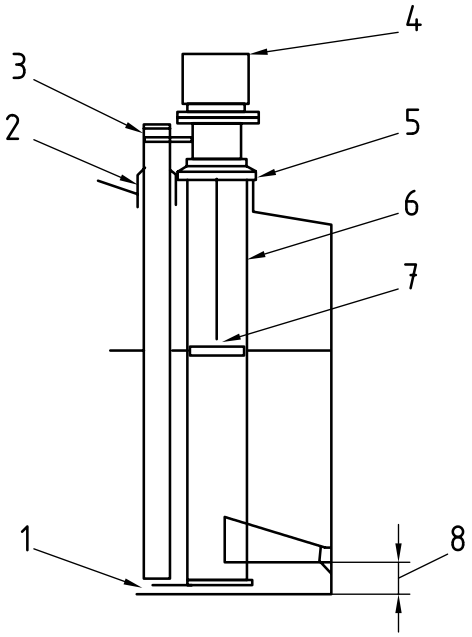
NOTE 2 The installations shown in Figure 2 a) and b) are typical for some intrusive ALGs. Non-intrusive top-mounted ALGs can be installed in a similar way.

NOTE 3 Local environmental restrictions can require the use of non-perforated still-well(s) on external floating-roof (EFR) tanks, but this can result in serious gauging errors and have safety implications (risk of tank overflow) in certain circumstances (see 6.5.7).

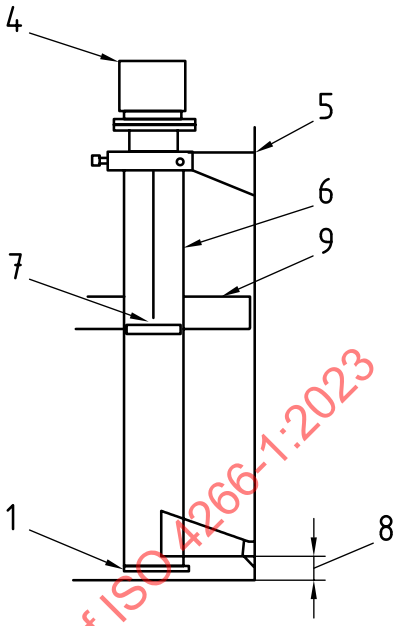
NOTE 4 It is expected that the datum plate is mounted on the tank bottom located below the still-well, or attached to the still-well (as shown).

NOTE 5 An ALG can also be mounted on the stable section of the roof of a fixed-roof tank (not shown in this figure).

Figure 1 — Example of an ALG (intrusive or non-intrusive) mounted on a still-well supported by the tank bottom



a) Installation of top-mounted ALG on fixed-roof tanks with still-well



b) Installation of top-mounted ALG on external floating-roof tanks or on internal floating-roof tanks with still-well

Key

1 datum plate (see note 5)
2 still-well sliding guide and weather seal
3 separate still-well (see note 1)
4 automatic level gauge (ALG) attached to top of still-well
5 still-well sliding guide
6 perforated still-well (see notes 1 and 3)
7 level-detecting element (see note 2)
8 support bracket (see note 4)
9 pontoon

NOTE 1 Separate still-wells for manual gauging and temperature measurement can be installed adjacent to the ALG still-well.

NOTE 2 The installations shown in Figure 2 a) and b) are typical for some intrusive ALGs. Non-intrusive, top-mounted level ALGs can be installed in a similar way.

NOTE 3 Local environmental restrictions can require the use of non-perforated still-well(s) on external floating-roof (EFR) tanks, but this can result in serious gauging errors and have safety implications (risk of tank overflow) in certain circumstances (see 6.5.7).

