BRITISH STANDARD

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Petroleum and liquid petroleum products — Temperature measurements — Manual methods

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National foreword

This British Standard reproduces verbatim ISO 4268:2000 and implements it as the UK national standard.

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

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Summary of pages

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Petroleum and liquid petroleum products — Temperature measurements — Manual methods

Pétrole et produits pétroliers liquides — Mesurages de la température — Méthodes manuelles

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Contents

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

International Standard ISO 4268 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Subcommittee SC 3, *Static petroleum measurement*.

Introduction

In all calculations concerned with the measurement of bulk quantities of petroleum and petroleum products, whether in terms of volume at standard temperature or in terms of mass or apparent mass-in-air, a knowledge of the mean temperature of the oil is required. The following recommendations for the determination of the temperature of the contents of storage tanks, including tanks carried by road and rail vehicles and compartments of barges and ships, are designed to provide the most reliable measurement of the mean temperature under the given conditions.

It cannot be too strongly emphasized that errors in temperature measurement can account for the larger part of the total error in quantitative measurement of petroleum and liquid petroleum products, and great care is therefore needed in the selection and use of temperature-measuring equipment. The methods specified should be followed in scrupulous detail if the final measurement is to have the smallest possible uncertainty.

Gaugers employed in temperature measurement should be fully trained and instructed in the application of the procedures of this International Standard. They should be instructed to report any deviations that are unavoidable.

Petroleum and liquid petroleum products — Temperature measurements — Manual methods

1 Scope

This International Standard specifies methods, procedures and equipment for the manual measurement of the temperature of bulk quantities of petroleum and petroleum products in storage tanks.

The preferred method is to use a portable electronic thermometer as described in clause 7. Other methods included use permanently installed indicating thermometers of the spot-measurement type and temperature determination by sampling methods using cup-case thermometers, flushing-case thermometers, and thermometers within conventional tank samples taken in accordance with ISO 3170.

This International Standard excludes averaging thermometers forming part of an automatic gauging system. These are described in ISO 4266.

It is realized that, in many countries, some or all of the items covered by this International Standard are the subject of mandatory regulations imposed by the laws of those countries; such regulations must be rigorously observed. In cases of conflict between such mandatory regulations and this International Standard, the former prevails.

2 Normative references

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

ISO 386:1977, *Liquid in-glass laboratory thermometers — Principles of design construction and use.*

ISO 3170:1988, *Petroleum liquids — Manual sampling.*

ISO 4266:1994, *Petroleum and liquid petroleum products — Direct measurement of temperature and level in storage tanks — Automatic methods.*

ISO 4512:—[1)], *Petroleum and liquid petroleum products — Equipment for measurement of liquid levels in storage tanks — Manual methods*.

3 Introduction to precautions

Clauses 4 and 5 outline the precautions which are applicable whenever the temperature of a bulk quantity of oil is to be determined. For emphasis, the precautions necessary to ensure the safety of the operator or the safe working of the plant (clause 5) are dealt with separately from those precautions that shall be taken during the procedure used, to ensure the most reliable measurement of temperature (clause 4).

1) To be published.

Certain special precautions that are necessary when applying some of the equipment specified are dealt with subsequently in the clauses relating to that equipment.

4 Precautions relating to procedures

Whatever apparatus is used for taking temperature measurements, the following precautions shall be taken.

a) Whenever determination of the temperature of the contents of a tank is made before and after a movement of a bulk quantity of oil, the same general procedure shall be followed in each case.

NOTE 1 To minimize measurement uncertainties, it is recommended that the same equipment should be used for both the opening and closing measurements.

If liquid-in-glass thermometers are used, care shall be taken to avoid parallax errors.

b) Temperature determination for referee purposes shall be made under the immediate supervision of a skilled person with previous experience in oil measurement. Readings shall be recorded immediately and agreed upon by all interested parties before the gauger and apparatus leave the tank or container.

c) The thermometer reading obtained on each spot measurement made at each level in a tank, the date and the time shall be recorded immediately the reading is taken. The number of the tank, the position of the access point (gauge-hatch or vapour-lock valve), and the level at which each measurement was made (or from which each sample was drawn) shall be clearly indicated in the gauger's notes. In general, the calculation of the mean temperature of the contents of the tank from the observed temperatures shall not be part of the gauger's duties.

d) Temperature determination shall be made through openings giving direct access to the bulk of oil in the tank. Still-wells or thermo-wells shall not be used, except as described in this International Standard.

NOTE 2 If temperature measurements are made through a still-well (guide pole), it is essential that the still-well be perforated throughout its working length to ensure that the temperature measurements are representative of the bulk tank contents.

e) Temperature measurements shall be made immediately after the level of the contents within the tank has been determined (see ISO 4512).

The depth of any free water in a tank shall be ascertained before temperature determinations are made, so that the correct levels for the measurement of temperature can be properly determined (see Table 2).

f) If protective metal cases are used for liquid-in-glass thermometers [8.6 and Figures 1a) and 1b)], they shall permit free access of the oil to the thermometer bulb, and ample provision shall be made for viewing the scale. Sufficient time shall always be allowed for the case to take up the temperature of the oil before the reading is taken.

g) If a tank is provided with more than one access point (gauge-hatch or vapour-lock valve), each one shall have a number, or other means of identification, clearly marked on or near it. The recorded results of all temperature measurements shall clearly indicate the access point from which they were obtained.

NOTE 3 Temperatures should not be taken within 500 mm of the walls (shell) of a vertical cylindrical tank in order to avoid extraneous thermal effects. In older vertical cylindrical tanks, gauge-hatches and roof manholes may be situated nearer the tank shell. In such cases, it is recommended that consideration be given to the provision of a new access point in the preferred position. In new tanks, it is recommended that access points (gauge-hatches or vapour-lock valves) should be positioned with their centres not less than 500 mm from the tank shell and sited so as to be clear of bottom fittings.

NOTE 4 While it may be possible to obtain temperature measurements from more than one access point, the associated measurement of stock level within the tank should only be obtained from that access point to which the tank capacity table relates.

5 Precautions relating to safety

5.1 Introduction

The safety precautions given in 5.2 and 5.3 constitute good practice, but the list is not comprehensive. It is essential that the list be read in conjunction with any relevant sections of national/ international codes of safe practice in the petroleum industry.

In cases of conflict between this International Standard and legal regulations or national safety codes, the latter shall be followed; otherwise, the provisions of this International Standard shall be observed.

5.2 General safety precautions

The following safety precautions apply in all cases.

a) All regulations covering entry into hazardous areas shall be rigorously observed.

b) Access ladders, stairways, platforms and handrails shall be maintained in a structurally safe condition.

c) The plant and equipment shall be adequately maintained, and it is strongly recommended that a regular inspection be made by a competent person.

d) Gaugers shall be provided with carriers for their equipment in order that at least one hand is free for climbing ladders, etc.

e) Hand lamps and electric torches (flashlights) shall be of an approved type.

f) Footwear and clothing (for example nylon overalls) capable of causing sparks shall not be worn in areas where flammable vapours are likely to be present.

NOTE 1 Footwear and gloves should be sufficiently conductive to dissipate any electrostatic charge safely.

g) Care shall be taken when opening tank access points (gauge-hatches or vapour-lock valves), particularly on vapour-tight tanks, which may be under pressure. If temperature measurements are obtained using closed or restricted Portable Electronic Thermometers (PETs) or sampling methods, the equipment shall be connected to the vapour-lock valve before the valve is opened. If gauge hatches or covers are used for open gauging measurements, the retaining clips on the hatch (or cover) shall be loosened but kept in position until any pressure has been released. **Persons on the tank top shall stand well clear of any vapours that are expelled**.

h) Care shall be taken to ensure that any metallic component of the equipment that could act as an insulated electrical conductor is effectively earthed and bonded before opening the access point (gauge-hatch or vapour-lock valve), during measurement, and until after closure of the access point. If a cord is used for lowering equipment into tanks, it shall be made of natural fibre and not of synthetic material, in order to minimize the hazard of static electricity.

i) In order to earth (ground) any static charges on his person, a gauger shall touch some earthed (grounded) part of the tank structure immediately before carrying out any gauging operation.

j) When carrying out any gauging, sampling or temperature-measuring operation, only one access point shall be open at any one time. Such operations shall not be carried out during electrical storms, when all access points shall be closed. Special attention is drawn to the fact that electrical discharges capable of igniting petroleum vapours, such as might be issuing from an open gauge-hatch, may take place under a variety of weather conditions other than thunderstorms.

NOTE 2 In the case of static accumulator oils in non-inerted tanks at temperatures above their flash point, it is strongly recommended that tanks should not be gauged whilst the product is being transferred into it and until at least 30 min have elapsed after transfer has ceased. This allows time for any electrostatic charge that may be present on the surface of the

liquid to dissipate and for the oil surface to become quiescent. This restriction does NOT apply if measurement is made via a permanently installed stilling well that is electrically bonded to the tank shell.

NOTE 3 It is strongly recommended that gaugers should be thoroughly trained in gas safety, including the uses and limitations of rescue equipment.

NOTE 4 It is recommended that trays or other receptacles should be provided near gauge-hatches on the roofs of tanks containing non-volatile products to hold equipment after it has been used, in order to prevent unnecessary spillage on the roof.

k) Temperature-measurement apparatus that may be used in a flammable atmosphere shall not be made of aluminium or its alloys (to prevent any possible risk of a Thermite reaction resulting in the ignition of flammable vapours).

5.3 Special safety precautions

5.3.1 Leaded fuels

Regulations on the handling of leaded fuels shall be rigorously observed.

5.3.2 Liquefied petroleum gases

Liquefied petroleum gases can cause serious cold burns. Care shall be taken, therefore, to prevent the liquid from coming into contact with the skin.

5.3.3 Pressure-type and vapour-tight tanks

The following precautions shall be observed.

a) All gauging equipment used on pressure-type tanks shall be designed to withstand a pressure equal to the working pressure plus an adequate safety margin (typically 1,5 times the designed maximum working pressure).

b) Measurements shall only be made through a vapour-lock valve or vapour-lock. Such systems are available for various ranges of operating pressures. In no circumstances shall measurement apparatus be used on tanks at a higher pressure than that for which it was designed.

5.3.4 Floating-roof tanks

Floating-roof tanks are usually gauged from the platform, but in exceptional circumstances it may be necessary to descend onto the roof. Toxic and flammable vapours may accumulate above the roof, and if it is necessary for a gauger to descend on the roof, he shall at all times be kept under observation by another operator from the top platform. It is essential, before the gauger descends on the roof, that he shall be equipped with a safety-line and harness. Both the gauger and observer shall have breathing apparatus in the following circumstances:

a) whenever the product contained in the tank may contain volatile mercaptans or hydrogen sulfide;

b) when the roof is at rest on its supports, or is within the tank roof's critical flotation zone;

c) when the roof is out of round or when the roof-seal is known to be faulty;

d) in any other circumstances, when there may be vapours present in dangerous concentrations.

5.3.5 Benzene

Benzene is a known carcinogen. Personal protective equipment shall therefore be used to minimize the risk of vapour inhalation and/or skin contact when gauging or sampling tanks containing benzene.

