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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

DRAFT INTERNATIONAL STANDARD

ISO/DIS 5167-1

ISO/TC 30/SC 2

Secretariat: BSI

Voting begins on:
2021-07-08

Voting terminates on:
2021-09-30

Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full —

Part 1: General principles and requirements

Mesure de débit des fluides au moyen d'appareils déprimogènes insérés dans des conduites en charge de section circulaire —

Partie 1: Principes généraux et exigences générales

ICS: 17.120.10

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ISO/CEN PARALLEL PROCESSING



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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 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.

ISO 5167-1 was prepared by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*, Subcommittee SC 2, *Pressure differential devices*.

This third edition of ISO 5167-1 cancels and replaces the second edition (ISO 5167-1:2003), which has been technically revised.

The main changes compared with the previous edition are as follows:

There is improved consistency between Parts 1 to 6 (some items that were new in Parts 5 and 6 have been moved to Part 1).

A primary element is set as part of a differential pressure flowmeter system.

A short section on diagnostics and CBM (Condition Based Monitoring) is included.

A limitation on the use of the 5 % 2° rule for an acceptable profile is noted.

Improved text about uncertainty calculation and an example in an annex are provided.

Annexes on turndown and permanent pressure loss are included.

A list of all parts in the ISO 5167 series can be found on the ISO website.

Introduction

ISO 5167, consisting of six parts, covers the geometry and method of use (installation and operating conditions) of orifice plates, nozzles, Venturi tubes, cone meters and wedge meters when they are inserted in a conduit running full to determine the flowrate of the fluid flowing in the conduit. It also gives necessary information for calculating the flowrate and its associated uncertainty.

ISO 5167 is applicable only to pressure differential devices in which the flow remains subsonic throughout the measuring section and where the fluid can be considered as single-phase, but is not applicable to the measurement of pulsating flow. Furthermore, each of these devices can only be used uncalibrated within specified limits of pipe size and Reynolds number, or alternatively they can be used across their calibrated range.

ISO 5167 deals with devices for which direct calibration experiments have been made, sufficient in number, spread and quality to enable coherent systems of application to be based on their results and coefficients to be given with certain predictable limits of uncertainty. ISO 5167 also provides methodology for bespoke calibration of differential pressure meters.

The devices introduced into the pipe are called primary devices. The term primary device also includes the pressure tapplings. All other instruments or devices required to facilitate the instrument readings are known as secondary devices, and the flow computer that receives these readings and performs the algorithms is known as a tertiary device. ISO 5167 covers primary devices; secondary devices¹⁾ and tertiary devices will be mentioned only occasionally.

ISO 5167 is divided into the following six parts:

- a) ISO 5167-1 gives general terms and definitions, symbols, principles and requirements as well as methods of measurement and uncertainty that are to be used in conjunction with Parts 2 to 6 of ISO 5167.
- b) ISO 5167-2 specifies orifice plates, which can be used with corner pressure tapplings, D and $D/2$ pressure tapplings²⁾, and flange pressure tapplings.
- c) ISO 5167-3 specifies ISA 1932 nozzles³⁾, long radius nozzles and Venturi nozzles, which differ in shape and in the position of the pressure tapplings. Throat-tapped long-radius nozzles are included.
- d) ISO 5167-4 specifies classical Venturi tubes⁴⁾.
- e) ISO 5167-5 specifies cone meters.
- f) ISO 5167-6 specifies wedge meters.

Aspects of safety are not dealt with in Parts 1 to 6 of ISO 5167. It is the responsibility of the user to ensure that the system meets applicable safety regulations.

Additional documents that may provide assistance include:

- ISO/TR 3313 - Measurement of fluid flow in closed conduits — Guidelines on the effects of flow pulsations on flow-measurement instruments
- ISO/TR 9464 - Guidelines for the use of ISO 5167:2003
- ISO/TR 12767 - Measurement of fluid flow by means of pressure differential devices — Guidelines on the effect of departure from the specifications and operating conditions given in ISO 5167

1) See ISO 2186:2007, *Fluid flow in closed conduits — Connections for pressure signal transmissions between primary and secondary elements*.

