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Measurement of fluid flow in closed conduits — Guidance for the use of electromagnetic flowmeters for conductive liquids

Mesurage du débit des fluides dans les conduites fermées — Lignes directrices pour l'utilisation des débitmètres électromagnétiques dans les liquides conducteurs

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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).

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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 30, *Measurement of fluid flow in closed conduits*, Subcommittee SC 5, *Velocity and mass methods*.

This first edition of ISO 20456 cancels and replaces ISO 6817:1992, ISO 9104:1991 and ISO 13359:1998, which has been technically revised.

Introduction

Clauses 3 to 7 cover the definitions, symbols and basic theory of electromagnetic flowmeters. This document does not cover insertion type meters, partially filled meters or meters for non-conductive and highly conductive fluids.

Clause 8 covers installation types and practice, the different types of meter construction, transmitters, lay lengths and sizing, in order to achieve the best performance of the electromagnetic flowmeter in the field.

Clauses 9 to 11 cover some methods of calibration, verification, evaluation, and uncertainty analysis, which can be useful for users or independent testing establishments to verify manufacturer's relative performance and to demonstrate suitability of application

The tests specified in this document are not necessarily sufficient for instruments specifically designed for unusually difficult duties. Conversely, a restricted series of tests may be suitable for instruments designed to perform within a limited range of conditions.

This document is for users and manufacturers.

Measurement of fluid flow in closed conduits — Guidance for the use of electromagnetic flowmeters for conductive liquids

1 Scope

This document applies to industrial electromagnetic flowmeters used for the measurement of flowrate of a conductive liquid in a closed conduit running full. It covers flowmeter types utilizing both alternating current (AC) and pulsed direct current (DC) circuits to drive the field coils and meters running from a mains power supply and those operating from batteries or other sources of power.

This document is not applicable to insertion-type flowmeters or electromagnetic flowmeters designed to work in open channels or pipes running partially full, nor does it apply to the measurement of magnetically permeable slurries or liquid metal applications.

This document does not specify safety requirements in relation to hazardous environmental usage of the flowmeter.

2 Normative references

There are no normative references in this document.

3 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:

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

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

3.1
electromagnetic flowmeter
flowmeter which creates a magnetic field perpendicular to the direction of flow, so enabling the flowrate to be deduced from the induced voltage, U_V, produced by the motion of a conducting fluid through the magnetic field

Note 1 to entry: The electromagnetic flowmeter consists of a *sensor* (3.2) and a *transmitter* (3.3).

3.2
sensor
device containing at least the following elements:

— an electrically insulating meter tube through which the conductive fluid to be measured flows;

— one pair of electrodes across which the signal generated in the fluid is measured;

— an electromagnet for producing a magnetic field in the *meter tube* (3.4)

Note 1 to entry: The sensor produces a signal proportional to the flowrate and, in some cases, a *reference signal* (3.9). See 6.2.

Note 2 to entry: For a sensor, the wording primary device or flowtube has previously been used.

Note 3 to entry: In some cases, further electrodes are used such as grounding electrodes, full pipe detection electrodes (empty pipe detection) (see 3.5).

3.3
transmitter
equipment which contains the circuitry which drives the field coils and extracts the flow signal

Note 1 to entry: This equipment may be mounted directly onto the *sensor* (3.2) or remotely, connected to the sensor by a cable.

Note 2 to entry: For a transmitter, the wording secondary device, converter or electronic unit has previously been used.

3.4
meter tube
pipe section of the *sensor* (3.2) through which the liquid flows, at least part of whose inner surface is electrically insulating

3.5
measuring electrodes
one or more pairs of electrical contacts or capacitor plates by means of which the induced voltage is detected

3.6
lower range value
lowest value of the measured variable that a device is set to measure

3.7
upper range value
highest value of the measured variable that a device is set to measure

3.8
span
difference between the upper and *lower range values* (3.6)

3.9
reference signal
signal which is proportional to the magnetic flux created in the *sensor* (3.2) and which is compared in the *transmitter* (3.3) with the flow signal

3.10
output signal
signal from the *transmitter* (3.3) which is a function of the flowrate

3.11
Reynolds number
dimensionless parameter expressing the ratio between the inertial and the viscous forces

Note 1 to entry: For closed pipe flow through an *electromagnetic flowmeter* (3.1), Reynolds number should be based on the nominal diameter of the meter and corresponding mean velocity through a section of that size.

3.12
accuracy
closeness of the agreement between the result of a measurement and the (conventional) true value of the measurement

Note 1 to entry: The quantitative expression of accuracy should be in terms of uncertainty (see Annex E).

Note 2 to entry: The use of the term precision for accuracy should be avoided.

3.13
uncertainty
<of measurement> range within which the true value of the measured quantity can be expected to lie with a specified value and confidence level

Note 1 to entry: See Clause 11.

3.14
calibration factor
number, determined by liquid calibration, that enables the *output signal* (3.10) to be related to the volumetric flowrate

3.15
calibration
operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

3.16
verification
<in-situ electronic verification> means of verifying that an *electromagnetic flowmeter* (3.1) is operating correctly, normally with a poorer uncertainty than under controlled laboratory conditions

3.17
calibration validation
number of runs (one or more) at flowrates between zero and the *upper range value* (3.7) in order to verify that the flowmeter does perform in the expected way and within the manufacturer's specification

3.18
measuring window
period of time during which the voltage representing the flow velocity is measured

3.19
ideal flow conditions
conditions that exist when a pipe is infinitely long and straight with no internal disturbances

Note 1 to entry: For *electromagnetic flowmeters* (3.1), it may, in addition, also be assumed that the metering liquid has a viscosity and density similar to water. Under these conditions, the flow is axisymmetric and will be fully developed and turbulent at flowrates and pipe sizes most often found in industry.

4 Symbols

Symbol	Quantity	Units (SI)
$\vec{B}$	magnetic field strength	Tesla (T)
$\bar{B}$	mean magnetic field strength	Tesla (T)
d	inside diameter of meter tube	metres (m)[a]
$\vec{E}$	electric field strength	volt per metre (V/m)
U_c	electrochemical voltage	volt (V)
U_t	transformer voltage	volt (V)
U_v	velocity related voltage	volt (V)
$F_{Lorentz}$	Lorentz force	newton (N)
k_1	constant	dimensionless (—)
k_2	constant	dimensionless (—)

Symbol	Quantity	Units (SI)
L_e	distance between measuring electrodes	metres (m)
q_V	volumetric flowrate of the liquid	cubic meters per second (m^3/s)
$\bar{v}$	mean axial liquid velocity	metres per second (m/s)
∇	Nabla or Del operator	dimensionless (—)
a See Annex D for a conversion table of nominal diameters from metric to US units.		

