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Liquid hydrocarbons — Volumetric measurement by turbine flowmeter

Hydrocarbures liquides — Mesurage volumétrique au moyen de compteurs à turbine

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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 2715:1981), which has been technically revised.

Introduction

This document gives recommendations on the design, installation, operation and maintenance of turbine metering 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.

Turbine meters for liquids 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 and non-hydrocarbon liquids.

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 turbine flowmeters.

Liquid hydrocarbons — Volumetric measurement by turbine flowmeter

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 turbine flowmeters. Attention is given to the factors to be considered in the application of turbine 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 turbine meters in the metering of two-component liquid mixtures 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 and 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 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

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 Terms and definitions

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 causes 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 will remain for a considerable distance downstream of the meter even if pressure recovers.

3.1.7
flow conditioner
flow straightener
device installed upstream of a turbine meter to reduce swirl and velocity profile distortions

3.1.8
K-factor
ratio of the number of pulses obtained from a meter, and the quantity passed through the meter

3.1.9
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.

3.1.10
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.

3.1.11
meter factor
ratio of the quantity indicated by the reference standard and the quantity indicated by the meter

3.1.12
performance indicator
derived value which may be used to indicate the performance of the meter

EXAMPLE Error, K-factor, or meter factor.

3.1.13
proving
calibration 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.

3.1.14
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.

3.1.15
range
measuring range
set of values of flowrate for which the error of a measuring instrument (flowmeter) is intended to lie within specified limits

[SOURCE: ISO Guide 99:1993]

3.1.16
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.

3.1.17
repeatability
a
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]

3.1.18
slip
measure of the fluid which passes through the meter without being directly measured

3.1.18.1
dynamic slip
slip measured when the meter is rotating

3.1.18.2
static slip
slip measured when the meter is not rotating

3.1.19
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]

3.1.20
swirl
condition where the liquid flowing through a pipeline rotates with an associated high tangential component of velocity relative to the axial component

3.1.21
uncertainty
non-negative parameter characterizing the dispersion of the quantity values attributed to a measurand based on the information used

Note 1 to entry: 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.

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

3.1.22
velocity profile distortion
deviation from a fully developed velocity profile within a pipeline

3.2 Symbols and units

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 turbine flowmeters

4.1 Basic characteristics and mode of operation

An axial-flow turbine meter comprises a meter body, normally a section of pipe, containing a free-running rotor assembly mounted on an axial central shaft. The shaft is supported on bearings held within hanger assemblies, which align the rotor centrally within the meter body and parallel to the direction of the flow.

The rotor is fitted with multiple straight or curved blades positioned round the rotor and extending outward to the body wall, minimizing blade tip clearance. It is the action of the flowing liquid on the blades which causes rotation of the rotor at a speed proportional to the fluid velocity.

Although rotor speed is proportional to fluid velocity, it is normal to relate rotor speed to volumetric flowrate.

Rotor design varies widely with 2 to 20, or more, blades fitted. These can be straight and angled to the flow, contoured, or helically cut covering up to 180° circumference.

Some designs have a ring around the outside of the blade tips (rimmed rotor).

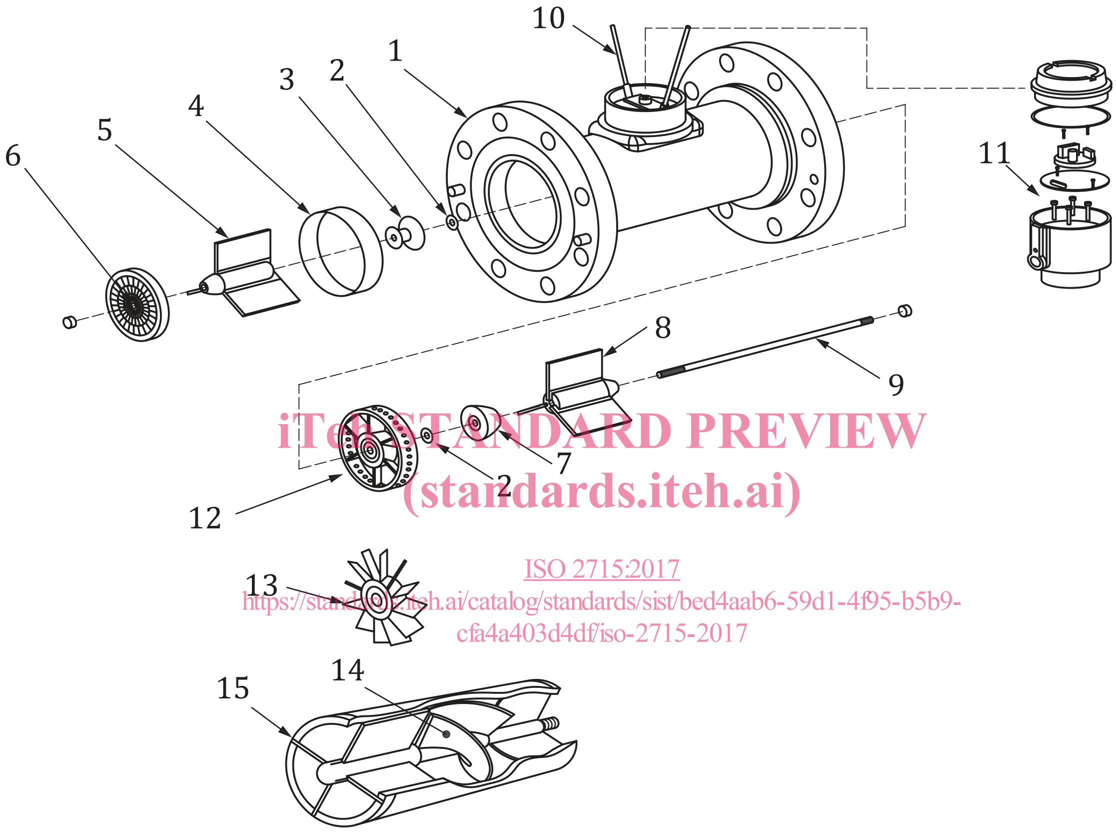
The bearings can be journal or ball bearing type, and chosen to suit the liquid and application. The bearings are housed in the upstream and downstream hangers. Thrust bearings take the force generated by the flow. Many designs have hydro-dynamically designed cones upstream and downstream of the rotor, allowing the rotor to "float" between the bearings, hence, minimizing drag and wear.

