INTERNATIONAL STANDARD

ISO 2714

Second edition
2017-11

Liquid hydrocarbons — Volumetric measurement by displacement meter

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

Reference number
ISO 2714:2017(E)

Contents

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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);

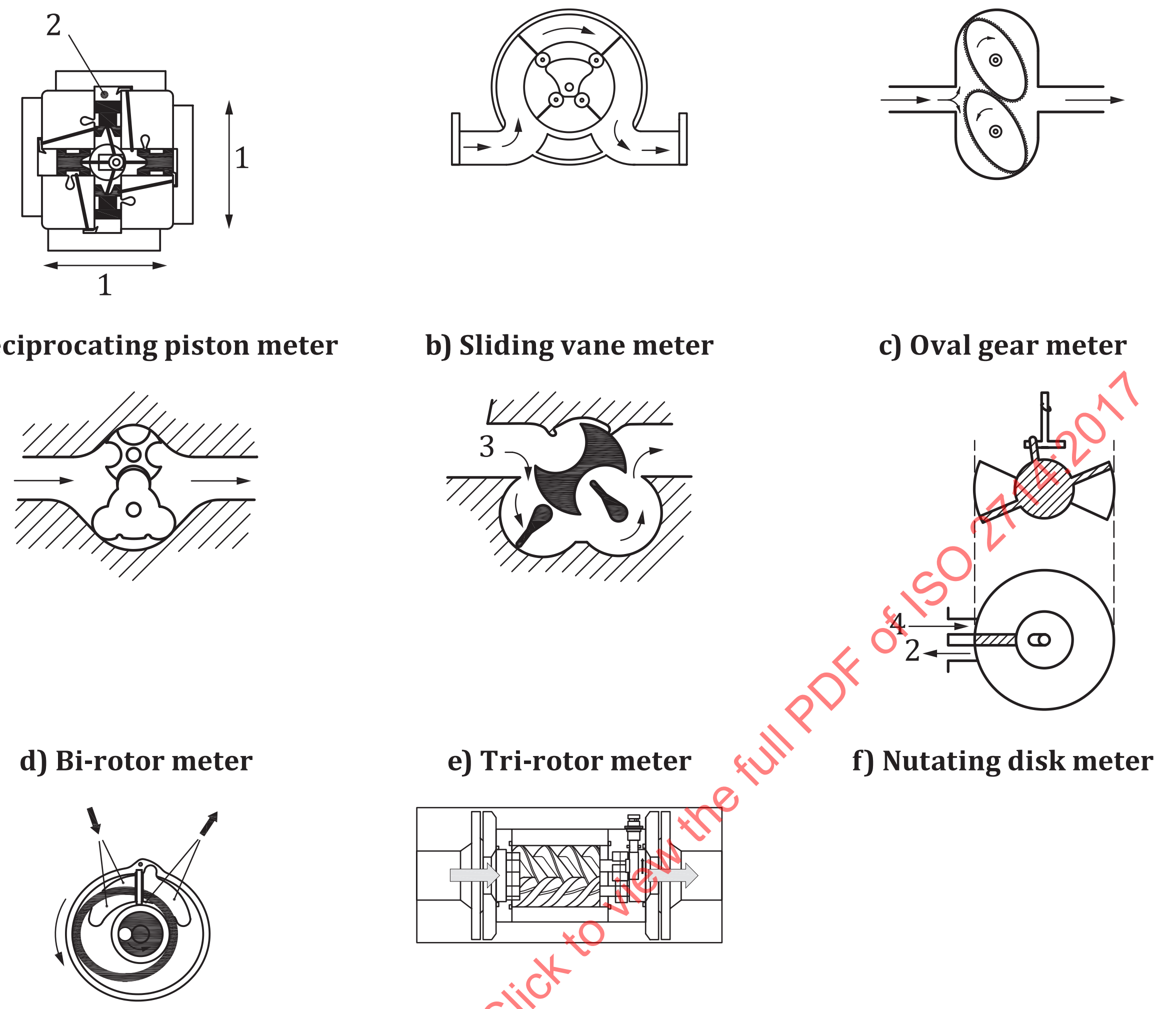
b) rotating motion (vanes and gear types);

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

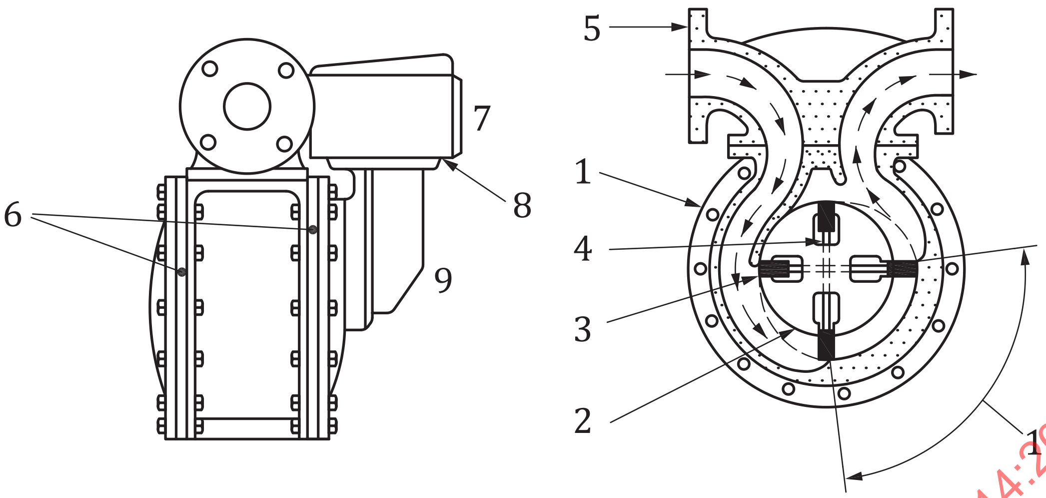
In this class of PD meter, the measuring element is a piston (or series of pistons arranged in a line or radially) that drives a common crank connected to the output shaft. The crank synchronizes the movement of the pistons. Slide or rotary valves allow liquid to alternately fill and exhaust from the 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.



Key

1 outer casing
2 rotor
3 vanes
4 coupling rod
5 inlet manifold
6 outer covers
7 register or indicator
8 counter
9 gear box, calibrator and pulse generator
10 measuring crescent

Figure 2 — Details of a typical vane type PD meter

The other concept is the gear meter, of which there are many designs. One common basic design is the oval gear meter. This design consists of two oval shaped rotors, which are forced to contra-rotate. This is driven by the flow created by the pressure on the inlet. The close fit between the inter-meshing rotors and the measuring chamber walls traps discrete liquid volumes, which are then continually discharged through the outlet port.

Helical gear meters are design variants where the two rotors mesh in the longitudinal plane. They are more commonly used on more viscous products. Because the sealing surfaces are relatively long, they are more susceptible to over-speed and bearing damage.

Also in this group are the bi-rotor and tri-rotor meters, which are a combination of the vane and gear types. Two or three synchronized rotors revolve within the chamber, again, trapping liquid in discrete pockets. Each rotor shaft carries a timing gear, and each of the bladed displacement rotors moves alternately through the measuring chamber half cylinder bores. In the tri-rotor design, the single blocking rotor produces a continuous capillary seal between inlet and outlet, forcing the liquid to flow through the measuring section. The blocking rotor is geared to revolve at half the speed of the displacement elements.

4.4 Intermeshing screw spindle type

Screw-type meters consist of an axial mounted screw element with a second intermeshing screw creating the sealed measured volume(s) and seal. Liquid trapped between the screw elements is transferred from the inlet to outlet as the screws rotate.

