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

Part 4: Measurement of temperature in atmospheric tanks

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

Partie 4: Mesurage de la température dans les réservoirs à pression atmosphérique

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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 part of ISO 4266 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 4266-4 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Subcommittee SC 3, *Static petroleum measurement*.

ISO 4266-4, together with ISO 4266-1 to ISO 4266-3 and ISO 4266-5 and ISO 4266-6, cancels and replaces ISO 4266:1994, which has been technically revised.

ISO 4266 consists of the following parts, under the general title *Petroleum and liquid petroleum products — Measurement of level and temperature in storage tanks by automatic methods*:

— *Part 1: Measurement of level in atmospheric tanks*

— *Part 2: Measurement of level in marine vessels*

— *Part 3: Measurement of level in pressurized storage tanks (non-refrigerated)*

— *Part 4: Measurement of temperature in atmospheric tanks*

— *Part 5: Measurement of temperature in marine vessels*

— *Part 6: Measurement of temperature in pressurized storage tanks (non-refrigerated)*

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

Part 4:
Measurement of temperature in atmospheric tanks

1 Scope

This part of ISO 4266 gives guidance on the selection, accuracy, installation, commissioning, calibration and verification of automatic tank thermometers (ATTs) in fiscal/custody transfer applications in which the ATT is used for measuring the temperature of petroleum and liquid petroleum products having a Reid vapour pressure less than 100 kPa, stored in atmospheric storage tanks.

This part of ISO 4266 is not applicable to the measurement of temperature in caverns or in refrigerated storage tanks.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 4266. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 4266 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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

ISO 4266-1:2002, *Petroleum and liquid petroleum products — Measurement of level and temperature in storage tanks by automatic methods — Part 1: Measurement of level in atmospheric tanks*

ISO 4268:2000, *Petroleum and liquid petroleum products — Temperature measurements — Manual methods*

3 Terms and definitions

For the purposes of this part of ISO 4266, the terms and definitions given in ISO 1998, and the following, apply.

3.1
automatic tank thermometer
ATT
instrument that continuously measures temperature in storage tanks

NOTE An ATT, which may also be known as an automatic tank temperature system, typically includes precision temperature sensors, field-mounted transmitters for electronic signal transmission, and receiving/readout device(s).

3.2
resistance temperature detector
RTD
electrical temperature-sensing element in common use to measure the temperature of the contents of a storage tank

3.3
single-point ATT
spot ATT
ATT that measures the temperature at a particular point in a tank by the spot temperature element

3.4
multiple-point ATT
ATT consisting of multiple (usually three or more) spot temperature elements to measure the temperature(s) at selected liquid level(s)

NOTE The readout equipment should average the readings from the submerged temperature elements to compute the average temperature of the liquid in the tank, and may also display the temperature profile in the tank.

3.5 Averaging ATT

3.5.1
multiple-point averaging ATT
averaging ATT where the readout equipment selects the individual, spot temperature element(s) that are submerged in the liquid to determine the average temperature of the liquid in the tank

3.5.2
variable-length averaging ATT
averaging ATT consisting of several temperature elements of varying length, with all the elements extending upwards from a position close to the bottom of the tank, and where the readout equipment selects the longest, completely submerged temperature element to determine the average temperature of the liquid in the tank

3.6
temperature transmitter
instrument that typically provides electrical power to the temperature element(s), converts the temperature measured by the element(s) to an electrical or electronic signal, and transmits the signal to a remote readout

NOTE A local readout may be provided. Often, the function of the temperature transmitter is provided by the level transmitter of the automatic level gauge (ALG).

4 Precautions

4.1 Safety precautions

International Standards and government regulations on safety and material-compatibility precautions should be followed when using ATT equipment. In addition, the manufacturer's recommendations on the use and installation of the equipment should be followed. All regulations covering entry into hazardous areas should be observed.

4.2 Equipment precautions

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

4.2.2 ATTs 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 ATT have the same electrical potential as the tank.

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

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

4.2.6 The temperature elements should be located so that the temperature of any sediment deposits or free water bottoms that may be present in the tank is not measured.

