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Measurement of fluid flow in closed conduits — Flowrate measurement by means of vortex shedding flowmeters inserted in circular cross-section conduits running full

Mesurage du débit de fluide dans les conduites fermées — Mesurage du débit par débitmètres à effet vortex insérés dans les conduites de section circulaire remplies au droit

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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 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 12764 cancels and replaces ISO/TR 12764:1997. In general this document reflects the current state of vortex shedding flow meter methodology, with advancements that have occurred since the original TR was published. In particular:

— the terms “systematic measurement error” and “measurement uncertainty” are more clearly defined;

— the terms “rangeability”, “lowest local pressure”, “response time” and “fade” have been removed;

— 6.1.1.4 and 6.1.2 have been added;

— Clause 8 and Clause 9 have been revised;

— Annex A has been revised;

— a new Annex B has replaced the previous version;

— Annex C has been incorporated into 7.2 and updated.

Introduction

This document is one of the series of International Standards and Technical Reports covering a variety of devices that measure the flow of fluids in closed conduits.

The term “vortex shedding flowmeter”, commonly referred to as a “vortex meter”, covers a large family of devices with varying proprietary designs. These devices have in common the shedding of vortices from an obstruction (called a bluff body) which has been deliberately placed in the flow path in the meter. The natural laws of physics relate the shedding frequency of the vortices (f) to the fluid velocity and hence the volumetric flowrate (q_V) of the fluid in the conduit. The vortices can be counted over a given period of time to obtain total flow.

The vortex shedding phenomenon has become an accepted basis for fluid flow measurement. Meters are available for measuring the flow of fluids from cryogenic liquids to steam and high pressure gases. Many vortex shedding flowmeter designs are proprietary and, therefore, their design details cannot be covered in this document.

Insufficient data have been collected and analysed to be able to state, in this document, an expected uncertainty band for this type of vortex-shedding flowmeter.

Measurement of fluid flow in closed conduits — Flowrate measurement by means of vortex shedding flowmeters inserted in circular cross-section conduits running full

1 Scope

This document

a) describes the use of vortex shedding flow meters for liquids, gases, and steam, including a glossary and a set of engineering equations used for specifying performance,

b) provides technical information to assist the user in selecting, specifying and applying vortex shedding flowmeters, including influence effects,

c) describes typical construction and provides recommendations for inspection, certification, and material traceability,

d) describes availability of diagnostics associated with vortex shedding flowmeters,

e) provides calibration guidance,

f) does not apply to insertion type vortex shedding flowmeters,

g) applies only to closed conduits running full,

h) applies only to fluid flow that is steady or varies only slowly with time, and

i) applies to fluids considered to be single-phase.

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*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4006 and ISO/IEC Guide 99:2007 (JCGM 200:2012) and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

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

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

3.1 Definitions specific to this vortex flowmeter standard

3.1.1
***K*-factor**
ratio of the meter output in number of pulses to the corresponding total volume of fluid passing through the meter during a measured period

Note 1 to entry: The variations in the *K*-factor can be presented as a function of either the pipe Reynolds number or flowrate at a specific set of thermodynamic conditions. The mean *K*-factor is commonly used and is defined by the following formula:

$$K_{\text{mean}} = \frac{K_{\text{max}} + K_{\text{min}}}{2}$$

where

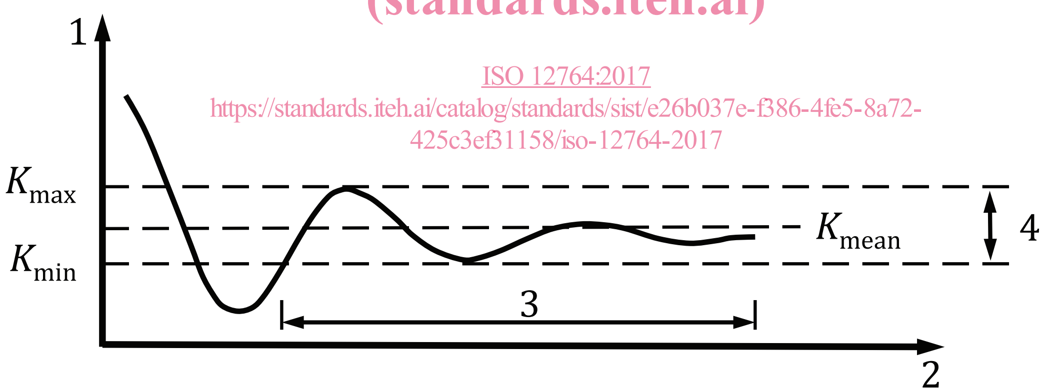
K_{max} is the maximum *K*-factor over a designated range;

K_{min} is the minimum *K*-factor over the same range.

