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Refrigerated hydrocarbon and non-petroleum based liquefied gaseous fuels — Dimethylether (DME) — Measurement and calculation on board ships

Hydrocarbures réfrigérés et combustibles gazeux liquéfiés à base non pétrolière — Diméthyléther (DME) — Mesurage et calculs à bord des navires

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Contents

Page

Foreword

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ISO 16384 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*.

Introduction

Measures for environmental protection are required on a global scale. In this connection, various methods of achieving these aims have been independently studied or undertaken in many countries. One such project, the development of the use of dimethylether (DME) as a new form of energy has been undertaken in several countries. Use of DME generates neither sulfur-oxide nor any other particulate matter known to cause environmental pollution at the time of combustion.

Another benefit of the use of DME as a petroleum alternative is that it can be produced easily from natural gases, coals and biomasses with only slight additional development of the existing techniques of production, transportation, storage and consumption.

In international trade, liquefied gases in bulk are carried by specialized ships which are equipped with fully refrigerated or semi-refrigerated type tanks, or pressurized type tanks. For assessing the quantity, measurement on board these ships is preferable because shore tanks at loading/discharging ports usually engage in transferring to/from tank cars by pipelines, etc. simultaneously with the delivery/receipt of the cargo to/from the ships.

To prevent dispute over the delivered quantity of DME, uniform practice of volumetric measurement and consequent calculation methods is called for.

Since detailed requirements on installation, calibration and verification of level gauges and thermometers are standardized in their own respective International Standards, this International Standard focuses on the practice of custody transfer and subsequent calculation of DME.

Refrigerated hydrocarbon and non-petroleum based liquefied gaseous fuels — Dimethylether (DME) — Measurement and calculation on board ships

1 Scope

This International Standard provides guidance on the practices for custody transfer of dimethylether (DME) on board ships, at both the loading and the discharging ports. It covers such aspects of volumetric calculation on board as measurement of liquid volume, vapour volume, temperature and pressure; and accounting for the total quantity of DME on board before and after loading/discharging, regardless of the type of ship's tank.

2 Terms and definitions

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

2.1
absolute pressure
pressure in excess of a perfect vacuum, equal to the algebraic sum of atmospheric pressure and effective pressure

2.2
automatic tank gauge
ATG
instrument that continuously measures liquid height (dip or ullage) in storage tanks

[ISO 18132-1:2011, definition 2.1.1 and ISO 18132-3:2011, definition 2.1.1]

NOTE 1 An automatic tank gauge usually includes a level sensor, a gauge head and associated mounting hardware, and in some cases local display.

NOTE 2 Automatic tank gauges are also known as automatic level gauges (ALGs).

2.2.1
float-type ATG
ATG that uses a float to detect the liquid level

[ISO 18132-1:2011, definition 2.1.5 and ISO 18132-3:2011, definition 2.1.4]

NOTE The float is guided by a tape or wire that is connected to a drum or a ratchet in the gauge head, where the level measured is displayed locally and/or remotely.

2.2.2
magnetic-type ATG
ATG that measures the liquid level by magnetic reed switches with a float sensor including magnets, or by magneto-strictive principle

[ISO 18132-3:2011, definition 2.1.7]

2.2.3
radar-type ATG
microwave-type ATG
ATG that utilizes an antenna to transmit electromagnetic continuous waves toward the liquid in a tank, and to receive electromagnetic waves which are reflected at the surface of the liquid

[ISO 18132-1:2011, definition 2.1.7 and ISO 18132-3:2011, definition 2.1.8]

2.3
custody transfer
measurement of liquid level, liquid and vapour temperature, and vapour pressure of the DME to be delivered to/from a tank, by which volume and other data are determined as the basis of payment or the assessment of duty

2.3.1
closing custody transfer
custody transfer implemented after loading or discharging cargo from the tank(s)

2.3.2
opening custody transfer
custody transfer implemented before loading or discharging cargo from the tank(s)

2.4
heel
amount of cargo retained in a cargo tank prior to loading or after discharge

[ISO 10976:2012, definition 3.1.16]

2.5
saturated vapour pressure
vapour pressure
pressure exerted by the vapour above the liquid in equilibrium at a given temperature

3 Characteristics and properties of DME

3.1 General

DME has the following typical characteristics and properties (see ISO 29945), in consideration of which, safety precautions should be taken.

