BRITISH STANDARD

BS ISO
4266-5:2002

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

Part 5: Measurement of temperature in marine vessels

ICS 75.180.30

National foreword

This British Standard reproduces verbatim ISO 4266-5:2002 and implements it as the UK national standard. Together with BS ISO 4266:2002 Parts 1 to 4 and Part 6, it supersedes BS 7812:1995 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee PTI/12, Petroleum measurement and sampling, to Subcommittee PTI/12/1, Static and dynamic petroleum measurement, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international publications referred to in this document may be found in the *BSI Catalogue* under the section entitled "International Standards Correspondence Index", or by using the "Search" facility of the *BSI Electronic Catalogue* or of British Standards Online.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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This British Standard, having been prepared under the direction of the Materials and Chemicals Sector Policy and Strategy Committee, was published under the authority of the Standards Policy and Strategy Committee on 9 December 2002

Summary of pages

This document comprises a front cover, an inside front cover, the ISO title page, pages ii to v, a blank page, pages 1 to 12, an inside back cover and a back cover.

The BSI copyright date displayed in this document indicates when the document was last issued.

Amendments issued since publication

Amd. No.	Date	Comments

ISBN 0 580 40921 X

BS ISO 4266–5:2002

INTERNATIONAL STANDARD

ISO 4266-5

First edition
2002-11-15

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

Part 5: Measurement of temperature in marine vessels

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

Partie 5: Mesurage de la température dans les citernes de navire

Reference number
ISO 4266-5:2002(E)

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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 4266-5 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Subcommittee SC 3, *Static petroleum measurement*.

ISO 4266-5, together with ISO 4266-1 to ISO 4266-4 and also 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)*

Annex A of this part of ISO 4266 is for information only.

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

Part 5:
Measurement of temperature in marine vessels

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 cargo tanks on board marine vessels.

This part of ISO 4266 is not applicable to the measurement of temperature in refrigerated storage tanks, or pressurized cargo tanks on board marine vessels.

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 terms and definitions given in ISO 1998, and the following, apply.

3.1
automatic tank thermometer
ATT
instrument that continuously measures temperature in storage (or cargo) tanks

NOTE A marine ATT, which may also be known as an automatic tank temperature system, typically includes precision temperature sensors, deck-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
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, government regulations, classification society rules and ISGOTT regulations on safety and material-compatibility precautions should be followed when using marine 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 marine ATTs should be capable of withstanding the pressure, temperature and other environmental conditions likely to be encountered in marine service. When an ATT is installed in a corrosive service, any parts exposed to the liquid or vapour should be of durable, corrosion-resistant construction to avoid both product contamination and ATT corrosion. All ATTs should be sealed to withstand the vapour pressure of liquid in the tank. ATTs mounted on vessels with an inert gas system (IGS) should be designed to withstand the operating pressure of the IGS.

4.2.2 All marine ATTs should be specified and installed in accordance with the appropriate national and/or International (IMO, IEC, CENELEC, ISGOTT, ISO, etc.) marine electrical safety standards. ATTs should be certified for use in the hazardous-area classification appropriate to their installation.

4.2.3 All external metal parts of ATTs mounted on tanks should be firmly connected to an electrical earth, i.e. the ship's hull.

4.2.4 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 In the case of multiple port loading and/or discharge, 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.

NOTE 1 This protection may require mounting the ATT sensor(s) in a thermowell.

NOTE 2 ATT sensors can be an integral part of the ALG level sensor assembly (e.g. float and tape, pole). Some design (e.g. float and tape) may need the level/temperature sensor assembly to be raised to a "store" position when it is not being used. Note that such ATTs cannot be used during tank washing.

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.

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 onboard transmitters used for fixed, automatic tank temperature measurement are calibrated prior to installation. The transmitters normally do not provide on-board calibration adjustments.

5.3 Calibration prior to installation

5.3.1 General

The ATT 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 for custody transfer service 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

— cargo-heating method and/or location of heating coils;

— multiple sources of supply;

— viscosity of the liquid in the tanks;

— tank insulation;

— adjacent tank temperatures, and

— sea water temperature for tanks in contact with the ship's hull and bottom.

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. Temperatures in wing tanks can also be horizontally stratified due to the effect of the sea temperature.