5 Theory and basic formulae

When a conductive liquid moves through a magnetic field, voltage(s), U_v, are generated in accordance with Faraday's law (see Formula 2). The strength of the induced voltages is given by the simplified expression shown in Formula (1):

$$F_{\text{Lorentz}} = q\left(\vec{E} + \vec{v} \times \vec{B}\right) = 0 \tag{1}$$

$$\vec{E} = -\vec{v} \times \vec{B} = \nabla\left(U_v\right);$$

$$\nabla\left(U_v\right) = -\vec{v} \times \vec{B}$$

Spatial integration of Formula (1) results in Formula (2):

$$U_v = k_1 \bar{B} L_e \bar{v} \tag{2}$$

The volume flowrate in the case of a circular pipe is given in Formula (3):

$$q = \frac{\pi d^2}{4} \bar{v} \tag{3}$$

Which, combined with Formula (2), gives Formula (4):

$$q = \frac{\pi d^2}{4 k_1 L_e} \left(\frac{U_v}{\bar{B}}\right) \tag{4}$$

Or Formula (5):

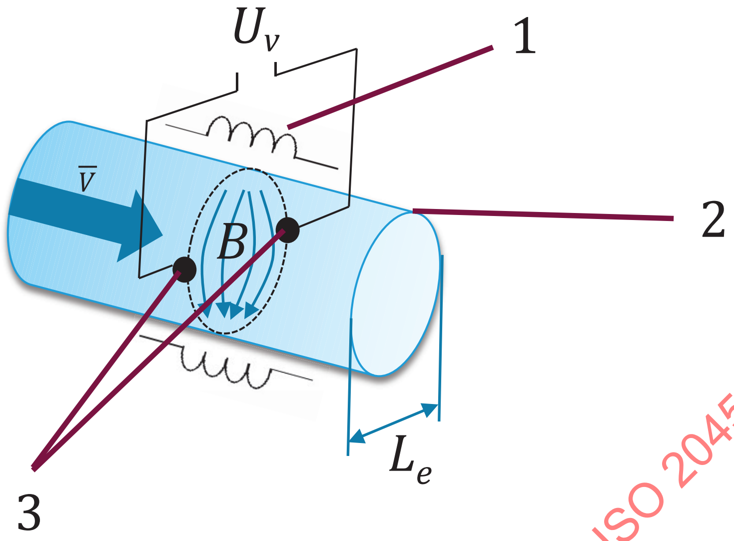
$$q = k_2 U_v \tag{5}$$

Formula (5) may be interpreted in various ways to produce a calibration factor which in practice is usually determined by wet calibration, as described in 9.1.

6 Construction and principle of operation

6.1 General

As indicated schematically in Figure 1, the magnetic field is so placed with respect to a lined meter tube that the path of the conductive liquid, flowing in the meter tube, is normal to the magnetic field. In accordance with Faraday's law, motion of the liquid through the magnetic field induces a voltage, U_v, in the liquid in a path mutually normal both to the field and the direction of liquid motion. By placing electrodes which contact the liquid in insulated mountings or by using insulated electrodes with capacitance-type coupling in the meter tube in a diametrical plane normal to the magnetic field, a voltage proportional to the flow velocity is produced which can be processed by a transmitter. Meters based on this principle are capable of measuring flow in either direction through the meter tube.



Key

1 coil system
2 lined meter tube
3 measuring electrodes
B magnetic flux density
L_e distance between measuring electrodes
U_v flow signal (velocity related voltage)
$\bar{v}$ mean axial liquid velocity

Figure 1 — Principle of Faraday's law

The electromagnetic flowmeter consists of a sensor through which the process liquid flows and a transmitter which converts the flow signal generated by the sensor into a standardized signal for suitable acceptance by industrial instrumentation (see, for example, IEC 60381-1 and IEC 60381-2).

The system produces an output signal proportional to volume flowrate (or average velocity). Its application is generally limited only by the requirement that the metered liquid shall be electrically conductive.

The sensor and transmitter can be separate, linked by one or more electrical cables, or integrated with the transmitter directly joined to the sensor.

6.2 Sensor

Figure 2 shows an exploded drawing of an industrial version of a sensor with an integrated transmitter. The principal components of the sensor are as follows.

a) The meter tube is the pipe section of the sensor through which the liquid flows. For a meter with field coils mounted outside the meter tube, this would be constructed from a non-magnetic material. On a design where the field coils are inside the meter tube, it may be made of a magnetic material.

b) An insulating liner which electrically insulates the measuring electrodes from the meter tube preventing the induced U_v from short circuiting through the meter tube. The liner may be concentric with the pipe or be profiled to provide a specific cross-section at the plane of the measuring electrodes; if the meter tube is non-conductive, then a liner is not mandatory.

c) The field coils produce the magnetic field. The most common configuration is to have two field coils mounted diametrically opposite to each other, though single field coil designs are available. Field coils may be mounted on the outside of the meter tube or within the meter tube isolated from the fluid. The field coils can be either:

— excited by sinusoidal alternating current (AC), as described in 6.3.4, or

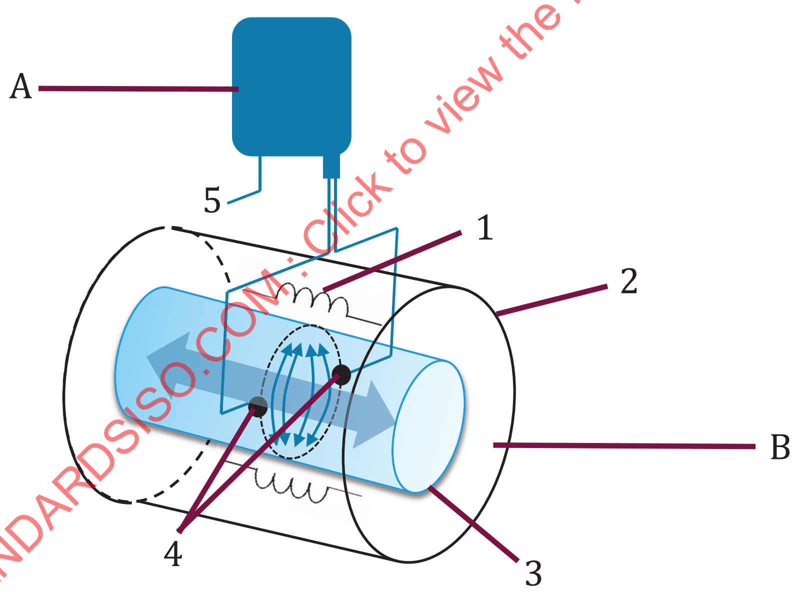
— excited by direct current. In this case, it is usual to use a pulsed direct current (DC) as described further in 6.3.3;

d) The measuring electrodes which detect the induced U_V. These normally comprise two metallic contacts diametrically opposite to each other standing slightly out from the liner which are in direct contact with the fluid. In some designs for harsh applications, capacitive electrodes may be used which are not in direct contact with the fluid.