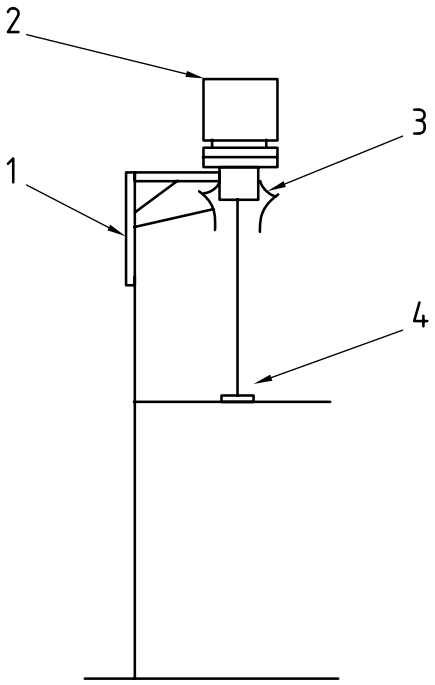
NOTE 4 It is expected that the support bracket is as close to the tank bottom as practical, typically 250 mm or less from the bottom.

NOTE 5 It is expected that the datum plate is attached to the still-well (as shown), or on the tank bottom plate.

NOTE 6 An ALG can also be mounted on the stable section of the roof of a fixed-roof tank (not shown in this figure).

NOTE 7 In order to minimize the vertical movement of the still-well due to hydrostatic deformation of the tank shell, it is expected that the support bracket design decouples the still-well from the tank shell.

Figure 2 — Example of an ALG (intrusive or non-intrusive) mounted on a still-well that is supported by a bracket hinged to the lower tank shell



Key

1 bracket welded to upper ring-segment of tank

2 automatic level gauge (ALG) mounted on a bracket

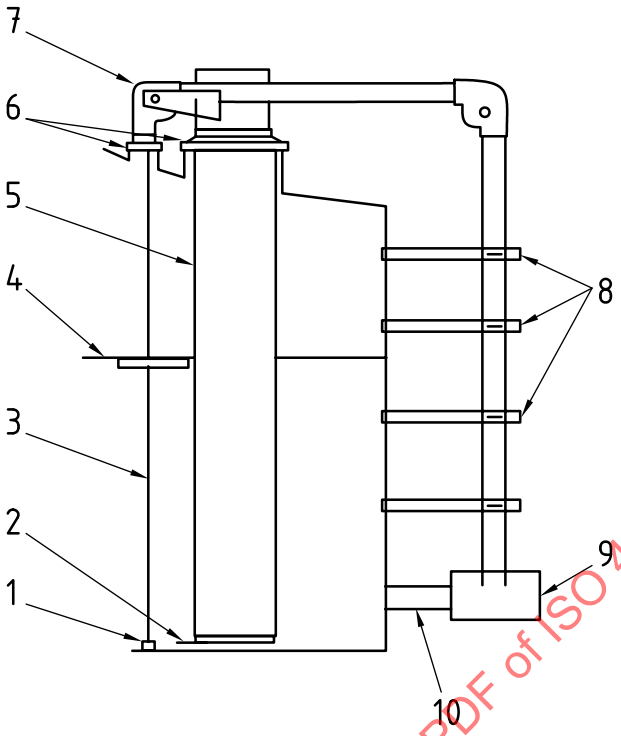
3 flexible seal to prevent emission of vapour from tank (see note 2)

4 level-detecting element (see note 1)

NOTE 1 The installations shown in Figure 2 a) and b) are typical for some intrusive ALGs. Non-intrusive, top-mounted ALGs can be installed in a similar way.

NOTE 2 Environmental regulations can apply when using a flexible seal.

