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Liquid hydrocarbons — Volumetric measurement by displacement meter

Hydrocarbures liquides — Mesurage volumétrique au moyen de compteurs à chambre mesureuse

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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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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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 Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*.

This second edition cancels and replaces the first edition (ISO 2714:1980), which has been technically revised.

Introduction

This document gives recommendations on the design, installation, operation and maintenance of positive displacement meter systems used for liquid measurement. This widens the application scope from the previous document, which was primarily aimed at hydrocarbon custody transfer applications. The guidance now applies to all suitable liquids measured across different applications and industry sectors.

Displacement meters are extensively used in general fluid measurement in addition to fiscal, custody transfer and legal metrology applications involving hydrocarbon and non-hydrocarbon products. These can range from the light products such as gasoline, through to higher viscosity fluids.

The document has an extended scope from the first edition to cover applications for a wider range of liquids and duties and to remove restriction to hydrocarbon liquids. It now provides guidance, rather than mandatory requirements, on performance to allow meters to be specified and verified to meet relevant regulatory, fiscal and custody transfer specifications. The document also now includes additional meter designs. This revision has been achieved through the participation of ISO/TC 30 in the preparation, hence, providing a single standard for the measurement of flowing liquids using positive displacement flowmeters.

Liquid hydrocarbons — Volumetric measurement by displacement meter

WARNING — The use of this document might 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 and discusses the characteristics of displacement flowmeters. Attention is given to the factors to be considered in the application of positive displacement meters to liquid metering. These include the properties and nature of the liquid to be metered, the correct installation and operation of the meter, environmental effects, and the wide choice of secondary and ancillary equipment. Aspects of meter proving and maintenance are also discussed.

This document is applicable to the metering of any appropriate liquid. Guidance is given on the use of positive displacement meters in the metering of two-component mixtures of the same phase such as water and oil.

It is not applicable to two-phase flow when gases or solids are present under metering conditions (i.e. two-phase flow). It can be applied to the many and varied liquids encountered in industry for liquid metering only. It is not restricted to hydrocarbons.

Guidance on the performance expected for fiscal/custody transfer applications for hydrocarbons is outlined.

This document is not applicable to cryogenic liquids such as liquefied natural gas (LNG) and refrigerated petroleum gas. It does not cover potable water and fuel dispenser applications.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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/IEC Guide 99, *International vocabulary of basic and general terms in metrology (VIM)*

ISO 4006, *Measurement of fluid flow in closed conduits — Vocabulary and symbols*

3 Terms, definitions, symbols and abbreviated terms

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 https://www.electropedia.org/

3.1.1
accuracy
closeness of the agreement between the 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: ISO/IEC Guide 99:2007, 2.13, modified]

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

EXAMPLE This entails bringing a measuring instrument (meter) into a satisfactory performance and accuracy.

Note 1 to entry: Adjustment can be of zero point, span, linearity or other factors affecting the performance of the meter.

Note 2 to entry: Adjustment should not be confused with calibration, which is a prerequisite for adjustment.

Note 3 to entry: After adjustment, a recalibration is usually required.

[SOURCE: ISO/IEC Guide 99:2007, 3.11]

3.1.3
calibration
set of operations that establish, under specified conditions, the relationship between quantities indicated by an instrument and the corresponding values realized by standards

Note 1 to entry: Calibration should not be confused with adjustment of a measuring system.

[SOURCE: ISO/IEC Guide 99:2007, 2.39, modified]

3.1.4
cavitation
phenomenon related to, and following, *flashing* (3.1.6), where vapour bubbles or voids form and subsequently collapse or implode

Note 1 to entry: Cavitation causes significant measurement error and also potentially cause damage to the pipe and meter through erosion.

3.1.5
error
measured value minus a reference value

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

[SOURCE: ISO/IEC Guide 99:2007, 2.16, modified]

3.1.6
flashing
phenomenon which occurs when the line pressure drops to, or below, the vapour pressure of the liquid, allowing gas to appear from solution or through a component phase change

Note 1 to entry: Vapour pressure of the fluid can reduce with increasing temperature.

Note 2 to entry: Flashing is often due to a local pressure drop caused by an increase in liquid velocity, and generally causes significant measurement error.

