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Petroleum measurement systems — Calibration — Volumetric measures, proving tanks and field measures (including formulae for properties of liquids and materials)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 28, *Petroleum and related products, fuels and lubricants from natural or synthetic sources*, Subcommittee SC 2, *Measurement of petroleum and related products*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 19, *Gaseous and liquid fuels, lubricants and related products of petroleum, synthetic and biological origin*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 8222:2002), which has been technically revised. The main changes to the previous edition are as follows:

— revision of the title and scope to allow the document to cover the design, calibration and use of a wide range of volumetric measures comprising proving tanks, test measures, field and standard measures;

— provision of revised, updated and extended formulae to allow calculation of temperature correction including the addition of formulae for saline water, other liquids and material properties.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Volumetric, or capacity, measures are used to provide an accurate measure of volume, thereby providing a calibration reference for other volume-measuring devices, such as pipe displacement provers or flowmeters.

Volume measures are categorized in terms of capacity, test measures being below 20 l. Measures above 20 l are categorised as prover tanks. Standard measures are designed to comply with regulatory guidance and hence have specified volumes. Other measures have non-standard volumes specifically designed to suit an application, for example measures to accompany a small volume prover.

Volumetric measures can be used to calibrate flowmeters, both duty and reference meters. They can also be used to calibrate secondary volume measures, displacement (pipe) provers and storage tanks.

Annex A provides the recommended formulae used in the calibration and use of volumetric measures and for other volumetric measurements. This includes pure and saline water properties, the properties of hydrocarbon liquids and the materials of construction of volumetric measuring devices.

Petroleum measurement systems — Calibration — Volumetric measures, proving tanks and field measures (including formulae for properties of liquids and materials)

WARNING — The use of this document could involve hazardous materials, operations and equipment. This document does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this document to establish appropriate safety and health practices.

1 Scope

This document describes the design, use and calibration of volumetric measures (capacity measures) which are intended for use in fixed locations in a laboratory or in the field. This document gives guidance on both standard and non-standard measures. It also covers portable and mobile measures. This document is applicable to the petroleum industry; however, it may be applied more widely to other applications.

This document excludes measures for cryogenic liquids and pressurized measures as used for liquid petroleum gas (LPG) and liquefied natural gas (LNG).

Volumetric measures are classified as test measures or prover tanks depending on capacity and design.

Measures described in this document are primarily designed, calibrated and used to measure volumes from a measure which is wetted and drained for a specified time before use and designated to deliver. Many of the provisions, however, apply equally to measures which are used to measure a volume using a clean and dry measure and designated to contain.

Guidance is given regarding commonly expected uncertainties and calibration specifications.

The document also provides, in Annex A, reference formulae describing the properties of water and other fluids and materials used in volumetric measurement more generally.

2 Normative references

There are no normative references in this document.

3 Terms, definitions, symbols and units

3.1 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
accuracy
closeness of the agreement between a measured quantity value and a true quantity value of a measurand

Note 1 to entry: The concept 'measurement accuracy' is not a quantity and should not be given a numerical value. The quantitative expression of accuracy should be in terms of uncertainty. "Good accuracy" or "more accurate" implies small measurement error. Any given numerical value should be taken as indicative of this.

[SOURCE: VIM:2012, 2.13]

3.1.2
adjustment
set of operations carried out on a measuring system so that it provides prescribed indications corresponding to given values of a quantity to be measured

Note 1 to entry: Adjustment should not be confused with calibration, which is a prerequisite for adjustment.

Note 2 to entry: After adjustment, a recalibration is usually required.

[SOURCE: VIM:2012, 3.11]

3.1.3
automatic pipette
overflow pipette
high precision measure, where the volume withdrawn is defined by a top overflow weir rather than a gauge scale

3.1.4
brim measure
field measure where the volume is defined by an overflow from the top edge of the neck

3.1.5
calibration
operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and in a second step uses this information to establish a relation for obtaining a measurement result from an indication

Note 1 to entry: A simplified definition is 'set of operations that establish, under specified conditions, the relationship between quantities indicated by an instrument and the corresponding values realized by standards'.

Note 2 to entry: Calibration should not be confused with adjustment of a measuring system.

Note 3 to entry: The word "proving" is used in the oil industry and has the same meaning but can include a check of the results against specified acceptance criteria.

