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

Part 3: Nozzles and Venturi nozzles

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

Partie 3: Tuyères et Venturi-tuyères

Reference number
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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 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

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

This first edition of ISO 5167-3, together with the second edition of ISO 5167-1 and the first editions of ISO 5167-2 and ISO 5167-4, cancels and replaces the first edition of ISO 5167-1:1991, which has been technically revised, and ISO 5167-1:1991/Amd.1:1998.

ISO 5167 consists of the following parts, under the general title *Measurement of fluid flow by means of pressure differential devices inserted in circular-cross section conduits running full*:

— *Part 1: General principles and requirements*

— *Part 2: Orifice plates*

— *Part 3: Nozzles and Venturi nozzles*

— *Part 4:Venturi tubes*

Introduction

ISO 5167, consisting of four parts, covers the geometry and method of use (installation and operating conditions) of orifice plates, nozzles and Venturi tubes 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 (all parts) 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 within specified limits of pipe size and Reynolds number.

ISO 5167 (all parts) 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.

The devices introduced into the pipe are called "primary devices". The term primary device also includes the pressure tappings. All other instruments or devices required for the measurement are known as "secondary devices". ISO 5167 (all parts) covers primary devices; secondary devices[1] will be mentioned only occasionally.

ISO 5167 consists of the following four 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 ISO 5167-2, ISO 5167-3 and ISO 5167-4.

b) ISO 5167-2 specifies orifice plates, which can be used with corner pressure tappings, D and $D/2$ pressure tappings[2], and flange pressure tappings.

c) ISO 5167-3 specifies ISA 1932 nozzles[3], long radius nozzles and Venturi nozzles, which differ in shape and in the position of the pressure tappings.

d) ISO 5167-4 specifies classical Venturi tubes[4].

Aspects of safety are not dealt with in Parts 1 to 4 of ISO 5167. It is the responsibility of the user to ensure that the system meets applicable safety regulations.

1) See ISO 2186:1973, *Fluid flow in closed conduits — Connections for pressure signal transmissions between primary and secondary elements*.

2) Orifice plates with "vena contracta" pressure tappings 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.

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

Part 3: Nozzles and Venturi nozzles

1 Scope

This part of ISO 5167 specifies the geometry and method of use (installation and operating conditions) of nozzles and Venturi nozzles when they are inserted in a conduit running full to determine the flowrate of the fluid flowing in the conduit.

This part of ISO 5167 also provides background information for calculating the flowrate and is applicable in conjunction with the requirements given in ISO 5167-1.

This part of ISO 5167 is applicable to nozzles and Venturi nozzles in which the flow remains subsonic throughout the measuring section and where the fluid can be considered as single-phase. In addition, each of the devices can only be used within specified limits of pipe size and Reynolds number. It is not applicable to the measurement of pulsating flow. It does not cover the use of nozzles and Venturi nozzles in pipe sizes less than 50 mm or more than 630 mm, or where the pipe Reynolds numbers are below 10 000.

This part of ISO 5167 deals with

a) two types of standard nozzles:

   1) the ISA[5] 1932 nozzle;

   2) the long radius nozzle[6];

b) the Venturi nozzle.

The two types of standard nozzle are fundamentally different and are described separately in this part of ISO 5167. The Venturi nozzle has the same upstream face as the ISA 1932 nozzle, but has a divergent section and, therefore, a different location for the downstream pressure tappings, and is described separately. This design has a lower pressure loss than a similar nozzle. For both of these nozzles and for the Venturi nozzle 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.

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

6) The long radius nozzle differs from the ISA 1932 nozzle in shape and in the position of the pressure tappings.

2 Normative references

The following referenced documents are indispensable for the application 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 4006:1991, *Measurement of fluid flow in closed conduits — Vocabulary and symbols*

ISO 5167-1:2003, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4006 and ISO 5167-1 apply.

4 Principles of the method of measurement and computation

The principle of the method of measurement is based on the installation of a nozzle or a Venturi nozzle into a pipeline in which a fluid is running full. The installation of the primary device causes a static pressure difference between the upstream side and the throat. The flowrate can be determined from the measured value of this pressure difference and from the knowledge of the characteristics of the flowing fluid as well as the circumstances under which the device is being used. It is assumed that the device is geometrically similar to one on which calibration has been carried out and that the conditions of use are the same, i.e. that it is in accordance with this part of ISO 5167.

The mass flowrate can be determined by Equation (1):

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

The uncertainty limits can be calculated using the procedure given in Clause 8 of ISO 5167-1:2003.

