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Refrigerated hydrocarbon and non-petroleum based liquefied gaseous fuels — Calibration of membrane tanks and independent prismatic tanks in ships — Manual and internal electro-optical distance-ranging methods

Hydrocarbures réfrigérés et combustibles gazeux liquéfiés à base non pétrolière — Étalonnage des réservoirs à membrane et réservoirs pyramidaux — Méthodes manuelles et par mesurage électro-optique interne de la distance

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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.

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The committee responsible for this document is ISO/TC 28, *Petroleum products and lubricants*, Subcommittee SC 5, *Measurement of refrigerated hydrocarbon and non-petroleum based liquefied gaseous fuels*.

This second edition cancels and replaces the first edition (ISO 8311:1989), which has been technically revised.

Introduction

Large quantities of light hydrocarbons consisting of compounds having one to four carbon atoms are stored and transported by sea as refrigerated liquids at pressures close to atmospheric. These liquids can be divided into two main groups, liquefied natural gas (LNG) and liquefied petroleum gas (LPG). Bulk transportation of these liquids requires special technology in ship design and construction to enable ship-borne transportation to be safe and economical.

Quantification of these cargoes in ships' tanks for custody transfer purposes has to be of a high order of accuracy. This International Standard (together with others in the group) specifies methods of internal measurement of ships' tanks, from which tank capacity tables can be derived.

This International Standard covers calibration techniques applicable to membrane type tanks, i.e. self-supporting independent tanks in which the containment system comprises a relatively thin membrane of either stainless steel or high-nickel steel alloy. This International Standard, with some modification, can also be applicable to the calibration of independent prismatic tanks.

Annex A gives uncertainty associated with the measurement of membrane tanks.

Annex B gives an example of a tank capacity table relating partial filling volume as a function of liquid level and Annexes C and D give examples of trim correction and list correction tables, respectively.

Refrigerated hydrocarbon and non-petroleum based liquefied gaseous fuels — Calibration of membrane tanks and independent prismatic tanks in ships — Manual and internal electro-optical distance-ranging methods

1 Scope

This International Standard specifies a method for the internal measurement of membrane tanks used in ships for the transport of refrigerated light hydrocarbon fluids. In addition to the actual process of measurement, it sets out the calculation procedures for compiling the tank capacity table and correction tables to be used for the computation of cargo quantities. This International Standard, with some modification, can also be applicable to the calibration of independent prismatic tanks.

For the manual measurement of membrane tanks, the procedures of this International Standard utilize the scaffolding used for the installation of the membranes to support the measuring equipment but, for the internal electro-optical distance-ranging (EODR) method, other safe means of access to the required measuring positions are intended to be used.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7507-1:2003, *Petroleum and liquid petroleum products — Calibration of vertical cylindrical tanks — Part 1: Strapping method*

ISO 7507-4:2010, *Petroleum and liquid petroleum products — Calibration of vertical cylindrical tanks — Part 4: Internal electro-optical distance-ranging method*

IEC 60079-10-1, *Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres*

IEC 60079-10-2, *Explosive atmospheres — Part 10-2: Classification of areas — Combustible dust atmospheres*

IEC 60825-1, *Safety of laser products — Part 1: Equipment classification and requirements*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
automatic tank gauge
ATG
automatic level gauge
ALG
instrument that continuously measures liquid height (dip or ullage) in storage tanks

3.2
chamfer
slanting surface connecting the walls of a tank with its top or bottom surface

3.3
deadwood
any tank fitting that affects the capacity of a tank

3.4
gauge reference point
point from which the liquid depth are measured

3.5
horizontal plane
any plane established parallel to the tank bottom

3.6
horizontal reference line
any horizontal line established by a string

Note 1 to entry: A calibration method using this line is adopted as an alternative to direct measurements, where it is considered impractical to take direct measurements.

3.7
list
transverse inclination of a ship

Note 1 to entry: It is expressed in degrees.