The sensor may also contain a reference or ground electrode to provide a reference value for the measured U_V, and/or an empty pipe detection electrode which triggers an alarm when not in contact with the fluid.

The materials for the lining and for the electrodes shall be selected depending on the liquid to be measured (see Annex A).

The sensor is usually connected to the piping by means of flanges; however, measuring devices with flangeless versions and other process connections are also available. The process fluid shall be electrically connected to the body of the flowmeter by means of a grounding electrode or electrically conductive and unlined adjacent pipework or grounding (potential equalizing) rings; see 8.1.3.



Key

1 field coils

2 coil housing

3 lined meter tube

4 measuring electrodes

5 power supply

A transmitter

B sensor

Figure 2 — Elements of an industrial electromagnetic flowmeter

NOTE The sensor can have a non-circular cross-section.

6.3 Transmitter

6.3.1 General

The transmitter carries out the following functions:

a) provides the current to drive the field coils;

b) amplifies and processes the measuring electrode signal in order to derive a signal proportional to the flowrate;

c) reduces various noise signals, e.g. fluid noise, electrical noise and common mode noise;

d) provides means of compensating for supply voltage and frequency variations where necessary;

e) provides the various outputs specified by the user or incorporated in the meter. These may include a visual display and/or electronic outputs of the flowrate, alarm functions, totalised values and diagnostics;

f) provides an interface for the user to configure the meter using buttons, touchpad or connections to a PC or other device;

g) may provide an interface to a network.

Instruments may include additional circuitry to perform self-verification.

The transmitter may be mounted directly onto the sensor or remotely, connected to the sensor by a cable.

6.3.2 Alternating magnetic field in the measuring system

Electromagnetic flowmeters use an alternating magnetic field to avoid any voltages which may interfere with the measurement of flow.

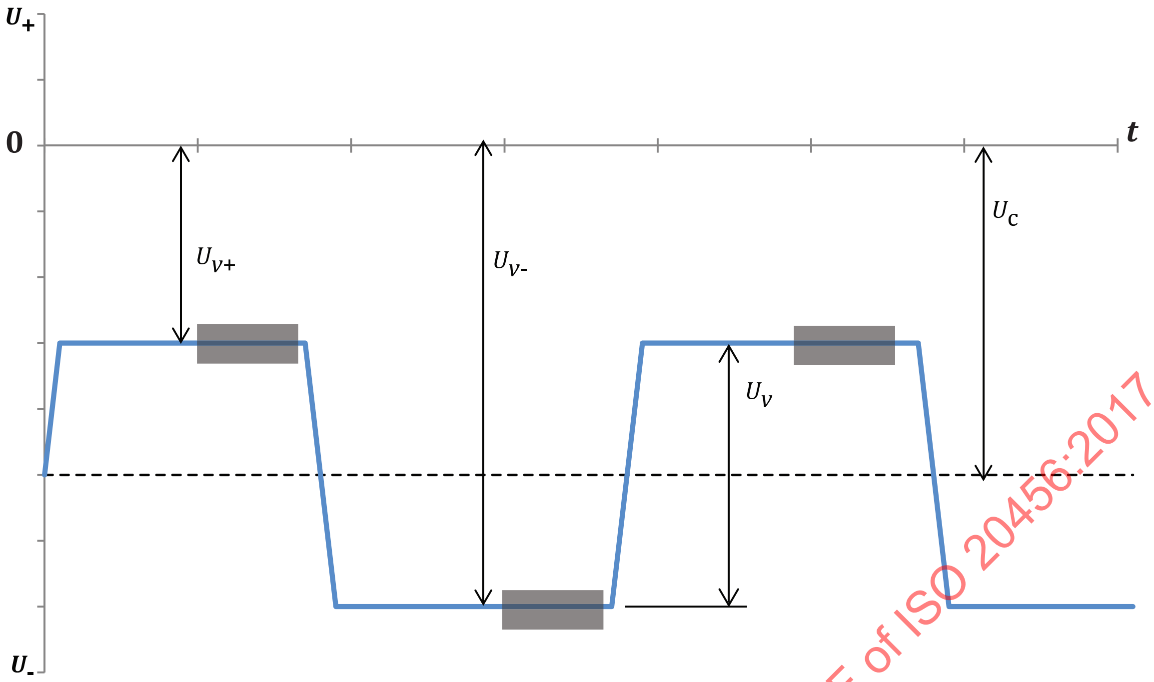
In addition to the flow related voltage, U_v, described in Clause 5, two other source voltages exist in electromagnetic flowmeters. These are the electrochemical voltage, U_c, and the voltage created by changes in the magnetic field, the transformer voltage, U_t. Both of these voltages may have a similar or larger magnitude than U_v.

Further details may be found in Annex B.

6.3.3 Measuring system with applied pulsed DC excitation (simplified model)

In measuring systems with applied pulsed DC excitation, the magnetic field polarity is alternately reversed. During each magnetic field polarity cycle, the electrode voltage is measured once the magnetic field is considered to be constant. This period is called the measuring window (see Figure 3). This measured voltage is a sum of both U_c and U_v.

The difference between minimum and maximum value of the measured voltage, U_v, is proportional to the flow velocity in the meter tube (see Figure 3).



