भारतीय मानक
Indian Standard

IS 14615 (Part 3) : 2024
ISO 5167-3 : 2022

पूर्ण भरे बहाव वाले वृत्ताकार अनुप्रस्थ काट वाले कॉन्डुइट में प्रविष्ट दाब विभेदी युक्तियों द्वारा द्रव प्रवाह का मापन

भाग 3 नोज़ल और वेंचुरी नोजल

(पहला पुनरीक्षण)

Measurement of Fluid Flow by Means of Pressure Differential Devices Inserted in Circular Cross-Section Conduits Running Full

Part 3 Nozzles and Venturi Nozzles

(First Revision)

ICS 17.120.10

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुर शाह ज़फर मार्ग, नई दिल्ली - 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI - 110002
www.bis.gov.in www.standardsbis.in

March 2024 **Price Group 14**

Hydrometry Sectional Committee, WRD 01

NATIONAL FOREWORD

This Indian Standard (Part 3) (First Revision) which is identical to ISO 5167-3 : 2022 'Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 3: Nozzles and venturi nozzles' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Hydrometry Sectional Committee and approval of the Water Resources Division Council.

This Indian Standard was originally published in 2018 which was identical with ISO 5167-3 : 2003 'Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 3: Nozzles and venturi nozzles'.

This standard is being published in five parts. Other parts in the series are:

Part 1 General terms and definitions
Part 2 Orifice plates
Part 4 Venturi tubes
Part 5 Cone meters

The text of ISO standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is especially drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'; and
b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

This Indian Standard is confirming the sustainable development goals:

a) Affordable and clean energy; and
b) Industry, innovation and infrastructure

In this adopted standard, reference appears to the following International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their place, are listed below along with their degree of equivalence for the edition indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
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	IS 14615 (Part 1) : 2018/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 (*first revision*)	Identical

The Committee responsible for the preparation of this standard has reviewed the provisions of the following ISO standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
ISO 4006 : 1991	Measurement of fluid flow in closed conduits — Vocabulary and symbols

(*Continued on third cover*)

Contents

Page

Introduction ..... **v**

1 Scope **1**

2 Normative references **1**

3 Terms and definitions **2**

4 Principles of the method of measurement and computation **2**

5 Nozzles and Venturi nozzles **3**
5.1 ISA 1932 nozzle 3
5.1.1 General shape 3
5.1.2 Nozzle profile 3
5.1.3 Downstream face 5
5.1.4 Material and manufacture 5
5.1.5 Pressure tappings 5
5.1.6 Coefficients of ISA 1932 nozzles 7
5.1.7 Uncertainties 8
5.1.8 Pressure loss, $\Delta\varpi$ 8
5.2 Long radius nozzles 9
5.2.1 General 9
5.2.2 Profile of high-ratio nozzle 9
5.2.3 Profile of low-ratio nozzle 11
5.2.4 Material and manufacture 12
5.2.5 Pressure tappings 12
5.2.6 Coefficients of long radius nozzles 12
5.2.7 Uncertainties 13
5.2.8 Pressure loss, $\Delta\varpi$ 13
5.3 Throat-tapped nozzles 13
5.3.1 General 13
5.3.2 Profile of throat-tapped nozzle 14
5.3.3 Material and manufacturing 15
5.3.4 Pressure tappings 15
5.3.5 Coefficients 16
5.3.6 Uncertainties 16
5.3.7 Calibration and extrapolation 17
5.3.8 Pressure Loss 17
5.4 Venturi nozzles 18
5.4.1 General shape 18
5.4.2 Material and manufacture 20
5.4.3 Pressure tappings 20
5.4.4 Coefficients 21
5.4.5 Uncertainties 22
5.4.6 Pressure loss 22

6 Installation requirements **23**
6.1 General 23
6.2 Minimum upstream and downstream straight lengths for installation between various fittings and the primary device 23
6.3 Flow conditioners 29
6.4 Circularity and cylindricality of the pipe 29
6.5 Location of primary device and carrier rings 30
6.6 Method of fixing and gaskets 31

7 Flow calibration of nozzles **31**
7.1 General 31
7.2 Test facility 32

7.3 Meter installation ... 32
7.4 Design of the test programme ... 32
7.5 Reporting the calibration results ... 32
7.6 Uncertainty analysis of the calibration ... 32
7.6.1 General ... 32
7.6.2 Uncertainty of the test facility ... 33
7.6.3 Uncertainty of the nozzle ... 33

Annex A (informative) **Tables of discharge coefficients and expansibility [expansion] factors** ... **34**

Annex B (informative) **Akashi type (Mitsubishi type) flow conditioner** ... **41**

Bibliography ... **42**

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 (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. ISO 5167 also provides methdology 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 tappings. 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 (all parts) covers primary devices; secondary devices (ISO 2186) and tertiary devices will be mentioned only occasionally.

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

Indian Standard

MEASUREMENT OF FLUID FLOW BY MEANS OF PRESSURE DIFFERENTIAL DEVICES INSERTED IN CIRCULAR CROSS — SECTION CONDUITS RUNNING FULL

PART 3 NOZZLES AND VENTURI NOZZLES

(First Revision)

1 Scope

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

This document 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 document deals with

a) three types of standard nozzles:

   1) ISA 1932[1)] nozzle;

   2) the long radius nozzle[2)];

   3) the throat-tapped nozzle

b) the Venturi nozzle.

The three types of standard nozzle are fundamentally different and are described separately in this document. 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 all 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.

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.

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

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

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

ISO 5167-1, *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.

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 https://www.electropedia.org/

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 document.

The mass flowrate can be determined by Formula (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 ISO 5167-1:2022, Clause 8.

Similarly, the value of the volume flowrate can be calculated by Formula (2) 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;

q_V is the volume flowrate.

Computation of the flowrate, which is a purely arithmetic process, is performed by replacing the different items on the right-hand side of Formula (1) by their numerical values. Tables A.1 to A.5 are given for convenience. Tables A.1, A.2 and A.4 give the values of C as a function of β. Table A.3 gives the values of C as a function of Re_d. Table A.5 gives expansibility (expansion) factors, ε. They are not intended for precise interpolation. Extrapolation is not permitted.

The discharge coefficient C may be dependent on Re_D or 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 Formula (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 with a 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;

— 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 $d = (2/3)D$, the radial width of this flat part is zero.

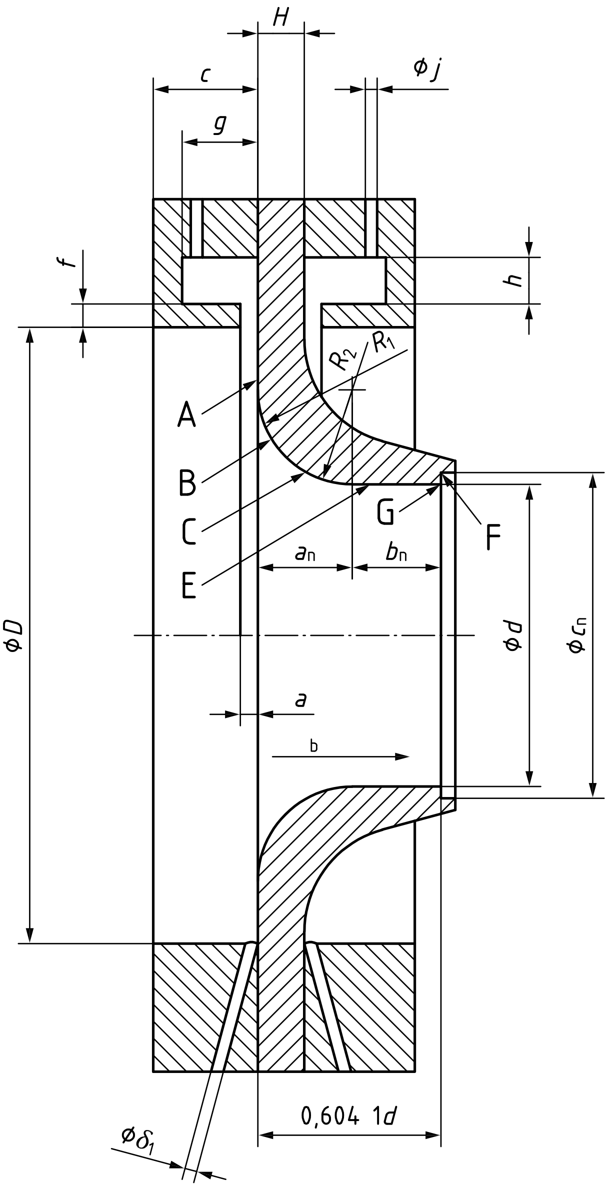
When d is greater than $(2/3)D$, the upstream face of the nozzle does not include a flat inlet part within the pipe. In this case, the nozzle is manufactured as if D were greater than 1,5d, and the inlet flat part is then faced off so that the largest diameter of the convergent profile is just equal 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 $d < (2/3)D$ while its radius R_1 is equal to $0{,}2d \pm 0{,}02d$ for $\beta < 0{,}5$ and to $0{,}2d \pm 0{,}006d$ for $\beta \geq 0{,}5$. Its centre is at 0,2d from the inlet plane and at 0,75d from the axial centreline.

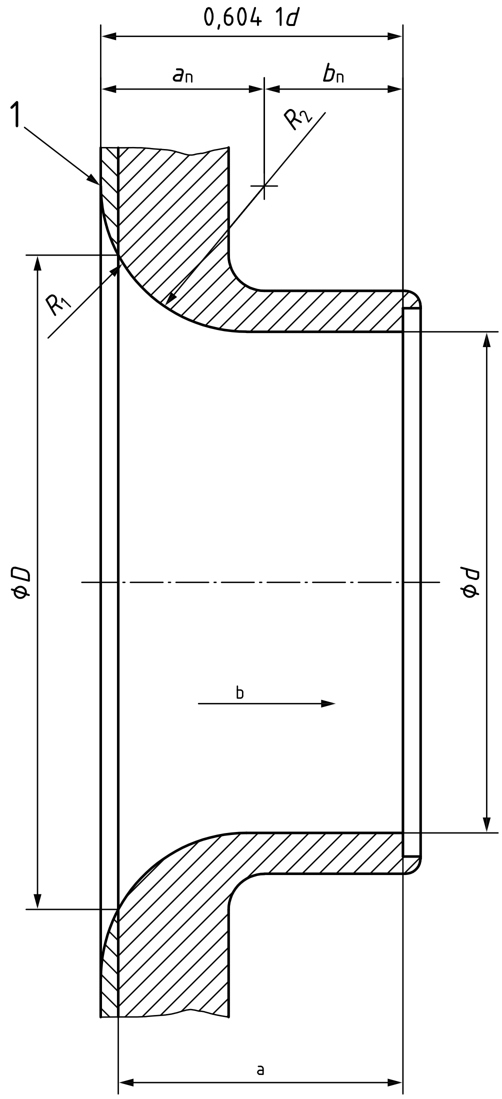
5.1.2.4 The arc of circumference C is tangential to the arc of circumference B and to the throat E. Its radius R_2 is equal to $d/3 \pm 0{,}033d$ for $\beta < 0{,}5$ and to $d/3 \pm 0{,}01d$ for $\beta \geq 0{,}5$. Its centre is at $d/2 + d/3 = (5/6)d$ from the axial centreline and as given by Formula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

$$a_n = \left(\frac{12 + \sqrt{39}}{60} \right) d = 0{,}304\,1\, d \quad (3)$$

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 depth $(c_n - d)/2$ 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

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

and

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

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 such that they have a roughness criterion $Ra \le 10^{-4}d$.

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 $\beta \le 0{,}65$: $0{,}005D \le a$ or $\delta_1 \le 0{,}03D$

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

For any value of β:

— for clean fluids: 1 mm ≤ a or δ_1 ≤ 10 mm

— for vapours, in the case of annular chambers: 1 mm ≤ a ≤ 10 mm

— for vapours and for liquefied gases, in the case of single tappings: 4 mm ≤ δ_1 ≤ 10 mm.

NOTE The requirements on size as a fraction of pipe diameter are based on geometrical similarity to the original nozzle runs on which the discharge coefficient is based. For vapours and for liquefied gases, there are pipe diameters for which it is not possible to manufacture a system using single tappings that is in accordance with this document.

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:

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

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 subclause.

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

— ≤0,15D for β ≤ 0,67;

— ≤0,20D for β > 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.

The diameter of pressure tappings shall be less than 0,13D and less than 13 mm.

No restriction is placed on the minimum diameter, which is determined in practice by the need to prevent accidental blockage and to give satisfactory dynamic performance. The upstream and downstream tappings shall have the same diameter.

The pressure tappings shall be circular and cylindrical over a length of at least 2,5 times the internal diameter of the tapping, measured from the inner wall of the pipeline.

The centrelines of the pressure tappings may be located in any axial plane of the pipeline.

The axis of the upstream tapping and that of the downstream tapping may be located in different axial planes.

5.1.6 Coefficients of ISA 1932 nozzles

5.1.6.1 Limits of use

This type of nozzle shall only be used in accordance with this document when

— 50 mm ≤ D ≤ 500 mm;

— 0,3 ≤ β ≤ 0,8;

and when Re_D is within the following limits:

— for 0,30 ≤ β < 0,44 $\quad$ $7 \times 10^4 \leq Re_D \leq 10^7$;

— for 0,44 ≤ β ≤ 0,80 $\quad$ $2 \times 10^4 \leq Re_D \leq 10^7$.