Similarly, the value of the volume flowrate can be calculated since

$$q_V = \frac{q_m}{\rho} \tag{2}$$

where ρ is the fluid density at the temperature and pressure for which the volume is stated.

Computation of the flowrate, which is a purely arithmetic process, is performed by replacing the different items on the right-hand side of Equation (1) by their numerical values. Tables A.1 to A.4 are given for convenience. Tables A.1 to A.3 give the values of C as a function of β. Table A.4 gives expansibility (expansion) factors ε. They are not intended for precise interpolation. Extrapolation is not permitted.

The coefficient of discharge C may be dependent on Re_D, which is itself dependent on q_m and has to be obtained by iteration. (See ISO 5167-1 for guidance regarding the choice of the iteration procedure and initial estimates.)

The diameters d and D mentioned in Equation (1) are the values of the diameters at working conditions. Measurements taken at any other conditions should be corrected for any possible expansion or contraction of the primary device and the pipe due to the values of the temperature and pressure of the fluid during the measurement.

It is necessary to know the density and the viscosity of the fluid at working conditions. In the case of a compressible fluid, it is also necessary to know the isentropic exponent of the fluid at working conditions.

5 Nozzles and Venturi nozzles

5.1 ISA 1932 nozzle

5.1.1 General shape

The part of the nozzle inside the pipe is circular. The nozzle consists of a convergent section, of rounded profile, and a cylindrical throat.

Figure 1 shows the cross-section of an ISA 1932 nozzle at a plane passing through the centreline of the throat.

The letters in the following text refer to those shown on Figure 1.

5.1.2 Nozzle profile

5.1.2.1 The profile of the nozzle may be characterized by distinguishing:

— a flat inlet part A, perpendicular to the centreline;

— a convergent section defined by two arcs of circumference B and C;

— a cylindrical throat E; and

— a recess F which is optional (it is required only if damage to the edge G is feared).

5.1.2.2 The flat inlet part A is limited by a circumference centred on the axis of revolution, with a diameter of 1,5d, and by the inside circumference of the pipe, of diameter D.

When d = 2D/3, the radial width of this flat part is zero.

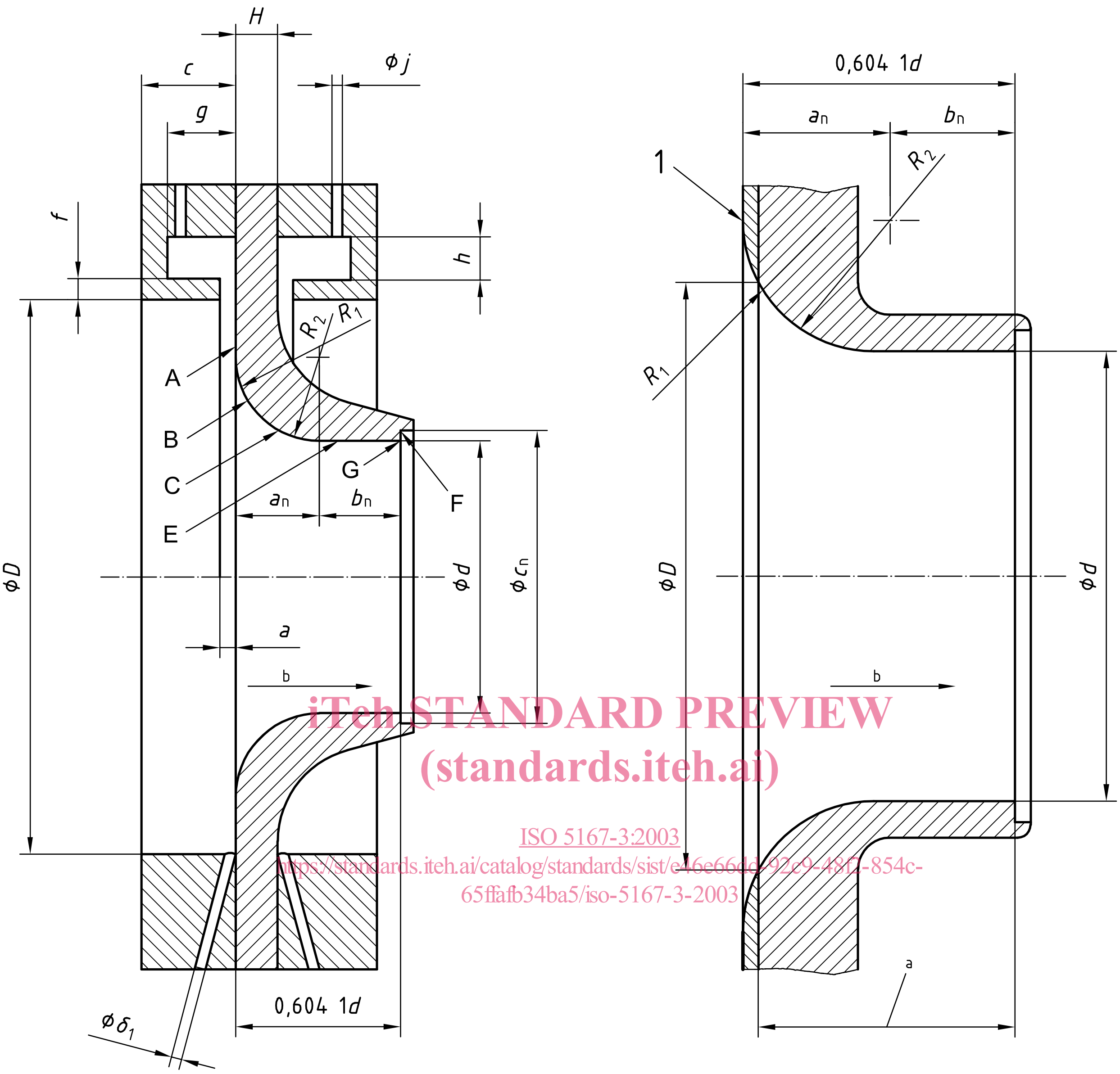
When d is greater than 2D/3, the upstream face of the nozzle does not include a flat inlet part within the pipe. In this case, the nozzle is manufactured as if D is greater than 1,5d, and the inlet flat part is then faced off so that the largest diameter of the convergent profile is just equal to D [see 5.1.2.7 and Figure 1 b)].