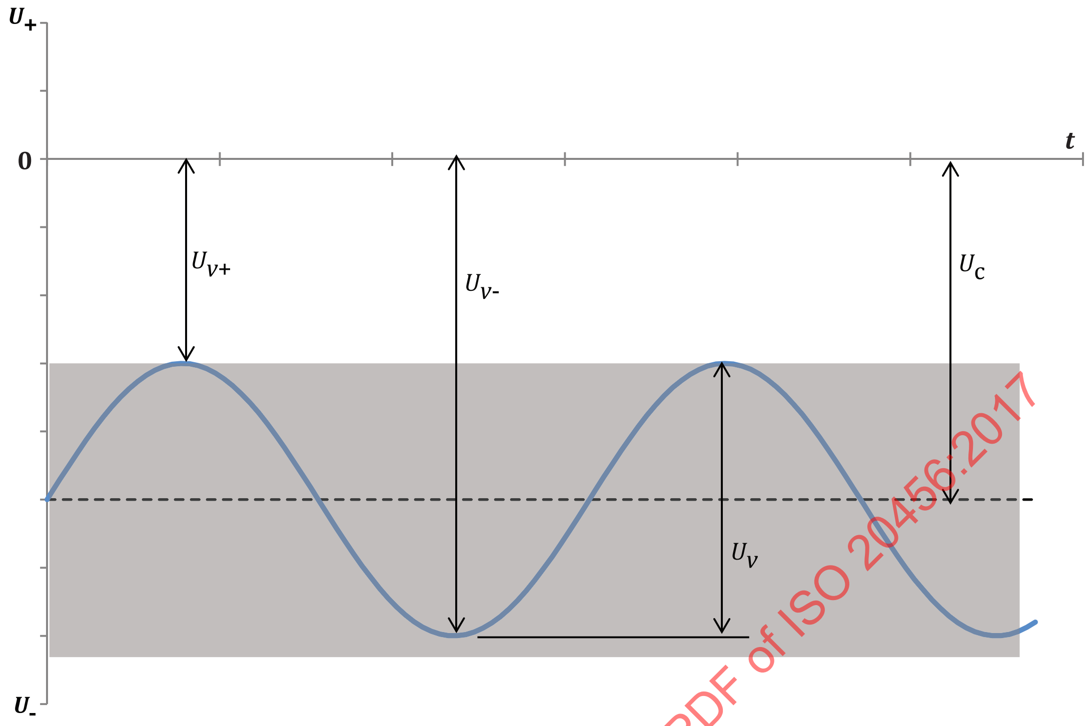
Key

measuring window

Figure 3 — Principle of pulsed DC system (simplified model)

6.3.4 Measuring system with applied AC excitation (simplified model)

In AC excitation, line voltage (typically 115 V or 230 V at 50 Hz or 60 Hz) is applied directly to the field coils or is supplied by the transmitter. This voltage generates a magnetic field in the sensor that varies in strength with the amplitude of the applied voltage. The variation follows the pattern of a sine wave (see Figure 4). This means that the flow signal, U_v, will also be a sine wave. The peak to peak value of the sine wave, U_v, will be proportional to the flow velocity.



Key

measuring window

Figure 4 — Principle of AC excitation systems (simplified model)

6.4 Flowmeter/Transmitter output

The system output can be one or more of the following:

a) analogue direct current in accordance with IEC 60381-1;

b) analogue direct voltage in accordance with IEC 60381-2;

c) a frequency data output in the form of scaled or un-scaled pulses;

d) alarm output(s);

e) digital (e.g. communication buses);

f) wireless;

g) display.

NOTE Electromagnetic flowmeters are available as 2-wire and 4-wire systems.

7 Equipment marking

7.1 Recommended data

7.1.1 Sensor

The following data should be displayed either on the sensor or on a name plate:

a) instrument manufacturer;

b) serial number;

c) nominal diameter;

d) maximum process temperature;

e) rated ambient temperature range;

f) maximum process pressure;

g) instrument classification (e.g. degree of protection, hazardous area classification);

h) model number.

NOTE 1 Rated ambient temperature range can be omitted if it is the same as the rated process temperature range.

NOTE 2 Additional labelling requirements can be required for specific applications or to meet national regulations (e.g. Ex approvals).

7.1.2 Transmitter

The following data should be displayed on a name plate:

a) instrument manufacturer;

b) serial number;

c) voltage, frequency, and power requirements;

d) instrument classification (e.g. degree of protection, hazardous area classification);

e) rated ambient temperature range;

f) model number.

NOTE Additional labelling requirements can be required for specific applications or to meet national regulations (e.g. Ex approvals).

8 Installation design and practice

8.1 Sensor

8.1.1 Sizing

Usually, the sensor process connection size will be the same as that of the adjacent pipework. However, care should be taken if the optimum performance is desired. Points to be considered are, for example:

— pipe size;

— pipe connection;

— flowrates;

— minimum and maximum flow to be measured;

— pressure loss.

The manufacturer's specifications, such as minimum span, velocity, abrasive fluid, low flow conditions etc., should be followed. Typically, the measurement uncertainty of electromagnetic flowmeter will be lowest above 1 m/s and below 1 m/s, the uncertainty will tend to increase. Although there is no theoretical maximum flowrate for an electromagnetic flowmeter, in practice, meters are sized such that the maximum velocity does not exceed 10 m/s under normal operational conditions.

NOTE If flowmeter size is different from that of the adjacent pipework, then the effect of this discontinuity can affect the flowmeter performance and pressure loss.

8.1.2 Mounting conditions

8.1.2.1 General

Provided the pipe remains full at all times, there is no theoretical restriction on the orientation in which the sensor should be mounted. Where possible, if installing in a pipeline running vertically, ensure the flow direction is upwards through the sensor to eliminate the possibility of annual flow errors. In practice, the following conditions should be observed.

8.1.2.2 Effects of non-ideal flow conditions

Calibration laboratories strive to have flow conditions that are as close to ideal flow conditions. Installing a flowmeter in conditions that are significantly different from ideal flow conditions, such as placing the flowmeter closely downstream of an elbow or valve, may result in reduced performance. Differences in the flowmeter design may have an effect on how much the performance is affected by such non-ideal flow conditions.

8.1.2.3 Electrode position

In a horizontal pipe, since any gas bubbles will rise and collect at the top of the pipe, or sediment may collect at the bottom of the pipe, the sensor should be mounted so that neither measuring electrode is in these positions.

8.1.2.4 Zero-checking provision

If it is necessary to check the flowmeter zero in situ, then valves should be provided to stop the flow through the device, leaving it filled with stationary liquid. When the flowmeter is equipped with an automatically adjusting zero, this provision may not be necessary.

8.1.2.5 Multiphase flow through the sensor

8.1.2.5.1 Entrained solids

When solids are entrained in the liquid, care should be taken in the selection of the lining material and electrode material (see Annex A). Where there is a possibility that material may settle in the sensor, it should be mounted vertically or provision should be made to flush it through.

On spool piece devices, a ring to protect the leading edge of the electromagnetic flowmeter lining is sometimes used. This ring shall be designed to ensure streamlined flow.

8.1.2.5.2 Entrained gases

Entrained gases cause measurement inaccuracies in direct relation to the volume percentage of gas to liquid. An electromagnetic flowmeter measures velocity and computes the total volume flow by multiplying the velocity by the cross sectional area. Precautions should be taken to reduce this effect by increasing the liquid pressure, e.g. by locating the sensor on the high-pressure side of a restrictor such as a control valve, or by eliminating the entrained gas.

NOTE High amounts of entrained gas can lead to a noisy measurement signal, or complete loss of the signal.

An automatic gas/air relief valve may be mounted at an appropriate distance before the sensor.

