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**Measurement of fluid flow in closed conduits — Clamp-on ultrasonic transit-time meters for liquids and gases**

*Mesurage du débit des fluides dans les conduites fermées — Débitmètres non-intrusifs à ultrasons à temps de transit pour les liquides et les gaz*

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## Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document 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](http://www.iso.org/directives)).

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For an explanation of 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 [www.iso.org/iso/foreword.html](http://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*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

Non-intrusive (clamp-on) ultrasonic meters (USMs) have become one of the accepted flow measurement technologies for a wide range of applications, including process and control measurements. Non-intrusiveness also brings characteristics relevant for economics, safety, and environment. Ultrasonic technology has inherent features such as no pressure loss and wide rangeability. USMs can deliver diagnostic information through which it may be possible to demonstrate that an ultrasonic flowmeter is performing in accordance with specification.

This document provides a description of the non-intrusive (clamp-on) meter, typical application areas, the measures which should be used in assessing the likely performance in terms of error, repeatability and reproducibility when used under ideal and non-ideal operational conditions.

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## Measurement of fluid flow in closed conduits — Clamp-on ultrasonic transit-time meters for liquids and gases

### 1 Scope

This document specifies requirements and recommendations for non-intrusive (clamp-on) ultrasonic flowmeters (USMs), which use the transit time of ultrasonic signals to measure the volumetric flowrate in closed conduits. Transit time flowmeters are predominantly used on single-phase fluids (liquid and gases) but can also be used where small quantities of additional phases are present.

This document specifies performance, calibration, and output characteristics, and deals with installation conditions.

### 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 4006, *Measurement of fluid flow in closed conduits — Vocabulary and symbols*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4006 and the following apply.

ISO and IEC maintain terminology 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 Quantities

##### 3.1.1

##### volume flowrate

$q_V$

$$q_V = \frac{dV}{dt}$$

$$q_V = \frac{dV}{dt}$$

where

$V$  is volume;

$t$  is time

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[SOURCE: ISO 80000-4:2006, 4-31<sup>[2]</sup>]

### 3.1.2 mean flow velocity

$v_p$   
volume flowrate (3.1.1) divided by the cross-sectional area of the pipe

### 3.1.3 path velocity

$v_l$   
average fluid velocity on an ultrasonic path

### 3.1.4 Reynolds number

$Re_D$   
dimensionless parameter expressing the ratio between the inertia and viscous forces in the fluid

$$Re_D = \frac{\rho v_a D}{\mu} = \frac{v_a D}{\nu_{kv}}$$

$$Re_D = \frac{\rho v_A D}{\mu} = \frac{v_A D}{\nu_{kv}}$$

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where

$\rho$  is density;

$v_a$  is the mean flow velocity;

$D$  is the pipe internal diameter;

$\mu$  is the dynamic viscosity;

$\nu_{kv}$  is the kinematic viscosity

## 3.2 Meter design

### 3.2.1 ultrasonic path

path travelled by an ultrasonic signal between a pair of ultrasonic transducers

### 3.2.2 electronic unit

part of the meter that controls the transducers, processes the signals into a flow-rate and provides outputs (see ~~subclause~~ 4.2.3)

## 3.3 Thermodynamic conditions

### 3.3.1 metering conditions

conditions, at the point of measurement, of the fluid of which the volume flow is to be measured

Note 1 to entry: Also known as operating conditions or actual conditions.

### 3.3.2

**standard conditions**

defined temperature and pressure conditions used in the measurement of fluid quantity so that the standard volume is the volume that would be occupied by a quantity of fluid if it were at standard temperature and pressure

Note 1 to entry: Standard conditions may be defined by regulation or contract.

Note 2 to entry: Not preferred alternatives: reference conditions, base conditions, normal conditions, etc (see ISO-91:2017<sup>[3]</sup>).

Note 3 to entry: Metering and standard conditions relate only to the volume of the fluid to be measured or indicated and should not be confused with rated operating conditions or reference conditions (see ISO/IEC Guide 99:2007, 4.9 and 4.11<sup>[4]</sup>), which refer to influence quantities (see ISO/IEC Guide 99:2007, 2.52<sup>[4]</sup>).

**3.4 Statistics**

**3.4.1**

**error**

measured quantity value minus a reference quantity value

[SOURCE: ISO/IEC Guide 99:2007, 2.16<sup>[4]</sup>]

**3.4.2**

**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

Note 1 to entry: These conditions are called repeatability conditions.