3.2 General characteristics

DME has the following general characteristics, which should be considered with respect to personal safety precautions:

a) non-corrosive;

b) relatively small temperature coefficient of volume expansion;

c) acts as an effective solvent of many materials;

d) hydrophilic.

3.3 Chemical and physical properties

DME has the following general chemical and physical characteristics:

a) boiling point: −25,1 °C at atmospheric pressure;

b) saturated vapour pressure: 0,61 MPa at 25 °C;

c) explosive range: 3,4 volume % to 27,0 volume %;

d) relative gas density: 1,59 relative to air;

e) liquid density: 677 kg/m3 at 15 °C.

4 General precautions

4.1 General

Nothing contained in this International Standard is intended to supersede any regulatory requirements or recommended operating practices issued by organizations such as the International Maritime Organization (IMO), International Chamber of Shipping (ICS), Oil Companies International Marine Forum (OCIMF), International Association of Classification Societies (IACS) and individual operating companies, nor is this International Standard intended to conflict with any safety or environmental considerations, local regulations, or the specific provisions of any contract.

4.2 Equipment precautions

4.2.1 Accuracy inspection and verification of gauges

Level gauges, temperature measuring equipment and pressure gauges to be used for custody transfer shall be subject to accuracy inspection at the time of installation on board and at subsequent periodic inspections as required by regulation and/or the sales contract.

Certificates of these accuracy verifications shall document the inaccuracies of gauges and provide statements with regard to their operational condition and suitability for use. They shall be dated and indicate the person and company performing the verification. The most current certificate(s) shall be kept on board for inspection by any party to subsequent custody transfer operations.

4.2.2 Maintenance of gauges

Level gauges, temperature measuring equipment and pressure gauges shall be maintained by ship's personnel so as to guarantee effective cargo control and accurate custody transfer.

4.2.3 Operation of gauges

Level gauges, temperature measuring equipment and pressure gauges shall be operated by ship's personnel designated by the shipmaster.

4.2.4 Malfunction of gauges

In the event that a level gauge, temperature measuring equipment or a pressure gauge malfunctions during a voyage, the shipmaster shall endeavour to repair it and report the incident and outcome of any actions taken at the destination without delay.

4.2.5 Tolerance of gauges against cargo nature

In accordance with the type of tank, i.e. fully refrigerated, semi-refrigerated or fully pressurized, level gauges, temperature measuring equipment and pressure gauges shall be designed to withstand low temperatures or high pressure as well the solubility of DME.

4.2.6 Change of gauges

Any changes to level gauges, temperature measuring equipment and pressure gauges require the approval of the ship's flag administration and/or classification society, and require external verification

of accuracy by a competent metrological authority for DME custody transfer. All described equipment shall meet minimum requirements as detailed by the ship's flag administration and classification society.

4.2.7 Use of other type of gauge

Level gauges, temperature measuring equipment and pressure gauges including those which use measurement technologies not described in this International Standard are considered acceptable for use in DME custody transfer service if they are judged to be compatible with those gauges in this International Standard by the parties to the sales contract of DME, and approval by national regulations.

5 Tank capacity table

5.1 General

Static measurement of DME in a ship's tank requires determination of liquid level expressed as innage or ullage, average temperature of liquid and vapour, and vapour pressure. The volume of the liquid is given by the ship's tank capacity table; the volume of vapour is calculated by subtracting the liquid volume from the full capacity of the tank.

5.2 Contents of tank capacity table

Regardless of the type of cargo tanks, ship's tank capacity tables shall contain the following:

a) calibration certificate, issued by a qualified calibration organization, which states uncertainty of the tank calibration;

b) location of level gauges in relation to cargo tank geometry;

c) volume in terms of cubic metres with three decimal places corresponding to the innage or ullage expressed in centimetres or millimetres between bottom datum point and tank top;

d) reference temperature and full capacity of the tank including top dome;

e) example of the use of tank capacity table;

f) trim and list correction tables;

g) thermal correction table and density correction table for float-type ATG where applicable;

h) table of volume corrections due to thermal contraction of tank material in the case of fully refrigerated or semi-refrigerated tanks.