8.1.2.6 Buried sensors

Where it is necessary to install sensors in underground pipework, they should be installed in appropriate chambers. However, where it is necessary to backfill over the sensor, advice should be sought from the manufacturer and appropriate steps taken to protect the sensor from corrosive ground conditions, soil loading, and impact from excavators. For an installation below heavily stressed surfaces, e.g. streets, a metal plate may need to be installed above the sensor. Connecting cables to the transmitter should be run in a continuous length without joints which could be penetrated by groundwater.

8.1.2.7 Submerged sensors

Sensors installed in a location where they may be flooded or submerged should be rated to the appropriate depth as expected in the application.

8.1.2.8 Access for maintenance and cleaning

Sensors installed in pipelines containing wastewater and some process waters with grease, fat or entrained solids should be installed in such a way as to allow the bore to be cleaned. This may include rodding points or tappings through which inspection and maintenance tools can be inserted. See Figure 5.

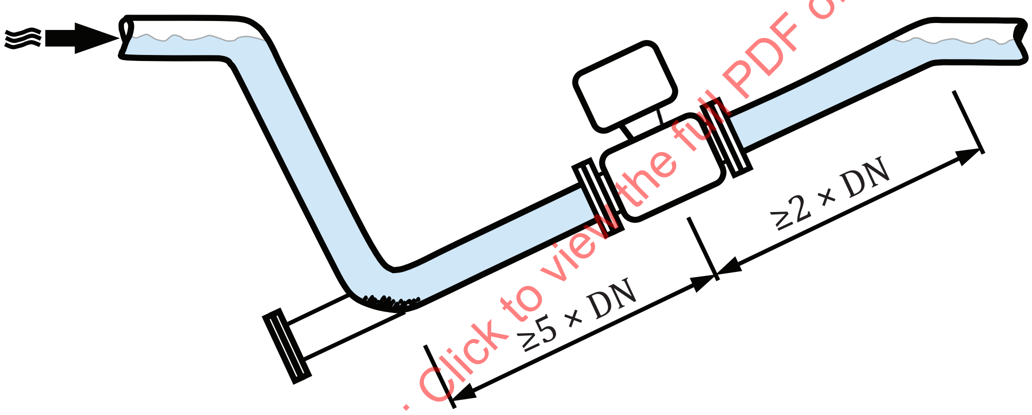


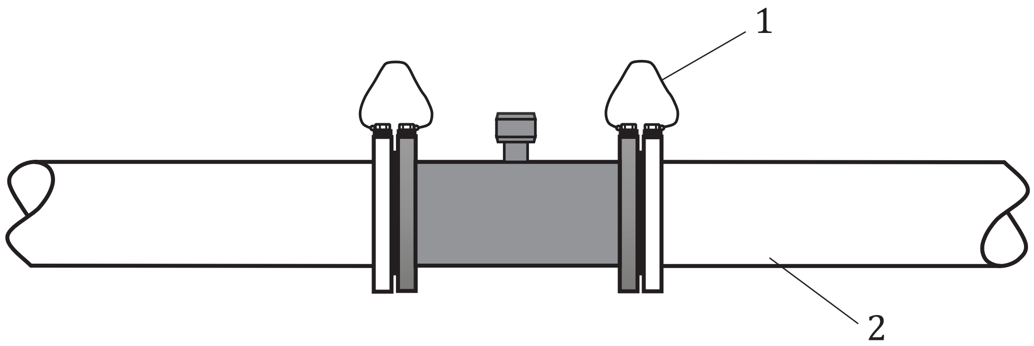
Figure 5 — Design of typical installation diagram

8.1.3 Potential equalization — General requirements

In general, the flowmeter requires a connection to the metered liquid. This connection starts with one of three things contacting the liquid, a metallic pipe, a grounding ring(s) (potential equalizing ring), or a grounding electrode (see Figures 6 and 7). Usually, one of those is connected to the sensor body, which is then connected to the correct terminal in the transmitter. In some cases, this connection to the transmitter is not made via the sensor body. In the case of a cathodically protected pipeline, special precautions shall be taken (see Annex C).

Some transmitters are constructed such that a connection to the metered liquid is not required. The manufacturer's installation guidance should be followed.

NOTE The dotted connection in Figure 7 indicates that with non-metallic adjacent piping the dotted connection can be omitted.

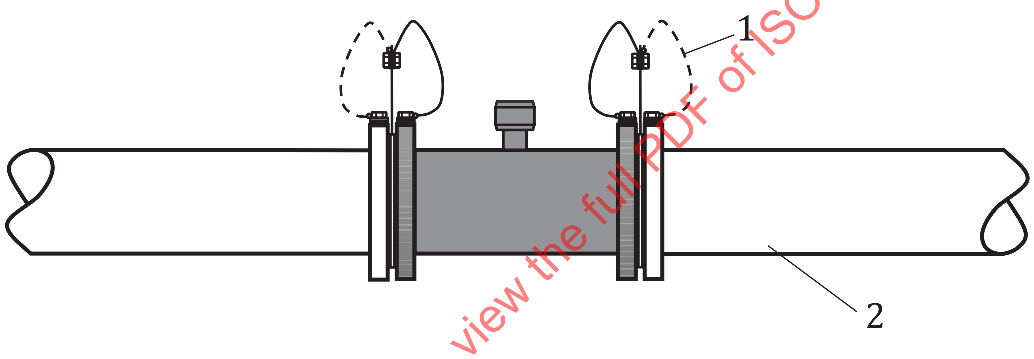


Key

1 potential equalizing ring

2 non-coated metallic pipe work

Figure 6 — Installation in non-coated metallic pipe work



Key

1 equalizing ring

2 non-metallic or internally coated pipe work

Figure 7 — Installation in non-metallic or internally coated pipe work

8.1.4 Electrical connections

The manufacturer's instructions shall be carefully followed for connections between the sensor and the transmitter. Instructions in relation to electrical grounding of the flowmeter system shall be followed.

8.1.5 Sensor mounting

8.1.5.1 Full pipe requirements

The sensor shall be mounted in such a position that it will be completely filled with the liquid being metered; otherwise, the measurement will not be within the manufacturer's stated accuracy. Some sensors include an additional electrode to detect when the meter is not running full and trigger an alarm. Such systems are intended for horizontal pipe runs and the sensor would be installed with the extra electrode in line with the crown of the pipe. Partially-filled sensor meters are used, for example, in sewage applications, but these merit special consideration outside the scope of this document.

8.1.5.2 Mechanical connections

There are different varieties of fittings including flanges, wafer, hygienic couplings, clamps, threads and welded connections. It is essential that the sensor is correctly aligned on the pipe axis.