3.8
longitudinal line
line formed by a longitudinal plane crossing a horizontal plane

3.9
longitudinal plane
vertical plane running parallel to the centreline of the tank

3.10
measuring point
one of a series of points on the inside surface of the tank shell from/to which the distance is measured by a tape or a hand-held laser distance meter in case of manual method, or to which the slope distance, vertical angles and horizontal angles are measured by use of the electro-optical distance-ranging instrument

3.11
port
left-hand side of a ship facing forward

3.12
reference target point
fixed point clearly marked on the inside surface to the tank shell or a prism mounted on a tripod

3.13
section line
line formed by a section plane crossing a horizontal plane

3.14
section plane
plane parallel with the fore and aft end walls of a ship's tank

3.15
slope distance
distance measured from the electro-optical distance-ranging instrument to any measuring point or a reference target point

3.16
starboard
right-hand side of a ship facing forward

3.17
tank-calibration reference temperature
temperature at which the calibration of a tank has been calculated

3.18
tank capacity table
tank table
calibration table
capacity table
table showing the capacities of, or volumes in, a tank corresponding to various liquid levels measured from a reference point

3.19
trim
difference between the fore and aft draught of the vessel

Note 1 to entry: When the aft draught is greater than the forward draught, the vessel is said to be trimmed by the stern. When the aft draught is less than the forward draught, the vessel is said to be trimmed by the head.

3.20
uncertainty
U()
estimate characterizing the range of values within which the true value of a measurand lies

Note 1 to entry: Various types of uncertainty are defined in ISO/IEC Guide 98-3.

3.21
vertical line
line formed by a section plane on the side walls and formed by a longitudinal plane on the fore and aft end walls

4 Precautions

4.1 General

This clause outlines the precautions to be taken during measurement. Utmost care and attention shall be exercised in taking measurements, and any unusual occurrence during the measuring work, which might affect the results, shall be recorded.

4.2 Ship's condition during calibration

The calibration methods described in this International Standard may be applied to ships whether afloat or in a dry dock. However, its use for ships in a dry dock is preferred, because trim or list, if any, will remain the same throughout the calibration procedure. Adjustments, manually or automatically shall be made to any measurement by optical level and EODR if the ship's attitude has changed.

4.3 Tank distortion

If unusual distortion is found in the tank, additional measurement shall be taken by the calibrator as considered necessary and sufficient. Notes by the calibrator detailing the extra measurements and the reasons for them shall be included in the calibration report.

The calibrator shall provide detailed sketches of any abnormality of the tank or its fittings where such sketches can materially assist the interpretation of the recorded data.

4.4 Comparison with drawings

If drawings for the tank are available, all measurements taken shall be compared with the corresponding dimensions shown on the drawings. Any measurement showing a significant discrepancy in this comparison shall be rechecked; however, the tank capacity table shall be based on the actual measurements.

4.5 Measurements by measuring tape

When measurements are made with a measuring tape:

a) the tension specified in the tape calibration certificate shall be applied;

b) the measuring tape shall be supported so as to prevent it from sagging. If tape sag is unavoidable, the calibrator shall note this and a catenary correction shall be applied during calculation;

c) take multiple measurements. If the first three consecutive measurements agree within the tolerances specified in d) below, take their mean as the measurement and their standard deviation as the standard uncertainty. If they do not agree within the tolerances specified in d) below, repeat the measurements until two standard deviations of the mean of all measurements is less than the half of the tolerance specified in d) below. Use the mean as the measurement and the standard deviation as the standard uncertainty. Use standard procedures to eliminate obvious outliers;

d) the following table shows the tolerances against the measurement distance:

Measurement	Tolerance within
Up to 25 m	2 mm
over 25 m	3 mm
for offset	0,5 mm

e) if the measurements have been interrupted, the last measurements shall be repeated. If the new measurements do not agree, within the required tolerance, with the earlier measurements, then the earlier set shall be rejected.