6 Level gauges

6.1 Type of level gauges

Ships with fully refrigerated or semi-refrigerated tanks are usually equipped with radar-type, float-type or magnetic-type ATGs whereas ships with pressurized tanks are usually equipped with float-type or magnetic-type ATGs or slip-tubes (see ISO 18132-3).

6.2 Accuracy of level gauge

Accuracy of a level gauge depends much on the type of the gauge. ISO 18132-3 requires the accuracy of a level gauge to be better than ±10 mm with minimum resolution of 1 mm throughout the measuring range.

It should be noted that the accuracy stated on the accuracy certificate is the accuracy defined at the time of accuracy verification under atmospheric conditions, not the accuracy at time of use under service conditions.

6.3 Use of designated level gauge

Where two sets of level gauges are installed in a cargo tank, they shall be designated as the primary level gauge and the secondary level gauge. Functioning of a primary level gauge may be monitored by the corresponding secondary level gauge, and vice versa; however, it is recognized that such a comparison cannot verify the accuracy of a level gauge to ensure it meets the tolerance. Nevertheless, cross-checking and tracking of the history provide an indication of the performance of the level gauges on the ship.

7 Temperature measuring equipment

7.1 Type of temperature sensor

Temperature measuring equipment consists of temperature sensors fitted in the tanks and display apparatus located on deck or in the cargo control room.

Platinum resistance thermometers are commonly used as temperature sensors (see ISO 8310). However, other types of sensors can be seen in the measurement of DME on board ships.

7.2 Accuracy of temperature measuring equipment

It should be noted that the accuracy stated on the accuracy certificate is the accuracy defined at the time of accuracy verification where the sensors are inspected as a part of the temperature measuring equipment. Accordingly, when one of the sensors is replaced, the display unit shall be adjusted for the new sensor and the results be verified.

Performance criteria of temperature measurement equipment are established in International Standards, government regulations, the sales contract, the manufacturer's instructions and calibration certificates. In the absence of specified tolerances to be referred to, the accuracy of the temperature measuring equipment, regardless of the type of the sensor, should be better than ± 0,5 °C with the minimum resolution of 0,1 °C (see ISO 8310) covering between −50 °C and 30 °C.

7.3 Number and position of temperature sensors

In the cargo tank, at least one sensor shall be mounted in a position which is always occupied by the vapour irrespective of loading condition. Multiple sensors should be mounted vertically in the cargo tank to measure the liquid temperature, one of which shall be mounted as near to the tank bottom as possible to measure the temperature of the heel.

8 Pressure gauge

8.1 Type and number of pressure gauges

Any kind of pressure gauge may be used. It may be one consisting of both transmitter and receiver or with local display only. It also may be one that measures the gauge pressure or absolute pressure.

When a gauge-pressure type pressure gauge is employed for custody transfer, the absolute pressure shall be calculated by adding the reading of a certified barometer to the reading of the pressure gauge.

A pressure gauge should be installed in each cargo tank to measure the pressure of the cargo tank vapour space.

8.2 Accuracy of pressure gauge

Performance criteria are established in International Standards, government regulations, the sales contract and the manufacturer's instructions. In the absence of specified tolerances to be referred to, the accuracy of pressure gauges should be within 1 % of their measuring span.

9 Preparation for custody transfer

9.1 Facilities for cargo operation

Functioning of level gauges, temperature measurement equipment and pressure gauges as well as the various facilities used for cargo operation shall be confirmed with their proper functioning before the ship's arrival at the loading/discharging port.

Activities which may affect the measurement of liquid level, temperature and pressure in the cargo tanks shall be stopped in advance of the custody transfer operation.

9.2 Pipelines

The liquid line and vapour return line shall be connected during the ship/shore meeting for quick dispatch. The valves of these lines shall be kept closed until the custody transfer measurement has been completed.

The ship's delivery lines may be full or empty, but they should preferably be in an identical condition before and after loading/discharging.