Traditionally, this type of meter was restricted to high viscosity, low accuracy applications. More specialized designs are now available with excellent performance, even in low viscosity liquids, and perform well in custody transfer applications. These precision-made (spindle type) devices are used as master meters due to the excellent linear performance comparable with that of the other common types of PD meters.

4.5 Oscillating displacement types

The semi-rotary or oscillating piston meter, Figure 1 g), is one of the most widely used PD meters in low accuracy process applications. Typical applications include any clean non-abrasive liquids where flow measurement range is not important and where low flowrates are not involved. These meters tend to exhibit increased slip as both viscosity and flowrate decrease. The metering piston is constrained by the chamber wall, the barrier plate and the central boss, so that it moves in an oscillatory manner, sweeping liquid from inlet to outlet during the cycle. They are better suited to viscosity applications in excess of 100 mm^2/s, and also to cryogenic applications, where they tend to be used in customized measurement systems.

4.6 Disc type meters

This type of meter is generally applicable to clean, non-abrasive liquids. The operating principle is shown in Figure 1 f). The metering disc is mounted within the casing, but is constrained from pure rotation by a radical partition attached to the measuring chamber wall. It does, however, swivel about its vertical axis, with the incoming liquid alternately filling the spaces above and below the disc. The pressure differential causes the metering element to nutate (wobble), and a central drive pin mounted on the upper surface of the disc transfers this movement into rotary motion to drive the meter register.

5 Performance aspects

5.1 General

This clause discusses the general performance of displacement meters and the various factors which can affect the characteristic curve. Performance is normally stated in terms of variation in performance indicator as function of volumetric flowrate through the meter. The performance indicator is usually meter factor. However, error and K-factor are also used.

Meters can have a single value determined and applied across the flowrange, or a number of values determined across the range and by appropriate interpolation applied to the operating flowrate.

5.2 Factors affecting meter performance

The performance of displacement meters is affected by a number of variables, depending on the metering element design and the geometry of body and measuring chambers. The most important are:

a) liquid flowrate;

b) liquid viscosity;

c) liquid temperature;

d) liquid pressure and pressure drop through the meter;

e) meter construction and metering element design;

f) lubricating properties of the liquid;

g) debris and deposits;

h) wear characteristics affecting clearances between key components;

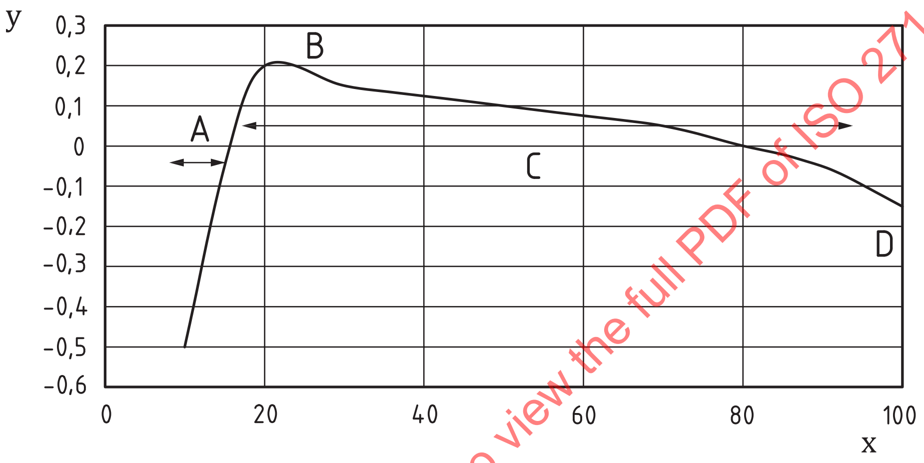
i) secondary components, e.g. solids or gases.

5.3 General performance characteristics

While displacement meters are supplied with a nominal meter factor and performance characteristic, to achieve accurate measurement, all displacement meters would need calibration. This establishes the meter factor and general performance characteristics such as the sensor output signal and pressure drop. Typical characteristics of the variation in error as a function of flowrate through the meter for low viscosity hydrocarbon usage are shown in Figure 3. The error curve can be divided into distinct parts.

The length of the linear portion of this curve depends primarily on meter size, metering element design and liquid viscosity. If the meter is sized and operated within this portion of its measurement range, the use of an arithmetic or weighted mean value of the meter factor (or K-factor) would cause only a small additional measurement error. This practice can be acceptable in situations where the flowrate is fairly constant for extended periods, such as in pipeline operations.

As flowrate decreases, the value of the meter factor (error or K-factor) changes sharply. At very low flowrates, the retarding torque overcomes the driving torque and the rotor stops, even though a very small flow is still slipping through the meter clearances. This is evident for low viscosity fluids, e.g. gasoline, where the low liquid viscosity reduces the measurement range, as well as affecting the meter factor.



Key

A low flow; high slip; negative error

B almost no slip

C linear operating range

D increased pressure loss and friction; higher slip

x flowrate (% of full measurement range)

y error (%)

NOTE This is a typical performance curve, with representative error given as percentage error. It might not represent any particular meter or type. The meter characteristics show a general bias of +0,05 % error.

Figure 3 — General performance curve for PD meter

Meter performance can be significantly affected by liquid viscosity. Increasing the viscosity reduces slippage and so improve low flow performance, but at high flowrates, higher viscosities cause an increase in pressure drop, hence internal forces on the meter, which might cause damage to the internal mechanism. Increasing the clearances within the meter could allow better performance for high viscosity fluids. However, it would create unacceptable leakage if the meter is then used for low viscosity liquids.

Generally, a measurement range of 10:1 can be achieved within a linearity band of 0,2 % for fluids with viscosity less than 20 cSt. However, this might reduce to 2:1 for higher viscosity liquids. Using a meter in the non-linear portion of the measurement range might be invalid, since the non-repeatability, which is present in this portion of the characteristic, causes unacceptable errors.

An assessment of meter performance can best be made through calibration at different viscosities and subsequent use of a meter control chart (see ISO 4124) to record performance with time and fluid. The control chart plots successive meter factors (or meter K-factors) obtained on a given liquid over a period of time and calibrations. It enables change in meter factor (or meter K-factor) to be identified over short or long periods, and gives confidence in the reproducibility of the meter. Further guidance is given in 11.4.

5.4 Pressure drop and back pressure considerations

Pressure drop and outlet pressure are both important to meter linearity. The pressure drop through the meter is proportional to the square of the flowrate when the meter is operated in the turbulent flow regime. The pressure drop is, however, proportional to flowrate when the meter operates in the laminar flow regime (at low velocity and/or in high viscosity fluid). For a constant inlet pressure, there is a maximum flowrate at which a PD meter can be operated within acceptable error limits before performance deteriorates. Pressure drop below that of the vapour pressure of the liquid could allow cavitation or flashing of the fluid to occur locally within the meter or at the outlet. Adequate performance might require a higher operating pressure than that dictated by overall pressure drop considerations to ensure this does not occur.

It is difficult to provide firm guidelines on back pressure requirements, as they are dependent on the fluid, the meter design, and the speed of flow and rotor. Low pressure in the metering chambers, cavitation, or flashing causes significant measurement error and might damage the meter. Their occurrence can be indicated by cavitation noise and a sharp change in the value of the meter factor.

5.5 Flow profile

In general, due to the nature of a positive displacement meter physically interrupting the flow, these meters are mostly unaffected by the flow profile entering the meter. It is prudent, however, to avoid extremes of flow disturbance to the profile entering the meters.