4.3 General precautions

4.3.1 The general precautions given in 4.3.2 to 4.3.6 apply to all types of ATTs and should be observed where they are applicable.

4.3.2 Tank levels should be measured at the same time as the tank temperature is measured.

4.3.3 Temperatures measured for bulk transfer should be recorded when they are taken, unless the remote readout equipment of the ATT automatically records the temperatures periodically.

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

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

4.3.6 The design and installation of ATTs may be subject to the approval of the national measurement organization, who will normally have issued a type or pattern approval ("Type Approval") for the design of the ATT for the particular service for which it is to be employed. Type approval is normally issued after an ATT has been subjected to a specific series of tests and is subject to the ATT being installed in an approved manner. Type approval tests may include the following: visual inspection, performance, vibration, humidity, dry heat, inclination, fluctuations in power supplies, insulation, resistance, electromagnetic compatibility and high voltage.

5 Accuracy

5.1 General

The accuracy of petroleum temperatures taken by the ATTs should be consistent with the accuracy of the levels taken by the automatic level gauging system so that the overall accuracy of the standard volume measurement is not seriously degraded. Observance of the accuracy requirements for level and temperature gauging systems gives in ISO 4266-1 and in this part of ISO 4266 will ensure that this is avoided.

5.2 Intrinsic error of ATTs

The intrinsic error of the ATT, i.e. the accuracy of the ATTs when tested under controlled conditions as specified by the manufacturers, can be a major component of the uncertainty of the temperature measurement of the ATT as installed. The calibration reference device used to calibrate the ATT should be traceable to appropriate national standards.

NOTE The temperature elements and field transmitters used for fixed, automatic tank temperature measurement are calibrated prior to installation. The transmitters normally do not provide field calibration adjustments.

5.3 Calibration prior to installation

5.3.1 General

ATTs to be used in fiscal/custody transfer applications can be calibrated/verified either as a system (see 3.1), or by components.

5.3.2 ATT calibrated as a system

If verified as a system, the temperature reading of the ATT readout should agree with that of the thermostatically controlled reference bath or oven temperature within 0,25 °C at a minimum of three test temperatures spanning the anticipated working range of the ATT.

NOTE Subclauses 9.2.1, 9.3.1 and 9.4.1 refer to this clause for calibration of an ATT in the field “as a whole” or “as a system”.

5.3.3 ATT calibrated by components

If the ATT is verified by components:

a) the temperature equivalent of the measured resistance should agree with the reference bath temperature within 0,20 °C at each temperature;

b) the temperature transmitter/converter and the ATT readout should be checked using precision resistors or a recently calibrated thermal calibrator. The ATT readout should agree with the temperature equivalent of the resistors or calibrator within 0,15 °C at each temperature.

NOTE See 9.2.1, 9.3.1 and 9.4.1 for calibration of an ATT in the field by components.

5.3.4 Multiple-point ATTs

The required accuracy for each spot temperature sensor should be as given in 5.3.2 or 5.3.3, depending on the method used.

5.3.5 Variable-length ATTs

The required accuracy for each temperature element should be as given in 5.3.2 or 5.3.3, depending on the method used.

5.3.6 Uncertainty of the reference

The uncertainty of the reference should not exceed ± 0,05 °C.

5.4 Error caused by installation and operating conditions

The total error of the ATT in fiscal/custody transfer applications can be affected by the installation and by variations in the operating conditions.

NOTE 1 The accuracy of an ATT depends on the following:

— the number of the temperature-sensing elements;

— the location of the temperature-sensing elements.

NOTE 2 The tank content’s temperature may be subject to stratification which varies with

— tank mixing;

— multiple sources of supply;

— viscosity of the liquid in the tanks, and

— tank insulation.

NOTE 3 Temperatures in large tanks (i.e. 750 m^3 or larger) are often vertically stratified unless the contents are thoroughly mixed. Larger stratification may be expected in high-viscosity petroleum liquids.

NOTE 4 With other level-measurement technologies (e.g. hydrostatic tank gauges which are pressure-based), a single spot temperature may suffice.