In addition, the relative roughness of the pipe shall conform to the values given in Table 1.

Table 1 — Upper limits of relative roughness of the upstream pipe for ISA 1932 nozzles

β	≤0,35	0,36	0,38	0,40	0,42	0,44	0,46	0,48	0,50	0,60	0,70	0,77	0,80
$10^4\ Ra/D$	8,0	5,9	4,3	3,4	2,8	2,4	2,1	1,9	1,8	1,4	1,3	1,2	1,2

NOTE Most of the data on which this table is based were probably collected in the range $Re_D \leq 10^6$; at higher Reynolds numbers more stringent limits on pipe roughness are probably required.

Most of the experiments on which the values of the discharge coefficient C given in this document are based were carried out in pipes with a relative roughness $Ra/D \leq 1{,}2 \times 10^{-4}$. Pipes with higher relative roughness may be used if the roughness for a distance of at least 10D upstream of the nozzle is within the limits given in Table 1. Information as to how to determine Ra is given in ISO 5167-1.

5.1.6.2 Discharge coefficient, C

The discharge coefficient, C, is given by Formula (5):

$$C = 0{,}990\ 0 - 0{,}226\ 2\beta^{4{,}1} - \left(0{,}001\ 75\beta^2 - 0{,}003\ 3\beta^{4{,}15}\right)\left(\frac{10^6}{Re_D}\right)^{1{,}15} \tag{5}$$

Values of C as a function of β and Re_D are given for convenience in Table A.1. These values are not intended for precise interpolation. Extrapolation is not permitted.

5.1.6.3 Expansibility [expansion] factor, ε

The expansibility [expansion] factor, ε, is calculated by means of Formula (6):

$$\varepsilon = \sqrt{\left(\frac{\kappa\tau^{2/\kappa}}{\kappa-1}\right)\left(\frac{1-\beta^4}{1-\beta^4\tau^{2/\kappa}}\right)\left(\frac{1-\tau^{(\kappa-1)/\kappa}}{1-\tau}\right)} \tag{6}$$

Formula (6) is applicable only for values of β, D and Re_D as specified in 5.1.6.1. Test results for determination of ε are only known for air, steam and natural gas. However, there is no known objection to using the same formula for other gases and vapours for which the isentropic exponent is known.

However, Formula (6) is applicable only if $p_2/p_1 \geq 0{,}75$.

Values of the expansibility [expansion] factor for a range of isentropic exponents, pressure ratios and diameter ratios are given for convenience in Table A.5. These values are not intended for precise interpolation. Extrapolation is not permitted.

5.1.7 Uncertainties

5.1.7.1 Uncertainty of discharge coefficient, C

When β, D, Re_D and Ra/D are assumed to be known without error, U_C', the relative expanded uncertainty of the value of C at $k = 2$ (approximately 95 % confidence level), is equal to

— 0,8 % for $\beta \leq 0{,}6$;

— $(2\beta - 0{,}4)$ % for $\beta > 0{,}6$.

5.1.7.2 Uncertainty of expansibility [expansion] factor ε

U_ε', the relative expanded uncertainty of the value of ε at $k = 2$ (approximately 95 % confidence level), is equal to

$$2\frac{\Delta p}{p_1}\ \%$$

5.1.8 Pressure loss, $\Delta\varpi$

The pressure loss, $\Delta\varpi$, for the ISA 1932 nozzle is approximately related to the differential pressure Δp by Formula (7)

$$\Delta\varpi = \frac{\sqrt{1-\beta^4\left(1-C^2\right)}-C\beta^2}{\sqrt{1-\beta^4\left(1-C^2\right)}+C\beta^2}\Delta p \tag{7}$$

This pressure loss is the difference in static pressure between the pressure measured at the wall on the upstream side of the primary device at a section where the influence of the approach impact pressure adjacent to the device is still negligible (approximately D upstream of the primary device) and that measured on the downstream side of the primary device where the static pressure recovery by expansion of the jet may be considered as just completed (approximately $6D$ downstream of the primary device).

The pressure loss coefficient, K, for the ISA 1932 nozzle is

$$K=\left[\frac{\sqrt{1-\beta^4\left(1-C^2\right)}}{C\beta^2}-1\right]^2 \tag{8}$$

where K is defined by Formula (9):

$$K=\frac{\Delta\varpi}{\frac{1}{2}\rho_1 U^2} \tag{9}$$

5.2 Long radius nozzles

5.2.1 General

There are two types of long radius nozzles, which are called

— high-ratio nozzles ($0{,}25 \leq \beta \leq 0{,}8$);

— low-ratio nozzles ($0{,}20 \leq \beta \leq 0{,}5$).

For β values between 0,25 and 0,5 either design may be used.

Figure 2 illustrates the geometric shapes of long radius nozzles, showing cross-sections passing through the throat centrelines.

The reference letters used in the text refer to those shown on Figure 2.

Both types of nozzles consist of a convergent inlet, whose shape is a quarter ellipse, and a cylindrical throat.

That part of the nozzle which is inside the pipe shall be circular, with the possible exception of the holes of the pressure tappings.

5.2.2 Profile of high-ratio nozzle

5.2.2.1 The inner face can be characterized by

— a convergent section A;

— a cylindrical throat B;

— a plain end C.

5.2.2.2 The convergent section A has the shape of a quarter ellipse.

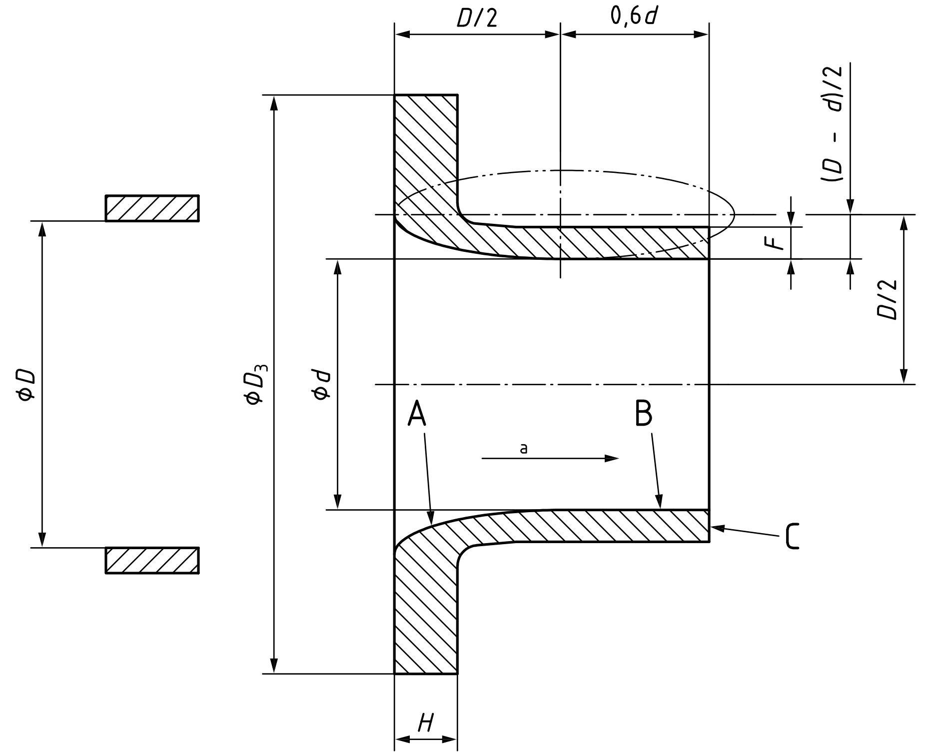
The centre of the ellipse is at a distance $D/2$ from the axial centreline. The major centreline of the ellipse is parallel to the axial centreline. The value of half the major axis is $D/2$. The value of half the minor axis is $(D - d)/2$.

The profile of the convergent section shall be checked by means of a template. Two diameters of the convergent section in the same plane perpendicular to the centreline shall not differ from each other by more than 0,1 % of their mean value.

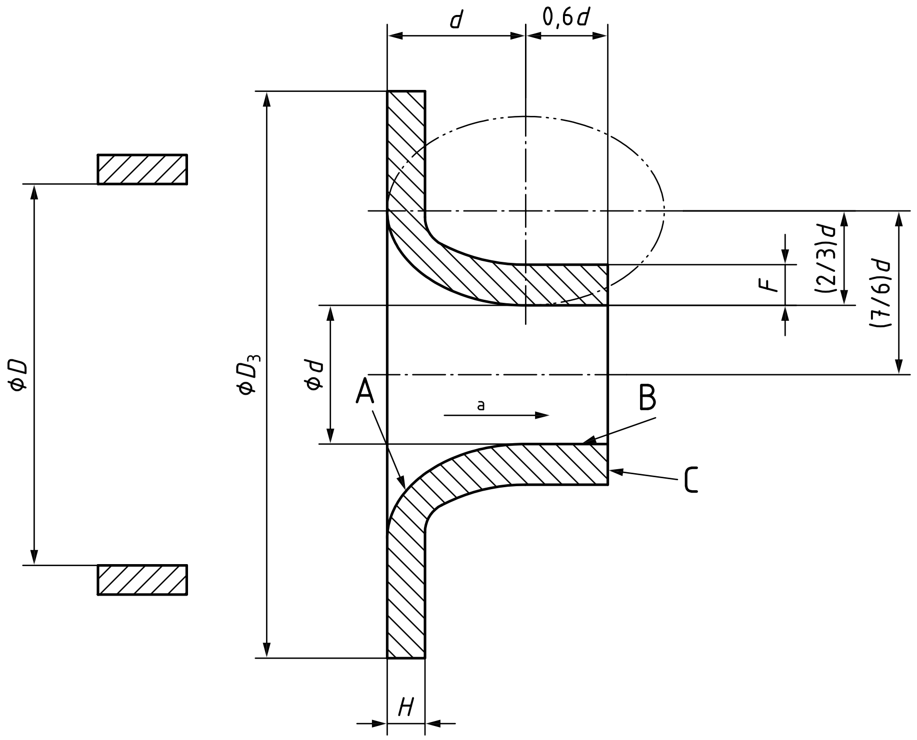
5.2.2.3 The throat B has a diameter d and a length $0{,}6d$.

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. Any diameter of any cross-section shall not differ by more than 0,05 % from the value of the mean diameter. Measurement at a sufficient number of cross-sections shall be made to determine that under no circumstances is the throat divergent in the direction of flow; within the stated uncertainty limits it may be slightly convergent. The section nearest the outlet is particularly important in this respect. 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 its deviation from the mean.



a) High ratio 0,25 ≤ β ≤ 0,8



b) Low ratio $0,2 \leq \beta \leq 0,5$

a Direction of flow.

Figure 2 — Long radius nozzles

5.2.2.4 The distance between the pipe wall and the outside face of the throat shall be greater than or equal to 3 mm.

5.2.2.5 The thickness H shall be greater than or equal to 3 mm and less than or equal to $0,15D$. The thickness F of the throat shall be greater than or equal to 3 mm, unless $D \leq 65$ mm, in which case F shall be greater than or equal to 2 mm. The thickness shall be sufficient to prevent distortion due to machining stresses.

5.2.2.6 The surface of the inner face shall have a roughness criterion $Ra \leq 10^{-4}d$.

5.2.2.7 The shape of the downstream (outside) face is not specified but shall comply with 5.2.2.4 and 5.2.2.5 and the last sentence of 5.2.1.

5.2.3 Profile of low-ratio nozzle

5.2.3.1 The requirements given in 5.2.2 for the high-ratio nozzle shall apply also to the low-ratio nozzle with the exception of the shape of the ellipse itself which is given in 5.2.3.2.

5.2.3.2 The convergent inlet A has the shape of a quarter ellipse. The centre of the ellipse is at a distance $d/2 + (2/3)d = (7/6)d$ from the axial centreline. The major axis of the ellipse is parallel to the axial centreline. The value of half the major axis is d. The value of half the minor axis is $(2/3)d$.

5.2.4 Material and manufacture

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

5.2.5 Pressure tappings

5.2.5.1 The centreline of the upstream tapping shall be at $1D^{+0,2D}_{-0,1D}$ from the inlet face of the nozzle.

The centreline of the downstream tapping shall be at $0,50D \pm 0,01D$ from the inlet face of the nozzle except in the case of a low ratio nozzle with $\beta < 0,318\ 8$ for which the centreline of the downstream tapping shall be at $1,6D^{+0}_{-0,02D}$ from the inlet face of the nozzle.

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

5.2.5.2 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 to a minimum 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.

The diameter of pressure tappings shall be less than $0,13D$ and less than 13 mm.

No restriction is placed on the minimum diameter, which is determined in practice by the need to prevent accidental blockage and to give satisfactory dynamic performance. The upstream and downstream tappings shall have the same diameter.

The pressure tappings shall be circular and cylindrical over a length of at least 2,5 times the internal diameter of the tapping, measured from the inner wall of the pipeline.

The centrelines of the pressure tappings may be located in any axial plane of the pipeline.

The axis of the upstream tapping and that of the downstream tapping may be located in different axial planes.