6 Liquid property effects

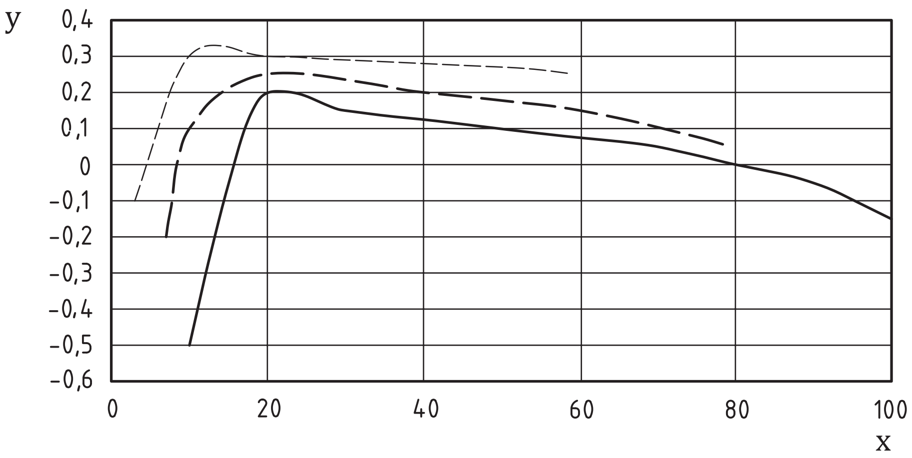
6.1 General

This clause discusses the more important liquid property effects. The performance of any meter is likely to change as the liquid conditions change. To ensure the lowest metering uncertainty, the meter should be proved with a liquid having the same physical properties as the liquid it is intended to measure. If there are differences between the physical properties of the operational liquid and the liquid on which the meter is proved, then changes in meter factor are expected between proving and operation.

6.2 Effect of viscosity

General guidance for the metering of viscous hydrocarbons is given in ISO 9200.

Displacement meters are sensitive to the liquid viscosity, particularly in the smaller sizes, and at low flowrates. Figure 4 shows the basic effect that an increase in viscosity has on a PD meter (this example is for a gear meter). With low viscosity products, the metering errors generally increase due to leakage and slip through the component clearances. This effect becomes more pronounced with decreasing flowrate. Both meter linearity and flow measurement range improve with an increase in viscosity due to added viscous resistance in the clearances between moving parts.



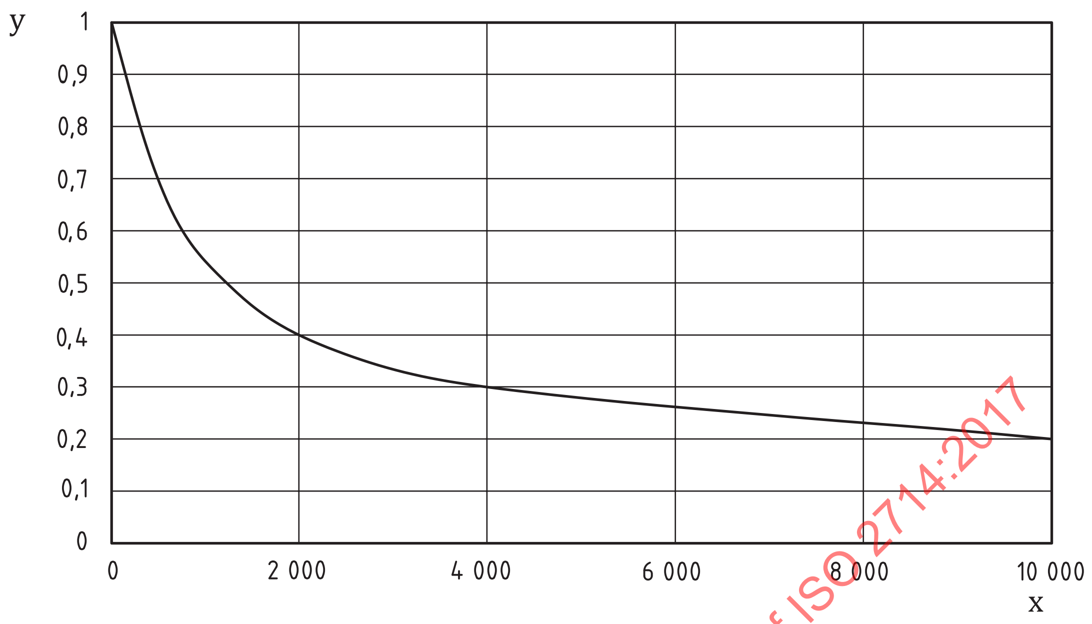
Key

———	low viscosity	x	flowrate (% of full measurement range)
— —	mid viscosity	y	error (%)
- - - -	high viscosity		

Figure 4 — Effect of viscosity on PD meter performance

There is an associated increase in pressure drop, due to shearing effects, with the more viscous products. Meters with larger clearances are sometimes used in these applications. Most manufacturers specify a maximum meter pressure drop, and may de-rate meter capacity as viscosity increases. A typical de-rating curve is shown in Figure 5. The curve is for illustrative purposes, as each meter type and design will have a different viscosity range. The maximum flowrate at a low viscosity (e.g. 1 cSt for water) is multiplied by the de-rating factor to give the maximum flowrate at a higher viscosity. The curve shown would move to the right if extra clearance rotors are employed.

Each design of meter has a different viscosity characteristic curve, which is also temperature dependent. It is important to validate the characteristics by proving, and the manufacturer's advice should be sought. Any mathematical corrections should only be applied to individual meters when they are operated within the range of conditions over which they have been calibrated.



Key

x viscosity, cSt

y de-rating factor

Figure 5 — Typical de-rating capacity curve

6.3 Effect of temperature

In addition to the effect on the liquid viscosity, significant changes in liquid temperature can also affect meter performance by causing changes in the physical dimensions of the meter components and/or clearances. The thermal expansion or contraction vary from design to design; so general rules cannot be made. Liquid properties can also change with temperature. Thus, a change in liquid temperature could simultaneously affect meter performance in several different ways by an amount dependent on the materials of construction, the meter design, liquid properties, and the application.

Changes in the physical dimensions of the meter can be estimated from the cubical expansion factor of the materials of construction for the meter casing. This does not fully account for all changes in clearances and friction. Calibrating over the complete range of expected temperatures might allow this effect to be determined directly. Commonly, meters are calibrated at operating temperature, avoiding the need for estimated corrections.

High-temperature trimmed rotors can be used to compensate for the differences in thermal expansion between rotor and housing material to prevent meter seizure.

Jacketing and trace heating might be required to avoid thermal shocks or transients, which can cause the vanes or rotors and the chamber walls to become damaged. A cold fluid within the meter body could have a viscosity above the one which the meter is designed to handle. In extreme cases, the fluid might solidify or turn to wax. Positive displacement meters should, therefore, be started and run at low speed when starting up. It might be necessary to heat the meter body before starting the flow.

It is important to ensure temperature equilibrium exists within the meter prior to calibration.

Temperature effects on the liquid being metered are discussed in Clause 7.

6.4 Effect of pressure

For single-case meters, if there are large variations in pressure, particularly between the proving pressure and the operating pressure, then the actual meter dimensions might also change. Pressure can expand the volume of the housing, changing the displaced volume and the metering element clearances. For double-case designs, this does not apply. Meter dimensional changes can be estimated from the mechanical properties of the materials of construction. For high-accuracy applications, where large pressure changes occur, the meter should be proved over the expected range of operating conditions. Pressure effects on the liquid being metered are discussed in Clause 7.