6 Equipment

Clauses 7 to 13 describe and give detailed specifications for equipment used for temperature measurement. Precautions that are necessary when using or installing certain items of equipment are listed, and procedures for calibration or verification are given.

7 Portable electronic thermometers (PETs)

7.1 Introduction

A wide range of portable electronic tank thermometers are available which are designed to take spot temperatures at any location within a tank which is accessible from the available gauging access point(s). Suitable sensing elements include resistance thermometers and thermistors, but other sensors capable of meeting the required accuracy may also be used.

7.2 Accuracy requirements

The minimum resolution of measurement of a PET shall be 0,1 °C.

The electronic thermometer shall be calibrated against a reference thermometer certified by an approved laboratory (see 7.5.3), to ensure that the overall accuracy shall be within ± 0,2 °C for a range of – 10 °C to + 35 °C, and within ± 0,3 °C for ranges of – 25 °C to – 10 °C and + 35 °C to + 100 °C (with the calibration correction(s) applied).

7.3 Sensing elements

7.3.1 Resistance thermometers

Nickel-wound resistance thermometers have a useful range from – 200 °C to + 350 °C, and platinum-wound resistance thermometer elements have a useful range of – 200 °C to + 600 °C. Copper-wound resistance elements are also employed, but over a more restricted range of – 40 °C to + 175 °C.

A suitable protective sheath shall be provided to protect the sensing element, and the connecting leads shall be carefully sealed to prevent the ingress of moisture.

It is essential to ensure that the effective change in electrical resistance only occurs in the temperature-sensitive element. This will usually be accommodated by the circuit employed, which accurately balances out, and automatically compensates for, changes in the electrical resistance of all other parts of the resistance-thermometer circuit. The measuring instrument may be located a relatively long distance from the sensing element without introducing errors in the reading.

NOTE The abbreviation RTD (resistance temperature detector), is commonly used, and is synonymous with the term “resistance thermometer”. Platinum RTDs are also commonly referred to as Pt100s, indicating that they are platinum RTDs with 100 Ω ice-point.

7.3.2 Thermistors

These are used as an alternative to the resistance thermometers for portable electronic thermometers. Given the small size of the semiconductor used in the sensitive element of a thermistor, the thermometer will usually have a very quick response. By a suitable choice of the semiconductor, linearity of response can be obtained over a wide range of temperatures. Some zero-drift may be experienced with thermistors, and errors can arise from auto-heating of the semiconductor. Zero-adjusting facilities are therefore usually incorporated in thermistor-based portable electronic thermometers.

7.4 Electrical safety

All portable electronic thermometers shall be suitable for the hazardous areas where they will be used. They shall be either intrinsically safe or explosion proof, and grounded via the gauge-hatch or vapour-lock valve.

7.5 Selection and operation of portable electronic thermometers

7.5.1 General

The portable electronic thermometer may be used as a precise measuring device for measuring the temperature of oil at one or several points within a tank. It may also be used as a reference thermometer for verifying the calibration of other (permanently installed) temperature-measuring devices.

7.5.2 Specification for portable electronic thermometers (PETs)

7.5.2.1 Range

The thermometer shall have any convenient range to cover the minimum and maximum operating temperatures expected. Thermometers may be provided with a dual scale and a range-change switch to enable them to cover the maximum anticipated range.

7.5.2.2 Accuracy

The accuracy of a PET shall comply with the specification in 7.2.

7.5.2.3 Resolution

If the display is digital, the last digit shall correspond to 0,1 °C or better. The readout numerals shall be clear and bold, with no possibility of misinterpretation, even with partial failure of light emission, or for any other reason.

Analogue PETs are acceptable, provided that they can ensure the same resolution of measurement.

7.5.2.4 Housing

The instrument shall have a protective case or enclosure and be self-contained. It shall be robust and shock proof, but shall be sufficiently light to be carried by an operator without undue fatigue.

7.5.2.5 Cables/tapes

The cable or tape connecting the sensing element to the measuring instrument shall be resistant to immersion in petroleum products. It shall be long enough to cover the full depths of the tanks for which the thermometer is likely to be used. It may be marked at metre intervals or graduated in millimetres in order to assist in lowering to the required level.

NOTE For convenience, the cable or tape should be wound on a reel.

7.5.2.6 Calibration check facilities

Calibration resistances may be used for verifying the electronic circuitry of resistance-thermometer based PETs. They may either be integrated into the equipment or connected into the circuit by a test plug. Alternative means may be provided for checking the calibration of other types of PET.

7.5.2.7 Battery charger

If the equipment has a rechargeable battery, a battery charger suitable for the voltages used shall be provided. Battery charging shall only take place in a safe area.

7.5.3 Initial calibration

Before a portable electronic thermometer is used it shall be calibrated by a calibration laboratory, which shall issue a calibration certificate. The certificate shall detail the uncertainty of measurement and the traceability of the calibration to a national standard. The certificate shall be dated, and shall refer to the unique serial number of the PET.

The laboratory shall calibrate the complete PET (i.e. the sensor, cable/tape, electronic circuitry, and display/readout) at several different temperatures over the desired measurement range. This shall be achieved by direct comparison with a standardized reference thermometer when both sensors are immersed at the same location within a series of temperature controlled baths. To obtain an uncertainty of ± 0,2 °C for the PET, the reference thermometer that it is compared with shall be accurate to ± 0,05 °C (or better), have a resolution of 0,02 °C (or better), and be traceable to a national standard.

NOTE If the PET uses a resistance-thermometer sensor, the laboratory may also check the operation of the electronic circuitry and readout by substitution of a resistance box containing precision resistances for the sensing element. The uncertainty of the standard resistances should be at least five times better than that required for the PET.

7.5.4 Pre-commissioning checks

Before a new PET is commissioned, the following checks shall be carried out.

a) Check that the PET conforms to the specification itemized in this International Standard and has no visual damage.

b) Check the state of the battery. Replace or recharge as necessary.

c) Check the PET against a certified reference thermometer. If the PET is fitted with a checking facility, press the test button or insert the calibration resistance.

d) Check the thermometer's response time. Equilibrium should be established when the indicated temperature is stable to 0,1 % for 30 s. Check the practical response time of the thermometer, i.e. the time in seconds that it takes for the thermometer to respond to a known step change in temperature.

NOTE To be considered fit for the purpose of tank measurement applications, the response time should typically be less than 15 s.

7.5.5 Storage precautions

The cable/tape shall be kept wound in order to avoid kinks and bends.

NOTE When not in use, a rechargeable instrument should be placed on charge. On non-rechargeable units, the battery should be removed prior to a period of extended storage.

7.5.6 Operating procedures

When using a PET, the following operating procedures shall be carried out.

a) Earth the case or housing of the PET to the tank structure before opening the gauge-hatch or vapour-lock valve.

b) Before and after each use for custody transfer measurements, check the state of the charge of the battery.

c) If applicable, check the electronic circuitry and readout using the test facilities provided with the equipment.

d) Lower the sensing probe to the first predetermined level, see 15.4.1 and Table 2.

It is important to immerse the PET sensor to the correct depth, and this is facilitated by observing the graduations on the tape or cable. The predetermined level(s) shall be calculated in accordance with the guidance given in 15.4.

e) Gently raise and lower the sensor through a distance of approximately 0,3 m above and below the predetermined level to allow rapid equilibration of the sensor with the surrounding liquid.

NOTE 1 Equilibrium should be established when the indicated temperature is stable to 0,1 °C for 30 s.

NOTE 2 When the indicated temperature has not changed by more than 0,1 °C in 30 s, the thermometer may be considered to have reached equilibrium with the surrounding liquid.

f) Ensure that each reading has stabilized before recording it to the nearest 0,1 °C.

g) If multiple spot temperatures are required, repeat steps d) to f) above at each of the other predetermined levels.

h) Assess the results from steps d) to g). If temperatures have been recorded at more than one level and the range of the individual spot measurements exceeds 1,0 °C, the oil is stratified and additional temperature measurements shall be obtained at intervening levels before an average is calculated.

i) Where the PET is used to verify the reading of a fixed-installation averaging tank thermometer, the reading of the fixed system shall be compared directly with the tank temperature as determined by the average of the PET measurements taken at a number of liquid levels (see clause 19).

Where the PET is used to verify the reading of a fixed single-sensor tank thermometer, the suitability of the fixed sensor for providing an average tank temperature shall be assessed in the same way, but an additional comparison shall also be performed by making a measurement with the PET sensor immersed at the same depth and position as close as possible to the fixed tank thermometer sensor (see clauses 19 and 20).

7.5.7 Periodic checks on accuracy

7.5.7.1 Introduction

There are a number of different checks applicable to the use of PETs, including those described in 7.5.7.2 to 7.5.7.4.

7.5.7.2 Working spot checks

The working spot checks shall be performed by direct comparison with a standard reference thermometer. Both temperature sensors shall be immersed to the same level with a Dewar flask (or other appropriate vessel capable of maintaining a constant temperature) of liquid at approximately the mean measurement temperature for which it is anticipated the PET will be used. The difference between the PET reading and the reference thermometer reading, both after application of any necessary correction from its calibration certificate, shall not exceed 0,3 °C.

These checks also include any test system supplied with the thermometer. It is good practice to conduct a working spot check on a daily basis (or before each measurement if used less frequently) for PETs that are used for custody transfer measurements.

7.5.7.3 Verification check

The thermometer shall be verified at regular intervals (typically every month), or at any time when there is a doubt about the reading. The verification shall be performed by direct comparison with standard reference thermometer at a minimum of two temperature points (corresponding to approximately 20 % and 80 % of the working range of the PET).

The difference between the PET reading (after application of any necessary correction from its calibration certificate) and the reference thermometer reading (also after application of any necessary correction from its calibration certificate) shall not exceed 0,3 °C over the entire working range of the PET.

NOTE If the difference does exceed 0,3 °C the PET should be adjusted (where this facility is available) and recalibrated.

7.5.7.4 Recalibration

Recalibration requires the thermometer to be returned to a certified laboratory (or the manufacturer) for a calibration over its working range. The recalibration shall be in accordance with the initial calibration specified in 7.5.3, and a new certificate issued.

8 Liquid-in-glass thermometers

8.1 General

If a PET is not available then a liquid-in-glass thermometer is the preferred alternative method (see clauses 10 and 11). Alternatively, a permanently installed spot tank thermometer method may be used (see clause 12). Subclauses 8.2 to 8.6 describe the liquid-in-glass thermometers that shall be used for such a measurement.

NOTE Alcohol-in-glass thermometers may be preferred to mercury-in-glass thermometers for health and safety reasons, but the users should satisfy themselves that the required accuracy and resolution of measurement (see 8.2) can be achieved.

8.2 Accuracy and resolution

The accuracy and resolution of a liquid-in-glass thermometer that is used in a thermo-well as part of a fixed-installation spot tank thermometer shall be the same as those specified for PETs in clause 7.