5.5 Overall accuracy

5.5.1 General

The overall accuracy of temperature measurement by the ATT, as installed, is limited by the intrinsic error of the ATT equipment (temperature-sensing element, transmitter and readout), the effect of installation methods, and the effect of the operating conditions.

When using automatic level gauges (ALGs) which measure the level for fiscal/custody transfer measurement, an ATT should be used which can provide a representative average temperature of the tank contents. In tanks with vertical temperature stratification, the temperature gradient is rarely linear. In circumstances where it has been demonstrated that the operational conditions (e.g. use of tank mixers and/or recirculation of the tank contents) can result in measurements from a single-point temperature sensor being representative (see ISO 4268), such a single-point ATT may be considered adequate. In other circumstances, a multiple-point or other averaging ATT system is recommended.

5.5.2 Use of ATT for fiscal/custody transfer purposes

An ATT system should be considered suitable for fiscal/custody transfer services if the ATT system meets the field verification tolerances given below.

The ATT should meet the calibration tolerances prior to installation (see 5.3).

Including the effects of installation methods and changes in operating conditions, the ATT should meet the field verification tolerance (see 9.2.2, 9.3.2 and 9.4.2).

The remote readout, if used, should meet the requirements of this part of ISO 4266 (see clause 10).

6 Selection of ATTs

6.1 General

Copper or platinum temperature element bulbs, i.e. resistance temperature detectors (RTDs), are normally used for this application. Three types of ATT elements are widely used:

— single-point (spot) ATT (see 3.3);

— multiple-point ATT (see 3.4);

— variable-length averaging ATT (see 3.5).

Other types of ATT elements, which provide comparable performance, may be used.

The selection of a suitable ATT should be made based on the following criteria:

a) the accuracy required;

b) the operating conditions which may affect the accuracy (e.g. expected product temperature stratification);

c) the minimum level in the tank at which temperature measurement is required;

d) environmental conditions;

e) number, type and size of the tanks;

f) available tank entries for new or existing tanks;

g) requirements for local and remote readout, signal transmission, and cabling.

6.2 ATTs for fiscal/custody transfer purposes

Tanks using an automatic method to determine temperature in fiscal/custody transfer should be fitted with average temperature equipment, except when

— the tanks are equipped with operational mixer(s), or an effective recirculation system,

— the maximum vertical temperature variation is less than 1 °C,

— the tanks have a capacity less than 159 m^3 (1 000 barrels) or the level is less than 3 m, and

— the manual average temperature measurement is used for fiscal/custody transfer.

Single-point or spot tank temperature measurement may be used when the temperature of the liquid in the tank has been demonstrated to be uniform, or any temperature stratification in the tank has been shown to be small and acceptable (see ISO 4268).

The mid-level temperature of the tank contents may not give an accurate average temperature.

Small tanks, tanks storing a uniform temperature material, or tanks with adequate mixing equipment have less temperature stratification. Therefore, a single-point temperature measurement may be sufficiently representative.

Heated tanks or tanks storing viscous materials will rarely have uniform temperatures.

Tanks with multiple sources of supply will rarely have a uniform temperature. Single-point temperature elements should not be considered in these circumstances.

NOTE It may be possible to determine the average temperature of a tank transfer quantity by using a single-point (spot) temperature element located on the inlet or outlet of a tank, using the ALG to calculate a volume-weighted average temperature of a parcel being loaded into or discharged out of the tank.

7 Description of ATT equipment

7.1 Introduction

Most above-ground bulk storage tanks are equipped with at least one local direct-reading thermometer mounted in a fixed thermowell. This local thermometer is not considered as part of the ATT and should not be used for fiscal/custody transfer temperature determination, unless it has been demonstrated that its readings are representative of the temperatures of the tank contents under typical operating conditions (see ISO 4268).

7.2 Electrical temperature elements

7.2.1 Resistance temperature detectors

Temperature-measuring equipment commonly used for automatic temperature measurement operates on the basic principle that the electrical resistance of a metal (e.g. copper or platinum) varies with changes of temperature.