6.5 Lubricity and liquid cleanliness

The lubricity of the liquid (see 3.1.10) can affect meter linearity, measurement range, repeatability and reproducibility. With dry liquids (such as LPG), friction between moving surfaces can be large, as the liquid film, normally present with oils and similar liquids, is absent. Therefore, accelerated wear, increased friction, and more leakage can be present with non-lubricating liquids. Similarly, the presence of solid particles can also accelerate component wear, increase friction and, in extreme cases, block the meter. This occurs when particles become trapped between moving components and the meter seizes. Attention should be paid to the lubricating nature of the liquid and the presence of particles, since these can affect the choice of metering element and materials of construction.

Adequate filtration should normally be provided upstream of the meter so that critical dimensions and components are not affected through abrasion or mechanical damage from solid particles. However, this depends on the application. Failure to protect in this manner can result in meter seizure, effectively stopping the flow. The strainer should be positioned upstream of the air eliminator and a check should be made of any local regulations that apply.

6.6 Two-phase flow and air elimination

Two-phase flow covers the presence of gas in the liquid, or solids in the liquid. Both have an effect on the performance and life of the meter.

All displacement meters are affected by the presence of gas in the flow. This can be a situation where gas is entrained in the fluid entering the meter, or be due to gas flashing from the liquid due to a pressure drop within the meter or in an upstream component, such as a filter.

The presence of gas has an unpredictable effect on the error, and can cause damage to the meter, particularly, if there are "slugs" of free gas entering the meter. This document covers the use of meters for single-phase liquid metering only; hence, any gas should be removed before entering the meter through the use of gas separators or eliminators. Flashing should be avoided by raising the system pressure or reducing pressure loss.

Note The requirement to install gas separators or eliminators can be a mandatory or legal requirement for some applications.

Displacement meters are sensitive to the presence of solid particles such as pipeline rouge, scale, and other particulate matter. These can cause wear to be accelerated. Such effects lead to the loss of meter linearity, an increase in non-repeatability, or possibly both effects together.

6.7 Two-component operation

Two-component operation (e.g. oil and water) might be possible, but care should be exercised to avoid significant viscosity influences. When light oils and water mix, the resulting viscosity of the emulsion formed can be quite different from that of the individual component viscosities. In such cases, proving at operating conditions is strongly recommended. The presence of water in the mixture can also promote corrosion of key surfaces or components within the meter. Regular inspections are recommended in these cases. The operating nature of PD meters does not permit liquid component differentiation; so water content cannot be determined directly.

6.8 Pulsating and fluctuating flow

Pulsations in the flowing fluid can affect the performance of a displacement meter. The extent to which this affects the meter is dependent on the amplitude and frequency of the fluctuation, and the interaction with the particular meter design. Extreme pulsation or fluctuation can damage the meter, or cause measurement errors if a "harmonic" frequency is experienced.

By their nature, displacement meters introduce pulsations to the flowing fluid, and this should be recognized particularly if used as reference flowmeters to calibrate other devices.

7 System design

7.1 Design considerations

The installation should be capable of handling the complete range of flow rates (minimum to maximum), the maximum working pressure over the decided temperature range, and the liquid (or range of different liquids) to be measured. Protective devices should be installed where necessary to ensure the meter operates within design limits. Where a large flow measurement range is required, meters should be installed in parallel. The installation should provide facilities for the proving of each meter (see Clause 10). Where reliability is important, the meter system design often includes a spare or standby meter run.

The installation should be designed to ensure maximum and reliable operating life. Filters, strainers, vapour/air eliminators or other devices should be provided upstream of the meter so that any debris or vapours which are present do not affect volumetric measurement uncertainty. The system operating pressure should be adequate to ensure that the liquid being metered will be in the liquid state at all times.

If the installation operates with flow in both directions, ancillary equipment, such as filters, need to be installed at both ends of the metering section. All materials of construction in contact with the liquid(s) should neither be affected by, nor affect, the metered liquid(s).

Factors which should be considered at the design stage are listed in Table 1. These parameters are not in order of importance, but are for general guidance only.

Table 1 — Factors affecting the selection of displacement meter type

	Category	Items for consideration
1	Performance considerations	Desired level of overall performance Desired level of linearity Desired level of repeatability/reproducibility Range of operating flowrates Maximum pressure drop allowed Response time Output characteristics
2	Installation considerations	Pipework orientation Line size Provision of ancillaries Presence of pulsation/vibration Location access for servicing Electrical power and connection requirements
3	Liquid property considerations	Pressure range Temperature and viscosity range Lubricity Compressibility effects Liquid abrasiveness Corrosive nature Presence of other phases
4	Environmental considerations	Ambient temperature effects Effect of humidity Electrical interference Presence of hazardous atmospheres External corrosive effects

7.2 Selection of displacement meter type

The type of displacement meter should meet the defined performance criteria over the range of flows and liquid property changes. Each of the conditions listed in Table 1 should be addressed. Any or all of these can influence the performance of the meter system. The meter manufacturer's advice should be sought to ensure the correct selection of metering element design, bearing material, pulse generating and collection system, flange rating, etc. In addition, the following factors should be considered:

a) operating flowrate, uni-directional or bi-directional, continuous, intermittent or fluctuating;

b) fidelity and security of pulse data transmission systems (see ISO 6551);

c) existing space and method by which a bank of meters can be put online, or taken offline;

d) the method used to prove that meter is *in situ* or by removal;

e) the signal amplification and conditioning system;

f) the use of automatic temperature, viscosity and flowrate compensation equipment;

g) types of readout, computer or print devices to be used;

h) meter readout or pulse generator resolution for measurement and calibration.

Experience has shown that certain types of displacement meter are selected based on the liquid type. For example, in low viscosity service, where low pressure losses are required, the design of the rotating meter selected is usually one with fixed clearances between the rotor blade tips and the body housing. This is operationally robust with lower maintenance costs. Where high turndown is required with a low viscosity influence, higher pressure drop meters with carbon vane tips are preferred. These could be subject to higher wear on the vanes or more prone to damage from effects such as pipeline scale.

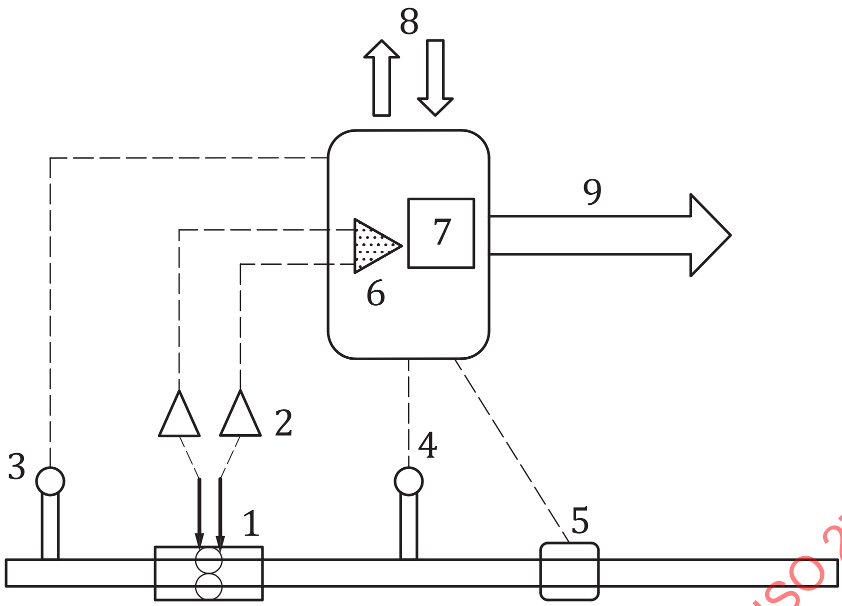
For higher viscosity duties, the choice of meter can be influenced by the viscosity of the oil when starting the meter. Oils, which are semi-solid at ambient temperatures, can cause damage to vanes or blades when the flow is stationary. In such applications, oval gear or bi-rotor design might be more applicable. For the highest performance, however, a sliding vane type meter is preferred.