NOTE 1 The accuracy and resolution of a liquid-in-glass thermometer that is used in conjunction with one of the tank sampling methods should also be the same as that specified for PETs, but there may be practical limitations in achieving this when the thermometer is required to measure temperatures that are substantially different from the ambient temperature. Ideally, the minimum graduation interval should be 0,2 °C or better (thereby permitting a minimum resolution of measurement of 0,1 °C). In practice, the minimum resolution for tank sampling methods should be 0,1 °C for temperature ranges less than 40 °C, 0,25 °C for temperature ranges between 40 °C and 80 °C and 0,5 °C for temperature ranges above 80 °C.

NOTE 2 The overall accuracy of thermometers used with tank sampling methods should be ± 0,1 °C for a range of – 10 °C to + 35 °C; ± 0,25 °C for a range of – 40 °C to – 10 °C and + 35 °C to + 80 °C, and ± 0,5 °C for a range of + 80 °C to + 120 °C.

Liquid-in-glass thermometers that are used as reference thermometers (for verifying the accuracy of PETs or working liquid-in-glass thermometers) shall have a minimum accuracy of ± 0,05 °C (or better), a minimum resolution of 0,02 °C (or better), and be traceable to a national standard. (see 7.5.3).

8.3 Specifications

8.3.1 All liquid-in-glass thermometers used either in conjunction with tank sampling methods for the determination of bulk oil temperatures (clauses 10 and 11) or within thermo-wells situated within tanks (clause 12) shall conform to the general and special requirements detailed in clauses 8 and 9.

The recommended temperature ranges for various conditions are given in Table 1.

Table 1 — Recommended temperature ranges for thermometers

Purpose	Range °C
Unheated oils, cold climates	– 40 to 30
Unheated oils, temperate climates	– 15 to 40
Unheated oils, tropical climates	10 to 65
Heated oils	35 to 120
Unheated and heated ships' cargoes	0 to 80

8.4 General requirements for liquid-in-glass thermometers

Liquid-in-glass thermometers shall conform to the following requirements.

a) All liquid-in-glass thermometers shall be of the solid-stem-gas — (not air) filled type.

b) The stem of the thermometer shall be made of suitable glass tubing and have an enamel back.

c) The bulb of the thermometer shall be made of thermometric glass selected and processed so that the finished thermometer shows the characteristics set out in ISO 386.

d) No enlargement of the bore (e.g. for the expansion and contraction chamber) shall be within 10 mm of any part of the graduated scale.

e) The scale marks shall be clearly etched and of uniform thickness, not exceeding 0,15 mm. The marks shall be at right angles to the axis of the thermometer. When the thermometer is viewed from the front and is in a vertical position, the marks shall all finish on a line, i.e. the scale base, at the left-hand side, parallel to the axis of the thermometer.

f) Each thermometer shall be marked with the immersion depth at which it is to be used, e.g. “60 mm immersion”.

g) Each thermometer shall be marked with a unique serial number, which shall be specified on the calibration certificate and recorded whenever the accuracy is verified.

h) Stress in the glass shall be reduced by annealing to a level sufficient to minimize the possibility of fracture due to mechanical or thermal shock.

i) Thermometers shall be artificially aged, before graduation, by means of suitable heat treatment in order to ensure stability.

j) Thermometers that are to be used as reference thermometers shall be certified by a calibration laboratory with traceability to a national standard. The minimum accuracy and resolution requirements for reference thermometers shall be in accordance with the specification detailed in 8.2.

8.5 Periodic checks of liquid-in-glass thermometers

8.5.1 Introduction

There are a number of different checks applicable to liquid-in-glass thermometers, including those described in 8.5.2 to 8.5.4.

8.5.2 Working spot checks

The basic check is that the thermometer reads the same (within a defined tolerance) as a certified reference thermometer at a given spot temperature. The tolerance shall not exceed 0,5 °C.

8.5.3 Verification check

The thermometer shall be verified at regular intervals, or at any time when there is a doubt about the reading. The verification shall compare the working thermometer with a certified reference thermometer at a minimum of two temperature points (corresponding to approximately 20 % and 80 % of the working range). The difference between the two thermometers shall not exceed 0,5 °C.

NOTE If the difference exceeds this figure, the thermometer should be destroyed. If the thermometric liquid is mercury, precautions should be taken to contain the mercury safely when a thermometer is destroyed, thereby avoid any health, safety and/or environmental impact associated with this toxic material.

8.5.4 Recalibration

Recalibration requires the thermometer to be returned to a calibration laboratory (or the manufacturer) for a calibration over its working range. The recalibration shall be equivalent to that specified for PETs (7.5.3), and will involve comparisons at between three to five temperature points dependent on the range.

The maximum period between successive recalibrations of any liquid-in-glass thermometer shall not exceed 5 years.

8.6 Armoured cases for liquid-in-glass thermometers

8.6.1 General

Armoured cases shall be made of thin metal tubing, with an internal diameter which will accommodate the liquid-in-glass thermometer that the case is designed to protect. Armoured cases shall not be manufactured from aluminium or its alloys.

NOTE Armoured metal cases extend the time needed for thermometers to reach equilibrium and also may affect the temperature of a sample if used in the sampling bottle method (17.3.4). Armoured cases should not be used with thermometers used for reference measurements or for custody-transfer measurements.

8.6.2 Construction

The dimensions of the cut-away portion shall be such that the whole of the scale of the thermometer is clearly visible. The portion of the case enclosing the bulb of the thermometer shall be pierced with a sufficient number of holes of such dimensions as will permit the easy access of oil to the thermometer bulb without reducing the effective strength of the case.

8.6.3 Types of armoured case

A typical plain-type armoured case is shown in Figure 1a). An alternative type of armoured case is illustrated in Figure 1b). The main drawback of this type of case is that special thermometers are required that are finished with a flattened button top. This case is, however, preferable to the normal type of armoured case because the flow of oil round the thermometer bulb is less impeded.

9 Precautions to be taken when selecting and using liquid-in-glass thermometers

9.1 Selection of thermometers

9.1.1 Only thermometers conforming to the specifications given in 8.1 to 8.3 or local national equivalents shall be used.

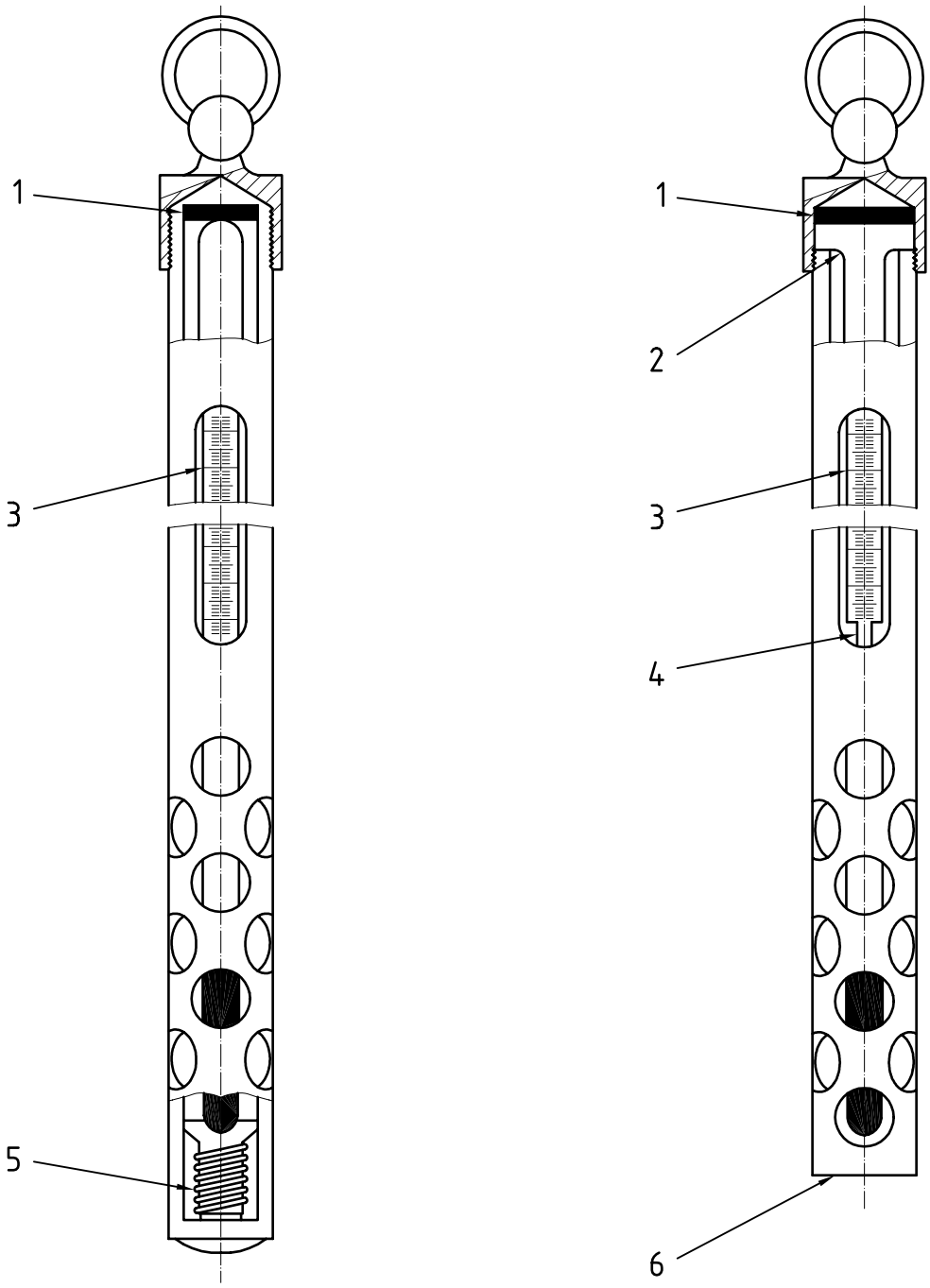
9.1.2 The range of the thermometer selected shall be such that the expected temperature reading will not be within 1 °C of either of the terminal scale marks.

The use of a thermometer which has lost a substantial amount of enamel from its engravings should be avoided. Such a thermometer shall be discarded or have its engravings refilled with a suitable enamel. In no circumstances should an enamel requiring any form of heat treatment be used.

9.1.3 The following precautions shall be observed when using liquid-in-glass thermometers.

a) In order to avoid errors due to parallax, the thermometer shall be held so that the line of vision is approximately at right angles to the stem when the reading is taken. The thermometer bulb shall remain immersed, and that portion of the stem specified as the immersion depth during calibration shall be immersed when the thermometer is read.

b) When a thermometer is not used under calibration immersion conditions, apply the emergent-stem correction, as detailed in 9.3, in order to obtain the correct reading.



a) Plain type **b) Top-suspension type**

Key

1 Cork
2 Button top of thermometer
3 Standard ISO tank thermometer
4 Clip supporting thermometer
5 Spring protecting bulb of thermometer
6 Open end

Figure 1 — Armoured case for solid-stem thermometers

9.2 Detection and prevention of errors in liquid-in-glass thermometers

9.2.1 Sudden heating or cooling of liquid-in-glass thermometers may affect their accuracy and, when thermometers are used at high temperatures, they may develop permanent errors owing to slight softening and distortion of the glass of the bulb. Thermometers shall be compared periodically with a certified reference thermometer. The frequency with which such comparisons are made will depend upon the use to which the thermometers have been put, but for those used at temperatures in excess of 50 °C, yearly intervals shall not be exceeded. More frequent checking is recommended. Thermometers which are in daily use shall be checked at approximately monthly intervals using the method described in 8.5.2. Verification checks shall be conducted at regular intervals using the method described in 8.5.3.