5.2.6 Coefficients of long radius nozzles

5.2.6.1 Limits of use

The long radius nozzles shall only be used in accordance with this document when

— $50\ \text{mm} \leq D \leq 630\ \text{mm}$;

— $0,2 \leq \beta \leq 0,8$;

— $10^4 \leq Re_D \leq 10^7$;

— $Ra/D \leq 3,2 \times 10^{-4}$ in the upstream pipe work.

Pipes with higher relative roughness may be used if the roughness for a distance of at least $10D$ upstream of the nozzle is within the limit given above. Information as to how to determine *Ra* is given in ISO 5167-1.

NOTE Most of the data on which this pipe roughness limit is based, were probably collected in the range $Re_d \leq 10^6$; at higher Reynolds numbers more stringent limits on pipe roughness are probably required.

5.2.6.2 Discharge coefficient, C

The discharge coefficients, C, are the same for both types of long radius nozzle when the tappings are in accordance with 5.2.5.

The discharge coefficient, C, is given by Formula (10), when referring to the upstream pipe Reynolds number Re_D:

$$C = 0{,}9965 - 0{,}00653\sqrt{\frac{10^6\beta}{Re_D}} \tag{10}$$

When referring to the Reynolds number at the throat Re_d, Formula (10) becomes

$$C = 0{,}9965 - 0{,}00653\sqrt{\frac{10^6}{Re_d}} \tag{11}$$

Values of C as a function of β and Re_D are given for convenience in Table A.2. These values are not intended for precise interpolation. Extrapolation is not permitted.

5.2.6.3 Expansibility [expansion] factor, ε

The indications given in 5.1.6.3 (ISA 1932 nozzle) apply also to the expansibility [expansion] factor for long radius nozzles, but within the limits of use specified in 5.2.6.1.

5.2.7 Uncertainties

5.2.7.1 Uncertainty of discharge coefficient C

When β and Re_d are assumed to be known without error, U_C', the relative expanded uncertainty of the value of C at $k = 2$ (approximately 95 % confidence level), is 2,0 % for all values of β between 0,2 and 0,8.

5.2.7.2 Uncertainty of expansibility [expansion] factor ε

U_ε', the relative expanded uncertainty of the value of ε at $k = 2$ (approximately 95 % confidence level), is equal to

$$2\frac{\Delta p}{p_1}\ \%$$

5.2.8 Pressure loss, $\Delta\varpi$

Subclause 5.1.8 (ISA 1932 nozzle) applies equally to the pressure loss of long radius nozzles.

5.3 Throat-tapped nozzles

5.3.1 General

Figure 3 illustrates the geometric shapes of throat-tapped nozzles, showing cross-sections passing through the throat centrelines.

The reference letters used in the text refer to those shown on Figure 3.

Both types of nozzles consist of a convergent inlet, whose shape is a quarter ellipse, and a cylindrical throat.

The difference between the two throat-tapped nozzles is the pressure tapping in the throat: either pressure tapping is allowed. The upstream tapping shall be located D upstream of the inlet face.

5.3.2 Profile of throat-tapped nozzle

5.3.2.1 The inner face can be characterized by

— an inlet face E;

— a convergent section A;

— a cylindrical throat B.

5.3.2.2 The arc of circumference A is not always tangential to the inlet face E.

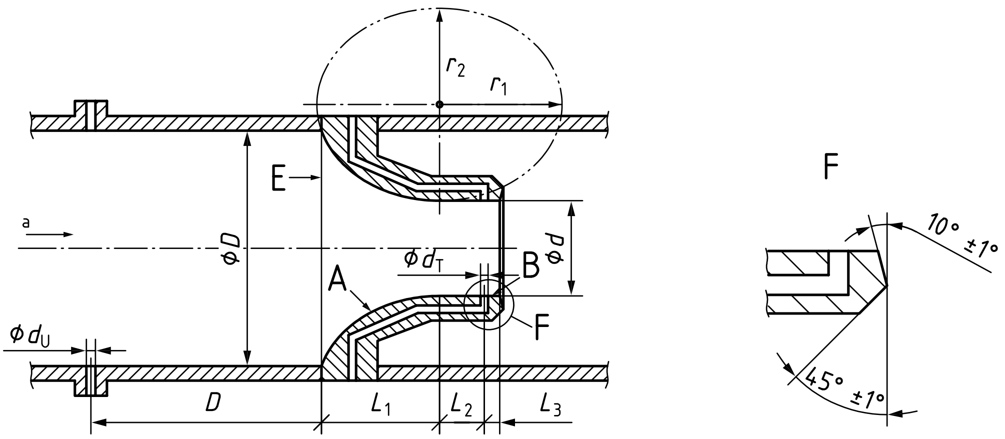
5.3.2.3 The shape of A is an ellipse with $r_1 = d \pm 0{,}000\ 2d$ and $0{,}625d < r_2 < 0{,}67d$.

5.3.2.4 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.

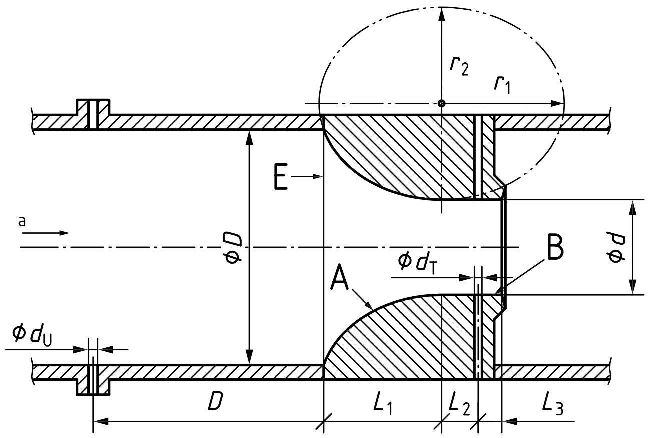
5.3.2.5 In the cylindrical throat B, L_2 is 0,5d. The tolerance of $L_1 + L_2$ shall be ±0,005d. L_3 shall be $0{,}25d \le L_3 \le 0{,}3d$.

5.3.2.6 The internal surfaces A and B should be hydraulically smooth. The roughness factor Ra should satisfy the following relation.

$$\frac{Ra}{d} < 14 {Re_d}^{-0{,}92} \qquad (12)$$



a) Detail of F



b)

a Direction of flow.

Figure 3 — Throat-tapped nozzles

5.3.3 Material and manufacturing

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

The throat-tapped flow nozzle is usually made of metal and shall be erosion- and corrosion-proof against the fluids with which it is to be used.

5.3.4 Pressure tappings

5.3.4.1 Angular position of the pressure tappings

The centrelines of the pressure tappings may be located in any axial sector of the pipe. However, consideration should be given to tapping position if contaminants, liquid droplets or gas bubbles are likely to be present. In these cases, the base and top of the pipe should be avoided.

The upstream and downstream tappings shall each comprise at least two single pressure tappings leading into an annular chamber, a piezometer ring or, if there are four tappings, a “triple-T” arrangement (see ISO 5167-1:2022, 5.4.3). Annular slots or interrupted slots shall not be used.

5.3.4.2 Circularity and edge of pressure tappings

The pressure tappings shall be circular over a length of at least 2,5 times the internal diameter of the tappings, measured from the inner wall of the nozzle. The edge of the pressure tappings shall be a sharp corner without any burrs.

5.3.4.3 Upstream tapping

The centreline of the upstream tapping shall be at $1D^{+0,2D}_{-0,1D}$ from the inlet face of the nozzle. The diameter d_U shall be from 2 mm to 7 mm.

5.3.4.4 Throat tapping

The centrelines of the throat tappings shall meet the centreline of the throat-tapped flow nozzle and shall be at equal angles to each other. The centrelines of the throat tappings shall lie in a plane perpendicular to the centreline of the nozzle.

The diameter d_T shall be from 2 mm to 7 mm and d_T/d shall be from 0,01 to 0,04. It is recommended that d_U and d_T should be the same.

5.3.5 Coefficients

5.3.5.1 Limits of use

The throat-tapped flow nozzle shall only be used in accordance with this document when

— 100 mm ≤ D ≤ 630 mm,

— 0,4 ≤ β ≤ 0,5,

— 8 × 10^5 ≤ Re_d ≤ 2 × 10^7,

— 2 mm ≤ d_U ≤ 7 mm,

— 2 mm ≤ d_T ≤ 7 mm,

— 0,01 ≤ d_T/d ≤ 0,04,

— $Ra/D \leq 28\ Re_D^{-0,92}$ in the upstream pipe work within 4D.

5.3.5.2 Discharge coefficient, C

The discharge coefficient C (see References [5] to[8]) is given by Formulae (13) and (14),

$$C = 1{,}0090 - \frac{0{,}255}{Re_d^{0{,}2}}\left(1 - \frac{400\ 000}{Re_d}\right)^{0{,}8} \quad (\text{for } 8{,}0 \times 10^5 \leq Re_d < 3{,}0 \times 10^6) \tag{13}$$

$$C = 0{,}9823 - \frac{0{,}255}{Re_d^{0{,}2}}\left(1 - \frac{400\ 000}{Re_d}\right)^{0{,}8} + 0{,}0018\ln(Re_d) \quad (\text{for } 3{,}0 \times 10^6 \leq Re_d) \tag{14}$$

Values of C as a function of Re_d are given for convenience in Table A.3. They are not intended for precise interpolation. Extrapolation is not permitted.

5.3.5.3 Expansibility [expansion] factor, ε

The indications given in 5.1.6.3 (ISA 1932 nozzle) apply also to the expansibility factor for throat-tapped flow nozzles, but within the limits of use specified in 5.3.5.1.

5.3.6 Uncertainties

5.3.6.1 Uncertainty of discharge coefficient C

Within the limits of use specified in 5.3.5.1, U_C', the relative expanded uncertainty of the value of C at k = 2 (approximately 95 % confidence level), without calibration is 0,7 %.

NOTE In compressible flow the uncertainty can increase where there is a change in throat tapping diameter at the right-angled bend within the nozzle and nearest to the throat itself.

5.3.6.2 Uncertainty of expansibility [expansion] factor ε

U'_{ε}, the relative expanded uncertainty of the value of ε at $k = 2$ (approximately 95 % confidence level), is equal to

$$2\frac{\Delta p}{p_1}\ \%$$

5.3.7 Calibration and extrapolation

To obtain more precise uncertainty, the calibration shall be done according to the following.

— Measurement shall be done at 6 or more different Reynolds numbers.

— Maximum Reynolds number of the calibration shall be $Re_d > 2{,}5 \times 10^6$. Minimum Reynolds number of the calibration shall be $8{,}0 \times 10^5 < Re_d < 1{,}5 \times 10^6$.

— The correction coefficient k in the following Formula is calculated for each measurement Reynolds number using the discharge coefficient C_c obtained from the calibration.

$$k = C_c + \frac{0{,}255}{{Re_d}^{0{,}2}}\left(1 - \frac{400\ 000}{Re_d}\right)^{0{,}8} - 0{,}196\frac{d_T}{d}\quad \text{(for } 8{,}0 \times 10^5 \le Re_d < 3{,}0 \times 10^6\text{)} \tag{15}$$

$$k = C_c + \frac{0{,}255}{{Re_d}^{0{,}2}}\left(1 - \frac{400\ 000}{Re_d}\right)^{0{,}8} - \{0{,}074\ 6\ln(Re_d) - 0{,}905\ 1\}\frac{d_T}{d}\quad \text{(for } 3{,}0 \times 10^6 \le Re_d\text{)} \tag{16}$$

The discharge coefficient can be calculated by installing the mean value of k in the next equation.

$$C = \bar{k} - \frac{0{,}255}{{Re_d}^{0{,}2}}\left(1 - \frac{400\ 000}{Re_d}\right)^{0{,}8} + \{0{,}074\ 6\ln(Re_d) - 0{,}905\ 1\}\frac{d_T}{d} \tag{17}$$

Formula (17) can be used where $3{,}0 \times 10^6 < Re_d < 2{,}0 \times 10^7$ and $Re_d d_T/d < 4{,}5 \times 10^5$ as the extrapolation of the calibration result. U'_C, the relative expanded uncertainty of the value of C at $k = 2$ (approximately 95 % confidence level), is given by the following:

$$\sqrt{0{,}3^2 + {U'_{C,\mathrm{cal}}}^2}\ (\%)$$

where $U'_{C,\mathrm{cal}}$ is the relative expanded uncertainty of the value of the discharge coefficient from the calibration facility at $k = 2$ (approximately 95 % confidence level). The calibration shall be performed at a facility operating in accordance with ISO/IEC 17025. The operational pipe design should be replicated at the calibration facility in order to reduce the uncertainty of the throat-tapped flow nozzle in its installation. If a flow conditioner is used, the calibration pipe work is considered to replicate the operational pipe work sufficiently when the pipe work is in accordance with 6.3.2 and the same upstream pipe and flow conditioner are used in both calibration and operation.

NOTE In compressible flow the uncertainty can increase where there is a change in throat tapping diameter at the right-angled bend within the nozzle and nearest to the throat itself.

5.3.8 Pressure Loss

Subclause 5.1.8 (ISA 1932 nozzle) applies equally to the pressure loss of throat-tapped flow nozzles.

