# INTERNATIONAL STANDARD

# ISO 10790

Third edition
2015-04-01

# Measurement of fluid flow in closed conduits — Guidance to the selection, installation and use of Coriolis flowmeters (mass flow, density and volume flow measurements)

*Mesure de débit des fluides dans les conduites fermées — Lignes directrices pour la sélection, l'installation et l'utilisation des mesureurs à effet Coriolis (mesurages de débit-masse, masse volumique et débit-volume)*



Reference number
ISO 10790:2015(E)

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Published in Switzerland

# Contents

Page





 

# 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 meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.



The committee responsible for this document is ISO/TC 30, *Measurement of fluid flow in closed conduits*, Subcommittee SC 5, *Velocity and mass methods*.



This third edition cancels and replaces the second edition (ISO 10790:1999), which has been technically revised. It also incorporates the Amendment ISO 10790:1999/Amd 1:2003.

# Introduction

This International Standard has been prepared as a guide for those concerned with the selection, testing, inspection, operation, and calibration of Coriolis flowmeters (Coriolis flowmeter assemblies). A list of related International Standards is in the Bibliography.

This International Standard provides the following:

a) description of the Coriolis operating principle;

b) guideline to expected performance characteristics of Coriolis flowmeters;

c) description of calibration, verification, and checking procedures;

d) description of potential error sources;

e) common set of terminology, symbols, definitions, and specifications.

The next paragraphs contain an explanation of when to use the measurement terminology, uncertainty, and accuracy.

The VIM definition (see 3.2) of accuracy: closeness of agreement between a measured quantity value and a "true quantity value" of a measurand. Per the VIM, accuracy is a quality and should not be given a numerical value.

To understand the preceding paragraph, one needs to understand that a "true quantity value" does not exist. The best that can be done is to determine the measured quantity value with measurement instrumentation calibrated with a very good but imperfect reference. Therefore, the measurement is an estimate. Uncertainty is used to define these measurement estimates (see 3.2.2).



Many Coriolis manufacturers use accuracy and zero stability as part of their published performance specifications. The manufacturer's accuracy specification includes repeatability, hysteresis, and linearity but can also include other items that might be different for each manufacturer.



This International Standard will use uncertainty to quantify the results of a flow measurement system. This International Standard will only use accuracy when it is very clear that it is referring to or using all or part of the manufacturers published specifications.

 

# Measurement of fluid flow in closed conduits — Guidance to the selection, installation and use of Coriolis flowmeters (mass flow, density and volume flow measurements)

## 1 Scope

This International Standard gives guidelines for the selection, installation, calibration, performance, and operation of Coriolis flowmeters for the measurement of mass flow and density. This International Standard also gives appropriate considerations regarding the type of fluids measured, as well as guidance in the determination of volume flow and other related fluid parameters.

NOTE Fluids defined as air, natural gas, water, oil, LPG, LNG, manufactured gases, mixtures, slurries, etc.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5168, *Measurement of fluid flow — Procedures for the evaluation of uncertainties*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO/IEC Guide 99:2007 (JCGM 200:2012), *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*



## 3 Terms and definitions

### 3.1 Definitions specific to this Coriolis flowmeter standard

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

**3.1.1**
**Coriolis flowmeter**
device consisting of a flow sensor (primary device) and a transmitter (secondary device) which measures mass flow and density by means of the interaction between a flowing fluid and the oscillation of a tube or tubes

Note 1 to entry: This can also provide measurement of the tube(s) temperature.

**3.1.2**
**flow sensor (primary device)**
mechanical assembly consisting of an oscillating tube(s), drive system, measurement sensor(s), supporting structure, and housing

**3.1.3**
**transmitter (secondary device)**
electronic control system providing the drive electrical supply and transforming the signals from the flow sensor to give output(s) of measured and inferred parameters

Note 1 to entry: It also provides corrections derived from parameters such as temperature.

Note 2 to entry: The transmitter (secondary device) is either integrally mounted (compact device) on the flow sensor (primary device) or remotely installed away from the primary device and connected by a cable.

**3.1.4**
**oscillating tube**
tube through which the fluid to be measured flows

**3.1.5**
**drive system**
means for inducing the oscillation of the tube(s)

**3.1.6**
**sensing device**
sensor to detect the effect of the Coriolis force and to measure the frequency of the tube oscillations

**3.1.7**
**supporting structure**
support for the oscillating tube(s)

**3.1.8**
**housing**
environmental protection of the flow sensor and/or transmitter

**3.1.9**
**secondary containment**
housing designed to provide protection to the environment in the event of tube failure

**3.1.10**
**calibrating factor**
numerical factor unique to each sensor derived during sensor calibration

Note 1 to entry: The calibrating factor is programmed into the transmitter to enable flowmeter operation.