Figure 3 — Example of an ALG supported by a "gallows"



Key

1 anchor bar or weight
2 datum plate (see note 3)
3 guide wire
4 level-sensing element
5 perforated still-well (see notes 1 and 2)
6 sliding guides
7 pulley housing attached to top of still-well
8 sliding guides
9 automatic level gauge (ALG) attached to tank shell
10 bracket

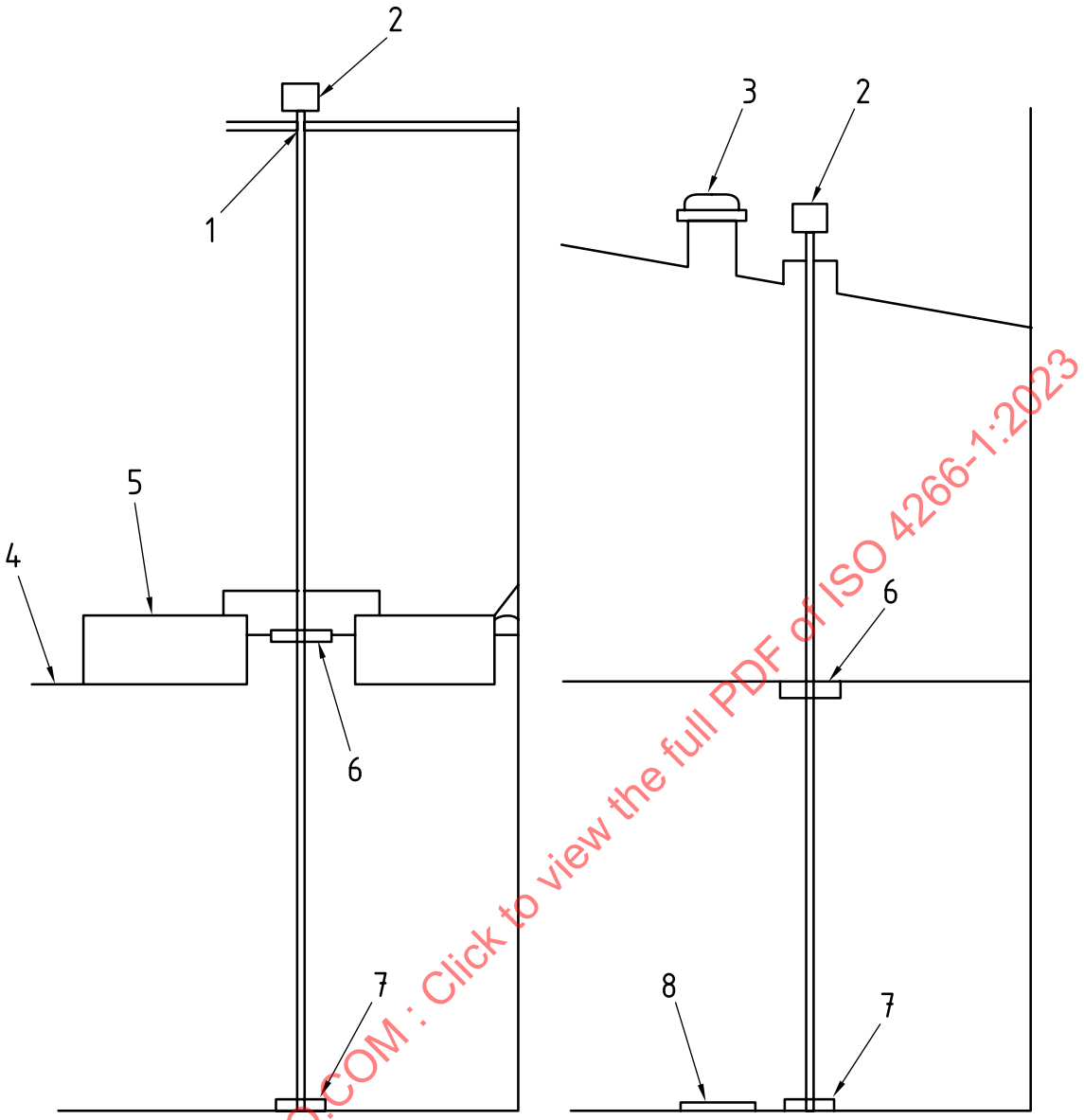
NOTE 1 A separate still-well for an automatic tank thermometer can be installed adjacent to the manual still-well.

