INTERNATIONAL STANDARD

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Second edition
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# Measurement of fluid flow in closed conduits — Guidance to the selection, installation and use of Coriolis meters (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)*



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## Contents







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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 10790 was prepared by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*, Subcommittee SC 12, *Mass methods.*

This second edition cancels and replaces the first edition (ISO 10790:1994), which has been extended to include all measured and inferred parameters obtainable from a Coriolis meter including mass flow, density, volume flow and other related parameters.

Annexes A, B, C and D of this International Standard are for information only.

## Introduction

This International Standard has been prepared as a guide for those concerned with the selection, testing, inspection, operation and calibration of Coriolis meters (Coriolis meter assemblies) for any kind of fluid.

A list of related standards is given in the bibliography.

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

## 1 Scope

This International Standard gives guidelines for the selection, installation, calibration, performance and operation of Coriolis meters for the determination of mass flow, density, volume flow and other related parameters of fluids. It also gives appropriate considerations regarding the fluids to be measured.

The primary purpose of Coriolis meters is to measure mass flow. However, some of these meters offer additional possibilities for determining the density and temperature of fluids. From the measurement of these three parameters, volume flow and other related parameters can be determined.

The content of this International Standard is primarily applied to the metering of liquids. This International Standard also gives guidance within specified limits, to the metering of other fluids, mixtures of solids or gas in liquids, and mixtures of liquids. Although Coriolis meters may be used for gas measurement, specific guidance for gas measurement is not within the scope of this International Standard.



## 2 Terms and definitions

For the purpose of this International Standard, the following terms and definitions apply.

**2.1**
**Coriolis meter**
device consisting of a flow sensor (primary device) and a transmitter (secondary device) which primarily measures the mass flow by means of the interaction between a flowing fluid and the oscillation of a tube or tubes; it may also provide measurements of the density and the process temperature of the fluid

**2.2**
**flow sensor (primary device)**
mechanical assembly consisting of an oscillating tube, drive system, measurement sensor(s), supporting structure and housing

**2.2.1**
**oscillating tube(s)**
tube(s) through which the fluid to be measured flows

**2.2.2**
**drive system**
means for inducing the oscillation of the tube(s)

**2.2.3**
**sensing device**
sensor to detect the effect of the Coriolis force and to measure the frequency of the tube oscillations

**2.2.4**
**supporting structure**
support for the oscillating tube(s)

**2.2.5**
**housing**
environmental protection of the flow sensor

**2.2.6**
**secondary containment**
housing designed to provide protection to the environment in the event of tube failure

**2.3**
**transmitter (secondary device)**
electronic control system providing the drive and transforming the signals from the flow sensor, to give output(s) of measured and inferred parameters; it also provides corrections derived from parameters such as temperature

**2.4**
**flow rate**
ratio of the quantity of fluid passing through the cross-section of the flowsensor and the time taken for this quantity to pass through this section

**2.4.1**
**mass flow rate**
flow rate in which the quantity of fluid which passes is expressed as mass

**2.4.2**
**volume flow rate**
flow rate in which the quantity of fluid which passes is expressed as volume



**2.5**
**accuracy of measurement**
closeness of the agreement between the result of a measurement and a true value of the measurand [VIM[1]]



**2.6**
**repeatability**
<of results of measurements> closeness of the agreement between the results of successive measurements of the same measurand carried out under the same conditions of measurement [VIM[1]]

**2.7**
**uncertainty of measurement**
parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand [VIM[1]]

**2.8**
**error**
<of measurement> result of a measurement minus a true value of the measurand [VIM[1]]

**2.9**
**calibration factor(s)**
numerical factor(s) unique to each sensor derived during sensor calibration, which when programmed into the transmitter ensures that the meter performs to its stated specification

**2.9.1**
**flow calibration factor(s)**
associated with mass flow measurement

**2.9.2**
**density calibration factor(s)**
associated with density measurement

**2.10**
**zero offset**
measurement output indicated under zero flow conditions, usually as a result of stress being applied to the oscillating tubes by the surrounding pipework and by process conditions

NOTE The zero offset can be reduced by means of a zero adjustment procedure.

**2.11**
**zero stability**
magnitude of the meter 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

NOTE The stated value for zero stability is valid for stable conditions where the fluid is free of bubbles and heavy sediment.

**2.12**
**flashing**
phenomenon which occurs when the line pressure drops to, or below, the vapour pressure of the liquid

NOTE This is often due to pressure drops caused by an increase in the liquid velocity.