5.4 Venturi nozzles

5.4.1 General shape

5.4.1.1 The profile of the Venturi nozzle (see Figure 4) is axisymmetric. It consists of a convergent section with a rounded profile, a cylindrical throat and a divergent section.

5.4.1.2 The upstream face is identical with that of an ISA 1932 nozzle (see Figure 1).

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

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

When *d* is greater than (2/3)*D*, 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* were greater than 1,5*d* and the inlet flat part is then faced off so that the largest diameter of the convergent profile is just equal to *D*.

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

5.4.1.5 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 $d/3 \pm 0{,}033d$ for $\beta < 0{,}5$ and to $d/3 \pm 0{,}01d$ for $\beta \geq 0{,}5$. Its centre is at $d/2 + d/3 = (5/6)d$ from the axial centreline and at

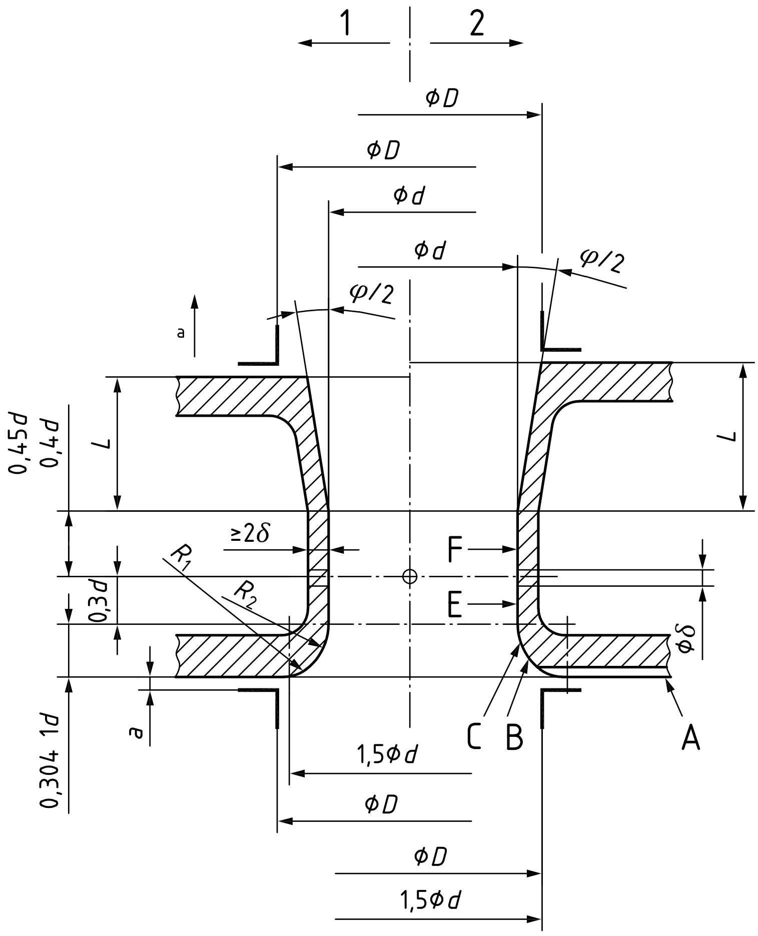
$$a_n = \frac{12+\sqrt{39}}{60} d = 0{,}304\ 1d \tag{18}$$

from the flat inlet part A.

5.4.1.6 The throat (see Figure 4) consists of a part E of length 0,3*d* and a part F of a length 0,4*d* to 0,45*d*.

The value *d* of the diameter of the throat shall be taken as the mean of 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 as 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.



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

Key

1 truncated divergent section

2 non-truncated divergent section

a Direction of flow.

Figure 4 — Venturi nozzle

5.4.1.7 The divergent section (see Figure 4) shall be connected with the part F of the throat without a rounded part, but any burrs shall be removed.

The included angle of the divergent section, φ, shall be less than or equal to 30°.

The length L of the divergent section has practically no influence on the discharge coefficient C. However, the included angle of the divergent section, and hence the length, does influence the pressure loss.

5.4.1.8 A Venturi nozzle is called "truncated" when the outlet diameter of the divergent section is less than the diameter D and "not truncated" when the outlet diameter is equal to diameter D. The divergent portion may be truncated by about 35 % of its length without notably modifying the pressure loss of the device.

5.4.1.9 The internal surfaces of the Venturi nozzle shall have a roughness criterion $Ra \leq 10^{-4}d$.

5.4.2 Material and manufacture

5.4.2.1 The Venturi nozzle may be manufactured from any material provided that it is in accordance with the description given in 5.4.1 and will remain so during use. In particular, the Venturi nozzle shall be clean when the flow measurements are made.

5.4.2.2 The Venturi nozzle is usually made of metal and shall be erosion- and corrosion-proof against the fluid with which it is to be used.

5.4.3 Pressure tappings

5.4.3.1 Angular position of the pressure tappings

The centrelines of the pressure tappings may be located in any axial sector of the pipe. However, consideration should be given to tapping position if contaminants, liquid droplets or gas bubbles are likely to be present. In these cases the base and top of the pipe should be avoided.

5.4.3.2 Upstream pressure tappings

The upstream pressure tappings shall be corner tappings (see 5.1.5.1). The tappings may be located either in the pipe or its flanges or in carrier rings as shown in Figure 5.

5.4.3.3 Throat pressure tappings

The throat pressure tappings shall comprise at least four single pressure tappings leading into an annular chamber, piezometer ring or, if there are four tappings, a “triple-T” arrangement (see ISO 5167-1:2022, 5.4.3). Annular slots or interrupted slots shall not be used.

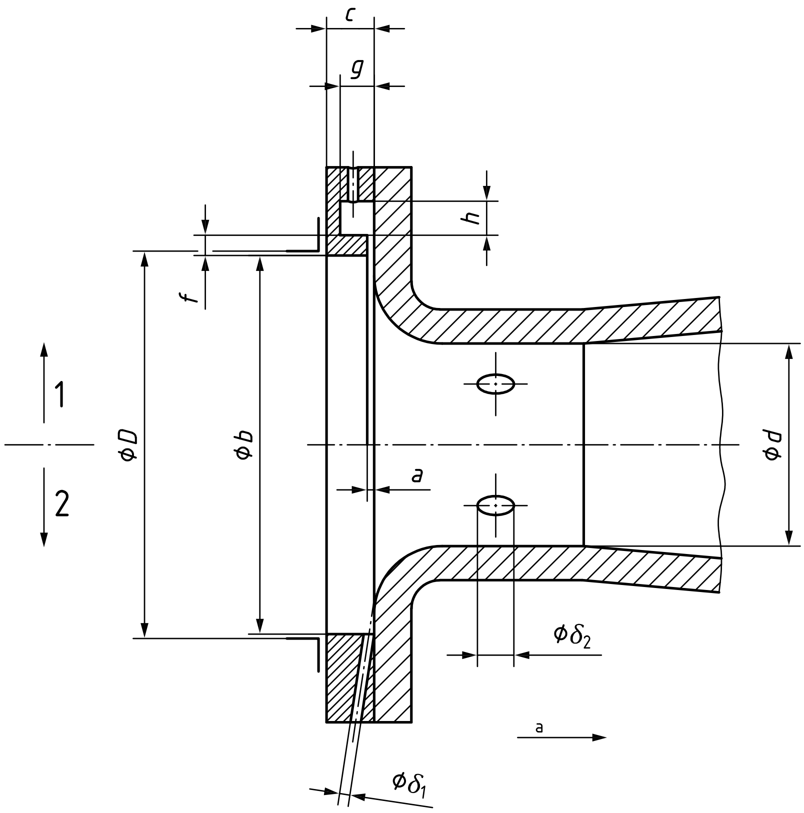
The centrelines of the pressure tappings shall meet the centreline of the Venturi nozzle and shall be at equal angles to each other. The centrelines of the throat pressure tappings shall lie in the plane perpendicular to the centreline of the Venturi nozzle, which is the imaginary border between the parts E and F of the cylindrical throat.

The diameter δ_2 of the individual tappings in the throat of Venturi nozzles shall be less than or equal to $0{,}04d$ and moreover shall be between 2 mm and 10 mm.

The pressure tappings shall be circular and cylindrical over a length of at least 2,5 times the internal diameter of the tappings, measured from the inner wall of the Venturi nozzle.

At the point of break-through the hole shall be circular. The edges shall be flush with the internal surface of the Venturi nozzle 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 to a minimum 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 Venturi nozzle, or on the pipe wall close to the pressure tapping.

Conformity of the pressure tappings with the requirements specified may be judged by visual inspection.



Key

1 with annular slot

2 with individual corner tappings

a Direction of flow.

Figure 5 — Venturi nozzle — Pressure tappings

5.4.4 Coefficients

5.4.4.1 Limits of use

Venturi nozzles shall only be used in accordance with this document when

— 65 mm ≤ D ≤ 500 mm,

— d ≥ 50 mm,

— 0,316 ≤ β ≤ 0,775,

— 1,5 × 10^5 ≤ Re_D ≤ 2 × 10^6.

In addition, the roughness of the pipe shall conform to the values given in Table 2.

Most of the experiments on which the values of the discharge coefficient C are based were carried out on pipes with a relative roughness Ra/D < 1,2 × 10^{-4}. Pipes with higher relative roughness may be used if the roughness over a distance of at least 10D upstream of the Venturi nozzle is within the limits of Table 2. Information as to how to determine Ra is given in ISO 5167-1.

Table 2 — Upper limits of relative roughness of the upstream pipe for Venturi nozzles

β	≤0,35	0,36	0,38	0,40	0,42	0,44	0,46	0,48	0,50	0,60	0,70	0,775
$10^4\ Ra/D$	8,0	5,9	4,3	3,4	2,8	2,4	2,1	1,9	1,8	1,4	1,3	1,2

5.4.4.2 Discharge coefficient, C

The discharge coefficient, C, is given by the formula

$$C = 0{,}985\ 8 - 0{,}196\beta^{4{,}5} \tag{19}$$

Values of C as a function of β are given for convenience in Table A.4. They are not intended for precise interpolation. Extrapolation is not permitted.

NOTE Within the limits specified in 5.4.4.1, C is independent of the Reynolds number and of the pipe diameter D.

5.4.4.3 Expansibility [expansion] factor, ε

The indications given in 5.1.6.3 (ISA 1932 nozzle) apply also to the expansibility [expansion] factor for Venturi nozzles, but within the limits of use specified in 5.4.4.1.

5.4.5 Uncertainties

5.4.5.1 Uncertainty of discharge coefficient C

Within the limits of use specified in 5.4.4.1 and when β is assumed to be known without error, U'_C, the relative expanded uncertainty of the value of C at k = 2 (approximately 95 % confidence level), is equal to

$$\left(1{,}2 + 1{,}5\beta^4\right)\%$$

5.4.5.2 Uncertainty of expansibility [expansion] factor ε

U'_ε, the relative expanded uncertainty of the value of ε at k = 2 (approximately 95 % confidence level), is equal to

$$\left(4 + 100\beta^8\right)\frac{\Delta p}{p_1}\ \%$$

5.4.6 Pressure loss

The indications given in 5.4.6 apply to Venturi nozzles when the divergent angle is not greater than 15°.

The relative pressure loss, ξ, is the value of the pressure loss $\Delta p'' - \Delta p'$ related to the differential pressure Δp:

$$\xi = \frac{\Delta p'' - \Delta p'}{\Delta p} \tag{20}$$

It is shown in Figure 6 and depends, in particular, on

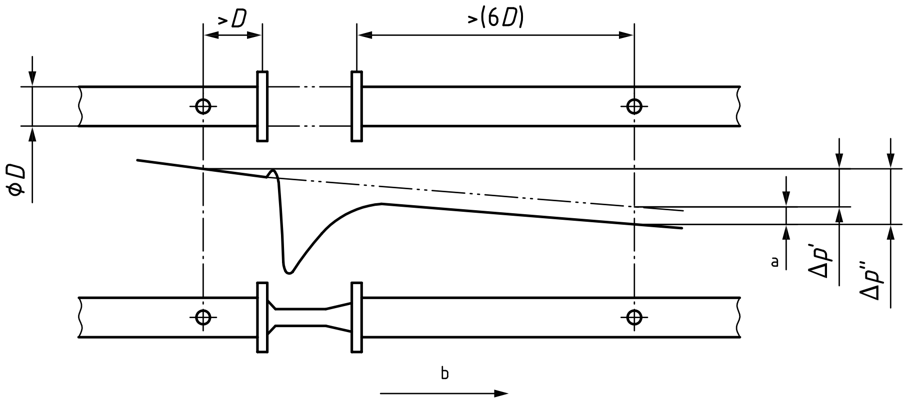
— the diameter ratio (ξ decreases when β increases),

— the Reynolds number (ξ decreases when Re_D increases),

— the manufacturing characteristics of the Venturi nozzle, i.e. angle of the divergent, manufacturing of the convergent, surface finish of the different parts, etc (ξ increases when φ and Ra/D increase),

— the installation conditions (good alignment, roughness of the upstream conduit, etc.).

For guidance, when the divergent angle is not greater than 15° the value of the relative pressure loss can be accepted as being generally between 5 % and 20 %.



a Pressure loss.

b Direction of flow.