9.3 Ship/shore meeting

9.3.1 Prior to loading/discharging, the shipmaster shall hold a meeting to be attended by the representatives of the ship, terminal and qualified inspection organization. Minutes of the meeting shall be signed by these attendees.

9.3.2 At the meeting, the ship shall provide or confirm the following information:

a) names and roles of ship personnel who will be responsible for cargo transfer;

b) pre-arrival instructions on cargo;

c) the fact that all necessary ship equipment inspections and tests have been carried out;

d) cargo tank data such as temperatures, pressures, cargo tank quantities, liquid heel and arrival dip, composition of tank vapour, and total quantity of cargo on board;

e) the previous three cargoes carried by the ship;

f) ship regulations and emergency procedures with particular attention to emergency shut-down valve closure times and to the agreed emergency shut-down procedures.

9.3.3 The terminal shall provide or confirm the following information:

a) names and roles of terminal personnel who will be responsible for cargo transfer;

b) that the relevant terminal equipment is satisfactory and that appropriate inspection checks have been carried out;

c) port and jetty regulations with particular attention to berth operating limits, fire-fighting capabilities and other emergency procedures.

9.3.4 The ship and terminal shall agree on the following:

a) a common language for communication;

b) equipment and procedures for normal and emergency communications;

c) the order of loading/discharging;

d) the total quantities of cargo to be transferred;

e) the sequence of discharging and receiving tanks;

f) the intended transfer rates;

g) the transfer temperatures and pressures to be expected;

h) the use of vapour return lines;

i) any further information or procedures relevant to the operation.

NOTE 1 Adapted from SIGTTO *Liquefied gas handling principles on ships and in terminals*[8].

NOTE 2 Refer to OCIMF *International safety guide for oil tankers and terminals (ISGOTT)*[7] for the ship/shore safety checklist.

10 Custody transfer measurement

10.1 General

Opening custody transfer is implemented immediately before loading or discharging DME. Closing custody transfer is implemented immediately after loading or discharging. Both custody transfers include measurement of liquid level, liquid and vapour temperature, and vapour pressure of DME, based on which the quantity of DME delivered to/from the tanks is determined.

Custody transfer shall be witnessed by an independent qualified inspection organization with or without representatives from the terminal. Results of the measurement shall be recorded on a blank form. Measurement shall be performed without interruption.

10.2 Measurement of liquid level

The primary level gauge shall be used for custody transfer measurement unless it is identified as being out of order. The secondary level gauge shall always be in operational condition.

A sufficient number of measurements shall be made and averaged according to the condition of the liquid surface. In the case of slip tubes, note that accurate level measurement is achieved only by skilful operation.

Prior to measurement, the settings of the ATG shall be confirmed. For example, the settings of a float-type ATG can be confirmed at the top reference point.

The ship's draft shall be observed by the ship's responsible officer for calculation of trim and list correction. Trim and list may be ascertained by an inclinometer or draft gauge.

10.3 Measurement of temperature

There may be cases in which a measured temperature can be judged to be of liquid or of vapour based on the temperature itself; however, precise determination requires comparison of the position of the temperature sensor and the liquid level. In addition, temperature measured by a sensor in the tank dome should not be taken into account when it is judged to be subject to heat input.

Liquid temperature and vapour temperature at each cargo tank shall be separately averaged.

10.4 Measurement of vapour pressure

Vapour pressure shall be measured by the pressure gauges installed in each cargo tank.

11 Quantitative calculation

11.1 General

Referring to the ship's tank capacity table, the independent qualified inspector and ship's responsible officer shall calculate the volume and mass of DME in the ship's tanks from the data collected through custody transfer measurement. Representatives of the terminal can occasionally participate in the calculation process. Density of DME, expressed in kilograms per cubic metre to one decimal place, shall be presented by the loading terminal.