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.

In tanks with vertical temperature stratification, the temperature gradient is rarely linear. An average temperature should be used for fiscal/custody transfer services. The mid-level temperature of the tank contents may not give an accurate average temperature.

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 on-board 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 on-board 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. The following types of ATT elements are widely used:

— 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.

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) requirement for local and remote readout, signal transmission, and cabling.

6.2 ATTs for fiscal/custody transfer purpose

Tanks using an automatic method to determine temperature in fiscal/custody transfer should preferably be fitted with a multiple-point ATT except when

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

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

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

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

7 Description of ATT equipment — Electrical temperature elements

7.1 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 in a stainless steel enclosure. The electronic circuits should be intrinsically safe as required. The temperature element is suitably contained within a thermowell. The length of the temperature-sensitive portion of a spot element should not exceed 100 mm.

7.2 Other temperature elements

Other types of temperature elements (thermocouples, thermistors, semiconductors, 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 marine ATTs

8.1 General

Marine ATTs should be installed in accordance with the ATT and ALG manufacturer's instructions.

8.2 Location of temperature-sensing element(s)

The single-point (spot) and/or multiple-point temperature-sensing elements should be installed close to a vapour lock valve, gauging hatch, or other suitable gauging access point. The following methods of installation are in general use.

a) The elements are installed in a metal thermowell through the deck (tank roof). This vertical thermowell should allow for one or more (usually three) temperature-sensing elements to be mounted from the deck, suspended by their individual metal cabling, down to various depths in the tank. When three temperature-sensing elements are used, they should be located respectively in the upper third (approximately 70 % to 80 % of the tank height), in the middle (approximately 40 % to 50 % of the tank height) and in the lower third (approximately 15 % to 20 % of the tank height).

b) The elements are installed as an integral part of ALGs with level-sensing element(s) in contact with the liquid. The height of each temperature element may depend on the ALG mounting.

For both of the above methods, the ullage corresponding to the depth of each individual temperature-sensing element for each tank should be readily available for the operator together with other ALG/ATT system data.

8.3 Location of manual (temperature) gauge hatch

To permit accurate comparison between manual and automatic temperature measurement, the ATT deck penetration should be close (e.g. preferably within 1 m) to a location where manual gauging can be performed.

8.4 Temperature measurement of inerted tanks

On cargo tanks connected to the vessel's inert gas system (IGS), the ATT should be designed and installed so that it can be maintained and calibrated without depressurizing the IGS.

9 Calibration and on-board verification of marine 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 appropriate national standards.

NOTE 1 The precision electronic temperature elements and on-board transmitters/converter used for fixed, automatic tank temperature measurement are calibrated prior to installation. The transmitters normally do not provide on-board 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 (with any necessary calibration corrections applied).

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

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

9.2.1 Calibration prior to installation

Prior to installation, single-point 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 verification at shipyard or during sea trials

9.2.2.1 General

Initial verification and adjustment procedures at the shipyard or during sea trials should be performed in accordance with the ATT manufacturer's instructions. In addition, one of the procedures given in 9.2.2.2 or 9.2.2.3 should be used, if practical.

9.2.2.2 Verification by components

9.2.2.2.1 Temperature element

Use a recently calibrated, portable electronic thermometer (PET) to verify the measurement by the temperature element. With the cargo tank filled, lower the thermometer to the depth at which the element is located and move the PET 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 0,75 °C.

NOTE The tolerance is larger than that for shore-tank-based ATT systems because the location where manual temperature measurements are taken with a portable electronic thermometer (through a vapour lock valve or other suitable gauging access point) is often not close to the location of the ATT temperature elements, and there are other additional factors which can result in marine cargo temperature measurement being less precise (see annex A).

9.2.2.2.2 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 readout for each temperature element of a multiple-point ATT should agree with the temperature equivalent of the resistors within 0,25 °C at each temperature.

9.2.2.3 Verification as a system

As an alternative to separate calibration checks of the temperature element and the transmitter, a portable electronic thermometer (PET), calibrated immediately prior to verification, may be used to verify the entire ATT, preferably with the cargo tanks nearly full and all temperature elements submerged. Because it may not be possible to position the PET close to the temperature element, and because slight horizontal temperature stratification may exist, the measurement by the thermometer may not agree completely.