9.2.2 Liquid-in-glass thermometers shall be carefully examined on each occasion before use, and if any thermometer is found to be defective, it shall be withdrawn from use and another employed. Defects which may be encountered include: a broken liquid column, the separation of part of the liquid column into the expansion chamber at the top of the thermometer, or gas bubbles being trapped in the bulb due to mishandling during transport.

9.3 Emergent-stem correction

The corrections for various lengths of emergent stem and ambient temperature conditions may be estimated for practical purpose by means of the following formula:

$$\text{Emergent-stem correction} = n\alpha\left(t - t_{\mathrm{F}}\right)$$

where

t is the observed thermometer reading;

n is the number of degree graduations between the oil level (or the mouth of the thermo-well) and the observed reading;

t_{F} is the average temperature of the emergent column;

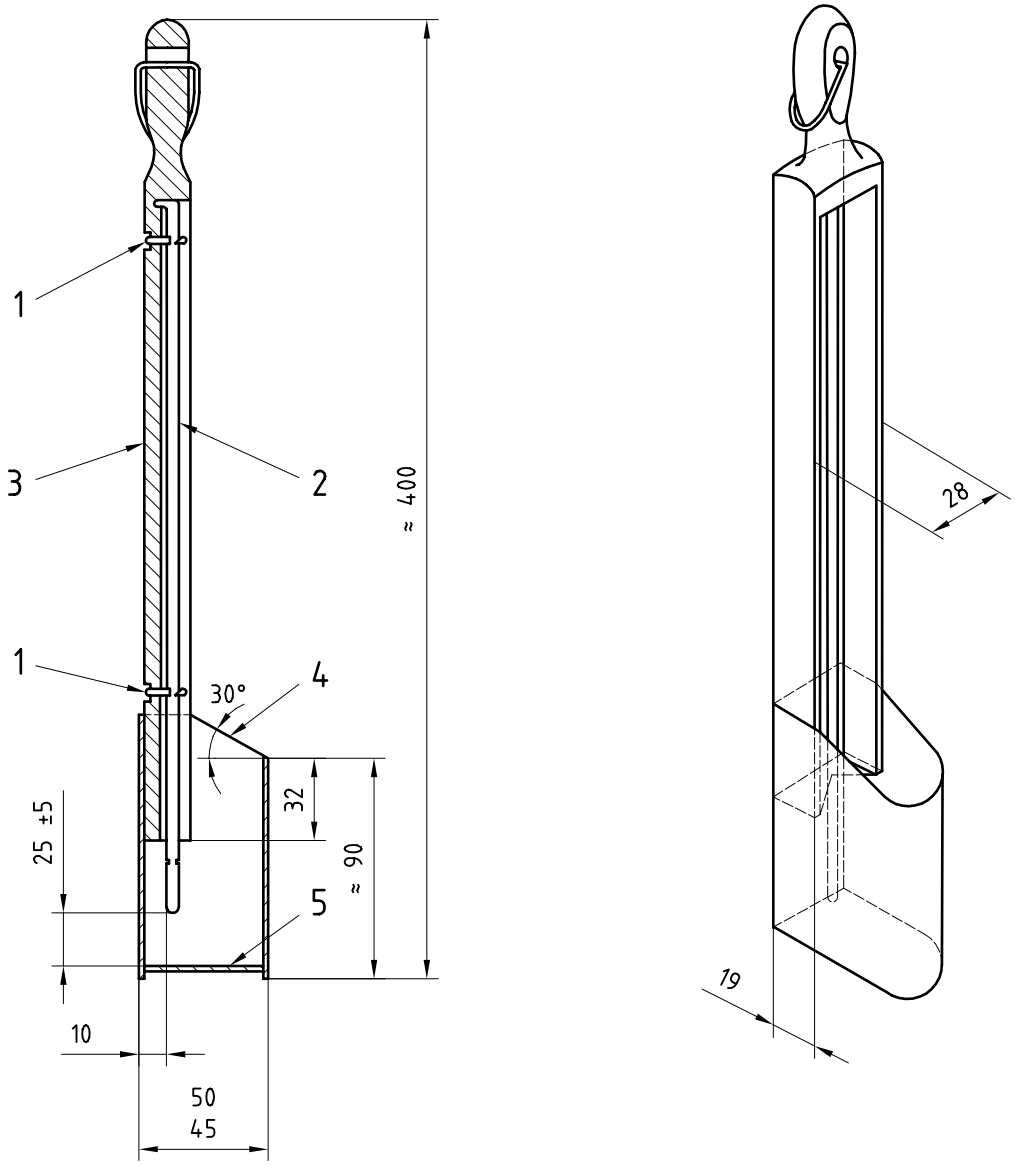
α is the apparent coefficient of cubical expansion in glass of the thermometric liquid, obtained by subtracting the coefficient of cubical expansion of glass from the coefficient of cubical expansion of the liquid. For mercury-in-glass thermometers, α is approximately 0,000 16 for temperatures measured in degrees Celsius.

10 Tank sampling methods

10.1 Cup-case thermometer

A typical cup-case thermometer assembly is illustrated in Figure 2. The cup-case may be made of either varnished hardwood or non-sparking corrosion-resistant material, with a cup of at least 100 ml capacity, and with dimensions such that the side of the bulb will be at least 10 mm from the nearest wall, and the bottom of the bulb 25 mm ± 5 mm above the bottom of the cup. The accuracy and resolution of the thermometer within the cup-case shall comply with the specification detailed in 8.2.

Dimensions in millimetres



Key

1 Clamp
2 ISO thermometer
3 Hard wood or metal frame
4 Cup of corrosion-resistant metal, 100 ml
5 Closed bottom

Figure 2 — Typical cup-case assembly

10.2 Flushing-case thermometer

10.2.1 Description of apparatus

A schematic diagram of a typical flushing-case thermometer is given in Figure 3.

The case shall consist of a cylindrical chamber of at least 200 ml capacity, and a protecting tube for the thermometer, rigidly attached to the chamber. The case and tube shall not be made of aluminium or its alloys. The

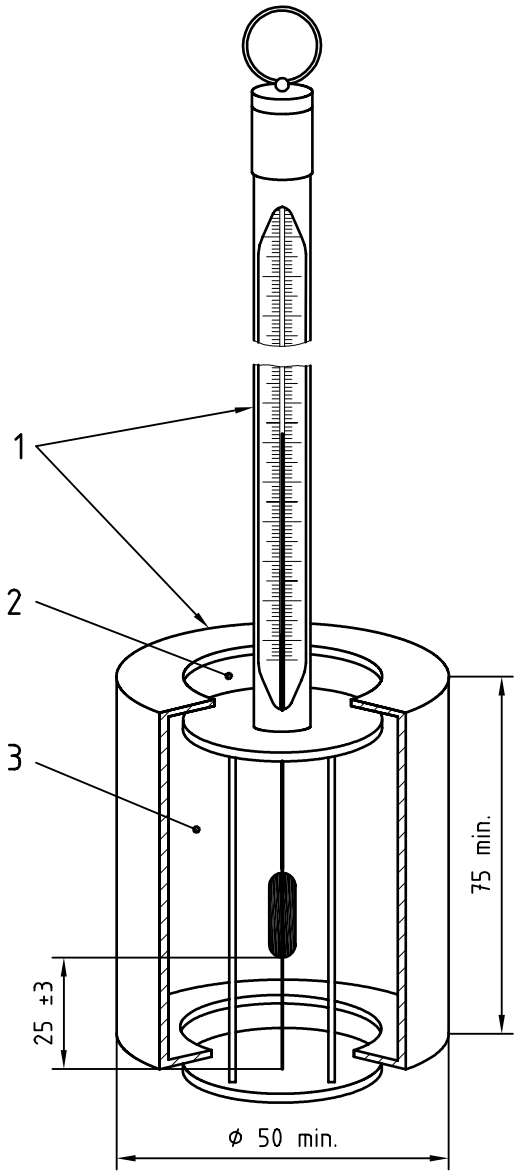
thermometer shall be attached to the case so that the bottom of the bulb shall be approximately 25 mm ± 3 mm above the bottom of the case.

The chamber shall be made of a suitable insulating material which shall be fully resistant to petroleum products, or shall have some form of insulating sleeve to retard heat loss. It shall have a quick-acting closure at the top and bottom which, in the open position, will assure a free path for liquid flow through the chamber and across the thermometer bulb. In the closed position, the closures shall assure the retention of a full chamber of liquid.

The apparatus shall be designed so that the closures can be operated by a jerk of the suspension cord or by some other suitable remote control.

The device shall be of such material and construction that not more than the specified flushing time will be required for the determination of the temperature of any petroleum oil (see 17.3.3).

Dimensions in millimetres



Key

1 Non-sparking metal

2 Design of opening and closing mechanism to be chosen by manufacturer

3 Minimum capacity 200 ml

Figure 3 — Typical flushing-type case and thermometer assembly

10.2.2 Thermometers for flushing-cases

Because the thermometer stem is not immersed in the oil when readings are being taken, the thermometer used shall be calibrated for partial immersion.

The accuracy and resolution of the thermometer within the flushing-case shall comply with the specification detailed in 8.2.

10.3 Sampling-bottle methods

The temperature may be obtained from tank samples by inserting a liquid-in-glass thermometer into a sample of the oil that is taken in accordance with ISO 3170 and the procedure described in 17.3.4. The bottles used in the weighted cage shall be deep enough to accommodate the thermometer to its stated partial immersion depth. The bottle shall also be of sufficient capacity to prevent any rapid change of the sample temperature once it is removed from the bulk tank contents. A 500 ml capacity bottle should prove adequate for most routine measurements.

NOTE The use of metal sample cans is not recommended, see 17.3.4.

The accuracy and resolution of the thermometer used within the sample bottle shall comply with the specification detailed in 8.2.

11 Vapour-lock samplers and associated thermometers

11.1 Vapour-locks on pressurized tanks

A vapour-lock is a device designed to enable pressure-type tanks to be gauged or sampled manually while under full operating pressure.

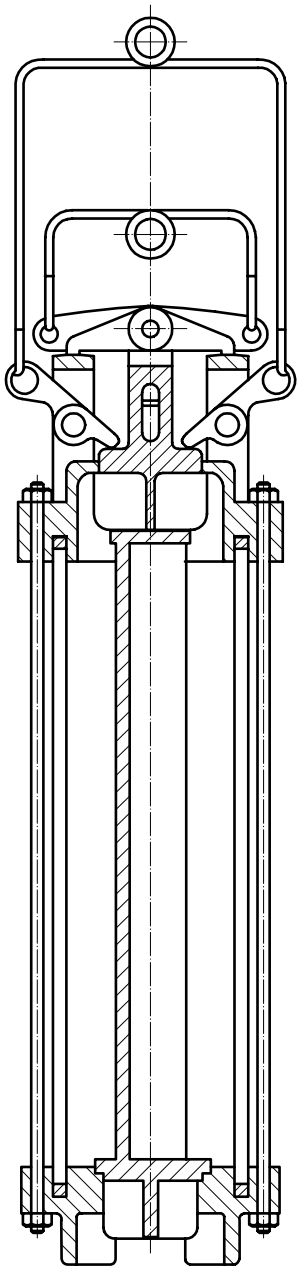
NOTE This equipment has generally been superseded by use of PETs through vapour-lock valves (see clause 7), but in certain circumstances it may still be used.