Alternatively, the average of several values of *K*-factor taken over the whole flow range of a meter can be calculated. The *K*-factor can change with pressure and thermal effects on the body of the meter; see Clause 11. The manufacturer of the meter should be consulted concerning the difference, if any, of the *K*-factor between liquid and gas and due to differences between pipe schedules of the adjacent pipe.

Note 2 to entry: It is expressed in pulses per unit volume.

Note 3 to entry: See Figure 1.



Key

1 *K*-factor
2 pipe Reynolds number
3 designated linear range
4 linearity (%)

Figure 1 — Typical shape of a *K*-factor curve

3.1.2
linearity
constancy of the *K-factor* (3.1.1) over a specified range defined either by the pipe Reynolds number or flowrate

Note 1 to entry: The upper and lower limits of the linear range are specified by the manufacturer.

Note 2 to entry: See Figure 1.

3.1.3
cavitation
phenomenon following flashing, in which the pressure recovers above the vapour pressure and the vapour bubble collapses (implodes)

Note 1 to entry: Cavitation can result in measurement error as well as mechanical damage to the meter.

3.1.4
flashing
formation of vapour bubbles

Note 1 to entry: Flashing occurs when the pressure falls below the vapour pressure of the liquid.

3.2 Definitions related to measurement of fluid flow in closed conduits

3.2.1
pressure loss
irrecoverable pressure loss caused by the presence of a primary device in the conduit

3.2.2
Strouhal number
dimensionless parameter relating the vortex shedding frequency, f, generated by a characteristic dimension, l, to the fluid velocity, v, given by the following formula:

$$Sr = \frac{f \cdot l}{v}$$

where

f is vortex shedding frequency;

l is a characteristic length of the system in which the flow occurs;

v is the fluid velocity.

3.2.3
Reynolds number
dimensionless parameter expressing the ratio between the inertia and viscous forces given by the following formula:

$$Re = \frac{U \cdot l}{\nu}$$

where

U is the mean axial fluid velocity across a defined area;

l is a characteristic length of the system in which the flow occurs;

ν nu (Greek alphabet) is the kinematic viscosity of the fluid.

Note 1 to entry: For pipe flows and closed pipe flow measurement, Reynolds number is usually based on the diameter of the pipe.

3.3 Definitions related to the vocabulary used in metrology

3.3.1
systematic measurement error
systematic error of measurement
systematic error
component of measurement error that, in replicate measurements, remains constant or varies in a predictable manner

Note 1 to entry: A reference quantity value for a systematic measurement error is a true quantity value, or a measured quantity value of a measurement standard of negligible measurement uncertainty, or a conventional quantity value.

Note 2 to entry: Systematic measurement error, and its causes, can be known or unknown. A correction can be applied to compensate for a known systematic measurement error.

Note 3 to entry: Systematic measurement error equals measurement error minus random measurement error.

3.3.2
measurement uncertainty
uncertainty of 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: The parameter can be, for example, a standard deviation called standard measurement uncertainty (or a specified multiple of it), or the half-width of an interval, having a stated coverage probability.

Note 3 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 a 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.

Note 4 to entry: In general, for a given set of information, it is understood that the measurement uncertainty is associated with a stated quantity value attributed to the measurand. A modification of this value results in a modification of the associated uncertainty.

4 Symbols and subscripts

4.1 Symbols

Symbol	Quantity	Dimensions	SI units
A	effective area	L^2	m^2
A_p	manufacturer supplied constant	L^2	m^2
c_1,c_2	empirical constant	dimensionless	
D	diameter of meter bore	L	m
f	frequency of vortex shedding	T^{-1}	Hz
K	K-factor, meter factor = $1/K$	L^{-3}	m^{-3}
l	characteristic length	L	m
N	number of pulses	dimensionless	
NOTE Fundamental dimensions: M = mass, L = length, T = time, θ = temperature			

