INTERNATIONAL STANDARD

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Refrigerated light hydrocarbon fluids — Measurement of cargoes on board LNG carriers

Hydrocarbures légers réfrigérés — Mesurage des cargaisons à bord des navires méthaniers

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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 10976 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Subcommittee SC 5, *Measurement of refrigerated hydrocarbon and non-petroleum based liquefied gaseous fuels*.

This first edition of ISO 10976 cancels and replaces ISO 13398:1997, which has been technically revised.

Introduction

This International Standard provides accepted methods for measuring quantities on liquefied natural gas (LNG) carriers for those involved in the LNG trade on ships and onshore. It includes recommended methods for measuring, reporting and documenting quantities on board these vessels.

This International Standard is intended to establish uniform practices for the measurement of the quantity of cargo on board LNG carriers from which the energy is computed. It details the commonly used current methods of cargo measurement, but is not intended to preclude the use or development of any other technologies or methods or the revision of the methods presented. It is intended that the reader review, in detail, the latest editions of the publications, standards and documents referenced in this International Standard in order to gain a better understanding of the methods described.

This International Standard is not intended to supersede any safety or operating practices recommended by organizations, such as the International Maritime Organization (IMO), the International Chamber of Shipping (ICS), the Oil Companies International Marine Forum (OCIMF), the International Group of LNG Importers (GIIGNL) and the Society of International Gas Tanker and Terminal Operators (SIGTTO), or individual operating companies. This International Standard is not intended to supersede any other safety or environmental considerations, local regulations or the specific provisions of any contract.

The International System of units (SI) is used throughout this standard as the primary units of measure since this system is commonly used in the industry for these types of cargoes. However, as some LNG carrier's tanks are calibrated in US customary units and some sales and purchase agreements (SPA) are made in US customary units, both SI and US customary equivalents are shown. Proper unit conversion is intended to be applied, documented and agreed upon among all parties involved in the LNG custody transfer.

Refrigerated light hydrocarbon fluids — Measurement of cargoes on board LNG carriers

1 Scope

This International Standard establishes all of the steps needed to properly measure and account for the quantities of cargoes on liquefied natural gas (LNG) carriers. This includes, but is not limited to, the measurement of liquid volume, vapour volume, temperature and pressure, and accounting for the total quantity of the cargo on board. This International Standard describes the use of common measurement systems used on board LNG carriers, the aim of which is to improve the general knowledge and processes in the measurement of LNG for all parties concerned. This International Standard provides general requirements for those involved in the LNG trade on ships and onshore.

2 Normative references

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

ISO 8310, *Refrigerated light hydrocarbon fluids — Measurement of temperature in tanks containing liquefied gases — Resistance thermometers and thermocouples*

ISO 8943, *Refrigerated light hydrocarbon fluids — Sampling of liquefied natural gas — Continuous and intermittent methods*

ISO 18132-1, *Refrigerated hydrocarbon and non-petroleum based liquefied gaseous fuels — General requirements for automatic tank gauges — Part 1: Automatic tank gauges for liquefied natural gas on board marine carriers and floating storage*

IEC 60533, *Electrical and electronic installations in ships — Electromagnetic compatibility*

EN 1160, *Installations and equipment for liquefied natural gas — General characteristics of liquefied natural gas*

API Standard 2217A, *Guidelines for Work in Inert Confined Spaces in the Petroleum and Petrochemical Industries*

IACS Unified Requirements E10

ICS Tanker Safety Guide — Liquefied Gas

ICS/OCIMF/IAPH International Safety Guide for Oil Tankers and Terminals (ISGOTT)

IMO International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)

NOTE Earlier versions of the gas codes can apply to older ships (see the note to 3.1.13).

