TECHNICAL REPORT

ISO/TR 12764

First edition
1997-12-01

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

Mesure de débits des fluides dans les conduites fermées — Mesure de débit par débitmètres à effet vortex insérés dans les conduites de section circulaire remplies au droit

ISO/TR 12764:1997(E)

Contents

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet central@iso.ch
X.400 c=ch; a=400net; p=iso; o=isocs; s=central

Printed in Switzerland

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 main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid.

ISO/TR 12764, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits.*

This document is being issued in the technical report (type 2) series of publications (according to subclause G.3.2.2 of part 1 of the IEC/ISO Directives) as a “prospective standard for provisional application” in the field of flow measurement using vortex flowmeters, because there is an urgent need for guidance on how standards in this field should be used to meet an identified need.

This document is not to be regarded as an “International Standard”. It is proposed for provisional application so that information and experience of its use in practice may be gathered. Comments on the content of this document should be sent to the Secretary of ISO/TC 30, via the ISO Central Secretariat.

A review of this technical report (type 2) will be carried out not later than three years after its publication with the options of: extension for another three years; conversion into an International Standard; or withdrawal.

Annexes A, B and C of this Technical Report are for information only.

Introduction

ISO/TR 12764 is one of a 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 deliberatley placed in the flow path in the meter. The natural laws of physics relate the shedding frequency of the vortices (f) to 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 analyzed to be able to state, in this document, an expected uncertainty band for this type of 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 Technical Report provides generic information on vortex shedding flowmeters, including a glossary and a set of engineering equations useful in specifying performance. It describes the typical construction of vortex shedding flowmeters and identifies the need for inspection, certification, and material traceability. It also provides technical information to assist the user in selecting and applying vortex shedding flowmeters, and provides calibration guidance. It explains the relevant terminology and describes test procedures, together with a list of specifications, application notes, and equations with which to determine the expected performance characteristics.

This Technical Report describes how the frequency of the vortices is a measure of the fluid velocity; how volume, mass, and standard volume flowrate are determined; and how the total fluid that has flowed through the meter in a specified time interval can be measured.

This Technical Report applies only to full-bore flowmeters (not insertion types) and applies only to fluid flow that is steady or varies only slowly with time, and is considered to be single-phased, with the closed conduit running full.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices — Part 1: Orifice plates, nozzles and venturi tubes inserted in circular cross-section conduits running full*

ISO 5168, *Measurement of fluid flow -— Estimation of uncertainty of a flowrate measurement*

ISO 7066-1, *Assessment of uncertainty in the calibration and use of flow measurement devices -— Part 1: Linear calibration relationships*

ISO 7066-2, *Assessment of uncertainty in the calibration and use of flow measurement devices — Part 2: Non-linear calibration relationships*

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

IEC 60381-1, *Analogue signals for process controls systems — Part 1: Direct current signals*

IEC 60381-2, *Analogue signals for process controls systems — Part 2: Direct voltage signals*

IEC 60359, *Expressions of the functional performance of electronic measuring equipment*

IEC 60529, *Degrees of protection provided by enclosures (IP code)*

3 Terms and definitions

For the purposes of this Technical Report, the terms and definitions given in ISO 4006, ISO 5168, ISO 7066-1 and ISO 7066-2, and the following definitions apply.

3.1
random error
component of the error of measurement which, in the course of a number of measurements of the same measurand, varies in an unpredictable way

NOTE It is not possible to correct for random error.

3.2
systematic error
component of the error of measurement which, in the course of a number of measurements of the same measurand, remains constant or varies in a predictable way

NOTE Systematic errors and their causes may be known or unknown.

3.3
uncertainty
estimate characterizing the range of values within which the true value of a measurement lies

3.4
random uncertainty
component of uncertainty associated with a random error

NOTE Its effect on mean values can be reduced by taking many measurements.

3.5
systematic uncertainty
component of uncertainty associated with a systematic error

NOTE Its effect cannot be reduced by taking many measurements.

3.6
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

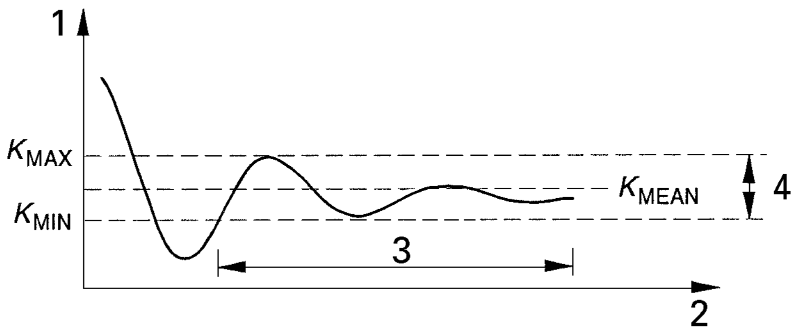
See Figure 1.