Note 3 to entry: The free gas produced by flashing will remain for a considerable distance downstream of the meter even if pressure recovers.

3.1.7
K-factor
ratio of the number of pulses obtained from a meter and the quantity passed through the meter

3.1.8
linearity
total range of deviation of the accuracy curve from a constant value across a specified measurement range

Note 1 to entry: The maximum deviation is based on the mean of derived values at any one flow point.

Note 2 to entry: The deviation is the largest minus the smallest value of mean values at each flowrate.

Note 3 to entry: Relative linearity is the range of values divided by a specified value, e.g. the independent linearity as defined in ISO 11631.

3.1.9
lubricity
liquid property which affects friction between moving surfaces

Note 1 to entry: Good lubricity allows the formation of a liquid film between surfaces, and thereby reduces friction. Poor lubricity, where little or no film is formed, can result in accelerated component wear.

3.1.10
meter factor
ratio of the quantity indicated by the reference standard and the quantity indicated by the meter

3.1.11
performance indicator
derived value which may be used to indicate the performance of the meter

EXAMPLE Error, K-factor, or meter factor.

3.1.12
proving
calibration (3.1.3) with comparison to defined acceptance criteria

Note 1 to entry: Proving is a term 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, regulation or procedures providing a determination of the errors of a meter and showing (proving) it performs to defined acceptance criteria.

3.1.13
pulse interpolation
means of increasing the effective resolution of the pulses output from a meter by multiplying the pulse frequency or measuring the fraction of a pulse associated with the total collected across a time period

Note 1 to entry: The latter is the most common method through a double timing technique.

3.1.14
range
measuring range
set of values of flowrate for which the *error* (3.1.5) of a measuring instrument (flowmeter) is intended to lie within specified limits

[SOURCE: ISO Guide 99:1993]

3.1.15
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, e.g. mean, minimum or other calculated value.

3.1.16
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 imply 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. Some standards suggest dividing by the minimum value.

[SOURCE: ISO/IEC Guide 99:2007, 2.21, modified]

3.1.17
slip
measure of the fluid which passes through the meter without being directly measured

3.1.17.1
dynamic slip
slip measured when the meter is rotating

3.1.17.2
static slip
slip measured when the meter is not rotating

3.1.18
standard conditions
conditions 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: Quantities expressed at standard conditions are shown by prefixing the volume unit by “S”, e.g. 4 Sm^3 or 700 kg/Sm^3.

Note 4 to entry: Definition has been adapted from Energy Institute HM 0 and OIML R 117. Some other petroleum standards employ the term “base” conditions.

Note 5 to entry: In some other documents, “standard” conditions are described as “base” conditions and, incorrectly, as “reference” conditions. Reference conditions are conditions of use (influence quantities) prescribed for testing the performance of a measuring instrument.

[SOURCE: ISO Guide 99:1993]

3.1.19
swirl
condition where the liquid flowing through a pipeline rotates with an associated high tangential component of velocity relative to the axial component

3.1.20
uncertainty
non-negative parameter characterizing the dispersion of the quantity values attributed to a measurand based on the information used

[SOURCE: ISO/IEC Guide 99:2007, 2.26, modified]

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.

3.2 Symbols and abbreviated terms

For the purposes of this document, the symbols given in ISO 4006 and ISO/IEC Guide 99 apply.

NOTE The preferred unit for kinematic viscosity is metre 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.

4 Design and operation of positive displacement meters

4.1 Basic characteristics and mode of operation

Positive displacement (PD) flowmeters, as the name implies, are devices which continuously divide the flowing stream into volumetric segments, and momentarily isolate these segments for measurement purposes. The total of the volumes contained within the segments as the meter rotates over a period of time is the total volume passed. The frequency at which the segments pass is a measure of the volume flowrate. PD meters are driven by the flow, and it is the pressure drop across the meter internals that creates a hydraulic imbalance which causes rotation.

