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Refrigerated light hydrocarbon fluids — Measurement of temperature in tanks containing liquefied gases — Resistance thermometers and thermocouples

*Hydrocarbures liquides légers réfrigérés — Mesurage de température
dans les réservoirs contenant le gaz liquéfié — Thermomètres à
résistance et thermocouples*



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Contents

	Page
1 Scope	1
2 Normative references	1
3 Definitions	2
4 Types of temperature detector	2
5 Errors in the temperature-measurement system	2
6 Requirements on receiving instruments	3
7 Insulation resistance	3
8 Environmental conditions and permissible power-supply fluctuations	3
9 Verification procedures	5
10 Instrumentation requirements for gas-dangerous spaces	5

Annexes

A Details of accuracy check	6
B Design and use of fixed-point temperature device and controlled-temperature device	7

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Foreword

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

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.

International Standard ISO 8310 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Sub-Committee SC 5, *Measurement of light hydrocarbon fluids*.

Annexes A and B of this International Standard are for information only.

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Refrigerated light hydrocarbon fluids — Measurement of temperature in tanks containing liquefied gases — Resistance thermometers and thermocouples

1 Scope

This International Standard specifies the essential requirements and verification procedures for resistance-thermometer sensors, thermocouples and associated equipment to be used for ship and shore tanks containing refrigerated hydrocarbon fluids.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IPTS-68, *The International Practical Temperature Scale* — 1968.

IEC 79-0:1983, *Electrical apparatus for explosive gas atmospheres — Part 0: General requirements*.

IEC 79-1:1971, *Electrical apparatus for explosive gas atmospheres — Part 1: Construction and test of flameproof enclosures of electrical apparatus*.

IEC 79-1A:1975, *Electrical apparatus for explosive gas atmospheres — First supplement: Appendix D: Method of test for ascertainment of maximum experimental safe gap*.

IEC 79-2:1983, *Electrical apparatus for explosive gas atmospheres — Part 2: Electrical apparatus — type of protection “p”*.

IEC 79-3:1972, *Electrical apparatus for explosive gas atmospheres — Part 3: Spark test apparatus for intrinsically-safe circuits*.

IEC 79-4:1975, *Electrical apparatus for explosive gas atmospheres — Part 4: Method of test for ignition temperature*.

IEC 79-4A:1970, *Electrical apparatus for explosive gas atmospheres — First supplement*.

IEC 79-5:1967, *Electrical apparatus for explosive gas atmospheres — Part 5: Sand-filled apparatus*.

IEC 79-6:1968, *Electrical apparatus for explosive gas atmospheres — Part 6: Oil-immersed apparatus*.

IEC 79-7:1969, *Electrical apparatus for explosive gas atmospheres — Part 7: Construction and test of electrical apparatus, type of protection “e”*.

IEC 79-10:1986, *Electrical apparatus for explosive gas atmospheres — Part 10: Classification of hazardous areas*.

IEC 79-11:1984, *Electrical apparatus for explosive gas atmospheres — Part 11: Construction and test of intrinsically-safe and associated apparatus*.

IEC 79-12:1978, *Electrical apparatus for explosive gas atmospheres — Part 12: Classification of mixtures of gases or vapours with air according to their maximum experimental safe gaps and minimum igniting currents*.

IEC 92-504:1974, *Electrical installations in ships — Part 504: Special features — Control and instrumentation*.

IEC 533:1977, *Electromagnetic compatibility of electrical and electronic installations in ships*.

IEC 584-1:1977, *Thermocouples — Part 1: Reference tables*.

IEC 584-2:1982, *Thermocouples — Part 2: Tolerances*.

IEC 654-1:1979, *Operating conditions for industrial-process measurement and control equipment — Part 1: Temperature, humidity and barometric pressure*.

IEC 654-2:1979, *Operating conditions for industrial-process measurement and control equipment — Part 2: Power*.

IEC 751:1983, *Industrial platinum resistance thermometer sensors*.

The International Code for the construction and equipment of ships carrying liquefied gases in bulk (IGC Code), 1983, published by IMO.

3 Definitions

3.1 temperature-measurement system: A system consisting of a temperature detector, a receiving instrument which processes the signal and gives a temperature display, and cables linking the detector to the receiving instrument.