**2.13**
**cavitation**
phenomenon related to and following flashing if the pressure recovers causing the vapour bubbles to collapse (implode)



## 3 Coriolis meter selection criteria

### 3.1 General



The Coriolis meter should be selected to measure parameters within the required range and accuracy. Consideration should be given to the following points when selecting a Coriolis meter.

### 3.2 Accuracy

The expression of accuracy varies depending on the parameter to which it applies. For specific recommendations on mass flow, density and volume flow accuracies, see 5.2, 6.3 and 7.3, respectively. For other parameters see clause 8.

NOTE Manufacturers' accuracy statements should be given for specified reference conditions. If the conditions of use are significantly different from those of the original calibration, the meter's performance may be affected.

### 3.3 Physical installation

#### 3.3.1 General

The manufacturer should describe the preferred installation arrangement and state any restrictions of use. See annex C.

The installation arrangement should be designed to provide a maximum operating lifetime. If needed, strainers, filters, air and/or vapour eliminators or other protective devices should be placed upstream to the meter for the removal of solids or vapours that could cause damage or provoke errors in measurement.

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

### 3.3.2 Installation criteria

Consideration should be given to the following points:

a) the space required for the Coriolis meter 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 climatic and environmental effects on the sensor, for instance temperature, humidity, corrosive atmospheres, mechanical shock, vibration and electromagnetic field;

e) the mounting and support requirements.

### 3.3.3 Full-pipe requirement

The primary device should be mounted such that the oscillating tube(s) fill completely with the fluid being metered; this will prevent 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.

### 3.3.4 Orientation

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



### 3.3.5 Flow conditions and straight length requirements

The performance of a Coriolis meter is usually not affected by swirling fluid or non-uniform velocity profiles induced by upstream- or downstream-piping configurations. Although special straight-piping lengths are normally not required, good piping practices should be observed at all times.



### 3.3.6 Valves

Valves upstream and downstream to a Coriolis meter, 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 meter should be installed downstream in order to maintain the highest possible pressure in the meter and thus reduce the chance of cavitation or flashing.

### 3.3.7 Cleaning

For certain applications (for instance hygienic services), the Coriolis meter may require in-situ cleaning which can be accomplished by:

a) mechanical means (using a pig or ultrasonically);

b) self-draining;

c) hydrodynamic means:

- sterilization (steaming-in-place, SIP);
- chemical or biological (cleaning-in-place, CIP).

NOTE 1 Care should be taken to avoid cross-contamination after cleaning fluids have been used.

NOTE 2 Chemical compatibility should be established between the sensor wetted-materials, process fluid and cleaning fluid.

### 3.3.8 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 meter may 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 3.4.7) and/or vibration isolators and/or flexible connections.

#### 3.3.9 Flashing and/or cavitation

The relatively high fluid velocities which often occur in Coriolis meters, cause local dynamic pressure drops inside the meter which may result in flashing and/or cavitation.

Both flashing and cavitation in Coriolis meters (and immediately upstream and/or downstream of them), should be avoided at all times. Flashing and cavitation may cause measurement errors and may damage the sensor.

#### 3.3.10 Pipe stress and torsion

The flow sensor will be 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 performance of the Coriolis meter. Care should be taken to ensure that no forces are exerted on the meter from clamping arrangements.

Measures should also be taken to prevent excessive stresses from being exerted on the Coriolis meter by connecting pipes. Under no circumstances should the Coriolis meter be used to align the pipework.

#### 3.3.11 Cross-talk between sensors

If two or more Coriolis meters are to be mounted close together, interference through mechanical coupling may occur. This is often referred to as cross-talk. The manufacturer should be consulted for methods of avoiding cross-talk.



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



#### 3.4.1 General

Variations in fluid properties such as density, viscosity and process conditions such as pressure and temperature, may influence the meter's performance. These effects have influences which differ depending on which parameter is of interest. Refer to clauses 5.3, 6.4, 7.4 and 8.3.

#### 3.4.2 Application and fluid properties

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

a) the operating flow rates and the following flow characteristics: unidirectional or bi-directional, continuous, intermittent or fluctuating;

b) the range of operating densities;

c) the range of operating temperatures;

d) the range of operating pressures;

e) the pressure on the liquid adequate to prevent cavitation and flashing;

f) the permissible pressure loss;

g) the range of operating viscosities;

h) the properties of the metered fluids, including vapour pressure, two-phase flow and corrosiveness;

i) the effects of corrosive additives or contaminants on the meters and the quantity and size of foreign matter, including abrasive particles, that may be carried in the liquid stream.