Copper or platinum electrical-resistance detectors (RTDs) are normally used for temperature measurement for fiscal/custody transfers because of their high accuracy and stability. The resistance of an RTD is measured by a Wheatstone bridge circuit or other suitable electronic package. The RTD may be a resistance wire wound on a supporting non-conductive core, a thin film type, or other type. The element should be properly encased. The electronic circuits should be intrinsically safe if required. The temperature element is usually contained within a thermowell. The length of the temperature-sensitive portion of a spot element should not exceed 100 mm.

7.2.2 Other temperature elements

Other types of temperature elements (thermocouples, thermistors, semi-conductors, fibre optics, etc.) are available. Unless calibrated and meeting the verification tolerance given in this part of ISO 4266, their accuracy is not considered suitable for fiscal/custody transfer services.

8 Installation of ATTs

8.1 General

The temperature elements of an ATT should be located as far as possible from heating coils and swing arms. They should be mounted in the tank in relation to the position of the inlet and outlet connections and tank mixers so that the effect of turbulence on the mounting of the element is minimized. They should, where possible, be sited on the shaded side of the tank and should be accessible from the gauger's platform.

8.2 Single-point (spot) temperature elements

Single-point (spot) temperature elements should be installed in positions which permit their *in-situ* verification. The following three methods of installation are in general use.

a) The elements are installed in a metal thermowell through the tank shell, projecting at least 1 m into the tank to reduce heat transfer effects through the thermowell. They should be located at an elevation of at least 1 m above the tank-bottom surface.

b) The elements are installed suspended from the tank roof in a suitable metallic or non-metallic tube/hose secured to the tank bottom or stabilized by anchor weights. The element should be located at least 900 mm from the tank shell and the low point should be at an elevation of approximately 1 m above the tank-bottom surface.

c) The elements are installed by either attaching the temperature element to the flexible elbow of the swing suction line or by suspending the element on a pulley arrangement from the floating roof (see 8.3.5).

8.3 Averaging temperature elements

8.3.1 General

The installation of the temperature elements for fixed temperature averaging equipment should conform to the same recommendations as those for single-point or spot temperature elements (i.e. the elements should be located at least 900 mm from the tank shell). Various configurations, given in 8.3.2 to 8.3.7, are in general use.

8.3.2 Upper, middle and lower temperature elements

The upper temperature element is suspended about 1 m below the liquid surface. The mid-level temperature element is suspended at the mid-point of the liquid. This can be accomplished either by attaching the element to the flexible elbow of the swing suction line or by suspending the element on a pulley arrangement. The lower temperature element is installed about 1 m from the tank bottom. The resistances of the three elements are electrically combined, or their readings averaged, to give the average temperature.

8.3.3 Multiple-point temperature elements

Multiple-point temperature elements (see Table 1) are typically installed at equidistant intervals (at approximately 3 m). The lowest element which is used for average tank temperature calculation is usually located at approximately 1 m from the bottom of the tank. Where the tank is operated at a level lower than 1 m, an extra temperature element can be located at a level as low as practical but it should only be used in this condition.

NOTE The measurement by this extra temperature element (below 1 m) may be affected by ground temperature.

Table 1 — Number of temperature elements for multiple-point ATTs

Tank heights	Minimum number of elements
Less than 9 m	4
9 m to 15 m	5
More than 15 m	6
NOTE 1 If the liquid level is 3 m or less, a single mid-level temperature located at approximately half of the tank height may be considered to meet the minimum requirement. NOTE 2 If the lowest temperature element is less than 1 m from the tank bottom, the measured temperature may be affected by ground temperature.	

In fixed-roof tanks, the ATT elements may be installed in thermowells extending through the tank shell. In floating-roof or internal floating tanks, they may be installed in a special perforated temperature standpipe or similar device passing through a sleeve or bushing. All temperatures are generally measured and transmitted to a central temperature-readout device with computing ability integral to the ALG system. The temperature-readout device averages only the submerged elements. Alternatively, the device may transmit the individual temperature of the submerged elements to provide a vertical profile of temperature. A typical multiple-point temperature element installation is shown in Figure 1.