SIGTTO Liquefied Gas Handling Principles on Ships and in Terminals

SIGTTO Liquefied Gas Fire Hazard Management

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

3.1.1
absolute pressure
total of the gauge pressure plus the pressure of the surrounding atmosphere

3.1.2
aerating
<context of preparing a tank for entry> introduction of fresh air with an acceptable dew point into the tank to purge inert gases and to increase the oxygen content to approximately 21 % of volume so as to ensure a breathable atmosphere

3.1.3
approved equipment
equipment of a design approved by a recognized authority, such as a governmental agency, classification society or other accredited agency which certifies the particular equipment as safe for use in a specified hazardous atmosphere

3.1.4
automatic tank gauge
ATG
instrument that automatically measures and displays liquid levels or ullages in one or more tanks, either continuously, periodically or on demand

3.1.5
automatic tank thermometer
ATT
instrument that automatically measures and displays the temperature of the contents in a tank, continuously, periodically or on demand

3.1.6
boil off
process of evaporation of a liquid resulting from heat ingress or a drop in pressure

3.1.7
boil-off gas
vapour produced by boil off

3.1.8
cool down
process of reducing the temperature of equipment, such as piping, transfer arms and tanks associated with custody transfer cargo movements, to required operating temperatures

3.1.9
constant pressure/floating piston sample container
CP/FP sample container
sample container, usually used for intermittent sampling, usually used for intermittent sampling, capable of maintaining constant pressure during the sampling of gas from the process line into the gas cylinder

NOTE Adapted from ISO 8943:2007, definition 3.4.

3.1.10
continuous sampling
sampling from gasified LNG with constant flow rate

[ISO 8943:2007, definition 3.5]

3.1.11
drying
process of reducing the moisture in the ship tank by displacement or dilution with an inert gas or by the use of a drying system

3.1.12
filling limit
filling ratio
quantity to which a tank may be safely filled, taking into account the possible expansion (and change in density) of the liquid

NOTE Filling limit (i.e. volume) and filling ratio are expressed as a percentage of the total capacity of a tank.

3.1.13
gas codes
regulations on the construction of ships carrying liquefied gases developed by the International Maritime Organization

NOTE These include the IMO *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (IGC Code) (generally applies to ships built after 17 July 1986), the IMO *Code for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (GC Code) (generally applies to ships built on or after 31 December 1976 but prior to 17 July 1986) and the IMO *Code for Existing Ships Carrying Liquefied Gases in Bulk* (generally applies to ships delivered before 31 December 1976), as applicable to each vessel.

3.1.14
gas sample container
sample container, usually used for continuous sampling and used for the retention of the gas sample and for its transfer to an analysing instrument

[ISO 8943:2007, definition 3.6]

3.1.15
gassing up
process of replacing an inert atmosphere in a cargo tank with the vapour from shore or from another cargo tank to a suitable level to allow cooling down and subsequent loading to achieve a specified environment with at least a defined methane (CH_4), carbon dioxide (CO_2) and oxygen (O_2) content

3.1.16
heel
amount of cargo retained in a cargo tank prior to loading or after discharge

3.1.17
inerting
introduction of inert gas into a tank with the object of attaining the inert condition

3.1.18
intermittent sampling
sampling from gasified LNG with predetermined intervals or with predetermined flow amount intervals

[ISO 8943:2007, definition 3.9]

3.1.19
letter of protest
letter issued by any participant in a custody transfer citing any condition with which issue is taken and which serves as a written record that a particular action or finding was observed/questioned at the time of occurrence

3.1.20
LNG carrier
cargo ship specifically constructed and used for the carriage of LNG in bulk

3.1.21
LNG sample vaporizer
apparatus to completely gasify the LNG sample collected from the LNG transfer line

[ISO 8943:2007, definition 3.11]

3.1.22
multiple-spot ATT
multiple-point ATT
ATT consisting of multiple spot temperature element sensors to measure the temperature(s) at selected liquid level(s)

NOTE 1 The readout equipment for a multiple-point averaging ATT averages the readings from the submerged temperature elements sensors to compute the average temperature of the liquid in the tank, and can also display the temperature profile in the tank.

NOTE 2 Adapted from ISO 4266-5:2002, definition 3.4.