#### 3.4.3 Multiphase flow

Liquid mixtures, homogeneous mixtures of solids in liquids or homogeneous mixtures of liquids with low ratios of gas, may be measured satisfactorily in most cases. Multiphase applications involving non-homogeneous mixtures can cause additional measurement errors and in some cases can stop operation. Care should be taken to ensure that gas bubbles or condensate droplets are not trapped in the meter.

#### 3.4.4 Influence of process fluid

Erosion, corrosion and deposition of material on the inside of the vibrating tube(s) (sometimes referred to as coating) can initially cause measurement errors in flow and density, and in the longer term, sensor failure.

#### 3.4.5 Temperature effects

A change in temperature will affect the properties of sensor materials, and thus will influence the response of the sensor. A means of compensation for this effect is usually incorporated in the transmitter.

#### 3.4.6 Pressure effects

Static pressure changes can affect the accuracy of the sensor, the extent of which should be specified by the manufacturer. These changes are not normally compensated except in cases of certain precision measurements and certain meter designs and sizes.

#### 3.4.7 Pulsating flow effects

Coriolis meters generally are able to perform under pulsating flow conditions. However, there may be circumstances where pulsations can affect the performance of the meter (see 3.3.8). The manufacturers' recommendations should be observed regarding the application and the possible use of pulsation damping devices.



#### 3.4.8 Viscosity effects

Higher viscosity fluids may draw energy from the Coriolis excitation system particularly at the start of flow. Depending on the meter design, this phenomenon may cause the sensor tubes to momentarily stall until the flow is properly established. This phenomenon should normally induce a temporary alarm condition in the transmitter.

### 3.5 Pressure loss

A loss in pressure will occur as the fluid flows through the sensor. The magnitude of this loss will be a function of the size and geometry of the oscillating tube(s), the mass flow rate (velocity) and dynamic viscosity of the process fluid. Manufacturers should specify the loss in pressure which occurs under reference conditions and should provide the information necessary to calculate the loss in pressure which occurs under operating conditions. The overall pressure of the system should be checked to ensure that it is sufficiently high to accommodate the loss in pressure across the meter.

### 3.6 Safety

#### 3.6.1 General

The meter should not be used under conditions which are outside the meter's specification. Meters also should conform to any necessary hazardous area classifications. The following additional safety considerations should be made.

#### 3.6.2 Hydrostatic pressure test

The wetted parts of the fully-assembled flow sensor should be hydrostatically tested in accordance with the appropriate standard.

#### 3.6.3 Mechanical stress

The meter should be designed to withstand all loads originating from the oscillating tube(s) system, temperature, pressure and pipe vibration. The user should respect the limitations of the sensor at all times.

### 3.6.4 Erosion

Fluids containing solid particles or cavitation can cause erosion of the measuring tube(s) during flow. The effect of erosion is dependent on meter size and geometry, particle size, abrasives and velocity. Erosion should be assessed for each type of use of the meter.

### 3.6.5 Corrosion

Corrosion, including galvanic corrosion, of the wetted materials can adversely affect the operating lifetime of the sensor. The construction material of the sensor should be selected to be compatible with process fluids and cleaning fluids. Special attention should be given to corrosion and galvanic effects in no-flow or empty-pipe conditions. All process-wetted materials should be specified.

### 3.6.6 Housing design

The housing should be designed primarily to protect the flowsensor from deleterious effects from its surrounding environment (dirt, condensation and mechanical interference) which might interfere with operation. If the vibrating tube(s) of the Coriolis meter were to fail, the housing containing the tube(s) would be exposed to the process fluid and conditions which could possibly cause housing failure. It is important to take into consideration the following possibilities:

a) the pressure within the housing might exceed the design limits;

b) the fluid might be toxic, corrosive or volatile and might leak from the housing.

In order to avoid such problems, certain housing designs provide:



— secondary pressure containment;

— burst discs or pressure-relief valves, fluid drains or vents, etc.

For guidelines on specifying secondary pressure containment, see annex B.



### 3.6.7 Cleaning

For general guidelines see 3.3.7.

Care should be taken to ensure that cleaning conditions (fluids, temperatures, flow rates, etc.) have been selected to be compatible with the materials of the Coriolis meter .