The temperature read by the ATT system (temperature sensor, temperature transmitter/converter, and readout) should agree with the temperature measured by a recently calibrated, portable electronic thermometer within 1 °C.

NOTE The tolerance is larger than that for shore-tank-based ATT systems because the location where manual temperature measurements are taken with the PET (through a vapour lock valve or other suitable gauging access point) is often not close to the location of the ATT temperature elements, and there are other additional factors which can result in marine cargo temperature measurement being less precise (see annex A).

9.3 Calibration of multiple-point ATTs for fiscal/custody transfer purposes

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 ATTs (see 5.3.4 for the required accuracy).

9.3.2 Initial on-board verification at shipyard or during sea trials

9.3.2.1 General

Initial verification and adjustment procedures at the shipyard or during sea trials should be performed in accordance with the ATT manufacturer's instructions. In addition, one of the two procedures described in 9.3.2.2 or 9.3.2.3 should be followed, if practical.

9.3.2.2 Verification by components

9.3.2.2.1 Temperature element

Use a recently calibrated portable electronic thermometer to verify the measurement by the temperature element. With the cargo tank almost full, 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 0,75 °C.

9.3.2.2.2 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.

9.3.2.3 Verification as a system

As an alternative to separate calibration checks of the temperature element and the transmitter, a portable electronic thermometer (PET), calibrated immediately prior to the verification, may be used to verify the entire ATT. The tank should preferably be nearly full[1)] with all temperature elements submerged. Take temperature measurements at the depths of the temperature elements. At each measurement location, move the PET up and down (over a range of approximately 300 mm) until the temperature is stable. The manual average temperature read by the PET 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 PET within 1 °C.

NOTE The tolerance is larger than that for shore-tank-based ATT systems because the location where manual temperature measurements are taken with the PET (through a vapour lock valve or other suitable gauging access point) is often not close to the location of the ATT temperature elements, and there are other additional factors which can result in marine cargo temperature measurement being less precise (see annex A).

9.4 Subsequent verification of ATTs

9.4.1 General

A regular verification programme should be established for ATTs used in fiscal/custody transfer. 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 9.2.2 or 9.3.2 (initial field verification).

9.4.2 Frequency of subsequent verification

ATTs used for fiscal/custody transfer measurement should be verified on a regular basis. The ATT should initially be inspected and its calibration verified at least once per quarter. If operating experience confirms stable performance within the verification tolerance, the verification schedule can be extended to once per year.

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. The records should be kept for a minimum of one year or twenty voyages.

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 Some readout equipment can be programmed to alarm at high at low temperatures.

NOTE 2 Some ATTs do not provide temperature readout locally at the tank.

1) An “upper-middle-lower” ATT, which automatically adjusts according to the liquid level, does not require the tank to be full.

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.

Annex A
(informative)

Accuracy limitations of tank-temperature measurements on board marine vessels

Tank temperature measurements using marine ATTs are limited by the following inherent limitations, regardless of the ATTs used.

a) Change of the cargo temperature due to loading temperature.

Shortly after loading, in cargo holds in contact with sea water, a sharp temperature step gradient in the vertical direction will develop under the influence of a very different rate of heat exchange of the cargo above and below the water line, assuming that the cargo temperature is above the sea water temperature. Below the water line, a strong convection circulation is set into motion by the heat exchange between the cargo and sea water through vertical parts of the ship's hull. In the horizontal direction, the temperature differences in a cargo are only very small, due to the equalizing effects of the convection circulation. A marked temperature difference may, however, exist initially between wing and centre tanks, because the centre tanks mainly exchange heat with the sea water via the wing tanks forming a barrier.

b) Change of the cargo temperature due to sea water temperature.

Temperature differences may exist because the tank bulkheads may be in contact with the ocean, making it difficult to determine an accurate average cargo temperature.

c) Change of the cargo temperature due to adjacent cargo tank temperature.

d) Change of the cargo temperature due to cargo heating.

e) Thermal offsets and time delays due to thermowell design and properties.

The limitations listed above may have significant impact on the overall accuracy of temperature measurement by all types of marine automatic tank thermometers.

Bibliography

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

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