Symbol	Quantity	Dimensions	SI units
n	number of period measurements	dimensionless	
p	pressure	$ML^{-1}T^{-2}$	Pa
$p_{d,min}$	minimum downstream pressure limit	$ML^{-1}T^{-2}$	Pa
p_p	permanent pressure loss	$ML^{-1}T^{-2}$	Pa
Δp	overall pressure drop	$ML^{-1}T^{-2}$	Pa
p_{vap}	liquid vapour pressure at the flowing temperature	$ML^{-1}T^{-2}$	Pa
Q_V	totalized volume flow at actual flowing conditions	L^3	m^3
Q_m	totalized mass	M	kg
q_V	volume flowrate at actual flowing conditions	L^3T^{-1}	m^3/s
q_m	mass flowrate	MT^{-1}	kg/s
Re	Reynolds number	dimensionless	
Sr	Strouhal number	dimensionless	
T	temperature	θ	K
t	two-tailed Student's at 95 % confidence	dimensionless	
U	average fluid velocity in meter bore	LT^{-1}	m/s
v	fluid velocity	LT^{-1}	m/s
α	coefficient of linear expansion of material	θ^{-1}	K^{-1}
δ	% error in the average period	dimensionless	
μ	absolute viscosity (dynamic)	$ML^{-1}T^{-1}$	Pa · s
ν (nu)	kinematic viscosity	M^2/s	m^2/s
ρ	fluid density	ML^{-3}	kg/m^3
σ	estimate of standard deviation of the average period	T	s
τ	average period of vortex shedding	T	s
NOTE Fundamental dimensions: M = mass, L = length, T = time, θ = temperature			

4.2 Subscripts

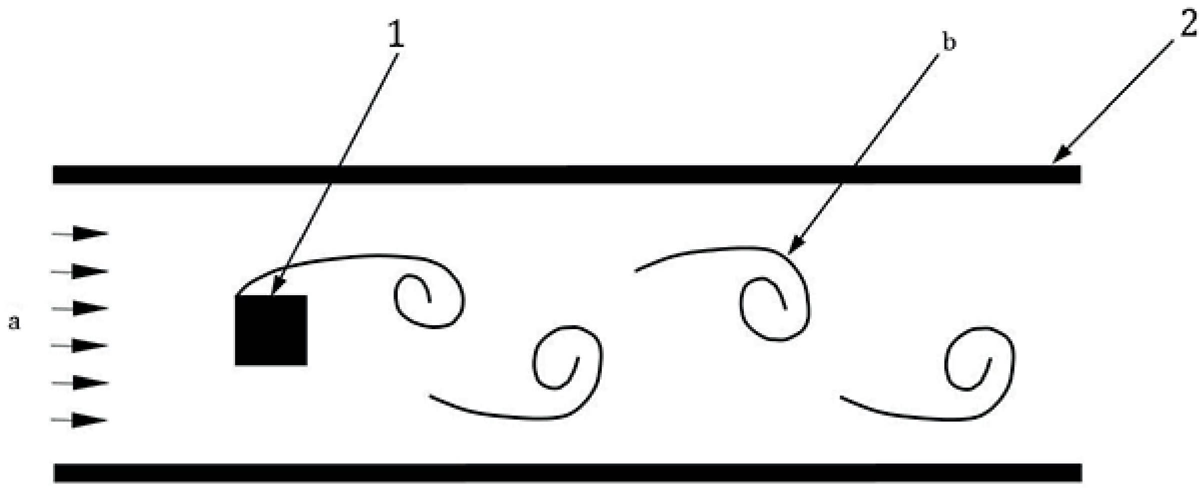
Subscript	Description
b	base conditions
m	mass unit
V	volume units, flowing conditions
mean	average of extreme values
max	maximum value
min	minimum value
i	the i^{th} measurement
d	downstream

5 Principle

5.1 Bluff body

When a bluff body, sometimes referred to as shedder bar, is placed in a pipe in which fluid is flowing, a boundary layer forms and grows along the surface of the bluff body. Due to insufficient momentum and an adverse pressure gradient, separation occurs and an inherently unstable shear layer is formed. Eventually, this shear layer rolls up into vortices that shed alternately from the sides of the body and propagate downstream. This series of vortices is called a Von Karman-like vortex street (See Figure 2).

The frequency at which pairs of vortices are shed is directly proportional to the fluid velocity. Since the shedding process is repeatable, it can be used to measure the flow.



Key

1 bluff body

2 conduit

a Flow.

b Vortex.

Figure 2 — Principle of Von Karman-like vortex street

5.2 Shedding vortices detection/sensors

Sensors are used to detect shedding vortices, i.e. to convert the pressure or velocity variations associated with the vortices to electrical signals. Vortex shedding sensor technology varies and is typically based on force, pressure, or velocity.

5.3 Strouhal number

The Strouhal number, *Sr*, relates the frequency, *f*, of generated vortices, the bluff body characteristic dimension, *l*, and the fluid velocity, *U*, as shown in Formula (1).

$$Sr = \frac{f \cdot l}{U} \quad (1)$$

remains essentially constant within a large range of Reynolds number. This means that the Strouhal number is independent of density, pressure, viscosity and other physical parameters. Given this