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Petroleum and liquid petroleum products — Direct static measurements — Measurement of content of vertical storage tanks by hydrostatic tank gauging

Pétrole et produits pétroliers liquides — Mesurage statique direct — Mesurage du contenu des réservoirs verticaux de stockage par jaugeage hydrostatique des réservoirs

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Foreword

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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 11223 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Subcommittee SC 3, *Static petroleum measurement*.

This first edition of ISO 11223 cancels and replaces ISO 11223-1:1995, which has been technically revised.

Introduction

Hydrostatic tank gauging (HTG) is a method for the determination of total static mass of liquid petroleum and petroleum products in vertical cylindrical storage tanks.

HTG uses high-precision stable pressure sensors mounted at specific locations on the tank shell.

Total static mass is derived from the measured pressures and the tank capacity table. Other variables, such as level, observed and standard volumes and observed and reference densities, can be calculated from the product type and temperature using the established industry standards for inventory calculations.

The term “mass” is used in this International Standard to indicate mass in vacuum (true mass). In the petroleum industry, it is not uncommon to use apparent mass (in air) for commercial transactions.

Petroleum and liquid petroleum products — Direct static measurements — Measurement of content of vertical storage tanks by hydrostatic tank gauging

1 Scope

This International Standard gives guidance on the selection, installation, commissioning, maintenance, validation and calibration of hydrostatic tank-gauging (HTG) systems for the direct measurement of static mass in petroleum storage tanks. It is intended to cover custody transfer applications, although details of other, less accurate, measurements are included for information. It also gives guidance on calculations of standard volume from measured mass and independently measured reference density. Information is also included on measurements of observed and standard volume using density measured by the HTG system itself.

This International Standard is applicable to hydrostatic tank-gauging systems which use pressure sensors with one port open to the atmosphere. It is applicable to the use of hydrostatic tank gauging on vertical, cylindrical, atmospheric storage tanks with either fixed or floating roofs.

This International Standard is not applicable to the use of hydrostatic tank gauging on pressurized tanks.

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 91-1:1992, *Petroleum measurement tables — Part 1: Tables based on reference temperatures of 15 degrees C and 60 degrees F*

ISO 91-2:1991, *Petroleum measurement tables — Part 2: Tables based on a reference temperature of 20 degrees C*

ISO 1998 (all parts), *Petroleum industry — Terminology*

ISO 3170:2004, *Petroleum liquids — Manual sampling*

ISO 3675:1998, *Crude petroleum and liquid petroleum products — Laboratory determination of density — Hydrometer method*

ISO 3838:2004, *Crude petroleum and liquid or solid petroleum products — Determination of density or relative density — Capillary-stoppered pyknometer and graduated bicapillary pyknometer methods*

ISO 3993:1984, *Liquefied petroleum gas and light hydrocarbons — Determination of density or relative density — Pressure hydrometer method*

ISO 4266-4:2002, *Petroleum and liquid petroleum products — Measurement of level and temperature in storage tanks by automatic methods — Part 4: Measurement of temperature in atmospheric tanks*

ISO 4267-2:1988, *Petroleum and liquid petroleum products — Calculation of oil quantities — Part 2: Dynamic measurement*

ISO 4268:2000, *Petroleum and liquid petroleum products — Temperature measurements — Manual methods*

ISO 4512:2000, *Petroleum and liquid petroleum products — Equipment for measurement of liquid levels in storage tanks — Manual methods*

ISO 7078:1985, *Building construction — Procedures for setting out, measurement and surveying — Vocabulary and guidance notes*

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

ISO 9857:— [1] *Petroleum and liquid petroleum products — Continuous density measurement*

ISO 12185:1996, *Crude petroleum and petroleum products — Determination of density — Oscillating U-tube method*

IEC 60079-0:2004, *Electrical apparatus for explosive gas atmospheres — Part 0: General requirements*

API, *Manual of Petroleum Measurement Standards Chapter 3 — Tank Gauging Section 1A — Standard Practice for the Manual Gauging of Petroleum and Petroleum Products*, First Edition

3 Terms and definitions

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

3.1
ambient air density
density of ambient air at the tank side on which the pressure sensors are mounted

3.2
ambient air temperature
representative temperature of the ambient air at the tank side on which the HTG pressure sensors are mounted

3.3
apparent mass in air
value obtained by weighing in air against standard masses without making correction for the effect of air buoyancy on either the standard masses or the object weighed

[ISO 3838]

3.4
capacity table
table, often referred to as a tank table or a tank calibration table, showing the capacities of, or volumes in a tank corresponding to various liquid levels measured from a stable reference point

[ISO 7507-1]

3.5
critical zone height
upper limit of the critical zone; the level at which one or more of the floating-roof or floating-blanket legs first touch the tank bottom

1) To be published.