NOTE 2 Local environmental restrictions can require the use of non-perforated still-well(s) on external floating-roof (EFR) tanks, but this can result in serious gauging errors and have safety implications (risk of tank overflow) in certain circumstances (see 6.5.7).

NOTE 3 It is expected that the dipping datum plate is mounted on the tank bottom, located below the still-well or attached to the still-well (as shown).

NOTE 4 The manual gauging still-well can alternatively be supported by a hinged trunnion arrangement, as shown in Figure 2.

Figure 4 — Example of an intrusive ALG (displacement type) attached to the tank shell near the tank bottom



Key

1 ALG guided through gauger's platform
2 ALG (see notes 1 et 3)
3 manual gauge hatch
4 floating roof
5 pontoon
6 level sensor
7 ALG support
8 dipping datum plate

A still-well is often not required for innage ALGs, especially in small tanks. Where a still-well is provided for protection, for stability of mounting, and to minimize turbulence, it is expected to be perforated (see 6.5.7).

It is expected that a means to secure and support the innage ALG is provided at the tank bottom.

An innage ALG should not be rigidly mounted on, nor supported from, the tank roof (fixed-roof tanks) or the gauger's platform (external floating-roof tanks). Instead, it should be guided through the roof and platform so that it remains vertical and is not affected by movement of the roof/platform due to tank-shell bulging with increasing hydrostatic head of the tank contents, and/or thermal expansion/contraction effects.

Figure 5 — Example of an innage ALG supported on the tank bottom

6.5 Still-well design

6.5.1 The still-well should be attached in either of the two ways described in 6.5.2 and 6.5.3.

6.5.2 The still-well may be supported on the bottom of the tank. Figure 1 a) is an example of an ALG mounted on a still-well supported on the floor of a fixed-roof tank. Figure 1 b) is an example of an ALG mounted on a still-well supported on the floor of a floating-roof tank.

NOTE When a tank is filled, the bottom of the tank can be deflected upwards by the angular deflection of the shell in the area immediately adjacent to the bottom joint. Further from the shell, the bottom can be deflected downwards. The amount of deflection depends on the soil conditions, the foundation design and the material and construction of the tank shell and bottom.

In most cases, bulging of the shell ceases to cause bottom movement, approximately 450 mm to 600 mm from the shell. For tank construction considerations, the still-well and its supports should be located beyond this distance (see Figures 1 and 2).

6.5.3 The still-well may be supported by a trunnion or hinge connected to the bottom course of the shell. The trunnion-supported still-well should be designed to minimize vertical movement. Figure 2 a) is an example of an ALG mounted on a still-well supported by a trunnion on the shell of a fixed-roof tank. Figure 2 b) shows an ALG mounted on a still-well supported by a trunnion on the shell of a floating-roof tank.

In order to minimize the vertical movement of the still-well due to hydrostatic deformation of the tank shell, it is recommended that the support bracket design decouples the still-well from the tank shell.

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

If the ALG level-detecting element is subjected to excessive turbulence, certain types of ALGs may be thrown out of calibration. When using these ALGs, the level-detecting element should be located far enough away from the tank inlet and outlet connections to minimize the effect of eddies, currents and turbulence. When this cannot be done, the level-detecting element should be protected by means of a still-well. Where tank mixers are installed, the ALG manufacturer should be consulted.

6.5.5 The recommended minimum still-well diameter is 200 mm. Smaller diameter still-wells may be used depending on the type and design of the ALGs used. If smaller diameter still-wells are used, the design and construction should be checked for mechanical rigidity and strength. Larger diameter still-wells may be required to accommodate larger level-sensing elements for some types of ALGs.

6.5.6 The distance from the bottom of the still-well to the bottom of the tank should be less than 300 mm. The top of the still-well should be above the maximum liquid level.

6.5.7 The still-well should be perforated with one or two rows of slots or holes, about 25 mm wide. The perforations should continue above the maximum liquid level. The spacing between the perforations should be less than 150 mm, or as recommended by the manufacturer of the ALG. The still-well should be straight with internal burrs and welds removed.