7.3 Ancillary equipment

7.3.1 General

There is a large selection of ancillary equipment which can be used with displacement meters. Some of these are shown in Figure 6. Computers and controllers enable on-site monitoring, on-line computation to the required reference conditions and system control, thereby removing most human errors and allowing online compensation to be performed effectively and economically. Special consideration should be given to secondary equipment to prevent difficulties arising from environmental, layout and electrical incompatibility effects. Ancillary equipment is installed to meet the requirements of the application and installation.

Environmental considerations include electrical safety, weather-proofing, corrosion protection, and the change in ambient temperature. Layout considerations include stand-by power supplies, alternative or back-up devices, and access for maintenance. Electrical compatibility includes all devices and cabling associated with the displacement meter, particularly the input/output characteristics of all elements in the data transmission/reading system.



Key

1 two sensors on flowmeter
2 amplifiers
3 pressure sensor
4 temperature sensor
5 densitometer
6 pulse comparator circuit
7 flow computer
8 input and output to flow control valves and meter prover
9 output: flowrate, total volume, standard volume, and mass; transmission to storage, displays, printers and reporting

Figure 6 — Electronic ancillary equipment for use with displacement meters

7.3.2 Mechanical accessories

Displacement meters are available with a wide range of mechanical accessories. These include readout devices and counters, both resettable and non-resettable, mechanical compensators and gear boxes that change readout units. The output shaft may also drive pulse generators. Gear boxes and mechanical compensators are normally installed between the rotor assembly and the readout device. The shaft encoder or pulse generator is best installed directly onto the output shaft so that the pulse train generated can be directly fed into the secondary electronics for compensation and processing. If electronic processing is unavailable, the pulse generator may be fitted after the meter gearbox and mechanical calibrator.

7.3.3 Pulse generators and secondary electronic instrumentation

Pulse generators are commonly employed on many designs of displacement meters, to provide an output signal to the counter. There are many types, but the method of attachment should be carefully noted. A major source of error experienced in using reference meters has been the position of the pulse generator in the system. Many manufacturers attach the pulse generator onto secondary shafts geared to the main rotor shaft. This usually results in poor short-term repeatability due to backlash in the output gear train. For high-resolution operations, the pulse generator should be directly attached to the main rotor shaft without gearing. The positioning of a pulse generator after a non-continuous calibrator mechanism should be avoided.

The output shaft of some meters (e.g. oval gear meters) does not rotate at constant angular velocity at constant flowrate. This could also apply to other types, where the output shaft is connected to external gears. This can lead to high degrees of both inter and intra rotational non-linearity, which give high repeatability problems when used with pulse interpolation, and if inadequate number of complete metering element rotations or cycles are used for measurement or calibration. In extreme cases, this variation can give rise to false flowrate indications or fluctuations, particularly at low flowrates. Careful design of the pulse generator or drive connections might be required.

On some types of displacement meter, it is preferable to use low torque devices or optical encoders. This reduces drag, hence, improves the measurement range and linearity of the meter. Other types of meter might require a positive torque (drag) to be applied by the encoder to improve meter performance and avoid spurious pulses when the flow is stopped or fluctuates. Sometimes, a reed switch can be employed to indicate the complete revolutions to aid in the monitoring of individual pulses during each revolution of the meter. This may be used as an indication but lacks the resolution required for accurate measurement.

Pulse counters range from the simple display of frequency and/or total pulses (or indicated flowrate or total volume based on a single meter factor) through to full flow computers, which can apply "linearization" through the use of multiple meter factor values. By having an input of temperature, these devices can provide temperature correction and calculation of volume at standard conditions. They can also provide batch control functions, control and measure several streams, and control proving operations.

7.4 Flow algorithms

Considerable measurement discrepancies can be introduced into the measurement for trade of hydrocarbons, unless the volume metered is converted to a standard volume at defined (standard) temperature and pressure. Alternatively, the volume can be used to calculate mass using the liquid density. It is recommended that the appropriate conversions be made to minimize this error whenever the liquid volume changes significantly with temperature and pressure, and that the standard volume is clearly defined on any meter documentation. Changes in product volume are sometimes corrected to an accepted standard temperature with automatic temperature compensations. Temperature correction factors are calculated to provide volume correction. A variation in liquid pressure also results in a change in the liquid volume due to compressibility. Compressibility factors can be applied to correct for pressure. Standard conditions and correction factors for hydrocarbons are available from ISO 91 and ISO 9770.

The standard volume through a meter can be determined using Formula (1):

$$V_{ref} = V_m \times MF \times C_{tlm} \times C_{plm} \times C_{tsm} \times C_{psm} \quad (1)$$

where

V_{ref} is the volume at reference (base) conditions;

V_m is the meter registration during a proving or measurement time interval;

MF is the meter factor at line reference conditions, or that obtained from calculation;

C_{tlm} is the correction factor for the liquid temperature;

C_{plm} is the correction factor for pressure on the liquid;

C_{tsm} is the correction factor for the temperature effect on the meter body;

C_{psm} is the correction factor for liquid pressure effect on the meter body.

Corrections for the effect of temperature and pressure on the meter body, C_{tsm} and C_{psm}, although used in some countries, are no longer recommended. These two additional terms are only used when meters are not re-proved when significant changes in temperature and pressure occur between the provings. Local operating practice should be followed to determine which constants are acceptable.

Common methods for calculation and rounding of the calculations should be applied where required. Further guidance is given in ISO 4267-2.

8 Installation aspects

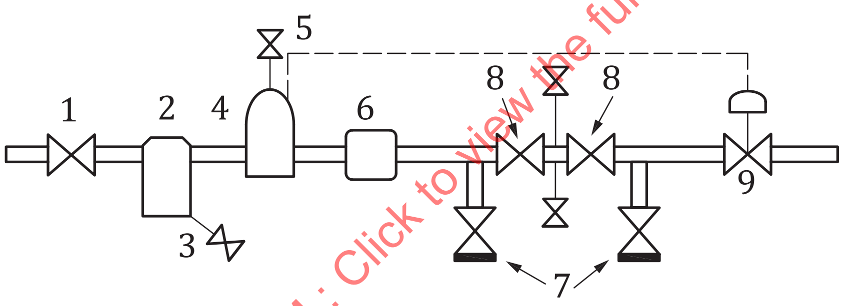
8.1 General

This clause includes details for the installation of metering systems incorporating displacement meters. Due to the mode of operation of physically dividing the flow into discrete pockets, displacement meters are very tolerant of changes in upstream and downstream flow conditions. Meter performance is largely unaffected by velocity profile, swirl and other hydraulic disturbances with the exception of pulsating flow. There are cases, however, where severe swirl can change the impact loading on the metering element and cause changes in clearances between components. In these instances, meter error might increase.