5.1.2.3 The arc of circumference B is tangential to the flat inlet part A when $d < 2D/3$ while its radius R_1 is equal to 0,2d ± 0,02d for $\beta < 0{,}5$ and to 0,2d ± 0,006d for $\beta \geqslant 0{,}5$. Its centre is at 0,2d from the inlet plane and at 0,75d from the axial centreline.

5.1.2.4 The arc of circumference C is tangential to the arc of circumference B and to the throat E. Its radius R_2 is equal to d/3 ± 0,033d for $\beta < 0{,}5$ and to d/3 ± 0,01d for $\beta \geqslant 0{,}5$. Its centre is at d/2 + d/3 = 5d/6 from the axial centreline and at

$$a_n = \left(\frac{12 + \sqrt{39}}{60} \right) d = 0{,}304\,1 \ d$$

from the flat inlet part A.



a) $d \leq (2/3)D$ **b)** $d > (2/3)D$

Key

1 portion to be cut off

a See 5.1.2.7.

b Direction of flow.

Figure 1 — ISA 1932 nozzle

5.1.2.5 The throat E has a diameter d and a length $b_n = 0{,}3d$.

The value d of the diameter of the throat shall be taken as the mean of the measurements of at least four diameters distributed in axial planes and at approximately equal angles to each other.

The throat shall be cylindrical. No diameter of any cross-section shall differ by more than 0,05 % from the value of the mean diameter. This requirement is considered to be satisfied when the deviations in the length of any of the measured diameters comply with the said requirement in respect of deviation from the mean.

5.1.2.6 The recess F has a diameter c_n equal to at least 1,06d and a length less than or equal to 0,03d. The ratio of the height $(c_n - d)/2$ of the recess to its axial length shall not be greater than 1,2.

The outlet edge G shall be sharp.

5.1.2.7 The total length of the nozzle, excluding the recess F, as a function of β is equal to

$$0{,}604\,1d \text{ for } 0{,}3 \leqslant \beta \leqslant \frac{2}{3}$$

and

$$\left(0{,}404\,1 + \sqrt{\frac{0{,}75}{\beta} - \frac{0{,}25}{\beta^2} - 0{,}522\,5}\right) d \text{ for } \frac{2}{3} < \beta \leqslant 0{,}8 .$$

5.1.2.8 The profile of the convergent inlet shall be checked by means of a template.

Two diameters of the convergent inlet in the same plane perpendicular to the axial centreline shall not differ from each other by more than 0,1 % of their mean value.

5.1.2.9 The surface of the upstream face and the throat shall be polished such that they have a roughness criterion $Ra \leqslant 10^{-4}d$.