## 3.7 Transmitter (secondary device)

Coriolis meters are multivariable instruments providing a wide range of measurement data from only a single point in the process. In selecting the most appropriate transmitter, consideration should be given to:

a) the electrical, electronic, climatic and safety compatibility;

b) the mounting, i.e. integrally or remotely mounted;

c) the required number and type of outputs;

d) the ease and security of programming;

e) the outputs demonstrating adequate stability and reasonable response times, and in the case of an analogue output including the minimum and maximum span adjustments;

f) the output(s) indicating system errors;

g) the required input options, for instance remote zero adjustment, totalizer resetting, alarm acknowledgement;

h) the type of digital communication.

## 4 Inspection and compliance

As Coriolis meters are an integral part of the piping (in-line instrumentation), it is essential that the instrument be subjected to testing procedures similar to those applied to other in-line equipment.

In addition to the instrument calibration and/or performance checks, the following optional tests may be performed to satisfy the mechanical requirements:

— dimensional check;

— additional hydrostatic test, in accordance with a traceable procedure, as specified by the user;

— radiographic and/or ultrasonic examination of the primary device to detect internal defects (i.e. inclusions) and verify weld integrity;

Results of the above tests should be presented in a certified report, when requested.

In addition to the above reports, the following certificates should be available at final inspection:

— material certificates, for all pressure-containing parts;

— certificate of conformance (electrical area classifications);

— certificate of compliance;

— calibration certificate and test results.



## 5 Mass flow measurement

### 5.1 Apparatus



#### 5.1.1 Principle of operation

Coriolis meters operate on the principle that inertia forces are generated whenever a particle in a rotating body moves relative to the body in a direction toward or away from the centre of rotation. This principle is shown in Figure 1.

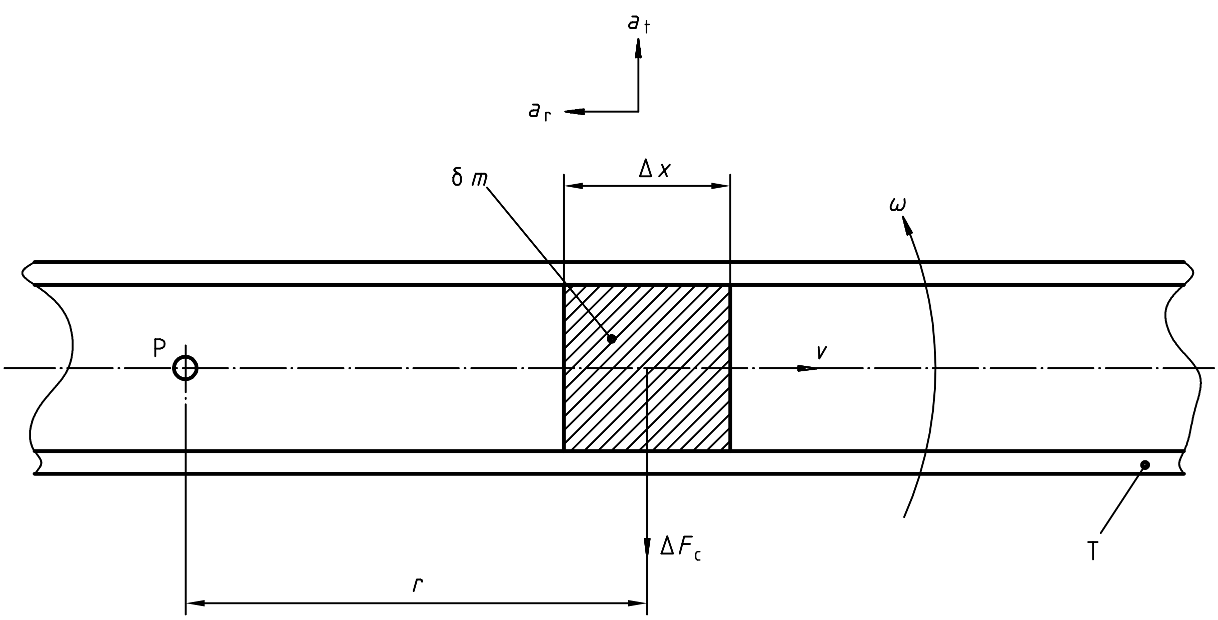


**Figure 1 — Principle of operation of a Coriolis meter**