3.2 gas-dangerous space: A space where gas or vapour may form flammable mixtures when mixed with air. This is equivalent to the "hazardous area" as provided by IEC 79-10 for shore tanks, and to the "gas-dangerous space or zone" as provided by IMO resolution A.328(IX), 1.4.16 (see IGC Code), for ships' tanks.

3.3 maximum permissible error: The extreme value of the error permitted, by specification, in a system.

4 Types of temperature detector

Temperature detectors shall be either platinum resistance-thermometer sensors (IEC 751 recommends 100 Ω except for high-temperature use) or copper/constantan thermocouples (type T) (see IEC 584-1 and IEC 584-2). The materials of the temperature detectors and the leads connecting the detectors to the receiving instruments shall have properties which change only minimally with time.

Resistance-thermometer sensors shall be either three- or four-wire types.

5 Errors in the temperature-measurement system

5.1 Temperature detector

5.1.1 Class A resistance-thermometer sensors used for measurement of the temperature of the liquid phase (see table 1) shall have an error not greater than

a) $\pm 0,15$ °C for LNG

or

b) $\pm 0,3$ °C for LPG and other cryogenic fluids.

NOTE 1 These different error limits have been specified owing to the difference in the coefficients of expansion of LNG and LPG.

5.1.2 Class A resistance-thermometer sensors used for measurement of the temperature of the vapour phase shall have an error not greater than $\pm 0,3$ °C.

5.1.3 The measurement current in the resistance thermometer sensors shall be of such a value that the electrical power dissipated in the thermometer does not cause the temperature to rise by more than one-fifth (IEC 751) of the maximum permissible error specified in 5.1.1 and 5.1.2.

5.1.4 Class A thermocouples used for measurement of the temperature of the vapour phase shall have a maximum permissible error equal to or less than $\pm 0,5$ °C or 1 % whichever is the greater, in the measurement range (– 200 °C to 0 °C).

5.1.5 The error due to the compensating cable connected to class A thermocouples shall be not greater than $\pm 0,5$ °C when the temperature of the connecting terminals lies between – 25 °C and 100 °C (IEC 584-1 and IEC 584-2).

5.2 Overall error

5.2.1 The overall temperature-measurement error, including error in the temperature measurement system elements, shall be not greater than the value given in table 1 for the appropriate application.

Table 1 — Overall error

Class A	Use	LNG	LPG and others
	Liquid phase	$\pm 0,3\text{ }^{\circ}\text{C}$	$\pm 1\text{ }^{\circ}\text{C}$
Class B	Vapour phase	$\pm 2\text{ }^{\circ}\text{C}$	$\pm 2\text{ }^{\circ}\text{C}$
	Liquid phase	$\pm 2\text{ }^{\circ}\text{C}$	$\pm 2\text{ }^{\circ}\text{C}$
Class B	Vapour phase	$\pm 2\text{ }^{\circ}\text{C}$	$\pm 2\text{ }^{\circ}\text{C}$
	Liquid phase	$\pm 2\text{ }^{\circ}\text{C}$	$\pm 2\text{ }^{\circ}\text{C}$

NOTES

2 Class A: for applications requiring high accuracy.

3 Class B: for applications not requiring high accuracy.

Class A accuracy is preferable for determining the quantity in commercial transactions.

4 The individual error is specified depending on the difference of the coefficients of expansion between LNG and LPG and others.

5.2.2 The overall error shall be taken as the square root of the sum of the squares of the maximum instrument errors given by the tests specified in clause 9.

6 Requirements on receiving instruments

6.1 Receiving instruments shall be installed in a location free from temperature variations of a magnitude likely to cause measurement errors outside the limits specified in 5.2.1.

6.2 A receiving instrument shall have a high-impedance receiving circuit so as to minimize the error.

7 Insulation resistance

7.1 Temperature detectors shall have an insulation resistance of not less than 10 M Ω , when tested by the method specified in 7.2.

7.2 The insulation resistance shall be tested by applying a voltage of 500 V d.c. between each terminal and the sheath or the protecting tube while keeping the temperature of the sensor portion of the detector at ambient, near 100 $^{\circ}\text{C}$ and near $-196\text{ }^{\circ}\text{C}$.

8 Environmental conditions and permissible power-supply fluctuations

The environmental conditions of the various parts of the resistance thermometers or thermocouples shall be as shown in tables 2 and 3. Fluctuations of power supply shall not exceed the values shown in table 4.

NOTE 5 These limits are imposed to prevent damage to the system, not to maintain its accuracy.