3.6
critical zone
level range through which the floating roof or floating blanket is partially supported by its legs

3.7
density
mass of the substance divided by its volume

[ISO 3838]

NOTE When reporting the density, it is necessary to explicitly state the unit of density used, together with the temperature. The standard reference temperature for international trade in petroleum and its products is 15 °C (see ISO 5024). Other reference temperatures might be required for legal metrology or other special purposes (see ISO 3993).

3.8
dip
innage
depth of a liquid in a tank

[adapted from ISO 7507-1]

3.9
dipped volume
observed volume of product, sediment and water, calculated from the dip level and the tank capacity table

3.10
fixed-roof tank
vertical cylindrical storage vessel with either a cone- or domed-shaped roof of either the non-pressurized (freely vented) type or the low-pressure type

[ISO 1998]

3.11
floating blanket
cover
screen
light-weight cover of either metal or plastic material designed to float on the surface of the liquid in a fixed-roof tank

NOTE The blanket is used to retard the evaporation of volatile products in a tank.

[adapted from ISO 7507-1]

3.12
floating-roof mass
value of the floating-roof mass, inclusive of any mass load on the roof, manually entered in the data processor

3.13
floating-roof tank
tank in which the roof floats freely on the surface of the liquid contents except at low levels when the weight of the roof is taken, through its supports, by the tank bottom

[ISO 7507-1]

3.14
free-water level
level of any water and sediment that exist as a separate layer underneath the product

3.15
gross standard volume
volume of oil, including dissolved water, suspended water and suspended sediment, but excluding free water and bottom sediment, calculated at standard conditions

3.16
head mass
total measured mass between the HTG bottom sensor and the top of the tank

3.17
heel space
space inside the tank, below the bottom HTG sensor

3.18
HTG reference point
stable reference point from which the HTG sensor positions are measured

3.19
hydrostatic tank gauging
HTG
method of direct measurement of liquid mass in a storage tank based on measuring static pressures caused by the liquid head above the pressure sensor

3.20
in-tank vapour density
density of the gas or vapour (mixture) in the ullage space at the observed conditions of product temperature and pressure

3.21
observed density
value obtained at a test temperature which differs from the calibration temperature of the apparatus

[adapted from ISO 3838]

3.22
pin height
lower limit of the critical zone, i.e. the level at which the floating roof or floating blanket rests fully on its legs

3.23
product heel mass
mass of product below the bottom HTG sensor

3.24
product heel volume
observed volume of product below the bottom HTG sensor, calculated by subtracting the water volume from the total heel volume

3.25
product mass
sum of the head mass and the product heel mass, reduced by the floating-roof mass (if applicable) and the vapour mass

3.26
product temperature
temperature of the tank liquid in the region where the HTG measurements are performed

3.27
reference density
density at the reference temperature

3.28
reference temperature
temperature to which reference density and standard volumes are referred

3.29
tank average cross-sectional area
average cross-sectional area between the level of the bottom HTG sensor and the dip level, over which the hydrostatic pressures are integrated in order to obtain the head mass

3.30
tank lip
tank bottom plate on the outside of the tank shell

3.31
tank shell
outer casing of a storage tank that on land is secured to the ground and includes the roof, if it is a **fixed-roof tank** (3.10)

3.32
total heel volume
observed volume below the bottom HTG sensor, calculated from the level of the bottom sensor and the tank capacity table, corrected for observed temperature

3.33
total volume
indicated volume, including all water and sediment without correction for temperature and pressure.

[adapted from ISO 4267-2]

3.34
ullage pressure
absolute pressure of the atmosphere (air or vapour) inside the tank, above the product

3.35
vapour relative density
ratio of molecular mass of vapour (mixture) to that of air (mixture)

3.36
water volume
observed volume of free sediment and water, calculated from the free water level and the tank capacity tables

3.37
ullage
outage
capacity of the tank not occupied by the liquid

[ISO 7507-1]