11.2 Outline description

A cup-case or flushing-case thermometer may be used via a vapour-lock, or alternatively, a special type of flushing sampler may be used with an integral liquid-in-glass thermometer. A typical sampler is illustrated in Figure 4, but any similar equipment supplied for use with a vapour-lock that permits a sample to be taken at any specified depth, and which has a capacity of not less than 450 ml is suitable.

The sampler illustrated consists of a glass body having a capacity of about 1 l and closed at the top and bottom with a valve assembly held in place with draw bolts. The valves are operated by two sets of levers which are actuated by taking the weight of the sampler on them.

The interior of the glass body is fitted with clips for holding a liquid-in-glass thermometer so that no part of the bulb is closer than 10 mm to the walls or bottom of the sampler. The accuracy and resolution of the thermometer used within the sampler shall comply with the specification detailed in 8.2.



NOTE Integral thermometer is not shown.

Figure 4 — Example of special sampler for use via a vapour-lock

12 Permanently installed spot thermometers

12.1 Angle-stem thermometers

Angle-stem thermometers are liquid-in-glass thermometers where the scale portion of the stem is at an angle to the rest of the stem and bulb. This is to facilitate the reading of a vertical scale while the main stem and bulb are inserted within a thermo-well that penetrates the tank wall horizontally (or at an angle which is close to horizontal). The external part of the thermometer stem may be reinforced to minimize the risk of accidental breakage.

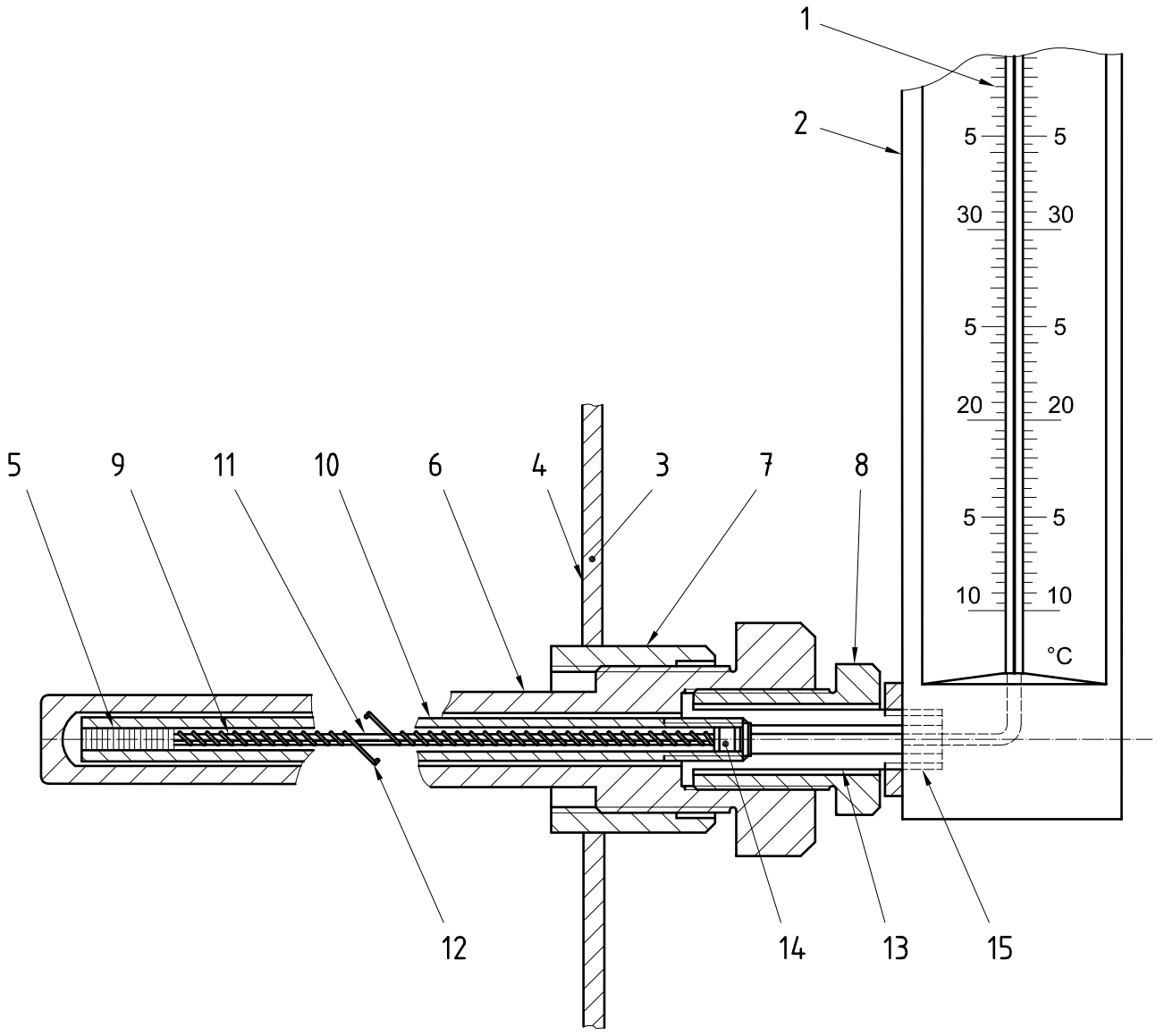
Angle-stem thermometers shall be calibrated for partial immersion corresponding to the effective length of the bulb and stem contained within the thermo-well.

A typical assembly is shown in Figure 5.

Angle-stem thermometers and their thermo-wells shall be manufactured so that the thermometer bulb shall be not less than 500 mm from the tank shell.

NOTE 1 Preferably the thermometer bulb should be located not less than 900 mm from the tank shell.

NOTE 2 Industrial-type angle-stem thermometers are not suitable for installation in volumetric calibration tanks or other meter-proving equipment where special high accuracy thermometers are specified.



Key

1 Metal scale
2 Metal-scale frame
3 Tank shell
4 Inside of tank
5 Graphite grease for good conductivity
6 Thermometer pocket
7 Half coupling welded to tank shell
8 Revolving union
9 Sensitive bulb
10 Thermometer tail
11 Mercury-in-glass thermometer
12 Heat-resisting packing string
13 Spigot
14 Packing box made up of suitable packing material between two washers
15 Socket

Figure 5 — Typical angle-stem thermometer assembly

12.2 Tank-bottom liquid-in-glass thermometers

Liquid-in-glass thermometers for this application are typically 1,3 m in length and 10 mm in diameter. The thermometer is permanently installed in the lower part of the tank in a horizontal or slightly inclined thermo-well, penetrating into the tank by at least 900 mm.

The thermo-well shall contain low viscosity oil (e.g. kerosine or gas-oil) in order to ensure good thermal contact between the thermo-well and the thermometer.

12.3 Accuracy and resolution

The accuracy and resolution of fixed installation liquid-in-glass thermometers shall meet the specification detailed in 8.2.

13 Bimetal-actuated thermometer with dial

13.1 Introduction

For certain applications, where it is not desirable to use liquid-in-glass thermometers on tanks (e.g. high temperature products like bitumen), or where a local indication is required, it may be appropriate to use a bimetal-actuated thermometer with dial.

13.2 Description

A bimetal-actuated thermometer with dial indicator shall be installed in a standard metal separable well or socket in the tank, similar to the installation shown in Figure 5. The stem of the thermometer shall be at least 500 mm long and the sensitive portion shall be not more than 60 mm long. The assembly shall be attached to the well by a threaded coupling.

13.3 Accuracy and resolution

Measurements from bimetal-actuated thermometers shall not be used for custody-transfer measurement applications unless calibration verification tests have demonstrated that the accuracy and resolution of measurement are comparable with the other measurement methods described in this International Standard.

NOTE The accuracy and resolution of bimetal-actuated thermometers should be comparable with PETs and liquid-in-glass thermometers, but this may be difficult to achieve in practice.

14 Procedures

Clauses 15 to 20 describe the procedures.

15 Liquids in pressurized tanks

15.1 Introduction

Subclauses 15.2, 15.3 and 15.4 describe procedures which are applicable for the temperature measurement of liquefied petroleum gases (LPG), casing-head gasolines, live crude oils, etc., when these products are contained in pressurized tanks, pressurized rail cars, or pressurized road vehicles.

15.2 General principles

Determination of the temperature of liquids in pressurized storage tanks presents peculiar difficulties because the liquid will boil under normal atmospheric temperature and pressure. For this reason, tank sampling methods for temperature determination will not be appropriate unless special apparatus is used via a vapour-lock (see clause 11). Depending on the pressure rating of the equipment, it may be possible to use a PET via a vapour-lock valve, or it may be preferable to use thermometer(s) inserted in thermo-well(s). Alternatively, permanently installed averaging thermometers, as described in ISO 4266, may be used in place of the equipment described in 15.3.

15.3 Equipment

It may be possible to determine temperatures by means of a PET inserted directly via a vapour-lock valve (see 15.4.1). Alternatively, it may be necessary to determine temperatures by means of thermometer(s) inserted in thermo-well(s) extending into the bulk of the liquid.

Thermo-wells installed in the sides of a tank shall extend into the tank for a distance of at least 500 mm, and preferably 900 mm, to avoid local thermal effects at the tank wall. In spheres and spheroids, good results may be obtained with electronic thermometers in long thermo-wells installed vertically from the top of the tank and extending downwards throughout the tank height.

NOTE 1 In other tanks where thermo-wells are inserted horizontally (or slightly inclined), there should be at least four wells, one at a level approximately 600 mm above the lower capacity mark, another 1,2 m below the upper capacity mark, and at least two at intermediate levels equally spaced between these. In smaller tanks, fewer thermo-wells may be used according to the size of tank, but adjacent thermo-wells should not be spaced at intervals greater than 3 m.

In LPG tanks, provision shall also be made for temperature-measuring equipment to be installed in the vapour space.

All thermometers employed via thermo-wells shall be installed with the temperature-sensitive element brought into intimate thermal contact with the inside of the thermo-well by means of a film or a filling of thin oil such as kerosine or gas-oil. The sensing element of electronic thermometers shall not make electrical contact with the thermo-wells.

NOTE 2 Permanently installed spot thermometers or bimetal-actuated thermometers may give inaccurate readings when the atmospheric temperature differs greatly from that of the contents of the tank, but when significant differences do not occur their use is permissible.

NOTE 3 Permanently installed electronic thermometer elements are generally located within capped pockets, i.e. thermo-wells with external extensions and connecting heads (usually watertight), hence they should be completely sealed. The construction should ensure that the temperature sensor is unaffected by external ambient temperature conditions.