8.2 Installation pipework

The meter should be installed so that it is full of liquid at all times. As most displacement meters are unaffected by flow profile, disturbance due to upstream devices (bends, etc.) generally do not affect the performance. As a result, meter runs can be as short as practical. It is usually acceptable to have devices such as valves, flow controllers, filters or air eliminators mated to the meter inlet and/or outlet flanges without degrading meter performance. It is prudent, however, to allow one to five diameters of upstream pipe to avoid all possibility of a disturbance, allow flexibility to remove components, and provide location for pipe support.

A typical installation is shown in Figure 7.

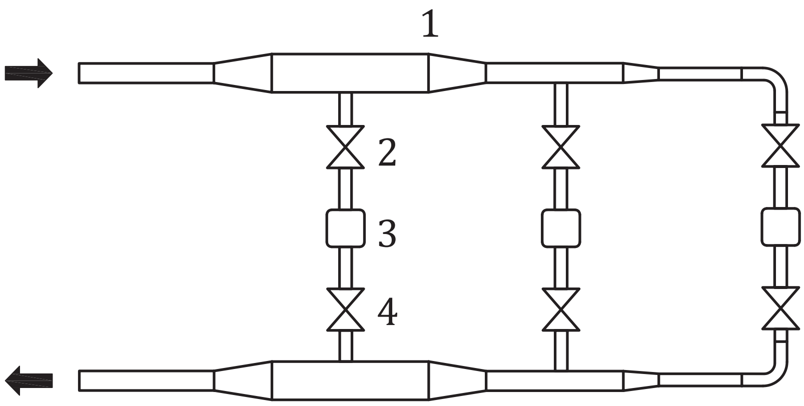


Key

1 inlet isolator
2 strainer-filter
3 drain
4 air eliminator/separator
5 vent and gas detection switch
6 meter
7 isolators for proving
8 double block and bleed valves
9 flow control and shut off if air detected

Figure 7 — Typical PD metering package for liquid measurement

Where multiple meter runs are employed, it is important to ensure that the inlet pressures are balanced in each line to avoid excess flowrates through individual meters. As a guide, the minimum header cross-sectional areas should be 50 % greater than the sum of the areas of the individual meter tubes. A fully hydraulically balanced inlet header is shown in Figure 8. Installation with zero velocity zones at the end of the inlet or outlet headers should be avoided.



Key

1 hydraulically balanced header (diameter reducing to maintain constant velocity)

2 meter run inlet isolating valve

3 meter

4 downstream valve(s) — possibly double block and bleed and flow balancing valves

Figure 8 — Hydraulically balanced inlet header

The flow can be controlled by a valve installed downstream of each meter. (Fitting a control valve upstream would reduce the line pressure at the meter giving potential for flashing, cavitation, or even a part filled pipe.) Control valves allow the required flow to be controlled and flow balanced between streams. The sizing of control valves should take into account the range of expected flowrates, including any seasonal or liquid property effects. Inlet isolation valves should be fitted in each meter run.

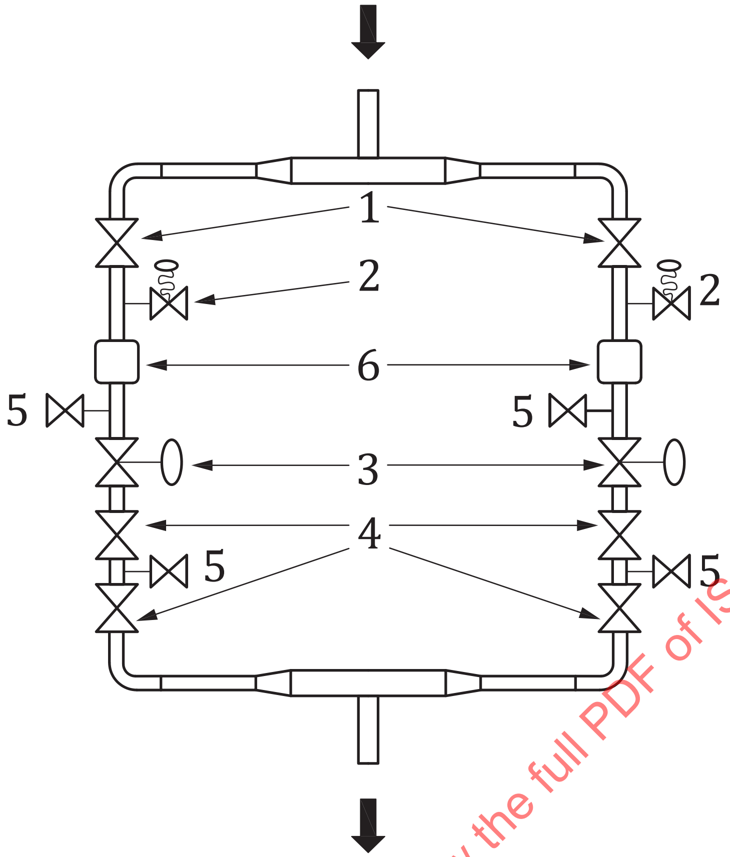
Installation of valves in a parallel meter installation is shown in Figure 9.

Where meters are to be proved *in situ*, it is recommended that each meter run be fitted with flow control, since the addition of the meter prover into the system changes the resistance and, hence, affects flowrate. Individual valves allow the flows to be adjusted to compensate for this effect.

Control valves cannot be relied on to provide a leak tight seal. Where meters have to be removed for servicing, or where a stream has to be shown not to pass liquid when not in service, an additional downstream valve, possibly a double block and bleed valve, should be installed downstream of the control valve. An upstream isolator valve might be required to allow removal of a meter for maintenance. This is a requirement for fiscal and custody transfer meters.

When operating, any valve on the inlet to the meter run should be fully open.

When a run is closed down and isolated, both inlet and outlet valves should be fully closed and the pressure in the run reduced so that any leakage can be detected through a line pressure rise.



Key

1 inlet isolating valve- full bore ball valve
2 pressure relief bleed valve.
3 flow control/balancing valve
4 double block isolating valves
5 air vent/bleed and drain valves
6 flowmeters

Figure 9 — Parallel meter runs and valves

8.3 Flow pulsation

Pulsating flows should be avoided, as they can cause the meter to over-read and can also cause mechanical damage. Common sources of flow pulsation are oscillating valves and regulators, reciprocating pumps or hydraulic oscillation caused by poor pipework design. Pulsation effects can be reduced through the use of pulsation dampers or by long lengths of pipe between the pulsation source and the meter. Alternative equipment can include surge tanks, expansion chambers or pressure limiting valves.

Certain types of displacement meter introduce pulsations into the flow. In extreme cases where this occurs, it might be necessary to add pulsation dampers downstream of the meter.

8.4 Electrical installation

All electrical or electronic equipment which could be installed in potentially hazardous areas should be selected and applied in accordance with the manufacturer's guidelines and existing safety standards. Installation, earthing, and maintenance procedures should be strictly followed for each component in the system. Where portable electronic or electrical calibration is required, the following should be addressed:

a) safe system of work, including permits;

b) power supply and earthing requirements;

c) sequence of connection and disconnection;

d) specific installation operating procedures.

8.5 Pulse security

When appropriate, the pulse security system should be designed in accordance with ISO 6551. Care should be exercised in the data transmission system so that the signal amplitude can be maintained at the highest level whilst reducing the magnitude and influence of the noise. This can be attained by:

a) limiting the length of the transmission line between the meter and data readout or acquisition system;

b) use of the recommended cable with suitable impedance;

c) use of a pre-amplifier at the meter;

d) ensuring the correct supply voltage to the pre-amplifier and not introducing an unacceptable ripple characteristic;

e) attention to the presence of potential differences in the electrical system due to the lack of earthing or through earthing at two points.