[SOURCE: VIM:2012, 2.39]

3.1.6
calibrated volume
volume of a measure between a top and bottom datum as determined by calibration and expressed at a standard temperature

3.1.7
clingage
film of liquid that adheres to the inside surface of a volumetric measure after it has been emptied, resulting in a residual volume

3.1.8
correction factor
numerical factor by which the uncorrected result of a measurement at the measured conditions is multiplied

Note 1 to entry: Correction factors to standard conditions are used to convert a volume at observed conditions to the volume at another (standard) condition.

3.1.9
plunger
displacement plunger
device consisting of a piston which is used for adjusting the volume of a volumetric measure

3.1.10
drain time
total time taken to empty the measure or tank to leave a consistent residual volume

Note 1 to entry: Drain time commences when the drain valve is opened and ceases when closed after a defined time or condition. Drain time may be divided into two parts: first drain time and final drain time.

Note 2 to entry: A dry measure can be employed where the product evaporates quickly, for example petrol. These measures will not have a drain time and the means to ensure they are dry will be specified in documents regulating their use.

3.1.11
final drain time
time which follows the cessation of the first drain time and finishes at a defined time, or condition, such as rate of dripping

3.1.12
first drain time
time to drain the majority of the fluid from the measure

Note 1 to entry: The first drainage flow commences when the drain valve is opened and ends at a defined level, time or when flow breaks into a defined trickle or drip rate. This is prior to the start of the final drain time.

3.1.13
dry measure
contents measure which is calibrated and used with the internal surface completely dry (i.e. no clingage or residual volume)

Note 1 to entry: The volume of a dry measure may be marked and designated to contain.

3.1.14
error
measured quantity value minus a reference quantity value

Note 1 to entry: Note1 to entry: Relative error is error divided by a reference value. This can be expressed as a percentage.

[SOURCE: VIM:2012, 2.16]

3.1.15
field measure
measure designed to be used in the regular calibration of other devices

Note 1 to entry: While most field measures are portable, some can be in a fixed location.

3.1.16
gauge glass
clear tube in parallel with, or a window set into, the neck of a measure to show the level of liquid in the neck

Note 1 to entry: There is an associated scale to indicate the measured volume.

3.1.17
nominal volume
design volume of a volumetric measure

3.1.18
primary measure
reference measure calibrated gravimetrically

Note 1 to entry: Primary measures should be calibrated by a national measurement institute (NMI) or a competent laboratory meeting ISO/IEC 17025.

3.1.19
proving
calibration with comparison to defined acceptance criteria

Note 1 to entry: The term "proving" is used in the oil industry and is similar to verification.

Note 2 to entry: Proving is a calibration, sometimes of limited measurement range, according to methods defined by standards, regulations or procedures, providing a determination of the errors of a device and showing (proving) it performs to defined acceptance criteria.

3.1.20
proving tank
volumetric measure which generally has capacity greater than 20 l and has a bottom drain

Note 1 to entry: A prover tank can be free-standing or mounted on a truck or trailer.

3.1.21
pour
individual quantities of liquid poured from, or received into, a volumetric measure

3.1.22
range
range of values
difference between the maximum and minimum values of a set of values

Note 1 to entry: This can be expressed as a half range (±) number. Relative range is normally expressed as a percentage of a specified value, for example mean, minimum or other calculated value.

3.1.23
reference conditions
operating conditions prescribed for evaluating the performance of the measure

Note 1 to entry: This is the range of ambient and fluid conditions with which the measure is evaluated, verified or operated.

3.1.24
reference measure
volumetric measure calibrated, used and maintained to provide traceability to other volume measures and devices, including pipe provers and reference flowmeters

Note 1 to entry: A reference measure can be calibrated gravimetrically (primary measure) or volumetrically by means of a primary measure which itself has been calibrated gravimetrically.

3.1.25
repeatability
measurement precision
closeness of agreement between indications or measured quantity values obtained by replicate measurements under specified conditions

Note 1 to entry: Specified conditions normally implies the same reference, same conditions, same operators and procedures and that the data are obtained sequentially over a short period of time.

Note 2 to entry: Repeatability can be expressed as the range (difference between the maximum and minimum) values of error or K-factor. Alternatively, repeatability can be expressed as a function of the standard deviation of the values.

Note 3 to entry: Dividing repeatability by the mean gives the relative value which can be expressed as a percentage. It is noted some standards suggest dividing by the minimum value.

[SOURCE: VIM:2012, 2.15]

3.1.26
residual volume
volume or quantity remaining in the measure after draining for the defined drain time

3.1.27
resolution
quantitative expression of the ability of an indicating device to distinguish meaningfully between closely adjacent values of the quantity indicated

3.1.28
scale datum
fixed reference point or mark, established at manufacture or initial calibration, from which subsequent adjustments to the scale can be referred

Note 1 to entry: This may be an engraved mark on the neck, or another defined fixed point such as a support bracket. The location should be referenced on calibration certificates.