3.1.23
notice of apparent discrepancy
notice issued by any participant in a custody transfer citing any discrepancy in cargo quantities and which serves as a written record that such a discrepancy was found

3.1.24
offline analysis
procedure of analysis implemented on the representative sample gas that is once charged into a gas sample container or a CP/FP sample container

[ISO 8943:2007, definition 3.13]

3.1.25
online analysis
procedure of analysis implemented using analytical equipment that is directly connected through pipelines or other means to the sampling device

[ISO 8943:2007, definition 3.14]

3.1.26
online gas chromatograph
gas chromatograph that is directly connected to the pipelines or sampling device to implement online analysis

[ISO 8943:2007, definition 3.15]

3.1.27
seal water
water used in the water seal type gas sample holder to preclude contact of the gas sample with the atmosphere

[ISO 8943:2007, definition 3.19]

3.1.28
tank capacity table
numeric tables that relate the liquid level in a tank to the volume contained in that tank

3.1.29
vapour
fluid in the gaseous state that is transferred to/from or contained within the cargo tank

3.1.30
vapour pressure
pressure at which a liquid and its vapour are in equilibrium at a given temperature

3.1.31
verification
process of confirming the accuracy of an instrument by comparing to a source with known accuracy

3.1.32
warming up
process of warming the cargo tanks from cargo carriage temperature to required temperature

3.1.33
waterless-type gas sample holder
holder without seal water (typically using an expandable/contractible, transformable rubber membrane) and used for collecting gasified LNG

[ISO 8943:2007, definition 3.22]

3.1.34
water-seal-type gas sample holder
holder with seal water used for collecting gasified LNG

[ISO 8943:2007, definition 3.23]

3.2 Abbreviated terms

API	American Petroleum Institute
ATG	Automatic tank gauge
ATT	Automatic tank thermometer
BOG	Boil-off gas
CTMS	Custody transfer measurement system
EMC	Electromagnetic compatibility
FSRU	Floating storage and re-gasification unit
GCU	Gas combustion unit
GIIGNL	Groupe International des Importateurs de Gaz Naturel Liquéfié
GNG	Gaseous natural gas
GPA	Gas Processors Association
IACS	International Association of Classification Societies
IAPH	International Association of Ports and Harbors
ICS	International Chamber of Shipping
IEC	International Electrotechnical Commission
IGC Code	International Gas Carrier Code
IMO	International Maritime Organization
ISGOTT	International Safety Guide for Oil Tankers and Terminals
ISO	International Organization for Standardization
LNG	Liquefied natural gas
LNGC	Liquefied natural gas carrier
MPMS	Manual of Petroleum Measurement Standards
MSDS	Material safety data sheet
OBQ	On board quantity
OCIMF	Oil Companies International Marine Forum

ROB	Quantity remaining on board
SI	International System of Units (Système International d'Unités)
SIGTTO	Society of International Gas Tanker and Terminal Operators Limited
SPA	Sales and purchase agreement
VEF	Vessel experience factor

4 General operating safety precautions and regulatory requirements

4.1 General

Clause 4 applies to all types of measurement on board LNG carriers. However, while these precautions represent safe operating practices, they should not be considered complete or comprehensive. In addition to those listed in this International Standard, reference should be made to all safety precautions contained in any relevant governmental, local or company operating guidelines.

IMPORTANT Anyone working with the vessel's measurement equipment shall be, at all times, under the direction and supervision of the Master of the vessel or its designated representative and be properly trained in its use.

Personnel involved in the handling of liquefied natural gas should be familiar with its physical and chemical characteristics, including potential for fire, explosion, cryogenic burns (frostbite) and reactivity, as well as the appropriate emergency procedures. These procedures should comply with the individual company's safe operating practices, in addition to local, state and federal regulations, including those covering the use of proper protective clothing and equipment. Personnel should be alert in order to avoid potential sources of ignition.

SIGTTO publications *Liquefied Gas Fire Hazard Management* and *Liquefied Gas Handling Principles on Ships and in Terminals* should be consulted to ensure familiarity with the characteristics and hazards of LNG, all fire protection and fire fighting equipment on board LNG carriers along with the appropriate fire hazard management plan.

API Standard 2217A and any applicable regulations should be consulted where entering into confined spaces.

Information regarding particular material safety and conditions should be obtained from the employer, manufacturer or supplier of that material or the material safety data sheet (MSDS).

LNG is carried and handled at extremely low temperatures. The very nature of liquids at very low temperatures is a hazard, added to which LNG itself has properties that shall be taken into account at all times. Any party involved in handling operations shall read and act on information contained within the appropriate MSDS and supporting documents.