NOTE 4 One or more thermometers are sometimes inserted in gauge-glasses which may be fitted to high-pressure tanks. Such thermometers are, however, used solely to ensure that gauge-glass contents are at, or near, the temperature of the contents of the tank before gauge-glass readings are taken. In no circumstances should the temperatures indicated by these thermometers be used in determining the mean temperature of the tank contents.

15.4 Procedures for pressurized tanks

15.4.1 Portable electronic thermometers

Provided that the pressure rating of the PET is sufficient to withstand the pressure rating of the tank, direct insertion via a vapour-lock valve is feasible. Where the pressure rating of the tank is greater than that of the PET, measurements shall be made within a suitable thermo-well.

Dependent on the depth of liquid within the tank, select the minimum number of measurement positions required by referring to Table 2.

Earth the PET and proceed as described in 7.5.6.

15.4.2 Other thermometers in thermo-wells

All liquid-in-glass thermometers shall be read to the nearest one-half scale graduation, and all the individual readings shall be recorded without rounding. The average of the readings obtained on all thermometers situated in the vapour space of the tank, rounded to the nearest 0,1 °C, shall then be taken as the mean vapour-space temperature. The average of the readings obtained on all thermometers situated below the liquid level (with the exception of any thermometer situated within 150 mm of the liquid surface, which shall be ignored), rounded to the nearest 0,1 °C, shall be taken as the mean temperature of the liquid.

NOTE The pressure in the vapour space is usually also required, and this should be read and recorded to the nearest 10 kPa.

15.4.3 Vertical cylindrical tanks, spheres and spheroids

The minimum number and position of temperature measurement locations depend on the liquid level in the tank, and are defined in Table 2.

Table 2 — Minimum number of temperature-measurement locations for various depths of oil

Depth of oil m	Number of measurements	Location
> 4,5	3	upper, middle and lower
3,0 to 4,5	2	upper and lower
< 3,0	1	middle

The upper, middle and lower levels are calculated as being equivalent to five-sixths, one-half and one-sixth of the liquid depth respectively.

NOTE 1 If the depth of liquid significantly exceeds 4,5 m, consideration should be given to taking additional measurements at equidistant (or equivolume) levels as described in clauses 18, 19 and 20.

Temperature measurements shall not be made from levels less than 150 mm below the oil surface or less than 150 mm above the bottom of the liquid layer.

NOTE 2 In the case of tanks fitted with mechanical stirrers, temperature measurement at a single point may be sufficient after mixing, but this should be verified by comparative measurements (see clause 20).

If a PET is used, follow the procedure detailed in 7.5.6. Where liquid-in-glass thermometers are permanently installed in thermo-wells, they shall be read to the nearest one-half of the smallest scale graduation.

15.4.4 Horizontal and inclined cylindrical tanks

In horizontal and inclined cylindrical tanks which are full or nearly full, measurements shall be taken at upper, middle and lower levels equivalent to five-sixths, one-half and one-sixth of the oil depth.

If the temperature is measured with a portable electronic thermometer, each reading shall be taken and recorded to the nearest 0,1 °C. If the temperature is measured with a liquid-in-glass thermometer, each thermometer shall be read to the nearest one-half of the smallest scale graduation. The mean temperature shall then be taken as one-tenth of the sum of three times the temperature of the upper measurement, four times the temperature of the middle measurement and three times the temperature of the lower measurement, rounded off to the nearest 0,1 °C.

Partially filled horizontal cylinders require measurements at levels corresponding to five-sixths, one-half and one-sixth of the total volume of the oil. These levels can be found only by reference to the tank capacity table. The temperature shall be read and recorded to the nearest 0,1 °C (or one-half of the smallest scale graduation if a liquid-in-glass thermometer is used), and the average of the temperatures so recorded, rounded off to the nearest 0,1 °C, shall be taken as the mean temperature of the tank contents. When, however, the depth of the tank content

is less than 2 m, only one measurement need be taken. This shall be measured at the level corresponding to half the oil volume. This temperature shall be read and recorded as described above, and shall be regarded as the mean temperature of the tank contents.

15.4.5 Segmented tanks

In segmented tanks at all conditions of fill above 3,5 m, measurements shall be taken at levels corresponding to five-sixths, one-half and one-sixth of the volume of liquid contained in the tank, these levels being obtained from the capacity table.

If the temperature is measured with a portable electronic thermometer, each reading shall be read and recorded to the nearest 0,1 °C. If the temperature is measured with a liquid-in-glass thermometer, each thermometer shall be read to the nearest one-half of the smallest scale graduation. The average of the three temperatures, rounded-off to the nearest 0,1 °C, shall be taken as the mean temperature of the tank contents, provided that the middle temperature does not differ from the mean by more than 0,5 °C. If a greater difference is found, additional measurements shall be taken at levels which are intermediate between the three measurements and above the upper and below the lower measurement corresponding to volumes which fall equally on either side of the previous three locations. The mean temperature of all the measurements taken, rounded off to the nearest 0,1 °C, shall be regarded as the mean temperature of the tank contents.

If the depth of product is less than 3,5 m, two measurements only shall be taken at levels corresponding to three-quarters and one-quarter of the volume contained in the tank, and the mean temperature shall be taken as the average of these two measurements, rounded off to the nearest 0,1 °C.

In tanks containing 2 m or less of product, one measurement only shall be taken at a level corresponding to half the volume. If the temperature is measured with a portable electronic thermometer, it shall be read and recorded to the nearest 0,1 °C. If the temperature is measured with a liquid-in-glass thermometer, it shall be read to the nearest one-half of the smallest scale graduation. This temperature shall be regarded as the mean temperature of the tank contents.

15.4.6 Pressurized rail wagons and road vehicles for carrying tanks

Temperature measurements in pressurized rail wagons and road vehicles are not normally required, since their contents are usually weighed. If the temperature is required, it may be obtained with a portable electronic thermometer or a liquid-in-glass thermometer in conjunction with a vertical thermo-well installed in the top cover of the tank.

The thermo-well shall contain low-viscosity oil (e.g. kerosine or gas oil) in order to ensure good thermal contact between the thermo-well and the thermometer.

If a PET is used, follow the procedure detailed in 7.5.6. If liquid-in-glass thermometers are permanently installed in thermo-wells, they shall be read to the nearest one-half of the smallest scale graduation.

Where it is feasible to use a non-permanently installed liquid-in-glass thermometer, it shall be lowered into the well to a position corresponding to the centre of the volume of the tank contents and shall remain at this level for at least 10 min to enable it to reach thermal equilibrium. The bulb of the thermometer shall be kept in the well while the reading is being taken. The temperature shall be read to the nearest one-half of the smallest scale graduation, and recorded as the temperature of the contents of the tank.

16 Liquids in vapour-tight tanks

16.1 Introduction

Subclauses 16.2, 16.3, 16.4 and 16.5 describe the procedures that are applicable for the temperature measurement of crude oils, gasolines and other volatile products when these are contained in vapour-tight tanks which are maintained at a small positive pressure.

16.2 General principles

16.2.1 Frequently the contents of a storage tank are not uniform in temperature, and temperatures have to be obtained from a sufficient number of points within the bulk of the oil to enable the calculation of a meaningful average temperature.

16.2.2 Except for storage tanks fitted with automatic averaging thermometers (as outlined in ISO 4266), the general practice for temperature measurement is to use a PET or an appropriate liquid-in-glass thermometer in conjunction with one of the sampling devices described in clause 10.

16.3 Equipment

16.3.1 Portable electronic thermometers

These thermometers shall comply with the specification detailed in clause 7.

16.3.2 Other thermometers

Liquid-in-glass thermometers shall comply with the specification detailed in clause 8. Other permanently installed thermometers shall comply with the same resolution and accuracy specifications.

16.4 Procedure for vapour-tight tanks

16.4.1 Portable electronic thermometers

Connect the PET to the vapour-lock valve and ensure earth continuity prior to opening the valve. Follow the procedures detailed in 7.5.6.

16.4.2 Thermometers in thermo-wells

The procedure in 15.4.2 shall be used, except that measurements in the vapour space are not required.

16.4.3 Vapour-lock sampler with integral liquid-in-glass thermometer

Ensure that the valve between the vapour-lock and the tank is closed. Open the vapour-tight windowed door, and attach the sampler (clause 11) to the winding gear, taking care that the thermometer is in such a position that it can be read through the window, that the latter is clean, and that the sampler is open. The vapour-lock door shall then be closed and fastened, the valve opened, and the sampler lowered to the required level within the tank contents.

Flush the sampler for at least 2 min by repeatedly raising and lowering it through a distance of approximately 0,3 m. Then close it and rapidly draw it up to the window. Read the temperature to the nearest one-half of the smallest scale graduation of the thermometer, taking care to avoid parallax errors, and record the reading immediately.

Then empty the sampler by operating the winding gear. Alternatively, it may be necessary to withdraw it from the lock for emptying. To do this, close the valve and release the pressure from the lock before opening the door to remove the sampler for emptying and resetting.

The above procedure shall then be repeated at the next measurement location selected from Table 2.

16.4.4 Cup-case thermometer method

A cup-case thermometer may be used in vapour-tight tanks provided that it is inserted via (and read within) a vapour-lock. The recommended procedure detailed in 17.3.2 should be followed, except that the valve in the vapour-lock should be closed before reading the thermometer.

The temperature shall be read and recorded to the nearest one-half of the smallest scale graduation of the thermometer. Where temperatures are obtained at more than one level, the average of the temperatures so recorded, rounded off to the nearest 0,1 °C, shall be taken as the mean temperature of the tank contents.

16.4.5 Flushing-case thermometer method

A flushing-case thermometer may be used in vapour-tight tanks provided that it is inserted via (and read within) a vapour-lock. The recommended procedure detailed in 17.3.3 shall be followed except that the valve in the vapour-lock shall be closed before reading the thermometer.

The temperature shall be read and recorded to the nearest one-half of the smallest scale graduation of the thermometer. Where temperatures are obtained at more than one level, the average of the temperatures so recorded, rounded off to the nearest 0,1 °C, shall be taken as the mean temperature of the tank contents.

17 Liquids in non-pressurized non-insulated tanks at or near ambient temperature, or in non-pressurized insulated tanks

17.1 Introduction

The following procedures are applicable to the measurement of the temperature of all liquid petroleum products contained in non-pressurized storage tanks, including road and rail vehicle tanks and ship and barge compartments, when the difference between the oil and ambient temperature does not exceed 15 °C. These procedures are also generally applicable to insulated storage tanks regardless of the ambient temperature.

17.2 Equipment

Temperatures shall be taken using a PET as described in clause 7, or by one of the sampling methods using a liquid-in-glass thermometer as described in clause 10.

NOTE The three liquid-in-glass thermometer methods (17.3.2, 17.3.3 and 17.3.4) can result in significant errors due to the risk of inadequate pre-equilibration of the apparatus with the surrounding oil and/or the effect of adverse weather conditions at the tank top when the thermometer is read. Where such practical difficulties may arise, it is recommended that measurements should be obtained using either a portable electronic thermometer or a permanently installed automatic averaging tank thermometer system.

If tests have demonstrated that a permanently installed spot thermometer measurement is acceptable (clause 20), it is acceptable to use the equipment that is described in clauses 12 or 13.