4.6 Measurements by electro-optical distance-ranging (EODR) instrument

When measurements are carried out with an EODR instrument:

a) the electro-optical distance-ranging instrument shall be verified prior to calibration. The accuracy of the distance-ranging unit as well as the angular measuring unit shall be verified using the procedures given by ISO 7507-4:2010, Annex A;

b) the tank shall be free from vibration and air-borne dust particles. The floor of the tank should be as free as possible from debris, dust and scales;

c) lighting, when required, shall be placed within the tank so as not to interfere with the operation the EODR instrument;

d) the laser beam fitted to the EODR instrument shall be operated in conformity with IEC 60825-1. The hazards, if any, in the area in which the calibration is to be carried out shall be assessed in accordance with IEC 60079-10. The instrument to be used shall be declared (certified) as being safe for use in the area of operation.

4.7 Condition of membrane

Care shall be taken to ensure that the membrane is in contact with the supporting material. In some cases, it may be possible to ensure this contact by applying a vacuum to the space behind the membrane.

4.8 Safety precautions for work in membrane tanks

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

b) Before a tank which has been in use is entered, a safe-entry certificate issued in accordance with local or national regulations shall be obtained. All lines entering the tank shall be disconnected and blanked.

c) Hand lamps and other electric instruments shall be of a type approved for use in explosive atmospheres.

d) The safety of operating personnel shall be safeguarded by strict attention to the following.

   1) Ladders shall be inspected before use, and extendable ladders used only within their safe operating range. The footing for each ladder shall be level and firm, and all ladders shall be securely lashed in position before being used.

   2) Where painters' cradles or boatswains' (bo'suns') chairs are used, blocks, falls, ropes, etc., shall be tested before erection, and any item of questionable strength or condition shall be replaced. Every care shall be paid to the securing of the equipment and its operational use.

   3) If calibration cannot be carried out without the use of scaffoldings, properly constructed steel tube or timber scaffolding shall be erected. Loose bricks, drums, boxes, etc., shall not be used to form staging. Special attention shall be paid at the corners of the scaffolding. It is not uncommon for a plank to be moved from its position on the scaffolding when the tank wall is being lined with membranes.

   4) Where appropriate, safety harnesses shall be worn by the calibrator working above ground level.

e) In some cases, edges of the anchor plates projecting from membrane can be sharp. The use of protective gloves and helmets is especially advised.

f) Care shall be taken not to damage the membranes with shoes, measuring equipment, etc.

5 Equipment

The equipment used to calibrate the tanks in accordance with this International Standard are intended to confirm to the relevant national or other standard.

5.1 Electro-optical distance-ranging (EODR) instrument, capable of achieving uncertainties of tank volumes acceptable in legal metrology. The angular measuring part of the instrument should have a resolution of equal to or better than $3{,}142 \times 10^{-6}$ rad (0,2 mgon), and the distance-measuring part of the instrument, which is to be used for direct determination of distances, should have a resolution of equal to or better than 1 mm.

The accuracy of EODR equipment can be affected by variations of temperature. The manufacturer's guidance should be followed.

5.2 Hand-held laser distance meter, which may be used, instead of measuring tape, to measure the distance. The hand-held laser distance meter should have a resolution of equal to or better than 1 mm.

5.3 Measuring tape, complying with the specifications for strapping tapes given in ISO 7507-1 or equivalent.

5.4 Automatic level, having an erect image and a magnification of × 20 or greater, capable of being focused to 1,5 m or less and with a spirit level sensitivity of 40 s of arc per 2 mm or less.

5.5 Rule, with graduations in centimetres and millimetres, used to measure deadwood, the offsets between the strings and the tank walls in the case of the manual method, etc. If a wooden rule is used, it shall be fitted with a brass ferrule at each end and shall be free of warp.

5.6 Thermometer, having a suitable range, of an accuracy of ±0,5 °C.

A mercury thermometer should not be used.

6 Determination of measuring points

The calibration of membrane tanks is basically the measurement of the tank length, width and height between known points. These measuring points are determined by setting out a number of horizontal, longitudinal and section planes.