All PD meters can be considered as possessing three basic elements: the external housing, the metering element and the output shaft. The housing can be of single-case or double-case construction. The external housing contains the fluid, and is designed to suit the operating conditions of temperature and pressure. A double-case design minimizes the effect of pressure expansion on the outer external housing by having a secondary internal housing around the metering element. The measuring unit is a precise component (or series of components), which performs the liquid segmentation and comprises a chamber and displacement mechanism. The cyclic volume displaced is a function of the number of chambers or the precise design of the volume being swept by rotation or reciprocation.

The metering chamber (and the associated readout registers) is often sealed to prevent tampering and fraud. Widespread type approval for trade use by relevant authorities is more common with PD meters than most other types of flowmeter.

The output shaft is used to drive mechanical or electrical (pulsed) outputs. This could be a direct drive to a pulse generator or through a gear box to a mechanical readout. Various calibration devices and drives to compensators and printers can be attached. Some designs might have electronic pickups fitted to detect rotation through the meter casing, thus, avoiding shaft seals.

PD meters can be subdivided into five classes, based on the type of motion:

a) reciprocating motion (single and multiple pistons);

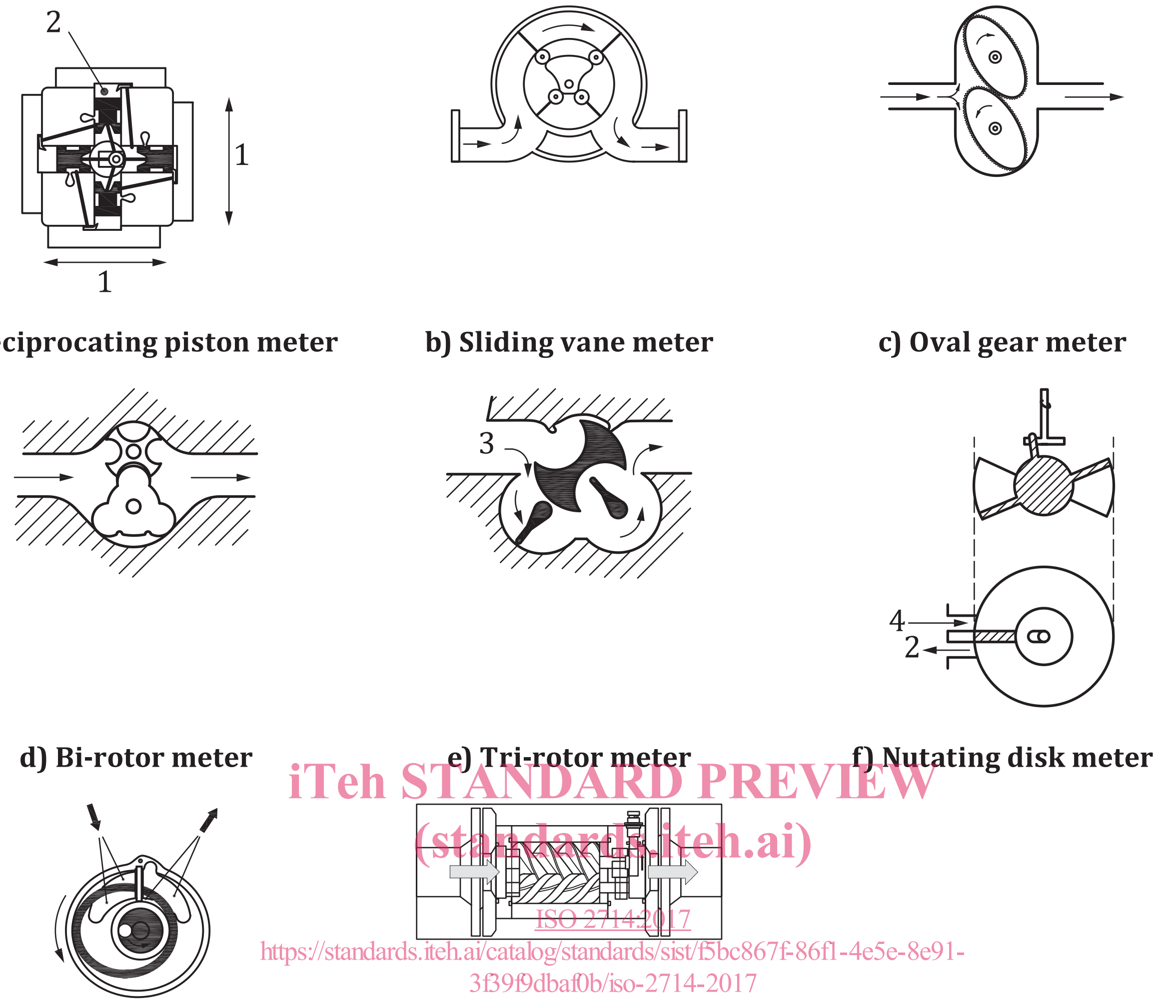
b) rotating motion (vanes and gear types);