8.3.4 Variable-length RTD temperature elements

A number of RTDs of varying lengths, all of which extend within 900 mm of the bottom of the tank, are encased in a flexible sheath. Only the longest, fully submerged RTD is used to determine the average temperature of the liquid in the tank. The correct RTD is selected by either a switching device in the ALG, or by software in the ALG system's remote readout device (typically a computer). The multiple-element assembly can be installed in the tank in a closed thermowell which is filled with heat conductive oil and/or fitted with baffles, or directly immersed in the liquid and suspended from the tank roof or gauging platform. A typical installation of a variable-length ATT is shown in Figure 2.

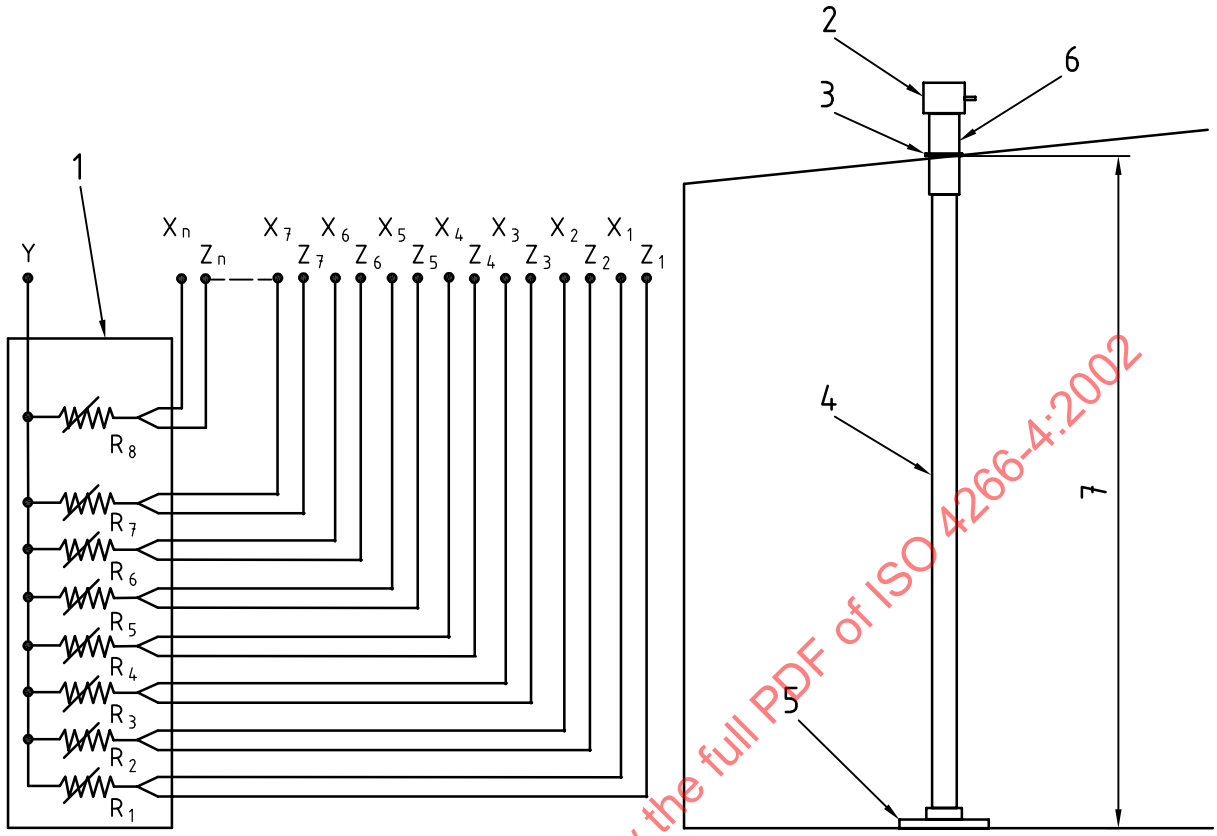
8.3.5 Mid-level temperature element

A mid-level temperature element is a single temperature element suspended at the mid-point of the liquid. This can be accomplished either by attaching the element to the flexible elbow of the swing suction line or by suspending the element on a pulley arrangement from the floating roof.

