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

Part 6:

**Measurement of temperature in pressurized
storage tanks (non-refrigerated)**

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

*Partie 6: Mesurage de la température dans les réservoirs de stockage sous
pression (non réfrigérés)*

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.ch
Web www.iso.ch

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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 4266-6 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Subcommittee SC 3, *Static petroleum measurement*.

ISO 4266-6, together with ISO 4266-1 to ISO 4266-5, 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 6:

Measurement of temperature in pressurized storage tanks (non-refrigerated)

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, stored in pressurized storage tanks.

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

2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this part of ISO 4266. For dated references, subsequent amendments to, or revisions of, this publication 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 edition of the normative document 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*

3 Terms and definitions

For the purposes of this part of ISO 4266, the following 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 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.

4.3 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 tank-level gauging system so that the overall accuracy of the standard volume measurement is not seriously degraded.

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 manufacturer, 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.

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 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 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 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 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;
- tank insulation, and
- tank shape (e.g. long, horizontal tanks or "bullets")

NOTE 3 Temperatures in large tanks (i.e. 750 m³ or larger) may be stratified due to a change of incoming liquid. Stratification due to high viscosity of the product is uncommon in pressurized tanks, since these products generally have a low viscosity.

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 following field verification tolerances.

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 and 9.3.2).

The remote readout, if used, should meet the recommendations 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. Two types of ATT elements are in general use for pressurized storage tanks:

- single-point (spot) ATT (see 3.3);
- multiple-point ATT (see 3.4).

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

NOTE Variable-length ATTs are not generally recommended because they will produce an erroneous average value of the product temperature in non-cylindrical tanks if temperature stratification is present. The linear distribution of the averaging elements requires a linear tank geometry.

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) requirement for local and remote readout, signal transmission, and cabling;
- h) the geometry of the tank (e.g. variable-length averaging ATTs should not be selected for non-linear tanks).

6.2 ATTs for fiscal/custody transfer purpose

Tanks using an automatic method to determine temperature in fiscal/custody transfer may be fitted with single-point ATTs or multiple-spot ATTs. Sometimes, a single-point ATT may be considered adequate for non-refrigerated LPG storage tanks. However, if product temperature stratification is expected, a multiple-spot ATT should be considered.

When multiple-spot ATTs are used, special care has to be taken concerning the averaging algorithm, since the shape of a pressurized tank is most often non-cylindrical. The computing of an average product temperature should take the tank shape into consideration, and the values from each individual temperature element should be weighted.

NOTE Generally, pressurized tanks are used for storage of low viscosity products which have less temperature stratification. Therefore, a single point temperature measurement may be sufficiently representative.

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.

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 transfer 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 temperature element is normally 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 mounted in the tank in relation to the position of the inlet and outlet connections 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.

8.2 Single-point (spot) temperature elements

Single-point (spot) temperature elements are normally installed in a pressure-tight thermowell through the tank shell, projecting at least 1 m into the tank to reduce any heat transfer effect through the thermowell. The spot temperature element for the liquid content should be located at an elevation of at least 1 m above the tank bottom surface.

Another spot temperature element for the vapour temperature should be located above the maximum fill height.

NOTE One of the purposes of the vapour-temperature element is to determine the vapour temperature for use in calculating the vapour to liquid equivalent, or the mass of the vapour.

8.3 Multiple-point temperature elements

Multiple-point temperature elements are typically installed in a pressure-tight thermowell at equidistant intervals (at approximately 3 m). The lowest element which is used for the 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 of 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. The temperature element(s) can also measure the vapour temperature when the element(s) is (are) above the liquid surface.

In pressurized tanks, the spot elements may be installed in thermowells extending through the tank shell. 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 should average only the measurements from the submerged elements. For non-cylindrical tanks, the averaging algorithm should be able to calculate a weighted average, which corresponds to the shape of the tank. Alternatively, the device may transmit the individual temperature of the submerged elements to provide a vertical profile of temperature.

8.4 Moveable spot temperature element

A spot temperature element attached to the displacer of a servo-operated ALG is driven through the liquid, stopping at various depths to determine the average tank temperature. Adequate time should be provided at each measurement location to ensure that thermal equilibrium is reached. To establish the average product temperature, the averaging algorithm should take into consideration the non-linear geometry of the tank.

NOTE A moveable spot temperature element attached to the displacer/float ALG does not provide continuous measurement.

8.5 Other methods

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

8.6 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, and designed for the specified pressure.

The thermowells should be located as far as possible from the tank inlet and outlet.

8.7 Thermowells for verification purposes

Since verification of an installed multiple-point ATT normally cannot be performed when the tank is pressurized, a separate thermowell installed close to the thermowell of the ATT may be used. This thermowell may be used when manually verifying the measurement accuracy of the ATT with a portable electronic thermometer.

NOTE Safety requirements often preclude installation of a separate thermowell on pressurized storage tanks, and therefore this thermowell is often not available.

9 Calibration and field verification of ATTs

9.1 Introduction

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

NOTE 1 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.

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 0,1 °C.

9.2 Calibration of single-point temperature element ATTs used for fiscal/custody transfer purpose

9.2.1 Calibration prior to installation

Prior to installation, 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 applicable national standards.