c) oscillating motion (semi-rotary types);

d) nutating motion (disc types);

e) intermeshing screw type.

Eight of the more common types are shown in Figure 1.



a) Reciprocating piston meter b) Sliding vane meter c) Oval gear meter

d) Bi-rotor meter e) Tri-rotor meter f) Nutating disk meter

g) Oscillating piston meter h) Screw (spindle) meter

Key

1 pistons slide
2 outlet
3 flow
4 inlet

Figure 1 — Eight common types of displacement flowmeter

More details of the basic components of one of these, the sliding vane type, are shown in Figure 2.

Although the means for separating and counting the liquid pockets are many and varied, the whole group possesses similar basic characteristics. The performance indicator is usually given in terms of meter error, meter factor or meter K-factor as a function of volumetric flowrate or Reynolds number. A general performance curve is shown in Figure 3 for a small rotary device to illustrate the basic performance.

At low flowrates, the metering mechanism has to overcome frictional resistance before motion commences and, as a result, liquid slip may be significant. As flowrate increases, the percentage of slip diminishes and metering error reduces. Certain designs, when operated within controlled conditions, have measurement uncertainties, which are comparable with the method of proving in the laboratory or in the field, and a full assessment of actual potential performance cannot be realized.

The pressure drop follows a classical relationship, increasing with the square of the flowrate when the flow regime is turbulent, and linearly proportional when the flow regime is laminar.

In certain applications, component wear (and hence slip) can be accelerated by excessive pressure drop. This might increase linearity at low flowrates, particularly if gear trains and other drag producing components are fitted and are in poor condition. Most modern designs use shaft encoders or pulse generators to enable the meter to resolve smaller volumes with reduced frictional loading. Such devices have shown that some designs are capable of very low repeatability specifications even in the non-linear region at the lower end of the measurement range. This allows these meters to be used as master meters, transfer standards or custody transfer devices for the bulk shipment of high value liquids such as refined hydrocarbons.

4.2 Reciprocating displacement types

In this class of PD meter, the measuring element is a piston (or series of pistons arranged in a line or radially) that drives a common crank connected to the output shaft. The crank synchronizes the movement of the pistons. Slide or rotary valves allow liquid to alternately fill and exhaust from the measuring cylinders. In other designs, ports in the cylinder walls are used instead of valves. These are covered and uncovered in sequence by the reciprocating motion of the pistons.

The volume measured in one cycle is the product of piston stroke, cylinder area, and the number of pistons. This volume may be adjusted by altering the stroke length, but more usually, by adjusting the readout mechanism driven from the crank. Good sealing is essential through fine tolerances or appropriate ring seals. Frictional effects can increase if sealing is too tight. Where high viscosity liquids are metered, drag on the metering elements might result in increased pressure drop.

4.3 Rotating displacement types

In this group are found the majority of PD meter types used for metering hydrocarbons. The two basic designs are vane and gear types.

The major elements of a vane type are shown in Figure 2. There is a cylindrical rotor mounted within a profiled body. The rotor assembly carries vanes (usually four or five) so that they slide freely within slots machined within the assembly. The proximity of the rotor assembly and the vanes to the outer casing causes a good seal during motion through the measuring crescent. The radius of this section is constant, so the liquid trapped between the inlet and outlet porting is maintained at constant volume. An output shaft connected to the rotor assembly drives the volume registration equipment. The performance is usually de-rated (in flowrate terms) with dry (non-lubricating) or with abrasive liquids to avoid component wear.