Table 2 — Environmental conditions for the various parts of resistance thermometers and thermocouples (for shore tanks)

	Inside the tank	Outside the tank	
		Exposed area	Other areas
Temperature	LNG: $-165\text{ }^{\circ}\text{C}$ to $+55\text{ }^{\circ}\text{C}$ LPG: $-50\text{ }^{\circ}\text{C}$ to $+55\text{ }^{\circ}\text{C}$	$-25\text{ }^{\circ}\text{C}$ to $+70\text{ }^{\circ}\text{C}$ (Quoted from IEC 654-1)	$0\text{ }^{\circ}\text{C}$ to $55\text{ }^{\circ}\text{C}$ (Quoted from IEC 654-1)
Relative humidity	5 % to 100 % at $0\text{ }^{\circ}\text{C}$ to $40\text{ }^{\circ}\text{C}$ (Quoted from IEC 654-1) 5 % to 70 % above $40\text{ }^{\circ}\text{C}$		

NOTES

1 In the case of liquids other than liquefied natural gas or liquefied petroleum gas, the lower temperature limit inside the tank may be specified on the basis of the boiling points of the liquids.

2 Any part of the equipment installed inside the tank shall possess sufficient strength and be secured to withstand the static pressure and wave motion or other action of the liquids.

Table 3 — Environmental conditions for the various parts of resistance thermometers and thermocouples (for ships' tanks)

	Inside the tank	Outside the tank	
		Exposed area	other areas
Temperature	LNG: – 165 °C to + 80 °C LPG: – 50 °C to + 80 °C	– 25 °C to + 70 °C (Quoted from IEC 92-504)	0 °C to 55 °C
Vibration	Equipment shall have no natural frequencies within the range 0 Hz to 80 Hz (Quoted from IEC 92-504) Amplitude: ± 1,0 mm within the range 2,0 Hz to 13,2 Hz Acceleration: 0,7 G within the range 13,2 Hz to 80 Hz Maximum acceleration: 0,7 G		
Relative humidity	0 % to 100 % at 0 °C to 40 °C (Quoted from IEC 92-504) 0 % to 70 % above 40 °C		
Inclination	Inclination angle (in all directions): 22,5° (Quoted from IEC 92-504) Roll (10 s period): 22,5°		
Pitch	Acceleration: + 1,0 G, in vertical direction (Quoted from IEC 92-504)		
Electromagnetic compatibility	To IEC 533		
NOTES			
1 All values in the above table indicate operating conditions.			
2 Wiring to the sensors and inside the tank shall possess ample strength and be secured to withstand wave motion or other action of the liquid contained in the tank.			
3 All equipment installed on the weather deck of a ship shall have adequate protection against exposure to or immersion in sea water.			
4 For liquids other than liquefied natural gas or liquefied petroleum gas, a lower temperature limit inside the tank may be specified on the basis of the boiling points of the liquids.			

Table 4 — Fluctuations in the power supply

Power source	Variant	Variation		
		Permanent	Transient	
		Variant value, %	Variant value, %	Recovery time, s
Alternating current	Voltage frequency	± 10 ¹⁾ ± 5	± 20 ¹⁾ ± 10	3 ¹⁾ 3
Battery	Voltage	+ 30 ¹⁾ — 25	—	—
NOTE — When the equipment is not connected to the battery during charging or when voltage-stabilizing equipment is used, the value of the voltage variation of a battery may be reduced to ± 20 %.				
1) Quoted from IEC 654-2 and IEC 92-504.				

9 Verification procedures

9.1 Verification prior to installation

The following tests shall be performed.

9.1.1 Temperature detectors

The accuracy of the temperature detectors shall be checked by a fixed-point method or by calibration against standard thermometers.

It is recommended that the fixed-point temperature device, the constant-temperature device, the standard thermometers and the method used to determine the errors in the temperature detectors be as given in annexes A and B.

9.1.2 Receiving instruments

Errors in the receiving instruments shall be determined as follows:

- a) Feed a standard value to the input terminals. This value may be a resistance or an electromotive force, depending whether a resistance thermometer or a thermocouple is to be calibrated.
- b) Read the indicated value.
- c) Compare the indicated value with the standard value fed to the input terminals.

9.2 Verification after installation

After the temperature detector is completely installed, the following tests shall be performed:

9.2.1 Check all wire, cable connections and hook-ups and all other installation-related devices to ensure they are in accordance with the manufacturer's recommendations.