Figure 6 — Pressure loss across a Venturi nozzle

6 Installation requirements

6.1 General

General installation requirements for pressure differential devices are contained in ISO 5167-1:2022, Clause 7 and should be followed in conjunction with the additional specific installation requirements for nozzles and Venturi nozzles given in this clause. The general requirements for flow conditions at the primary device are given in ISO 5167-1:2022, 7.3. The requirements for use of a flow conditioner are given in ISO 5167-1:2022, 7.4. For some commonly used fittings, as specified in Table 3, the minimum straight lengths of pipe indicated may be used (detailed requirements are given in 6.2).

6.2 Minimum upstream and downstream straight lengths for installation between various fittings and the primary device

6.2.1 The minimum straight lengths of pipe required upstream and downstream of the primary device for the specified fittings in the installation without flow conditioners are given in Table 3.

6.2.2 When a flow conditioner is not used the lengths specified in Table 3 shall be regarded as the minimum values. For research and calibration work in particular, it is recommended that the upstream values specified in Table 3 be increased by at least a factor of 2 to minimize the measurement uncertainty.

6.2.3 When the straight lengths used are equal to or longer than the values specified in Columns A of Table 3 for "zero additional uncertainty", it is not necessary to increase the uncertainty in discharge coefficient to take account of the effect of the particular installation.

6.2.4 When the upstream or downstream straight length is shorter than the value corresponding to "zero additional uncertainty" shown in Columns A and either equal to or greater than the "0,5 % additional uncertainty" value shown in Columns B of Table 3 for a given fitting, an additional relative uncertainty of 0,5 % shall be added arithmetically to the relative expanded uncertainty of the discharge coefficient.

Table 3 — Required straight lengths for nozzles and Venturi nozzles

Values expressed as multiples of internal diameter, D

Diameter ratio β[a]	Upstream (inlet) side of the primary device																				Downstream (outlet) side of the primary device	
	Single 90° bend or tee (flow from one branch only)		Two or more 90° bends in the same plane		Two or more 90° bends in different planes		Reducer 2D to D over a length of 1,5D to 3D		Expander 0,5D to D over a length of D to 2D		Globe valve fully open		Full bore ball or gate valve fully open		Abrupt symmetrical reduction		Thermometer pocket or well[b] of diameter ≤0,03D		Thermometer pocket or well[b] of diameter between 0,03D and 0,13D		Fittings (Columns 2 to 8)	
1	2		3		4		5		6		7		8		9		10		11		12	
	A[c]	B[d]	A[c]	B[d]	A[c]	B[d]	A[c]	B[d]	A[c]	B[d]	A[c]	B[d]	A[c]	B[d]	A[c]	B[d]	A[c]	B[d]	A[c]	B[d]	A[c]	B[d]
0,20	10	6	14	7	34	17	5	e	16	8	18	9	12	6	30	15	5	3	20	10	4	2
0,25	10	6	14	7	34	17	5	e	16	8	18	9	12	6	30	15	5	3	20	10	4	2
0,30	10	6	16	8	34	17	5	e	16	8	18	9	12	6	30	15	5	3	20	10	5	2,5
0,35	12	6	16	8	36	18	5	e	16	8	18	9	12	6	30	15	5	3	20	10	5	2,5
0,40	14	7	18	9	36	18	5	e	16	8	20	10	12	6	30	15	5	3	20	10	6	3
0,45	14	7	18	9	38	19	5	e	17	9	20	10	12	6	30	15	5	3	20	10	6	3
0,50	14	7	20	10	40	20	6	5	18	9	22	11	12	6	30	15	5	3	20	10	6	3
0,55	16	8	22	11	44	22	8	5	20	10	24	12	14	7	30	15	5	3	20	10	6	3
0,60	18	9	26	13	48	24	9	5	22	11	26	13	14	7	30	15	5	3	20	10	7	3,5
0,65	22	11	32	16	54	27	11	6	25	13	28	14	16	8	30	15	5	3	20	10	7	3,5
0,70	28	14	36	18	62	31	14	7	30	15	32	16	20	10	30	15	5	3	20	10	7	3,5
0,75	36	18	42	21	70	35	22	11	38	19	36	18	24	12	30	15	5	3	20	10	8	4
0,80	46	23	50	25	80	40	30	15	54	27	44	22	30	15	30	15	5	3	20	10	8	4

NOTE 1 The minimum straight lengths required are the lengths between various fittings located upstream or downstream of the primary device and the primary device itself. All straight lengths shall be measured from the upstream face of the primary device.

NOTE 2 These lengths are not based on modern data.

[a] For some types of primary device not all values of β are permissible.

[b] The installation of thermometer pockets or wells will not alter the required minimum upstream straight lengths for the other fittings.

[c] Column A for each fitting gives lengths corresponding to "zero additional uncertainty" values (see 6.2.3).

[d] Column B for each fitting gives lengths corresponding to "0,5 % additional uncertainty" values (see 6.2.4).

[e] The straight length in Column A gives zero additional uncertainty; data are not available for shorter straight lengths which could be used to give the required straight lengths for Column B.

6.2.5 This document cannot be used to predict the value of any additional uncertainty when either

a) straight lengths shorter than the "0,5 % additional uncertainty" values specified in Columns B of Table 3 are used, or

b) both the upstream and downstream straight lengths are shorter than the "zero additional uncertainty" values specified in Columns A of Table 3.

6.2.6 The valves included in Table 3 shall be set fully open during the flow measurement process. It is recommended that control of the flowrate be achieved by valves located downstream of the primary device. Isolating valves located upstream of the primary device shall be set fully open, and these valves shall be full bore. The valve should be fitted with stops for alignment of the ball or gate, in the open position. The valve shown in Table 3 is one which is of the same nominal diameter as the upstream pipe, but whose bore diameter is such that a diameter step is larger than that permitted in 6.4.3.

6.2.7 In the metering system, upstream valves which are match-bored to the adjacent pipework and are designed in such a manner that in the fully opened condition there are no steps greater than those permitted in 6.4.3, can be regarded as part of the metering pipework length and do not need to have added lengths as in Table 3 provided that when flow is being measured they are fully open.

6.2.8 The values given in Table 3 were determined experimentally with a very long straight length mounted upstream of the fitting in question so that the flow immediately upstream of the fitting was considered as fully developed and swirl-free. Since in practice such conditions are difficult to achieve, the following information may be used as a guide for normal installation practice.

a) If the primary device is installed in a pipe leading from an upstream open space or large vessel, either directly or through any other fittings covered by Table 3, the total length of pipe between the open space and the primary device shall never be less than 30*D*. If a fitting covered by Table 3 is installed then the straight lengths specified in the Tables shall also apply between this fitting and the primary device.

   A metering system header is not an open space or large vessel in this instance. A large vessel shall have a cross-sectional area of at least 10 times that of the metering tube. In the case of a normal header whose cross-sectional area is typically equal to 1,5 times the cross-sectional area of the operating flowmeter tubes, it is strongly recommended that a flow conditioner be installed downstream of the header (see ISO 5167-1:2022, 7.4) since there will always be distortion of the flow profile and a high probability of swirl.

b) If several fittings of the type covered by Table 3 (treating the combinations of 90° bends already covered by these tables as a single fitting) are placed in series upstream of the nozzle, the following shall be applied:

   1) Between the nozzle and fitting 1 (the fitting immediately upstream of the nozzle) there shall be a straight length greater than or equal to the minimum length given in Table 3 appropriate for the specific nozzle diameter ratio used with fitting 1.

   2) Between fitting 1 and fitting 2 (the next fitting upstream of the nozzle), there shall be a straight length greater than or equal to half the minimum length given in Table 3 for a nozzle of diameter ratio 0,7 used with fitting 2 (irrespective of the actual diameter ratio of the nozzle).

      NOTE If the pipe diameter changes at fitting 1, the pipe diameter between fitting 1 and fitting 2 is used to calculate this minimum length.

   3) If either of the minimum straight lengths is selected from Column B (i.e. prior to taking the half value from fitting 1 to 2 of Table 3), a 0,5 % additional relative uncertainty shall be added arithmetically to the relative expanded uncertainty of the discharge coefficient.

4) If fitting 1 is a full-bore valve (as in Table 3), then the valve can be installed at the outlet of fitting 2.

   The required length between the valve and fitting 2 [as calculated from 2)] should be added to the length between the nozzle and fitting 1 specified in Table 3; see Figure 7. It should be noted that 6.2.8 c) shall also be satisfied (as it is in Figure 7).

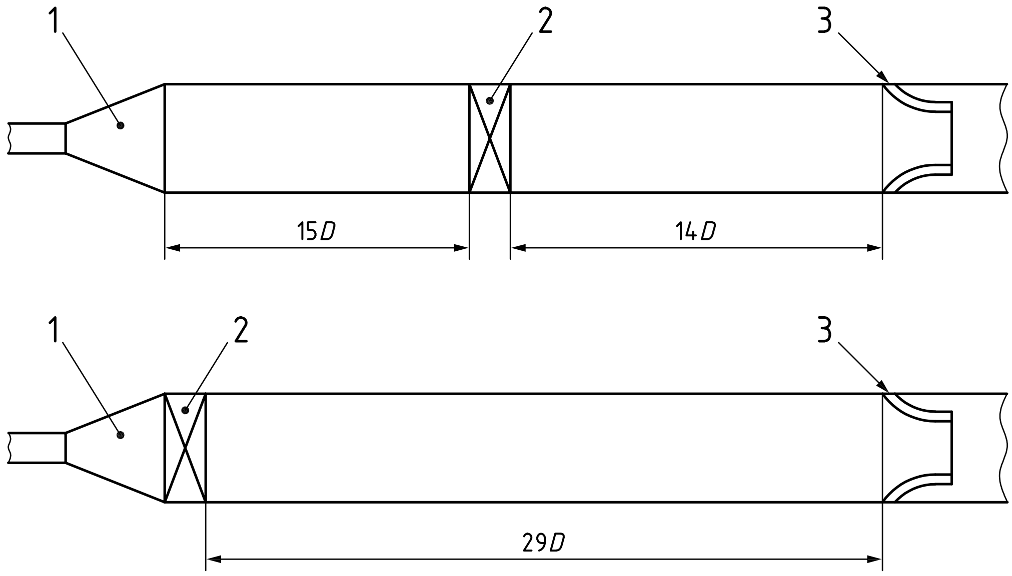
c) Between the nozzle and any upstream fitting (treating any two consecutive 90° bends as a single fitting), the straight length shall be greater than or equal to the minimum length given in Table 3 appropriate for the specific nozzle diameter ratio used with that fitting.

   NOTE The pipe diameter upstream of the orifice plate is used to calculate this minimum length.

   The distance between the nozzle and the fitting shall be measured along the pipe axis.

   If, for any upstream fitting, the distance meets this requirement using the number of diameters in Column B but not that in Column A, then a 0,5 % additional relative uncertainty shall be added arithmetically to the relative expanded uncertainty of the discharge coefficient. However, this additional uncertainty shall not be added more than once under the provisions of b) and c).

d) For the case of two or more 90° bends, these shall be treated as a single fitting in accordance with Table 3 Columns 3 and 4, if the length between the consecutive bends is less than 15*D*.



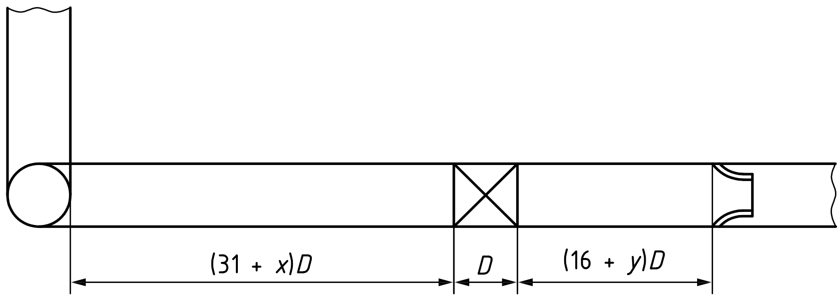
Key

1 expander

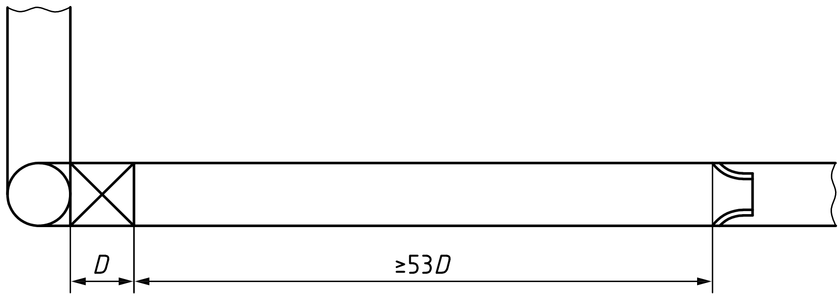
2 full bore ball valve or gate valve fully open