**3.1.11**
**zero offset**
indicated flow when there are zero flow conditions present at the meter

Note 1 to entry: This could be due to mechanical or electrical noise superimposed on the sensor output but equally could be due to installation effects such as torsional loading caused by improper torqueing of the flange bolts or temperature extremes creating deflection of the pipeline.

**3.1.12**
**zero stability**
variation of the flowmeter output at zero flow after the zero adjustment procedure has been completed, expressed by the manufacturer as an absolute value in mass per unit time

**3.1.13**
**flashing**
phenomenon, which occurs when the line pressure drops to, or below, the vapour pressure of the liquid

Note 1 to entry: This is often due to pressure drops caused by an increase in liquid velocity.

Note 2 to entry: Flashing is not applicable to gases.

**3.1.14**
**cavitation**
phenomenon related to and following flashing of liquids if the pressure recovers causing the vapour bubbles to collapse (implode)

**3.1.15**
**flow rate**
quotient of the quantity of fluid passing through the cross-section of the conduit and the time taken for this quantity to pass through this section

**3.1.16**
**mass flow rate**
flow rate in which the quantity of fluid is expressed as mass

**3.1.17**
**volume flow rate**
flow rate in which the quantity of fluid is expressed as volume

## 3.2 Definitions from VIM, ISO/IEC Guide 99 (JCGM:2012)

**3.2.1**
**repeatability (condition of measurement)**
condition of measurement, out of a set of conditions that includes the same measurement procedure, same operators, same measuring system, same operating conditions, and same location, and replicate measurements on the same or similar objects over a short period of time

Note 1 to entry: A condition of measurement is a repeatability condition only with respect to a specified set of repeatability conditions environmental protection of the flow sensor and/or transmitter.

**3.2.2**
**measurement uncertainty**
non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used

Note 1 to entry: Measurement uncertainty includes components arising from systematic effects, such as components associated with corrections and the assigned quantity values of measurement standards, as well as the definitional uncertainty. Sometimes estimated systematic effects are not corrected for but, instead, associated measurement uncertainty components are incorporated.



Note 2 to entry: Measurement uncertainty comprises, in general, many components. Some of these can be evaluated by Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from series of measurements and can be characterized by standard deviations. The other components, which can be evaluated by Type B evaluation of measurement uncertainty, can also be characterized by standard deviations, evaluated from probability density functions based on experience or other information.

**3.2.3**
**error**
measured quantity value minus a reference quantity value

Note 1 to entry: The concept of "measurement error" can be used both a) when there is a single reference quantity value to refer to, which occurs if a calibration is made by means of a measurement standard with a measured quantity value having a negligible measurement uncertainty or if a conventional quantity value is given, in which case the measurement error is known, and b) if a measurand is supposed to be represented by a unique true quantity value or a set of true quantity values of negligible range, in which case the measurement error is not known.

**3.2.4**
**calibration**
operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

Note 1 to entry: A calibration can be expressed by a statement, calibration function, calibration diagram, calibration curve, or calibration table. In some cases, it can consist of an additive or multiplicative correction of the indication with associated measurement uncertainty.

Note 2 to entry: Calibration should not be confused with adjustment of a measuring system, often mistakenly called "self-calibration", nor with verification calibration.