Nothing contained in this International Standard is intended to supersede any regulatory requirements or recommended operating practices issued by the vessel's flag administration, classification societies or organizations, such as IMO, SIGTTO or OCIMF, or individual operating companies. This International Standard is not intended to conflict with any safety or environmental considerations, local conditions or the specific provisions of any contract.

Accordingly, the latest editions of relevant IMO, SIGTTO, API and OCIMF publications, and, in particular, the latest editions of the ICS *Tanker Safety Guide — Liquefied Gas,* the OCIMF/ICS/IAPH *International Safety Guide for Oil Tankers and Terminals* (ISGOTT) and SIGTTO *Liquefied Gas Fire Hazard Management* should be consulted for applicable safety precautions.

Any changes to measurement systems require the approval of the vessel's flag administration and/or classification society and require external verification of accuracy by a competent metrological authority for LNG custody transfer measurement purposes.

All described equipment shall meet minimum requirements as detailed by the vessel's flag administration and classification society.

4.2 Electrical equipment classification

All measurement equipment used shall be approved equipment (see 3.1.3), which is certified intrinsically safe or otherwise approved for its intended use, including appropriate grounding. Also, all measurement equipment shall be designed and installed to meet applicable national and international marine safety codes and regulations.

4.3 Electromagnetic disturbance

All custody transfer measurement systems (CTMS) shall be designed for electromagnetic compatibility (EMC), complying with user requirements and other proper standards. This means that the equipment shall neither interfere with nor be affected by interference from other equipment. Requirements and tests shall be in accordance with IACS Unified Requirements E10 and IEC 60533.

4.4 Maintenance

All measurement equipment shall be maintained in safe operating condition and in compliance with the manufacturers' instructions.

4.5 Service conditions

All measurement equipment shall be capable of withstanding the vibration, pressure, temperature, humidity and other environmental operating conditions likely to be encountered in the LNG carrier's service.

4.6 Compatibility

All measurement equipment shall be constructed with appropriate materials suitable for use in LNG service in accordance with the appropriate gas codes (see the note to 3.1.13) or EN 1160, and other applicable regulations.

4.7 Personnel protection

All personnel involved in LNG cargo activities should wear the appropriate personnel protective equipment required for the operation and be trained in its proper use. They should also be trained regarding the inherent hazards of LNG, as required by the ICS *Tanker Safety Guide — Liquefied Gas* and the LNG material safety data sheet (MSDS).

4.8 Procedures

An adequate work procedure shall be established and available as guidance for safe work by the ship and terminal personnel.

5 Measurement systems and equipment

5.1 General

Determination of cargo quantities on board an LNG carrier by the static measurement method requires measurement of the liquid level (which is the liquid/vapour interface) as well as the pressure of the vapour and average liquid and vapour temperature of each cargo tank. The volume of the liquid cargo is calculated using the tank capacity table with any necessary corrections made. The custody transfer measurement system (CTMS) includes the following:

a) cargo tank capacity tables;

b) inclinometers and/or draft gauges;

c) automatic tank gauges (see 3.1.4);

d) multiple-spot ATTs (see 3.1.22);

e) pressure sensors;

f) a CTMS computer.

NOTE As LNG quantities are generally transferred in units of energy, an automatic sampler system, typically located onshore, provides a representative sample of the cargo, which is analysed for the determination of cargo quality, including density by compositional analysis using a gas chromatograph.

To determine the quantities of cargoes on board LNG carriers, the amount of liquid in each tank shall be determined. The factors needed to accomplish this include a calibrated tank as well as liquid level, pressure, temperature and trim/list measurement equipment. The tank gauging systems used shall be of the closed type. The most commonly used equipment is described in this clause. Certified systems other than those described in this International Standard may be used for custody transfer measurement if the accuracies of each can be ascertained and if the SPA permits their use.

5.2 Measurement equipment performance

The performance criteria of the primary and secondary equipment used to determine measured variables are established in International Standards, governmental regulations, SPAs, manufacturers' instructions and calibration certificates, and are limited by the uncertainty of the instrument. In the absence of specified tolerances, the maximum permissible error from certification shall meet the tolerances described in Table 1.