11.2 Concept of quantitative calculation

a) Using tank capacity tables, calculate the liquid volume in each tank in terms of cubic metres to three decimal places at the averaged liquid temperature in the tank, applying necessary corrections as appropriate (see Table 1). Calculate the total mass of DME in liquid state on board in kilograms. The density of DME at a given temperature may be estimated using the equation presented in Annex A.

b) Calculate total vapour volume (V_V) in each tank by deducting liquid volume at the averaged liquid temperature from the tanks' full capacity, then calculate total mass in kilograms of DME in the vapour state (M_V) on board using the following equation:

$$M_V = V_V \times \frac{M}{0{,}022\ 4} \times \frac{273{,}15}{T_V} \times \frac{P_V}{101{,}325}$$

where

M_V is the mass of DME in the vapour state (kg);

V_V is the vapour volume of DME (m^3);

M is the molecular weight of DME (kg/mol);

T_V is the average vapour temperature (K);

P_V is the vapour pressure (kPaA).

c) Calculate the total mass in kilograms of DME on board by adding the values obtained in a) and b).

d) Deduct the total mass before loading from that after loading and define the mass of DME loaded on board or deduct the total mass after discharging from that before discharging and define the mass of DME discharged.

Table 1 — Corrections required for volumetric calculation

Type of level gauge	Fully/semi-refrigerated tank	Pressurized-tank
Float-type ATG	Tape [a]	
	Density [b]	
	Trim and list [c]	
	Tank shrinkage [d]	
Magnetic-type ATG	Pipe [e]	Pipe [e]
	Density [b]	Density [b]
	Trim and list [c]	Trim and list [c]
	Tank shrinkage [d]	—
Radar-type ATG	Pipe [e]	—
	Trim and list [c]	
	Tank shrinkage [d]	
Slip tube	—	Location [f]
		Trim and list [c]

[a] Correction for expansion/contraction of float tape/wire due to change of vapour temperature.

[b] Correction for buoyancy of float due to change of DME density.

[c] Correction for ship's trim and list.

[d] Correction for expansion/contraction of tank due to change of liquid/vapour temperature.

[e] Correction for expansion/contraction of guide pipe due to change of vapour temperature.

[f] Correction for the location of gauging in accordance with liquid level.

12 Preparation for sailing

12.1 Pipelines and other facilities

The refrigeration plant or compressor shall not be operated until custody transfer has completed. Liquid and vapour return lines shall be disconnected after the completion of custody transfer measurement.

12.2 Ship/shore meeting

After loading/discharging, the shipmaster shall hold a meeting to be attended by the representatives of the ship, terminal and qualified inspection organization. Minutes of the meeting shall be signed by these attendees.

12.3 Information to cargo receiver

Cargo information such as the density shall be relayed to the receiver after loading.

Annex A
(informative)

Estimation of density of DME

Density of dimethylether (DME) at a given temperature may be estimated using the following equation[1)]:

$$d = \frac{A}{B \wedge \left[1 + \left(1 - \frac{T}{C}\right)^{D}\right]}$$

where

d is the density (kg/m^3);

A is equal to 55,600 1;

B is equal to 0,236 704;

C is equal to 401,406;

D is equal to 0,243 367;

T is the temperature (K).

1) C. F. Spencer, R. P. Danner, *Journal of Chemical & Engineering Data*, 17 (1972).

Bibliography

[1] ISO 8310, *Refrigerated hydrocarbon and non-petroleum based liquefied gaseous fuels — General requirements for automatic tank thermometers on board marine carriers and floating storage*

[2] ISO 10976:2012, *Refrigerated light hydrocarbon fluids — Measurement of cargoes on board LNG carriers*

[3] ISO 18132-1:2011, *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*

[4] ISO 18132-3:2011, *Refrigerated hydrocarbon and non-petroleum based liquefied gaseous fuels — General requirements for automatic tank gauges — Part 3: Automatic tank gauges for liquefied petroleum and chemical gases on board marine carriers and floating storage*

[5] ISO 29945, *Refrigerated non-petroleum-based liquefied gaseous fuels — Dimethylether (DME) — Method of manual sampling onshore terminals*

[6] SPENCER C.F., & DANNER R.P.J.*J. Chem. Eng. Data*. 1972, 17

[7] OCIMF. *International safety guide for oil tankers and terminals (ISGOTT)*. 5th Edition

[8] SIGTTO. *Liquefied gas handling principles on ships and in terminals*. 3rd Edition

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