Hangers can be flat plates or tube bundles, aligned to the flow direction, and secured to the body. They can assist in conditioning the flow.

The body is a piece of pipe which contains the pressure of the liquid. To provide ease of assembly, and to minimize the pressure effect on the measuring section, a double-case construction can be used, where the rotor is enclosed in a second internal housing. Some designs have such a construction as a replaceable “cartridge” containing the rotor and components, allowing a meter to be pre-calibrated in one body, then used in another.

A further modification allows such a construction to provide a reduced diameter for the rotor assembly through the use of carefully designed cones. This increases the velocity of the fluid in the meter, potentially improving the measurement range.

The major components of typical designs are shown in Figure 1.



Key

1 meter body
2 thrust washer
3 upstream cone
4 deflector ring
5 upstream hanger
6 optional flow conditioner (plate/tubes)
7 downstream cone
8 downstream hanger
9 shaft
10 pick-ups A and B
11 head pre-amplifier
12 rimmed rotor
13 bladed rotor
14 helical bladed rotor
15 cartridge insert

Figure 1 — Components of a turbine meter

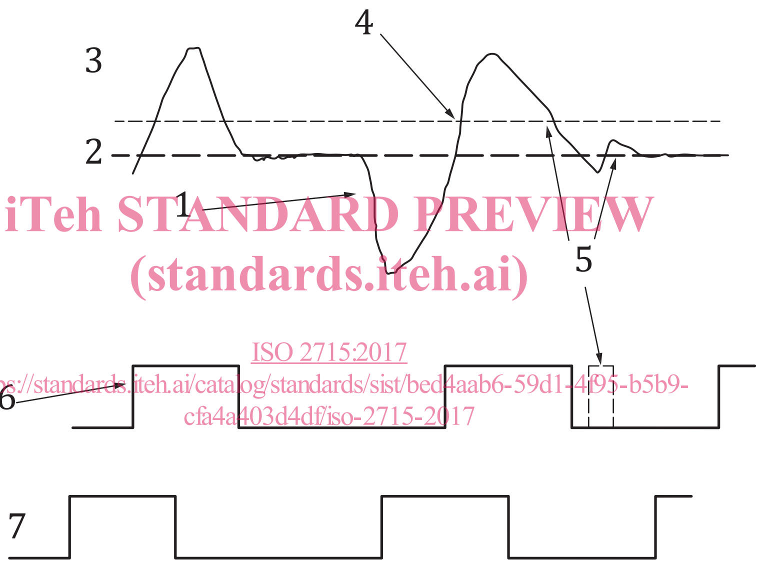
4.2 Output signal

The meter output is in the form of electrical pulses generated by a sensor located in the body wall. This detects the rotation of the rotor through inductive, magnetic, or radio-frequency sensing of the blade tip passage. Alternatively, a rimmed rotor ring can carry magnetic markers or slots, which allow a higher pulse output resolution. More novel detection methods are possible, such as optical sensors.

Pick-ups are normally located in a fitting on the pipe wall, and can sense the rotor through the wall, ensuring pressure integrity of the body. As the sensing is through the wall, it is vital that the pick-up is fully inserted into the fitting, as an increased distance from the pipe wall will lead to a reduced amplitude signal.

By using magnetic/inductive sensing, the signal is generally a modified sine wave with an amplitude, which increases with speed of the rotor. Generally, the amplitude of the pulses is in the range between 10 mV and 1 V, depending on speed and design. Care should be taken to ensure that the detection of pulses allows for this change in amplitude with speed and to avoid the danger of missing pulses at low flowrates or double counting as the amplitude rises. A typical signal is shown in Figure 2.

Pulse output frequency varies with flowrate, but also with rotor design. Straight-bladed turbines normally operate at a maximum frequency of 10 kHz, while helical rotors with two blades operate with a significantly lower frequency output. A low frequency gives rise to issues regarding electronic noise filtering and also a low resolution, especially when proving.



Key

1 typical raw signal from magnetic pick up
2 zero volts
3 maximum voltage increasing with frequency (e.g. 10 mV to 200 mV)
4 pulse counter trigger threshold
5 potential for noise pick up and false pulses
6 amplified signal
7 amplified output from second pick-up

Figure 2 — Typical pulse output signal

Each generated pulse can be related to the passage of a quantity of liquid and, hence, the primary output parameter describing the meter performance indicator is K-factor, expressed as pulses per unit volume.

Where security of measurement is important or a regulatory requirement, the meter pulse pick-up can be sealed, and in some cases, the meter body and associated pipework can also be sealed to prevent misalignment. Two pick-ups are installed for fiscal meters, allowing integrity of pulse counting to be ensured. Suitable spacing of the pick-ups allows direction sensing.

A pre-amplifier can be installed at the meter to provide amplified and square-edged pulses for transmission. Proprietary pre-amplifiers are available from manufacturers to match the potential signal amplitudes, frequencies, and pulse shape from their design. The amplifier may incorporate a digital to analogue converter, allowing a 4 mA to 20 mA signal to be transmitted. However, this would