NOTE Use of still-wells without perforations can lead to serious level measurement errors.

6.5.8 After the tank has been hydrostatically tested, the still-well should remain vertical.

7 Initial setting and initial verification of ALGs in the field

7.1 General

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

7.2 General precautions

7.2.1 Initial requirements

Prior to initial setting or initial verification of a new or repaired ALG, the tank shall be allowed to stand at a constant level long enough for air or vapour to be released from the liquid and for the tank bottom to reach a stable position. New tanks shall be filled and allowed to stand to minimize the errors caused by initial bottom settlement. The tank mixer shall be turned off long enough before setting or verification, to allow the liquid to come to rest. The tank shall be run through at least one operational cycle, filling and emptying the tank within normal working limits of filling and discharge rate.

7.2.2 Manual reference level measurement procedure

When an ALG is set to level or verified by comparison with manual reference level measurement, the manual measurements should be performed to obtain the highest accuracy (see ISO 4512). Manual reference measurements should be performed by skilled operators.

7.2.3 Reference measurement tape and weight certification

The measurement tape and weight used for ALG setting or verification should be a reference master tape/weight combination certified by an accredited calibration laboratory. It is expected to be traceable to a national measurement standard, or a working tape/weight combination that has been recently compared with a certified reference tape and weight which meets the maximum permissible error limits specified in ISO 4512. The calibration corrections for the tape/weight combination should be applied.

7.2.4 Effect of weather

High winds, heavy rain, snow, or severe storms can cause movements of the tank shell, the ALG mounting and/or the liquid surface. These movements can influence both manual and ALG readings. The effect on manual gauging can be different from that on the ALG. Setting and verification should not be carried out under adverse weather conditions or at wind speeds exceeding 8 m/s.

7.2.5 ALG technology-specific considerations

There may be additional technology-specific considerations which affect ALG verification. Specific, additional steps can be necessary to prepare the ALG prior to the initial setting (see 7.3). Technology-specific considerations include, for example, the effect of physical and electrical properties of the liquid and vapour in the tank, the need of checking free movement of the level sensor, and others. Reference should be made to ALG manufacturer's documentation.

7.2.6 Application-specific considerations

In tanks storing heavy or viscous liquids, it can be difficult to measure or verify the manual or ALG reference heights. It is possible that the procedures for measuring reference heights described in 7.3 and 7.4 are not be feasible under these circumstances.

7.3 Initial settings of ALGs

7.3.1 Setting against manual reference ullage measurements

a) With the tank contents static at a level between one-third and two-thirds full, record the stable ALG reading before the gauger arrives at the tank. Also record the ALG reading immediately before making the manual reference measurements. Check whether the presence of the gauger on the tank top affects the ALG reading. If the ALG reading varies by more than 1 mm, investigate the cause before proceeding.

b) Measure the tank reference height at the official gauging access position specified in the tank calibration table until three consecutive measurements agree within a range of 1 mm, or five consecutive measurements agree within a range of 2 mm. Calculate the arithmetic average value for the 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, difficulties can be experienced with the initial verification procedure. Investigate the cause before proceeding.

NOTE Failure to achieve repeatable tank reference height measurements can be due to adverse weather conditions, build-up of debris on the datum plate, turbulence of the liquid or inconsistency in the measurement technique. Failure to achieve agreement between the measured and calibration reference heights can be due to one or more of the reference datums being affected by variations in the hydrostatic head of the liquid at different levels within the tank.

c) Determine the manual reference 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, or five consecutive measurements agree within a range of 2 mm. Calculate the arithmetic average value of the ullage (i.e. the average of the consecutive measurements).

d) Determine the equivalent dip by subtracting the average manual ullage from the average measured tank reference height.