These planes intersect to form lines along which the measurements of length, width and height shall be taken. The various planes shall be set out at intervals not greater than 5 m; the interval shall be adjusted so that the resulting measurements reflect any change of section and adequately describe any deformation. The points at which measurements are to be taken shall be determined by the calibrator but shall not be more than 5 m apart.

Having determined the measuring points, mark the lines which run on the tank inner walls. Mark the section and longitudinal lines on the top and bottom plates, horizontal and vertical lines on the fore and aft end walls and horizontal and vertical lines on the port and starboard end walls. When measurements are made by an EODR, coordinates of the planned measuring points may be stored in the instrument instead of actually marking the lines or points on the tank inner walls.

7 Calibration by manual method

7.1 General

In the manual method, measurements of the distances between opposite walls of a tank shall be taken by tensioning the tape as specified on the tape certificate. A hand-held laser distance meter, in place of a tape, may be used for the direct measurements.

The lengths of the tanks shall be measured along all the longitudinal lines at each level of the horizontal planes in accordance with 7.2.

The widths of the tanks shall be measured along all the section lines set in each horizontal plane in accordance with 7.3.

The total heights, upper chamfer heights and side wall heights shall be measured and from these lower chamfer heights shall be calculated in accordance with 7.4.

Annex A gives uncertainty associated with the measurement of membrane tanks with the manual method.

7.2 Tank length measurement

7.2.1 Length measurement on the bottom plate

Measure the distances between the fore and aft end walls along all the longitudinal lines marked on the bottom plate with a measuring tape stretched thereon. The average length on the bottom plate is calculated using Formula (1):

$$L_{\mathrm{l}} = \frac{1}{n}\sum_{i=1}^{n} L_{\mathrm{l,i}} \tag{1}$$

where

$L_{\mathrm{l,i}}$ is the length of a longitudinal line on the bottom plate;

L_{l} is the average length of the bottom plate;

n is the number of longitudinal lines on the bottom plate.

7.2.2 Length measurement on the top plate

Measure the distances on the top plate in a manner similar to that for the bottom plate (see 7.2.1). Care shall be taken to keep the measuring tape in contact with the top plate. The average length on the top plate is calculated using Formula (2):

$$L_{\mathrm{u}} = \frac{1}{n}\sum_{i=1}^{n} L_{\mathrm{u,i}} \tag{2}$$

where

$L_{\mathrm{u,i}}$ is the length of a longitudinal line on the top plate;

L_{u} is the average length of the top plate;

n is the number of longitudinal lines on the top plate.

7.2.3 Length measurement in an intermediate horizontal plane

To avoid inaccurate measurement due to excessive sagging of the measuring tape, apply the horizontal reference line method using a string line.

As shown in Figure 1, lengths in these imaginary planes can be obtained by applying offset corrections at both ends, a_2, a_3 … $a_{\mathrm{n-1}}$ and b_2, b_3 … $b_{\mathrm{n-1}}$, to the length measured directly on the side wall. In practice, carry out the following.

a) Mark P_1 and P_2, S_1 and S_2, on both side walls at equal distances from the end walls. Measure the length (L_{P}, L_{S}) between the fore and aft end walls with a measuring tape extended along both side walls, supporting the tape on the wall to prevent it from sagging.

b) Stretch strings between the opposite points P_1 and S_1, P_2 and S_2, and measure the offsets between the strings and the end walls (a_1, a_2 … a_{n} and b_1, b_2 … b_{n}) with a rule.

c) In measuring these offsets, take care to put the measuring rule at a right angle to the string.