- a) The ATT (including the temperature sensor, 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 sensor 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

The verification of single-point elements normally cannot be performed with the elements installed in a pressurized storage tank, unless a separate thermowell is available (see 8.3). The normal practical procedure is therefore to verify the measurement each time the tank is depressurized, i.e. when the tank is out of service or by removal of the single-point ATT for verification outside the tank. When verified outside the tank, the procedure in 9.2.1 should be followed.

When the ATT temperature elements are verified as installed with the tank depressurized but containing liquid (e.g. during hydrostatic tank testing), the following procedure should be followed.

Use a recently calibrated portable electronic thermometer to verify the measurement by the temperature element. 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 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.

9.2.2.2 Verification as a system

The following procedure may be followed if the tank is depressurized or if a separate thermowell is available.

As an alternative to separate calibration checks of the temperature element and the transmitter, a portable electronic thermometer, calibrated immediately prior to verification, may be used to verify the entire ATT. Because it may not be possible to position the thermometer close to the temperature element, and because slight horizontal temperature stratification may exist, the measurements may not agree completely. Generally, for ambient storage tanks, if the sensing element of the portable electronic thermometer can be placed within 1 m of the fixed temperature element, calibration by a portable electronic thermometer should be acceptable.

The temperature measured by the ATT system (temperature sensor, temperature transmitter/converter and readout) should agree with the temperature measured by the calibrated portable electronic thermometer within 0,5 °C.

9.3 Calibration of upper, middle and lower or multiple-point ATTs

9.3.1 Calibration prior to installation

Each point (i.e. temperature-sensing element) of the ATT should be checked following the calibration procedure described in 9.2.1, for single-point or mid-level ATTs (see 5.3.4 for the required accuracy).

9.3.2 Initial field verification

9.3.2.1 Verification by components

9.3.2.1.1 Temperature element

The verification of multiple-spot elements normally cannot be performed with the elements installed in a pressurized tank, unless a separate thermowell is available (see 8.3). The normal practical procedure is therefore to verify the measurement each time the tank is depressurized, i.e. when the tank is out of service. Removal of the multiple-spot elements for verification outside the tank is often impractical, and may damage the assembly.

When multiple-spot elements are verified as installed in a depressurized tank or in a separate thermowell, the following procedure should be followed.

Use a recently calibrated portable electronic thermometer to verify the measurement by the temperature element. Lower the thermometer to the depths at which the RTDs are located and move the thermometer up and down (over a range of approximately 300 mm) until the temperature is stable. Each temperature sensor (of a multiple-point ATT) should agree with the temperature measured by the calibrated portable electronic thermometer within 0,4 °C.

9.3.2.1.2 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 for each temperature element should agree with the temperature equivalent of the resistors within 0,25 °C at each temperature.

9.3.2.2 Verification as a system

The following procedure may be followed if the tank is depressurized or if a separate thermowell is available.

A portable electronic thermometer, calibrated immediately prior to the verification, may be used to verify the entire ATT. Take temperature readings at evenly spaced intervals, or every 500 mm to 600 mm, covering the entire measuring height. At each measurement location, move the thermometer up and down (over a range of approximately 300 mm) until the temperature is stable. The manual average temperature read by the portable thermometer is the average of the readings. The average temperature read by the ATT is the average temperature of all temperature elements submerged in the liquid. The average temperature read by the ATT system should agree with the average of the temperatures read by the calibrated portable electronic thermometer within 0,5 °C (with due allowance for volume weighting of the individual spot sensor readings if necessary).

NOTE A multiple-spot automatic tank temperature system may provide both individual temperatures and average tank temperatures.

9.4 Subsequent verification of ATTs

9.4.1 General

All essential components of the ATT installation should be checked as recommended by the manufacturer's instructions. Each ATT should be inspected and its calibration verified using the procedure described in 9.2.

9.4.2 Frequency of subsequent verification

ATTs used for fiscal/custody transfer should be verified on a regular basis. As a minimum, ATTs used in fiscal/custody transfer services should be inspected and verified whenever the tank is taken out of service.

9.4.3 Record keeping

Full records should be kept of the initial calibration and the periodic verifications of each ATT used for fiscal/custody transfer.

10 Data communication and receiving

This clause gives recommendations for the specification of the communication between temperature transmitter(s) and receiver(s) or vice versa.

The remote readout of an acceptable ATT may be used for custody transfer provided that the whole system, including the remote readout, meets the calibration tolerances given in this part of ISO 4266.

NOTE 1 Modern ALG equipment in common use provide readout equipment to display and/or log both levels and temperatures. This readout equipment can determine average temperatures by averaging selected, submerged spot elements.

NOTE 2 The readout equipment can usually be programmed to alarm at high or low temperatures. It can also look up the tank capacity table, apply the appropriate coefficients of expansion and calculate the standard volumes.

The ATT should be designed and installed such that data transmission and receiving should

- not compromise the accuracy of the measurement, i.e. the difference between the temperatures displayed by the remote receiving unit and displayed (or measured) by the temperature transmitter at the tank should not exceed 0,1 °C,
- not compromise the resolution of the measurement output signal,
- provide proper security and protection of the measured data to ensure its integrity,
- provide adequate speed to meet the update time required for the receiving unit, and
- be electromagnetically immune.

Bibliography

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

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