3 nozzle

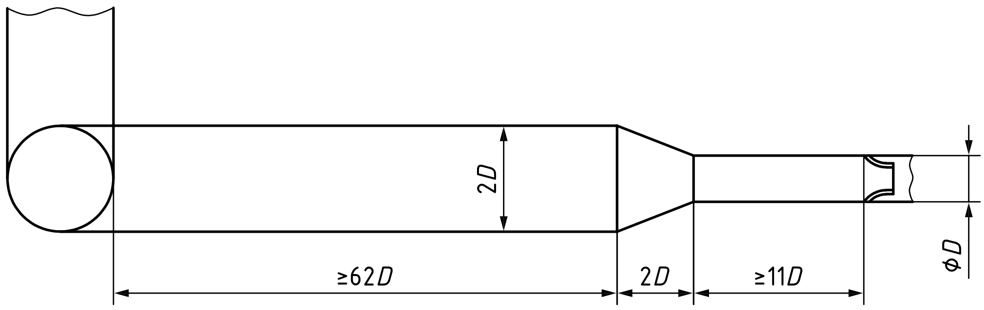
Figure 7 — Layout including a full bore valve for β = 0,6



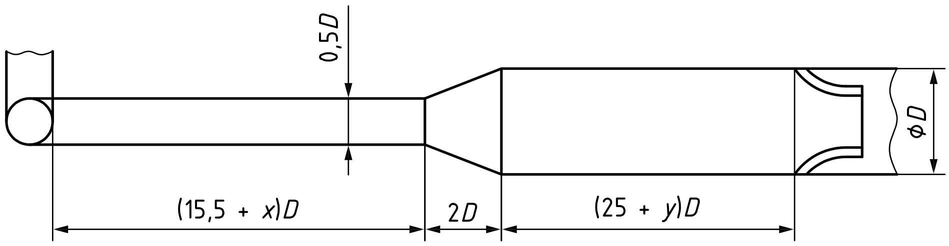
a) $x \geq 0, y \geq 0, x + y \geq 6$



b)



c)



d) $x \geq 0, y \geq 0, x + y \geq 11{,}5$

Figure 8 — Examples of acceptable installations (see 6.2.9)

6.2.9 By way of example three cases of the application of 6.2.8 b) and c) are considered. In each case fitting 2 is two bends in perpendicular planes and the nozzle has diameter ratio 0,65.

a) If fitting 1 is a full bore ball valve fully open [see Figure 8 a)] the distance between the nozzle and the valve shall be at least 16*D* (from Table 3) and that between the valve and the two bends in perpendicular planes shall be at least 31*D* [from 6.2.8 b)]; the distance between the nozzle and the two bends in perpendicular planes shall be at least 54*D* [from 6.2.8 c)].

If the valve has length 1*D* an additional total length of 6*D* is required which may be either upstream or downstream of the valve or partly upstream and partly downstream of it. The recommendations given in 6.2.8 b) 3) could be applied and the valve moved to a position adjacent to the two bends in perpendicular planes provided that there is at least 54*D* from the nozzle to the two bends in perpendicular planes [see Figure 8 b)].

b) If fitting 1 is a reducer from 2*D* to *D* over a length of 2*D* [see Figure 8 c)] the distance between the nozzle and the reducer shall be at least 11*D* (from Table 3) and that between the reducer and the two bends in perpendicular planes shall be at least 31 × 2*D* [from 6.2.8 b)]; the distance between the two bends in perpendicular planes and the nozzle shall be at least 54*D* [from 6.2.8 c)]. So no additional length is required because of 6.2.8 c).

c) If fitting 1 is an expander from 0,5*D* to *D* over a length of 2*D* [see Figure 8 d)], the distance between the nozzle and the expander shall be at least 25*D* (from Table 3) and that between the expander and the two bends in perpendicular planes shall be at least 31 × 0,5*D* [from 6.2.8 b)]; the distance between the nozzle and the two bends in perpendicular planes shall be at least 54*D* [from 6.2.8 c)]. So an additional total length of 11,5*D* is required which may be either upstream or downstream of the expander or partly upstream and partly downstream of it.

6.3 Flow conditioners

6.3.1 A flow conditioner can be used to reduce upstream straight lengths either through meeting the compliance test given in ISO 5167-1:2022, 7.4.1, in which case it can be used downstream of any upstream fitting, or through meeting the requirements of ISO 5167-1:2022, 7.4.2, which gives additional possibilities outside the compliance test. In either case, the test shall be carried out using the same type of nozzle as that used for the measurement of flow.

6.3.2 When a throat-tapped nozzle is used the installation is compliant with this document where a flow conditioner is installed 16*D* ± 0,5*D* upstream of the inlet face, E, and there is at least 4*D* of straight pipe upstream of the flow conditioner. In this case, a perforated plate type flow conditioner is recommended (e.g. Akashi type in Annex B).

6.4 Circularity and cylindricality of the pipe

6.4.1 The 2*D* length of the upstream pipe section adjacent to the nozzle (or to the carrier ring if there is one) shall be manufactured with special care and shall meet the requirement that no diameter in any plane in this length shall differ by more than 0,3 % from the mean value of *D* obtained from the measurements specified in 6.4.2.

6.4.2 The value for the pipe diameter, *D*, shall be the mean of the internal diameters over a length of 0,5*D* upstream of the upstream pressure tapping. The internal mean diameter shall be the arithmetic mean of measurements of at least twelve diameters, namely four diameters positioned at approximately equal angles to each other, distributed in each of at least three cross-sections evenly distributed over a length of 0,5*D*, two of these sections being at distance 0*D* and 0,5*D* from the upstream tapping and one being in the plane of the weld in the case of a weld-neck construction. If there is a carrier ring (see Figure 5) this value of 0,5*D* shall be measured from the upstream edge of the carrier ring.

6.4.3 Beyond 2*D* from the primary device, the upstream pipe run between the primary device and the first upstream fitting or disturbance may be made up of one or more sections of pipe.

Between 2*D* and 10*D* from the nozzle no additional uncertainty in the discharge coefficient is involved provided that the diameter step (the difference between the diameters) between any two sections does not exceed 0,3 % of the mean value of *D* obtained from the measurements specified in 6.4.2. Moreover, the actual step caused by misalignment and/or change in diameter shall not exceed 0,3 % of *D* at any point of the internal circumference of the pipe. Therefore, mating flanges would require the bores to be matched and the flanges aligned on installation. Dowels or self-centring gaskets could be used.

Beyond 10*D* from the nozzle no additional uncertainty in the discharge coefficient is involved provided that the diameter step (the difference between the diameters) between any two sections does not exceed 2 % of the mean value of *D* obtained from the measurements specified in 6.4.2. Moreover, the actual step caused by misalignment and/or change in diameter shall not exceed 2 % of *D* at any point of the internal circumference of the pipe. If the pipe diameter upstream of the step is greater than that downstream of it the permitted diameter and actual steps are increased from 2 % of *D* to 6 % of *D*. On each side of the step the pipe shall have a diameter between 0,98*D* and 1,06*D*. Beyond 10*D* from the nozzle, the use of gaskets between sections will not violate this requirement provided that in use they are no thicker than 3,2 mm and they do not protrude into the flow.

Beyond the first location where an expander could be fitted in accordance with Column 6A of Table 3, no additional uncertainty in the discharge coefficient is involved, provided that the diameter step (the difference between the diameters) between any two sections does not exceed 6 % of the mean value of *D* obtained from the measurements specified in 6.4.2. Moreover, the actual step caused by misalignment and/or change in diameter shall not exceed 6 % of *D* at any point of the internal circumference of the pipe. On each side of the step, the pipe shall have a diameter between 0,94*D* and 1,06*D*. The first location where an expander could be fitted in accordance with Column 6A of Table 3 depends on the diameter ratio of the primary device, for example, it is 22*D* from the primary device if $\beta = 0,6$.

6.4.4 An additional relative uncertainty of 0,2 % shall be added arithmetically to the relative expanded uncertainty of the discharge coefficient if the diameter step ΔD between any two sections exceeds the limits given in 6.4.3, but complies with the following relationships:

$$\frac{\Delta D}{D} \leq 0{,}002\left(\frac{\frac{s}{D}+0{,}4}{0{,}1+2{,}3\beta^4}\right) \quad (21)$$

and

$$\frac{\Delta D}{D} \leq 0{,}05 \quad (22)$$

where s is the distance of the step from the upstream pressure tapping or, if a carrier ring is used, from the upstream edge of the recess formed by the carrier ring.

6.4.5 If a step is greater than any one of the limits given in the inequalities above or if there is more than one step outside the limits in 6.4.3, the installation is not in accordance with this document. For further guidance refer to ISO 5167-1:2022, 6.1.1.

6.4.6 No diameter of the downstream straight length, considered along a length of at least 2*D* from the upstream face of an ISA 1932 nozzle or a long radius nozzle, shall differ from the mean diameter of the upstream straight length by more than 3 %. This can be judged by checking a single diameter of the downstream straight length.

The diameter of the pipe immediately downstream of a Venturi nozzle need not be measured accurately but it shall be checked that the downstream pipe diameter is not less than 90 % of the diameter at the end of the divergent section. This means that, in most cases, pipes having the same nominal bore as that of the Venturi nozzle tube can be used.

6.5 Location of primary device and carrier rings

6.5.1 The primary device shall be placed in the pipe in such a way that the fluid flows from the upstream face towards the throat.

6.5.2 The primary device shall be perpendicular to the centreline of the pipe to within 1°.

6.5.3 The primary device shall be centred in the pipe. The distance e_x between the centreline of the throat and the centrelines of the pipe on the upstream and downstream sides shall be less than or equal to

$$\frac{0{,}005D}{0{,}1+2{,}3\beta^4}.$$

In the case where

$$e_x > \frac{0{,}005D}{0{,}1+2{,}3\beta^4}$$

this document gives no information by which to predict the value of any additional uncertainty to be taken into account.

6.5.4 When carrier rings are used, they shall be centred such that they do not protrude into the pipe at any point.

6.6 Method of fixing and gaskets

6.6.1 The method of fixing and tightening shall be such that once the primary device has been installed in the proper position, it remains so.

It is necessary, when holding the primary device between flanges, to allow for its free thermal expansion and to avoid buckling and distortion.

6.6.2 Gaskets or sealing rings shall be made and inserted in such a way that they do not protrude at any point inside the pipe or across the pressure tappings or slots when corner tappings are used. They shall be as thin as possible, with due consideration taken in maintaining the relationship as defined in 5.1.5.2 or 5.2.5.1 as appropriate.

6.6.3 If gaskets are used between the primary device and the annular chamber rings, they shall not protrude inside the annular chamber.

7 Flow calibration of nozzles

7.1 General

For users of nozzles of the geometry described in this document that require a lower discharge coefficient uncertainty than that stated in 5.1.7.1, 5.2.7.1, 5.3.6.1 or 5.4.5.1 or for users of devices where the geometry differs from that described in this document, the nozzle shall be calibrated. For further information on the use of throat-tapped nozzles see 5.3.7.

The purpose of a flow calibration is to determine the discharge coefficient of an individual nozzle and its associated uncertainty.

Where the geometry of the nozzle differs from that described in this document, the expansibility equation given in Formula (6) shall not be used unless verified. In such a case, the manufacturer of the nozzle shall provide an appropriate formula for the expansibility (expansion) factor.

Calibrated meters shall only be used within the calibrated Reynolds number range, except throat-tapped nozzles. For further information on throat-tapped nozzles see 5.3.7.

NOTE For gas applications (other than those at ambient process conditions or using throat-tapped nozzles), an ambient-temperature water calibration is unlikely to produce the required Reynolds number range. The Reynolds number range is used to help determine the choice of test facility.

7.2 Test facility

The nozzle shall be calibrated in such a manner as to ensure appropriate traceability for the user of the nozzle for the intended application.

NOTE For guidance on what might be appropriate, ISO/IEC 17025 is applicable.

7.3 Meter installation

The nozzle should be installed with, as a minimum, the upstream and downstream straight lengths specified in Clause 6.

If the nozzle is to be used with a flow conditioner a package consisting of at least $4D$ of pipe upstream of the flow conditioner, the flow conditioner, the pipe between the flow conditioner and the nozzle, the nozzle and at least $6D$ of pipe downstream of the nozzle shall be calibrated.

The orientation of the nozzle is irrelevant.

If the nozzle in operation will be installed in pipe work that differs significantly from the installation guidelines in this document, the operational pipe design should be replicated at the calibration facility in order to reduce the uncertainty of the nozzle in its installation.

7.4 Design of the test programme

The nozzle should be calibrated, as a minimum, over the entire Reynolds number range the meter is expected to see in operational service. The number of test points (i.e. nominal Reynolds numbers at which data are collected) shall be appropriate for the metering application. The test facility can calibrate the nozzle using liquid or gas, or both liquid and gas in separate tests to cover the required Reynolds number range.

The calibration data of a nozzle are not transferrable to another nozzle. If the meter has multiple sets of tappings, each set shall be calibrated as if it were a separate meter. Extrapolation of the calibration shall not be permitted.

7.5 Reporting the calibration results

The calibration test report should as a minimum provide tabulated results of the differential pressure, Reynolds number, and discharge coefficient values. The provision of graphs is also recommended for ease of analysis.

The discharge coefficient versus Reynolds number relationship determined in the calibration process shall be implemented according to the user's requirements. If this relationship is not constant to within the user's tolerance, then a non-constant mathematical expression should be used which will require an iterative solution. Consistent with 7.4, the user shall not extrapolate this mathematical expression.