NOTE 1 The variations in the K-factor may 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:

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

where: K_{max} is the maximum K-factor over a designated range, and 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 may 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 It is expressed in pulses per unit volume.



Key:

1 K-factor

2 Pipe Reynold's number

3 Designated linear range

4 Linearity (± %)

Figure 1 — Typical shape of a K-factor curve

3.7
linearity
constancy of the K-factor over a specified range defined either by the pipe Reynolds number or flowrate

See Figure 1.

NOTE The upper and lower limits of the linear range are specified by the manufacturer.

3.8
rangeability
ratio of the maximum to minimum flowrates or Reynolds numbers in the range over which the meter meets a specified accuracy (uncertainty)

3.9
Reynolds number
Re
<pipe> dimensionless ratio of inertial to viscous forces which is used as a correlating parameter that combines the effects of viscosity, density and pipeline velocity

3.10
Strouhal number
St
dimensionless parameter that relates the measured vortex shedding frequency to the fluid velocity and the bluff body characteristic dimension

NOTE In practice the K-factor, which is not dimensionless, replaces the Strouhal number as the significant parameter.

3.11
lowest local pressure
lowest pressure found in the meter

NOTE This is the pressure of concern regarding flashing and cavitation. Some of the pressure is recovered downstream of the meter.

3.12
pressure loss
difference between the upstream pressure and the pressure downstream of the meter after recovery

3.13
flashing
formation of vapour bubbles

NOTE Flashing occurs when the pressure falls below the vapour pressure of the liquid.

3.14
cavitation
phenomenon following flashing, in which the pressure recovers above the vapour pressure and the vapour bubble collapses (implodes)

NOTE Cavitation can result in measurement error as well as mechanical damage to the meter.

3.15
response time
time needed for the indicated flowrate to differ from the true flowrate by a prescribed amount (for example, 10%), in response to a step change in flowrate

3.16
fade
failure of a vortex shedding flowmeter to shed or detect vortices

4 Symbols and subscripts

4.1 Symbols

Symbol	Quantity	Dimensions	SI units
a	Response Time	T	s
D	Diameter of meter bore	L	m
f	Frequency of vortex shedding	T^{-1}	Hz
d	Width of bluff body normal to the flow	L	m
K	K-factor, meter factor=1/K	L^{-3}	m^{-3}
N	Number of pulses	dimensionless	
q_v	Volume flowrate	L^3T^{-1}	m^3/s
q_m	Mass flowrate	$M\ T^{-1}$	kg/s
Q_v	Totalized volume flow	L^3	m^3
Q_m	Totalized mass flow	M	kg
Re	Reynolds number	dimensionless	
St	Strouhal number	dimensionless	
U	Average fluid velocity in meter bore	LT^{-1}	m/s

α	Coefficient of linear expansion of material	θ^{-1}	K^{-1}
μ	Absolute viscosity(dynamic)	$ML^{-1} T^{-1}$	Pa•s
ρ	Fluid density	ML^{-3}	kg/m^3
T	Temperature	θ	K
δ	% error in the average period	dimensionless	
t	Two-tailed Student's *t* at 95% confidence	dimensionless	
σ	Estimate of standard deviation of the average period	T	s
τ	Average period of vortex shedding	T	s
n	Number of period measurements	dimensionless	
P	Pressure	$ML^{-1}T^{-2}$	Pa
P_{dmin}	Minimum downstream pressure limit	$ML^{-1}T^{-2}$	Pa
c_1,c_2	Empirical constant	dimensionless	
ΔP	Overall pressure drop	$ML^{-1}T^{-2}$	Pa
P_{vap}	Liquid vapour pressure (at the flowing temperature	$ML^{-1}T^{-2}$	Pa