9 Environmental considerations

9.1 General

The ambient conditions and possible variations expected around the meter should be taken into account in the design of each displacement meter system used for liquid measurement. This clause discusses some of the more important parameters.

It is usual to locate the electronics away from the meter in those cases where ambient temperature effects are severe. In cases where electronics cannot be mounted remotely, the use of temperature-controlled housings should be considered.

9.2 Electrical interference

Output signals from displacement meters fitted with pulse generators and remote electronics can be susceptible to the presence of large power sources. These power sources (e.g. cables, electric motors or switchgear) can produce surges in the cables that are detected as additional unwanted pulses from the meter.

The use of short-wave radio transmitters near the meter causes similar problems. Signal cables should be routed well away from power sources to minimize electromagnetic and radio-frequency interface (commonly called EMI or RFI) effects. Shielding is also recommended.

9.3 Humidity

High humidity can accelerate atmospheric and electrolytic corrosion, and can also lower electrical insulation. Low humidity can induce static electricity. Problems with humidity can be caused by rapid ambient or process temperature changes. The user should be aware of the range of expected humidity variations and check that this does not lead to operational difficulties.

9.4 Safety

In applications within hazardous environments, meters should be selected with regard to electrical area classification, atmospheric compatibility, and other safety regulations, local or standard, which can apply. Of these, the area classification is the most important, and all equipment will be expected to conform exactly to the appropriate hazardous area rating. The use of explosion-proof, intrinsically safe, or other types of equipment might be appropriate.

10 Calibration

10.1 Proving and verification

The term "proving" refers to a calibration resulting in a determination of the performance indicator of a meter under test and showing (proving) that it performs to a defined acceptance criteria. For positive displacement meters error, meter factor or K-factor may be used as the performance indicator. Proving is a term used in the petroleum industry, particularly. The procedures, measurement range and requirements for proving are usually defined in regulation, contracts, local procedures or standards. Proving is usually carried out using the operating fluid or a close substitute. It is good practice to ensure that a proving and proving method produces a result with an uncertainty defined. Verification has a similar definition and is usually associated with meters complying with trade regulation.

Guidance regarding how to interpret the results of a calibration or proving, and examples of acceptability for fiscal/custody transfer operations are given in Annex A.

10.2 General considerations

Proving consists of passing liquid through the meter under test, and comparing the reading with a reference volume measurement of lower uncertainty than that expected from the meter under test. The reference will be connected in series. The reference should be traceable to appropriate national measurement standards. It is preferred that proving systems, calibration laboratories, or service providers be accredited to ISO/IEC 17025. Calibration certificates for the flowmeter should include information regarding the test, traceability, and the estimated uncertainty. The reference can be of the volumetric or gravimetric type and either open or closed to the atmosphere, depending on the application and the liquid vapour pressure.

10.3 Proving conditions

Any displacement meter should be proved, *in situ*, in a central proving facility, or in an accredited laboratory, within the range of flowrates for the duty. The properties of the liquid used in the proving should be as close as possible to that expected in normal operation over the range of temperatures, pressures, and viscosities to be encountered. The orientation of the meter should be the same during the proving as during operation.

10.4 Proving methods

Proving in the laboratory can be carried out using volumetric start–stop methods, dynamic methods as described in ISO 4185, or by using master meters, which have been proven against accepted reference standards. In the first of these methods, the flow is zero at the start and end of each run. The reading of the meter is simply compared with the reading from the reference to determine the error at each proving flowrate. In the dynamic method, liquid passes through the meter at the desired flowrate at all stages of the proving.

For field proving, volumetric start-stop methods, master meters or pipe provers can be used. Pipe prover devices can be the conventional sphere provers (either folded or straight pipe), or small volume (compact) provers. Small volume provers can be used to prove positive displacement meters, but, in many cases, can give rise to poor repeatability. To prove correctly, the pulse generator should give an even pulse period, provided from a direct drive mechanism which has little or no cyclic variations. Many designs, however, do not provide this. Pulse generators driven from the gear box output should be avoided. Several rotations of the measuring element should be completed in each proving pass.

A master meter which is used to prove a displacement meter should have its meter factor or meter K-factor determined, with the liquid and operating conditions as close as possible to those normally encountered. Master meters are normally installed downstream of the meter to be proved. Volumetric tanks are not recommended for proving if the liquid has a high vapour pressure at line temperature, since this can result in a significant loss due to evaporation.

10.5 Proving frequency

There are no fixed guidelines on the frequency of either laboratory or field proving, both of which depend on the required uncertainty and acceptance of risk for the measurement. Local, company, regulatory or contractual guidelines on the frequency of proving might be in force. A risk-based approach can be employed, where the additional financial exposure caused by meter drift over time is compared with the cost of calibrating or proving the meter. A judgement can then be made on the calibration frequency.

This can be combined with a meter-performance-based approach where the history of the meter is monitored, and the proving frequency can be adjusted, prolonged or reduced, based on the expectation of potential change.

In those cases where liquid density, viscosity, temperature or pressure might change rapidly and often, it can be necessary to prove for each transaction or at daily or weekly intervals, depending on the magnitude of the changes.

For a new metering installation, when *in-situ* proving is used, frequent (daily or weekly) proving can be necessary to establish meter factors for use in control charts (see 11.4). Further guidance is given in ISO 4124, which can be used to establish proving frequency.

For installations where flowrate and liquid properties are constant, proving might only need to be performed at three-, six-, twelve-month or longer intervals, after confidence in the meter stability has been developed.

In those cases where meter maintenance has been performed, the meter should be proved over the operating measurement range before being returned to service. The fixed proving frequency can then be progressively reduced depending on the experience of the installation.

Monitoring of a process mass balance or comparison with other measurement points in the process can also be used as an indication that a meter might have changed performance and indicating that additional proving is required.

11 Operation and maintenance

11.1 General

This clause covers recommended operating and maintenance practices for displacement meter installations. All operating data pertaining to both measurement and proving should be accessible to interested parties.

11.2 Initial start-up

When placing a new meter in service, means should be provided to protect the meter from damage and malfunction arising from over-speeding or the influence of foreign matter such as thread cuttings, pipe debris, weld spatter, or similar material arising from the construction. Means of accomplishing mechanical protection are the use of a temporary by-pass, temporary spool pieces, or the installation of a protective device upstream to collect the debris.

Over-speeding can damage either the bearing, or the measuring element, unless care is exercised during start-up. The line should be filled slowly by allowing line pressure to rise slowly with the downstream valve being closed. Any gas that is present should be vented. Once the pressure is stable, the downstream valve can be opened slowly to allow flow to start.

11.3 Meter maintenance

Meters should be maintained, in accordance with the manufacturer's instructions. A full maintenance policy should be established in conjunction with all interested parties, where the key components can be identified. Normally, positive displacement meters can be expected to perform well for long periods if operated within agreed limits. Indiscriminate adjustment or disassembly is neither necessary nor recommended.

Because of the many different designs, the variety of ancillary equipment and the range of liquid properties that can be metered, it is difficult (and often inadvisable) to establish a maintenance schedule for all installations. It is best to determine when to inspect or repair the meter from control chart data for each liquid and for each meter in the system. If the change in meter factor (or meter K-factor) exceeds three times the standard deviation on the control chart (see 11.4), the reasons should be investigated.

NOTE The suggested “trigger” value of three times the standard deviation (3σ) is a practical balance between triggering an investigation based on an insignificant change and a value where a real problem is being observed. Further guidance can be found in ISO 4124.