For flange connections:

— bolts should be tightened evenly and in moderation in order to avoid damage to the lining; the manufacturer should state the maximum permissible torque;

— the manufacturer shall provide a reasonable clearance between the rear face of the flange and the meter housing for installation and removal.

Care should be taken when handling the sensor; slings around the sensor or lifting lugs should be used. Lifting by any means that could damage the liner, for example, hooks in the bore, shall not be used. Under no circumstances shall the sensor be lifted using the cable which connects it to the transmitter.

Where gaskets are fitted between the meter and the pipe connection, care should be taken to ensure that they are concentric with the pipe bore and do not intrude into the flow.

8.1.5.3 Pipeline stress

Every effort should be made to minimize piping loads and resulting strains at the sensor connecting flanges, particularly in plastic meters which are not intended to sustain piping loads. Permissible values should be checked with the manufacturer.

8.1.5.4 Pipe size reduction

To minimize pressure loss in cases where a sensor with a smaller nominal bore than the connecting pipe is installed, it is advisable to connect the sensor into the pipe work by means of shallow tapered cone pieces (recommended maximum included angle is 16°) (see Figure 8). Eccentric taper pipes may be used when the pipeline is horizontal to prevent air pockets from forming; alternatively, air relief valves may be fitted upstream of the upstream taper. In such cases, the inlet and outlet straight pipe sections shall be the same size as the flowmeter. The pipe reduction may affect the performance of the flowmeter and eccentric reducers will have a larger effect on accuracy than concentric reducers (see 8.1.2.1).

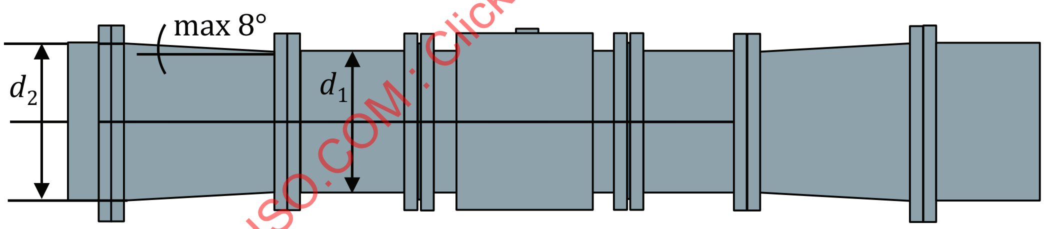


Figure 8 — Shallow taper entry and exit reducers to minimize pressure loss

8.1.6 Installation dimensions for flanged connections

For each meter size designation, there is a corresponding fixed overall length, L (for definition, see Figure 9), and tolerance both as specified in Table 1.

The length, L, includes the liner if it covers the flange face but excludes accessories such as gaskets, grounding and protection rings.

NOTE Other standards include alternative recommended lengths for meters.

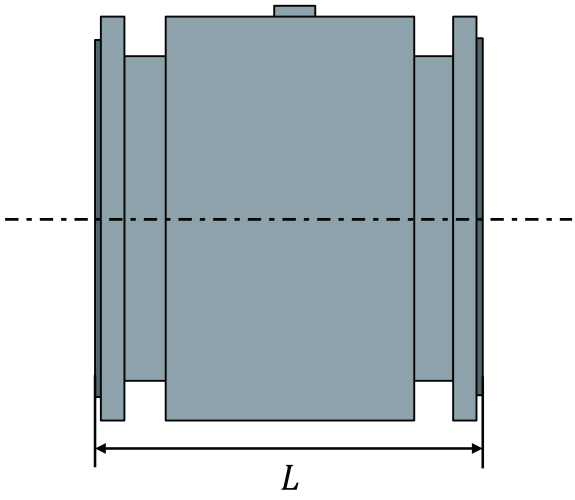


Figure 9 — Definition of overall length, *L*, and overall length in function of size

Table 1 — Dimensions for flanged connections

Dimensions in SI units		
Nominal size of flange connections DN	**Nominal length** *L* (mm)	**Tolerance of length** (mm)
15	200	L_{-3}^{0}
20	200	
25	200	
32	200	
40	200	
50	200	
65	200	
80	200	
100	250	
125	250	
150	300	
200	350	
250	450	L_{-5}^{0}
300	500	
350	550	
400	600	
For DN 450 to DN 2 000, recommended length of 1 to 1,3 × DN should be applied. Tolerance on length of meters greater than DN 400 should be agreed between the user and manufacturer. For dimensions smaller than DN 15, there are no preferred installation lengths.		

8.2 Transmitter location

Transmitters should be installed in an accessible position free from excessive vibration, due regard being given to the manufacturer's specifications for ambient temperature and humidity. In particular, a suitable sunshade or canopy shall be installed over the transmitter to avoid direct solar irradiation.

The cables carrying the electrode and reference signals between the transmitter and the sensor should be of the type specified by the manufacturer. These cables should be as short as possible and not exceed the limit imposed by the manufacturer. Care should be taken to ensure that signal cables are not routed in proximity to cables carrying high electrical currents. Good earthing practice should be observed with particular attention being paid to the prevention of “earth loops”.

8.3 Operational considerations

8.3.1 General

Wherever possible, the user should comply with the manufacturer’s recommendations for installation in order to minimize the effects of different operating conditions. Many conditions, such as vibration, ambient temperature, process temperature, solids or gases in the process liquid, those listed in 8.3.2 to 8.3.4, and others can affect the flow measurement and may increase the overall measurement uncertainty.

8.3.2 Effect of the liquid conductivity

Minimum operational conductivity requirements shall be specified by the manufacturer.

If the conductivity is not uniform throughout the fluid in the meter, it may have an effect on flowmeter performance.

8.3.3 Reynolds number effect

If the Reynolds number (*Re*) is higher than 10,000, the effect of *Re* is usually so small that, for practical purposes, it can be ignored. At lower *Re*s, the accuracy of flow measurement may be reduced.

8.3.4 Velocity profile effect

Distortions in velocity profiles may be caused by pipe fittings (bends, valves, reducers, etc.) placed upstream or downstream from the flowmeter; the resulting velocity profiles may have an influence on the performance of the meter.

9 Flowmeter calibration, validation, and verification

9.1 Flowmeter calibration

Calibration of an electromagnetic flowmeter usually consists of passing liquid (normally water) through the flowmeter in a calibration facility at the time of manufacture. The flowmeter is compared with a reference at two or more flowrates, and then the calibration factor is adjusted to meet the manufacturer's specification. At this point, the calibration is complete.

After the calibration is completed, the flowmeter is often operated again to validate that the meter meets the performance requirements. The data from this calibration validation step is usually included in a report from the manufacturer. The number of calibration validations runs and the flowrates at which they are performed are usually defined by the manufacturer, but may be specified by the user.