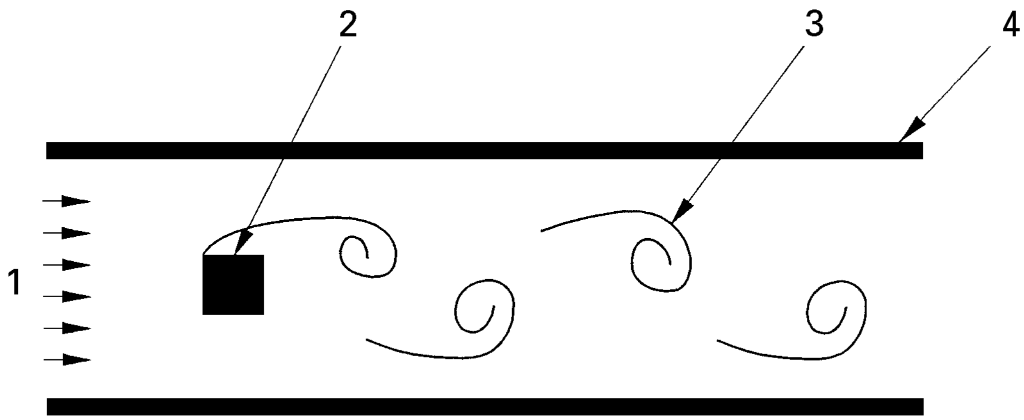
NOTE Fundamental dimensions: M=mass, L=length, T=time, θ =temperature

4.2 Subscripts

Subscript	**Description**
b	base conditions
flow	flowing fluid conditions
D	unobstructed diameter of meter bore, see above
m	mass unit
0	refers to reference condition
V	volume units, reference conditions
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 When a bluff body 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 flow.



Key:

1 Flow

2 Bluff body

3 Vortex

4 Conduit

Figure 2 — Principle

5.2 Sensors are used to detect shedding vortices , i.e. to convert the pressure or velocity variations associated with the vortices to electrical signals.

5.3 The Strouhal number, *St,* relates the frequency *f* of generated vortices, the bluff body characteristic dimension *d* and the fluid velocity *U*.

$$U = \frac{f \times d}{St}$$

5.4 For certain bluff body shapes, the Strouhal number 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 situation, the flow velocity is directly proportional to the frequency at which the vortices are being shed, i.e. the vortex pulse rate,

$$U = \xi \times f$$

where ξ is a constant equal to d/St,

and the volumetric flowrate at flowing conditions, i.e. the volume flowrate, is given by

$$q_V = A \times U = \left[\frac{(A \times d)}{St}\right] \times f$$

where *A* is defined by the effective area of attack for the flow of the considered pipe/flowmeter configuration.

The K-factor for a vortex shedding flowmeter is defined by

$$K = \frac{St}{(A \times d)} = \frac{f}{q_V}$$

hence,

$$q_V = \frac{f}{K}$$

To obtain mass flowrate or volumetric flowrate at base conditions, i.e. standard volume flowrate, the density at flowing temperature and pressure is needed.

Mass flowrate: $q_m = \rho_f \times \frac{f}{K}$

Volume flowrate at base conditions: $q_{vb} = \left(\frac{\rho_f}{\rho_b}\right) \times \frac{f}{K}$

The total amount of fluid that has flowed through a meter over a specified time interval is given by

$$Q_V = \frac{N}{K},\ Q_m = \rho_f \times \frac{N}{K}, \text{ or } Q_V = \left(\frac{\rho_f}{\rho_b}\right) \times \frac{N}{K}$$

where N is the total number of vortices shed, i.e. total number of vortex pulses, over that time interval.

6 Flowmeter description

6.1 Physical components

The vortex shedding flowmeter consists of two elements: the flowtube (sometimes referred to as the primary device or Primary) and the output device (sometimes referred to as the secondary device or Secondary).

6.1.1 Flowtube

The flowtube, which is an integral part of the piping system, is made up of the meter body, the bluff body(s), and the sensor.

6.1.11 The meter body is normally available in two styles: a flanged version which bolts directly to the flanges on the pipeline and a wafer version, without flanges, that is clamped between the two adjacent pipeline flanges via bolts.

6.1.1.2. The bluff body(s) is a structural element positioned in the cross-section of the meter body. Its shape and dimensions and its ratio in relation to the open area in the meter body cross-section influence the linearity of the K-factor. An ideal bluff body shape is not known. Figure 2 shows it as a square, but this is not intended to imply a preferred, or even practical, shape.

6.1.1.3 The sensor detects the passage of the shedding vortices. Sensor location and principle varies among the various flowmeter designs. (See Annex B)

6.1.2 Output device

The output device converts sensed signals to a digital flowrate readout, digital total flow readout, a pulse of scaled pulse signal, and/or a standardized analog output (see IEC 60381)