2) Orifice plates with vena contracta pressure tapplings are not considered in ISO 5167.

3) ISA is the abbreviation for the International Federation of the National Standardizing Associations, which was succeeded by ISO in 1946.

4) In the USA the classical Venturi tube is sometimes called the Herschel Venturi tube.

- ISO/TR 15377 - Measurement of fluid flow by means of pressure-differential devices — Guidelines for the specification of orifice plates, nozzles and Venturi tubes beyond the scope of ISO 5167

Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full —

Part 1: General principles and requirements

1 Scope

This part of ISO 5167 defines terms and symbols and establishes the general principles for methods of measurement and computation of the flowrate of fluid flowing in a conduit by means of pressure differential devices (orifice plates, nozzles, Venturi tubes, cone meters, and wedge meters) when they are inserted into a circular cross-section conduit running full. This part of ISO 5167 also specifies the general requirements for methods of measurement, installation and determination of the uncertainty of the measurement of flowrate. It also defines the general specified limits of pipe size and Reynolds number for which these pressure differential devices are to be used.

ISO 5167 (all parts) is applicable only to flow that remains subsonic throughout the measuring section and where the fluid can be considered as single-phase. It is not applicable to the measurement of pulsating flow.

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 5167-2:20xx, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 2: Orifice plates*

ISO 5167-3:20xx, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 3: Nozzles and Venturi nozzles*

ISO 5167-4:20xx, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 4: Venturi tubes*

ISO 5167-5:20xx, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 5: Cone meters*

ISO 5167-6:20xx, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 6: Wedge meters*

ISO 5168:2005, *Measurement of fluid flow — Procedures for the evaluation of uncertainties*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

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 terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

Note 1 to entry: The following definitions are given only for terms used in some special sense or for terms for which it seems useful to emphasize the meaning.

3.1 Pressure measurement

3.1.1

wall pressure tapping

annular slot or circular hole drilled in the wall of a conduit in such a way that the edge of the hole is flush with the internal surface of the conduit

Note 1 to entry The pressure tapping is usually a circular hole but in certain cases may be an annular slot.

3.1.2

static pressure of a fluid flowing through a pipeline

p

pressure which can be measured by connecting a pressure-measuring device to a wall pressure tapping

Note 1 to entry: Only the value of the absolute static pressure is considered in ISO 5167 (all parts).

3.1.3

differential pressure

DP

Δp

difference between the (static) pressures measured at the wall pressure tappings, one of which is on the upstream side and the other of which is on the downstream side of a primary device (or in the throat for a throat-tapped nozzle, a Venturi nozzle or a Venturi tube), inserted in a straight pipe through which flow occurs, when any difference in height between the upstream and downstream tappings has been taken into account

Note 1 to entry: In ISO 5167 (all parts) the term “differential pressure” is used only if the pressure tappings are in the positions specified for each standard primary device.

3.1.4

pressure ratio

τ

ratio of the absolute (static) pressure at the downstream pressure tapping to the absolute (static) pressure at the upstream pressure tapping

3.1.5***vena contracta***

location in a fluid stream where the diameter of the stream is smallest

3.2 Primary devices**3.2.1****orifice****throat**

opening of minimum cross-sectional area of a primary device

Note 1 to entry: Standard primary device orifices are circular and coaxial with the pipeline.

3.2.2**orifice plate**

thin plate in which a circular opening has been machined

Note 1 to entry: Standard orifice plates are described as “thin plate” and “with sharp square edge”, because the thickness of the plate is small compared with the diameter of the measuring section and because the upstream edge of the orifice is sharp and square.