NOTE The method of computing the flowmeter sensor signal based on electromagnetic field strength measurements and on physical dimensions, commonly referred to as “dry calibration,” is beyond the scope of this document.

9.2 Flowmeter verification (*in-situ* electronic verification)

Electronic verification systems perform a number of electronic measurements on the sensor, transmitter and the interconnections between sensor and transmitter to check that certain parameters are within acceptable tolerances.

Ideally, a record of these parameters will be made during the initial manufacturer calibration. This enables direct comparison of site values against the original values at calibration. If an initial record is not taken, then a less accurate site verification can be undertaken against average values for flowmeters of the same manufacturer, size, and type.

For some flowmeters, manufacturers provide a separate unit for this which connects to the flowmeter under test; for others, the functionality is built into the flowmeter transmitter.

Note that electronic verification can be used to verify the operation and integrity of the flowmeter but will not be able to detect all measurement errors due to external influences (for example, flow disturbances) or too low conductivity.

10 Evaluation of flowmeter performance

10.1 General

There are two types of influence quantities to be considered, those affecting the liquid within the flowmeter sensor and those arising externally.

Internal effects include changes in, for example, the liquid temperature, the flow velocity distribution and liquid conductivity, flow rate, flow regime and liquid type.

External influence quantities include variations in temperature or humidity, barometric pressure and variations in supply current, voltage or frequency, and electromagnetic fields. Unless otherwise stated, the effect of each of these quantities shall be assessed by determining the deviation of the meter output from those obtained under reference conditions. The other conditions of use not under investigation shall remain constant at the reference value during the tests.

10.2 Applications within the scope of other standards

Flowmeters used for specific applications may be within the scope of other standards which specify certain methods of evaluation. ISO 4064, OIML R49, OIML R117, and OIML R75 cover drinking water, fluids other than water that are subject to legal metrology controls, and heat metering, respectively.

11 Uncertainty analysis

Uncertainty analysis is used to estimate a range of values within which the true flow rate is expected to lie for a specific installed application. It is intended to include all relevant effects and includes a confidence interval. This is distinct from the manufacturer's accuracy specification (see Annex E), which applies only to one set of reference conditions, and usually does not include a confidence interval.

The calculation of the uncertainty in the measurement of flowrate can be carried out as specified in ISO 5168. For electromagnetic flowmeter, the relevant conditions may include:

a) ambient conditions:

- temperature;
- humidity;
- external magnetic fields;

b) process conditions:

- fluid temperature;
- conductivity;
- pressure;

— entrained gases/solids;

— flow regime for multiphase fluids;

— expected flowrate range;

— viscosity or Reynolds number;

c) installation:

— flow direction;

— orientation (vertical, horizontal);

— alignment with up /downstream pipework;

— non-concentric gaskets;

— upstream flow disturbance;

— downstream flow disturbance if very close to meter;

— pipeline vibration.

Annex A
(informative)

Materials for construction of sensors

A.1 General

It is very important to choose construction materials suitable for the liquid to be metered. It is essential that account is taken of any other chemicals liable to pass through the meter tube, such as sterilizing agents, cleaners and solvents. As the user knows the properties of the liquid to be metered, the ultimate decision on the materials to be used should rest with them.

It is also important that the lining material is not subjected to temperatures outside the range recommended by the manufacturer. The maximum permissible pressure of the sensor is normally decreased as the temperature of the process fluid is increased.

A.2 Meter tube linings

Table A.1 provides examples of types of lining materials that are available. Table A.1 is intended as a general guidance and not for material selection for specific applications. Manufacturer's recommendations and previous user experience should be used to select a material for specific applications. National regulations may also have to be taken into account in the selection of electrode materials.

Table A.1 — Selection of meter tube lining materials and grades for suitability

	Abrasion resistance	**High temperature** (>100 °C)	**Chemical resistance**	**Hygienic design**	**Drinking water**	**Vacuum resistance**	**...**
Elastomers[a]							
Hard rubber (ebonite)	B	D	B	D	B	B	
Abrasion-resistant rubbers (natural, soft)	A	D	B	D	D	B	
Neoprene/Chloroprene (CR)	B	D	B	D	D	B	
Polyurethane (PU)	A	D	D	D	B	B	
Plastics							
Polytetrafluoroethylene (PTFE)	C	A	A	B	A	D	
Perfluoroalkoxy-Ploymere (PFA)	C	A	A	A	A	B	

A = Suitable

B = Usually suitable

C = Limited suitability

D = Not suitable

n.a. = No data available

[a] All rubber-based materials are attacked by high concentrations of free halogens, aromatics and halogenated hydrocarbons and high concentration of oxidizing chemicals.

Table A.1 *(continued)*

	Abrasion resistance	High temperature (>100 °C)	Chemical resistance	Hygienic design	Drinking water	Vacuum resistance	...
Ethylen-Tetrafluoroethylene (ETFE)	C	B	A	B	n.a.	B	
Polyamide (PA)	C	D	B	D	A	A	
Chlorinated polyether	n.a.	C	A	n.a.	n.a.	n.a.	
Glass-reinforced plastics (GRP)	n.a.	D	n.a.	n.a.	A	A	
Ceramics	A	B	A	B	C	A	

A = Suitable

B = Usually suitable

C = Limited suitability

D = Not suitable

n.a. = No data available

[a] All rubber-based materials are attacked by high concentrations of free halogens, aromatics and halogenated hydrocarbons and high concentration of oxidizing chemicals.

A.3 Examples of electrode materials

A.3.1 General

Manufacturer's recommendations and previous user experience should be used to select a material for specific applications.

A.3.2 For non-corrosive liquids

Stainless steel is generally used.

A.3.3 For corrosive liquids

The following may be suitable, depending on the chemical properties of the liquid to be metered. The materials are ranked from generally least corrosion resistant to generally most corrosion resistant, however, there are exceptions:

— stainless steel;

— some nickel-based alloys;

— titanium;

— tantalum;

— carbon loaded plastics;

— platinum (usually alloyed with iridium or rhodium).

A.3.4 Materials for specialized applications

For specialized applications other materials, material combinations or coatings are used.

EXAMPLES Tungsten carbide, ceramic-coated electrodes, zirconium and carbon-loaded plastics.

A.4 Meter tube and enclosure

The materials used for the meter tube, process connections (e.g. flanges) and enclosure are usually specified by the manufacturer. It is essential that they be compatible with the environmental conditions in which they are to be used.

The materials listed in A.3 may be used for parts of meter tubes that come into contact with the metered liquid, i.e. partially lined tubes.

Annex B
(informative)

Practical considerations for measuring system with AC and DC excitation

B.1 General

Two source voltages were introduced in 6.3.1, which are described here in more detail.