3.1.29
secondary measure
volumetric measure which is calibrated by a primary measure

3.1.30
standard condition
base condition
condition of temperature and pressure to which measurements of volume or density are referred to standardize the quantity

Note 1 to entry: These are the specified values of the conditions to which the measured quantity is converted.

Note 2 to entry: For the petroleum industry, these are usually 15 °C, 20 °C or 60 °F and 101,325 kPa.

Note 3 to entry: Standard conditions can refer to the liquid or the volume of the measure. These may be different.

Note 4 to entry: Quantities of volume expressed at standard conditions may be indicated by prefixing the volume unit by “S”, for example 4 Sm^3 or 700 kg/Sm^3. This abbreviation is used in place of the unit m^3 (standard conditions) where there is limited space and there is no risk of confusion regarding the unit.

Note 5 to entry: Standard conditions should not be confused with the reference (operating) conditions prescribed for evaluating the measure.

3.1.31
standard measure
volumetric measure which is designed to meet the requirements of regulatory standards

Note 1 to entry: Examples of regulatory standards are OIML R 120, Measurement Instruments Directive (MID) and NIST 105-3.

3.1.32
standard volume
base volume
volume expressed as being at standard conditions

3.1.33
strike measure
brim measure where the volume is defined from the top edge of the neck which has been designed to be struck by sliding a ground glass disk over it to leave a consistent volume within the measure

3.1.34
test measure
hand portable volumetric measure up to 20 l capacity

Note 1 to entry: A test measure can be inverted to drain or be fitted with a bottom drain.

Note 2 to entry: A test measure can also be non-portable, in a fixed frame or on a vehicle. It may in some cases be classified as a prover tank.

3.1.35
thermowell
metal pocket which protrudes through, or is attached to, the wall of a pipe or volumetric measure to hold a temperature-measuring device

3.1.36
volume to contain
standard volume of liquid a measure contains with respect to its reference line or datum when filled from a clean dry condition

3.1.37
volume to deliver
standard volume of liquid which can be withdrawn from or filled into a pre-wetted measure with respect to its reference line or datum and following specified drainage times and procedures

Note 1 to entry: A wet condition is obtained by filling the measure and draining it for the specified drain time and procedure.

Note 2 to entry: The volume to deliver is always less than the volume to contain due to the volume of residual liquid left on the walls of the measure after the specified drain time.

Note 3 to entry: A measure marked with a volume to deliver can be used either to withdraw or to fill volumes as long as the wetting and drainage procedures are followed.

3.1.38
fill
receive
In
technique for using or calibrating a volumetric measure by filling from top or bottom with liquid from the device under test or the reference

Note 1 to entry: The reference may be volumetric or gravimetric.

Note 2 to entry: 'In' is the term adopted by EURAMET guide cg21[2].

3.1.39
withdraw
water draw
Ex
technique for using or calibrating a volumetric measure by withdrawing liquid from the measure into the device under test or the reference

Note 1 to entry: The reference may be volumetric or gravimetric.

Note 2 to entry: 'Water draw' is usually applied to the calibration of pipe provers.

Note 3 to entry: 'Ex' is the term adopted by EURAMET guide cg21[2].

3.1.40
traceability
metrological traceability
property of a measuring result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty

[SOURCE: VIM:2012, 2.41]

3.1.41
transfer point
point or location in a fluid transfer where the quantity and accountability of the fluid passes from one measurement system to another

3.1.42
uncertainty
non-negative parameter characterizing the dispersion of the quantity values attributed to a measurand based on the information used

[SOURCE: VIM:2012, 2.26]

Note 1 to entry: The uncertainty is normally expressed as a half width range along with the probability distribution with that range. It can be expressed as a value or as a percentage of the perceived true value.

3.1.43
volumetric measure
measure used to provide an accurate measure of a volume, hence providing a calibration reference for other volume-measuring devices, such as pipe displacement provers or flowmeters

3.1.44
water pour
technique for calibrating a measure by decanting liquid from a reference measure or a gravimetric system to a device under test

3.1.45
wet measure
volumetric measure which has been wetted and drained before use in accordance with defined drain times and procedures given in the calibration certificate and specification

3.1.46
wetted
portion of the internal surface of a volumetric measure which has been in contact with the liquid during use

3.1.47
weir
device, usually a horizontal edge, where a consistent liquid level is established to provide a datum

3.2 Symbols and units

NOTE 1 The preferred unit for kinematic viscosity is metres squared per second (m^2/s) or millimetres squared per second (mm^2/s). The practical unit used in this document is the industry-recognized unit centistoke (cSt); 1 cSt = 1 mm^2/s.