Table 1 — LNG measurement equipment performance criteria

	Tolerance	Display resolution
Level	±5,0 mm[a]	1 mm
Pressure	±0,3 kPa	0,1 kPa
Temperature		
≤ –145 °C	±0,2 °C	0,1 °C
> –145 °C	±1,5 °C	0,1 °C
Draft reading	±50 mm	10 mm
List (inclinometer)	±0,05°	0,01°

[a] Some existing ATGs are not able to meet this verification tolerance, in which case a verification tolerance of ± 7,5 mm may be applied.

5.3 Calibration and certification of measurement equipment

All specified measurement equipment used on board an LNG carrier shall be certified prior to initial use. Subsequently, measurement equipment and systems shall be re-calibrated and re-certified on a periodic basis, subject to SPA or national requirements. Measurement equipment shall be re-certified where modification or repairs are carried out and which affect the accuracy of the measurement data.

The components of the CTMS and the accuracy of the quantity calculation of the CTMS shall be certified by a recognized inspection body.

Calibration and re-calibration shall be performed by a qualified technician and witnessed by an independent inspector. Upon successful calibration, the results shall be certified by the party witnessing the calibration and a certificate of calibration issued.

Manufacturers of the measurement equipment and systems may participate in the calibration, which often require setting, maintenance or replacement prior to final calibration of the equipment and the related measurement system. For measurement equipment and systems, the calibration work should be witnessed by the parties or their appointed independent inspector, who should be responsible for incorporating the results in the certificate issued.

Calibration shall cover the local and remote readout, and data transmission to ensure the equipment, which may consist of components of the measurement subsystem(s), delivers the specified accuracy.

5.4 Verification of measurement equipment between dry dockings

In addition to calibration during each dry docking, all measurement devices used in custody transfer shall be checked before use at each loading or discharge to ensure they are in good working condition.

The comparison of the primary and secondary measurement device within a tank should be performed as one means of verification. The results of this comparison should be recorded and tracked by the vessel operator. One method of evaluating the results is through the use of a control chart. For control charts, see B.3.

Other devices may be verified while the ship is in service. For example, pressure gauges may be verified against a reference standard device. Trim/list gauges, such as inclinometers or draft gauges (if used for level corrections) may be verified/calibrated at even keel by comparison to manual draft measurements or other equivalent procedure.

Where equipment is suspect or has failed, secondary devices shall be used in its place until the equipment is repaired or verified to be in good working order. For example, *in situ* temperature verification/calibration at cryogenic conditions is not practicable; therefore, temperature sensors which have been shown to be faulty when verified during normal operation shall be replaced as soon as practicable.

Where the measurement equipment can be verified against a known value, the results of this verification should be recorded and tracked. If the primary measurement system is found to be out of calibration, use of the secondary measurement system should be considered in accordance with contractual agreement.

5.5 Inspection of measurement equipment during transfer operations

Prior to and during a custody transfer, the involved parties or an appointed independent inspector should inspect the measurement equipment described in 5.1 to ensure that it is fully functional, and should also identify any deficiencies. The ship's records should be reviewed to determine whether the calibration certificates are valid and current.

Exceptions and malfunction of measurement equipment, if any, prior to and during a custody transfer should be immediately reported to the LNG carrier operator and the involved parties.

Upon specific request by the involved parties, on board testing, checks or verification may be carried out on the measurement devices in question, and the results should be documented.

5.6 Static measurement systems and equipment

5.6.1 General

Static measurement systems and equipment are those individual systems and equipment which are used to measure cargo in the tank. They include the following components (see 5.6.2 to 5.6.9).

5.6.2 Tank capacity tables

5.6.2.1 General

An independent company usually performs the calibration and generates the tank capacity tables during the building of the LNG carrier. They take into account the configuration of the tank, its contraction according to the temperature of the liquid, and the volume occupied by various devices, e.g. cargo pumps.

Tank capacity tables are divided into:

a) main gauge tables correlating liquid level and volume under reference conditions;

b) correction tables or methods, taking into account actual conditions of the LNG carrier and its measuring instruments.