B.2 Electrochemical voltage, U_c

Electrochemical voltage may also result from chemical reaction occurring in the process fluid. The electrochemical voltage originates from electrochemical reactions between the metallic electrodes of the flowmeter and the process fluid, which is an electrolyte. The reaction is similar to that in a battery and although the electrochemical motive force is much weaker than that in a typical battery, it is often many times larger than the flow related voltage, U_v.

Since U_c varies slowly over time, alternating the magnetic field (either as a pulsed DC or sinusoidal AC excitation) reverses the polarity of U_v, but not U_c, which allows the two voltages to be differentiated as required for flow measurement.

B.3 Transformer voltage, U_t

This voltage originates from the rate of change of the magnetic field created by the field coils, following the ideal transformer formula. Alternating the magnetic field minimizes the problem of interference with U_c, but it also introduces another potential source of voltage interference, the transformer voltage (U_t).

$$V_s = -N_s \times A \times \mathrm{d}B/\mathrm{d}t \quad \text{(should we eliminate the number of turns and the area)}$$

where

V_s is the U_t (or voltage) induced in the transformer secondary;

N_s is the number of turns in the secondary;

A is the area of the single loop transformer secondary through which the magnetic field passes;

$\mathrm{d}B/\mathrm{d}t$ is the instantaneous rate of change of the magnetic field.

Thus, in addition to being an electromagnetic flowmeter, the sensor also acts as a weak transformer, with the field coils being the transformer primary. The single-loop transformer secondary is formed by the electrodes and their connecting wires, with the circuit completed by the conductive process liquid. In a magnetic sensor with applied DC field coil excitation, the rapid change in the field coil current as the polarity changes creates a voltage spike on the electrodes that is unrelated to the flow rate. This voltage spike may be similar in magnitude or larger than the flow related voltage, U_v.

In order to minimize the risk that the transformer voltage, U_t, interferes with the flow related voltage, U_v, manufacturers of electromagnetic flowmeters design the flowmeter internal electrode wiring loop such that it is parallel to the magnetic field lines so that the transformer effect is minimized. In addition, they use time sampling techniques to avoid the voltage spikes.

Annex C
(informative)

Cathodic protection

When an electromagnetic flowmeter is installed in a cathodic protected pipeline, special precautions are necessary to ensure that the direct current component of the cathode current does not affect the accuracy and stability of the flowmeter system. In such a case, the flowmeter manufacturer should always be consulted for installation advice.

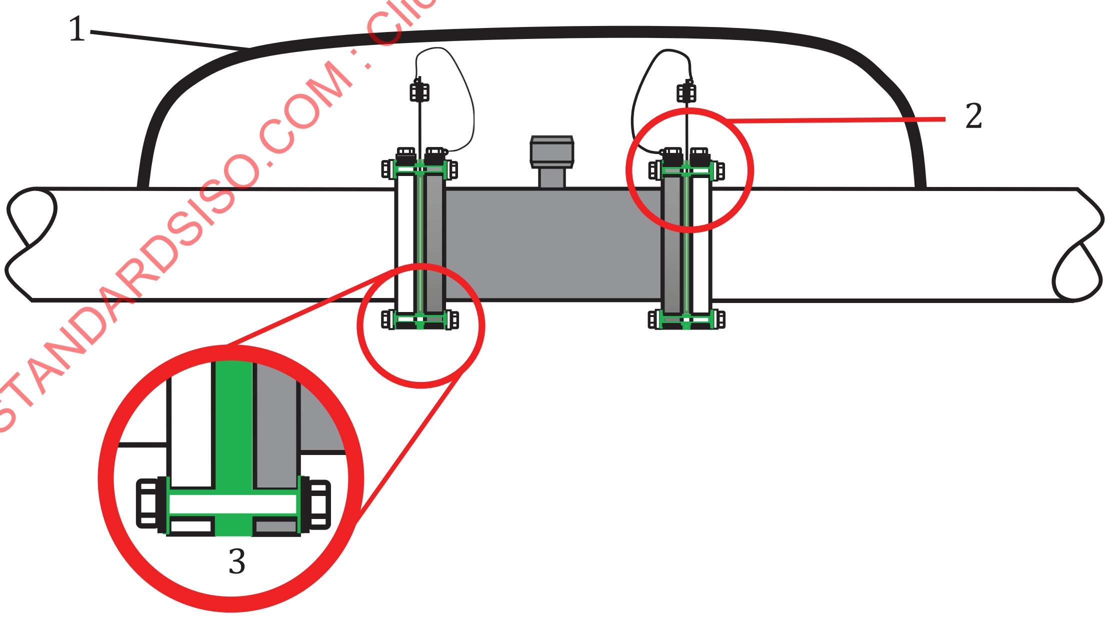
The precautions necessary depend on the location of the sensor relative to other parts of the cathodic protection system.

A requirement often applied is that the sensor body and the liquid are at the same potential. This may be achieved simply by adequate electrical bonding between the sensor body and the adjacent piping, or, where insulated or non-conductive pipe work is used, one of the conductive "earthing" rings or electrodes.

Under bonded conditions with cathode protection, the electric supply earth should not be connected to the sensor body; otherwise, the protection current will be bypassed to the supply earth.

With cathode protection systems on long pipelines, the cathode current is often obtained from several sources. These may be a considerable distance apart, and at different potentials owing to variation in earth resistance along the length of the pipeline. This can cause high currents to flow in the pipeline, which, if allowed to flow through a sensor body, can cause inaccuracy in measurements. Provision of an insulating flange and conductive links, as shown in Figure C.1, obviates this effect.

Contact the manufacturer for specific requirements.



Key

1 cathodic current bypass link

2 flowmeter connected ONLY to potential equalizing ring at BOTH ends

3 flowmeter insulated from pipework at BOTH ends

Figure C.1 — Cathodically-protected pipelines: conductive links across flange joints

Annex D
(informative)

Conversion of nominal diameters from metric to US units

Table D.1 — Conversion table for nominal diameters

Nominal diameter				
DN 4 to DN 400			DN 450 to DN 2 000	
(mm)	(in)		(mm)	(in)
4[a]	1/8		450	18
8[a]	3/8		500	20
15	1/2		600	24
20	3/4		700	28
25	1		750	30
32	1 1/4		800	32
40	1 1/2		900	36
50	2		1 000	40
65	2 1/2		—	42
80	3		1 200	48
100	4		—	54
125	5		1 400	
150	6		—	60
200	8		1 600	—
250	10		—	66
300	12		1 800	72
350	14		—	78
375	15		2 000	
400	16			

[a] These line sizes are most commonly used with DN 15 flanges.