7.6 Uncertainty analysis of the calibration

7.6.1 General

All uncertainties calculated as part of this flow calibration shall be stated to $k = 2$ (approximately 95 % confidence level).

7.6.2 Uncertainty of the test facility

The uncertainty of the instrumentation used by the test facility shall be calculated and recorded for each test point of the flow calibration. The uncertainty in the flow measurement shall be computed from this data utilizing a method detailed in either ISO 5168[3] or ISO/IEC Guide 98-3[4]. Both the chosen method and the results shall be recorded in the calibration report.

Where both liquid and gas tests are separately used to cover the Reynolds number range, the uncertainties of each test facility for the relevant test points shall be clearly detailed in the calibration report.

7.6.3 Uncertainty of the nozzle

The calibration procedure and the calculated uncertainty of the nozzle under test shall be recorded in the calibration report. As so few measurements are taken at each Reynolds number, an appropriate statistical methodology shall be used, as, for instance, standard deviation should only be used for larger data sets.

Annex A
(informative)

Tables of discharge coefficients and expansibility [expansion] factors

Table A.1 — ISA 1932 nozzle — Discharge coefficient, C

Diameter ratio	Discharge coefficient, C, for Re_D equal to								
β	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	2×10^6	1×10^7
0,30	—	—	—	0,985 5	0,986 5	0,987 8	0,988 2	0,988 3	0,988 4
0,32	—	—	—	0,984 7	0,985 8	0,987 3	0,987 7	0,987 8	0,987 9
0,34	—	—	—	0,983 8	0,985 0	0,986 6	0,987 1	0,987 2	0,987 3
0,36	—	—	—	0,982 8	0,984 0	0,985 9	0,986 4	0,986 5	0,986 6
0,38	—	—	—	0,981 6	0,983 0	0,984 9	0,985 5	0,985 6	0,985 7
0,40	—	—	—	0,980 3	0,981 8	0,983 9	0,984 5	0,984 6	0,984 7
0,42	—	—	—	0,978 9	0,980 5	0,982 7	0,983 3	0,983 4	0,983 5
0,44	0,961 6	0,969 2	0,975 0	0,977 3	0,978 9	0,981 3	0,982 0	0,982 1	0,982 2
0,45	0,960 4	0,968 2	0,974 1	0,976 4	0,978 1	0,980 5	0,981 2	0,981 3	0,981 4
0,46	0,959 2	0,967 2	0,973 1	0,975 5	0,977 3	0,979 7	0,980 4	0,980 5	0,980 6
0,47	0,957 9	0,966 1	0,972 2	0,974 6	0,976 3	0,978 8	0,979 5	0,979 7	0,979 7
0,48	0,956 7	0,965 0	0,971 1	0,973 6	0,975 4	0,977 9	0,978 6	0,978 7	0,978 8
0,49	0,955 4	0,963 8	0,970 0	0,972 6	0,974 3	0,976 9	0,977 6	0,977 7	0,977 8
0,50	0,954 2	0,962 6	0,968 9	0,971 5	0,973 3	0,975 8	0,976 6	0,976 7	0,976 8
0,51	0,952 9	0,961 4	0,967 8	0,970 3	0,972 1	0,974 7	0,975 4	0,975 6	0,975 7
0,52	0,951 6	0,960 2	0,966 5	0,969 1	0,970 9	0,973 5	0,974 3	0,974 4	0,974 5
0,53	0,950 3	0,958 9	0,965 3	0,967 8	0,969 6	0,972 2	0,973 0	0,973 1	0,973 2
0,54	0,949 0	0,957 6	0,963 9	0,966 5	0,968 3	0,970 9	0,971 7	0,971 8	0,971 9
0,55	0,947 7	0,956 2	0,962 6	0,965 1	0,966 9	0,969 5	0,970 2	0,970 4	0,970 5
0,56	0,946 4	0,954 8	0,961 1	0,963 7	0,965 5	0,968 0	0,968 8	0,968 9	0,969 0
0,57	0,945 1	0,953 4	0,959 6	0,962 1	0,963 9	0,966 4	0,967 2	0,967 3	0,967 4
0,58	0,943 8	0,952 0	0,958 1	0,960 6	0,962 3	0,964 8	0,965 5	0,965 6	0,965 7
0,59	0,942 4	0,950 5	0,956 5	0,958 9	0,960 6	0,963 0	0,963 8	0,963 9	0,964 0
0,60	0,941 1	0,949 0	0,954 8	0,957 2	0,958 8	0,961 2	0,961 9	0,962 0	0,962 1
0,61	0,939 8	0,947 4	0,953 1	0,955 4	0,957 0	0,959 3	0,960 0	0,960 1	0,960 2

NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.

Table A.1 *(continued)*

Diameter ratio	Discharge coefficient, C, for Re_D equal to								
β	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	2×10^6	1×10^7
0,62	0,938 5	0,945 8	0,951 3	0,953 5	0,955 0	0,957 3	0,957 9	0,958 0	0,958 1
0,63	0,937 1	0,944 2	0,949 4	0,951 5	0,953 0	0,955 1	0,955 8	0,955 9	0,956 0
0,64	0,935 8	0,942 5	0,947 5	0,949 5	0,950 9	0,952 9	0,953 5	0,953 6	0,953 7
0,65	0,934 5	0,940 8	0,945 5	0,947 3	0,948 7	0,950 6	0,951 1	0,951 2	0,951 3
0,66	0,933 2	0,939 0	0,943 4	0,945 1	0,946 4	0,948 1	0,948 7	0,948 7	0,948 8
0,67	0,931 9	0,937 2	0,941 2	0,942 8	0,944 0	0,945 6	0,946 0	0,946 1	0,946 2
0,68	0,930 6	0,935 4	0,939 0	0,940 4	0,941 4	0,942 9	0,943 3	0,943 4	0,943 5
0,69	0,929 3	0,933 5	0,936 7	0,937 9	0,938 8	0,940 1	0,940 5	0,940 5	0,940 6
0,70	0,928 0	0,931 6	0,934 3	0,935 3	0,936 1	0,937 2	0,937 5	0,937 5	0,937 6
0,71	0,926 8	0,929 6	0,931 8	0,932 6	0,933 2	0,934 1	0,934 4	0,934 4	0,934 4
0,72	0,925 5	0,927 6	0,929 2	0,929 8	0,930 3	0,930 9	0,931 1	0,931 1	0,931 2
0,73	0,924 3	0,925 6	0,926 5	0,926 9	0,927 2	0,927 6	0,927 7	0,927 7	0,927 8
0,74	0,923 1	0,923 5	0,923 8	0,923 9	0,924 0	0,924 1	0,924 2	0,924 2	0,924 2
0,75	0,921 9	0,921 3	0,920 9	0,920 8	0,920 7	0,920 5	0,920 5	0,920 5	0,920 5
0,76	0,920 7	0,919 2	0,918 0	0,917 6	0,917 2	0,916 8	0,916 6	0,916 6	0,916 6
0,77	0,919 5	0,916 9	0,915 0	0,914 2	0,913 6	0,912 8	0,912 6	0,912 6	0,912 5
0,78	0,918 4	0,914 7	0,911 8	0,910 7	0,909 9	0,908 8	0,908 4	0,908 4	0,908 3
0,79	0,917 3	0,912 3	0,908 6	0,907 1	0,906 0	0,904 5	0,904 1	0,904 0	0,904 0
0,80	0,916 2	0,910 0	0,905 3	0,903 4	0,902 0	0,900 1	0,899 6	0,899 5	0,899 4

NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.

Table A.2 — Long radius nozzle — Discharge coefficient, C

Diameter ratio	Discharge coefficient, C, for Re_D equal to								
β	1×10^4	2×10^4	5×10^4	1×10^5	2×10^5	5×10^5	1×10^6	5×10^6	1×10^7
0,20	0,967 3	0,975 9	0,983 4	0,987 3	0,990 0	0,992 4	0,993 6	0,995 2	0,995 6
0,22	0,965 9	0,974 8	0,982 8	0,986 8	0,989 7	0,992 2	0,993 4	0,995 1	0,995 5
0,24	0,964 5	0,973 9	0,982 2	0,986 4	0,989 3	0,992 0	0,993 3	0,995 1	0,995 5
0,26	0,963 2	0,973 0	0,981 6	0,986 0	0,989 1	0,991 8	0,993 2	0,995 0	0,995 4
0,28	0,961 9	0,972 1	0,981 0	0,985 6	0,988 8	0,991 6	0,993 0	0,995 0	0,995 4
0,30	0,960 7	0,971 2	0,980 5	0,985 2	0,988 5	0,991 4	0,992 9	0,994 9	0,995 4
0,32	0,959 6	0,970 4	0,980 0	0,984 8	0,988 2	0,991 3	0,992 8	0,994 8	0,995 3
0,34	0,958 4	0,969 6	0,979 5	0,984 5	0,988 0	0,991 1	0,992 7	0,994 8	0,995 3
0,36	0,957 3	0,968 8	0,979 0	0,984 1	0,987 7	0,991 0	0,992 6	0,994 7	0,995 3
0,38	0,956 2	0,968 0	0,978 5	0,983 8	0,987 5	0,990 8	0,992 5	0,994 7	0,995 2

NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.

Table A.2 *(continued)*

Diameter ratio	Discharge coefficient, C, for Re_D equal to								
β	1 × 10⁴	2 × 10⁴	5 × 10⁴	1 × 10⁵	2 × 10⁵	5 × 10⁵	1 × 10⁶	5 × 10⁶	1 × 10⁷
0,40	0,955 2	0,967 3	0,978 0	0,983 4	0,987 3	0,990 7	0,992 4	0,994 7	0,995 2
0,42	0,954 2	0,966 6	0,977 6	0,983 1	0,987 0	0,990 5	0,992 3	0,994 6	0,995 2
0,44	0,953 2	0,965 9	0,977 1	0,982 8	0,986 8	0,990 4	0,992 2	0,994 6	0,995 1
0,46	0,952 3	0,965 2	0,976 7	0,982 5	0,986 6	0,990 2	0,992 1	0,994 5	0,995 1
0,48	0,951 3	0,964 5	0,976 3	0,982 2	0,986 4	0,990 1	0,992 0	0,994 5	0,995 1
0,50	0,950 3	0,963 9	0,975 9	0,981 9	0,986 2	0,990 0	0,991 9	0,994 4	0,995 0
0,51	0,949 9	0,963 5	0,975 6	0,981 8	0,986 1	0,989 9	0,991 8	0,994 4	0,995 0
0,52	0,949 4	0,963 2	0,975 4	0,981 6	0,986 0	0,989 8	0,991 8	0,994 4	0,995 0
0,53	0,949 0	0,962 9	0,975 2	0,981 5	0,985 9	0,989 8	0,991 7	0,994 4	0,995 0
0,54	0,948 5	0,962 6	0,975 0	0,981 3	0,985 8	0,989 7	0,991 7	0,994 4	0,995 0
0,55	0,948 1	0,962 3	0,974 8	0,981 2	0,985 7	0,989 7	0,991 7	0,994 3	0,995 0
0,56	0,947 6	0,961 9	0,974 6	0,981 0	0,985 6	0,989 6	0,991 6	0,994 3	0,995 0
0,57	0,947 2	0,961 6	0,974 5	0,980 9	0,985 5	0,989 5	0,991 6	0,994 3	0,994 9
0,58	0,946 8	0,961 3	0,974 3	0,980 8	0,985 4	0,989 5	0,991 5	0,994 3	0,994 9
0,59	0,946 3	0,961 0	0,974 1	0,980 6	0,985 3	0,989 4	0,991 5	0,994 3	0,994 9
0,60	0,945 9	0,960 7	0,973 9	0,980 5	0,985 2	0,989 3	0,991 4	0,994 2	0,994 9
0,61	0,945 5	0,960 4	0,973 7	0,980 4	0,985 1	0,989 3	0,991 4	0,994 2	0,994 9
0,62	0,945 1	0,960 1	0,973 5	0,980 2	0,985 0	0,989 2	0,991 4	0,994 2	0,994 9
0,63	0,944 7	0,959 9	0,973 3	0,980 1	0,984 9	0,989 2	0,991 3	0,994 2	0,994 9
0,64	0,944 3	0,959 6	0,973 1	0,980 0	0,984 8	0,989 1	0,991 3	0,994 2	0,994 8
0,65	0,943 9	0,959 3	0,973 0	0,979 9	0,984 7	0,989 1	0,991 2	0,994 1	0,994 8
0,66	0,943 5	0,959 0	0,972 8	0,979 7	0,984 6	0,989 0	0,991 2	0,994 1	0,994 8
0,67	0,943 0	0,958 7	0,972 6	0,979 6	0,984 5	0,988 9	0,991 2	0,994 1	0,994 8
0,68	0,942 7	0,958 4	0,972 4	0,979 5	0,984 5	0,988 9	0,991 1	0,994 1	0,994 8
0,69	0,942 3	0,958 1	0,972 2	0,979 3	0,984 4	0,988 8	0,991 1	0,994 1	0,994 8
0,70	0,941 9	0,957 9	0,972 1	0,979 2	0,984 3	0,988 8	0,991 0	0,994 1	0,994 8
0,71	0,941 5	0,957 6	0,971 9	0,979 1	0,984 2	0,988 7	0,991 0	0,994 0	0,994 8
0,72	0,941 1	0,957 3	0,971 7	0,979 0	0,984 1	0,988 7	0,991 0	0,994 0	0,994 7
0,73	0,940 7	0,957 0	0,971 5	0,978 9	0,984 0	0,988 6	0,990 9	0,994 0	0,994 7
0,74	0,940 3	0,956 8	0,971 4	0,978 7	0,983 9	0,988 6	0,990 9	0,994 0	0,994 7
0,75	0,939 9	0,956 5	0,971 2	0,978 6	0,983 9	0,988 5	0,990 8	0,994 0	0,994 7
0,76	0,939 6	0,956 2	0,971 0	0,978 5	0,983 8	0,988 4	0,990 8	0,994 0	0,994 7
0,77	0,939 2	0,956 0	0,970 9	0,978 4	0,983 7	0,988 4	0,990 8	0,993 9	0,994 7

NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.