It should be noted that the mid-level temperature may not be the average temperature of the tank. Calibration of a mid-level temperature-element-based ATT is the same as for a single-point temperature-element-based ATT.

8.3.6 Moveable spot temperature element

A spot temperature element attached to the displacer of a servo-operated ALG is driven through the liquid, stopping at appropriate points to determine the average tank temperature. Adequate time should be provided at each measurement location to ensure that thermal equilibrium is reached.



Key

1	Sensor housing
2	Junction box or temperature transmitter
3	Compression fitting (with or without flange)
4	Flexible element housing
5	Anchor weight
6	Extension fitting
7	Mounting height

Figure 1 — An example of a multiple-point temperature element installation

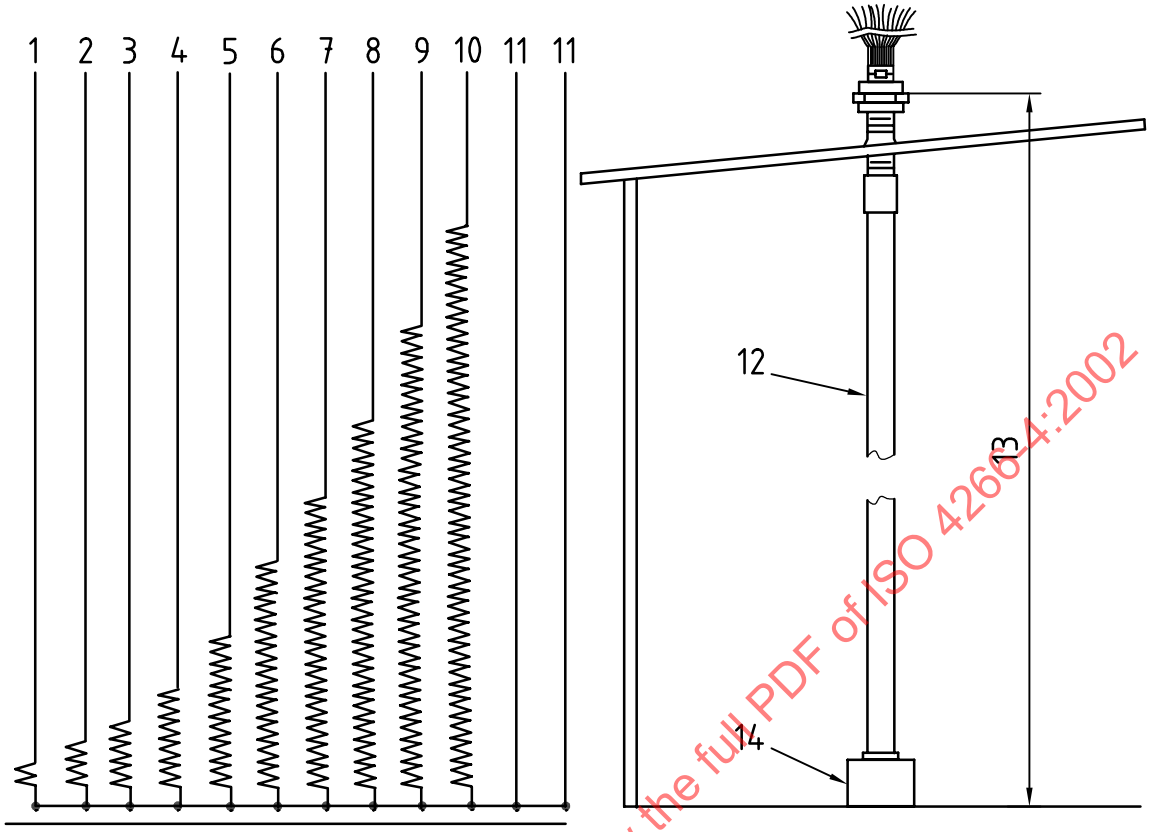
8.3.7 Other methods

Other methods may be used to meet the requirements of average tank-temperature measurements given in this part of ISO 4266.