Note 2 to entry: Repeatability conditions include:

- the same measurement procedure;
- the same observer;
- the same measuring instrument, used under the same conditions;
- the same location;
- repetition over a short period of time.

Note 3 to entry: Repeatability may be expressed quantitatively in terms of the dispersion characteristics of the results.

[SOURCE: ISO/IEC Guide 98-3:2008, B.2.15<sup>[5]</sup>]

**3.4.3**

**reproducibility (of results of measurements)**

closeness of the agreement between the results of measurements of the same measurand carried out under changed conditions of measurement

Note 1 to entry: A valid statement of reproducibility requires specification of the conditions changed.

Note 2 to entry: The changed conditions may include:

- principle of measurement;

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- method of measurement;
- observer;
- measuring instrument;
- reference standard;
- location;
- conditions of use;
- time.

Note 3 to entry: Reproducibility may be expressed quantitatively in terms of the dispersion characteristics of the results.

Note 4 to entry: — Results are here usually understood to be corrected results.

[SOURCE: ISO/IEC Guide 98-3:2008, B.2.16<sup>[5]</sup>]

### 3.4.4 resolution

smallest difference between indications of a meter that can be meaningfully distinguished

### 3.4.5 zero flow

meter reading when the fluid is at rest, i.e. both axial and non-axial velocity components are essentially zero

### 3.4.6 uncertainty (of measurement)

parameter, associated with the result of measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

Note 1 to entry: The parameter may be, for example, a standard deviation (or a given multiple of it), or the half-width of an interval having a stated level of confidence.

Note 2 to entry: Uncertainty of measurement comprises, in general, many components. Some of these components may be evaluated from the statistical distribution of the results of a series of measurements and can be characterized by experimental standard deviations. The other components, which can also be characterized by standard deviations, are evaluated from assumed probability distributions based on experience or other information.

Note 3 to entry: It is understood that the result of the measurement is the best estimate of the value of the measurand, and that all components of uncertainty, including those arising from systematic effects, such as components associated with corrections and reference standards, contribute to the dispersion.

[SOURCE: ISO/IEC Guide 98-3:2008, B.2.18<sup>[5]</sup>]

### 3.4.7 standard uncertainty

$u$   
uncertainty of the result of a measurement expressed as a standard deviation

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.1<sup>[5]</sup>]

**3.4.8 expanded uncertainty**  
*U*

quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.5<sup>[5]</sup>]

Note 1 to entry: The large fraction is normally 95 % and is generally associated with a coverage factor  $k = 1,96$ .

Note 2 to entry: The expanded uncertainty is often referred to as the uncertainty.

**3.4.9 coverage factor**

numerical factor used as a multiplier of the standard uncertainty in order to obtain an *expanded uncertainty* (3.4.9g)

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.6<sup>[5]</sup>]

**3.5 Calibration**

**3.5.1 flow calibration**

calibration of a meter against a reference using fluid flowing through the meter

**3.6 Symbols and subscripts**

The symbols and subscripts used in this document are given in Table 1 and Table 2.

**Table 1 — Symbols**

Quantity	Symbol	Dimension <sup>a</sup>	SI unit
Cross-sectional area of pipe	<i>A</i>	L <sup>2</sup>	m <sup>2</sup>
Speed of sound in fluid	<i>c</i>	LT <sup>-1</sup>	m/s
Internal pipe diameter	<i>D<sub>i</sub></i>	L	m
External pipe diameter	<i>D<sub>e</sub></i>	L	m
Integers (1,2,3, ...)	<i>i,j,n</i>	—	1
Calibration factor	<i>K</i>	—	1
Path-geometry factor	<i>K<sub>g</sub></i>	L <sup>b</sup> or LT <sup>-1 c</sup>	m <sup>b</sup> or m/s <sup>c</sup>
Velocity profile correction factor	<i>K<sub>p</sub></i>	—	1
Minimum distance to a specified upstream flow disturbance	<i>l<sub>min</sub></i>	L	m
Path length	<i>l<sub>p</sub></i>	L	m
Absolute pressure	<i>p</i>	ML <sup>-1</sup> T <sup>-2</sup>	Pa
Volume flowrate	<i>q<sub>v</sub></i>	L <sup>3</sup> T <sup>-1</sup>	m <sup>3</sup> /s
Pipe Reynolds number	<i>Re<sub>p</sub></i>	—	1
Transit time	<i>t<sub>tr</sub></i>	T	s
Time delay	<i>t<sub>0</sub></i>	T	s

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