Table A.2 *(continued)*

Diameter ratio	Discharge coefficient, C, for Re_D equal to								
β	1×10^4	2×10^4	5×10^4	1×10^5	2×10^5	5×10^5	1×10^6	5×10^6	1×10^7
0,78	0,938 8	0,955 7	0,970 7	0,978 3	0,983 6	0,988 3	0,990 7	0,993 9	0,994 7
0,79	0,938 5	0,955 5	0,970 5	0,978 1	0,983 5	0,988 3	0,990 7	0,993 9	0,994 7
0,80	0,938 1	0,955 2	0,970 4	0,978 0	0,983 4	0,988 2	0,990 7	0,993 9	0,994 7
NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.									

Table A.3 — Throat-tapped nozzles — Discharge coefficient, C

Reynolds number Re_d	Discharge coefficient C
8×10^5	0,999 34
9×10^5	0,998 73
1×10^6	0,998 31
$1,2 \times 10^6$	0,997 78
$1,5 \times 10^6$	0,997 42
$2,0 \times 10^6$	0,997 28
$2,5 \times 10^6$	0,997 35
3×10^6	0,997 63
4×10^6	0,998 46
5×10^6	0,999 16
6×10^6	0,999 75
7×10^6	1,000 27
8×10^6	1,000 72
9×10^6	1,001 13
1×10^7	1,001 49
$1,2 \times 10^7$	1,002 11
$1,5 \times 10^7$	1,002 88
2×10^7	1,003 86
NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.	

Table A.4 — Venturi nozzles — Discharge coefficient, C

Diameter ratio β	Discharge coefficient C
0,316	0,984 7
0,320	0,984 6
0,330	0,984 5
0,340	0,984 3
0,350	0,984 1
NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.	

Table A.4 *(continued)*

Diameter ratio β	Discharge coefficient C
0,360	0,983 8
0,370	0,983 6
0,380	0,983 3
0,390	0,983 0
0,400	0,982 6
0,410	0,982 3
0,420	0,981 8
0,430	0,981 4
0,440	0,980 9
0,450	0,980 4
0,460	0,979 8
0,470	0,979 2
0,480	0,978 6
0,490	0,977 9
0,500	0,977 1
0,510	0,976 3
0,520	0,975 5
0,530	0,974 5
0,540	0,973 6
0,550	0,972 5
0,560	0,971 4
0,570	0,970 2
0,580	0,968 9
0,590	0,967 6
0,600	0,966 1
0,610	0,964 6
0,620	0,963 0
0,630	0,961 3
0,640	0,959 5
0,650	0,957 6
0,660	0,955 6
0,670	0,953 5
0,680	0,951 2
0,690	0,948 9
NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.	

Table A.4 *(continued)*

Diameter ratio β	Discharge coefficient C
0,700	0,946 4
0,710	0,943 8
0,720	0,941 1
0,730	0,938 2
0,740	0,935 2
0,750	0,932 1
0,760	0,928 8
0,770	0,925 3
0,775	0,923 6
NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.	

Table A.5 — Nozzles and Venturi nozzles — Expansibility [expansion] factor, ε

Diameter ratio		Expansibility [expansion] factor, ε, for p_2/p_1 equal to								
β	β^4	1,00	0,98	0,96	0,94	0,92	0,90	0,85	0,80	0,75
for κ = 1,2										
0,200 0	0,001 6	1,000 0	0,987 4	0,974 7	0,961 9	0,949 0	0,935 9	0,902 8	0,868 7	0,833 8
0,562 3	0,100 0	1,000 0	0,985 6	0,971 2	0,956 8	0,942 3	0,927 8	0,891 3	0,854 3	0,816 9
0,668 7	0,200 0	1,000 0	0,983 4	0,966 9	0,950 4	0,934 1	0,917 8	0,877 3	0,837 1	0,797 0
0,740 1	0,300 0	1,000 0	0,980 5	0,961 3	0,942 4	0,923 8	0,905 3	0,860 2	0,816 3	0,773 3
0,795 3	0,400 0	1,000 0	0,976 7	0,954 1	0,932 0	0,910 5	0,889 5	0,839 0	0,790 9	0,744 8
0,800 0	0,409 6	1,000 0	0,976 3	0,953 3	0,930 9	0,909 1	0,887 8	0,836 7	0,788 2	0,741 8
for κ = 1,3										
0,200 0	0,001 6	1,000 0	0,988 4	0,976 6	0,964 8	0,952 8	0,940 7	0,909 9	0,878 1	0,845 4
0,562 3	0,100 0	1,000 0	0,986 7	0,973 4	0,960 0	0,946 6	0,933 1	0,899 0	0,864 5	0,829 4
0,668 7	0,200 0	1,000 0	0,984 6	0,969 3	0,954 1	0,938 9	0,923 7	0,885 9	0,848 1	0,810 2
0,740 1	0,300 0	1,000 0	0,982 0	0,964 2	0,946 6	0,929 2	0,912 0	0,869 7	0,828 3	0,787 5
0,795 3	0,400 0	1,000 0	0,978 5	0,957 5	0,936 9	0,916 8	0,897 1	0,849 5	0,803 9	0,759 9
0,800 0	0,409 6	1,000 0	0,978 1	0,956 7	0,935 8	0,915 4	0,895 5	0,847 3	0,801 3	0,757 0
for κ = 1,4										
0,200 0	0,001 6	1,000 0	0,989 2	0,978 3	0,967 3	0,956 1	0,944 8	0,916 0	0,886 3	0,855 6
0,562 3	0,100 0	1,000 0	0,987 7	0,975 3	0,962 8	0,950 3	0,937 7	0,905 8	0,873 3	0,840 2
0,668 7	0,200 0	1,000 0	0,985 7	0,971 5	0,957 3	0,943 0	0,928 8	0,893 3	0,857 7	0,821 9
0,740 1	0,300 0	1,000 0	0,983 2	0,966 7	0,950 3	0,934 0	0,917 8	0,878 0	0,838 8	0,800 0
0,795 3	0,400 0	1,000 0	0,980 0	0,960 4	0,941 1	0,922 3	0,903 8	0,858 8	0,815 4	0,773 3
0,800 0	0,409 6	1,000 0	0,979 6	0,959 7	0,940 1	0,921 0	0,902 2	0,856 7	0,812 9	0,770 5
for κ = 1,66										
0,200 0	0,001 6	1,000 0	0,990 9	0,981 7	0,972 3	0,962 8	0,953 2	0,928 6	0,903 1	0,876 6
0,562 3	0,100 0	1,000 0	0,989 6	0,979 1	0,968 5	0,957 8	0,947 1	0,919 7	0,891 7	0,862 9
NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.										

Table A.5 *(continued)*

Diameter ratio		Expansibility [expansion] factor, ε, for p_2/p_1 equal to								
β	β^4	1,00	0,98	0,96	0,94	0,92	0,90	0,85	0,80	0,75
0,668 7	0,200 0	1,000 0	0,987 9	0,975 9	0,963 7	0,951 6	0,939 4	0,908 8	0,877 8	0,846 4
0,740 1	0,300 0	1,000 0	0,985 8	0,971 8	0,957 7	0,943 8	0,929 9	0,895 3	0,860 9	0,826 5
0,795 3	0,400 0	1,000 0	0,983 1	0,966 4	0,949 9	0,933 6	0,917 6	0,878 2	0,839 7	0,802 0
0,800 0	0,409 6	1,000 0	0,982 7	0,965 8	0,949 0	0,932 5	0,916 2	0,876 3	0,837 4	0,799 4
NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.										

Annex B
(informative)

Akashi type (Mitsubishi type) flow conditioner

The Akashi type (Mitsubishi type) flow conditioner is shown in Figure B.1. *D* is the inner diameter of the pipe and *t* is the thickness of the plate. The flow conditioner is perforated plate type which has many small holes with approximately *D*/8 diameter. The holes around the centre of the plate are closer together than those further out. The axes of holes are given in Table B.1. The pressure loss is 1,7 times dynamic pressure.

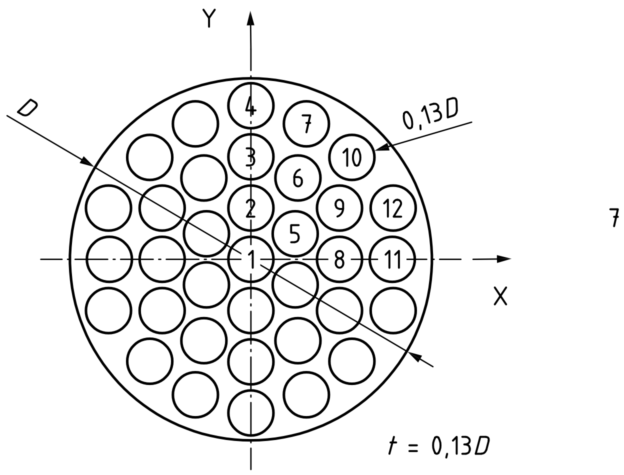


Figure B.1 — Akashi type flow conditioner

Table B.1 — Axis of holes in Akashi type flow conditioner

No.	X-axis	Y-axis
1	0	0
2	0	0,142*D*
3	0	0,283*D*
4	0	0,423*D*
5	0,129*D*	0,078*D*
6	0,134*D*	0,225*D*
7	0,156*D*	0,381*D*
8	0,252*D*	0
9	0,255*D*	0,146*D*
10	0,288*D*	0,288*D*
11	0,396*D*	0
12	0,400*D*	0,151*D*

Bibliography

[1] ISO 2186, *Fluid flow in closed conduits — Connections for pressure signal transmissions between primary and secondary elements*

[2] ISO 5167 (all parts), *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full*

[3] ISO 5168, *Measurement of fluid flow — Procedures for the evaluation of uncertainties*

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

[5] Furuichi N., Cheong K.H., Terao Y., Nakao S., Fujita K., Shibuya K., New Discharge Coefficient of Throat Tap Nozzle Based on ASME Performance Test Code 6 for Reynolds Number From 2.4×105 to 1.4×107, Journal of Fluid Engineering, **136**(1), 011105, 2013, doi:10.1115/1.4025513

[6] Furuichi N., Terao Y., Nakao S., Fujita K., Shibuya K., Further investigation of discharge coefficient for PTC 6 flow nozzle in high Reynolds number, Journal of Engineering for Gas Turbines and Power, **138**(4), 041605, 2016, doi:10.1115/1.4031310

[7] Furuichi N., Terao Y., Re-definition of the discharge coefficient of throat-tapped flow nozzle and investigations on the influence of geometric parameters, Flow Measurement and Instrumentation, **65**, 2019, pp.16–21

[8] Reader-Harris M.J., Gibson J., Hodges D., Nicholson I.G., Rushworth R., The performance of flow nozzles at high Reynolds number, In Proc. FLOMEKO 14, Sandton, South Africa, 2007

(*Continued from second cover*)

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act*, 2016 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the website-www.bis.gov.in or www.standardsbis.in.

This Indian Standard has been developed from Doc No.: WRD 01 (20344).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.gov.in

Regional Offices:		*Telephones*
Central	: 601/A, Konnectus Tower -1, 6th Floor, DMRC Building, Bhavbhuti Marg, New Delhi 110002	2323 7617
Eastern	: 8th Floor, Plot No 7/7 & 7/8, CP Block, Sector V, Salt Lake, Kolkata, West Bengal 700091	2367 0012 2320 9474
Northern	: Plot No. 4-A, Sector 27-B, Madhya Marg, Chandigarh 160019	265 9930
Southern	: C.I.T. Campus, IV Cross Road, Taramani, Chennai 600113	2254 1442 2254 1216
Western	: Plot No. E-9, Road No.-8, MIDC, Andheri (East), Mumbai 400093	2821 8093

Branches : AHMEDABAD. BENGALURU. BHOPAL. BHUBANESHWAR. CHANDIGARH. CHENNAI. COIMBATORE. DEHRADUN. DELHI. FARIDABAD. GHAZIABAD. GUWAHATI. HIMACHAL PRADESH. HUBLI. HYDERABAD. JAIPUR. JAMMU & KASHMIR. JAMSHEDPUR. KOCHI. KOLKATA. LUCKNOW. MADURAI. MUMBAI. NAGPUR. NOIDA. PANIPAT. PATNA. PUNE. RAIPUR. RAJKOT. SURAT. VISAKHAPATNAM.

Published by BIS, New Delhi