## 3.3 Symbols

**Table 1 — Symbols used in this International Standard**

| Symbol | Description | Dimensions | SI Units |
|---|---|---|---|
| $A_{id}$ | oscillating tube internal cross-sectional area | $L^2$ | $m^2$ |
| $a_r$ | radial acceleration | $LT^{-2}$ | $m/s^2$ |
| $a_t$ | transverse acceleration | $LT^{-2}$ | $m/s^2$ |
| $V$ | velocity | $LT^{-1}$ | m/s |
| $\delta m_f$ | delta mass of a flowing particle | M | kg |
| $\delta m_{tb}$ | mass of tube element | M | kg |
| $\delta F_C$ | delta Coriolis force | $MLT^{-2}$ | $m \cdot kg/s^2$ |
| $q_m$ | mass flow rate | $MT^{-1}$ | kg/s |
| $\rho$ | density | $ML^{-3}$ | $kg/m^3$ |
| $\rho_f$ | density of the fluid | $ML^{-3}$ | $kg/m^3$ |
| $\rho_{ref}$ | density of reference liquid | $ML^{-3}$ | $kg/m^3$ |
| $tb$ | tube | dim-less | — |
| $F_{C,Inlet}$ | resultant Coriolis force in the inlet | $MLT^{-2}$ | $m \cdot kg/s^2$ |
| $F_{C,Outlet}$ | resultant Coriolis force in the outlet | $MLT^{-2}$ | $m \cdot kg/s^2$ |
| $F_C$ | Coriolis force | $MLT^{-2}$ | $m \cdot kg/s^2$ |
| $sin_D$ | sinusoidal function (displacement, velocity, or acceleration) | L, $LT^{-1}$, or $LT^{-2}$ | m, m/s, or $m/s^2$ |
| $sin_A$ | sinusoidal function (displacement, velocity, or acceleration) | L, $LT^{-1}$, or $LT^{-2}$ | m, m/s, or $m/s^2$ |
| $sin_B$ | sinusoidal function (displacement, velocity, or acceleration) | L, $LT^{-1}$, or $LT^{-2}$ | m, m/s, or $m/s^2$ |
| $t_d$ | time delay | T | s |
| $K_R$ | a constant, primary flow calibration factor at reference conditions | $MT^{-1}$ | kg/s/s |
| $\omega$ | angular velocity | $T^{-1}$ | rad/s |
| $r$ | length | L | m |
| $\delta x$ | delta length | L | m |
| $f_{rf}$ | resonant frequency | T | Hz |
| $C$ | mechanical stiffness | $MT^{-2}$ | $kg/s^2$ |
| $m$ | mass | M | kg |
| $M$ | total mass – over a period of time | $MT^{-1}$ | kg/s |
| $m_{tb}$ | mass of oscillating tube(s) | M | kg |
| $m_f$ | mass of fluid within the oscillating tube(s) | M | kg |
| $V_f$ | volume of fluid within the oscillating tube(s) | $L^3$ | $m^3$ |
| $V$ | total volume – over a period of time | $L^3T^{-1}$ | $m^3/s$ |
| $K_1$, $K_2$ | density calibration factors | dim-less | — |
| $T_{rf}$ | is the period of the oscillating tube | T | s |
| $N_c$ | number of cycles | dim-less | — |
| $t_w$ | is the time window (gate) | T | s |
| $\rho_{ref}$ | the density of water at reference conditions | $ML^{-3}$ | $kg/m^3$ |



 

| Symbol | Description | Dimensions | SI Units |
|---|---|---|---|
| $U_v$ | expected uncertainty of the flow measurement volume | percent of reading | — |
| $U_m$ | expected uncertainty of the mass flow measurement | percent of reading | — |
| $U_\rho$ | expected uncertainty of the density measurement | percent of reading | — |
| $w_A$ | mass fraction of component A | dim-less | — |
| $w_B$ | mass fraction of component B | dim–less | — |
| $\varphi_A$ | volume fraction of component A | dim-less | — |
| $\varphi_B$ | volume fraction of component B | dim-less | — |
| $\rho_A$ | density of component A | $ML^{-3}$ | $kg/m^3$ |
| $\rho_B$ | density of component B | $ML^{-3}$ | $kg/m^3$ |
| $\rho_{ms}$ | density of measured mixture density | $ML^{-3}$ | $kg/m^3$ |
| $q_{mA}$ | mass flow rate of component A | $MT^{-1}$ | kg/s |
| $q_{mB}$ | mass flow rate of component B | $MT^{-1}$ | kg/s |
| $q_{mT}$ | total mass flow rate of the mixture | $MT^{-1}$ | kg/s |
| $q_{vA}$ | volume flow rate of component A | $L^3T^{-1}$ | $m^3/s$ |
| $q_{vB}$ | volume flow rate of component B | $L^3T^{-1}$ | $m^3/s$ |
| $q_{vT}$ | total volume flow rate of the mixture | $L^3T^{-1}$ | m3/s |

## 3.4 Abbrevations



**Table 2 — Abbreviations used in this International Standard**



| Abbreviations | Descriptions |
|---|---|
| cP | centipoise (dynamic viscosity) 1 cP = 1 mPa·s |
| cSt | CentiStokes (kinematic viscosity) 1 cSt = 1 $mm^2/s$ |
| cP/SG | viscosity used in petroleum industry |
| DN | European piping size (diameter nominal, millimetres) |
| SG | specific gravity |
| SIP | steaming-in-place |
| CIP | cleaning-in-place |

# 4 Coriolis flowmeter selection criteria

## 4.1 General

The Coriolis flowmeter should be selected to measure the user's parameters within their required ranges and uncertainty. Consideration should be given to the following points when selecting a Coriolis flowmeter.

Coriolis flowmeters are not generic devices. The potential user should review the manufacturer's data sheet(s) carefully.