NOTE 2 The preferred unit for a volume expressed at a standard condition is m^3 (standard condition). In practice this is conventionally abbreviated to Sm^3 where there is limited space and there would be no confusion of units used.

Symbol	Quantity	Unit
C_{tl}	volume correction factor for thermal expansion of liquid from measured temperature to the standard temperature	
C_{dtl}	volume correction factor for thermal expansion of liquid from reference device (measure) temperature to the temperature at the device under test	
C_{tlr}	volume correction factor for thermal expansion of liquid from reference device (measure) temperature to the standard temperature	
C_{tlt}	volume correction factor for thermal expansion of liquid from test device temperature to the standard temperature	
C_{pl}	volume correction factor for liquid compressibility from measured pressure to standard pressure	
C_{plt}	volume correction factor for liquid compressibility from pressure to standard pressure from a device under test	
C_{ts}	volume correction factor for the thermal expansion of the device (material) to volume at standard temperature	
C_{tsr}	volume correction factor for the thermal expansion of the reference measure material to the volume at standard temperature	
C_{tst}	volume correction factor for the thermal expansion of the device under test material to the volume at standard temperature	
C_{ps}	volume correction factor for the pressure expansion of the device under test to the volume at standard pressure	
F	meter factor of a flowmeter at operating temperature and pressure	
M	mass of water collected in weigh container	kg
t_r	temperature of the liquid in the reference device	°C
t_t	temperature of the liquid in the device under test	°C
t_{sr}	standard temperature for the reference measure	°C
t_{st}	standard temperature of the device under test	°C
V_m	indicated volume from a flowmeter at actual conditions	m^3 or l
V_r	volume measured by a reference, measure or flowmeter, at actual conditions of pressure and temperature	m^3 or l
V_{rs}	calibrated volume of a measure corrected for scale indication, i.e. the indicated volume, at standard conditions, from a reference measure, corrected for known calibrations errors	m^3 or l (standard conditions)
V_{ts}	volume of device under test at standard conditions	m^3 or l (standard conditions)
V_t	volume transferred to or from a reference to the device under test	m^3 or l
W_a	weight of liquid collected in the weigh container during gravimetric calibration	kg
α_r	linear expansion coefficient of the reference device	$°C^{-1}$
α_t	linear expansion coefficient of the device under test	$°C^{-1}$
ρ_a	density of air during weighing	kg/m^3
ρ_w	nominal density of weights used to calibrate weighing machines (normally defined as 8 000 kg/m^3)	kg/m^3

Symbol	Quantity	Unit
ρ_r	density of liquid in reference device at t_r	kg/m^3
ρ_t	density of liquid in device under test at t_t	kg/m^3

4 Traceability

All the volumetric measures described have a unique hierarchy in the traceability chain. All are traceable to standards of mass combined with the derived density of pure water. There is a hierarchy for traceability which is followed to provide the uncertainty required by the final application.

A primary measure would be calibrated by weighing the water withdrawn to a tank on a weigh scale or to directly weigh the measure and determine the weight of liquid filled or withdrawn. The weigh scale is calibrated with mass standards of the required class[3] and uncertainty. The mass and the density of the water are then combined to give the volume.

A primary measure can be used to determine the volume of a secondary measure. This can require multiple measurements fills. A secondary measure can be used to determine the calibration factor of a flowmeter. This can be a reference flowmeter used to measure volume in a pipe prover or large volume measure or to calibrate other meters.

Figure 1 shows schematically a primary measure being used to determine the volume of a small volume prover, which in turn is used to calibrate a reference flowmeter used to determine the volume of a large pipe prover.

Primary and reference measures are calibrated using pure water or clean drinking water. The water density is determined from the recommended formulae relating density to temperature and corrected where required through a measurement of relative density. The water density can also be experimentally determined by the use of a calibrated densitometer.

Some secondary measures, particularly large fixed measures, may need to be calibrated with impure water, seawater or a hydrocarbon product.

Applicable liquid property formulae are given in Annex A.

The uncertainty for volume determination should be specified according to the application. Indicative values of uncertainty applicable to different volumetric measures are given in Annex E.