3.2.3**nozzle**

device which consists of a convergent inlet connected to a cylindrical section generally called the “throat”

3.2.4**Venturi nozzle**

device which consists of a convergent inlet which is a standardized ISA 1932 nozzle connected to a cylindrical part called the “throat”, which is itself connected to an expanding section called the “divergent” which is conical

3.2.5**Venturi tube**

device which consists of a convergent inlet which is conical connected to a cylindrical part called the “throat”, which is itself connected to an expanding section called the “divergent” which is conical

3.2.6**cone meter**

device which consists of a cone-shaped restriction held in the centre of the pipe with the nose of the cone upstream

3.2.7**wedge meter**

device which consists of a wedge-shaped restriction

3.2.8**diameter ratio**

β

⟨of a primary device used in a given pipe⟩ square root of the ratio of the area of the throat of the primary device to the internal area of the measuring pipe upstream of the primary device

Note 1 to entry: In parts 2 and 3 the diameter ratio is the ratio of the diameter of the throat of the primary device to the internal diameter of the measuring pipe upstream of the primary device.

Note 2 to entry: In part 4, where the primary device has a cylindrical section upstream, having the same diameter as that of the pipe, the diameter ratio is the ratio of the throat diameter to the diameter of this cylindrical section at the plane of the upstream pressure tapings.

3.2.9

carrier ring

device which is used to hold the primary element in the centre of the pipe and may incorporate the pressure tapings

3.3 Flow

3.3.1

flowrate

rate of flow

q

mass or volume of fluid passing through the primary device per unit time

3.3.1.1

mass flowrate

rate of mass flow

q_m

mass of fluid passing through the primary device per unit time

3.3.1.2

volume flowrate

rate of volume flow

q_V

volume of fluid passing through the primary device per unit time

Note 1 to entry: In the case of volume flowrate, it is necessary to state the pressure and temperature at which the volume is referenced.

3.3.2

Reynolds number

Re

dimensionless parameter expressing the ratio between the inertia and viscous forces

3.3.2.1

pipe Reynolds number

Re_D

dimensionless parameter expressing the ratio between the inertia and viscous forces in the upstream pipe

$$Re_D = \frac{V_1 D}{\nu_1} = \frac{4q_m}{\pi \mu_1 D}$$

3.3.2.2

orifice or throat Reynolds number

Re_d

dimensionless parameter expressing the ratio between the inertia and viscous forces in the orifice or throat of the primary device

$$Re_d = \frac{Re_D}{\beta}$$

3.3.3**isentropic exponent** κ

ratio of the relative variation in pressure to the corresponding relative variation in density under elementary reversible adiabatic (isentropic) transformation conditions

Note 1 to entry: The isentropic exponent κ appears in the different formulae for the expansibility [expansion] factor ε and varies with the nature of the gas and with its temperature and pressure.

Note 2 to entry: There are many gases and vapours for which no values for κ have been published so far, particularly over a wide range of pressure and temperature. In such a case, for the purposes of ISO 5167 (all parts), the ratio of the specific heat capacity at constant pressure to the specific heat capacity at constant volume of ideal gases can be used in place of the isentropic exponent.

3.3.4**Joule Thomson coefficient** μ_{JT}

isenthalpic temperature-pressure coefficient

rate of change of temperature with respect to pressure at constant enthalpy:

$$\mu_{JT} = \left. \frac{\partial T}{\partial p} \right|_H$$

Note 1 to entry: The Joule Thomson coefficient varies with the nature of the gas and with its temperature and pressure and can be calculated.

Note 2 to entry: an approximation for the Joule Thomson coefficient for some natural gases is given in ISO/TR 9464 5.1.5.4.4.

3.3.5**discharge coefficient** C

coefficient, defined for an incompressible fluid flow, which relates the actual flowrate to the theoretical flowrate through a device, and is given by the formula for incompressible fluids

$$C = \frac{q_m \sqrt{1 - \beta^4}}{A_t \sqrt{2 \Delta p \rho_1}}$$

Note 1 to entry: Calibration of standard primary devices by means of incompressible fluids (liquids) shows that the discharge coefficient is dependent only on the Reynolds number for a given primary device in a given installation.

The numerical value of C for any individual differential pressure meter is the same for different installations whenever such installations are geometrically similar and the flows are characterised by identical Reynolds numbers.

The equations for the numerical values of C given in ISO 5167 (all parts) are based on data determined experimentally.

The uncertainty in the value of C can be reduced by flow calibration in a suitable laboratory.