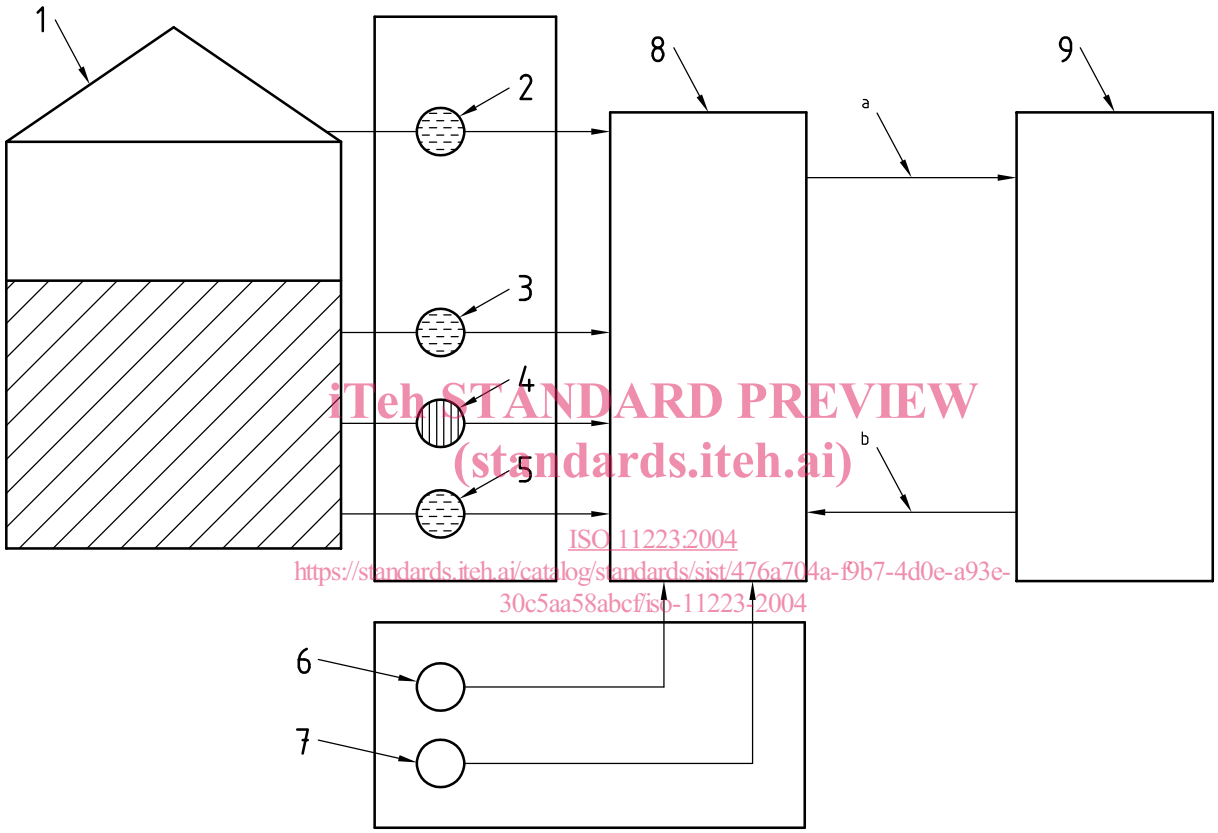
3.38
uncertainties
unless stated otherwise, all uncertainties, including maximum permissible errors, are assumed to be extended uncertainties with coverage factor $k = 2$

4 System description

4.1 General

A hydrostatic tank gauging (HTG) system is a static mass-measuring system. It uses pressure and temperature inputs, the parameters of the tank and of the stored liquid to compute the mass of the tank contents and other variables as described in Table 1 and Annex A (see Figure 1).

Determination of the other variables shown in brackets in Figure 1 is not included in the scope of this International Standard. However, information on them is given in Annexes B and C.



Key

1 storage tank
2 sensor P3 (ullage pressure)
3 sensor P2 (density measurements)
4 liquid temperature sensor
5 sensor P1 (liquid head measurements)
6 ambient pressure sensor
7 ambient temperature sensor
8 HTG processor (calculations)
9 HTG interface (display, printing, configuration, control)

a Calculated outputs: mass (volume, density, level).
b Input parameters: tank, ambient, sensor, liquid.

Figure 1 — HTG system — Functional diagram

4.2 Sensors

4.2.1 Pressure sensors

The hydrostatic tank gauging (HTG) system consists of up to three pressure sensors mounted on the tank shell. An ambient air pressure sensor (Pa) may be installed for measurements requiring high accuracy.

Sensor P1 is installed at or near the tank bottom.

Sensor P2 is the middle pressure sensor and is required for the calculation of density and levels. If the product density is known, the HTG system can operate without sensor P2 (in the absence of P2, the density data should be manually entered in the data processor). Sensor P2, if installed, should be at a fixed vertical distance above sensor P1.

Sensor P3 is the tank ullage space pressure sensor, normally installed on the tank roof. If the tank is freely vented, the HTG system can operate without P3. P3 is not required on floating-roof tanks.

4.2.2 Temperature sensors

Temperature sensors may be included to measure the temperature of the tank contents (T) and of the ambient air (T_a).