9.2.2 Check the insulation resistance value of the sensor and the cables connected to the temperature detector and compare with the original readings taken as specified in clause 7.

9.3 Verification during service life

It is advisable that the following test be performed as regularly as possible.

9.3.1 When the tank is opened and can be entered, check that the installation of the temperature detectors, their connecting cables and the associated connections are in accordance with this International Standard and the manufacturer's recommendations.

9.3.2 If two or more temperature detectors are installed in one tank, use the small differences in temperature in the liquid phase to monitor that the devices are operating correctly.

9.3.3 The receiving instruments shall then be tested again as specified in 9.1.2.

10 Instrumentation requirements for gas-dangerous spaces

The temperature-measurement system shall be in accordance with the relevant national or international standards, such as IEC 79-0 to 79-12, IEC 92-504 and IMO resolution A.328, 10.2 (see IGC Code).

Annex A (informative)

Details of accuracy check

A.1 Relative calibration

The temperature detector, together with a standard thermometer, is placed in a controlled- or fixed-point temperature device in order that the temperatures indicated by the two may be compared. In order to ensure that the detecting portions of the thermometers are at the same temperature, they are inserted in close contact with each other in a hole in a copper block in a Dewar flask filled with a well stirred cooling medium.

A.2 Standard thermometer

The standard thermometer used is a platinum resistance thermometer which has been calibrated to an accuracy of better than $\pm 0,03\text{ }^{\circ}\text{C}$ at the fixed points defined in IPTS-68, including at least the boiling point of water, the triple point of water and the condensation point of oxygen.

Applying resistance values of the thermometer at the above three fixed points to the resistance ratio ($W_{\text{CCT-68}}$) and the deviation function (ΔW_{S}), both defined in IPTS-68, the resistance ratio function (W_{S}) of the standard thermometer is obtained in the range between the condensation point of oxygen ($-182,962\text{ }^{\circ}\text{C}$) and $0\text{ }^{\circ}\text{C}$.

$$W_{\text{S}} = W_{\text{CCT-68}} + \Delta W_{\text{S}} \quad \dots (\text{A.1})$$

A.3 Determination of systematic error of resistance thermometers

The error of resistance thermometers in the measurement range may be determined as follows:

- a) Thermometers to be examined should be calibrated at three points: the first point near the

lower limit of the measurement range, the second at the ice point, and the third at a point approximately midway between the other two points. Either the fixed-point method or the relative-calibration method can be used for the ice point, and the relative-calibration method should be applied to the first point or the third.

- b) To determine the temperature by the relative-calibration method, measure the resistance values for the standard thermometer at the respective temperatures and substitute them in equation (A.1).
- c) The thermometer error within the measurement range may be determined by comparing the measured resistance value with the standard resistance value which determines the scale of the receiving instruments.

A.4 Determination of systematic error of thermocouples

The thermocouple error within the measurement range may be determined as follows:

- a) Carry out the calibration at three points by the same method as described in A.3. This procedure gives three values of the calibration temperature and the corresponding electromotive force.
- b) The thermocouple error at the calibration points may be determined by comparing the measured electromotive force with the standard electromotive force, which determines the scale of the receiving instruments.

Annex B (informative)

Design and use of fixed-point temperature device and controlled-temperature device

The methods described below are recommended for the construction of a fixed-point and controlled-temperature device.

B.1 Ice point

One method of producing the ice point, i.e. $0\text{ }^{\circ}\text{C}$, with an accuracy of $\pm 0,01\text{ }^{\circ}\text{C}$, is to operate the apparatus shown in figure B.1 in the following manner:

Wash thoroughly transparent pieces of commercially available ice, break into small pieces and place in a Dewar flask of an appropriate size. Pour enough chilled distilled water over the crushed ice to half-fill the Dewar flask.

Connect an auxiliary vessel filled with distilled water so that the upper water surface is slightly higher than the lower end of the thermometer.

Fill one end B of a syphon with distilled water, cover the end temporarily and insert the other end A into

the Dewar flask. Insert end B into the auxiliary vessel and uncover the end to allow the syphon to start operating.

Since any surplus water in the Dewar flask will be drained out through the syphon, the water level in the Dewar should be 20 mm or more above the bottom.

