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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.

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](http://www.iso.org/directives)).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at [www.iso.org/patents](http://www.iso.org/patents). ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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](http://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 4266-4:2002), which has been technically revised.

The main changes are as follows:

- in 4.3.2, it has been clarified that the tank level should be measured and recorded simultaneously with the temperature;
- in 9.2, it has been clarified that individual component verification is optional, but verification as a whole system is required.

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](http://www.iso.org/members.html).

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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

### 1 Scope

This document gives requirements and guidance on the selection, accuracy, installation, commissioning, calibration and verification of automatic tank thermometers (ATTs) in fiscal/custody transfer applications.

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 document is not applicable to the measurement of temperature in caverns or in refrigerated storage tanks.

### 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 tank thermometer**

##### **ATT**

instrument that continuously measures temperature in storage tanks

Note 1 to entry: An ATT, which can 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 automatic tank thermometer**

spot automatic tank thermometer

*automatic tank thermometer* (3.1) that measures the temperature at a particular point in a tank by the spot temperature element

### 3.4

#### **multiple-point automatic tank thermometer**

*automatic tank thermometer* (3.1) consisting of multiple (usually three or more) spot temperature elements to measure the temperature(s) at selected liquid level(s)

Note 1 to entry: The readout equipment can average the readings from the submerged temperature elements to compute the average temperature of the liquid in the tank and can also display the temperature profile in the tank.

### 3.5

#### **multiple-point automatic tank thermometer**

averaging *automatic tank thermometer* (3.1) 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

### 3.6

#### **variable-length averaging automatic tank thermometer**

averaging *automatic tank thermometer* (3.1) 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

### 3.7

#### **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 1 to entry: 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 can apply when using ATT 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 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 in an area where it can be ensured that the temperature of any sediment deposits or free water bottoms that can be present in the tank are 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 and recorded simultaneously, or as close as practical, as the tank temperature is measured. For more details on level measurement, refer to ISO 4266-1.

**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 can be subject to the approval of the national measurement organization, who 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 given in ISO 4266-1 and in this document will ensure overall accuracy of the standard volume measurement.

### 5.2 Intrinsic error of ATTs

The intrinsic error of ATTs, 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. It is presupposed that the calibration reference device used to calibrate the ATT is 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, 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.

### 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.

### 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  $\pm 0,05$  °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.

The accuracy of an ATT depends on the following:

- the number of the temperature-sensing elements;
- the location of the temperature-sensing elements.

The tank content's temperature can be subject to stratification which varies with:

- tank mixing;
- multiple sources of supply;
- viscosity or density of the liquid in the tanks, and
- tank insulation.

NOTE 1 Temperatures in large tanks (i.e. 750 m<sup>3</sup> or larger) are often vertically stratified unless the contents are thoroughly mixed. Larger stratification can be expected in high-viscosity or high-density petroleum liquids.

NOTE 2 With some mass measurement technologies (e.g. hydrostatic tank gauges which are pressure-based), a single spot temperature can 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.

### 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 in [9.2.2](#), [9.3.2](#) and [9.4.2](#).

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

The ATT should meet the field verification tolerance (see [9.2.2](#), [9.3.2](#) and [9.4.2](#)), as well as the effects of installation methods and changes in operating conditions.

The remote readout, if used, should meet the recommendations of [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;
- multiple-point ATT;
- variable-length averaging ATT.

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 can 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) type and size of the tank;
- 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 of less than 159 m<sup>3</sup> (1 000 barrels) or the level is less than 3 m.

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 when any temperature stratification in the tank has been shown to be small and acceptable (see ISO 4268).

It is possible that the mid-level temperature of the tank contents does 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 can be sufficiently representative.

Heated tanks rarely have uniform temperatures.

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

NOTE It is 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 General

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 temperature 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 these types of temperature elements are calibrated or unless they meet the verification tolerance given in [Clause 5](#), 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 located 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 permits 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 installed elements are 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 1 m 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 1 m from the tank shell). Various configurations, given in [8.3.2](#) to [8.3.6](#), 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) can be affected by ground temperature or heating coils.

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

Tank heights m	Minimum number of elements
Less than 9	4
9 to 15	5
More than 15	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 can 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 can be affected by ground temperature or heating coils.

In fixed-roof tanks, the ATT elements may be installed in thermowells extending through the tank shell. In floating-roof or internal floating tanks, ATT elements 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 1 m 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](#).