The tank content (product) temperature is needed for

a) calculation of volumetric expansion of the tank shell;

b) calculation of reference density from observed density (used in HTG systems which calculate level and density as well as mass).

If the reference density is known and sensor P2 is not used, a temperature sensor may still be required for calculation of observed density.

The ambient air temperature is needed for

a) calculation of ambient air density;

b) calculation of volumetric expansion of the tank shell;

c) corrections for thermal expansion of the tie bars to sensor P1 and between sensors P1 and P2.

4.2.3 System configuration

4.2.3.1 General

The sensor configurations vary depending on the application and data required. Some of the more common variations are as described in 4.2.3.2 to 4.2.3.5.

4.2.3.2 Known liquid density

Sensor P2 is normally used for the automatic measurement of the tank liquid density. It is not required if the average liquid density is known.

4.2.3.3 Known ullage pressure

Sensor P3 is not required for those tanks which are vented to atmosphere (the ullage gauge pressure equals 0). This includes all floating-roof tanks and all fixed-roof tanks that are freely vented or that have gauging hatches that are not sealed.

NOTE 1 Tanks with pressure/vacuum (PV) relief valves are not considered as vented to atmosphere for the purposes of hydrostatic gauging. Their ullage pressures normally vary more than the expected uncertainties of pressure measurements.

NOTE 2 Tank ullage pressure on atmospheric fixed-roof tanks might differ slightly from atmospheric pressure during transfers to and from the tank. Since inventory measurements are not taken during a transfer, errors due to this effect are not significant.

If the ullage pressure is known, pressure p_3 may be entered into the data processor as a constant and sensor P3 omitted on non-vented tanks.

4.2.3.4 Known tank liquid temperature

Tank liquid and ambient temperatures are used to correct for shell thermal expansion. The tank liquid temperature sensor is not required for mass measurement if the temperature of the liquid in the tank is known (see ISO 4266-4 or ISO 4268).

4.2.3.5 Varying atmospheric conditions

Ambient temperature and pressure sensors may be used to remove secondary errors for measurements requiring high accuracy. Single measurements of ambient air temperature and pressure may be used for all tanks at the same location.

4.3 HTG data processor

A processor receives data from the sensors and uses the data together with the tank and liquid parameters to compute the mass inventory in the storage tank (see Figure 1).

The stored parameters fall into four groups: tank data, sensor data, liquid data and ambient data (see Table 1). Those parameters in Table 1 that are required by the application should be programmed into the HTG system.

NOTE The data processor can also calculate level, observed and standard volumes, and observed and reference densities. These calculations are given for information in Annex A.

When the product level drops below the level of the sensor P2, density can no longer be measured by HTG. Below this level, the last measured value of product density may be used.

The data processor may be dedicated to a single tank or it may be shared among several tanks. The processor may also perform linearization and/or temperature-compensation corrections for the pressure sensors.

All variables provided by the data processor can be displayed, printed or communicated to another processor.

Computations normally performed by the data processor are described in Annex A

Table 1 — Stored parameters for HTG data processing

Parameter group	Parameter	Remarks
Tank data	Tank roof type	Fixed or floating or both
	Tank roof mass	Floating roofs only
	Critical zone height	Floating roofs only
	Pin height	Floating roofs only
	Tank wall type	Insulated or non-insulated
	Tank wall material	Two thermal expansion constants (see ISO 7507-1)
	Tank capacity table	Volumes at given levels
	Tank calibration temperature	Temperatures to which the tank capacity table was corrected
HTG sensor data	Sensor configuration	Tank with 1, 2 or 3 sensors
	HTG reference point height	To tank calibration datum point
	P1 sensor height	To HTG reference point
	P2 sensor height	Referenced to P1
	P3 sensor height	Referenced to P1
Liquid data	Liquid density	If no P2 sensor
	Liquid expansion coefficients	See ISO 91-1 and ISO 91-2
	Free water level	—
Ambient data	Local acceleration due to gravity	Obtained from a recognized source
	Ambient temperature	Optional
	Ambient pressure	Optional

5 Installation and initial commissioning

5.1 Pressure sensors

5.1.1 Selection of pressure sensors

The pressure sensors should be selected in accordance with the uncertainty calculation. The maximum permissible errors for custody transfer applications are given in Table 2. These figures are considered to be extended uncertainties with a coverage factor $k = 2$.

Table 2 — Maximum permissible errors for pressure sensor(s) for custody transfer applications

Maximum permissible error of pressure sensors			
P1		P3 [a]	
Zero error Pa	Linearity error % of reading	Zero error Pa	Linearity error % of reading
± 50	± 0,07	± 24	± 0,2

[a] If P3 is used.