17.3 Procedures

17.3.1 Portable electronic thermometers

The procedure detailed in 7.5.6 shall be followed except that it may not be necessary to make the measurement via a vapour-lock valve.

17.3.2 Cup-case thermometers

The procedure for the use of a cup-case thermometer is as follows.

a) Lower the cup-case thermometer into the tank to the first required level (from Table 2).

b) Allow the cup-case to remain at this level for sufficient time to equilibrate with the surrounding oil.

NOTE 1 The necessary immersion time will be dependent on the viscosity of the oil, the thermal conductivity of the cup-case, and the temperature differential between the oil and the cup-case assembly. The time taken for the cup-case thermometer to reach thermal equilibrium should be determined by practical tests to assess the response of the thermometer following a step change to the temperature of its surroundings. The immersion time can be reduced if the

cup-case assembly is continuously raised and lowered through a distance of about ± 0,3 m. As a guide, the recommended immersion times for Woodback cup-case thermometers are given in Table 3.

c) Withdraw the cup-case thermometer from the oil, but protect it from any adverse effects of the weather (e.g. by not withdrawing it above the edge of the gauge-hatch). Read the temperature immediately to the nearest one-half of the smallest scale graduation of the thermometer. Record the reading immediately, together with the level at which the sample was taken.

NOTE 2 The cup should be kept full when the assembly is withdrawn to read the temperature. These operations should be carried out with the minimum of delay.

d) Repeat steps a) to c) at the next lower level selected in accordance with Table 2.

e) Calculate the average of all the temperatures obtained (in accordance with the guidance given in 15.4.3 to 15.4.5), rounded off to the nearest 0,1 °C. This average shall be taken as the mean temperature of the tank contents.

NOTE 3 After use in crude or fuel oil, the thermometer and case should be cleaned with kerosine or gas oil and dried with a cloth to prevent the formation of an insulating film of heavy oil.

Table 3 — Recommended immersion times for a Woodback cup-case thermometer

Density at 15 °C kg/m^3	In motion min	Stationary min
< 775	5	10
775 to 825	5	15
825 to 875	12	25
875 to 925	20	45
> 925	45	80

17.3.3 Flushing-case thermometers

The procedure for a flushing-case thermometer is as follows.

a) Prepare the flushing-case thermometer by cocking its chamber open, and lower it into the tank.

b) Give the apparatus a preliminary flushing as it enters the oil. Then lower it to the first required level, selected in accordance with Table 2. Once at the desired level, flush it for at least 2 min by repeatedly raising and lowering the device through a distance of about 0,3 m.

NOTE 1 Care is required to avoid jerking the operating cord during the raising and lowering procedure as this may close the chamber prematurely.

c) When the flushing-case and the thermometer have reached an equilibrium temperature with the liquid, jerk the operating cord to close the chamber (or operate the remote closure mechanism). Retrieve the flushing-case assembly with the trapped oil sample and read the thermometer without delay while protecting it from any adverse effects of the weather (e.g. by not withdrawing it above the edge of the gauge-hatch). Read the temperature to the nearest one-half of the smallest scale graduation of the thermometer, and record the reading together with the level at which the sample was taken.

d) Repeat steps a) to c) at the next lower level selected in accordance with Table 2.

e) Calculate the average of all the temperatures obtained (in accordance with the guidance given in 15.4.3 to 15.4.5), rounded off to the nearest 0,1 °C. This average shall be taken as the mean temperature of the tank contents.

NOTE 2 After use in crude or fuel oil, the thermometer and case should be cleaned with kerosine or gas oil and dried with a cloth to prevent the formation of an insulating film of heavy oil.

17.3.4 Sampling-bottle method

The recommended procedure for taking the temperature of tank samples is as follows.

a) Place a glass sample bottle in a weighted sampling cage and close the mechanism to prevent any premature inflow of oil into the bottle.

NOTE 1 The use of glass sample bottles is recommended in preference to metal sample cans because glass provides better insulating properties and metal cans may deform under the hydrostatic pressure of the tank contents.

b) Lower the bottle and cage to the first required level (see Table 2).

c) Allow the sample bottle to remain at this level for at least 2 min (and preferably 3 min) while gently raising and lowering it through a distance of about ± 0,3 m to assist the equilibration of temperatures.

d) Then jerk the cord (or operate the appropriate mechanism) to open the neck of the bottle and collect an oil sample in the pre-equilibrated bottle.

e) Allow time for the bottle to fill and then raise the bottle to the top of the tank.

f) Insert a liquid-in-glass thermometer into the sample and stir gently until temperature equilibrium is attained, i.e. the temperature remains constant (to within one-half of the smallest scale increment) for 20 s. It is important that the sample bottle is held inside the body of the gauge-hatch (or otherwise protected) before and during the reading of the thermometer, in order to shield it from any adverse effects of the weather.

NOTE 2 A shorter 20 s equilibrium time is specified in this case because of the risk that the measurement may be affected by the local ambient temperature conditions. Where temperature measurements are made in-situ (so that they are not affected by the conditions at the gauging access point), a 30 s equilibrium time is specified (see 7.5).

g) Once the thermometer has reached the equilibrium temperature of the oil sample, take the reading to the nearest one-half of the smallest scale graduation of the thermometer. Record the reading together with the level at which the sample was taken.

h) Repeat steps a) to g) at the next selected lower level (see Table 2).

i) Calculate the average of all the temperatures obtained (in accordance with the guidance given in 15.4.3 to 15.4.5), rounded off to the nearest 0,1 °C. This average shall be taken as the mean temperature of the tank contents.

17.4 Vertical cylindrical fixed-roof tanks

17.4.1 Temperature determination shall be made using one of the procedures described in 17.3. The number and location of temperature readings depend on the liquid level in the tank and the minimum recommended locations are specified in Table 2.

NOTE 1 In certain conditions, however, it is desirable to improve the accuracy of the final mean temperature obtained for the contents of the tank, by obtaining temperature readings from more than one gauge-hatch. Such conditions may arise:

a) when opposite sides of the tank are exposed to very different weather conditions (e.g. wind or direct sunshine);

b) immediately after pumping a substantial quantity of oil at one temperature into a tank which already contains oil at a considerably different temperature;

c) generally, when there is any reason to suspect appreciable stratification, layering or similar irregular temperature variation in the tank contents.

17.4.2 The possibility of dealing adequately with the above conditions, and the procedure to be adopted, depend on whether the tank is fitted with more than one gauge-hatch, and if so, on the disposition of the hatches. The normal arrangements are

a) one hatch only, or

b) one central hatch plus several peripheral hatches.

17.4.3 The mean temperatures shall be calculated as described in 17.4.3.1 and 17.4.3.2.

17.4.3.1 When using one hatch only the mean temperature at the hatch rounded off to the nearest 0,1 °C shall be taken as the mean temperature of the whole tank contents.

17.4.3.2 When using one central hatch plus several peripheral hatches, proceed as follows.

The arithmetic means of the average temperatures at the central hatch with each of the peripheral hatches in turn, shall first be computed without rounding-off. The mean temperature of the tank contents shall then be taken as the sum of these arithmetic means, divided by the number of means (i.e. by the number of pairs of gauge-hatches obtained by pairing the centre hatch with each peripheral hatch in turn); rounded off to the nearest 0,1 °C.

17.5 Floating-roof tanks

17.5.1 Use one of the procedures detailed in 17.3, and take measurements via a perforated still-well if one is available. If the temperature is measured with a portable electronic thermometer, each reading shall be read and recorded to the nearest 0,1 °C. If the temperature is measured with a liquid-in-glass thermometer, it shall be read to the nearest one-half of the smallest scale graduation.

17.5.2 If there is no perforated still-well, temperature readings shall be taken from a gauge-hatch adjacent to the position corresponding to the gauger's platform, manipulating the hatch cover and the thermometer from the platform.

NOTE Where a floating roof has been subjected to strong sunlight, particularly if the roof is an older pan-type roof or a single-deck pontoon roof, the product in contact with the underside of the roof can become much hotter than the main body of product in the tank. Therefore the effective density of this upper layer will be less than is indicated by the mean temperature and the density at standard temperature of the tank contents. Any correction for roof displacement calculated from these latter figures will therefore be in error. In consequence, for the purpose of calculating roof-displacement corrections, the density of the product taken shall be that corrected to the temperature of the layer of liquid immediately under the roof and in which the roof floats. For this reason, the temperature of this upper layer shall be recorded by the gauger wherever roof displacements are required to be calculated.

17.6 Horizontal and inclined cylindrical tanks

The procedure for these tanks fitted with only one gauge-hatch is precisely as laid down in 15.4.4.

If the temperature is measured with a portable electronic thermometer, each reading shall be taken and recorded to the nearest 0,1 °C. If the temperature is measured with a liquid-in-glass thermometer, it shall be read to the nearest one-half of the smallest scale graduation. The mean tank temperature shall be computed in all cases to the nearest 0,1 °C.

NOTE When there is reason to suspect a variation of temperature between the ends of the tank and when suitable hatches are fitted, upper, middle and lower temperatures should be taken at each end of the tank. The average temperature at each end of the tank should be calculated as in 15.4.4, and the mean temperature of the tank should be taken as the arithmetic mean (rounded off to the nearest 0,1 °C) of the two average temperatures so obtained.

17.7 Rail wagons and road vehicles carrying tanks

In gauging vehicles having only a single compartment, subject to mutual agreement between parties, a single measurement at the middle location (i.e. the level corresponding to one-half of the contained volume) is normally adequate. If the temperature is measured with a portable electronic thermometer, it shall be read and recorded to

the nearest 0,1 °C. If the temperature is measured with a liquid-in-glass thermometer, it shall be read to the nearest one-half of the smallest scale graduation subject to mutual agreement of all interested parties. Subject to the mutual agreement between the parties, this temperature may generally be regarded as the mean temperature of the contents of the compartment.

If the vehicle is partitioned into a number of compartments, a measurement shall be made (and recorded as described above) at the middle location within each compartment. Where compartments contain the same grade of product, an overall average temperature may be calculated using the volume-weighting method. The average temperature of the contents of each compartment shall be multiplied by the volume it contains, these values should be added together and the sum divided by the total volume. The resulting volume-weighted average should be rounded to the nearest 0,1 °C.

17.8 Ship and barge cargo tanks

Temperature measurements shall be made at the upper, middle and lower positions corresponding to five-sixths, one-half and one-sixth of the oil depth. If the depth of the oil is less than 4,5 m, the number of temperature measurements may be reduced in accordance with Table 2.

If the temperature is measured with a portable electronic thermometer, each reading shall be read and recorded to the nearest 0,1 °C. If the temperature is measured with a liquid-in-glass thermometer, it shall be read to the nearest one-half of the smallest scale graduation.

Subject to mutual agreement between parties, the arithmetic average of the temperatures at the upper, middle and lower locations may generally be regarded as the mean temperature of the contents of a cargo tank on board a ship or barge.

18 Liquids in non-pressurized non-insulated tanks at temperatures differing by more than 15 °C from ambient

18.1 Introduction

The procedures in 18.2, 18.3 and 18.4 are applicable to the measurement of the temperature of all liquid petroleum products in non-pressurized non-insulated storage tanks when the oil and ambient temperatures differ by more than 15 °C.