8.4 Thermowells for electronic temperature elements

Thermowells for fixed temperature elements should extend through the tank shell for at least 900 mm to reduce errors due to temperature differences between the liquid in the tank and ambient temperature. The thermowell material should be compatible with the liquid.

The thermowells should be located near the ladder or stairway to facilitate maintenance, and located as far as possible from heating coils and the tank inlet and outlet.



Key

1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Grey
9	White
10	Pink
11	Black
12	Flexible hose
13	Mounting height
14	Anchor weight

Figure 2 — An example of a variable-length RTD temperature element installation

Thermowells extending through the tank shell cannot be used on floating-roof or pan-roof tanks above the minimum roof height. Various proprietary thermowells are available to support averaging temperature elements in floating-roof or pan-roof tanks.

Adequate clearance should be provided between the ATT sensor assembly and the thermowell for ease of installation. The clearance, however, should be kept as small as practical to reduce the time lag for heat transfer. To prevent measurement errors due to thermal convection circulation in the gap between the thermowell and the sensor assembly, the well should be filled with heat conductive fluid and should provide for thermal expansion of the filling fluid. In addition, baffles may be fitted in the thermowell.

9 Calibration and field verification of ATTs

9.1 Introduction

The ATT, including the temperature element(s), the transmitter and the readout, selected for fiscal/custody transfer temperature measurement, should meet the calibration tolerances given in this part of ISO 4266. The calibration reference for an ATT should be traceable to appropriate national standards.

NOTE 1 The precision electronic temperature elements and field transmitters used for fixed, automatic tank temperature thermometers are calibrated prior to installation. The transmitters normally do not provide calibration adjustments in the field.

NOTE 2 The purpose of the following procedures is to verify the adequacy of the calibration and the accuracy of the ATT (including the temperature elements, the transmitter, and the local/remote readout) as installed.

When an ATT is checked or calibrated by manual temperature measurement, the manual temperature measurement should be performed in accordance with ISO 4268. The uncertainty of the field calibration reference should not exceed $\pm$ 0,1 °C.

The ATT can be calibrated/verified either as a system (see 3.1) or by components.

9.2 Calibration of single-point, or mid-level temperature element ATTs for fiscal/custody transfer purposes

9.2.1 Calibration prior to installation

Prior to installation, single-point or mid-level ATTs should be calibrated, under controlled conditions (i.e. in the factory or in a testing laboratory), in one of the two ways described below. The calibration reference for an ATT should be traceable to appropriate national standards.

a) The ATT (including the temperature sensors, the temperature transmitter/converter, and the readout) as a whole may be calibrated with constant temperature baths, at three or more temperatures covering the operating range. The bath temperatures should be measured by reference thermometer(s) (see 5.3.2 for the required accuracy).

b) Alternatively, the components of the ATT may be separately calibrated. Measure the resistance of the temperature element in the bath. Separately, use precision resistors, or a thermal calibrator (recently calibrated against a reference traceable to a national standards agency) to simulate temperature input to the temperature transmitter/converter and readout of the ATT (see 5.3.3 for the required accuracy).

9.2.2 Initial field verification

9.2.2.1 Verification by components

9.2.2.1.1 Temperature element

Use a recently calibrated portable electronic thermometer to verify the measurement by the temperature element in accordance with ISO 4268. Lower the thermometer to the depth at which the element is located and move the thermometer up and down (over a range of approximately 300 mm) until the temperature measured is stable. The temperature measured by the RTD temperature sensor should agree with the temperature measured by the calibrated portable electronic thermometer within 0,4 °C.

9.2.2.1.2 Temperature transmitter

The ATT, excluding the temperature element, can be verified by using a temperature calibrator (e.g. precision resistors or a thermal calibrator) to simulate temperature input at three or more temperatures covering the expected tank operating temperatures. The ATT readout should agree with the temperature equivalent of the resistors within 0,25 °C at each temperature.