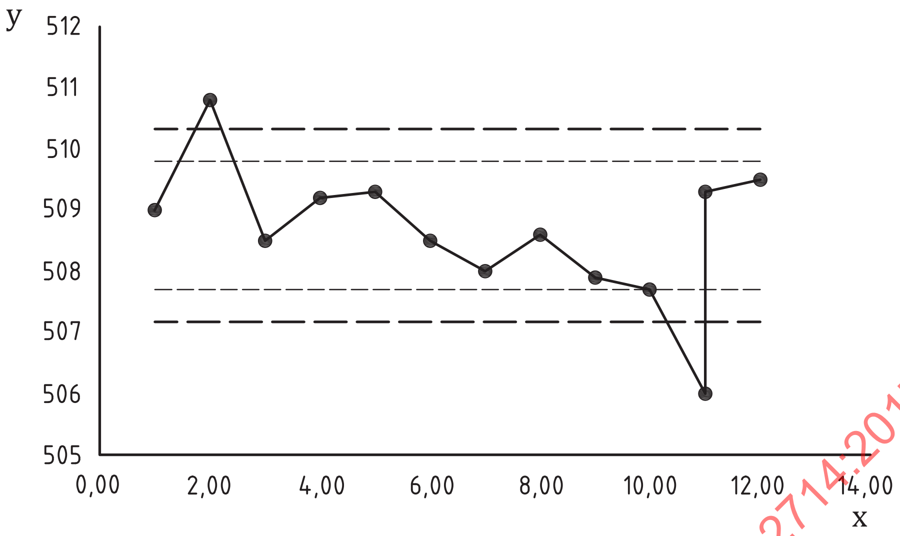
Correct performance of ancillary equipment should only be checked and maintained by personnel with suitable training in the particular item of equipment.

To ensure the metering system retains its design performance, regular inspections should be carried out in accordance with agreed procedures at regular intervals. *In-situ* proving is regarded as part of the inspection procedures. In those installations where off-site proving is used, the frequency of inspections depends on the demonstrated long-term repeatability of the meters and any significant change in operating parameter or conditions that have occurred since the last proving.

11.4 System diagnostics and control charts

A meter control chart is an adaptation of the statistical method described in ISO 4124. These charts are plots of meter factor or meter K-factor obtained at the same operating conditions against time and flowrate. An example is shown in Figure 10.

The charts can be used as a warning signal for problem diagnostics by showing deviations from the predetermined limits. They can be used to determine whether problems are present, but not the nature of the fault. When faults are diagnosed from the chart, as illustrated in Figure 10, a systematic check of the complete system is strongly recommended. The primary fault causes are changes in product, composition, temperature, fouling of the meter, meter-bearing failure or physical damage to the rotor assembly or other internal components of the meter. Debris left in new installations, or liquid-borne solid particles, are particularly significant. After these influences have been eliminated and no defects are noted, the following items should be checked: all valves, ancillary equipment (such as strainers or separators), counters, pre-amplifiers, cabling, prover spheres, sphere detectors and temperature-measuring, pressure-measuring or density-measuring equipment.



Key

x month

y K-factor

Figure 10 — Example of control charts for fault diagnosis

In Figure 10, the first two points show the system "settling down". Subsequently, there is a downward trend, perhaps, indicating wear. In month 11, there is a significant drop in K-factor, suggesting a fault. The meter was repaired/adjusted and the K-factor returned to the early value. The dashed lines indicate the chosen "trigger" levels where an action is required. The inside lines are twice the standard deviation (2σ) of the results around the mean taken in month 10. This would be a warning and perhaps lead to resetting of the K-factor in use. The outer two lines are three times the standard deviation (3σ) around the mean, showing there was a fault and action is required.

Annex A
(informative)

Specification of performance

A.1 General

The performance specification, or expectation, is normally defined by regulation, contract agreements, or the user for a particular application. A manufacturer can also provide a specification to detail the expected performance of the product.

To be accepted for trade, a meter has to be approved by the national trading standards authority. This is usually through a "type approval" followed by a system verification. Type approval of the meter type, pattern or model is granted through testing by the national authority, or by acceptance of an approval granted by another authority. The specification for the testing usually follows the international guidance given in the appropriate OIML recommendation (e.g. R117[14] covering type approval and verification and a wide range of characteristics of the meter from design and labelling to mechanical and EMC performance including the flow metering performance).

For fiscal or custody transfer applications, particularly for hydrocarbon transactions, the regulator or appropriate contract agreements specify the expected performance. Both initial (factory acceptance testing) and subsequent verification (site acceptance testing) are generally required, followed by ongoing verification at defined intervals. The specification might or might not require a trade-approved meter to be used.

It is important that for any application, the verification or approval covers the conditions of temperature, pressure, and viscosity for the duty.

While the document covers many aspects of the meter performance, there are only a few aspects which relate to flow measurement, and these are summarized within this annex. The normal performance expectations specified for most trade, fiscal, and custody transfer meters in the hydrocarbon industry are illustrated as a guide to expectations.

A.2 Performance criteria

A.2.1 Measurement range (flowrate)

The meter should have a specified measurement range of flowrates across which it remains within the specified linearity. This can vary with viscosity or a specified linearity. It would be expected that a meter would have a measurement range (ratio of maximum to minimum flowrate) of not less than 5:1. However, 10:1 would be the norm for lower viscosity hydrocarbons.

A.2.2 Linearity

A.2.2.1 General

Linearity is a measure of the deviation of the meter characteristic, or performance indicator, from a defined functional relationship. The functional relationship provides a nominal value at any flowrate across the measurement range of the meter. The nominal value may be calculated from a linear relationship or a more complex function to give different nominal values at different flowrates. The relationship in practice is usually a constant value (linear relationship with slope = 0).

Linearity is expressed as the range of deviation from a chosen "nominal" value, i.e. the maximum (most positive deviation) to the minimum (most negative deviation) as shown in Formula (A.1):

$$lin_r = \Delta_{max} - \Delta_{min} \quad (A.1)$$

where

lin_r is the linearity range of values;

Δ_{max} is the most positive deviation from the nominal value at that flowrate;

Δ_{min} is the most negative deviation from the nominal value at that flowrate;

When multiple test points are taken at any one flowrate, usually to determine repeatability, the mean of each batch of results represents the value at that flowrate. This method provides a realistic estimate of the linearity.

Where single points are taken at multiple flowrates across the measurement range of the meter, Δ_{max} and Δ_{min} can be estimated by using a "best fit" line placed through the points and taking the deviations of the line from the nominal value(s).

Linearity is usually expressed as relative to a nominal value and expressed as a ± percentage value as shown in Formula (A.2):

$$lin = \pm \frac{\Delta_{max} - \Delta_{min}}{2 \times N} \quad (A.2)$$

where

lin is the linearity range of values relative to the chosen nominal value;

Δ_{max} is the largest (most positive) deviation from the nominal value at that flowrate;

Δ_{min} is the smallest (most negative) deviation from the nominal value at that flowrate;

N is the chosen nominal value.

It is the choice of the "nominal" value that is ill-defined in standards and varies between different practices. The definition of nominal value may also differ from the nominal value used to define Δ_{max} and Δ_{min}.

There are a number of conventions used, and three have been outlined in A.2.2.2, A.2.2.3 and A.2.2.4.

If Δ_{max} and Δ_{min} are based on a function, and not a constant, they should be recalculated as values relative to the nominal value at the appropriate flowrate.

A.2.2.2 Mid-range method

The convention advised in this document is an implementation of the "independent linearity" method given in ISO 11631 and defined as the "mid-range" method.