5.1.3 Downstream face

5.1.3.1 The thickness H shall not exceed 0,1D.

5.1.3.2 Apart from the condition given in 5.1.3.1, the profile and the surface finish of the downstream face are not specified (see 5.1.1).

5.1.4 Material and manufacture

The ISA 1932 nozzle may be manufactured from any material and in any way, provided that it remains in accordance with the foregoing description during flow measurement.

5.1.5 Pressure tappings

5.1.5.1 Corner pressure tappings shall be used upstream of the nozzle.

The upstream pressure tappings may be either single tappings or annular slots. Both types of tappings may be located either in the pipe or its flanges or in carrier rings as shown in Figure 1.

The spacing between the centrelines of individual upstream tappings and face A is equal to half the diameter or to half the width of the tappings themselves, so that the tapping holes break through the wall flush with face A. The centreline of individual upstream tappings shall meet the centreline of the primary device at an angle of as near 90° as possible.

The diameter δ_1 of a single upstream tapping and the width a of annular slots are specified below. The minimum diameter is determined in practice by the need to prevent accidental blockage and to give satisfactory dynamic performance.

For clean fluids and vapours:

— for $\beta \leqslant 0{,}65$: $0{,}005D \leqslant a$ or $\delta_1 \leqslant 0{,}03D$;

— for $\beta > 0{,}65$: $0{,}01D \leqslant a$ or $\delta_1 \leqslant 0{,}02D$.

For any value of β:

— for clean fluids: 1 mm $\leqslant a$ or $\delta_1 \leqslant$ 10 mm;

— for vapours, in the case of annular chambers: 1 mm $\leqslant a \leqslant$ 10 mm;

— for vapours and for liquefied gases, in the case of single tappings: 4 mm $\leqslant \delta_1 \leqslant$ 10 mm.

The annular slots usually break through the pipe over the entire perimeter, with no break in continuity. If not, each annular chamber shall connect with the inside of the pipe by at least four openings, the axes of which are at equal angles to one another and the individual opening area of which is at least 12 mm^2.

The internal diameter b of the carrier rings shall be greater than or equal to the diameter D of the pipe, to ensure that they do not protrude into the pipe, but shall be less than or equal to 1,04D. Moreover, the following condition shall be met:

$$\frac{b-D}{D} \times \frac{c}{D} \times 100 \leqslant \frac{0{,}1}{0{,}1+2{,}3\beta^4}$$

The length c of the upstream ring (see Figure 1) shall not be greater than 0,5D.

The thickness f of the slot shall be greater than or equal to twice the width a of the annular slot. The area of the cross-section of the annular chamber, gh, shall be greater than or equal to half the total area of the opening connecting this chamber to the inside of the pipe.

All surfaces of the ring which are in contact with the measured fluid shall be clean and shall have a well-machined finish.

The pressure tappings connecting the annular chambers to the secondary devices are pipe-wall tappings, circular at the point of break-through and with a diameter j between 4 mm and 10 mm.

The upstream and downstream carrier rings need not necessarily be symmetrical in relation to each other, but they shall both conform to the preceding requirements.

The diameter of the pipe shall be measured as specified in 6.4.2, the carrier ring being regarded as part of the primary device. This also applies to the distance requirement given in 6.4.4 so that s shall be measured from the upstream edge of the recess formed by the carrier ring.

5.1.5.2 The downstream pressure tappings may either be corner tappings as described in 5.1.5.1 or be as described in the remainder of this section.

The distance between the centre of the tapping and the upstream face of the nozzle shall be

— $\leqslant$ 0,15D for $\beta \leqslant$ 0,67

— $\leqslant$ 0,20D for $\beta >$ 0,67

When installing the pressure tappings, due account shall be taken of the thickness of the gaskets and/or sealing material.

The centreline of the tapping shall meet the pipe centreline at an angle as near to 90° as possible but in every case within 3° of the perpendicular. At the point of break-through, the hole shall be circular. The edges shall be flush with the internal surface of the pipe wall and as sharp as possible. To ensure the elimination of all burrs or wire edges at the inner edge, rounding is permitted but shall be kept as small as possible and, where it can be measured, its radius shall be less than one-tenth of the pressure-tapping diameter. No irregularity shall appear inside the connecting hole, on the edges of the hole drilled in the pipe wall or on the pipe wall close to the pressure tapping. Conformity of the pressure tappings with the requirements of this paragraph may be judged by visual inspection.