Note 2 to entry: The quantity $1/\sqrt{1 - \beta^4}$ is called the “velocity of approach factor”, and the product

$$C \frac{1}{\sqrt{1 - \beta^4}}$$

is called the “flow coefficient”.

3.3.6

expansibility [expansion] factor

ε

coefficient used to take into account the compressibility of the fluid

$$\varepsilon = \frac{q_m \sqrt{1 - \beta^4}}{A_t C \sqrt{2 \Delta p \rho_1}}$$

Note 1 to entry: Calibration of a given primary device by means of a compressible fluid (gas) shows that the ratio

$$\frac{q_m \sqrt{1 - \beta^4}}{A_t \sqrt{2 \Delta p \rho_1}}$$

is dependent on the value of the Reynolds number as well as on the values of the pressure ratio and the isentropic exponent of the gas.

The method adopted for representing these variations consists of multiplying the discharge coefficient C of the primary device considered, as determined by direct calibration carried out with liquids for the same value of the Reynolds number, by the expansibility [expansion] factor ε .

The expansibility factor, ε , is equal to unity when the fluid is considered incompressible (liquid) and is less than unity when the fluid is compressible (gaseous).

This method is possible because experiments show that ε is practically independent of the Reynolds number and, for a given diameter ratio of a given primary device, ε only depends on the pressure ratio and the isentropic exponent.

The numerical values of ε for orifice plates given in ISO 5167-2 and for cone meters given in ISO 5167-5 are based on data determined experimentally. For nozzles (see ISO 5167-3), Venturi tubes (see ISO 5167-4) and wedge meters (see ISO 5167-6) they are based on the thermodynamic general equation applied to isentropic expansion.

3.3.7

arithmetical mean deviation of the roughness profile

R_a

arithmetical mean deviation from the mean line of the profile being measured

Note 1 to entry: The mean line is such that the sum of the squares of the distances between the effective surface and the mean line is a minimum. In practice R_a can be measured with standard equipment for machined surfaces but can only be estimated for rougher surfaces of pipes. See also ISO 4288.

Note 2 to entry: For pipes, the uniform equivalent roughness k may also be used. This value can be determined experimentally (see 7.1.5) or taken from tables (see Annex B).

4 Symbols and subscripts

4.1 Symbols

Table 1 — Symbols

Symbol	Quantity	Dimension ^a	SI unit
A_t	Area of throat	L^2	m^2
C	Coefficient of discharge	dimensionless	—
$C_{m,p}$	Molar-heat capacity at constant pressure	$ML^2T^{-2}\Theta^{-1}mol^{-1}$	$J/(mol \cdot K)$
d	Diameter of orifice (or throat) of primary device under working conditions	L	m
D	Upstream internal pipe diameter (or upstream diameter of a classical Venturi tube) under working conditions	L	m
H	Enthalpy	$ML^2T^{-2}mol^{-1}$	J/mol
k	Uniform equivalent roughness	L	m
K	Pressure loss coefficient (the ratio of the pressure loss, Δp , to the dynamic pressure, $\rho V^2/2$), also known as the minor loss coefficient	dimensionless	—
l	Pressure tapping spacing	L	m
L	Relative pressure tapping spacing: $L = l/D$	dimensionless	—
p	Absolute static pressure of the fluid	$ML^{-1}T^{-2}$	Pa
q_m	Mass flowrate	MT^{-1}	kg/s
q_V	Volume flowrate	L^3T^{-1}	m^3/s
R	Radius	L	m
R_u	Universal gas constant	$ML^2T^{-2}\Theta^{-1}mol^{-1}$	$J/(mol \cdot K)$
Ra	Arithmetical mean deviation of the (roughness) profile	L	m
Re	Reynolds number	dimensionless	—
Re_d	Throat Reynolds number	dimensionless	—
Re_D	Pipe Reynolds number	dimensionless	—
t	Temperature of the fluid	Θ	$^{\circ}C$
T	Absolute (thermodynamic) temperature of the fluid	Θ	K
U'	Relative uncertainty	dimensionless	—
V	Mean axial velocity of the fluid in the pipe	LT^{-1}	m/s