18.2 General principle

When the oil and ambient temperatures vary by more than 15 °C, it may be necessary to take temperature measurements at more locations than the minimum number specified in Table 2, in order to obtain a representative average temperature. For this reason, it is preferable to use a portable electronic thermometer for measuring temperatures.

NOTE If a PET is not available, the other methods detailed in this International Standard may be used, but the time required to make the measurements may be prohibitive. In such circumstances, consideration should be given to the installation of a fixed averaging tank thermometer system in accordance with ISO 4266. Wherever possible, a portable electronic thermometer should be used to check for stratification and make extra measurements at intermediate locations as described in 7.5.6 h) and/or 17.4.3. Practical time constraints may make it difficult to determine a representative average temperature of the tank contents within heated tankage when it is necessary to use one of the sampling methods detailed in 17.3.2, 17.3.3 or 17.3.4. Even when heating coils have been on for a sufficient time for the tank contents to attain a 'steady' temperature, some difficulty may be experienced in obtaining accurate temperatures, due to convection currents within the oil. Experience indicates that the most reliable temperatures are obtained when these convection effects are at a minimum, and this usually takes place after the heating coils have been turned off for between 2 h and 6 h. However, if the coils have been off for longer periods, reverse-direction convection currents may become significant. Circulation of the tank contents, mixing with internal tank mixers, and/or fresh application of heat may help to overcome the difficulty, but in the later case it is important to allow sufficient time for the tank contents to reach a new steady temperature and for the heat to be turned off again before attempting to make temperature measurements. It is impossible to give generic guidance on recommended time intervals, as heating and cooling rates of tanks will depend on the size and shape of the tank, heating arrangements, atmospheric conditions, for example.

In no circumstances shall temperature readings be made from within 300 mm of heating coils.

18.3 Equipment

18.3.1 Unheated and heated non-insulated tanks containing products other than bitumen

Temperature is normally determined using a portable electronic thermometer. When a PET is not available, one of the tank sampling methods described in 17.3.2, 17.3.3 or 17.3.4 shall be used with extended equilibration/flushing times as necessary (see 18.4).

18.3.2 Tanks containing heated bitumen

Bitumen tanks are normally fitted with permanently installed temperature-measuring equipment, as the taking of temperature by manual methods is usually impracticable.

If permanently installed equipment is used, its installation shall follow the appropriate recommendations in ISO 4266.

18.4 Measurement procedure

18.4.1 Portable electronic thermometer

Depending on the depth of liquid within the tank, select the minimum number of measurement positions required by referring to Table 2.

Earth the PET and proceed as described in 7.5.6.

18.4.2 Cup-case thermometer

The principles laid down in 17.3.2 shall be followed when using a cup case thermometer, but the cup-case assembly shall be given a minimum of two preliminary immersions, (emptying the cup after each immersion) before taking the sample where the temperature is read and recorded. This procedure is designed to assist the equilibration of the cup-case assembly (from ambient to tank temperature) prior to taking each temperature measurement.

NOTE After use in highly viscous oils the cup case should be thoroughly rinsed with kerosine or gas oil to prevent the formation of an insulating deposit.

18.4.3 Flushing-case thermometer

The principles laid down in 17.3.3 shall be followed, but the flushing case shall be given at least two preliminary rinses with the oil being sampled. When it is used in viscous oils heated to above 60 °C, the subsequent flushing time shall be increased to 5 min to ensure adequate equilibration of the apparatus with the tank contents.

NOTE 1 When used in viscous oils, some adjustment of the tension of the spring operating the closure of the chamber may be required. If the adjustment is too sensitive, the chamber may close prematurely when the device penetrates the oil surface. Alternatively, if the tension is increased too much the operator may find it difficult to give a sufficiently sharp jerk to the operating cord and to feel when the chamber closes.

NOTE 2 After use in viscous oils, the flushing case should be thoroughly rinsed with kerosine or gas oil, paying particular attention to the sheath round the thermometer, and then drained.

18.4.4 Sampling-bottle method

The principles given in 17.3.4 shall be followed, but the bottle and cage should be equilibrated at each sampling location (by gently raising and lowering the cage through about ± 0,3 m) for 5 min prior to opening the bottle to collect the sample.

19 Procedures for the verification of permanently installed tank thermometers

19.1 Introduction

The following procedures shall be used when measurements from a permanently installed tank thermometer system are to be verified against manual reference measurements. These procedures are equally applicable to the verification of single-point spot thermometers (as described in clauses 12 and 13) and automatic averaging tank thermometer (ATT) systems (as described in ISO 4266).

19.2 Specification of reference thermometer

A PET that complies with the specification detailed in clause 7 shall be used. The resolution of measurement shall be 0,1 °C (or better). The PET shall have been recently calibrated against a traceable laboratory standard with a resolution of 0,02 °C (or better). The uncertainty of measurement with the PET shall not exceed ± 0,1 °C at any point over its anticipated working range (after application of calibration corrections if appropriate).

The calibration certificate shall detail the traceability of the calibration to a national standard.

19.3 Verification procedure for vertical cylindrical tanks

19.3.1 Select the most suitable tank-temperature-measurement access point that will permit the taking of measurements from locations that are not closer than 500 mm to the tank wall (shell).

NOTE The chosen access point should also enable reference measurements to be taken at the same vertical height and within 1 m horizontal distance of the sensor/bulb of any permanently installed single-point spot thermometer.

19.3.2 Determine the level of product within the tank (see ISO 4512 or ISO 4266). If the tank also contains a separate bottom layer of free water and/or sediment, determine the level of the interface between the product and the bottom layer (see ISO 4512). If the measurements of level are based on dip (innage) measurements, convert them to the equivalent ullage (outage) distances by subtracting the dip values from the tank reference height.

19.3.3 Determine the total height of product within the tank (by subtracting the product ullage from the ullage that is equivalent to the interface level).

19.3.4 Divide the total height of product by 10, and calculate the distances that correspond to 1/10, 3/10, 5/10, 7/10 and 9/10 of the total product height. Calculate the equivalent ullage distances for each of these five locations by adding the distances to the product ullage measurement.

19.3.5 Lower the PET sensor to the uppermost location (from 19.3.4). Gently raise and lower the sensor through approximately ± 0,3 m until the reading is steady for 30 s. Record the temperature and the ullage distance of the measurement location.

19.3.6 Lower the PET sensor to the next position and repeat the measurement procedure until temperature readings have been obtained at all five locations. Apply any necessary calibration corrections (from the PET calibration certificate).

19.3.7 Provided that the range of the five individual spot reference temperature readings (i.e. the difference between the highest and lowest readings) does not exceed 1,0 °C, calculate the overall average temperature of the tank contents as the arithmetic mean of the five reference readings rounded to the nearest 0,1 °C.

If the range of the five individual spot reference temperature readings does exceed 1,0 °C, the oil is stratified within the tank and additional measurements shall be taken. Calculate the ullage distances that correspond to 1/20, 3/20, 5/20, 7/20, 9/20, 11/20, 13/20, 15/20, 17/20 and 19/20 of the total product height and make reference measurements with the PET at each of these locations. Calculate the overall average temperature of the tank contents as the arithmetic mean of these 10 reference readings rounded to the nearest 0,1 °C.

19.3.8 If the PET is used to verify the reading of a fixed installation averaging thermometer, compare the overall average reference temperature (from 19.3.7) with the reading obtained from the averaging tank thermometer, and record the magnitude and sign of any offset correction that is to be applied to the ATT reading.

If the PET is used to verify the reading of one or more fixed installation spot thermometer(s), compare the overall average reference temperature (from 19.3.7) with the reading(s) obtained from the spot tank thermometer(s), and assess the acceptability of using single-point spot thermometer(s) as described in clause 20. Additional comparisons(s) shall also be made by making a measurement with the reference PET sensor immersed to the same depth as (and positioned as close as possible to) each permanently installed spot thermometer. Provided that it has already been demonstrated that the range of reference measurements does not exceed 1,0 °C, the magnitude and sign of any offset correction shall be noted for each spot tank thermometer.

19.4 Verification procedure for other tanks with non-uniform vertical cross-sectional area

Determine the level of product within the tank and, by reference to the tank calibration table, determine the ullage levels within the tank contents that correspond to 1/10, 3/10, 5/10, 7/10 and 9/10 of the total product volume. Then follow the general procedure detailed in 19.3, but make the reference measurement at equispaced volumetric locations. If these measurements indicate the presence of stratification within the tank contents, take a new set of reference measurements at equispaced 1/20 volumetric locations.

20 Procedures for using a permanently installed spot thermometer

20.1 Introduction

Subclauses 20.2 to 20.5 detail the circumstances in which it may be acceptable to take measurements from permanently installed manual spot thermometers of the types described in clause 12.

NOTE This type of thermometer should only be installed in tanks that are on single product duty, where it may reasonably be assumed that operational practices will prevent the layering or stratification of successive batches of what is nominally the same quality product. Tank mixing or recirculation facilities will normally be required to ensure that the tank contents are sufficiently well mixed to enable representative temperature measurement from a single-point spot thermometer.

20.2 Location of single-point spot thermometers

Each thermometer shall be installed in a horizontal or slightly inclined thermo-well so that the sensing bulb or element is not less than 500 mm from the tank wall (shell) and not less than 1 m from the tank bottom.

NOTE Whenever possible, the thermo-well should preferably extend for a minimum of 900 mm into the tank.

20.3 Specification of thermometers

Thermometers shall be of such a size that they may be read conveniently without having to partially remove them from the thermo-well. The resolution of measurement and calibration accuracy for custody-transfer measurement applications shall comply with the specification detailed in 8.2.

20.4 Verification of representivity of single-point spot thermometer measurements

20.4.1 Before single-point spot thermometers are used, tank-temperature profile tests shall be conducted to verify the absence of temperature stratification following the receipt of a typical import quantity under both typical winter and summer operating conditions. Reference measurements shall be made with a calibrated PET in accordance with the procedure detailed in 19.3 (or 19.4). If the range of the five equispaced reference measurements exceeds 1,0 °C, or the reading of the single-point spot thermometer differs from the average of the reference PET measurements by more than 0,5 °C then the single-point spot thermometer is not suitable for custody-transfer measurements.

20.4.2 If it has been demonstrated that representative measurements can be obtained from a single-point spot thermometer, the profile tests described in 20.4.1 shall be repeated at intervals not exceeding 5 years or whenever the tank service changes (i.e. whenever the grade of product stored is changed, or the supplier changes).

NOTE If the tolerances detailed in 20.4.1 are exceeded at any time then the single-point spot thermometer should not be used for custody-transfer measurements. Instead, multi-point measurements should be obtained using a PET or one of the sampling methods described in 7.5.6 and 17.3.2 to 17.3.4 respectively.

20.5 Procedure for using single-point spot thermometers

Provided that tank-temperature profile tests have demonstrated the representativity of single-point spot measurements, a single reading may be read directly. The thermometer shall be read to the nearest one-half of the smallest scale graduation.

NOTE An emergent-stem correction may be applicable, see 9.3.

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