Immerse the detecting coil of a resistance thermometer or the junction of a thermocouple in the water layer. It should be inserted well into the Dewar flask but maintained at a height at least 2 cm from the bottom of the Dewar.

The following additional points shall be observed:

- a) To prevent impurities from dissolving in the water, all components contacting the water and ice, such as the inner surface of the Dewar flask and the bulb of the thermometer, shall be kept clean. Water and ice shall not be touched with bare hands.

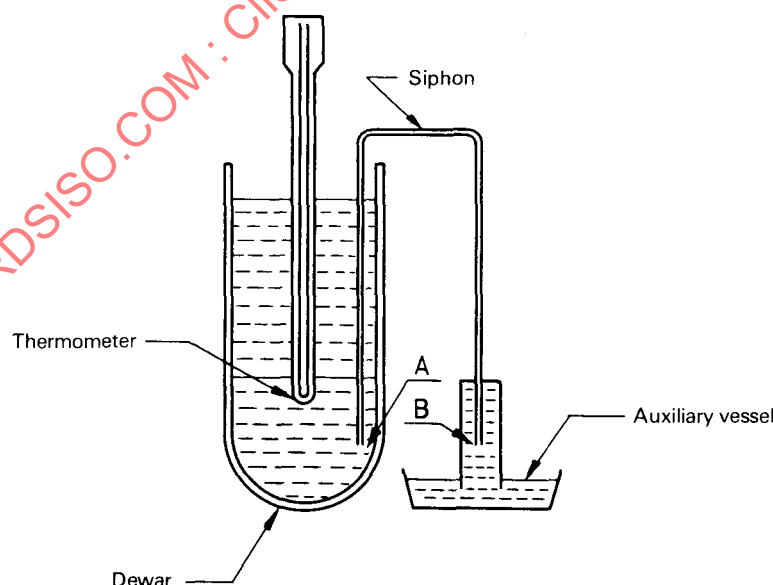


Figure B.1 — Ice-point device

- b) Since the Dewar flask filled with ice contains little water, a gap may be created around the thermometer due to melting of the ice, with the result that the temperature rises above 0 °C. In this case, it will be necessary to agitate the ice from time to time with a glass rod.
- c) When little ice remains in the Dewar flask, more shall be added.

B.2 Boiling point of water

In order to reproduce the boiling point of water with an accuracy of $\pm 0,02$ °C, an apparatus as shown in figure B.2 may be operated in the following manner:

Pour distilled water into the apparatus and boil vigorously at first so as to drive out the air remaining in the apparatus. Then control the heat, and read the thermometer when a slight variation in the depth of the detecting end of the thermometer or in the intensity of heating no longer affects the temperature reading.

The following additional points shall be observed:

- a) The boiling point shall be corrected for pressure. The pressure is the sum of the atmospheric pressure and the pressure difference read on a manometer (shown in figure B.2). The atmospheric pressure is normally measured with a Fortin-type barometer. Correct the barometric reading for instrumental error, temperature and gravity. Place the barometer in the same room together with the boiling-point apparatus and in a location where temperature variations are minimal.
- b) The calibration shall be carried out at constant atmospheric pressure.

B.3 Temperature range from 0 °C down to – 110 °C

Introduce a cooled liquid into a Dewar flask of at least 1 litre capacity and equipped with a mechanical stirrer in order to maintain a uniform temperature. Suitable liquids are listed in table B.1.

Table B.1

Temperature range, °C	Liquid
0 to 30	Mixture of ethylene glycol and water in the proportions 3 to 2 by volume
0 to – 50	Isopropanol, methyl ethyl ketone or methyl isobutyl ketone ¹⁾
– 20 to – 110	Low-boiling-point petroleum naphtha ¹⁾
1) Since these liquids are flammable, utmost care shall be exercised to prevent a fire or explosion.	

Cooling is performed with a freezer, dry ice (cooled to around – 65 °C) or liquid nitrogen.

Liquid air or liquid oxygen shall not be used.

Refrigerant that has been used frequently may contain much water and will not be easy to stir at the lower limit of the temperature range as the viscosity tends to increase in this region.

B.4 Temperature range from – 110 °C down to – 200 °C

Suspend a block of copper with a hole pierced through inside a Dewar flask and drip liquid nitrogen slowly into the flask.

Insert the sensing element of a thermometer into the hole in the block of copper for calibration.

By reducing the pressure of the liquid nitrogen, calibration can be carried out at temperatures down to about – 200 °C.