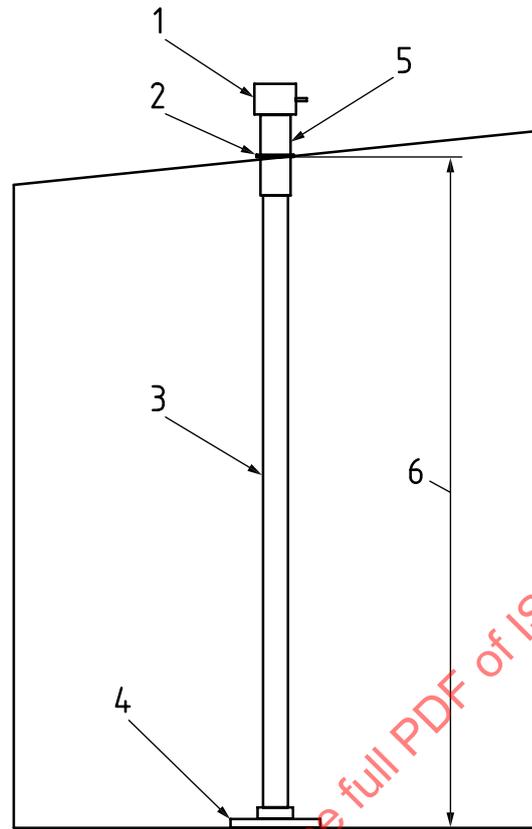
**8.3.5 Mid-level temperature element**

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**

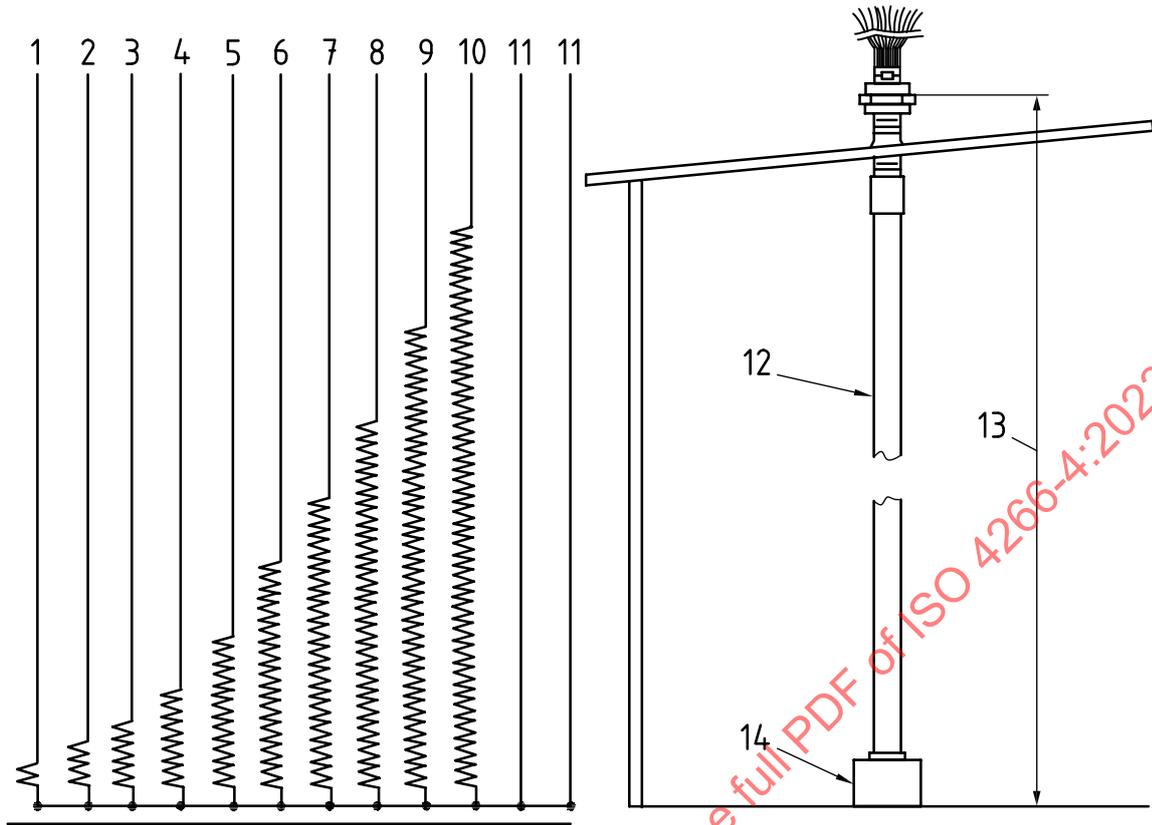
- 1 junction box or temperature transmitter
- 2 compression fitting (with or without flange)
- 3 flexible element housing
- 4 anchor weight
- 5 extension fitting
- 6 mounting height

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

#### 8.4 Thermowells for electronic temperature elements

Thermowells for fixed temperature elements should extend through the tank shell for at least 1 m 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 as far as possible from heating coils and the tank inlet and outlet.



**Key**

- |          |                    |
|----------|--------------------|
| 1 brown  | 8 grey             |
| 2 red    | 9 white            |
| 3 orange | 10 pink            |
| 4 yellow | 11 black           |
| 5 green  | 12 flexible hose   |
| 6 blue   | 13 mounting height |
| 7 violet | 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 General

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 [Clause 9](#). It is presupposed that the calibration reference for an ATT is 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 procedures in [Clause 9](#) 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 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 in a) and b) below. It is presupposed that the calibration reference for an ATT is 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 General

[9.2.2.1.2](#) and [9.2.2.1.3](#) are optional to verify the individual components, however [9.2.2.2](#) is required, even if the components are verified individually.

###### 9.2.2.1.2 Temperature element

The calibrated portable electronic thermometer can be used to verify the measurement by the temperature element according to 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.