## 4.2 Physical installation

### 4.2.1 General

The manufacturer should describe the recommended installation arrangement and state any restrictions of use.

The installation arrangement design enables measurement to meet the user's requirements. Installation for liquid and gas measurement can be different. Some applications might need strainers or filters, and other applications might need air and/or vapour eliminators.

Coriolis flowmeters are regularly placed in the mainstream of the flow but can also be placed in a by-pass arrangement for density measurements.

### 4.2.2 Installation criteria

Consider the following, noting that there might be differences for liquid and gas measurement applications:

a) the space required for the Coriolis flowmeter installation, including provision for external prover or master-meter connections, should *in situ* calibration be required;

b) the class and type of pipe connections and materials, as well as the dimensions of the equipment to be used;

c) the hazardous area classification;

d) the environmental effects on the sensor, for instance, temperature, humidity, corrosive atmospheres, mechanical shock, vibration, and electromagnetic field;

e) the mounting and support requirements.

### 4.2.3 Full-pipe requirement for liquids



The primary device should be mounted such that the oscillating tube(s) fill completely with the liquid being metered; this prevents the measuring performance of the instrument from being impaired. The manufacturer should state the means, if any, required to purge or drain gases or liquids from the instrument.



### 4.2.4 Orientation

Plugging, coating, trapped gas, trapped liquid, or settlement of solids can affect the flowmeter's performance. The orientation of the sensor depends on the intended application of the flowmeter and the geometry of the oscillating tube(s). The orientation of the Coriolis flowmeter should be recommended by the manufacturer.

### 4.2.5 Flow conditions and straight length requirements

The performance of a Coriolis flowmeter in single phase flow is usually not affected by swirling fluid or non-uniform velocity profiles induced by upstream or downstream-piping configurations.

### 4.2.6 Valves

Valves upstream and downstream to a Coriolis flowmeter, installed for the purpose of isolation and zero adjustment, can be of any type, but should provide tight shutoff. Control valves in series with a Coriolis flowmeter should be installed downstream to maintain the pressure required to ensure the product remains single phase and no flashing or cavitation can occur.

### 4.2.7 Cleaning

For certain applications (for instance hygienic services), the Coriolis flowmeter might require *in situ* cleaning which can be accomplished by

a) mechanical means (using a pig or ultrasonic device),

b) self-draining,

 

c) hydrodynamic means,

d) sterilization (steaming-in-place, SIP), and

e) chemical or biological (cleaning-in-place, CIP).

Care should be taken to avoid cross-contamination after cleaning fluids have been used.

Chemical compatibility should be established between the sensor wetted-materials, process fluid, and cleaning fluid.

#### 4.2.8 Hydraulic and mechanical vibrations

The manufacturer should specify the operating frequency range of the instrument to enable assessment of possible influences of process or other external mechanically imposed frequencies. It is possible that the performance of the flowmeter can be influenced by frequencies other than the operating frequencies. These effects can largely be addressed by appropriate mounting or clamping of the instrument.

In environments with high mechanical vibrations or flow pulsations, consideration should be given to the use of pulsation damping devices (see 4.3.7) and/or vibration isolators and/or flexible connections.

#### 4.2.9 Pipe stress and torsion

The flow sensor is subjected to axial, bending, and torsional forces during operation. Changes in these forces, resulting from variations in process temperature and/or pressure, can affect the Coriolis mass flow measurement. Care should be taken to ensure that no forces are exerted on the flowmeter from the clamping arrangements.



Measures should also be taken to prevent alignment stresses from being exerted on the Coriolis flowmeter by connecting pipes.



Under no circumstances should the Coriolis flowmeter be used to align the pipe work.

#### 4.2.10 Crosstalk between sensors

If two or more Coriolis flowmeters are to be mounted close together, interference through mechanical coupling might occur. This is often referred to as crosstalk. The manufacturer should be consulted for methods of avoiding crosstalk.

This should be recognized in the mechanical design of an installation to avoid interference or “crosstalk”. Testing should be carried out after installation as flowmeter errors introduced can be significant but not obvious in normal operation. If observed, the manufacturer should be consulted.

### 4.3 Effects due to process conditions and fluid properties

#### 4.3.1 General

Variations in fluid properties, such as density, viscosity, and process conditions, such as pressure and temperature, can influence the flowmeter’s performance. These effects have influences which differ depending on which parameter is of interest.

#### 4.3.2 Application and fluid properties

In order to identify the optimum flowmeter for a given application, it is important to establish the range of conditions to which the Coriolis flowmeter will be subjected. These conditions should include the following:

a) flow rates;

b) the range of densities;

 