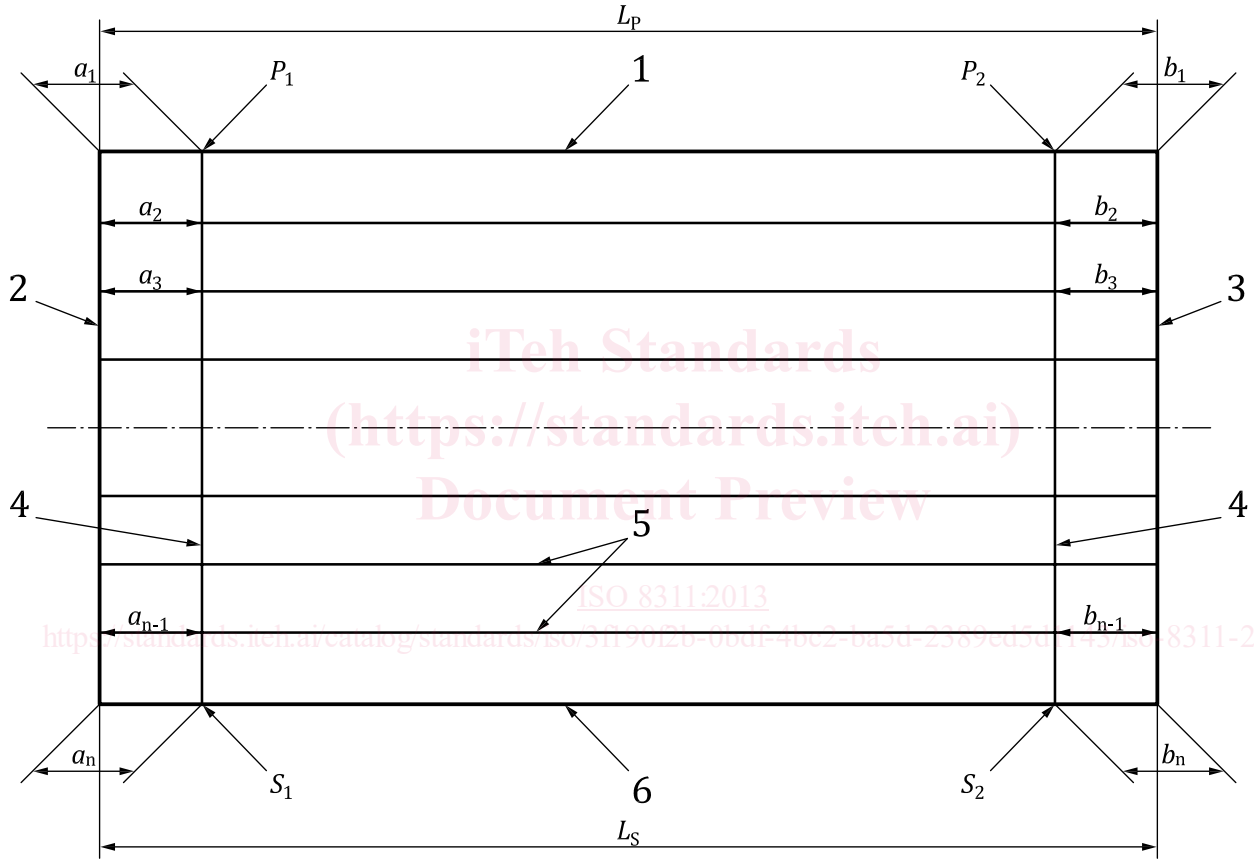
The average length of an intermediate horizontal plane, $L_{m,p}$ is calculated using Formula (3):

$$L_{m,p} = \frac{L_p + L_s - (a_1 + a_n + b_1 + b_n)}{2} + \frac{\sum_{i=1}^{n}(a_i + b_i)}{n} \quad (3)$$

The averaged length of intermediate part, L_m, is calculated using Formula (4):

$$L_m = \frac{1}{p-2}\sum_{j=2}^{p-1} L_{m,p} \quad (4)$$

where p is the number of intermediate planes.



Key

1	port side wall	4	string line
2	aft end wall	5	longitudinal lines
3	fore end wall	6	starboard side wall
L_P	length of port side wall		
L_S	length of starboard side wall		
P_1, P_2, S_1, S_2	markings on both side walls at equal distances from end walls		
$a_1, a_2 \ldots a_n$ and $b_1, b_2 \ldots b_n$	offsets between strings and end walls		

Figure 1 — Plan view of an intermediate horizontal plane