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

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

7.3.2 Setting against manual reference dip (innage) measurements

a) With the tank contents static at a level between one-third and two-thirds full, record the stable ALG reading before the gauger arrives at the tank. Also record the ALG reading immediately before making the manual reference measurements. Check whether the presence of the gauger on the tank top affects the ALG reading. If the ALG reading varies by more than 1 mm, investigate the cause before proceeding.

b) Measure the tank reference height at the official gauging access position specified in the tank calibration table until three consecutive measurements agree within a range of 1 mm, or five consecutive measurements agree within a range of 2 mm. Calculate the arithmetic average value for the 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, difficulties can be experienced with the initial verification procedure. Investigate the cause before proceeding.

NOTE Failure to achieve repeatable tank reference height measurements can be due to adverse weather conditions, build-up of debris on the datum plate, turbulence of the liquid or inconsistency in the measurement technique. Failure to achieve agreement between the measured and calibration reference heights can be due to one or more of the reference datums being affected by variations in the hydrostatic head of the liquid at different levels within the tank.

c) Determine the level of the tank contents by manual reference dip measurements until three consecutive measurements agree within a range of 1 mm, or five consecutive measurements agree within a range of 2 mm. The tank reference height should be verified every time a manual reference dip measurement is made. In any case where the reference height is found to be more than 1 mm different from the average value determined in step b), the dip measurement should be rejected as suspect.

   Failure to achieve manual measurements within these tolerances can 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 dip [i.e. the average of the consecutive measurements obtained in step c)].

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

f) Compare the ALG reading with the average manual reference dip. If the two do not agree (within the resolution of the ALG), set the ALG so that it reads the same as the average manual reference dip.

7.4 Initial verification

7.4.1 General

Ullage-based ALGs are designed to measure the distance from the ALG reference point to the liquid surface. Some types of ullage-based ALG can compensate for tank reference datum movement (where such movement has been quantified and found to be repeatable). However, most traditional types of ullage-based ALG cannot compensate for many of the limitations to the accuracy of tank level measurement given in this document.

Innage-based ALGs are designed to measure the liquid dip directly. They should be less prone to some of the tank stability problems that can cause level measurement errors with ullage-based ALGs, but they require the tank bottom on which the ALG is mounted to be stable.

Apart from the effect of the stability of the tank reference points (i.e. the dipping datum plate and the gauging reference point) on the accuracy of ALG and manual level measurements, several other factors can result in level measurement errors and should be considered during ALG verification. These include:

— tank installation errors;

— changes in operating conditions;

— changes in physical properties of the liquid and/or vapour;

— changes in electrical properties of the liquid and/or vapour;

— changes in local ambient conditions;

— manual gauging errors;

— errors inherent in the ALG.

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

— comparing the ALG against manual reference level measurement at three different levels and evaluating the differences between the ALG readings and the manual reference measurements, or

— measuring the tank reference height at each of the three levels, and evaluating any change in reference height.

Depending on the results, the tank and ALG combinations should be considered suitable for fiscal/custody transfer purposes, if the calibration/verification tolerances given in this document are met.

7.4.2 Verification conditions

The initial verification of an ALG 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 (see 7.3), 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.

7.4.3 Initial verification procedures

7.4.3.1 ALG verification by manual reference ullage (outage) measurements

a) After the initial setting of the ALG (see 7.3), 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's working capacity (7.4.2).

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

c) Measure the tank reference height at the official gauging position specified in the tank calibration table until three consecutive measurements agree within a range of 1 mm, or five consecutive measurements agree within a range of 2 mm. Calculate the arithmetic average value for the 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 2 mm, investigate the cause before proceeding.

NOTE Failure to achieve repeatable tank reference height measurements can be due to adverse weather conditions, build-up of debris on the datum plate, turbulence of the liquid or inconsistency in the measurement technique. Failure to achieve agreement between the measured and calibration reference heights can be due to one or more of the reference datums being affected by variations in the hydrostatic head of the liquid at different levels within the tank.

d) Determine the manual reference 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, or five consecutive measurements agree within a range of 2 mm.

Failure to achieve manual measurements within these tolerances can 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.